Application Tracks and Acronyms - Legend

T01 LTE and Sub-6GHz 5G	T02 Millimetre wave 5G	T03 Wireless LANs	T04 IoT and M2M	T05 Biomedical and health	T06 Aircraft (incl. UAV, UAS, RPAS) and automotive
T07 Defence and security	T08 Positioning, localization & tracking	T09 Space (incl. cubesat)	T10 EM modelling and simulation tools	T11 Fundamental research and emerging technologies	T12 Scientific/Industrial Workshops
CS: Convened Session	SW: Scientific Workshop	IW: Industrial Workshop	SC: Short-Course		
A: Antennas	E: Electromagnetics	P: Propagation	M: Measurements		

Time	Virtual 1	Virtual 2	Virtual 3	Virtual 4	Virtual 5	Virtual 6	Virtual 7	Virtual 8	Virtual 9	Virtual 10	Virtual 11	Virtual 12	Virtual 13	Virtual 14	Posters	Posters2	Posters3
Monday, March 22																	
09:00-10:00	*Opening Ceremony*																
10:00-10:40	*Keynote 1*																
10:40-11:10	*Coffee Break / Exhibition*																
11:10-11:50	*Keynote 2*																
11:50-12:30	*Keynote 3*																
12:30-13:00	*Lunch / Exhibition*												IW02: *Live at the Cylindrical / Planar Near-field antenna Chamber 'ATAM facility TÜBITAK (Turkey)*	*Lunch / Exhibition*			
13:00-13:30													IW07: *Drone based antenna measurements at SATCOM and RADAR bands. A comparison with standard far-field measurements (QuadSAT)*				
13:30-15:30	CS20: *(IET Session) Measurement Advances and Challenges for 5G & Beyond*	CS8: *Challenges and Solutions of Radio Frequency Tests for 5G Radios*	CS42: *IRACON Propagation Measurements and Modelling for 5G and beyond*		CS22: *Microwave Biomedical Imaging: Innovative Methods and Systems Towards Clinical Applications*	CS11: *Convergence of Mobile Radio and Radar*	CS17: *GNSS Antennas and Systems for Challenged RF Environment*	CS24: *Active Antennas for Space Telecon Applications*	CS12: *Developments and Results of Propagation Campaigns for Satellite Telecommunication Systems Operating at Ka, Q, V and W Frequency Bands*	CS16: *Fundamental Challenges and Novel Methodologies in the Next-generation Computational Electromagnetics*	CS6: *Application Aspects of Wideband Metasurfaces in RADAR*	CS35: *Recent Progress in Antennas and Propagation Research and Development in Latin America*					
15:30-15:50	*Coffee Break / Exhibition*																
15:50-17:50	T01-A02: *Wideband Antennas*	*CS8 continued*	*CS42 continued*		*CS22 continued*	CS39: *UAV-based Antenna Measurements*	*CS17 continued*	*CS24 continued*	*CS12 continued*	*CS16 continued*	CS23: *Novel Antenna Measurement Techniques and Data Analysis*	T11-E06: *Reconfigurable surfaces and metamaterials*					
17:50-19:00	*Welcome Reception*																

Tuesday, March 23

10:00-11:40	CS31: *(ISAP Session) Recent Advances in Asian Antennas and Propagation Research*	T02-A01: *5G communication architectures: Part 1 Base Stations*	T02-P01: *mm-wave propagation*	T04-A01: *Array Antennas 1*	T05-M01: *Dosimetry, Exposure, and SAR assessment*	T06-A02: *Wideband Arrays*		CS15: *From Science to System Design for High Sensitivity Astronomical Array Receivers*	T10-M01: *Antenna Design and Measurements*	T10-E01: *Theory of EM Fields and Antennas*	CS2: *Advances on Metasurfaces for Wavefront Manipulation*	T11-A01: *Small Antennas Theory*					
11:40-13:10													IW01: *Broadband compact mm-wave antenna array performance optimization (Optenni)*	IW04: *Methods for Simulation Driven Antenna Design (Ansys)*	P1: *Tuesday Interactive Posters*	Posters_A: *Best Paper Awards - Poster Session - Antennas*	Posters_E: *Best Paper Awards - Poster Session - Electromagnetics*
13:10-13:40														IW06: *Multiphysic Analysis for 5G Devices (Ansys)*			
13:40-14:25	Inv1a: *Invited Speaker Session:*	Inv2a: *Invited Speaker Session:*															
14:25-15:10	Inv1b: *Invited Speaker Session:*	Inv2b: *Invited Speaker Session:*															
15:10-15:30	*Coffee Break / Exhibition*																
15:30-17:10	T01-M01: *MIMO and OTA testing*	T02-A04: *Lens Antennas*	T02-P02: *Propagation for mm-wave 5G*		T05-M02: *Microwave Imaging and Dossimetry*	CS41: *(AMTA Session): Unmanned Aerial Vehicle (UAV) - Based Antenna Measurements*		T09-A04: *Reflector Analysis and Design*	CS19: *LMS Propagation Channel - a Focus on Multipath and Antenna Effects*	T10-E04: *EM Modelling and Numerical Techniques*	CS38: *Surface Wave and Metasurface Engineering: Recent Developments and Applications*	CS5: *Antennas for Harsh Environment*	T11-E04: *Optimisation Techniques and Applications*				

Wednesday, March 24

10:00-11:40	T01-A03: *Classic multi band antennas*	CS32: *Recent Advances on Electronically Steerable Antenna Arrays at mmWave and sub-THz Frequencies*		T04-A02: *Antennas for wireless power transfer*	T05-P01: *Propagation in biological tissues*	T06-A01: *Antennas for Aircraft and Automotive*	T07-A01: *Array antennas 2*	T09-A01: *Antennas for Satellite Communications*	CS10a: *(AMTA Session) Computational Modelling of Test Ranges Part 1*	T10-E02: *EM Theory and Analytical Techniques*	T11-M01: *Material Measurements*	T11-A03: *Reflector feeds*		SW04: *EurAAP Women In Antennas and Propagation*			
11:40-12:10													IW08: *Working together with Fast Antenna Measurements and Numerical Simulation in Antenna Placement Scenarios (MVG)*		P2: *Wednesday Interactive Posters*	Posters_M: *Best Paper Awards - Poster Session - Measurements*	Posters_P: *Best Paper Awards - Poster Session - Propagation*
12:10-12:30													IW05: *Virtual road testing: advanced electromagnetic simulation of radar systems for autonomous vehicle (Ansys)*				
12:30-13:40																	
13:40-14:25	Inv3a: *Invited Speaker Session:*	Inv4a: *Invited Speaker Session:*															
14:25-15:10	Inv3b: *Invited Speaker Session:*	Inv4b: *Invited Speaker Session:*															
15:10-15:30	*Coffee Break / Exhibition*																
15:30-17:10	T01-A05: *Adaptive and Reconfigurable Antennas*	T01-A04: *Coupling Suppression*	T02-A06: *Active integrated antennas*		T05-E02: *Medical Diagnosis and Treatment Methods*			T09-A02: *Reflect Arrays*	CS10b: *(AMTA Session) Computational Modelling of Test Ranges Part 2*	T10-P01: *Propagation modelling and simulation*	T11-A02: *THz Antennas*	T11-E01: *Imaging Techniques and Applications*	T11-M03: *Measurements of material properties*	T11-A06: *High Frequency antennas and components*			

Thursday, March 25

10:00-11:40	T01-P01: *Machine Learning for Propagation*	CS30a: *Propagation of Smart Mobility Empowered by 5G and Beyond (Part 1)*	T02-A02: *5G communication architectures: Part 2 handheld arrays*	T02-A09: *mm-wave antennas*	T05-E01: *Scattering and Imaging Techniques for Medical Applications*		T08-P01: *Propagation for Positioning, Localisation and tracking*		CS9a: *Characteristic Mode Analysis for Emerging Applications and New Structures Part 1*	CS14: *(EuMA / EurAAP Session) EM and Active Electronics Modelling in Antenna Systems for 5G*	T11-M02: *NearField & FarField Antenna Measurements*	T11-E02: *FSS and Metasurface Modelling and Design*	CS7: *Assessment and Modeling of Antennas and Radio Channels Jointly*	SW02: *Challenges of Modern Material Measurements*			
11:40-12:10														IW09: *Efficient full wave EM simulation of automotive radar and communication systems (IMST)*	P3: *Thursday Interactive Posters*	Posters_S: *Best Paper Awards - Poster Session - Student*	
12:10-13:10																	
13:10-13:40													IW11: *State-of-the-Art Test Methods for the Comprehensive Evaluation of Module and Vehicle Mounted Antenna-Dependent ADAS Features (ETS Lindgren)*	IW03: *Efficiently Simulating Connected Systems in Complex Environments: (Altair)*			
13:40-14:25	Inv5a: *Invited Speaker Session:*	Inv6a: *Invited Speaker Session:*															
14:25-15:10	Inv5b: *Invited Speaker Session:*	Inv6b: *Invited Speaker Session:*															
15:10-15:30	*Coffee Break / Exhibition*																
15:30-17:10	T01-A01: *5G Antennas*	CS30b: *Propagation of Smart Mobility Empowered by 5G and Beyond (Part 2)*	T02-A07: *mm wave integrated and planar antennas*			T06-M01: *UAV Measurements*	T07-A02: *Slotted Waveguide and leaky wave antennas*	T08-A02: *Dielectric resonator antennas*	CS9b: *Characteristic Mode Analysis for Emerging Applications and New Structures Part 2*	T10-E03: *Computational EM Modellling and Numerical Techniques*	T11-A07: *Additive manufacturing of antennas*	CS27: *(AMTA/EurAAP Session): Post Processing Techniques in Antenna Measurements*	T11-E05: *Metamaterial-enhanced antenna design*				

Friday, March 26

09:00-10:40	CS13: *Disruptive Antenna Technologies Making 5G a Reality*	CS29: *(IET/IRACON Session): Propagation Measurements and Modelling for 5G and beyond*	T02-A03: *MIMO Antenna Systems*	CS1: *(AMTA Session): 5G & mm-wave Antenna Testing*	CS18: *(EurAAP Session) IoT Antenna Modelling and Design*		CS33: *(EurAAP Session) Recent Advances on Propagation Research and Its Impact on Localizations*	CS4: *Antennas and Arrays for Radio Astronomy*	CS25: *COST Action CA18223 (SyMat): Periodic Structures with Higher Symmetries*	CS40: *Unconventional Techniques and Applications for Inverse Scattering Problems*	CS3: *Antenna Design and Fundamental Bounds with External Constraints*	CS34: *Recent Challenges in Small Antenna Design*	SW03: *Antennas and Propagation Aspects for THz Communications*	SW01a: *Integration challenges for mm-wave phased arrays Part 1*			
10:40-11:10	*Coffee Break / Exhibition*																
11:10-12:50	*CS13 continued*	*CS29 continued*		*CS1 continued*	*CS18 continued*	T05-A01: *Antennas for medical applications*	*CS33 continued*	*CS4 continued*	*CS25 continued*	*CS40 continued*	*CS3 continued*	*CS34 continued*	*SW03 continued*	*SW01a continued*			
12:50-13:50	*Closing Ceremony*																
14:00-14:30	SC01: *Short Course: Multibeam Antennas and Beamforming Networks*	SC02: *Short Course: Gap waveguides for mmWave antenna systems and electronic packaging*	SC03: *Short Course: User antennas for internet everywhere*				SC07: *Short Course: THz Technology and Instrumentation*						IW10: *Recent advances in antenna measurement systems in response to current and future test challenges (Asysol)*	SW01b: *Integration challenges for mm-wave phased arrays Part 2*			
14:30-16:00																	
16:00-18:00																	

Monday, March 22

Monday, March 22 9:00 - 10:00

Opening Ceremony

Room: virtual 1

Chairs: Thomas Kürner (Technische Universität Braunschweig, Germany), Cyril Mangenot (Api-Space, France)

Monday, March 22 10:00 - 10:40

Keynote 1

European research plans beyond 5G; the Smart Networks and Services partnership

Colin Willcock

Room: virtual 1

Chairs: Thomas Kürner (Technische Universität Braunschweig, Germany), Cyril Mangenot (Api-Space, France)

10:00 ***European Research Plans Beyond 5G; The Smart Networks and Services Partnership***

Colin Willcock (Nokia Bell Labs, Germany)

In this talk I will start by presenting the results from the existing 5G PPP research partnership which aimed at bring European leadership in 5G. Based on this success, I will then outline the future plans for a new public private partnership to create leadership in 6G. I will present the main high level goals for this new 6G partnership which will be called Smart Networks and Services, together with timelines and key technology blocks. I will complete the talk with some initial ideas about how 6G might change our lives in the future.

Monday, March 22 10:40 - 11:10

Coffee Break / Exhibition

Rooms: virtual 1, virtual 2, virtual 3, virtual 4, virtual 5, virtual 6, virtual 7, virtual 8, virtual 9, virtual 10, virtual 11, virtual 12, virtual 13, virtual 14, Posters, Posters2, Posters3

Monday, March 22 11:10 - 11:50

Keynote 2

Propagation and Channel modelling for automotive environments

Fredrik Tufvesson

Room: virtual 1

Chairs: Thomas Kürner (Technische Universität Braunschweig, Germany), Cyril Mangenot (Api-Space, France)

11:10 ***Propagation and Channel Modelling for Automotive Environments***

Fredrik Tufvesson (Lund University, Sweden)

Dependable vehicular communication is seen as an enabler for increased traffic safety and more efficient transportation solutions. It is a must for cooperative vehicles, and sometimes claimed to be so also for autonomous vehicles. In the talk we discuss vehicular channel characteristics and how these affect the possibilities to achieve dependable communication in this highly dynamic and challenging environment. We look at detailed scatterer behavior and the possibility for highly accurate multipath assisted positioning. We discuss different channel modelling approaches and wrap up with an outlook of future dependable vehicular communication in the millimeter wave bands.

Monday, March 22 11:50 - 12:30

Keynote 3

Contemplating MIMO options for millimeter wave networks

Robert Heath

Room: virtual 1

Chairs: Thomas Kürner (Technische Universität Braunschweig, Germany), Cyril Mangenot (Api-Space, France)

11:50 ***Contemplating MIMO Options for Millimeter Wave Networks***

Robert Heath (North Carolina State University & The University of Texas at Austin, USA)

MIMO communication is an important component of cellular networks. The way that MIMO is used has undergone a transition, led in part by the need to support millimeter wave communication. In this talk, I will review how MIMO changed in the evolution of 4G to 5G. I will discuss the different MIMO architectures and will reflect on why 5G ended up supporting a beam-based design. To conclude, I will describe alternatives and speculate on how MIMO will continue to evolve in later releases of 5G and towards 6G.

Monday, March 22 12:30 - 13:30

Lunch / Exhibition

Rooms: virtual 1, virtual 2, virtual 3, virtual 4, virtual 5, virtual 6, virtual 7, virtual 8, virtual 9, virtual 10, virtual 11, virtual 12, virtual 14, Posters, Posters2, Posters3

Monday, March 22 12:30 - 13:00

IW02: Live at the Cylindrical/Planar Near-field antenna Chamber 'ATAM facility of TÜBITAK (Turkey), showcasing its capabilities, infrastructures and technical details

Room: virtual 13

Mrs. Ellen Matthys, Emerson & Cuming

Monday, March 22 13:00 - 13:30

IW07: Drone based antenna measurements in the SATCOM and RADAR bands. A comparison with standard far-field measurements (QuadSAT)

Room: virtual 13

Linnea Berg Ingwersen, QuadSAT

Monday, March 22 13:30 - 15:30

CS20: (IET Session) Measurement Advances and Challenges for 5G & Beyond

T01 LTE and Sub-6GHz 5G / Convened Session / Measurements

Room: virtual 1

Chairs: Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)), Janet O'Neil (ETS-Lindgren, USA)

13:30 ***Fast and Accurate TRP Measurements Using a Reverberation Chamber***

Tianyuan Jia and Yi Huang (University of Liverpool, United Kingdom (Great Britain)); Qian Xu (Nanjing University of Aeronautics and Astronautics, China); Qiang Hua and Lyuwei Chen (University of Liverpool, United Kingdom (Great Britain))

Simultaneously achieving accuracy and efficiency is of crucial importance for reverberation chamber (RC) based total radiated power (TRP) measurement. For this purpose, an improved analytical uncertainty model is proposed in this paper. The unbiased maximum likelihood estimator (MLE) of the average Rician K-factor is derived, and two methods are introduced to estimate the number of independent sample numbers for improved accuracy. The proposed model enables fast characterization of the measurement dispersion

without the tedious and inefficient empirical estimation processes. Besides, it has the flexibility to allow different stirring configurations in the calibration stage and the measurement stage, which gives insight into the best practice for TRP measurement. Extensive 9-Point estimation measurements are also conducted in order to verify the performance of the proposed analytical model.

13:50 ***Nonlinear Distortion Investigation Using Mm-Wave Over-The-Air SISO and MISO Measurements***

Hamza Nachouane (Huawei Technologies Sweden AB, Sweden); Thomas Eriksson (Chalmers University of Technology, Sweden); Koen Buisman (University of Surrey, United Kingdom (Great Britain) & Chalmers University of Technology, Sweden)

This paper demonstrates different use cases in Over-the-Air (OTA) measurements to differentiate between different sources of distortion, for the purpose of receiver characterization. We propose to use both single-input single-output (SISO), as well as multiple-input single-output (MISO) test cases. To demonstrate the method, we operated the Chalmers mm-wave MIMO testbed, MATE, at 29.4 GHz in a line of sight test configuration. For the MISO case, a beamforming algorithm is used to steer the beams at one RX. The algorithm exhibits measurement results that agree well with theoretical analysis and are sufficiently stable over time. By sweeping the transmit power, in the SISO and MISO cases, the sources of distortion can be clearly differentiated.

14:10 ***Measurement Challenges for Spectrum Sensing in Communication Networks***

Daniel Kuester, Yao Ma, Dazeh Gu and Adam Wunderlich (NIST, USA); Joseph Mruk (MITRE, USA)

We summarize a few key spectrum sensing measurement challenges and recent advances. Laboratory tests of sensing are complicated by their inseparable and often imbedded role in modern hardware. Results are difficult to calibrate because physical parameters are often specified with ad-hoc or unclear definitions. The scope of testing is increased dramatically by sensors that demand more complex signal classification in addition to binary occupancy detection. Tests of spectrum sharing are encumbered even further by a lack of accepted, testable parameters for assessing the contribution of spectrum sensing to spectrum sharing between systems. The measurement needs and approaches we discuss here cross the domains of guided-wave and radiated physical measurements, network measurements, and commercial and government spectrum use.

14:30 ***Integrating LoS and RIMP Measurements in a Single Test Environment***

John Kvarnstrand, Patrik Svedjenäs, Erik Silfverswärd and Henrik Helmius (Bluetest AB, Sweden)

Bluetest has developed a test system that combines a Compact Antenna Test Range (CATR) with a Reverberation Chamber (RC). This provides a Line-Of-Sight (LoS) test environment together with a Rich Isotropic Multipath (RIMP) test environment simultaneously. This paper outlines the engineering approaches that have been used to make this work.

14:50 ***A Study of Experiment-Based Radio Frequency Electromagnetic Field Exposure Evidence on Stochastic Nature of A Massive MIMO System***

Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)); David Cheadle (National Physical Laboratory, United Kingdom (Great Britain)); Fabien Héliot (University of Surrey, United Kingdom (Great Britain)); Ayodeji Sunday (Keysight Technologies, United Kingdom (Great Britain)); Michael Dieudonné (Keysight Technologies, Belgium)

In this paper, a massive multiple-input-multiple-output (mMIMO) testbed that is capable of mimicking realistic 5G new radio (NR) base station (BS) beamforming performance has been utilised to gather experimental-based evidence of 5G BS RF-EMF exposure within a real-world indoor environment. The mMIMO testbed has up to 128 RF channels with user-programmable software defined radio (SDR) capability. The stochastic nature of the 5G NR mMIMO system has been statistically assessed by evaluating the spatial variation of the RF-EMF exposure surrounding the mMIMO testbed when taking into account different beam profiles and data rates. Several other factors that influence the RF-EMF of mMIMO system have also being considered.

15:10 ***Minimizing the Impact of Positioning Equipment and Support Structure on 5G mmWave Device Testing***

Michael D. Foegelle (ETS-Lindgren, USA)

At millimeter wave frequencies, the mounting and support structure used for positioning a device under test will have significant impact on the measured results. This paper looks at some of the symptoms and illustrates why current measures in the mmWave test plans are insufficient. It then provides some potential solutions.

CS8: Challenges and Solutions of Radio Frequency Tests for 5G Radios

T02 Millimetre wave 5G / Convened Session / Measurements

Room: virtual 2

Chairs: Wei Fan (Aalborg University, Denmark), Pekka Kyösti (Keysight Technologies & University of Oulu, Finland)

13:30 ***Determination of Instantaneous and Maximal Human Exposure to 5G Massive-MIMO Base Stations***

Christian Bornkessel (Technische Universität Ilmenau, Germany); Thomas Kopacz, Anna-Malin Schiffarth and Dirk Heberling (RWTH Aachen University, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

The roll-out of the 5G standard with novel functionalities brings with it the urgent need to evaluate the human exposure to massive-MIMO base stations. This paper discusses concepts for the measurement of instantaneous and maximal exposure in the sub-6 GHz frequency range (FR1). The concepts have been implemented with the NARDA SRM-3006 selective radiation meter. For instantaneous exposure, the Safety Evaluation mode with an averaging over multiple frequency sweeps has been identified appropriate. First results with provoked data traffic revealed exposures below 0.25 % of the ICNIRP 1998 power density reference levels. For maximal possible exposures, the exposure to the synchronization signal and physical broadcast channel block (SSB) should be measured in the Level Recorder mode and extrapolated to the signal bandwidth considering a measurement point-specific gain difference between traffic and broadcast beams. As another outcome of our studies, we argue that code-selective devices for SSB measurements are urgently needed.

13:50 ***Spatial Channel Model Validation for 3GPP FR2 MIMO OTA***

Alfonso Rodriguez-Herrera and Doug Reed (Spirent Communications, USA); Jukka-Pekka Nuutinen (Spirent Communications, Finland)

Recently, 3GPP finished the study item on radiated metrics, and methodologies to verify MIMO performance of UEs. A key aspect of the methodology is the spatial channel model employed to illuminate the UE. It is paramount to verify that the test system creates the intended spatial channel model. Metrics to judge the quality of the generated testing environment will be described, which include Power Delay Profile, Doppler Autocorrelation, V/H, and Power Angular Spectrum Similarity Percentage.

14:10 ***Supporting FR2 Channel Models with a Small Scale UE Chamber***

Jukka-Pekka Nuutinen (Spirent Communications, Finland); Doug Reed and Alfonso Rodriguez-Herrera (Spirent Communications, USA)

3GPP RAN4 has finalized the 5G FR2 (Frequency range 2) radiated test methodology Study Item. It is optimized to two down selected channel models, namely CDL-A InO and CDL-C UMi models. However, there is increasing demand to design a test system that is compliant to the standard, but also capable to implement channel models beyond the standard. This paper discusses the applicability of a standardized test solution to other channel models, as well as how we can include dynamic characterization into the test system.

14:30 ***Multiple CATR Reflector System for 5G Radio Resource Management Measurements***

Corbett Rowell (Rohde & Schwarz, Germany); Benoit Derat (Rohde & Schwarz, Germany); Adrian Cardalda-Garcia (Rohde & Schwarz, Germany)

This paper presents a novel method using multiple compact antenna test range (CATR) reflectors to fulfill the Radio Resource Management (RRM) measurements required for 5G devices capable of beam-forming in the millimeter wave (mmWave) frequency range. Four CATR reflectors are arranged on a vertical semi-circle with the device under test on a 3D positioner in the center of the intersection of four planar waves in order to generate five sets of Angular spreads, thereby capable of simulating multiple base-stations from different directions for mobility procedures and radio link monitoring of a 5G mmWave device. The reflectors create farfield conditions at the device under test so that large quiet zones of up to 30 cm in diameter can be measured in a compact setup. Measurements are performed with both CW and modulated signals in order to demonstrate the applicability of a multiple-CATR setup for simulation of multiple base-station RRM test scenarios.

14:50 ***New Approaches to EMF Measurements of mmWave Devices***

Johan Lundgren, Mats Gustafsson and Daniel Sjöberg (Lund University, Sweden)

Techniques for accurate, robust and efficient over-the-air testing for devices in the next generation communication system are important. One important measure is power density levels for electromagnetic field (EMF) compliance assessment of 5G. This work aims at presenting the use of two techniques. One is an electromagnetic aperture calibration technique, through which field values and power density values are reconstructed at an arbitrary plane in the near-field from a measurement of a separate plane for devices operating in 28-60 GHz. The technique calibrates for the probe interaction, and for the measured position. The second technique is a multiphysical approach in which the measurement is taken using a metasurface and an infrared camera. An investigation into how the techniques performs - for different frequencies, input signals, using synthetic input data, various grid sampling, noise and choice of numerical parameters - is carried out, showing the regions of applicability.

15:10 ***Preliminary Assesment of Millimeter Wave Plane Wave Generator for 5G Device Testing***

Francesco Scattone (Microwave Vision Group (MVG), Italy); Darko Sekuljica (MVG, Italy); Andrea Giacomini, Francesco Saccardi and Alessandro Scannavini (Microwave Vision Italy, Italy); Evgueni Kaverine (MVG Industries, France); Shoaib Anwar (Microwave Vision Group, Satimo Industries, France); Nicolas Gross (MVG Industries, France); Per Iversen (Orbit/FR, USA); Lars Foged (Microwave Vision Italy, Italy)

In this paper, early performance assessments on a newly developed plane wave generator (PWG) at millimeter wave frequencies are reported for the first time. The PWG is integrated in an automated system suitable for 5G testing. Far-field radiation from devices such as pattern, beam pointing, and typical over-the-air (OTA) parameters can be measured in 3D space. Devices are positioned in the quiet zone (QZ) using a RF transparent positioner. Live person testing is feasible, using a chair placed in the system such that the device including head and upper torso of the test person is within the QZ. The PWG based system is described in this paper, including a preliminary evaluation of measurement performance and accuracy at system level. The assessment is based on system simulation, measurement post-processing, and actual test on a pilot system. The PWG technology discussed in this paper is currently being integrated as a standard product.

15:30 Coffee Break

15:50 ***Water-Based Dual-Band Metamaterial Absorber***

Stanislav Stefanov Zhekov, Peng Mei, Wei Fan and Gert Pedersen (Aalborg University, Denmark)

This paper presents a study on a dual-band metamaterial absorber containing water in the structure. Two designs are considered as each absorber contains metal resonators printed on a substrate, a layer of pure water, a metal ground plane, and a layer of plastic isolating the water from the substrate and the metal plate. However, the two absorbers differ in the configuration of the used water container. One of the designs demonstrates one absorption peak at high frequency while the other one two peaks when the metal resonators are removed from the structure. The simulated results reveal that the designs have a narrow low and a wide high frequency absorption band. The absorption performance for different temperatures of the water is studied. The temperature change is taken through a change in the dielectric properties of the water. Some reconfiguration of the absorption performance can be achieved by changing the water temperature.

16:10 ***Near Field Test Methodology for 5G UE FR2 Radiated Performance Measurements***

Ya Jing (Keysight Technologies, China); Zhu Wen (Keysight Technologies Co. Ltd, China); Thorsten Hertel (Keysight Technologies, USA); Li Cao (Keysight Technologies (China) Co., Ltd., China)

This paper proposes a novel NF test methodology with simple transformation together with the associated minimum NF range length requirement. The new NF minimum test distance is derived using Matlab and CST simulations and spherical wave mode analyses. EIRP, phase array center offset estimations and TRP simulation statistical analyses are shown to demonstrate the applicability of the new NF testing methodology.

16:30 ***New CTIA Standard Phantoms for OTA Testing***

Michael D. Foegelle (ETS-Lindgren, USA); Niels Kuster (Foundation for Research on Information Technologies in Society, IT'IS Foundation, Switzerland); Fereshteh Rouholahnejad (SPEAG, Switzerland); Erdem Ofli (Schmid & Partner Engineering AG, Switzerland); Kevin Li (Fitbit, USA)

CTIA is introducing a new series of near-field phantoms for over-the-air testing. These phantoms cover a wide range of body-worn device usage cases and add support for 5G FR1 and FR2 testing.

16:50 ***Platform for Digital Voice Communication with Channel-Based Key Generation***

Jelle Jocqué and Patrick Van Torre (Ghent University, Belgium); Jo Verhaevert (Ghent University - imec, Belgium); Hendrik Rogier (Ghent University, Belgium)

This paper proposes a novel method for the integration of channel-based key generation in a real-time digital voice communication system. For this purpose, a specific hardware platform was developed. To obtain the keys for the cipher, channel-based key generation is used to generate identical keys on both sides of the channel, based on the unique reciprocal channel characteristics. Hamming code key reconciliation drastically reduces the probability of remaining key errors, while a cyclic redundancy check (CRC) is used as a final checking mechanism. As a proof of concept, the generated key is used to encrypt as well as decrypt the audio by means of an XOR operation at both sides of the link. Several measurements were performed, showing that new keys are continuously being formed and replaced. Additional measurements also create more insight into the key update rate and key entropy for different parameter settings in the algorithm.

CS42: IRACON Propagation Measurements and Modelling for 5G and beyond

T02 Millimetre wave 5G / Convened Session / Propagation

Room: virtual 3

Chairs: Marina Barbiroli (University of Bologna, Italy), Sana Salous (Durham University, United Kingdom (Great Britain))

13:30 ***What Can We Do with 5G?! [INDUSTRIAL KEYNOTE]***

Bo Göransson (Ericsson, Sweden & KTH, Royal Institute of Technology)

5G NR based networks are rolled out globally. A diverse set of deployment strategies and frequency bands can be used to provide large area coverage, very high capacity, and low latency networks for a diverse set of applications. Here we present some deployment strategies based on fundamental propagation properties. We also show the importance of using and combining the available spectrum asset in a deployment scenario to maximize performance. Finally, some results obtained from a deployment study in a major city is presented where the expected performance of the network based on deployment strategy is reported.

13:50 ***Angular-Resolved Measurements of Building Entry-Loss for Energy-Efficient Building at 28 GHz***

Martin Johansson (Ericsson Research, Sweden); Christina Larsson (Ericsson Research & Ericsson AB, Sweden)

This paper presents angular-resolved outdoor-to-indoor measurements on an energy-efficient building with open-plan offices at 28 GHz. The impact of floor level and distance from wall on path loss and angular spread for different indoor traces are presented.

14:10 ***Measurements of Reflection and Penetration Loss in Indoor Environments in the 39-GHz Band***

Wenfei Yang (The University of Sheffield, United Kingdom (Great Britain)); Jie Huang (Southeast University, China); Jiliang Zhang (The University of Sheffield, United Kingdom (Great Britain)); Yuan Gao (Ranplan Wireless Network Design Ltd, United Kingdom (Great Britain)); Sana Salous (Durham University, United Kingdom (Great Britain)); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

This paper presents measurements for reflection and penetration loss of building materials in the 39-GHz band. Measurements were conducted onsite of an interior wall in a conference room. Assuming the measured interior wall as an infinite homogeneous single-layer slab, the relative permittivity was estimated based on the measurements using the least-squares fitting. The measured material was found similar reflectivity but less transmissivity than the plasterboard given in the ITU standards. The measurement results provide insights into electromagnetic (EM) properties of building materials in the 39-GHz band, which can be employed in future indoor radio propagation predictions.

14:30 ***Experimental Characterization of Air-To-Ground Propagation at Mm-Wave Frequencies in Dense Urban Environment***

Enrico M. Vitucci (University of Bologna, Italy); Vasilii Semkin (VTT Technical Research Centre of Finland, Finland); Maximilian James Arpaio, Marina Barbiroli and Franco Fuschini (University of Bologna, Italy); Claude Oestges (Université Catholique de Louvain, Belgium); Vittorio Degli-Esposti (University of Bologna, Italy)

In the present study, a measurement setup utilizing mm-wave transceivers with steerable directive antennas, mounted on both a customized UAV and a ground station has been used to study Air-to-Ground (A2G) radio links and, more generally, full-3D mm-wave propagation in urban environment. We evaluate the double-directional characteristics of the channel by rotating the antennas, deriving Power-Angle Profiles at both link ends. Preliminary results provide useful understanding of A2G propagation, e.g. the influence of the antenna tilt angles, or the mechanisms allowing for the signal to propagate from street canyons to the air.

14:50 ***On the Parametrization and Statistics of Propagation Graphs***

Richard Prüller (TU Wien, Austria); Thomas Blazek (Silicon Austria Labs GmbH, Austria); Stefan Pratschner and Markus Rupp (TU Wien, Austria)

Propagation graphs (PGs) serve as a frequency-selective, spatially consistent channel model suitable for fast channel simulations in a scattering environment. In this contribution, we propose a new parametrization for PGs that adheres to the doubly exponentially decaying cluster structure of the Saleh-Valenzuela (SV) model. We show how to compute the newly proposed internal model parameters based on an approximation of the K-factor and the two decay rates from the SV model. Furthermore, via the singular values of multiple-input multiple-output (MIMO) channels, we compare the degrees of freedom (DoF) between our new and another frequently used parametrization. Specifically, we compare the DoF loss when the distance between antennas within the transmitter and receiver arrays or the average distance between scatterers decreases. It is shown that, in contrast to the typical parametrization, our newly proposed parametrization loses DoF in both scenarios, as one would expect from a spatially consistent channel model.

15:10 ***Multi-Band Measurements in Indoor Environments***

Sana Salous, Amar Al-Jzari, Mohamed Abdulali and Jack Towers (Durham University, United Kingdom (Great Britain))

This paper presents results of path loss measurements, in two indoor environments for both LoS and NLoS scenarios across a frequency range from 0.6-73 GHz using the multi-band custom designed channel sounders developed at Durham University. The data are analysed to estimate the path loss parameters for each frequency band with either the close in path loss model which assumes free space loss at 1 m reference distance and the floating intercept path loss model which estimates both parameters of the path loss model. The data across the multiple bands are then combined to generate a single set of coefficients for a frequency dependent path loss model. The median and 90% values of the rms delay spread values for a 20 dB threshold are presented across the frequency range of 0.6-39 GHz.

15:30 Coffee Break

15:50 ***Characterization of Slow and Fast Fading in V2I Channels for Smart Cities***

Nina Hassan, Christian Schneider and Reiner S. Thomä (Ilmenau University of Technology, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

A vehicle to X (V2X) propagation channel corresponds to a wideband channel that means a receiver (Rx) able to resolve multipath components. In contrast to a narrow band channel, multipath components are indistinguishable at the receiver and seen as a single composite signal, thus fading approximation has been assumed as the Rayleigh fading. It is interesting to see how the fading is characterized in V2X applications because the channel corresponds to the wideband and it can not be assumed to follow wide sense stationary uncorrelated scattering (WSSUS) assumption due to inherent mobility. The aim of this paper is to characterize and study slow fading and fast fading variations of each tap, which is selected from measurement data. This investigation pertains to three various scenarios, which are omnidirectional antenna, two antennas faced directly to each other and two antennas faced away from each other. In each scenario, LOS and two different NLOS categories are studied.

16:10 ***On the Modelling of the NLOS First Multi-Path Component in Stochastic Spatial Channel Models***

Diego Dupleich (Technische Universität Ilmenau, Germany); Hassan Mir (Techsnische Universität Ilmenau, Germany); Christian Schneider (Ilmenau University of Technology, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany); Reiner S. Thomä (Ilmenau University of Technology, Germany)

Positioning and localization is one of the key features in the 5G and beyond wireless networks. Since accuracy strongly depends on the channel conditions, channel models are of special importance for the testing and development of such applications. While several localization methods are based on the time of arrival (ToA) and time-difference of arrival (TDoA), stochastic spatial channel models (SCMs) as the 3GPP don't consider absolute values on the delays of the NLOS multi-path components (MPCs), making these models not appropriate for these applications. Therefore, we investigate the time and angular characteristics of the first multi-path component (FMPC) using multi-band ray tracing (RT) simulations in order to extend stochastic SCMs to support localization applications in NLOS.

16:30 ***Time-Gating Technique to Emulate New Scenarios***

Alejandro Ramírez-Arroyo (University of Granada, Spain); Antonio Alex-Amor (Technical University of Madrid, Spain); Carmelo García-García and Angel Palomares-Caballero (Universidad de Granada, Spain); Pablo Padilla (University of Granada, Spain); Juan Valenzuela-Valdés (Universidad de Granada, Spain)

This paper presents the applicability of using the time-gating technique to propagation measurements in order to recreate new scenarios. This technique, which has been studied previously in antenna measurements, is applied in propagation measurements to modify and tune the reflections that a particular propagation scenario exhibits. A new configuration for shielded chambers is proposed, where half of the chamber is covered with absorbers (anechoic chamber) and half without absorbers (reverberation chamber). This configuration and the time-gating technique allow the study of the propagation environment for the new recreated scenarios.

16:50 ***Measured Blockage Effect of a Finger and Similar Small Objects at 300 GHz***

Pekka Kyösti (Keysight Technologies & University of Oulu, Finland); Nuutti Tervo (University of Oulu, Finland); Markus Berg (University of Oulu & Excellant LTd., Finland); Marko E Leinonen, Klaus Nevala and Aarno Pärssinen (University of Oulu, Finland)

We study the effect of a finger, and other objects with similar shape, on the channel gain in short distance propagation measurements at 220-330 GHz. Channel impulse responses and channel gains of six objects are analyzed on different positions obstructing a 35 cm LOS link. The intention is to evaluate potential user effects on portable devices supporting the future 6G system. Very short wavelength and link distance cause strong fluctuation of channel gain even on millimetre scale movement of obstacles. The finger phantom causes 44 dB attenuation on close vicinity, 5 mm, of transmitter antenna and has similar attenuation pattern with corresponding metallic stripes. On the contrary, it is observed that some objects, such as the measured Teflon rod, may even increase the signal strength. These impacts are important when studying the wave propagation and network aspects of high frequencies systems.

17:10 ***A WSSUS Channel Based PER Model for 802.11p Communications on 5.9 GHz***

Nils Dreyer and Morten Diestelhorst (TU Braunschweig, Germany); Thomas Kürner (Technische Universität Braunschweig, Germany)

The simulation of V2V communication requires a suitable Packet Error Rate model that maps the predicted SNR to the expected PER. The simulators NS-3 and OMNeT++/Veins, both commonly used for V2V communications, apply the NIST model that is derived from analytical analysis of an AWGN channel. Investigations inside a link level simulator revealed a clear mismatch of the NIST PER when considering a realistic stochastic V2V channel. In this paper, a PHY layer simulator for IEEE 802.11p was used to model the true impact of channel estimation, modulation and coding on the PER. The radio channel was modelled by a WSSUS based V2X channel model as proposed by Acosta-Marum and Ingram. An extensive study with varying payload size and SNR revealed a new set of equations enabling the computation of a more realistic PER for arbitrary SNR values and packet sizes that can be easily applied inside system-level simulators.

CS22: Microwave Biomedical Imaging: Innovative Methods and Systems Towards Clinical Applications

T05 Biomedical and health / Convened Session / Electromagnetics

Room: virtual 5

Chairs: Sandra Costanzo (University of Calabria, Italy), Natalia Nikolova (McMaster University, Canada)

13:30 ***Elliptical Monopole Antenna Design for the Early Breast Cancer Imaging at High Frequencies***

Duy Hai Nguyen (Goethe University Frankfurt, Germany); Jochen Moll (Goethe University Frankfurt am Main, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany); Vittorio Memmolo (University of Naples Federico II, Italy); Joran Rixen (RWTH Aachen, Germany); Gernot Zimmer (Frankfurt University of Applied Sciences, Germany)

This paper presents a design of an ultra-wideband, slotted, elliptical monopole antenna for breast cancer imaging. The antenna has a compact size of 9 mm 7 mm to cover the frequency range from 16 to 24 GHz. Its operation is optimized to direct contact with the patient breast's skin without any coupling medium. On top of that, the antenna also features as an electrode for the electrical impedance tomography (EIT) applications. Experimental results on a female volunteer's breast verify the excellent microwave performance of the antenna. In addition, the results also indicate the reliability of the breast tissues models, which were used in the simulation. Finally, a simple EIT measurement setup also demonstrates the multifunctional detection capabilities from the antenna element.

13:50 ***Low-Complexity Amplitude-Only Breast Imaging Technique***

Sandra Costanzo and Giuseppe Lopez (University of Calabria, Italy)

A low-cost two-dimensional amplitude-only tomography procedure is analyzed in this work. An iterative phaseless inversion scheme is adopted, based on the contrast source formulation of the electric field integral equation for the transverse magnetic case. The inversion method does not involve a phase retrieval stage, thus resulting into a one-step reconstruction approach. The proposed strategy is tested on simple and more realistic numerical breast models, while the forward model is developed with a conjugate-gradient Fast Fourier Transform approach. Furthermore, the design of the required acquisition setup is discussed, as a first step towards an experimental validation of the proposed phaseless tomography approach.

14:10 ***A Quantitative Approach for Millimeter-Wave Breast Cancer Imaging***

Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy); Simona Di Meo (University of Pavia, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Tommaso Isernia (University of Reggio Calabria, Italy); Giulia Matrone and Marco Pasian (University of Pavia, Italy)

The incidence rate of breast cancer among women worldwide shows an increasing trend. Several breast-imaging methods are currently used. However, the proposal of new methods for breast imaging is still a hot topic in the scientific community. Microwave imaging

systems are attracting great interest. Several prototypes with central frequencies from few to tens of GHz have been proposed. In this paper, a quantitative solution combining both approaches for millimeter wave imaging of the breast is proposed. In particular, the radar approach is used to quickly detect the possible presence of a suspicious region, while the derivation of the nature of the lesion is pursued via a tomographic approach. Here the main idea is presented, along with a possible road map for further developments.

14:30 ***Validation of Wavelia Microwave Breast Imaging System Using Mammography Breast Density***

Yazan Abdoush (MVG Industries, France); Angie Fasoula (Microwave Vision Group, France); Luc Duchesne (MVG Industries, France); Julio Daniel Gil Cano (Microwave Vision (MVG), France); Brian M. Moloney, Sami M. Abd Elwahab and Michael Kerin (Lambe Institute for Translational Research, Ireland)

This paper presents a method for transforming the coordinates of regions of interest from 2D mammograms to a 3D spatial reference frame using estimates of breast tissue thickness provided by an available software for mammography data analysis. The method was developed to assist in interpreting and validating the 3D findings of a microwave breast imaging apparatus known as Wavelia against mammography. Results from the First-in-Human clinical investigation with the Wavelia system are used to illustrate the potential and feasibility of the proposed technique.

14:50 ***Optimisation of Artefact Removal Algorithm for Microwave Imaging of the Axillary Region Using Experimental Prototype Signals***

Daniela M. Godinho (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal)

Microwave Imaging (MWI) has the potential to aid breast cancer staging through the detection of Axillary Lymph Nodes (ALNs). This type of system can present some challenges, mainly due to the irregular axillary surface. The optimisation of the artefact removal algorithm to successfully remove the surface reflections is of great importance. In this paper, we propose using Singular Value Decomposition (SVD) as an artefact removal algorithm and study the effect of choosing different subsets of antenna positions for artefact removal on imaging results using experimental signals. We show that different subsets of antenna positions affect the results and in some cases prevent the targets detection. Our analysis allowed us to find an optimal combination of parameters which results in Signal-to-Clutter Ratio higher than 2.77 dB and Location Error lower than 14.9 mm for three different experimental tests. These results are relevant for the development of dedicated algorithms for ALN-MWI application.

15:10 ***UWB Planar Bias-Switched Imaging Array for Breast-Cancer Screening***

Vartika Tyagi, Natalia Nikolova, Farzad Foroutan, Chih-Hung Chen and Charl Baard (McMaster University, Canada)

Electronically switched arrays offer superior measurement speed and positioning certainty compared with mechanical scanning. These advantages are important in the applications of microwaves in medical imaging. However, current RF-switch architectures suffer from inherent limitations on the number of multiplexed ports, the relatively large size, the significant insertion loss, limited isolation, and high price. Here, we present a novel bias-switched architecture for microwave-imaging arrays, which eliminates the use of RF switches by shifting the burden of port multiplexing to the intermediate-frequency (IF) output. It makes full use of the dynamic range of a vector network analyzer while multiplexing hundreds of array elements. The design and performance of the system components is briefly described as well.

15:30 Coffee Break

15:50 ***A Microwave Imaging Technique for Neck Diseases Monitoring***

Chiara Dachena and Alessandro Fedeli (University of Genoa, Italy); Alessandro Fanti and Matteo Lodi (University of Cagliari, Italy); Matteo Pastorino and Andrea Randazzo (University of Genoa, Italy)

A microwave imaging approach for the diagnosis of neck diseases is proposed in this paper. Specifically, the case study of cervical myelopathy has been considered. The developed technique aims at retrieving the distributions of the dielectric properties of a cross section of the neck, from which information about the spinal canal size can be extracted. To this end, a new hybrid inversion procedure exploiting a qualitative delay-and-sum method together with a conjugate-gradient-like scheme developed in Lebesgue spaces has been used. The feasibility of the approach has been assessed by means of a prototype of measurement system equipped with ten bowtie-like antennas and using a simplified phantom. Preliminary experimental results are reported.

16:10 ***Microwave Imaging for Monitoring Patients Post-Radiation Treatment: An Initial Investigation***

Katrin Smith, Jeremie Bourqui and Petra Grendarova (University of Calgary, Canada); Mark Lesiuk (Tom Baker Cancer Center, Canada); Sarah Quirk, Michael Roumeliotis and Elise Fear (University of Calgary, Canada)

In this preliminary study, we investigate how changes in breast tissue due to radiation treatment can be quantified using microwave signals, images, and property estimates. Microwave scans of treated and healthy breasts from a group of cancer patients before and after radiation treatment are compared. Images of the treated breasts generally had an increase in permittivity after treatment, while the healthy breast remained relatively constant over the timeframe. In a case study, the permittivity estimated at various microwave sensor pairs was generally higher for the treated breast compared to the healthy breast, however changes were small in the reported patient. For this example, the signal correlation between scans was high and similar for both the treated and the healthy scan. For the same patient, image correlation highlighted differences between the baseline and follow-up scans, suggesting that image correlation may be a better metric for quantifying changes.

16:30 ***Impact of Rotational Artefact Removal on Microwave Breast Images***

Hamza Benchakroun (National University of Ireland Galway, Ireland); Martin O'Halloran (National University of Ireland, Galway, Ireland); Declan O'Loughlin (Trinity College Dublin, Ireland)

Microwave breast imaging continues to be evaluated in clinical investigations, with many ongoing at the moment worldwide. A key technical challenge of the method involves removing or compensating for the large reflection from the skin which many be more than an order of magnitude larger than reflections from the interior. Despite showing promise in experimental and clinical trials, the fundamental basis of rotational artefact removal and the potential impact on the resultant image has not been examined in detail. In this work, numerical simulations are used to demonstrate that the angle of rotation chosen may impair the resultant image quality and tumour detection. These results suggest that further investigation of rotational artefact removal is necessary.

16:50 ***A Terahertz Electromagnetically Induced Transparency-Like Metamaterial for Biosensing***

Shohreh Nourinovin and Akram Alomainy (Queen Mary University of London, United Kingdom (Great Britain))

In this paper, we proposed a metamaterial structure that exhibits electromagnetically induced transparency-like (EIT-like) Fano resonance. The structure is consisting of asymmetric split-ring resonators in which, by increasing the asymmetry, a transparency window occurs with a pick at 1.94 THz. The electromagnetic field distribution and surface current flow studied and also the EM simulation result of the transmission spectra validated through the theoretical calculation of the coupled harmonic oscillators model. It proves that by changing the asymmetry degree from 12 to 20 µm, non-radiation damping decreases from 11.7 to 6, and the coupling coefficient improves from 2.2 to 3.7. Furthermore, the potential of the structure for an ultra-sensitive, non-label, and low-cost biosensor investigated. For this aim, by applying an analyte with a thickness of 18 µm, remarkable theoretical sensitivity of 550 GHz/RIU along with a narrower FWHM and a higher Q factor of 6.46 achieved.

CS11: Convergence of Mobile Radio and Radar

T08 Positioning, localization & tracking / Convened Session / Propagation

Room: virtual 6

Chairs: Thomas Dallmann (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany), Reiner S. Thomä (Ilmenau University of Technology, Germany)

13:30 ***MIMO-OCDM-Based Joint Radar Sensing and Communication***

Lucas Giroto de Oliveira, Benjamin Nuss, Mohamad Basim Alabd, Yueheng Li and Liquan Yu (Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)

This study investigates two multiplexing schemes for enabling multiple-input multiple-output (MIMO) operation of orthogonal chirp-division multiplexing (OCDM)-based Radar-Communication (RadCom) systems, namely code-division multiplexing (CDM) via outer coding and frequency-division multiplexing (FDM) via frequency shift precoding (FSP). After detailed system model description for both multiplexing strategies, radar and communication aspects of the studied MIMO-OCDM RadCom system are analyzed having the conventional MIMO-OFDM RadCom as a baseline. Finally, it is concluded that CDM based on outer coding may yield better radar and communication performance than its FDM counterpart, while still outperforming MIMO-OFDM in terms of communication at the cost of higher range sidelobe level.

13:50 ***Joint Communication and Radar Sensing: An Overview***

Reiner S. Thomä (Ilmenau University of Technology, Germany); Thomas Dallmann (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Snezhana Jovanoska (Fraunhofer FKIE, Germany); Peter Knott and Anke Schmeink (RWTH Aachen, Germany)

This paper provides an overview of recent developments in Joint Communication and Radar Sensing (JCRS) systems and networks. Our discussion will focus on system architectures that can be used with JCRS and on approaches to select, generate and process waveforms suitable for both communication and sensing. In addition, advantages and challenges of assembling a network out of several JCRS nodes are addressed. Finally, we give an outlook to possible applications of JCRS networks, which we see in autonomous driving and low altitude air traffic control.

14:10 ***Experimental Investigation of Phase Coded FMCW for Sensing and Communications***

Utku Kumbul, Nikita Petrov and Fred van der Zwan (Delft University of Technology, The Netherlands); Cicero S Vaucher (NXP Semiconductors, Eindhoven & Delft University of Technology, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands)

The phase coded FMCW and its properties for joint sensing and communication are studied. Two different receiver structures for the sensing properties of this waveform are compared theoretically and experimentally. It is shown both by simulations and experiments that the phased coded FMCW combines communication capabilities of PMCW and sensing capabilities of FMCW while using a realizable hardware complexity for an automotive radar.

14:30 ***Interference Mitigation Methods for Coexistence of Radar and Communication***

Sumit Kumar (SnT, University of Luxembourg, Luxembourg); Kumar Vijay Mishra (United States Army Research Laboratory, USA); Sumit Gautam (University of Luxembourg, Luxembourg); Bhavani Shankar Mysore R (Interdisciplinary Centre for Security, Reliability and Trust & University of Luxembourg, Luxembourg); Björn Ottersten (University of Luxembourg, Luxembourg)

The aspect of coexistence between cellular communication systems and radar using spectrum sharing has gained significant research interest in the recent years. In this article, we consider a communication-centric spectrum sharing scenario where the communication link needs to meet a minimum service constraint, measured in terms of throughput, while the radar tries to maximize its Signal to Interference-plus-Noise Ratio (SINR). Prior works on joint power allocation indicate that under a communication-centric scenario, the radar gradually reduces its transmit power as the throughput demand for communication link increases. Such an approach results in severe degradation of radar SINR, especially when the communication link goes into outage. We address these issues and propose methods based on Successive-Interference-Cancellation to improve the SINR of radar. Our method is comprised of a combination of coexistence and coordination. Simulation results show significant improvement in radar SINR whenever communication throughput demand rises and eventually goes into outage.

14:50 ***Analysis of a Chirp-Based Waveform for Joint Communications and Radar Sensing (JC&S) Using Non-Linear Components***

Andre N Barreto (Barkhausen Institut gGmbH, Germany & Universidade de Brasilia, Brazil); Thuy Minh Pham (Barkhausen Institut gGmbH, Germany); Sandra George (Barkhausen Institut, Germany); Padmanava Sen (Research Group Leader, Barkhausen Institut gGmbH, Germany); Gerhard Fettweis (Barkhausen Institut, Germany)

Joint communications and radar sensing (JC&S) is expected to be one of the key features in beyond 5G (B5G) networks, allowing the provision of radar as a service (RaaS). In this paper, we are interested in a chirp-based waveform that can be effectively employed for both communication and radar applications. More specifically, we investigate the performance of such a waveform in the presence of realistic non-linear power amplifiers (PA) and low-noise amplifiers (LNA), operating at mmWave frequencies.

15:10 ***Design of Phased Array Architectures for Full-Duplex Joint Communications and Sensing***

Mikko Heino, Carlos Baquero Barneto, Taneli Riihonen and Mikko Valkama (Tampere University, Finland)

The short wavelength of millimeter-waves in fifth-generation (5G) mobile communications enables the implementation of multi-element antenna arrays in relatively small space, e.g., in user devices and small base stations. Joint communication and sensing (JCAS) is a scheme which utilizes the beamsteering capabilities of the multi-element antenna arrays for simultaneously maintaining a communication link and sensing the surroundings with a radar beam and receiving it with the same device. The simultaneous transmission and reception requires a beam weighting algorithm which cancels the self-interference while at the same time maintaining the integrity of both beams. In this paper, the performance of different linear patch antenna array architectures is studied in terms of obtained self-interference cancellation and obtained maximum gain in the beamsteering range. A mirror-beam problem in the SI-cancellation algorithm for parallel arrays is studied and novel coupling randomization is introduced for the arrays to prevent the forming of the mirror beams.

CS17: GNSS Antennas and Systems for Challenged RF Environment

T08 Positioning, localization & tracking / Convened Session / Antennas

Room: virtual 7

Chairs: Loic Bernard (ISL, France), Michel Clénet (Defence Research and Development Canada, Canada)

13:30 ***Automotive GNSS Antenna Platform-Induced Group Delay Biases on GPS L1 Signals***

Thomas Kaufmann and Olivier Julien (U-blox AG, Switzerland)

The placement of the antenna on a vehicle platform plays a crucial role in the performance of a GNSS positioning system. Based on empirical data, it is shown that different antenna positions on a vehicle yield variations in the C/N0 values and pseudo-range measurement biases over azimuth and elevation. Fast variations of the latter can impede the positioning accuracy. With simulations it was possible to coarsely recreate this behavior, demonstrating that these effects are real and important for the performance of a high integrity GNSS positioning system.

13:50 ***Real Time GNSS Spoofing Detection and Cancellation on Embedded Systems Using Software Defined Radio***

Jean-Michel Friedt (FEMTO-ST Time & Frequency, France); Weike Feng (Xidian University, China); David Rabus and Gwenhael Goavec-Merou (FEMTO-ST, France)

Global Navigation Satellite Systems have become ubiquitous to most daily activities requiring Positioning, Navigation and Timing and yet have become increasingly subject to spoofing and jamming, partly due to the availability of affordable software defined radio platforms allowing such functionalities. Despite novel modulation schemes and broader frequency bands, GPS L1 at 1575.42 MHz remains the main signal source for most consumer grade receivers. We address real time spoofing and jamming mitigation using a software defined radio approach in which the raw (I,Q) coefficients collected by the radiofrequency frontend are analyzed for spoofing detection by assessing the phase difference of the GPS signals collected by different antennas. These signals are possibly cleaned from the interfering sources by null-steering when spoofing or jamming is detected, and the cleaned signal are used for real time Position and Navigation information extraction using the opensource gnss-sdr framework.

14:10 ***Investigation of Printed Meander-Line Bow-Tie Structures for GNSS Antenna Elements and Arrays with Planar-3D Integral Equation Methods***

Thomas Vaupel (Fraunhofer FHR, Germany)

This contribution deals with the first design of an antenna element for the GPS-L1 frequency based on crossed dipoles with a meander-line bow-tie geometry leading to a high size reduction rate. The structure can be printed on a PCB together with other components leading to a cheap and robust fabrication. For the simulation of such structures, our planar-3D integral equation framework is very well suited with an own mesh generation and further enhanced quadrature strategies and redundancy reduction algorithms. SMD-elements for the matching circuit are incorporated as line impedances. First the admittance behavior of the dipole structure is derived to generate a circular polarization followed by a fine tuning of the combined structure to get minimum axial ratio. The element values of the matching circuit are determined with a particle swarm method which are further optimized by full simulations with the integrated matching network.

14:30 ***New Approach in Antenna Design Automation Applied to a Dual-Band GNSS Micro-Array***

Lionel Rudant and Lotfi Batel (CEA-Leti, France); Antonio Clemente (CEA-LETI Minatec, France); Christophe Delaveaud (CEA-LETI, France)

This article describes a new approach in antenna design automation. We propose to use a micro-array of coupled antennas loaded by impedances and to perform the optimization of these impedance values in order to reach specific design goals. In particular, we present a demonstration for dual-band GNSS that requires good RHCP gain (in the range -2 dBic to 0 dBic) and low LHCP gain (below -10 dBic). The proposed automated design process has been able to meet these requirements jointly in L2 (1215-1240 MHz) and L1 frequency bands (1560-1610 MHz). A prototype has been fabricated, and characterized in anechoic chamber to validate the proposed design methodology.

14:50 ***Performance Testing of a Distributed Automotive Satellite Navigation Array with Jammer in Virtual Environment***

Syed Naser Hasnain and Ralf Stephan (Technische Universität Ilmenau, Germany); Marius Brachvogel (RWTH Aachen University, Germany); Michael Meurer (German Aerospace Center (DLR) & RWTH Aachen University, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

State-of-the-art antenna arrays require a significant installation area when envisaged for compact passenger cars, whose footprint area can be reduced by splitting the full array into two smaller, spatially distributed sub-arrays. The challenge of grating lobes develops while arranging the sub-arrays several wavelengths apart mounted on distant parts of a car. As a consequence, spatial sampling of the incident waves leads to ambiguous direction-of-arrival estimation. An inhomogeneous L-shaped orthogonal arrangement can, however, mitigate such drawbacks to some extent while allowing easier installation. The performance of such an array needs to be tested in a virtual electromagnetic environment in the course of the development process, even long before homologation. An example of such distributed array mounted on a conventional passenger car for satellite navigation is shown in this paper, and the array performance is tested in terms of positioning accuracy in presence of a jammer in our automotive antenna test facility.

15:10 ***Agile Dielectric Resonator Antenna with an Integrated Feeding Circuit for Polarization Diversity***

Maksim Kuznetcov (Heriot Watt University, United Kingdom (Great Britain)); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain)); Jonathan Johnstone (The Royal Military College of Canada, Canada); Michel Clénet (Defence Research and Development Canada, Canada); Yahia Antar (Royal Military College of Canada, Canada)

A polarization agile dielectric resonator antenna (DRA) with an integrated feeding circuit is presented offering a bandwidth of 40%. The antenna utilizes a dielectric resonator (DR) with a relative dielectric constant of 27 and two bonded FR-4 PCBs to feed the antenna. This dielectric resonator circuit system (DRCS) consists of meandered power dividers, delay lines, and surface mount hybrid-couplers which feed four radial slots etched under the cylindrical DR element. This DRCS offers right-handed circular polarization (RHCP), left-handed circular polarization (LHCP), and two orthogonal linear polarization (LP) states. The described DRCS is compact with values of 90.0x90.0x18.1 mm 3 for operation in the L-band. Such a polarization diverse antenna can be used in RF challenging environments as well as GPS/GNSS scenarios where the dominant polarization is not known apriori. Other applications include duplex systems, radar, wireless communications, and signal processing techniques where polarization selectivity of the antenna is of interest.

15:30 Coffee Break

15:50 ***A Miniaturized All-GNSS Bands Antenna Array Incorporating Multipath Suppression for Robust Satellite Navigation on UAV Platforms***

Simon P Hehenberger and Veenu Tripathi (DLR- German Aerospace Center, Germany); Wahid Elmarissi and Stefano Caizzone (German Aerospace Center (DLR), Germany)

Nowadays, an increasing trend to use autonomous Unmanned Aerial Vehicles (UAV) for applications like logistics as well as security and surveillance can be recorded. Autonomic UAVs require robust and precise navigation to ensure efficient and safe operation even in strong multipath environments and (intended) interference. The need for robust navigation on UAVs implies the necessary integration of low-cost, lightweight, and compact array antennas as well as structures for multipath mitigation into the UAV platform. This article investigates a miniaturized antenna array mounted on top of vertical choke rings for robust navigation purposes. The array employs four 3D printed elements based on dielectric resonators capable of operating in all GNSS bands while compact enough for mobile applications such as UAV.

16:10 ***Versatile Wideband Annular DRA with Loaded Core***

Slobodan Jović (Defence R&D Canada, Canada); Michel Clénet (Defence Research and Development Canada, Canada); Yahia Antar (Royal Military College of Canada, Canada)

The concept of an antenna based on a loaded annular dielectric resonator (DR) is further developed. In this work it is shown that loading of an annular DR inner wall with a one-dimensional array of metalized periodic elements can induce versatile responses. Such loads appear to behave like the electromagnetic band-gap structure (EBG) affecting primarily the field line terminations around the loaded area. It is shown here that such antenna can produce a narrow or wide stop-band or just a wideband response using the same resonator. In all the cases the antenna demonstrates HE 11δ mode resonances outside the bandwidth of a simple cylindrical or annular DR of similar dimensions and the same ε r value.

16:30 ***Small CP Cavity-Backed Magneto-Electric Antenna with Parasitic Elements for GNSS Applications***

Alexandre Causse (Université de Rennes 1, France); Loic Bernard (ISL, France); Ala Sharaiha (Université de Rennes 1 & IETR, France); Sylvain Collardey (University of Rennes 1, France)

In this paper a small dual-band cavity-backed magnetoelectric (ME) antenna is proposed. This antenna is circularly polarized (CP) and designed to operate in all GNSS bands (1.164 - 1.30 GHz and 1.559 - 1.61GHz). Parasitic elements are added to create additional resonance. It exhibits axial ratio (AR) < 1.3dB in all the considered bands and small external dimensions of 90x90x37.5 mm3 (0.346x0.346x0.144 λ3 at lowest frequency). It also provides a regular broadside gain of 5.2 dBic.

16:50 ***Challenges of GNSS Reception Onboard a Small UAV in RF-Disturbed Environment***

Hrvoje Covic, Armin Schneider and Loic Bernard (ISL, France)

This paper gives an overview of the potential threats to GNSS navigation with the focus on the radio frequency interference and proposes solutions to mitigate them at the antenna level. Examples of single and antenna array solutions are presented, and finally it is shown what can be done with the small UAVs.

CS24: Active Antennas for Space Telecon Applications

T09 Space (incl. cubesat) / Convened Session / Antennas

Room: virtual 8

Chairs: Jean Philippe Fraysse (Thales Alenia Space, France), Carolina Tienda (Airbus Defence and Space, United Kingdom (Great Britain))

13:30 ***Ku-Band Feed with Integrated Matrix Power Amplifier***

Michael Kilian (Airbus Defence and Space GmbH, Germany); Jürgen Kassner and Patrick Soboll (IMST GmbH, Germany); Michael Schneider (Airbus Defence and Space GmbH, Germany)

Large geostationary high-power satellites for broadcast application still form an important market segment for satellite industry. They require, however, new technical features that enable cost reductions, in-orbit flexibility and efficient use of available resources. This paper addresses an active Ku-band feed chain as core element for future direct radiating arrays or array-fed reflector antennas on broadcast satellites.

13:50 ***Meandered Waveguides for Active Antennas***

Esteban Menargues (SWISSto12, Switzerland); María García-Vigueras (IETR-INSA Rennes, France); Santiago Capdevila (SWISSto12, Switzerland); Piero Angeletti (European Space Agency, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

Meandered Waveguides are novel RF components which may play a disruptive role in phased array antennas. They permit to guarantee low propagation losses, comparable to the ones of conventional waveguides, combined with an increased freedom in defining their path, comparable with the one associated to flexible coaxial cables. In addition, meandered waveguides can provide a full control of the phase, which is fundamental to design Beam Forming Networks. Additive Manufacturing represents today the best technology to realize meandered waveguides with improvements in terms of cost, complexity, accommodation, and accuracy. In the paper in order to demonstrate the effectiveness of meandered waveguides possible exploitations in active arrays and discrete constrained lenses are proposed.

14:10 ***Multi-Beam Electronically Steerable Antenna Array Concepts for an X-Band Deep Space Gateway Data Link***

Cesar Dominguez (Airbus DS, The Netherlands); Alessandro Garufo (TNO Defence Security and Safety The Netherlands); Antonio Montesano (AIRBUS DS, Spain); Stefania Monni (TNO Defence Security and Safety, The Netherlands); Benedetta Fiorelli (European Space Agency, The Netherlands)

In the recent years, the interest of active phased arrays for SATCOM and space data link application has increased. In particular, ESA has recently started several studies on multi-beam electronically steerable array antennas for data link applications in cis-lunar missions, which will deploy a space outpost that will perform crewed and un-crewed lunar surface operations, while orbiting around the moon and will provide data link for command and telemetry communication with the Earth. In this framework a multi-beam electronically steerable antenna allows simultaneous communication between the moon space station, the ground station on Earth, the Data Relay Satellite and the visiting vehicles from the Moon, reducing the need for multiple on-board equipment. Within the frame of ESA contract 4000123998/18/NL/AF, the multi-beam electronically steerable antenna system is studied covering two approaches: a standard array antenna and an array antenna equipped with a dielectric dome lens.

14:30 ***Airbus UK Active Antenna Developments, Challenges and the Future***

Sonya Amos, Carolina Tienda, David Dupuy and Glyn Thomas (Airbus Defence and Space, United Kingdom (Great Britain)); Steve McLaren (Airbus DS Ltd, United Kingdom (Great Britain)); Sylvain Defer (Airbus Defence and Space, United Kingdom (Great Britain))

As market applications demand increasingly complex solutions, and satellite operators require increased flexibility, we will summarise developments that support Commercial, VHTS and Government markets. System considerations and challenges will be highlighted along with implementation and technology evolutions.

14:50 ***Front-End Radiating Modular Architecture for Direct Radiating Antenna Applications***

Benoit Lejay and Jean Philippe Fraysse (Thales Alenia Space, France)

This paper presents a front-end radiating modular architecture for direct radiating antennas. This architecture is suitable for space applications thanks to its efficient thermal management and the space available to accommodate the RF chains. Its modularity and its

flexibility allow addressing the needs of several telecom satellite applications in medium earth orbit and in geostationary earth orbit. Moreover it can be used for low earth orbit applications by adding a lattice expander. Several applications of this architecture for different orbits are presented in this paper. Measurements of mock-ups developed for the medium earth orbit application are also shown.

15:10 ***Active Phased Array Antennas for Data Communications in Science ESA Missions***

Quiterio García, Ana Trastoy, Silvia Bourgeal and Iñigo Borda (Airbus Defence and Space, Spain); Erio Gandini (ESA - European Space Agency, The Netherlands); Dennis T. Schobert (European Space Agency, The Netherlands)

This paper presents the initial phases of the study of a communication system in Ka band intended for future ESA Deep Space (DS) Science Missions. The paper focuses on the different antenna architectures for the Ka-band system and the initial trade offs between the proposed antenna candidates, addressing the criticalities of the antenna requirements. The study is being currently conducted by Airbus DS España (ADSM) with the support of DA Design (Fi) in the frame of an ESA predevelopment project activity to study the TTC active phased array antenna (PAA) subsystem and it is intended to perform antenna studies of the communication system necessary to maintain a complete link between the DS spacecraft and the Earth ground stations.

15:30 Coffee Break

15:50 ***Efficient Estimation of Antenna System Performance for Multibeam Very High Throughput Satellites***

Alejandro Baldominos (Heriot-Watt University, United Kingdom (Great Britain)); Nelson Fonseca and Alberto Mengali (European Space Agency, The Netherlands); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain))

This paper presents an efficient methodology for the estimation of multibeam antenna system performance for satellite applications with a large number of beams typically required in very high throughput satellite systems. A typical antenna system composed of four offset reflectors with feed systems in a single-feed-per-beam configuration is used to achieve full Earth coverage. Acceleration techniques are applied to estimate farfield patterns for each beam with the aim of finding a trade-off between accuracy and computation time on system level metrics, such as aggregate gain and C/I. The software obtained as part of this work is of interest for payload trade-offs and parametric studies.

16:10 ***Joint Precoding and Resource Allocation Strategies Applied to a Large Direct Radiating Array for GEO Telecom Satellite Applications***

Florian Vidal (Heriot Watt University & Thales Alenia Space, France); Hervé Legay (Thalès Alenia Space, France); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Jean Philippe Fraysse (Thales Alenia Space, France)

Large active deployable direct radiating arrays are attractive solutions for very capacitive satellites with power flexibility and in-orbit coverage reconfiguration. This solution, however, requires very high numbers of radiating elements compared to more conventional reflector based solutions. Moreover, digital-only beamforming is power hungry due to the processing of large frequency bandwidths for each radiating element. Novel beamforming approaches must be investigated to save on-board power. A hybrid beamforming architecture based on analog beamforming at sub-array level and digital beamforming reduces the power consumption of the digital core. A disadvantage of hybrid beamforming is the appearance of grating lobes in the satellite field of view. A system approach to mitigate grating lobes is proposed. This strategy is based on the joint use of precoding and smart resource allocation. The impact of the non-uniformity of users distributions on capacity is also assessed.

16:30 ***Planar Quasi-End-Fire Antenna Design Using SIW Technology for CubeSats and Other Small Satellites***

Khalid M Alrushud (The University of Edinburgh & King Abdulaziz City for Science and Technology (KACST), United Kingdom (Great Britain)); Victoria Gómez-Guillamón Buendía (Antenna Company, The Netherlands); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

The work aims to design a quasi-end-fire antenna that can support high data rate downlink communications for small satellites. This developed end-fire antenna uses a parallelplate waveguide (PPW) launcher based on substrate integrated waveguide (SIW) technology that achieves power transfer to a grounded dielectric slab (GDS) by excitation of transverse magnetic (TM) surface waves (SWs) for radiation through a matching section represented by sub-wavelength patches. In particular, these SWs transfer from the T-junction of the SIW launcher to the GDS for end-fire radiation by a partially reflective screen made in one of the via sidewalls which has been designed using leaky-wave (LW) theory. This paper will firstly present the background information about small satellites and the challenges with antenna integration. Some theory is also discussed describing the proposed antenna design approach. After that, simulations and results of the SIW antenna, which is to operate at 18 GHz, are reported.

CS12: Developments and Results of Propagation Campaigns for Satellite Telecommunication Systems Operating at Ka, Q, V and W Frequency Bands

T09 Space (incl. cubesat) / Convened Session / Propagation

Room: virtual 9

Chairs: Laurent Castanet (ONERA, France), Antonio Martellucci (European Space Agency, The Netherlands)

13:30 ***Deutsche Telekom View on High Altitude Platforms for Ubiquitous Coverage [INDUSTRIAL KEYNOTE]***

Jaroslav Holis (Deutsche Telekom, Czech Republic)

Industrial keynote talk

13:50 ***Rain Drop Shapes and Scattering Calculations: A Case Study Using 2D Video Disdrometer Measurements and Polarimetric Radar Observations at S-Band During Hurricane Dorian Rain-Bands***

Merhala Thurai (Colorado State University, USA); Sophie Steger and Franz Teschl (Graz University of Technology, Austria); Michael Schönhuber (Joanneum Research, Austria); David B Wolff, Sr. (NASA, USA)

On 9 September 2019, rain-bands of category-1 Hurricane Dorian passed over a ground instrumentation site in Delmarva peninsula, USA. Drop shapes derived from 2D Video Disdrometer measurements at this site were used to compute the S-band radar cross sections (RCS) for horizontal and vertical polarizations for each drop with equi-volume diameter > 2 mm. These are combined with RCS for the smaller drops assuming equilibrium shapes. Radar reflectivity (ZH) and differential reflectivity (ZDR) are calculated for each of the 3 minutes throughout the event which lasted for more than 8 hours. These are compared with simultaneous observations from an S-band polarimetric radar 38 km away. The comparisons highlight the impact of large amplitude drop oscillations on ZDR.

14:10 ***Use of High-Resolution Numerical Weather Predictions for the Operation of Earth-Space Links***

Bastien Wioland, Lorenzo Luini and Carlo Riva (Politecnico di Milano, Italy)

The use of high-resolution Numerical Weather Prediction (NWP) data for electromagnetic wave propagation analysis along Extremely High Frequencies (EHF) is the focus of this work. The Weather Research and Forecast (WRF) model is coupled with the ERA5 meteorological data to produce NWP data, hence the link attenuation, at resolutions never explored for propagation purposes, i.e. 1 minute and 1 km x 1 km. By comparison with the Alphasat propagation data collected in Milan, light is shed on the best compromise between space-time resolution and computation time. Also, a statistical approach is proposed exploiting in a more reliable way the link attenuation forecasts to dynamically adapt the link parameters (e.g. modulation and coding scheme) and thus meet the target quality requirements (e.g. Bit Error Rate) in different weather conditions.

14:30 ***Prediction Model for the Effective Operation of Earth-Space Links Using Up-Link Power Control***

Léa Weinum, Lorenzo Luini and Carlo Riva (Politecnico di Milano, Italy)

A new model for the application of Up-Link Power Control in satellite communication systems is presented. The model consists in the combination of an ARIMA model to forecast the rain rate (5 minutes in the future) and of the Enhanced Synthetic Storm Technique (E-SST) to generate time series of the rain attenuation at two frequencies, from which the frequency scaling ratio can be calculated for the real time application of Up-Link Power Control. The performance of the model, tested against the Alphasat Ka- and Q-band propagation data collected in Milan, indicate that the proposed frequency scaling approach is accurate enough to allow the real-time effective application of ULPC in EHF satellite communication systems.

14:50 ***Combined Use of MultiEXCELL and Numerical Weather Prediction to Improve the Prediction of Rain Attenuation at Q Band***

Mojtaba Razavian (UCLouvain, Belgium); Claude Oestges (Université Catholique de Louvain, Belgium); Danielle Vanhoenacker-Janvier (Université catholique de Louvain, Belgium)

The future communication systems will use higher frequencies, Ka and Q band. For the implementation of fade mitigation techniques, it is important to have representative time series representing the degradations of the received signal for GEO and LEO satellites. This paper presents a model combining numerical weather prediction software WRF and MultiEXCELL rain cells model in order to have more accurate representation of the dynamics of the attenuation for GEO and non-GEO satellite links.

15:10 ***Propagation Experiments in Madrid for the Ka and Q Bands: Recent Results and Rain Attenuation Modelling in the Earth-Satellite Channel***

Domingo Pimienta-del-Valle and Jose M Riera (Universidad Politécnica de Madrid, Spain); Pedro Garcia-del-Pino (Universidad Politecnica de Madrid, Spain); Gustavo Siles (Universidad Privada Boliviana, Bolivia); Ana Benarroch (Universidad Politécnica de Madrid, Spain)

Most of the available rain attenuation models have been derived on the basis of experimental measurements carried out only at frequency bands below 20 GHz or with little data above this value. Universidad Politécnica de Madrid (UPM) is carrying out two experimental campaigns at the Ka and Q bands, measuring two beacon signals at 19.7 GHz (from the KA-SAT satellite) and 39.4 GHz (from the Alphasat satellite). Five years of measurements for each experiment are now available and have been processed. Attenuation results are presented in this paper and are used to assess the performance of fifteen rain attenuation models available in the literature. The best results are provided by the NTUA model, although some other ones, including the one recommended by the ITU-R, also yield relatively good predictions.

15:30 Coffee Break

15:50 ***Frequency Scaling Relying on the Estimation of the Drop Size Distribution from Dual Frequency Beacon Measurements***

Julien Queyrel (ONERA & Université de Toulouse, France); Liz-Angelica Ramos-Medina and Laurent Castanet (ONERA, France)

Frequency scaling for rain attenuation has become a critical issue in satcom systems that recently consider the extensive use of Q/V-band for their feeder links. We developed a frequency scaling model for rain attenuation that intends to take into account the specificities of rain attenuation when the frequency increases towards those bands (dependence on the drop size distribution, DSD). The model relies on the characterization of the DSD main parameters from the measurement of rain attenuation at two distinct frequencies. Knowing the DSD shape and slope, it is theoretically possible to derive the attenuation caused by the precipitation it represents. We present the idea behind the model, and the test results against ITALSAT propagation campaign data as measured in 1996 at Spino d'Adda (Italy), thus including three frequencies: 18.7 (Ka) and 39.6 GHz (Q) for the DSD parameters characterization, 49.5 GHz (V) being the target frequency of the scaling.

16:10 ***Requirement Analysis for a MEO Propagation Campaign***

Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal); Susana Mota (University of Aveiro & Institute of Telecommunications, Portugal); Augusto Marziani (Telespazio S.p.A. & Sapienza University of Rome, Italy); Frank S. Marzano (Sapienza University of Rome, Italy); Lorenzo Luini and Carlo Riva (Politecnico di Milano, Italy); Antonio Martellucci (European Space Agency, The Netherlands)

The modeling of the earth-satellite propagation channel requires experimental data that are usually obtained by monitoring CW signal sources installed in satellites (beacons). Although there is considerable experience in the development of beacon receivers for Geo satellites, this is not the case for MEO or LEO constellations. The main considerations for the development of propagation receivers for monitoring MEO satellites are addressed in this article. The target constellation is presented with a description of the satellite orbits, characteristics of the beacon payload and the project requirements. The receiver's requirements are then analyzed, starting with the antenna, satellite tracking, beacon detection and propagation data handling.

16:30 ***Synthesis of Attenuation Time Series for Non-GEO Satellite Paths***

Jean-Pascal Monvoisin (ONERA, France); Julien Queyrel (ONERA & Université de Toulouse, France); Laurent Castanet (ONERA, France); Xavier Boulanger (CNES, France)

In 2019, new methods to synthesize time series of single-site and multi-site tropospheric impairments on Earth-space paths have been adopted by ITU-R Study Group 3 in Recommendation ITU-R P.1853-2. However, these methods are only applicable in the case of a Geostationary Earth Orbit (GEO). As the deployment of multimedia services from Low-Earth Orbit (LEO) or Medium Earth Orbit (MEO) satellites constellations is gathering momentum worldwide, the access to simple attenuation and tropospheric scintillation time series synthesizers for Non-Geostationary Earth Orbit (NGEO) applications appears to become critical. This paper presents an adaptation of the recommendation ITU-R P.1853-2 to a NGEO link in single site configuration using elevation-dependent parameters to parameterize the statistical distribution of attenuation for time series generation.

16:50 ***Development and Application of Microwave Radiometric Techniques for Modeling Satellite-Earth Propagation at V and W Band***

Frank S. Marzano (Sapienza University of Rome, Italy); Lorenzo Luini (Politecnico di Milano, Italy); Domenico Cimini (IMAA-CNR & CETEMPS University of L'Aquila, Italy); George Brost (Air Force Research Laboratory, USA); Marianna Biscarini (Sapienza University of Rome, Italy); Carlo Riva (Politecnico di Milano, Italy); Sabrina Gentile and Saverio Nilo (Consiglio Nazionale delle Ricerche, Italy); Filomena Romano (IMAA-CNR, Italy); Emiliano Orlandi (RPG Radiometer Physics GmbH, Germany); Luca Milani (European Space Agency, Germany); Antonio Martellucci (European Space Agency, The Netherlands)

Sun-tracking microwave (ST-MW) radiometry is a ground-based technique where the Sun is used as a beacon source to infer the atmospheric path attenuation in all-weather conditions. ST-MW radiometry shows an appealing potential for overcoming the difficulties to perform satellite-to-Earth radiopropagation experiments in the unexplored millimeter-wave and submillimeter-wave frequency region, especially where experimental data from beacon receivers are not available. The theoretical framework, the ad hoc procedures and data processing will be presented, together with the estimate of the overall error budget. The applications and challenges during field deployments, such as the recent WRad campaign in Italy based on ST-MW data analysis, funded by ESA and carried out

together with AFRL (NY, USA), will be discussed.

17:10 ***Measurement and Characterisation of Atmospheric Depolarisation on Slant Paths at Ka, Q and V Bands***

Eric Regonesi (Politecnico di Milano, Italy); Flávio M. da Silva Jorge (University of Aveiro & Instituto de Telecomunicações, Portugal); Carlo Riva (Politecnico di Milano, Italy); Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal); Antonio Martellucci (European Space Agency, The Netherlands)

Spectral-efficient space communication links are impaired by atmospheric depolarisation caused by rain and ice along the Earth-space path. In this contribution three experiments experiencing three different climatological conditions are compared to assess the underlying mechanisms of depolarisation, in particular to evaluate a possible correlation between depolarisation and ice content.

17:30 ***The Q/W-Band CubeSat LEO Propagation Experiment***

Félix Cuervo (Joanneum Research, Austria); Arturo Martin Polegre (European Space Agency, The Netherlands); Danielle Vanhoenacker-Janvier (Université catholique de Louvain, Belgium); Joel Flávio (JOANNEUM RESEARCH, Austria); Michael Schmidt (Researcher & Joanneum Research, Austria)

Due to the congestion of the electromagnetic spectrum and the need for larger bandwidths, space radio-communication systems are moving towards the use of higher frequency bands (Ka, Q/V and W bands). These frequencies are severely impaired by atmospheric phenomena causing attenuation, scintillation and depolarization. This paper introduces a new propagation experiment which will extend the characterization of the Earth-space channel up to the W band and low Earth orbits (LEO)

CS16: Fundamental Challenges and Novel Methodologies in the Next-generation Computational Electromagnetics

T10 EM modelling and simulation tools / Convened Session / Electromagnetics

Room: virtual 10

Chairs: Zhen Peng (University of Illinois at Urbana-Champaign, USA), Francesca Vipiana (Politecnico di Torino, Italy)

13:30 ***Improved Discretization of the Full First-Order Magnetic Field Integral Equation***

Jonas Kornprobst, Alexander Paulus and Thomas F. Eibert (Technical University of Munich, Germany)

The inaccuracy of the classical magnetic field integral equation (MFIE) is a long-studied problem. We investigate one of the potential approaches to solve the accuracy problem: higher-order discretization schemes. While these are able to offer increased accuracy, we demonstrate that the accuracy problem may still be present. We propose an advanced scheme based on a weak-form discretization of the identity operator which is able to improve the high-frequency MFIE accuracy considerably - without any significant increase in computational effort or complexity.

13:50 ***Efficient Computation of Green's Functions for Multilayer Media in the Context of 5G Applications***

Raj Mittra (University of Central Florida, Turkey); Ozlem Ozgun (Hacettepe University, Turkey); Chao Li (Ecole Polytechnique de Montreal, Canada); Mustafa Kuzuoglu (Middle East Technical University, Turkey)

This paper presents a novel method for effective computation of Sommerfeld integrals which arise in problems involving antennas or scatterers embedded in planar multilayered media. Sommerfeld integrals that need to be computed in the evaluation of spatial-domain Green's functions are often highly oscillatory and slowly decaying. For this reason, standard numerical integration methods are not efficient for such integrals, especially at millimeter waves. The main motivation of the proposed method is to compute the Sommerfeld integral tails through extrapolation and analytical integration. The approach is inherently fast and accurate. Numerical examples have been provided to validate the accuracy and efficiency of the proposed method.

14:10 ***Aspects of the Fully Analytic Expressions for Matrix Elements of Integral Equation Operators and Their Simple Numerical Implementation***

Elizabeth Bleszynski (Monopole Resesarch, USA); Marek Bleszynski, Dr (Monopole Resaearch, USA); Thomas Jaroszewicz (Monopole Research, USA)

We consider an extension of the method of evaluating matrix elements of integral equations with the help ofsuitably constructed Laplacian-type representations of singular kernels. We present an outline of a general approach to analytic evaluation of Galerkin matrix elements arising in discretization of surface integral equations, for basis functions located on parallel planes. Our principal goal is to obtain analytic expressions that would not only be relatively simple, but also amenable to numerical evaluation and not adversely affected by loss of accuracy due to roundoff errors in cancellations of terms. Representative examples of the applications of the proposed method are discussed. Index Terms-Integral equations, Moment methods, Numerical

14:30 ***Evaluation of 6-D MoM Integrals by Application of the Divergence Theorem with Singularity Subtraction Acceleration***

Javier Rivero and Francesca Vipiana (Politecnico di Torino, Italy); Donald Wilton (University of Houston, USA); William Johnson (Private Consultant, USA)

We propose to evaluate the double-volumetric integrals appearing in MoM formulations for volumetric integral equations by applying the divergence theorem to reduce both source and test integrals to surface integrals. Their integrands consist of the original kernel, basis, and test functions integrated twice radially in closed form. Implementing the surface integrals directly in the physical domain eliminates the restrictions to well-shaped elements. For faceted volumetric elements, the surface integrals reduce to the evaluation of interaction integrals between source and test face pairs. Triangular facets may be either integrated directly in barycentric coordinates or in a cylindrical coordinate system whose axis is the line of intersection of planes containing source and test face pairs. Further smoothing of the integrand is provided by first removing the static asymptotic form of the integrand from the integral, then restoring its contribution as a closed form integral whose removal accelerates convergence of the difference integral.

14:50 ***Fast Direct Error-Controlled Solution of Scattering Problems via H-Matrix Acceleration of Locally Corrected Nystrom Method***

Reza Gholami (University of Toronto & University of Manitoba, Canada); Zhuotong Chen (University of California at Santa Barbara, USA); Mohammad Shafieipour (Safe Engineering Services and Technologies, Canada); Vladimir Okhmatovski (University of Manitoba, Canada)

The fast direct high-order solution of radiation problems in the presence of perfect electrically conducting (PEC) sphere with the Locally Corrected Nystrom (LCN) method is presented. Accelerated solution is obtained using error-controlled hierarchical H-matrix framework. Matrix fill time and direct solution time are shown to be substantially reduced compared to those needed by conventional LCN. The error of solution is computed via comparison against the analytical Mie series solution. Developed computational framework is shown to produce the higher order solution while preserving high compressibility of the corresponding H-matrix blocks. The memory cost and CPU time complexity scaling with the size of the problem is analyzed.

15:10 ***Efficient Analysis of Thick Curved Metal Sheets***

Eduard Ubeda (Universitat Politècnica de Catalunya (UPC), Spain); Juan M. Rius (Universitat Politècnica de Catalunya, Spain)

The scattering analysis of perfectly conducting plates with the method-of-moment discretization of the Electric-Field Integral Equation has been traditionally carried out according to the thin-sheet approximation, which neglects the current contributions over the plate rims. The plate is then modelled as an open surface and handles a restricted number of unknowns as compared with the canonical modelling as a closed object. The thin-sheet approximation, although used in many practical applications, becomes inaccurate for thick enough plates or plates under plane wave incidence at grazing angles. Recently, a thick-plate approach has been presented to address the time-efficient and accurate scattering analysis of thick plates. This scheme exploits the symmetry properties of fields and currents thereby giving rise to two uncoupled problems with roughly half the number of unknowns of the original problem. In this paper, we extend this thick-plate scheme to the efficient scattering analysis of thick curved sheets.

15:30 Coffee Break

15:50 ***MoM Interaction Evaluation Intended for Antennas Printed on Ultra-Thin Substrates***

Bilel Hamdi (UClouvain, Belgium); Husnain Kayani (Université Catholique de Louvain, Belgium); Denis Tihon (University of Cambridge, United Kingdom (Great Britain)); Francisco Mesa (University of Seville, Spain); Christophe Craeye (Université Catholique de Louvain, Belgium)

A new kernel is proposed for the accurate simulation of planar antennas printed on ultra-thin substrates by means of integral-equation methods. A scalar-potential representation is used and a number of spectral-domain asymptotic terms, in the form of a series of exponentials, are extracted and integrated in the spatial domain. The spatial-domain counterpart of the remainder is evaluated numerically via Hankel transforms to be simply convoluted numerically with basis and testing functions. So, a global Method of Moments (MoM) impedance matrix is obtained from the asymptotic and remaining parts, which allows for an efficient evaluation of the electromagnetic properties of antennas printed on very thin substrates. It is shown that the asymptotic parts can be estimated in closed form, which is validated against purely numerical or hybrid (numerical and analytical) solutions.

16:10 ***Combined Potential-Field Surface Formulations for Resonance-Free and Low-Frequency-Stable Analyses of Three-Dimensional Closed Conductors***

Ozgur Eris, Gokhan Karaova and Ozgur Ergul (Middle East Technical University, Turkey)

We present combined formulations involving the recently developed potential integral equations (PIEs) together with field formulations, particularly the magnetic-field integral equation (MFIE), for accurate, efficient, and stable analyses of three-dimensional closed conductors. This kind of combinations are required since PIEs suffer from internal resonances and are prone to numerical issues for relatively large conductors. By combining PIEs with MFIE, we obtain low-frequency-stable implementations that can be employed at both low and high frequencies without any resonance artifacts in numerical results.

16:30 ***A Note on the Convolution Integrals Entailed by the Cagniard-De Hoop Analysis of Layered Configurations***

Ioan E. Lager (Delft University of Technology, The Netherlands); Martin Štumpf (Brno University of Technology, Czech Republic); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium); Giulio Antonini (Università degli Studi dell'Aquila, Italy)

The evaluation of the convolution integrals that are of relevance for calculating the EM field radiated by a magnetic dipole embedded in a layered configuration is revisited. An effective and accurate strategy employing a polynomial interpolated/extrapolated replica of the calculated Green's function is proposed. The strategy allows calculating the largest part of the relevant integrals analytically. The method yields best results in the case of excitations with a finite temporal support, but is also beneficial for excitations with an infinite support.

16:50 ***Fast Modeling of Electromagnetic Scattering from Dielectrics or Conductors with an Extended Adaptive Integral Method***

Shashwat Sharma and Piero Triverio (University of Toronto, Canada)

The electromagnetic modeling of dielectrics is necessary in several radiation and scattering problems, such as those involving dielectric antennas and metasurfaces. The surface integral method, accelerated with algorithms such as the adaptive integral method (AIM), require computing interactions between nearby mesh elements with direct integration at each frequency point, which can be computationally expensive. In this work, we propose an extended AIM (AIMx) for the fast analysis of dielectric media, which is easy to implement within existing AIM-based code. The surface integral operators are decomposed into frequency-independent and frequency-dependent parts such that direct integration is only necessary for the frequency-independent part, which can be performed once and reused for each frequency point. Several realistic numerical examples demonstrate significant CPU time savings with no loss of accuracy.

CS6: Application Aspects of Wideband Metasurfaces in RADAR

T11 Fundamental research and emerging technologies / Convened Session / Antennas

Room: virtual 11

Chairs: Christophe Craeye (Université Catholique de Louvain, Belgium), Frank Weinmann (Fraunhofer FHR, Germany)

13:30 ***Metasurface Luneburg Lens Antenna Implemented with Substrate-Integrated-Holes at Ka-Band***

Oskar Zetterstrom and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this work, we study the substrate-integrated-holes (SIHs) metasurface. This metasurface consists of dielectric-filled cavities in the two conductors of a parallel plate waveguide (PPW). The accurate control of the effective refractive index in the SIH structure is demonstrated. Additionally, we design a metasurface Luneburg lens operating at 28 GHz based on the studied structure. The lens is fed with 11 waveguides with an angular spacing of 10 degrees, and thus, 100 degrees beam steering is obtained. A flare is used to match PPW to free-space. Since the wave propagates mainly in the air in the studied metasurface, low losses are obtained in the designed lens.

13:50 ***Circuit-Based Inverse Design of Metastructured MIMO Devices***

Luke J Szymanski (University of Michigan, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA); Gurkan Gok (University of Michigan, USA)

In this work, an inverse design method for multi-input multi-output (MIMO) metastructured devices is developed. Large-scale inverse design problems are difficult to solve directly and often require heuristic methods or design optimization to find a solution. Inherent errors introduced by heuristic methods makes design optimization a more promising route to the realization of high performance devices. Here, a fast frequency domain solver for grids of Y-parameter matrices is developed. The solver is used together with an

adjoint-based optimization routine to solve inverse metastructured design problems. The design procedure is demonstrated through the realization of a planar beamforming network for a multi-beam antenna.

14:10 ***Sparse Metasurfaces: From Theory to Practical Implementations***

Vladislav Popov (SONDRA, CentraleSupélec, Université Paris Saclay, France); Thomas Lepetit and Fabrice Boust (ONERA, France); Shah Nawaz Burokur (LEME, France)

Metagratings demonstrate an exceptional efficiency in controlling diffraction patterns. Still, they are essentially periodic structures excited by a plane wave. This induces two main drawbacks. First, periodicity limits metagratings to the control of a discrete set of scattered plane waves, not a continuous one. Second, plane-wave-like illumination assumes that the source is placed in the far-field, significantly reducing feeding efficiency. Here, we elaborate on the analytical model of metagratings and show how numerical calculation of Green's functions can be employed to overcome these drawbacks and design sparse metasurfaces capable of creating arbitrary radiation patterns for arbitrary external excitations.

14:30 ***A Ka-Band Monopulse Antenna Based on Modulated Metasurface Technology***

Marco Faenzi (University of Siena, Italy); Giovanni Petraglia (MBDA Missile Systems, Italy); Roberto Vitiello (MBDA Italia, Italy); Stefano Maci (University of Siena, Italy)

This paper aims to introduce a design method for a monopulse aperture capable to operate in radar tracking scenarios at Ka-band. The layout consists of a thin grounded laminate on top of which a film composed of several thousands of subwavelength metallic patches are printed. This upper layer composed by small patches behaves as a capacitive and variable sheet of impedance coupled in parallel with a dominant inductive contribution represented by the grounded slab. By design of the geometrical features of the metal elements, is possible to tailor a periodically modulated boundary condition (BC) of inductive kind to ease transverse radiation. Proposed aperture is circular and into four angular regions. Any region is is illuminated by a source and radiates an independent beam. By simple phasing scheme between the sources individual sectors radiations are recombined in the far field region to generate four distinct beams for monopulse operability.

14:50 ***Modulated Metasurface Antennas with Enhanced Broadband Response***

Marco Faenzi (University of Siena, Italy); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Stefano Maci (University of Siena, Italy)

This paper deals with the crucial need of enhancing the gain-bandwidth of typically narrowband modulated metasurface (MTS) antennas. Despite their low-profile and low-mass, modulated MTSs have typically been limited in terms of bandwidth. In broadside MTS antennas, this shortcoming stems from the progressive mismatch between the periodicity of the modulation (usually constant) and the wavenumber of the dispersive surface wave (SW). Here, an optimization scheme is introduced for the periodicity function, which is described as a piecewise monotonically increasing function along the antenna radius. The variable period leads to the generation of annular active regions, where the SW wavenumber matches the local periodicity, and a strong radiation occurs at the prescribed frequency. On the other hand, outside the annular region the SW weakly interacts with the MTS modulation. This works shows that the proposed method can considerably extend the bandwidth of MTS antennas.

15:10 ***Pattern Reconfigurable Metasurface Antenna with Three States***

Wenzhang Zhang, Lyuwei Chen, Yi Huang and Jiafeng Zhou (University of Liverpool, United Kingdom (Great Britain))

A nonuniform MTS antenna with pattern reconfigurable function is presented. The antenna uses 4×4 nonuniform unit cells as the main radiator. It is fed by three apertures and a feeding network with three branches. Fed by suitable feeding methods, either the fundamental MTS mode or the higher mode of the fundamental MTS mode can be excited. By exciting the fundamental MTS mode and higher MTS modes in three statuses with three switchable diodes on the feeding layer, three different main beam angles of the radiation pattern can be achieved. They are at -35°, 0° and +35° respectively. The characteristic mode analysis method is used to analyze the modes related to the unit cells and the apertures on the ground plane. The operation of the proposed MTS antenna can achieve 14% fractional bandwidth and gain ranging from 8.5 to 9.5 dBi in three statuses.

CS35: Recent Progress in Antennas and Propagation Research and Development in Latin America

T11 Fundamental research and emerging technologies / Convened Session / Propagation

Room: virtual 12

Chair: Felix Vega (Universidad Nacional de Colombia, Colombia & Technology Innovation Institute, United Arab Emirates)

13:30 ***Advances on the Detection of Landmines and IEDs in Colombia Using UWB GPR and Machine Learning Techniques***

Sergio Gutierrez (Universidad San Buenaventura, Colombia); John Pantoja (Universidad Nacional de Colombia, Colombia & Technology Innovation Institute, United Arab Emirates); Eder Fabian Ruiz (Universidad Nacional, Colombia); Nicolas Gonzalez (Universidad Nacional de Colombia, Colombia); Felix Vega (Universidad Nacional de Colombia, Colombia & Technology Innovation Institute, United Arab Emirates); Christoph Baer (Ruhr-Universität Bochum & Institute of Electronic Circuits, Germany); Jürgen Sachs (Ilmenau University of Technology, Germany); Chaouki Kasmi (Technology Innovation Institute & Helmut Schmidt University, Faculty of Electrical Engineering, United Arab Emirates)

In this paper we present the latest results of a research program on the use of ground penetrating radar and machine learning-based algorithms for humanitarian demining in Colombia. We describe the experimental setup developed, which includes a polarimetric GPR-UWB unit, a radar positioning system, and a control unit. We describe as well a soil characterization campaign and an IED classification technique based on Support Vector Machine.

13:50 ***Review of Low SAR Antennas for Wireless Applications***

Claudio E Fernandez-Rodriguez (IFRS, Brazil); Giovani Bulla (Federal University of Rio Grande do Sul, Brazil); Norton Soares (UFRGS, Brazil); Geraldo Fulgêncio de Oliveira, Nt. (Universidade Federal do Rio Grande do Sul, Brazil); Álvaro Salles (UFRGS, Brazil)

This is a review paper on planar directional antennas designed to reduce the Specific Absorption Rate (SAR) in the head and body of wireless device users. Metamaterials such as Artificial Magnetic Conductors (AMC) and Electronic Band Gap (EBG) structures are considered. Some results on a novel AMC based spiral antenna are shown. Reduction of the SAR from 3 to 20 dB in the head or body of the wireless device users are described. These techniques can be applied to many mobile and wearable devices designed to operate close to the head or body.

14:10 ***Assessment of Fermat's Spiral Arrays for Photonic Dielectric Antennas***

Rafaela Cardoso (University of Campinas, Brazil); Luciano P. Oliveira (Technology Innovation Institute, United Arab Emirates & University of Campinas, Brazil); Hugo Enrique Hernandez-Figueroa (Unicamp, Brazil)

An assessment of aperiodic wide-spaced antenna arrays based on the Fermat's spiral approach is presented through performance comparison against a genetic algorithm optimization strategy. Such assessment takes into account two planar arrays comprising 128-

and 512- elements showing the superior performance of the Fermat's spiral technique in terms of grating lobes suppression, sidelobe levels reduction and footprint.

14:30 ***A Modified Two-Ray Model with UTD and Atmospheric Effects: Analysis of Reflected Ray over Sloping Terrain***

Andres Navarro (Universidad Icesi, Colombia); Diego Parada (Federal University of Minas Gerais, Brazil); Dinael Guevara (Francisco de Paula Santander University, Colombia); Cássio Rego (Federal University of Minas Gerais, Brazil); Rodrigo Oliveira (Universidade Federal de Minas Gerais - UFMG & Companhia Brasileira de Trens Urbanos - CBTU, Brazil); Reinaldo J Velásquez Gómez (Universidad Francisco de Paula Santander, Colombia); María Lorena Gomezjurado Sillman Borges (Universidade Federal de Minas Gerais, Brazil)

This paper introduces preliminary results about a novelty formulation to calculate the first reflection over a sloping terrain for a Modified Two-ray model with atmospheric effects. For a case study of a lossy wedge and standard atmosphere conditions, the obtained results through the proposed formulation and the Discrete Mixed Fourier Transform (DMFT) numerical solution are compared, in order to validate the presented approach. The early results showed similar behavior for path loss, in this canonical scenario.

14:50 ***Improved Microstrip Antenna with FSS Superstrate for 5G NR Applications***

Thamyris da Silva Evangelista (Instituto Federal de Educação Ciência e Tecnologia da Paraíba, Brazil); Alfredo Neto (Federal Institute of Paraíba & Grupo de Telecomunicações e Eletromagnetismo Aplicado - GTEMA, Brazil); Alexandre Serres (UFCG, Brazil)

The development of a microstrip patch antenna with a band-pass frequency selective surface superstrate for 5G New Radio applications at 3.5 GHz is presented in this paper. The frequency selective surface is based on the four-arms star geometry. The structure proposed was manufactured and measurements were performed and compared to simulations. The superstrate performance in function of the distance between the microstrip patch antenna and the FSS is analysed in detail. A measured gain improvement of 5.74 dB is achieved for a distance of 4.5 cm, approximately $\lambda/2$.

15:10 ***Technological Solution for Enabling 5G NR and TVRO Peaceful Coexistence in C-Band***

L. C. Alexandre and Lucas de Oliveira Veiga (Inatel, Brazil); Agostinho Linhares, Filho (Anatel, Brazil); Hugo R. D. Filgueiras (Instituto Nacional de Telecomunicações - Inatel, Brazil); Arismar Cerqueira S. Jr. (INATEL, Brazil)

This work proposes a technological solution for allowing a peaceful coexistence between 5G New Radio (5G NR) and satellite Television Receive Only (TVRO) services in C-band. A detailed analysis and an efficient redesign of a typical low-noise block converter feeder (LNBF), used by TVRO home users, is conducted aiming to reduce the 5G NR interference, which is going to operate at TVRO adjacent channels in some countries. Basically, we exploit two enhancements on the LNBF topology, namely: increasing the 1 dB compress point (P1dB) level of its low noise amplifiers (LNAs), in both first and second stages; incorporating a low-cost and high-performance passband RF filter. As the main contribution, it is demonstrated the protection distance - calculated in accordance to the International Telecommunication Union (ITU) recommendations- might be significantly reduced for 29 km to only 3 m, by using the proposed high-performance LNBF.

Monday, March 22 15:30 - 15:50

Coffee Break / Exhibition

Rooms: virtual 1, virtual 2, virtual 3, virtual 4, virtual 5, virtual 6, virtual 7, virtual 8, virtual 9, virtual 10, virtual 11, virtual 12, virtual 13, virtual 14, Posters, Posters2, Posters3

Monday, March 22 15:50 - 17:50

T01-A02: Wideband Antennas

T01 LTE and Sub-6GHz 5G / / Antennas

Room: virtual 1

15:50 ***Ka-Band Circularly-Polarized Antenna Array with Wide Gain and Axial Ratio Bandwidth***

Amir Raeesi, Hussam Al-Saedi, Wael Abdel-Wahab, Suren Gigoyan and Safieddin Safavi Naeini (University of Waterloo, Canada)

In this paper, the design, simulation and measurement results of a 2×2 circularly polarized microstrip antenna sub-array at Ka-band are presented. The proposed antenna sub-array employs the sequential rotation technique for improvement of AR bandwidth with high circular polarization purity without degrading the circularly polarized gain. The 3-dB gain reduction due to using sequential rotation technique is compensated by employing an antenna element with wide axial ratio bandwidth. The antenna array has a wide impedance bandwidth (S11< -10 dB) of 6.5 GHz from 26-32.5 GHz. The antenna has a wide axial ratio bandwidth (AR< 3 dB) of 6.2 GHz from 25.4-31.6 GHz with high circular polarization purity. The 3-dB gain bandwidth of the antenna is from 25.5-31.2 GHz and the peak gain is 12.1 dBic. The antenna is fabricated through multilayer printed circuit board process and has a size of 18.5 mm × 18.5 mm × 1.02 mm.

16:10 ***Design of a Broadband Circularly-Polarized Single-Layer Metasurface Antenna Using CMA***

Ahmed El Yousfi (Universidad Carlos III De Madrid, Spain); Abdenasser Lamkaddem (Carlos III University of Madrid, Madrid, Spain); Kerlos Atia Abdalmalak and Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)

This paper presents a single layer low profile broadband circularly polarized (CP) metasurface (MTS) antenna fed through a Coplanar Waveguide (CPW). The MTS consists of 3x4 rectangular cells. Contrary to conventional technique based on plotting surface current distribution to demonstrate the CP operation, Characteristic Mode Analysis (CMA) is employed to give more insight into the MTS and explain the CP characteristic. It is revealed that modes 1 and 2 of the MTS have the potential to achieve CP along a wide frequency band. The proposed single-layer antenna has size of $1.0\lambda0 \times 1.0\lambda0 \times 0.059\lambda0$. The simulated results show 3-dB Axial Ratio band of 13.8% (5.6-6.43GHz), with an impedance bandwidth of 25.1% (4.86-6.26GHz) and a peak gain of 8 dBi.

16:30 ***A Low-Profile Ultra-Wideband Spiral Antenna Array for Global Mid-Band 5G Aerospace Applications***

Benjamin J Falkner, Hengyi Zhou and Wei Zhang (Swansea University, United Kingdom (Great Britain)); Amit Mehta (Swanse University, United Kingdom (Great Britain)); Volker Ziegler (AIRBUS Central R&T, Germany); Thomas Multerer (Airbus Group Innovations, Germany)

A low-profile, ultra-wideband beam steering spiral antenna array with complete coverage of mid-band 5G has been developed for aerospace applications. As 5G frequency bands have been allocated across the globe, the frequencies used by different regions has diverged (e.g. 3.4-3.8 GHz in the EU and 3.3-3.6 GHz & 4.8-5GHz in China). This provides a challenge for intercontinental aerospace communication as aircraft must be able to cover all frequencies. Here, an antenna array solution is presented that covers all the required frequency bands with only a single antenna system. This array consists of miniaturized spiral antenna elements which generates an axial beam from 3.3 GHz to 5 GHz. By placing this antenna in a 16-element array, it allows beam steering in elevation plane from 0 to 40 degrees across the bandwidth. While this is primarily developed for aerospace applications, this work could also provide advantages for ground vehicles and UAVs.

16:50 ***High-Gain Dual Circularly-Polarized Antenna with Wideband Feeding Structure***

Mahmoud Elsaadany (Ecole de Technologie Superieure (ETS), Canada); Mohamed Ali (Concordia University, Egypt); Shoukry Shams (University of Concordia, Canada); Ghyslain Gagnon (ETS, Canada)

High gain antennas are mandatory components in modern communication and radar systems to increase the coverage area. In addition, circularly-polarized antennas have a better penetration capability, which ensures the adequate reception with the presence of obstacles between the transmitter and the receiver. In this article, an X-band high-gain circularly-polarized antenna design is proposed. The introduced antenna has a dual polarization to double the channel capacity through the utilization of polarization diversity. The proposed antenna consists of two horn antennas fed by a magic-tee followed by a ferrite based phase shifter. The presented configuration ensures both, high gain and high power handling capability. The proposed antenna system is centered at 9.5 GHz with a percentage bandwidth beyond 30%.

17:10 ***A Wideband Monopolar Antenna Concept and Its Application to Design Multi-Polarized Radiators***

Nghia Nguyen-Trong (University of Adelaide, Australia); Son Xuat Ta (Hanoi University of Science and Technology, Vietnam)

This paper presents a simple low-cost wideband monopolar antenna. The design concept consists of an array of four identical monopoles fed by an equal power divider at the center. Different from the previous structures, this design scheme brings several practical advantages, which make the antenna suitable to be integrated into multi-polarized structures. Two design examples are demonstrated to show the applicability of this structure, including a dual-polarized omni-directional antenna and an ultra-wideband tri-polarized antenna.

17:30 ***Triple RSIW Fed Antipodal Vivaldi Antenna for Bandwidth Improvement***

Camila Caroline Rodrigues de Albuquerque (Federal University of Campina Grande, Brazil); Alfredo Neto (Federal Institute of Paraíba & Grupo de Telecomunicações e Eletromagnetismo Aplicado - GTEMA, Brazil); Georgina Karla de Freitas Serres (UFCG, Brazil); Alexandre Oliveira (Federal Institute of São Paulo, Brazil); Alexandre Serres (UFCG, Brazil)

In this paper, it is presented a new modified structure of antipodal Vivaldi antenna (AVA). The structure is fed by a triple ridged substrate integrated waveguide (RSIW) on a single layer low-cost FR4 substrate. The ridges insertion allows a bandwidth enhancement due to the cut-off frequency decrease and consequently the miniaturization. The new structure is compared to an AVA fed by a classical SIW designed for a cut-off frequency around 4 GHz. Numerical simulations were performed and a bandwidth enhancement of 810 MHz was achieved with a gain of 2.06-7.59 dBi within the frequency range.

CS8 continued

T02 Millimetre wave 5G / Convened Session / Measurements

Room: virtual 2

CS42 continued

T02 Millimetre wave 5G / Convened Session / Propagation

Room: virtual 3

CS22 continued

T05 Biomedical and health / Convened Session / Electromagnetics

Room: virtual 5

CS39: UAV-based Antenna Measurements

T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / Convened Session / Measurements

Room: virtual 6

Chairs: Hans-Juergen Steiner (Aeroxess UG, Germany), Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy)

15:50 ***Advanced Remote-Controlled Airborne Sensor Systems***

Thorsten Schrader (Physikalisch-Technische Bundesanstalt, Germany); Jochen Bredemeyer (FCS Flight Calibration Services GmbH, Germany); Thomas Kleine-Ostmann (Physikalisch-Technische Bundesanstalt, Germany); Marius Mihalachi (Physikalisch-Technische Bundesanstalt (PTB), Germany)

Based on commercially available octocopters, PTB has developed flight measurement platforms with RF front-ends for various frequency bands. The remote-controlled measurement systems are designed for calibrated on-site measurements of the signals emitted by terrestrial navigation systems and radars. They are used to measure signal strengths quantitatively and to investigate the disturbance potential of wind turbines.

16:10 ***Drone-Based Polarization Calibration Source for Mm-Wave Telescopes***

Rolando Dünner, Juan Fluxá, Sergio Best, Felipe Carrero and David Boettger (PUC from Chile, Chile)

To probe alternative cosmologies, future CMB experiments will require an exquisite absolute polarization angle calibration. The scarce number natural polarized calibrators makes artificial alternatives appealing. Moreover, ground loading restrictions force these sources to be located at high elevations. We have shown that commercial drones can operate at altitudes above 5200 meters, lifting 4 kg payloads for 10 minutes, being capable of reaching the far-field of small aperture telescopes. A drone-based calibration source, equipped with a high-precision metrology system based on an RTK GPS, a photogrammetry camera and a geo-referenced reconstruction of the site, can provide an absolute polarization angle reference accurate to 0.1 degrees. The metrology data must be synchronized in time with the detector time-streams to compensate the source movements. We implemented an electronically chopped, linearly polarized 150 GHz coherent source, for serving the experiments CLASS, ACT, Simons Array and Simons Observatory.

16:30 ***A Dual-Polarized Tapered Slot Antenna for UAV-Based Collection of Locally Coherent Field Data***

Arslan Azhar and Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

Commonly employed near-field far-field transformations (NFFFTs) require coherent (complex) measurement data. In contrast, phaseless NFFFTs work with magnitude-only measurements. The transformation success of phaseless data can be considerably improved by adding localized phase information in form of phase differences among neighbouring measurement samples, which can, e.g., be acquired by a cluster of coherent antenna receivers. Such an approach is especially suitable for near-field measurements based on unmanned-aerial-vehicles (UAVs). A probe element for the aforementioned application, which is operating between 1.5 to 4.5 GHz, is designed and realized in the form of a tapered slot antenna. The antenna is implemented as a printed circuit board version and also as a better performing machine-milled all-aluminium version. The resulting probe element is dual-polarized, light in weight, has a low aerodynamic profile and good back-radiation suppression (for UAV-mounting).

16:50 ***Preliminary Results on the Verification of the LOFAR-HBA with a Flying Test Source***

Giuseppe Virone and Stefania Matteoli (Consiglio Nazionale delle Ricerche, Italy); Fabio Paonessa (National Research Council of Italy (CNR - IEIIT), Italy); Pietro Bolli (INAF - Osservatorio Astrofisico di Arcetri, Italy); Stefan J. Wijnholds (ASTRON, The Netherlands); Lorenzo Ciorba (Institute of Electronics, Computer and Telecommunication Engineering (IEIIT-CNR), Torino & Politecnico di Torino, Torino, Italy); Giuseppe Addamo (Istituto di Elettr. e di Ingegneria dell'Inform. e delle Telecom. (IEIIT-CNR), Italy); Oscar A. Peverini (Istituto di Elettr. e di Ingegneria dell'Inform. e delle Telecom. (IEIIT- CNR), Italy)

This paper presents a preliminary set of results for the LOFAR High-Band Antenna (HBA) Array. The high signal-to-noise ratio and scan capability of the UAV-based measurement system allowed the array verification at both element and tile level. Such data could not have been obtained with astronomical sources. The reported results confirm both pointing angle and beamwidth of the HBA tiles from 120 to 180 MHz.

17:10 ***Aspects of Near-Field Antenna Measurement Technology When Using UAVs***

Hans-Juergen Steiner, Torsten Fritzel and Rüdiger Strauß (Aeroxess UG, Germany)

Due to the development of smart flight controller, powerful accumulator with LiPoly cells, global positioning/ navigation systems and light weight mechanical construction the UAV technology is applicable in nearly unlimited technical areas. The small construction and the mobile application is offering a wide area of opportunities in the area of antenna measurements and its characterization in their different function and localization. The paper will describe the special challenges of their interdisciplinary aspects during the design, development and operation phase.

17:30 ***Introduction to UAV Swarm Utilization for Communication on the Move Terminals Tracking Evaluation with Reinforcement Learning Technique***

Saki Omi (Cranfield University & QuadSAT, United Kingdom (Great Britain)); Hyo-Sang Shin (Cranfield University & KAIST, United Kingdom (Great Britain)); Antonios Tsourdos (Cranfield University, United Kingdom (Great Britain)); Joakim Espeland and Andrian Buchi (QuadSAT, Denmark)

As the growth of communication and satellite industry, the demand of satellite antenna evaluation is increasing. Particularly Communication On The Move (COTM) terminal antenna, including electronically steerable antennas (ESA) and for the communication between new constellations on LEO and MEO, requires tracking accuracy test for the communication on moving vehicles. The measurement capability of conventional methodologies have been limited due to their location fixed facilities and non-adjustable sensor's positions during the measurement. To overcome this drawbacks, we will present how multi-agent system of UAVs could be utilized for COTM tracking accuracy evaluation. This measurement needs instant actions for UAVs to keep them navigating in order to achieve accurate and stable measurement. Reinforcement learning (RL) techniques are investigated for this purpose in this paper. The performance improvement is demonstrated with the system using RL technique to adjust UAVs with sensors during the measurement.

CS17 continued

T08 Positioning, localization & tracking / Convened Session / Antennas

Room: virtual 7

CS24 continued

Room: virtual 8

CS12 continued

T09 Space (incl. cubesat) / Convened Session / Propagation

Room: virtual 9

CS16 continued

T10 EM modelling and simulation tools / Convened Session / Electromagnetics

Room: virtual 10

CS23: Novel Antenna Measurement Techniques and Data Analysis

T11 Fundamental research and emerging technologies / Convened Session / Measurements

Room: virtual 11

Chairs: Dennis Lewis (Boeing, USA), Janet O'Neil (ETS-Lindgren, USA)

15:50 ***Linear Phase Retrieval for Near-Field Measurements with Locally Known Phase Relations***

Alexander Paulus, Jonas Kornprobst, Josef Knapp and Thomas F. Eibert (Technical University of Munich, Germany)

A linear and thus convex phase retrieval algorithm for the application in phaseless near-field far-field transformations is presented. The formulation exploits locally known phase relations among sets of measurement samples, which can in practice be acquired with multi-channel receivers. Due to the linearity of the formulation, a reliable phaseless transformation is achieved, which completely avoids the problem of local minima - the Achilles heel of most existing phase retrieval techniques. Furthermore, the necessary number of measurements are kept close to that of fully-coherent antenna measurements. Comparisons with an already existing approach exploiting local phase relations demonstrate the accuracy and reliability for synthetic data.

16:10 ***Power Density Evaluation of Simulated and Measured Data Based on Equivalent Currents Method***

Francesca Mioc (Consultant, Switzerland); Lucia Scialacqua and Alessandro Scannavini (Microwave Vision Italy, Italy); Shoaib Anwar (Microwave Vision Group, Satimo Industries, France); Lars Foged (Microwave Vision Italy, Italy)

In 5G applications, commercial devices must be tested to verify compliance of the electromagnetic field (EMF) emission with the relevant EMF exposure limits in terms of peak average power density [1-3]. Proximity to the device testing is required for frequencies above 6 GHz [4]. This procedure, for 5G beamforming DUT, can require very long measurement times. To overcome this limitation a fast technique has been recently presented [5-7]. This technique combines Near Field (NF) measurements with the equivalent currents (EQC) method [8-9]. Thus, starting from a NF measurement of the DUT, the technique allows to evaluate power density, at any distance from the Device Under Test (DUT). This would allow to verify the pre-compliance of the DUT with EMF exposure limits. In a previous study, validation was performed on a Dual Ridge Horn [5]. In this paper, a Closed Boundary Quad-Ridge Horn is considered. Results and achievable accuracy are presented.

16:30 ***Overview of Novel Beam Steerable Antenna Concepts Enabling Internet of Space***

Yahya Rahmat-Samii (University of California Los Angeles (UCLA) & UCLA, USA); Junbo Wang (University of California, Los Angeles, USA)

Internet of space (IoS) aims to provide global network coverage from space through a constellation of satellites. The advancement of CubeSat technology has unlocked a new possibility to realize this vision of IoS. To make IoS a reality, one of the major challenges faced by engineers is the design of a broadband, circularly polarized, beam steerable antenna that can be integrated with the small form factor of CubeSats. This invited paper provides a brief overview of the antenna concepts that has the potential to be applied for CubeSats to enable IoS.

16:50 ***Extending Usable Low Frequency Range of an Anechoic Chamber for Antenna Calibrations Using Time Domain Deconvolution Filter***

Zhong Chen (ETS-Lindgren, USA)

It is usually impractical to calibrate antennas in an anechoic chamber down to the VHF frequency range, because absorbers do not perform adequately at these frequencies. Time domain gating can be used to the extent that the antenna ring-down time is short enough, and the reflections are far enough away, so that a gate can be applied without cutting into the antenna intrinsic response. Although it could be possible to apply time domain gating at a closer distance, it is typically not feasible to do so in the far field. We investigate calibrating broadband biconical antennas from 75 MHz to 2 GHz in a chamber designed for above 1 GHz measurements using time domain deconvolution filter before a gate is applied. After applying the deconvolution filter acquired from a 3 m measurement in the same chamber, we successfully obtained the free space response for a far field distance.

17:10 ***Investigation of Higher-Order Modal Scattering of Anechoic Absorbers at Mm-Wave Frequencies***

Anoop Adhyapak (ETS-Lindgren, USA); David Rolando (Ansys, USA)

An anechoic absorber is modeled and analyzed for specular and higher-order scattered modes at high frequencies. Computation of chamber reflectivity levels based on the geometric-optics ray-tracing approach including only specular modes is accurate at microwave frequencies but may fail to predict accurately at the mm-wave frequencies. Hence, the absorber is simulated in a unit cell model to extract the higher-order modes at the mm-wave frequencies. The absorber model results are then translated into a chamber model and the reflected energy due to the higher-order modes entering the quiet zone of the chamber is mapped at different frequencies. Heat-maps are used to depict the effect of the higher-order scattering at mm-wave frequencies.

17:30 ***Traditional to Modern Antenna Test Environments: The Impact of Robotics and Computational Electromagnetic Simulation on Modern Antenna Measurements***

Dennis Lewis (Boeing, USA); Jason Bommer (ANSYS Inc., USA); Greg Hindman (Next Phase Measurements, USA); Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain))

Many traditional antenna test facilities are designed with a specific measurement application in mind. As a result, these facilities tend to have fixed measurement geometries with much of the range performance analysis being performed only once, during the design phase of the test facilities implementation. Modern antenna measurement ranges employing multi-axis robotic positioners provide a near limitless degree of re-configurability in terms of measurement types and scan geometries. This drives an ongoing need to evaluate each unique setup and application. Model based Systems Engineering and development (MBSE/MBD) approaches can be employed to dramatically reduce the time, effort, and cost associated with the test development and validation phases of a given program. MBSE tools can also be used to optimize test configurations to greatly reduce measurement uncertainties. This paper provides an overview of how these engineering techniques are being harnessed during the implementation of a new dual multi-axis robotic antenna test system.

T11-E06: Reconfigurable surfaces and metamaterials

Room: virtual 12

15:50 ***Omega Bianisotropic Huygens' Metamaterial Lens for Matching Improvement of W-Band Substrate Integrated E-Plane Horn***

Nima Bayat-Makou and George V. Eleftheriades (University of Toronto, Canada)

An omega bianisotropic Huygens' metamaterial lens is utilized to alleviate the intrinsic discontinuity along the excited traveling wave at the radiating aperture area of a substrate integrated E-plane horn antenna at millimeter-wave frequencies at W-band. This discontinuity, which is mostly due to a wave impedance mismatch at the air and dielectric substrate, is smoothened by a Huygens' metamaterial lens comprising omega bianisotropic particles. This allows to match the impedance mismatch between the horn and free

space. For the presented E-plane integrated horn, the meta-lens improves the antenna matching bandwidth between 75 and 80 GHz, which is a significant improvement for this kind of antennas.

16:10 ***A New Metasurface-Enhanced Microstrip Patch Antenna for Haemorrhagic Stroke Detection***

Eleonora Razzicchia (King's College, United Kingdom (Great Britain)); Pan Lu, Wei Guo and Panagiotis Kosmas (King's College London, United Kingdom (Great Britain))

This paper presents a new printed square monopole antenna (PSMA) for haemorrhagic stroke detection, enhanced by a metasurface (MTS) superstrate. To show the capabilities of MTS technology in microwave brain imaging, three different tomographic systems are compared in CST. Our previous developed headband scanner operating in a lossy matching medium is compared to two brain scanners operating in air: a 8-PSMA system and a 8-MTS-enhanced PSMA system. For image reconstruction we used DBIM-TwIST algorithm. Our results indicate that a blood-mimicking target placed inside the brain volume of our head model can be detected avoiding the use of a liquid and bulky matching medium. In addition, our MTS superstrate enhances the antennas' return loss and increases the signal difference due to the presence of the target, which translates into more accurate reconstructions. Thus, MTS technology may be a significant hardware advancement towards the development of functional and ergonomic microwave brain scanners.

16:30 ***Spoof Plasmon Polariton-Antenna Transitions for Terahertz On- Chip Applications***

Andreas K. Klein, Christian Bojahr and Andreas Stöhr (University of Duisburg-Essen, Germany)

A transition to couple an antenna to spoof plasmon-polariton waveguides at terahertz frequencies is presented. The optimization of the transition is discussed. Examples of how antenna coupling can enable THz on-chip applications are given in a biosensor and a phase shifter. The sensing of deeply subwavelength biological cells demonstrates the high sensitivity to even small concentrations of bacteria. And while the phase shifter only exhibits a small angle range, its high transmission, and easy integration makes it suitable for applications such as an on-chip phased array.

16:50 ***Dual-Polarized Broad-Beam Reflective Metasurface Based on Multi-Sheet Configuration for Local 5G Application at 28.25 GHz***

Tanan Hongnara (Denki Kogyo Co. Ltd. & Japan, Japan); Yoshiki Shirasawa and Takayoshi Sasaki (DKK Co., Ltd., Japan); Katsumori Sasaki (Denki Kogyo Co., Ltd., Japan); Keisuke Sato (Denki Kogyo co., Ltd., Japan); Ichiro Oshima (Denki Kogyo Co., Ltd., Japan); Naobumi Michishita (National Defense Academy, Japan); Hiroaki Nakabayashi and Keizo Cho (Chiba Institute of Technology, Japan)

In order to simply broaden reflection beam of metasurface, the utilization concept of multi-sheet configuration is presented and investigated. Demonstration is based on four sheets of 28.25 GHz metasurface that have the same designed incident angle. Meanwhile, their reflection angles are designed to be moderately different for producing broad reflection beam. In full wave simulation, the combined metasurface perform broad-beam operation in corresponding to individual reflection angle of each metasurface. Then, in coverage area measurement of local 5G system, multi-sheet metasurface provides wider coverage with compact installation space comparing to conventional metallic reflector.

17:10 ***Graphene-Based Reconfigurable Intelligent Metasurface Structure for THz Communications***

Mohammad Ojaroudi (University of Limoges/CNRS, France); Valeria Loscrí (Inria Lille-Nord Europe, France)

In this paper, a graphene based reconfigurable intelligent metasurface structure is proposed for terahertz (THz) communication applications. The proposed structure consists of multilayer unit cells with a graphene radiating patch. By using different values of biasing voltages, the chemical potential (μc) of the graphene is changed which leads to have different reflected phases. Based on this property we are able to create different reflected phase distributions within the full structure metasurface array which can be controlled by coding pattern in processing units. The proposed unit cell can provide an acceptable reflection characteristic around 4.35 THz. In addition, by changing the biasing voltage, four states are generated which can transmit 1-bit and 2-bits data. The proposed metasurface structure has small size and high flexibility in controlling radiation patterns. The simulated results such as reflected phase distributions and reconfigurable radiation patterns show the effectiveness of the proposed design for THz communication.

17:30 ***Reconfigurable FSS Based on PIN Diodes for Shared-Aperture X/Ka-Band Antennas***

Mousa Abdollahvand (Tarbiat Modares University (TMU) Tehran, Iran); Keyvan Forooraghi (Tarbiat Modarres University, Iran); Zahra Atlasbaf (Tarbiat Modares University, Iran); Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain); Amir Ebrahimi (RMIT University, Australia); Saptarshi Ghosh (Indian Institute of Technology Indore, India)

This contribution presents a reconfigurable frequency selective surface (FSS) for shared-aperture satellite antennas in X and Ka bands. The FSS has been designed to be reflective at 20 and 30 GHz (transmit and receive frequencies in Ka-band) and to allow switching of transmission and reflection responses in X-band (between 9 and 12 GHz). The FSS unit cell comprises a multi-layer structure, and reconfigurability is achieved using four PIN diodes. An equivalent circuit model has been developed explaining the operating principle of the proposed FSS. The active FSS provides a stable performance for different polarizations under oblique incidence angles.

Monday, March 22 17:50 - 19:00

Welcome Reception

Room: virtual 1

Chairs: Thomas Kürner (Technische Universität Braunschweig, Germany), Cyril Mangenot (Api-Space, France)

Tuesday, March 23

Tuesday, March 23 10:00 - 11:40

CS31: (ISAP Session) Recent Advances in Asian Antennas and Propagation Research

T01 LTE and Sub-6GHz 5G / Convened Session / Antennas

Room: virtual 1

Chairs: Y. Jay Guo (University of Technology Sydney, Australia), Kunio Sakakibara (Nagoya Institute of Technology, Japan)

10:00 ***24-GHz Focused Beam 2 × 2 Patch Array with Coupling Strip for In-Vehicle Surveillance***

Yi-Lin Tsai, Po-Lin Huang, Huy Nam Chu and Tzyh-Ghuang Ma (National Taiwan University of Science and Technology, Taiwan)

A focused beam 2×2 patch array is proposed and demonstrated for in-vehicle vital sign signal surveillance systems at 24 GHz. The design goal is to overcome the undesired defocused effects caused by radome due to diffraction. To tackle the problem, a parasitic coupling strip is inserted between the pair of series-fed patch arrays. By properly controlling the length of conducting strip, the radiation from open ends of patches and coupling strips are added in phase to boost the peak gain at the zenithal direction. It thereby re-focuses the beam and alleviates EM wave leakage through windows of a vehicle. The design concept is illustrated in terms of parametric study and explained by simulated current distribution. In addition to S-parameters, radiation patterns are measured in terms of the normalized EIRP patterns taken from a fully-integrated active module for better approximating the real scenario. The experimental results clearly support the design concept.

10:20 ***A Dual Band Dual-Polarized Sub-6GHz Base Station Antenna***

Rong Cao, Chow-Yen-Desmond Sim and Jia-He Zhuang (Feng Chia University, Taiwan)

This paper proposes a dual band dual-polarized base station antenna. The radiator of this antenna is a pair of modified crossed dipoles, which helps the antenna to operate at two frequency bands. A flat reflector instead of a shaped one is used to shape the radiation pattern of this antenna. The simulation results show that this antenna has good performance (VSWR < 1.5 and isolation > 28 dB) at the 4G band and part of the 5G band. It also has good gains in the desired frequency bands.

10:40 ***A Review on Conformal Transmitarrays***

Lizhao Song (University of Technology Sydney, Australia); Peiyuan Qin (University of Technology, Sydney, Australia); Y Jay Guo (University of Technology Sydney, Australia)

This paper presents an overview of research on conformal transmitarrays conducted in University of Technology Sydney, Australia. More specifically, it includes our latest progress in beam scanning conformal transmitarrays and high-efficiency ones.

11:00 ***Mantle Cloak Antenna for Reducing Mutual Coupling at Close Frequency***

Thanh Binh Nguyen, Keisuke Sakakibara, Naobumi Michishita and Hisashi Morishita (National Defense Academy, Japan); Teruki Miyazaki and Masato Tadokoro (The Yokohama Rubber Co., Ltd., Japan)

In this paper, the mantle cloak antenna was developed to reduce the mutual coupling at a close frequency with the operating frequency of the antenna. The mantle cloak antenna using strip conductors and the mantle cloak antenna using composite right/left-handed (CRLH) structures were designed. By using the mantle cloak antennas, it confirmed that the stopband frequency was 750 MHz, and the antenna characteristics could be maintained at 720 MHz. The mantle cloak antenna using CRLH structures was prototyped and measured to validate the simulation results. The measurement results were found to approximately agree with the simulation results.

11:20 ***Microwave Metalens Antennas for 5G Network***

Zhi Ning Chen (National University of Singapore, Singapore); Teng Li (Southeast University, China & Karlsruhe Institute of Technology, Germany); Shun Li Li (Southeast University, China); Chunhua Xue (Guangxi University of Science & Technology, China); Qun Lou and Wei E. I. Liu (National University of Singapore, Singapore)

Microwave metalens has been long developed since the 1940s. The metalens is based on the same principle of an optical lens for electromagnetic wave control and implemented using microwave components rather than dielectric materials, for example, for power focusing. Recently, metamaterial-based lens technology has been developed in both optical and microwave bands for flat and low-cost designs. This paper presents the latest progress in the microwave metalens antennas for the 5G network. All metalens are flat and implemented by multilayered metasurfaces. Starting with a flat multiple-beam lens operating at 28 GHz for spatial multiple-input and multiple-output (MIMO), we review the designs of a large-scale metalens for massive MIMO, a three-beam metalens antenna for base stations, and Huygens' surface-based metalens for low reflection.

T02-A01: 5G communication architectures: Part 1 Base Stations

T02 Millimetre wave 5G / / Antennas

Room: virtual 2

10:00 ***5G Basestation Antenna System Challenges [INDUSTRIAL KEYNOTE]***

Ulrik Imberg (Huawei Technologies, Sweden AB, Sweden)

Industrial keynote talk.

10:20 ***Design of a Wideband Wide-Scanning Dual-Polarized Phased Array for Mobile Communications***

Riccardo Ozzola and Andrea Neto (Delft University of Technology, The Netherlands); Ulrik Imberg (Huawei Technologies, Sweden AB, Sweden); Daniele Cavallo (Delft University of Technology, The Netherlands)

We present the design of a wideband wide-scanning phased array for mobile communications. The array elements are dual-polarization connected slots, radiating in the presence of a superstrate made of artificial dielectric layers (ADLs). The matching of the array unit cell is investigated by means of simulations, based on a previously derived spectral domain methods and on commercial solvers. We show two different designs: one covering the 6-8 GHz frequency band, with active voltage standing wave ratio (VSWR)<2.2 and scanning up to 60° in all azimuth planes, and another covering 2-8 GHz with active VSWR<3 over the same scan range. These two designs retain the same radiating part (i.e. connect slots with the backing reflector) and differ only by the artificial dielectric `radome' covering the slots, which can be interchanged. The inter-element spacing is kept at 0.4\(\lambda\) at the highest frequency of operation, to improve the matching efficiency for wide scanning.

10:40 ***Broadband D-Band Antenna Array Based on 64 Stepped Horns for 5G Backhauling Applications***

Sherif R. Zahran and Luigi Boccia (University of Calabria, Italy); Giandomenico Amendola (IEEE, USA); Stefano Moscato (SIAE Microelecttronica, Italy); Matteo Oldoni (SIAE Microelettronica S.p.A., Italy); Dario Tresoldi (SIAE Microelecttronica, Italy)

this work proposes an 8×8 D-band antenna array constructed from 64 stepped horns. The structure is designed to be machined from single metallic block adhered with an additional bottom metallic cover. The proposed design can be realized using low-cost commercially accessible milling tools. The configuration at hand is composed of three building blocks: transition, power divider and horn radiator. The array footprint has a volume of 30×30×8 mm3 while a 29.5% fractional bandwidth is achieved from 130 till 175 GHz where reflection coefficient is lower than 7.8 dB. Radiation characteristics are investigated for both single horn radiator and 8×8 antenna arrays where the obtained average gain values are 15.25 and 32 dBi, respectively. Directive pencil beam, required for 5G backhauling communication, has been confirmed for 8×8 antenna array where the half power beam width is 1.5° for both E and H-planes while grating lobes appear at 28°.

11:00 ***Outphasing Methods for Beyond-5G Millimeter-Wave Base Station Applications***

Meerten M.A. Versluis, A. B. (Bart) Smolders, Roel X.F. Budé and Ulf Johannsen (Eindhoven University of Technology, The Netherlands)

This paper presents a review of various outphasing methods. Key performance indicators are formulated focusing on reliability, energy consumption and bandwidth and are used to compare state-of-the-art outphasing methods. Outphasing methods which show potential for beyond-5G base station applications are described and relevant advantages, disadvantages and literature gaps are pointed out. Specifically, the recent developments on using antenna elements to be co-designed with an outphasing system will be considered as a promising efficient solution. Findings in this paper show that a co-designed amplifier-antenna outphasing system achieves one of the highest peak power-added efficiencies at millimeter-wave frequencies compared to other PA topologies.

11:20 ***High Gain Phased Lens Array for 5G Fixed Wireless Access Points***

Huasheng Zhang, Sjoerd Bosma and Andrea Neto (Delft University of Technology, The Netherlands); Ulrik Imberg (Huawei Technologies, Sweden AB, Sweden); Nuria LLombart (Delft University of Technology, The Netherlands)

A dual-polarized 4x4 lens-enhanced leaky-wave phased array operating at 28 GHz is presented. Such an antenna can be used for point-to-point 5G communications that require high gain and wide bandwidth. The proposed array has a periodicity of two wavelengths, and the resulting grating lobes are suppressed by directive and steerable lens element patterns. To achieve a low-cost and low-profile solution, leaky-wave feeds are designed in printed circuit board in combination with plastic lenses. The lenses are optimized in the near-field region of feeds, with the goal of maximizing the lens aperture efficiency. The array performance obtained from the proposed approach was validated by full-wave simulations, showing scanning capability up to 20 degree with 2 dB of scan loss. An antenna prototype was fabricated and measured. Measurement results are in excellent agreement with full-wave simulations. The prototype array, at broadside, achieved a 20% relative bandwidth and a gain of 26.2 dB.

T02-P01: mm-wave propagation

T02 Millimetre wave 5G / / Propagation

Room: virtual 3

Chairs: Thomas Kürner (Technische Universität Braunschweig, Germany), Jose M Riera (Universidad Politécnica de Madrid, Spain)

10:00 ***On the Characterization of Beam Misalignment in Outdoor-To-Indoor 60 GHz mmWave Channel***

Monsij Biswal (University of California, Santa Barbara, USA); Aniruddha Chandra (National Institute of Technology, Durgapur, WB, India); Aniq Ur Rahman (King Abdullah University of Science and Technology, Saudi Arabia); Ales Prokes (Brno University of Technology & Sensor, Information and Communication Systems Research Centre, Czech Republic); Tomas Mikulasek and Jiri Blumenstein (Brno University of Technology, Czech Republic); Cezary Ziółkowski and Jan M. Kelner (Military University of Technology, Poland)

Measurement data of an outdoor-to-indoor channel at 60 GHz for various orientations of the receiver is analyzed. The variation of delay spread with respect to the misalignment angle suggests the existence of clusters which map to nearby buildings acting as scatterers. We divide the range of misalignment angle into sectors of 5 degrees each and analyzed the similarity between the TDL models of each sector. The analysis enabled us to group the sectors into two categories: (A) [0,10) degrees and (B) [10,25) degrees. The BER results are reported for BPSK modulation at 8 Gbps datarate. It is seen that when the misalignment angle exceeds 10 degrees, the BER floor goes up significantly, causing a BER increase of almost two orders.

10:20 ***Automatic Planning Algorithm of 300 GHz Backhaul Links Using Ring Topology***

Bo Kum Jung and Thomas Kürner (Technische Universität Braunschweig, Germany)

In the future, the base stations are expected to be deployed with higher density. To save cost and man forces, wireless links operating at 300 GHz can replace conventional cable-based backhaul connections. One of the goal of Horizon 2020 EU-Japan project ThoR is to design automatic planning tools for 300 GHz wireless backhaul network. To accomplish this task, a novel planning tool has been developed to plan backhaul links with the usage of a ring topology. To evaluate the proposed tool's functionality, system-level simulations are conducted with an in-house developed mobile network simulator. In this paper, the algorithm of the new planning tool for 300 GHz wireless backhaul network is introduced and the SINR characteristics of the planned THz links are evaluated using 3D ray optical path loss predictions. For that, a realistic scenario of an ultra-dense cellular network in Hanover, Germany, is used with the diverse tropospheric climate conditions.

10:40 ***Variability of Rain Attenuation in the 100-200 GHz Band Calculated from Experimental Drop Size Distributions***

Santiago Pérez-Peña, Jose M Riera, Ana Benarroch and Domingo Pimienta-del-Valle (Universidad Politécnica de Madrid, Spain); Pedro Garcia-del-Pino (Universidad Politecnica de Madrid, Spain)

The attenuation produced by rain can be derived from experimental Drop Size Distributions (DSD) using physical models of scattering in particles (Mie and its Raylegih approximation). As the frequency increases within the mm-wave bands, the specific attenuation becomes more dependent on the DSD, whereas attenuation is mainly determined by the rain rate R in lower frequency bands. As is well-known, Mie scattering becomes dominant in the mm-wave band instead of Rayleigh scattering, which is the main extinction mechanism in cm-wave frequencies. In this document, long-term DSD measurements from an optical Laser disdrometer available in Madrid, Spain, were used to estimate the specific attenuation produced by rain. A very long period of twelve years has been used for the analysis of rain attenuation in the 100-200 GHz band. The results compare well on average with the ITU-R specific attenuation model of Rec. P.838-3, but they show a significant variability.

11:00 ***Path Loss Results in an Indoor Corridor Scenario at the 26, 32 and 39 GHz Millimeter-Wave Bands***

Domingo Pimienta-del-Valle, Luis Mendo and Jose M Riera (Universidad Politécnica de Madrid, Spain); Pedro Garcia-del-Pino (Universidad Politecnica de Madrid, Spain)

Indoor propagation scenarios have drawn high interest, with several reported results being available. Nevertheless, more campaigns are still needed. Universidad Politécnica de Madrid (UPM) has carried out several indoor propagation campaigns at the 26, 32 and 39 GHz millimeter-wave frequency bands in a corridor indoor scenario. In this paper, multi-frequency path loss propagation results are presented for both line-of-sight (LOS) and non-light-of-sight (NLOS) conditions. These results are modeled with the CIF and ABG fittings and compared with available millimeter-wave models. Also, CI and FI coefficients for NLOS conditions are provided.

11:20 *8-Way Paralleled Power Amplifier for Mm-Wave 5G Backhauling Networks*

Stefano Moscato (SIAE Microelecttronica, Italy); Matteo Oldoni (SIAE Microelettronica S.p.A., Italy); Giandomenico Cannone (SIAE Microelettronica, Italy); Dario Tresoldi (SIAE Microelecttronica, Italy); Alberto Pini and Alberto Colzani (SIAE Microelettronica, Italy)

E-band communications are unique in terms of data throughput capabilities which in turn make them crucial for the 5G network evolution. Unfortunately, they suffer from severe path loss and limited output power of commercial power amplifiers. This manuscript presents a prototype of 8-way paralleled solid state power amplifier fed by a waveguide division/recombination network. The wideband and low-loss features of the feeding network are proven across the whole E-band and are achieved by adopting an ad-hoc magic-tee structure. The OP1dB enhancement target for the manufactured sample is +7dB within 71-76 GHz and experiments show a linear gain of 14.6 dB at 73.5 GHz. The entire system has also been tested with a modulated signal.

T04-A01: Array Antennas 1

T04 IoT and M2M / / Antennas

Room: virtual 4

Chair: Noori BniLam (University of Antwerp - imec, IDLab Research Group, Belgium)

10:00 *Synthesis of Low-Sidelobe Stepped-Amplitude Aperiodic Phased Arrays*

Yanki Aslan (Delft University of Technology, The Netherlands); Antoine Roederer (Technical University of Delft, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands)

A novel stepped-amplitude aperiodic phased array synthesis method is proposed. The presented technique is based on iterative convex element position perturbations and uses pre-defined excitation amplitudes. A 64-element irregular array with two discrete amplitude levels (0.5 at the edge-elements and 1 at the center-elements) is synthesized for demonstration purposes. The array achieves a side lobe level lower than - 30 dB and a directivity higher than 20 dBi within the given field-of-view (±60 degrees in azimuth and ±15 degrees in elevation). Through comparative studies of the array directivity, effective isotropic radiated power and maximal side lobe level with the ones of the uniformly-fed/amplitude-tapered periodic arrays and a uniformly-fed aperiodic array, it is shown that the proposed stepped-amplitude array provides the best complexity/performance trade-off.

10:20 *Generation of Vortex Waves Using Crossed 2λ-Dipole Antennas*

Mohamed Haj Hassan, Benedikt Sievert, Andreas Rennings and Daniel Erni (University of Duisburg-Essen, Germany)

In this paper, a simple and novel method is presented to generate Orbital Angular Momentum (OAM) waves for the first OAM mode order with radial polarization. This approach consists of two crossed 2λ-dipole antennas (CDA) where each antenna is fed in the center with identical amplitude but with a 90◦ phase shift to radiate vortex waves. Further, in order to enhance the gain, the number of crossed dipoles can be increased. Therefore, the simulation of two and four CDAs is performed with the full-wave simulator FEKO. Moreover, a crossed 2λ-dipole phased array of two elements can increase and focus the radiation in the broadside direction. A reflector of 100 mm × 100 mm is also added for one crossed 2λ-dipole antennas to improve the gain in the same direction.

10:40 *Calculation of Characteristics of Planar Antenna Arrays with Substrates Made of Chiral Metamaterials Taking into Account the Dispersion of Macroscopic Parameters*

Alexander Buzov, Maria Buzova, Mark Minkin, Dmitry Klyuev and Anatoly Neshcheret (Povolzhskiy State University of Telecommunications and Informatics, Russia)

The method of analysis of microstrip antennas and antenna arrays with chiral substrates based on the singular integral equations apparatus is considered. The frequency dispersion of material parameters for helices-based chiral substrates is taken into account. The dependences of the input impedances of such antennas are given.

11:00 *AoA Estimates for LPWAN Technologies: Indoor Experimental Analysis*

Noori BniLam and Robin Janssens (University of Antwerp - imec, IDLab Research Group, Belgium); Jan Steckel (University of Antwerp - Cosys-lab Research Group, Belgium); Maarten Weyn (University of Antwerp - imec, Belgium)

In this paper, we present an experimental analysis of the Angle of Arrival (AoA) estimation accuracy in an indoor environment. We utilized an AoA estimation system that is suitable for Low Power Wide Area Network (LPWAN) technologies. The AoA estimation system constituted 8 antenna elements that are distributed as Uniform Linear Array (ULA) antenna. Both Line-of-Sight (LoS) and Non-Line-of- Sight (NLoS) conditions were considered. The conventional beamformer, MUISC, Root MUSIC, ESPRIT and SAGE algorithms were employed to provide the AoA estimates. The experimental results reveal that the AoA estimation algorithms provide a very poor AoA estimation accuracy for signals that were originated within the endfire region of the ULA. Furthermore, the signals that were originated within the ULA broadside region have a maximum estimation error equals 10 and 15 degrees for the LoS and NLoS conditions, respectively.

11:20 *Quasi-Optical Beamforming Network for Millimeter-Wave Electronically Scanned Array Antennas with 1-Bit Phase Resolution*

Artem Vilenskiy (Chalmers University of Technology); Esmé Galesloot (Eindhoven University of Technology, The Netherlands); Yingqi Zhang (Chalmers University of Technology, Sweden); A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands); Marianna Ivashina (Chalmers University of Technology, Sweden)

State-of-the-art design solutions for electronically scanned array antennas are mostly limited to microwave to low mm-wave frequency bands. We attempt to fill in this knowledge gap by presenting a new linear array antenna architecture that can enable beam scanning with a compact and low-cost design. This concept is based on the combination of a quasi-optical system, providing predefined phase and amplitude excitation distributions, and using 1-bit phase shifters. We focus on the problem of sidelobe level minimization applying the optimum quasi-randomization of array phase errors. This is herein solved through an array factor spectral decomposition for arbitrary amplitude taperings. An analytical expression for the optimum focal ratio of the quasi-optical system has been derived to establish the relationships between the key design parameters. These results are verified through numerical simulations for a set of arrays revealing that the optimum focal ratio leads to the maximum sidelobe level minimization.

T05-M01: Dosimetry, Exposure, and SAR assessment

T05 Biomedical and health / / Measurements

Room: virtual 5

Chairs: Dirk Heberling (RWTH Aachen University, Germany), Dinesh Rano (Moscow Institute of Electronics and Mathematics, NRU, Higher School of Economics, Moscow, Russia)

10:00 ***A Novel Estimation Method of Local Peak SAR for 5G Sub-6GHz Antennas Using MIMO-OTA***

Kun Li (Kagawa University, Japan); Kazuhiro Honda (University of Toyama, Japan)

This study aims to provide a novel estimation method of local peak SAR for 5G sub-6GHz mobile antennas in human vicinity using the concept of MIMO-OTA testing. The correlation between local peak SAR and MIMO channel capacity at various sub-6GHz frequency bands is investigated using numerical approaches. The analytical results show the application range of the proposed method, where the dependence of MIMO antenna performance close to a human head phantom were clarified.

10:20 ***Effective SSB Beam Radiation Pattern for RF-EMF Maximum Exposure Assessment to 5G Base Stations Using Massive MIMO Antennas***

Thomas Kopacz, Sascha Schießl, Anna-Malin Schiffarth and Dirk Heberling (RWTH Aachen University, Germany)

Current extrapolation procedures for the assessment of theoretical maximum RF-EMF exposure to 5G massive MIMO base stations consider the antenna gain difference between SSB and traffic beams. The procedure strongly relies on the provided antenna patterns obtained under ideal conditions, but being distorted and smoothed in practice. In this paper, we investigate the impact of ground reflections (for different ground materials) as well as the vertical sweeping of the measurement antenna (in order to find the local maximum exposure) on the effective base station antenna pattern. It shows that for base station antenna heights ≥30 m, ground reflection dominates the impact and leads to an increase of null levels in the normalized antenna pattern to around -30 dB in case of concrete ground and furthermore, to a slight increase of side lobe levels. Both ground reflection and vertical antenna sweeping additionally lead to a broadening of the side lobes.

10:40 ***SAR Assessment Using Vector Probe Array System in the Context of RF Exposure Reduction Utilising Proximity Sensors and Time-Averaging Technologies***

Kammel Rachedi (ART-FI, France); Mounir Teniou (ART-Fi, France); Mehdi Ramdani and Romain Ferrier (ART-FI, France); Stephane Pannetrat (ART-Fi, France); Lyazid Aberbour (Art-Fi, France)

This paper introduces a measurement system architecture for Specific Absorption Rate (SAR) assessment in the context of RF exposure reduction. Focus is brought on two RF exposure reduction technologies: Proximity Sensing and Time averaged SAR (TAS). The proposed architecture is mainly based on the use of a vector-phasor probe array, combined with time domain RF acquisition chain. Coupled with a robotized arm and automation algorithms, the overall setup allows the user to test a device in its intended use without resorting to altered measurement set-ups currently used in state-of-the art techniques. The proposed approach has been successfully validated with experimental measurements on actual smartphone.

11:00 ***Cost-Effective Approach for the Determination of Specific Absorption Rate of Liquid Phantom***

Dinesh Rano (Moscow Institute of Electronics and Mathematics, NRU, Higher School of Economics, Moscow, Russia); Andrey Albertovich Yelizarov (Moscow Institute of Electronics and Mathematics, NRU Higher School of Economics, Russia); Andrey Andreevich Skuridin (Moscow Institute of Electronics&Mathematics, NRU Higher School of Economics, Russia); Elmira Alekseevna Zakirova (National Research University Higher School of Economics, Russia)

In this paper, point thermal specific absorption rate (SAR) of the liquid phantoms are determined by simulation and measurement on an elliptical cylinder for a microstrip patch antenna (MPA) operating in the medical body area network (MBAN) band. For this, we measured the temperature rise of the liquids exposed to EM wave (MPA) for a given time. The liquid phantom (homogeneous) is developed by varying the percentage of salt and sugar in 250g of water, whereas, skin phantom is developed by varying the weight of water 200g of in glycerin. The reported technique to measure SAR can provide measurements without the need for an expensive arrangement of dielectric probe kit and this demonstrates the cost-effectiveness of the proposed technique. Finally, we validated our proposed theory with simulation by keeping the conditions identical to measurement which demonstrates excellent resemblance.

11:20 ***Towards a Crowdsourcing-Based EMF Exposure Monitoring: Evaluation of Smartphone Measurements Using Kriging***

Sascha Schießl, Thomas Kopacz and Dirk Heberling (RWTH Aachen University, Germany)

Conventional methods for exposure assessment cannot provide comprehensive and continuous monitoring. A crowdsourcing-based approach relying on the signal strength measurements of common smartphones could be a potential solution. This paper deals with the evaluation of measurement data collected with smartphones under conditions similar to crowdsourcing. Kriging is used to interpolate and smooth the noisy measurement data. The smartphone measurement data is analyzed for three LTE cells and compared with code-selective measurements of a field strength meter. It is shown that areas with high and low exposure can be distinguished and that local hot spots can also be detected. Furthermore, it becomes clear that at least a rough estimate of the electric field strength can be derived from the signal strength measurements, provided that enough smartphone readings are available for this area.

T06-A02: Wideband Arrays

T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / / Antennas

Room: virtual 6

Chair: Marianna Ivashina (Chalmers University of Technology, Sweden)

10:00 ***Design of a Planar Wideband WideScan Phased Antenna Array***

Fuguo Zhu (Science and Technology on Antenna and Propagation Lab, the 14th Research Institute, CETC, China); Wen Jiang (Xidian University, China); Lei Sun (Science and Technology on Antenna and Microwave Laboratory, China); Zhipeng Zhou (Nanjing Research Institute of Electronics Technology, China); Qi Luo (University of Herfordshire, United Kingdom (Great Britain)); Steven Gao (University of Kent, United Kingdom (Great Britain))

The design of a novel planar wideband phased antenna array operating over 7.5-19.5 GHz has been presented. The array radiator consists of a feeding patch and a couple of shorting patches which are connected to the ground plane with shorting vias and isolating vias. Good impedance matching can be obtained due to the shorting vias while the common-mode resonance is eliminated by the isolating vias. Both the infinite unit-cell model and the finite simulation model have been implemented to investigate the performance of the proposed antenna array. The obtained results have shown that the active VSWR is less than 2 for wide scan in the E-plane while the active VSWR is less than 3 for 45° scan in the H-plane. The whole thickness of the radiator is 3.4mm, indicating the possibility for low-profile applications.

10:20 ***Dual-Polarized Connected Slot Array Design for Satellite Communication***

Alexander J van Katwijk and Andrea Neto (Delft University of Technology, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Daniele Cavallo (Delft University of Technology, The Netherlands)

We present the design of a dual-polarized wideband wide-scan antenna array that covers both Ku- and Ka- satellite communication (Satcom) transmit bands. The unit cell consists of two orthogonal connected slots radiating in the presence of artificial dielectric layers, to improve the scan range. The matching efficiency of the unit cell is investigated by means of full-wave simulations, which include the details of the feeding structure. The simulated active voltage sanding wave ratio (VSWR) is below 2.8 for scanning up to 60 degrees. Since polarization purity is an essential requirement for Satcom applications, an analysis of the polarization performance is also presented. The two slots are combined with appropriate amplitudes to cancel the cross-polarization for any scan angle and polarization condition.

10:40 ***Ultra-Wideband, Tightly-Coupled Magneto-Electric Phased Array***

Senglee Foo (Huawei Technologies Canada, Canada)

Extensive researches in the past decade showed that, in contrary to common intuition, a closely coupled dipole array (TCDA) can offer extremely wide frequency bandwidth that is unattainable by a conventional resonant types of phased arrays. This paper intend to show that TCDA is a form of CRLH structure and can be analyzed as such. Based on the CRLH theory, this paper presents a general form of closely-spaced phased array structure consisting of magneto (slots) and electric (planar monopoles) radiating sources. A UWB active phased array based on such CRLH model is presented. Furthermore, it is shown that such arrays can be designed to suppress potential "surface waves" that exist in such finite arrays. Advantage of this type of phased arrays include multi-octave broadband operation and does not require complex balun or costly feed structure.

11:00 ***3D Wide-Angle Impedance Matching for X-Band Phased Array***

Brandon Sun (Insa de Rennes, France); Renaud Loison and Raphael Gillard (IETR & INSA, France); Eric Estebe (Thales DMS France, France); Christian Renard (Thales Systèmes Aéroportés, France)

The design of 3D Wide-angle impedance matching is presented in this paper. The design of an X-band array element, further illustrating the use of 3D WAIMs, is first detailed. This X-band element presents limited scanning performance which is improved thanks to the addition of WAIMs. The need of 3D WAIMs is justified through an analytical model. Finally, the antenna design is presented with the optimized 3D WAIM placed above the X-band element. The improvements in scanning performance are analysed, through the active reflection coefficient and radiation patterns.

11:20 ***W-Band Waveguide Antenna Elements for Wideband and Wide-Scan Array Antenna Applications for Beyond 5G***

Yinggi Zhang, Artem Vilenskiy and Marianna Ivashina (Chalmers University of Technology, Sweden)

Energy-efficient and highly-compact beam-steering array antennas at W- and D-band frequencies are considered as future enabling technologies for beyond-5G applications. However, most existing solutions at these frequencies are limited to the fixed-beam and frequency-dependent beam-steering scenarios. This paper aims to fill in this knowledge gap by investigating various types of antenna elements as potential candidates for wideband and wide-scan arrays at W-band. We consider open-ended ridge and ridge gap waveguide radiating elements that could overcome the physical complexities associated with the integration of elements in large-scale electronically scanned arrays. An infinite array approach is used, where we have adopted a triangular uniform array grid and introduced E- and H-plane grooves to the element design to enhance the scan and bandwidth performance. Cross-comparison of several simulated array designs leads to the final array elements with 25% impedance bandwidth over the scan range of ±40deg. in both the E- and H-planes.

CS15: From Science to System Design for High Sensitivity Astronomical Array Receivers

T09 Space (incl. cubesat) / Convened Session / Antennas

Room: virtual 8

Chairs: David B Davidson (Curtin University, Australia & Stellenbosch University, South Africa), Karl Warnick (Brigham Young University, USA)

10:00 ***Preliminary Sensitivity Verification of the SKA-Low AAVS2 Prototype***

Marcin Sokolowski (Curtin University, Australia); Jess W. Broderick (ICRAR, Curtin University, Perth, WA, Australia); Randall Wayth (International Centre for Radio Astronomy Research (ICRAR), Australia); David B Davidson (Curtin University, Australia & Stellenbosch University, South Africa); Steven Tingay (Curtin University, USA); Daniel Ung (Curtin University, Australia); Pieter Benthem (ASTRON, The Netherlands); Mirko Bercigli (IDS Ingegneria Dei Sistemi S. p. A, Italy); Pietro Bolli (INAF - Osservatorio Astrofisico di Arcetri, Italy); Tom Booler (ICRAR, Curtin University, Perth, WA, Australia); Riccardo Chiello (University of Oxford, United Kingdom (Great Britain)); Gianni Comoretto (Istituto Nazionale di Astrofisica, Italy); Paola Di Ninni (INAF - Osservatorio Astrofisico di Arcetri, Italy); Maria Kovaleva (Curtin University & Macquarie University, Australia); Giulia Macario (INAF - Osservatorio Astrofisico di Arcetri, Italy); Alessio Magro (University of Malta, Malta); Andrea Mattana (INAF - IRA, Italy); Jader Monari and Federico Perini (INAF-IRA, Italy); Giuseppe Pupillo and Marco Schiaffino (INAF - IRA, Italy); Adrian Sutinjo (Curtin University, Australia); Andre van Es (SKA Organisation, United Kingdom (Great Britain)); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy); Mark Waterson (SKA Organisation, United Kingdom (Great Britain))

The sensitivity of a single station is a crucial performance characteristic of the low-frequency component of the Square Kilometre Array (SKA-Low). In this contribution, the sensitivity of a prototype station of the SKA-Low, the Aperture Array Verification System Version 2 (AAVS2), measured at frequencies 70.3, 110.2, 159.4, 229.7 and 320.3 MHz is presented and compared with electromagnetic simulations. The measured sensitivity data are in good agreement with the predictions of electromagnetic simulations, confirming good understanding of the instrument and its accurate representation in the simulations.

10:20 ***Higher-Order Spectral Analysis of Radio Pulsar Bursts Using MeerKAT***

Alexander Faustmann and Jacki Gilmore (Stellenbosch University, South Africa); Vereese van Tonder and Maciej Serylak (SARAO, South Africa)

The discovery of new radio pulsars is a key science goal for many next generation radio telescopes. The achievement of this objective relies both on the use of improved instrumental sensitivity and also on novel signal processing techniques. The MeerKAT is an example of a next generation radio telescope, emissions from a pulsar are recorded using one of its receivers and are tested for activity in the bispectrum. The test confirms bispectral activity and serves as a proof of concept for future pulsar detection algorithms based on non-Gaussian statistics.

10:40 ***Signal Transport and Digital Signal Processing for the ALPACA L Band Array Feed***

Erich Nygaard, Nathaniel Ashcraft, Mitchell Burnett, Brian D. Jeffs and Karl Warnick (Brigham Young University, USA)

The Advanced L band Phased Array Camera for Arecibo (ALPACA) will rely on RF-over-fiber signal transport and hybrid FPGA/GPU signal processing hardware for calibration, beamforming, and imaging. We report on signal transport system development, phase and

gain stability requirements, and array signal processing algorithm development.

11:00 ***SKA1-Low: Impact of Antenna Response and Mutual Coupling on the Off-Zenith Array Pointing***

Pietro Bolli and Paola Di Ninni (INAF - Osservatorio Astrofisico di Arcetri, Italy); Mirko Bercigli (IDS Ingegneria Dei Sistemi S. p. A, Italy); Maria Grazia Labate (SKA Organisation, United Kingdom (Great Britain)); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy)

SKA1-Low is a VHF radio telescope consisting of more than 130.000 dual-polarized antennas grouped in stations of 256 antennas each. Each station will observe the sky within 45 degrees from the local zenith by using an electronic beamforming. The individual pattern of the antenna and the mutual coupling among antennas can be responsible of a degradation in the synthesized station beam. In particular, the combination of those phenomena can produce an offset in the angular pointing and a reduction of the station directivity. A quantitative analysis for the off-zenith pointing is numerically computed for a technological demonstrator of SKA1-Low. Additional results to mitigate the mutual coupling effects are presented at the lower frequency where the phenomenon is more significant.

11:20 ***Developments in the Analysis of Large Antenna Arrays with Disjoint Elements***

Keshav Sewraj (Stellenbosch University, South Africa); Matthews Chose (Stellenbosch University & University of Stellenbosch, South Africa); Matthys M. Botha (Stellenbosch University, South Africa)

Efficient electromagnetic analysis of very large antenna arrays is important for various applications, including e.g., radio astronomy. The method of moments (MoM) is generally the most suitable computational electromagnetics method to deal with such open-region problems. However, its computational cost grows rapidly with problem size. This paper presents a brief overview of past work as well as the latest developments by the authors, on devising fast MoM-based methods for arrays with identical disjoint elements and arbitrary layouts. Two different lines of development are reported on, namely methods aimed at efficiently solving the full MoM system through the use of macro basis functions and adaptive cross approximation (ACA) acceleration, and a fast-converging iterative method involving localised solutions.

T10-M01: Antenna Design and Measurements

T10 EM modelling and simulation tools / / Measurements

Room: virtual 9

Chair: Olav Breinbjerg (Technical University of Denmark, Denmark)

10:00 ***The DTU-ESA 12 GHz Validation Standard Antenna - New Reference Pattern***

Javier Fernández Álvarez, Jeppe Nielsen, Kyriakos Kaslis and Olav Breinbjerg (Technical University of Denmark, Denmark); Luis Rolo (European Space Agency, The Netherlands)

The DTU-ESA 12 GHz Validation Standard (VAST12) Antenna has been updated with an integrated precision spirit level to ensure that different measurement facilities use the same coordinate system; in particular, the same polarization reference angle. The coordinate system defined by this integrated level is closely aligned with the previously used coordinate system,but it has anyway been necessary to define a new reference pattern from a range of measurements conducted at the DTU-ESA Spherical Near-Field Antenna Test Facility. In addition, an investigation has been conducted on the influence of the termination of the central open tube of the VAST12 antenna support structure on the radiation pattern. It is found that a well-defined termination is required for a unique pattern.

10:20 ***Synergic Use of Measurement and Simulation in the Design of Antenna Radomes***

Lucia Scialacqua (Microwave Vision Italy, Italy); Francesca Mioc (Consultant, Switzerland); Ruben Tena Sanchez (Technical University of Madrid, Spain); Lars Foged (Microwave Vision Italy, Italy)

The antenna radome is an indispensable component for the installation of antennas in many applications. Radomes are generally designed for minimum impact on the antenna performance but often the radome can be used as an integral part of the antenna design. For this reason, each radome should be designed specifically for the antenna using an accurate full-wave model. Unfortunately, the antenna model is not always available, as the antenna is often supplied by third-parties and thus protected by intellectual property rights. Recent publications show that highly accurate computational antenna models can be derived from measurements as Huygens box, compatible with most commercial numerical tools. Hence, designer have a complete numerical model of the antenna and radome reducing the risk of expensive reworking of the radome at a later stage. This paper will show the efficiency of this technique by design, manufacturing and testing of a radome for a commercial antenna.

10:40 ***Feasibility Study of near Field Multiprobe System as EMC Measurement Set-Up***

Ruben Tena Sanchez (Technical University of Madrid, Spain); Manuel Sierra-Castañer, Ricardo Albarracín-Sánchez and Fernando Rodríguez Varela (Universidad Politécnica de Madrid, Spain); Alessandro Scannavini and Lars Foged (Microwave Vision Italy, Italy)

Multiprobe spherical near-field measurements are a very powerful tool for fast and accurate characterization of electrical properties of antennas. The use of fast switching in one axis, and azimuth positioner and a near to far field transformation allows a strong time reduction in antenna measurements while maintaining high quality results. On the other hand, conventional EMC systems are typically based on the detection of the maximum power radiated by a device at different frequencies. The systems usually work in far field (or quasi-far field conditions), performing the measurements either at 3 or 10 meters. There are also well established standards for EMC measurements for getting these peak values and checking the good performance (low radiation) of the electronic devices. This paper analyzes the possibility of cost reduction for the EMC system based on an adjustment of the MVG MiniLab System, up to 6 GHz, analyzing the advantages and limitations.

11:00 ***Using a 3D Metamaterial to Enhance Surface Wave Propagation in HF Band***

Quentin Herbette (ONERA, France); Nicolas Bourey (Onera - The French Aerospace Lab, France); Muriel Darces (Sorbonne Universite, France); Marc Hélier (Sorbonne Université, France); Stéphane Saillant (ONERA - The French Aerospace Lab, France); Michel Menelle (Onera - The French Aerospace Lab, France)

This paper deals with the characterization of a 3D metamaterial structure to enhance the surface wave radiation of transmission antennas used with HF surface wave radars.The innovation is to use a corrugated surface with a negative effective permittivity to launch surface waves. In order to verify the predicted behaviour of this metamaterial antenna, near-field measurements were carried out at scale 1:100 in UHF band and scale 1:1 in HF band. Measurements at 1 GHz were performed on a small scale mock-up in a semi-anechoic chamber. The HF characterization was carried out outdoors thanks to an on-board measuring system on a Unmanned Aerial Vehicle (UAV) specially developed for this testing. The results are presented and allow to confirm the expected radiation of the system.

11:20 ***Modeling Finite-Radius VHF and HF Wire-Antennas for Numerical Dosimetry Applications in Near-Field Interaction Scenarios***

Abdelrahman Abdallah Ijjeh (Université Cote d'Azur, France); Marylène Cueille (University of Nice Sophia Antipolis CNRS, France); Jean-Lou Dubard (Université de Nice - Sophia Antipolis, CNRS, France); Michel Ney (IMT Atlantique, France)

This article presents a study of the impact of finite-radius wire antennas in the High Frequency (HF) and the Very High Frequency (VHF) bands on human operators located in the near-field zone. Modeling a finite-radius wire antenna can be a very tricky task, since the antenna parameters, such as the input impedance and the radiated power depend on the wire's shape and the air-gap, as well as its length and the input power source. However, to accurately model the wire shape and the air-gap a very fine resolution is normally needed since they are normally very small in size. In a nutshell, this article studies the impact of the previously mentioned antenna parameters on the Specific Absorbed Rate (SAR) distribution in humans and some possible techniques to speed up the simulation process.

T10-E01: Theory of EM Fields and Antennas

T10 EM modelling and simulation tools / / Electromagnetics

Room: virtual 10

10:00 ***On the Accurate Characterization of Pulsed Photo Conductive Sources: The Norton Circuit in Time Domain***

Andrea Neto (Delft University of Technology, The Netherlands); Angelo Freni (University of Florence, Italy); Nuria LLombart (Delft University of Technology, The Netherlands)

In circuit theory, the Norton and Thevenin equivalent generators are tools to simplify the solutions of networks including passive or active components and sources. They are extensively used with harmonic sources. Including the case of time varying components, a time stepped evolution is typically used. This contribution extends the applicability of Norton equivalent circuits to the investigation of pulsed THz photo-conducting sources, where a DC bias source, THz radiation and optical laser are connected. The proposed derivation relies on the recognition that Norton' and Thevenin circuits are consequences of the Equivalence Theorem in electromagnetics. The main point of the discussion is to recognize that of the three different portions of the electromagnetic spectrum involved (DC, THz and optics), only the THz radiation needs to be "equivalently" described. The theory is validated by a large campaign of measurements reported in a connected paper.

10:20 ***Near-Field Analysis of a Leaky-Wave Resonant Feed: Application to a Small Silicon Lens***

Sjoerd Bosma, Andrea Neto and Nuria LLombart (Delft University of Technology, The Netherlands)

In this work, we show that the near field of leaky-wave resonant-antennas radiating into dense media can be represented by a single spherical wave within a solid angle around broadside. Beyond this shadow-boundary angle, the residue contribution associated to the leaky-wave pole must also be considered to describe the near-field. We find that this shadow-boundary angle can also be used to define the truncated-lens geometry that couples to the leaky-wave-antenna with high aperture efficiency, even for electrically small lenses. We derive analytical formulas for the lens solid-angle and phase center based on the shadow-boundary angle. We combine the near-field calculation with an FO methodology in reception to calculate the aperture efficiency and radiation patterns of small lenses. A truncated silicon lens with a diameter of only 4 free-space wavelengths is presented that achieves almost 80% aperture efficiency. Excellent agreement with full-wave simulations demonstrates the accuracy of the near-field FO methodology.

10:40 ***Pulsed EM Field Scattering from a Narrow Superconducting Strip: A Solution Based on the Marching-On-In-Time Cagniard-DeHoop Method***

Martin Štumpf (Brno University of Technology, Czech Republic); Ioan E. Lager (Delft University of Technology, The Netherlands); Giulio Antonini (Università degli Studi dell'Aquila, Italy); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)

Pulsed electromagnetic (EM) scattering from a relatively narrow superconducting strip is analyzed with the aid of the EM reciprocity theorem and the Cagniard-DeHoop (CdH) technique. The analysis yields a stable convolution-type equation that is solved using the marching-on-in-time (MOT) technique for coefficients representing the time-domain (TD) electric current induced in the strip. Illustrative numerical examples are validated with the help of the CdH method of moments (CdH-MoM).

11:00 ***Tunable Bessel Beam Based "Transistor": An Alternative Controlled Switch at Millimeter and Sub-Millimeter Waves***

Santi Concetto Pavone (Università degli Studi di Catania, Italy); Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy)

In this paper, an alternative approach to design controlled switches at millimeter and sub-millimeter waves, based on coupled tunable Bessel-beam launchers in the radiative near field region, is proposed. In particular, we investigate the possibility of tuning the electromagnetic properties of the radiating apertures through the application of a driving voltage in order to dynamically switch the cover distance of the launchers. Such a controlled switch is intended to work in a bi-stable mode: when the control signal is high (low), the launchers exhibit an efficient (a poor) electromagnetic coupling through the Bessel-beam main lobe. Therefore, the device acts as a switching transistor, i.e., as in digital applications, and also as an opto-isolator at lower frequencies.

11:20 ***Investigation of Dispersion and Radiation Characteristics of Plasma Loaded Helical Antenna***

Ajay Kumar Pandey (Institute For Plasma Research, Homi Bhabha National University, India); Surya Pathak (Institute for Plasma Research, India)

In this paper, a numerical investigation of dispersion and radiation properties of plasma loaded helical antenna is carried out based on the sheath helix model. The analytical theory has been numerically solved for getting propagation constant and radiation characteristics using polarization and conduction current method. The effect of variation of pitch angle on dispersion characteristics is thoroughly investigated at 2.4 GHz and 5.5 GHz while keeping plasma frequency fixed at 3 GHz. Also, the normalized far-field radiation pattern is presented for different frequencies while keeping the value of pitch angle fixed at 15 degrees. It is observed from the result that when the operating frequency is increased above the plasma frequency, the antenna radiates in the end-fire direction and when the operating frequency is below the plasma frequency, radiation takes place in a normal direction. All the numerical solutions are carried out in MATLAB.

CS2: Advances on Metasurfaces for Wavefront Manipulation

T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics

Room: virtual 11

Chairs: Shah Nawaz Burokur (LEME, France), Kuang Zhang (Harbin Institute of Technology, China)

10:00 ***Millimeter-Wave Transmit-Arrays for Vector Vortex Beam Generation***

Zhi Hao Jiang (Southeast University, China); Bo Gao (ZTE Corporation, China)

In this paper, we present two designs of millimeter-wave transmit-arrays for producing multiple vector vortex beams that are generalized waveforms of cylindrical vortex beams with inhomogeneous polarization states across their wavefront. The first one exploits only the Berry phase while the second one utilizes both the Berry phase and dynamic phase. The proposed methods can be useful for generating complex beams with structured wavefronts from microwave frequencies to optical wavelengths.

10:20 ***Angular Response of Anomalous Reflectors: Analysis and Design Prospects***

Ana Diaz-Rubio and Sergei Tretyakov (Aalto University, Finland)

Metasurfaces for controlling wavefronts are typically designed for plane-wave illumination from a specific direction. However, the behaviour of these metasurfaces for arbitrary illuminations has not been analyzed so far. In this presentation, we study the angular response of anomalous reflectors for arbitrary illumination angles. We will compare the angular response of anomalous reflectors designed with different design strategies. In particular, we explain the dependence of the scattered power for arbitrary illumination angles in phase-gradient metasurfaces, strongly nonlocal metasurfaces, and power flow-conformal metasurfaces. This study will allow us to complete understanding of the scattering properties of anomalous reflectors and to discern the way to engineer their angular response.

10:40 ***Mechanically Tunable Metasurface Lens for Circularly-Polarized Wave***

Weixu Yang, Yilin Zheng, Ke Chen, Junming Zhao, Tian Jiang and Yijun Feng (Nanjing University, China)

In this article, we introduce an ultrathin mechanically tunable metasurface (MS) to realize microwave focusing for circularly-polarized wave. Based on the concept of Pancharatnam-Berry (PB) phase, the reflection phase of each meta-atom can achieve a tunable phase shift covering nearly 2π at will by a micro-motor to provide the required rotation angle. As an example, we design a meta-lens with switchable focusing performance with different focal distance around the center frequency of 4 GHz. The proposed MS and the design method can provide an alternative to realize multi-functional metasurface for versatile wavefront control.

11:00 ***Nonreciprocal Wavefront Manipulation with Transistor-Loaded Metasurfaces***

Guillaume Lavigne (Polytechnique Montreal, Canada); Christophe Caloz (KU Leuven)

We present four examples of metasurfaces nonreciprocal wavefront manipulations using transistor-loaded resonators: nonreciprocal phase-gradients, nonreciprocal waveplates, a nongyrotropic reflective isolator and a gyrotropic reflective isolator.

11:20 ***Passive Reflective Metasurfaces for Far-Field Beamforming***

Jordan Budhu (University of Michigan, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

A single-layer, passive metasurface is designed that controls the amplitude and phase of an aperture using the method of moments and gradient descent optimization. The single layer metasurface is backed by a grounded dielectric substrate. An integral equation is used to model the mutual coupling between surface currents on the homogenized elements, ground plane, and the polarization currents in the dielectric. The integral equation is solved by the method of moments. The metasurface is designed to transform an incident cylindrical wave into a scattered far field beam with a Taylor distribution sidelobe envelope that is scanned to 30° off broadside. Surface waves are introduced through the optimization to obtain a purely reactive and thus passive metasurface. Back-projection of the optimized far field shows both the amplitude and phase are reshaped in the near field.

T11-A01: Small Antennas Theory

T11 Fundamental research and emerging technologies / / Antennas

Room: virtual 12

Chair: Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy)

10:00 ***Localized Waves from Microwaves to Optics: Properties, Applications, and Realizations***

Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy); Santi Concetto Pavone (Università degli Studi di Catania, Italy)

The localized transmission of electromagnetic energy is of paramount importance for modern focusing applications, such as wireless power transfer, medical imaging, chip-to-chip communications, just to name but a few. While devices capable of generating localized waves at optical frequencies are now widespread, the microwave generation of localized waves is more recent. In this conference paper, we aim at giving the reader a clear perspective on the potentialities offered by localized waves as well as the difficulties that still hinder their full development in certain frequency ranges. Starting from well-consolidated techniques for the generation of monochromatic localized waves in both the optical and the microwave domain, we discuss the recent advancements in the generation of polychromatic localized waves in the microwave range. An outlook on possible future advances in this field will finally be provided.

10:20 ***The Number of Independent Wireless Links on a Given Volume Platform***

Riccardo Ozzola and Daniele Cavallo (Delft University of Technology, The Netherlands); Angelo Freni (Università degli studi Firenze, Italy); Nuria LLombart and Andrea Neto (Delft University of Technology, The Netherlands)

The number of independent links that can be hosted by an antenna platform for wireless communication is limited by the mutual coupling between the corresponding beams. These beam coupling can be minimized if the space available for the antennas is electrically large. For these large platforms, a good first order estimation for the number of independent links is the degrees of freedom of the field associated with the sphere enclosing the platform. However, when the antenna volume is moderate or small, the degrees of freedom of the field are not neatly defined and the aperture efficiency becomes larger than one, stopping to be a useful parameter. We resort instead to the concept of observable field, introducing a new coupling coefficient between incident field and antennas in reception. This coefficient allows a trade-off between beam coupling and platform size, to define the maximum number of independent links also for small volumes.

10:40 ***Compact and Broadband Uniplanar Yagi MSA for Sub-6 GHz 5G Frequency Band***

Rajbala S. (Indian Institute of Technology Bombay, India)

A compact and broadband Yagi MSA is proposed with a simple feed to achieve endfire radiation for a frequency band of sub-6 GHz 5G. To make the antenna compact along the boom length, the concept of a microstrip antenna is used so that the distance between the reflector and the driven element is reduced significantly. To increase bandwidth, a semi-elliptical driven patch is used instead of a rectangular driven patch. A parametric study of various parameters of the antenna is carried out to see their effects on the gain, bandwidth, and radiation pattern of the antenna. The proposed antenna having size 0.50λ0×0.13λ0×0.009λ0 provides a better figure of merit with a peak gain of 5.2 dBi, an average gain of 4.9 dBi, and 11.3% bandwidth.

11:00 ***Characteristic Mode Analysis for Antennas with Waveport Problem***

Xuan Deng and Yikai Chen (University of Electronic Science and Technology of China, China); Shiwen Yang (University of Electronic Science and Technology of China (UESTC), China)

Characteristic mode (CM) analysis and a waveport modeling method is combined for analyzing antenna radiation and scattering. Base on the mode matching method, a MoM waveports modeling method is presented for general metallic-dielectric structures. To analyze waveguide port fed antenna with characteristic modes analysis, a suitable weighted matrix is established based on energy relationship and the CMs can be obtained by solving the new eigenvalue problem. Once the CMs are found, modal weighted coefficients of CMs, equivalent electric and magnetic currents on the antenna can readily be obtained. Numerical results of a microstrip antenna with coaxial cable line feeding is given to validate the proposed method.

11:20 ***An Open-Ended Rectangular Waveguide Antenna with Metasurface at Ka-Band***

Jingwen Sun and Teng Li (Southeast University, China); Wenbin Dou (Southeast University & State Key Of MMW, Southeast University, China)

A compact antenna with low-profile is proposed in this paper. The antenna is composed of a layer of metasurface and a rectangular waveguide flange. Two stairs are carved on the broad walls of waveguide for impedance matching. The metasurface of 4×4 square patches and the electromagnetic band gap of mushroom structures based on Rogers RO4003C are introduced for radiation pattern improvement. The simulated return loss is better than 10dB between 29.1GHz and 32.5GHz. Good radiation characteristics are realized in the operating band.

Tuesday, March 23 11:40 - 13:10

IW01: Broadband compact mm-wave antenna array performance optimization (Optenni)

Room: virtual 13

Jaakko Juntunen, Optenni

IW04: Methods for Simulation Driven Antenna Design (Ansys)

Room: virtual 14

Christian Römelsberger, Ansys

Tuesday, March 23 11:40 - 13:40

P1: Tuesday Interactive Posters

Room: Posters

Chair: Christoph Herold (Technische Universität Braunschweig, Germany)

Compact Circularly Polarized Wideband Wearable Slot Antenna for WBAN/WLAN Applications

Alireza Gharaati, Azita Goudarzi and Rashid Mirzavand (University of Alberta, Canada)

In this paper, a new compact single-layer circularly polarized (CP) slot antenna useful for wearable applications is proposed. The overall size of the antenna is 34.9mm×34.9mm× 0.64mm which is almost 0.23λ 0 × 0.23λ 0 × 0.004λ 0 at the lowest frequency of the operating bandwidth. The antenna 10-dB impedance bandwidth of 33.6% (2.03 - 2.85 GHz), and 3-dB axial ratio bandwidth of 22% (2.34 - 2.92 GHz), make the antenna a good candidate for wireless body area network (WBAN) and wireless local area network (WLAN) applications. The antenna is co-planar waveguide (CPW)-fed, with a rectangular slot on the top, and four rectangular strips at the bottom sides of the substrate, to improve the performance of the antenna in terms of axial ratio. The maximum right handed circular polarization (RHCP) gain of the antenna is 3.2 dBic, occurring at 2.4 GHz and boresight.

Screen-Printed Dual-Band and Dual-Circularly Polarized Textile Antenna for Wearable Applications

Hongcai Yang and Xiongying Liu (South China University of Technology, China)

A dual-band textile antenna with dual circular polarization (CP) is designed for wearable devices at the 3.5-GHz WiMAX and 5.8-GHz industrial, scientific, and medical bands. The proposed antenna is made by textile material, making the antenna flexible and conformable. The dual CPs are enabled by placing a linearly polarized monopole on a polarization rotation artificial magnetic conductor, and the mechanism for linear and circular polarizations of the antenna is analyzed in theory. The simulated results on phantom show that the -10-dB impedance bandwidths of the two bands are 12.5% and 11.6% with the 3-dB axial ratio bandwidths of 0.9% and 6.1%, and with the peak gains of 6.0 and 5.8 dBi at the dual bands. Notably, a flexible prototype with the dimensions of 62 × 62 × 4 mm3 was fabricated by using screen printing. The measured results in different scenarios indicate that the proposed antenna has good robustness.

2.4 GHz Wearable Textile Antenna/Rectenna for Simultaneous Information and Power Transfer

Mahmoud Wagih (University of Southampton, United Kingdom (Great Britain)); Geoffrey Hilton (University of Bristol, United Kingdom (Great Britain)); Alex S Weddell and Stephen Beeby (University of Southampton, United Kingdom (Great Britain))

Antennas and rectennas for self-powered body area networks (BANs) have attracted significant interest, in an effort to improve the sustainability of e-textiles. This paper presents a novel dual-port fully-textile antenna, based on a simple microstrip patch, for simultaneous wireless information and power transfer (SWIPT) at 2.4 GHz, presenting the first antenna-rectifier codesign implementation for SWIPT. The proposed antenna's input bandwidth covers the license-free band achieving 8.9 dBi measured directivity and 41% efficiency at 2.4 GHz, with a simple proximity-coupled microstrip feed. For power harvesting, port 2 is designed to achieve a scalable complex impedance to directly match the rectifier without a separate matching network, and achieves 6.3 dBi off-body gain. The proposed rectenna feed improves the antenna's isolation by at least 15 dB compared to a microstrip feed similar to port 1. The rectenna achieves over 40% power conversion efficiency (PCE) from –10 dBm, with a 71% peak PCE.

Wearable Miniaturized PIFA for Smart Garments

Sandra Costanzo, Adil Masoud Qureshi and Vincenzo Cioffi (University of Calabria, Italy)

A miniaturized PIFA design for textile integrated wearable devices is presented. The footprint of the PIFA is reduced by modifying the radiating element, while a lateral feed mechanism is employed to ensure a low profile. The proposed design includes a felt substrate, making it suitable for integration into garments and clothing items. Simulations and experimental validations are discussed.

A Planar Dynamic Pattern-Reconfigurable Antenna

Bahare Mohamadzade (Macquarie University, Australia); Raheel M Hashmi (Macquarie University & IEEE, Australia); Roy B. V. B. Simorangkir (Tyndall National Institute, Ireland); Ali Lalbakhsh and Haider Ali (Macquarie University, Australia)

a circular patch antenna with the ability to reconfigure the pattern between broadside and monopole-like patterns is proposed. The proximity fed circular patch is loaded with four rectangular slots and an outer ring. These two patterns are achieved by reconfiguring the mode of the antenna between TM02 and perturbed TM02. The switching between these two modes is produced by placing four strips in the middle of rectangular slots and activating and deactivating the slots. The proposed antenna has the potential of being conformal by using fabrication based on the polymer-conductive fabric composite technique.

Stop-Band Radiation Properties of Higher-Order Space Harmonics-Enabled Broadside Multi-Beam Leaky-Wave Antenna

Mohammad reza Rahimi (Polytechnique Montréal, Canada); Mohammad S. Sharawi (Polytechnique Montreal, Canada); Ke Wu (Ecole Polytechnique (University of Montreal) & Center for Radiofrequency Electronics Research of Quebec, Canada)

In this work, we investigate the physical intrinsic characteristics of higher-order space harmonics (HSH) in one-dimensional periodic leaky-wave antenna (1D-periodic LWA) along with their stop-band frequencies. The band edge issue (BEI) of odd n ϵ [-1, -3] and even n ϵ [-2, -4] HSH is studied, analyzed, and examined in detail where a method is devised and demonstrated to overcome the mismatching issue of HSH. In addition, the radiation properties of HSH in different stop-bands are examined where we show how the stability and flexibility of HSH can be utilized for achieving a multi-beam LWA (MB-LWA). The proposed concept is experimentally validated by prototyping a LWA based on substrate integrated waveguide (SIW) technology with focusing on the broadside radiation of the n = -2 space harmonic with the capability of multi-beam scanning. The experimental results obtained in this work show a good agreement with the simulation and analysis counterparts.

Compact Bull's-Eye Antenna in Ridge Gap Waveguide with Circular Polarization at 60 GHz

Dayan Pérez (Public University of Navarra (UPNA) & Institute of Smart Cities (ISC), Spain); Iñigo Ederra (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain); Miguel Beruete (Universidad Publica de Navarra, Spain)

In this work, a Bull's-Eye (BE) antenna with circular polarization (CP) based on ridge gap waveguide (RGW) technology, working in the millimeter-wave band (60 GHz) is numerically and experimentally demonstrated. The structure is coupled through a step transition to a ridge-line that ends in two orthogonal arms of different lengths to generate CP. The wave is coupled to the top plate by a central diamond slot surrounded by the BE structure, which consists of four concentric periodic corrugations around the slot. Simulations and experimental results are in good agreement, with practical bandwidth of 6.8% with respect to center frequency and peak gain of 18.4 dB. The antenna has right-handed CP (RHCP) with polarization discrimination of more than 30 dB.

Slotted Waveguide Antenna with Inclined Stairs for Effective Side Lobes Suppression at 38 GHz

Wenbo Liu (Graduate School of Engineering, Takushoku University, Japan); Yasuhiro Tsunemitsu (Takushoku University, Japan)

We propose and optimize the slotted waveguide antenna with inclined reflection canceling stair to enhance the design flexibility and suppress the side lobes rising from the offset variation. By employing the inclined slope on the stair, better phase and amplitude matching condition have been achieved which results in ultra-low reflection of -77 dB for single unit. In addition, there is a tradeoff between the minimal reflection condition and the most flexible design condition of the inclined slope. By setting h1 as 0.36 mm, below - 40-dB reflection can be obtained when the h2 is within the range of 0.1 to 0.8 mm. Thus, we can tune the h2 to adjust the waveguide space of next slot to realize uniform radiation without introducing any varying offset. (The design and analysis of full model is under progress, we would like to present the final side lobes suppression result in the final manuscript.)

Single Feed Multi-Resonant Connected Metasurface Antenna for Nano-Satellite Applications

Daniel E. Serup, Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)

This paper presents a single-fed multi-resonant metasurface antenna structure. The structure has two layers, a patch antenna feed layer, and a metasurface layer. The proposed antenna structure is very adaptable to different substrate configurations and it supports low profile antennas designs. The proposed antenna structure will be presented through three design examples. The first design example is a dual-band configuration for 17GHz and 20GHz. The antenna is simulated to have a gain of more than 6dBi at both of these frequencies. The second design example shows how the feed patch and the metasurface layer of the dual-band configuration can be easily modified to achieve right hand circular polarization for the two bands without any performance loss. The last design example shows how the dual-band configuration can be extended to a triple-band configuration. An additional resonance at 12.5GHz is achieved by adding an additional metasurface ring on the top layer.

Analysis of Polarization Characteristics for Dynamic On-Body Channel at 28 GHz

Ping Yang, Yu Shao and Ping Wang (Chongqing University of Posts and Telecommunications, China); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

The polarization characteristics for dynamic on-body channel are analyzed at millimeter wave (mmWave) band in this paper. Five on-body links under four different polarization combination schemes are simulated during walking and running movement at 28 GHz. The statistical results of mean, standard deviation and peak-to-peak range of path gain are presented and discussed, and the depolarization effects are investigated by analyzing the cross polarization discrimination (XPD). The results show that the co-polarization scheme is the most stable for most links during walking. But for drastic body movements, i.e. running, most links are depolarized and all polarization combination schemes give similar path gains on average.

Impact of Human Blockage on 5G Communication System in the 26 GHz Band

Hamidou Dembélé (IMT Atlantique & Orange Labs, France); Francois Gallée (Télécom Bretagne, France); Marie Le Bot (Orange Labs, France)

This paper deals with the modelling and impact of human blockage on 5G communication systems in millimeterwave bands. The analysis of communication performance in terms of block error rate with and without the influence of human blockage is proposed in the 26 GHz band, thanks to the implementation of the 5G physical layer in a simulation tool. Based on the block error rate performance, a link budget is also established in order to evaluate the impact of blockage on the cell coverage.

Optimal Reconfigurable Intelligent Surface Placement in Millimeter-Wave Communications

Konstantinos Ntontin (NCSR Demokritos, Institute of Informatics and Telecommunications, Greece); Dimitrios Selimis (National Center for Scientific Research " Demokritos" & Univeresity of Peloponnese, Greece); Alexandros-Apostolos A Boulogeorgos (University of Piraeus, Greece); Antonis A Alexandridis and Aris Tsolis (NCSR Demokritos, Greece); Vasileios Vlachodimitropoulos (NCSR Demokritos, Switzerland); Fotis Lazarakis (NCSR Demokritos, Institute of Informatics & Telecommunications, Greece)

In this work, we examine the use of reconfigurable intelligent surfaces (RISs) to create alternative paths from a transmitter to a receiver in millimeter-wave (mmWave) networks, when the direct link is blocked. In this direction, we evaluate the end-to-end signal-to-noise ratio (SNR) expression of the transmitter-RIS-receiver links that take into account the transmitter-RIS and RIS-receiver distances and enables us to acquire important insights regarding the RIS position that maximizes it. Finally, the insights are corroborated by numerical results.

Impact of Reflected Energy from Surrounding Environments on BEL over the Cluttered Path at 3, 6, and 10 GHz

Khairunnisa Aziding (Mokpo National Maritime University, Korea (South)); Chul Woo Byeon (Wonkwang University, Korea (South)); Min So Park (Mokpo National Maritime University, Korea (South)); Dong Ouk Cho (Wonkwang University, Korea (South)); Young Chul Lee (Mokpo National Maritime University, Korea (South))

In this paper, we present BEL measurements on the LoS and nLoS path at 3, 6, and 10 GHz. To investigate impacts of reflected energy (RE) from surrounding environments on the BEL and whole propagation loss, measured and analyzed results are presented according to the presence or absence of the large clutter (a training ship) behind the building. A new parameter RE is proposed for the path loss prediction in the nLoS path and its value is extracted using the measurement results. As a result of the analysis, it was proved that accurate path loss prediction is possible by adding EL to the sum of clutter loss (CL) and building entry loss (BEL). Therefore, the proposed RE should be considered as a parameter to predict the received power indoors on the non-line-of-sight (nLoS) path. Finally, RE measurement and calculation methods are proposed.

Deep Learning Based Broadband DOA Estimation

Yi Ma, Jinfeng Zhang, Ping Chu and Bin Liao (Shenzhen University, China)

This paper proposes a fast and robust learning-based method for direction-of-arrival (DOA) estimation of multiple broadband far-field sources. The processing procedure involves two steps. First, a beamspace preprocessing which has the property of frequency invariant is applied to the array outputs to perform focusing over a wide bandwidth. By converting the outputs from the element-space to beamspace in this step, the computation can be reduced through adjusting the number of beamformers. In the second step, a hierarchical deep neural network is employed to achieve classification, which can output the DOA estimates. Simulation results verify the effectiveness and robustness of the proposed method.

Localisation of Trapped Victims Using Spatially Distributed, Synchronised FMCW Radar Sensors

Maksim Shargorodskyy (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR Wachtberg, Germany); Reinhold Herschel (Fraunhofer FHR, Germany)

For the localisation of trapped victims in complex surroundings, we propose a radar concept of spatially distributed, synchronised FMCW radar sensors with an associated algorithm. Multi-pass propagation and signal delay caused by propagation through inhomogeneous material are addressed by using the principle component analysis on redundant vital signatures and optimising refractive indexes, respectively. The algorithms are verified on real and simulated measurements.

Rectangular Microwave Waveguides for Subsea Communication in Oil and Gas Wells

Thomas Maetz (Goethe University Frankfurt, Germany); Jochen Moll (Goethe University Frankfurt am Main, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany)

In the drilling industry, communication between drilling rig and drill bit is of great importance, because of the necessity of data for process monitoring and control. In this paper, we examine the possibility of using rectangular waveguides outside the drill string in order to avoid contact with the medium transported in the drill string. The new developed watertight connection elements between waveguide segments were produced using injection molds made by additive manufacturing. First measurements at 20 GHz were carried out, which made it possible to estimate the distance between repeaters that would be necessary for data transmission over longer distances. These estimates were based on the worst measured attenuation (-3.77 dB/m) and best simulated attenuation (-0.40 dB/m).

Detection Probability Estimation of 96 GHz Millimeter-Wave Airport Foreign Object Debris Detection Radar Using Measured Radar Cross Section Characteristics

Shunichi Futatsumori (Electronic Navigation Research Institute, Japan); Naruto Yonemoto (Electronic Navigation Research Institute, MPAT, Japan); Nobuhiko Shibagaki (Hitachi Kokusai Electric, Japan); Yosuke Sato and Kenichi Kashima (Hitachi Kokusai Electric Inc., Japan)

Detection probabilities of a 96 GHz millimeter-wave airport foreign object debris (FOD) detection radar system are estimated based on both airport measurement results and radar cross section (RCS) measurement results. Firstly, a reflection power and a signal-to-noise ratio of a 1-inch height and 1-inch diameter metallic cylinder on an airport runway are measured using an experimental FOD detection system. Secondary, RCS values of the typical runway FODs are measured in an anechoic chamber. Then, the measured RCS values of the typical FOD are compared with detection threshold values obtained by the metallic cylinder. Finally, detection probabilities of the typical FOD samples are obtained at 250 m, 300 m and 500 m.

MEO Satellite Ka-Band Receiving Stations for Tropospheric Propagation Impairment Analysis: Design, Architecture and Preliminary Measurements

Augusto Marziani (Telespazio S.p.A. & Sapienza University of Rome, Italy); Fernando Consalvi (FUB, Italy); Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal); Susana Mota (University of Aveiro & Institute of Telecommunications, Portugal); Lorenzo Luini and Carlo Riva (Politecnico di Milano, Italy); Frank S. Marzano (Sapienza University of Rome, Italy)

The evolution of telecommunication systems leads to the use of the higher part of the frequency spectrum to achieve higher data rate. The use of such frequency can be very challenging due to the non-negligible effects of the atmosphere. This paper will describe the architecture and preliminary measurements of the receivers for the ESA-funded MEKaP experimentation. The activity involves several partners, Sapienza University, Instituto de Telecomunicações-Aveiro Pole, Politecnico di Milano, Fondazione Ugo Bordoni, and Thales Alenia Space-Italia. A total of four receivers (three in Italy and one in Portugal) will create a network of shared data with the main objectives of characterizing the Tropospheric Impairments in co-polarization as well as cross-polarization. The paper will focus on the detailed architecture of the Rome and Milan receiving stations, that share the same design, and on the preliminary measurements acquired and post-processed thanks to the overall effort of the whole international research group.

Weather-Forecast Based RMOP Link-Budget Approach Experimentation: Data-Transfer Optimization at Ka-Band with Hayabusa-2 Satellite Mission Support

Marianna Biscarini (Sapienza University of Rome, Italy); Saverio Di Fabio (CETEMPS, Italy); Klaide De Sanctis (HIMET, Italy); Maria Montagna (VisionSpace Technology GmbH @ ESA Germany); Luca Milani (LSE Space GmbH @ ESA Germany); Yuichi Tsuda (Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan); Frank S. Marzano (Sapienza University of Rome, Italy)

This work describes the operative experimentation of a weather-forecast-based satellite link-budget approach at Ka-band (RMOP) during 6 months of collaboration with JAXA and ESA within Hayabusa-2 deep-space mission. Operative link-budget design was performed 24 hours before each scheduled transmission window providing JAXA and ESA with optimized symbol-rates to adopt during the transmission and the corresponding expected signal-to-noise ratio values allowing a real-time monitoring of the predicted atmospheric channel status. The comparison between simulations and measurements proves the accuracy of the RMOP tool with correlation values higher than 0.9, bias lower than 0.8dB and error standard deviation lower than 0.7dB. The optimization analysis confirms the strong potential of the RMOP approach providing gain values higher than 5 dB in terms of signal-to-noise ratio and higher than 100% in terms of transmitted data-volume. These results pave the way to an operative scheduling of a weather-forecast based link-budget approach for future satellite missions.

Rain Attenuation Estimation with the Numerical Weather Prediction Model WRF: Impact of Rain Drop Size Distribution for a Temperate Climate

Laurent Quibus and Valentin Le Mire (ONERA, France); Julien Queyrel (ONERA & Université de Toulouse, France); Laurent Castanet (ONERA, France); Laurent Féral (Laboratoire d'Aérologie, Université de Toulouse, France)

Frequencies at and above K/Ka band are required for the deployment of (very) high throughput satellites. Yet, radio-links at those frequencies are strongly affected by tropospheric constituents, especially rain. The knowledge of the signal attenuation due to rain comes from dedicated propagation experiments with satellite beacons. Numerical Weather Prediction models could act as an alternative source of rain information, but the validation of their performances against beacon data remains incomplete, notably with respect to the local climatology. This work studies the rain attenuation predicted with the Weather Research and Forecasting (WRF) model 4.0.3 initialized with ERA-5 data, tests nine microphysics schemes, either single- or double-moment, and adapts rigorously the electromagnetic model to their assumed rain drop size distributions. Results are compared over three months in Toulouse, in a temperate region, at both 20.2 and 39.4 GHz, and a strategy is outlined to select the best parametrizations from the error metrics.

Fade Slope Analysis of Alphasat Satellite Measurements at Ka and Q Bands

Arsim Kelmendi (Jozef Stefan Institute, Slovenia); Andrej Hrovat (Jožef Stefan Institute, Slovenia); Ales Svigelj (Jozef Stefan Institute, Slovenia); Mihael Mohorcic (Jozef Stefan Institute & Jozef Stefan International Postgraduate School, Slovenia)

Fade slope analysis is important for the deployment and operation of satellite systems at high frequencies such as Ka/Q bands and above. In order to mitigate the attenuation of the signal due to atmospheric impairments, rain in particular, such systems have to implement appropriate fade mitigation techniques (FMT). The determination of the required tracking speed of FMT for following the signal variation and to enable the short-term prediction of the propagation conditions, is dependent on fade slopes. In order to characterize and model the fade slope statistics, long periods of measurement data are needed. In this paper, fade slope statistical distributions are presented, derived from the excess attenuation of three years' worth beacon measurements from the Alphasat satellite at 19.7 GHz and 39.4 GHz in Ljubljana, Slovenia, and compared to the fade slopes predicted by the ITU-R P.1623-1 model.

Validation of ITU-R P833-9 Tree Attenuation Model for Land Mobile Satellite Propagation Channel at Ku/Ka Band

Sebastien Rougerie (CNES, France); Jonathan Israel (ONERA - The French Aerospace Lab, France); Tomoshige Kan (National Institute of Information and Communications Technology, Japan)

This paper presents a comparison between the ITU-R P833-9 ("slant path" section), versus measurements acquired by CNES and NICT at 20 and 18 GHz. Although several comparisons to measurements have been done between 1 - 3 GHz in previous works, we show here also a good agreement between the ITU-R P833-9 model and the measurements at Ka band for satellite propagation channel, without excessive model tuning. The demonstration is done on isolated here and long wooden road with an innovating fitting process.

Dual-Mode Circular Microstrip Patch Antenna for Airborne Applications

Zubair Akhter, Atif Shamim and Rana Bilal (King Abdullah University of Science and Technology, Saudi Arabia)

A dual-mode, dual-band 2.4/ 5.2 GHz circular microstrip patch antenna for airborne application is presented. Initially, a reference circular patch antenna is designed on Rogers© 5880 substrate for dual-mode (TM11 and TM01) performance with a single feed location. The bandwidth (BW) of the reference antenna is found to be 33 MHz and 155 MHz at 2.4 GHz and 5.2 GHz band respectively. Later, the BW of the reference antenna at both the frequency band is enhanced with the help of proximity patches placed around the periphery of the reference/driven antenna. It is found that BW of the antenna at both the bands is enhanced by 2.5% at 2.4 GHz and 3.9 % at 5.2 GHz band and similar improvements in their gains are also observed. The proposed antenna is fabricated and tested in an anechoic chamber for its impedance bandwidth and radiation pattern performance.

Millimeter-Wave 5G Antenna-In-Package for Mobile Devices Featuring Intelligent Frequency Correction Using Distributed Surface Mount Technologies

Jaehyun Choi (Pohang University of Science and Technology, Korea (South)); Junho Park (Pohang University of Science & Technology, Korea (South)); Woonbong Hwang (Pohang university of science and Technology, Korea (South)); Wonbin Hong (Pohang University of Science and Technology (POSTECH), Korea (South))

A new class of frequency adaptive 5G front-end architecture incorporating three function blocks is proposed, analyzed, and verified using surface-mount technology (SMT) for a millimeter-wave (mmWave) 5G mobile devices. At high frequencies, such as mmWave spectrum, antenna systems oftentimes suffer from unexpected interference by internal or external factors. Therefore, a tunable matching network (TMN) topology is proposed using active components (multi-throw switching chip), which is applicable to feedline of antenna featuring any arbitrary input impedance. The distributed SMT is exploited for compatibility with the current mmWave phased array 5G architectures. The measured results demonstrate that the fabricated 5G AiP can radiate maximum depending on the switch state covering at 27 GHz and 28 GHz, respectively. As a result, the proposed architecture exhibits the peak gain of more than 12 dBi at both states with an output power of 5 dBm/channel.

Dual-Polarization Multi-Layer Antenna by Patch Asymmetry with Integrated Feeding for In-Band Full-Duplex Systems

Maksim Kuznetcov (Heriot Watt University, United Kingdom (Great Britain)); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain)); Ariel McDermott and Mathini Sellathurai (Heriot-Watt University, United Kingdom (Great Britain))

A new two-port dual-polarized antenna for In-Band Full-Duplex (IBFD) applications is proposed. The antenna consists of two H-shaped slots, asymmetrical stacked aperture coupled patches to improve bandwidth, and a simple Rat-Race hybrid coupler feeding system integrated within the antenna system. In this configuration, antenna port one can provide a differential phase shift of 180 ◦ between two H-shaped slots to excite linear polarization, while port two can generate an orthogonal linearly polarized mode. Using such a feeding scheme and patch asymmetry, only one hybrid coupler is required for dual-polarization. The antenna is well matched from about 2.3 to 2.4 GHz while isolation levels are above 35 dB. Maximum realized gains are 7.1 dBi and 8.2 dBi for port one and two, respectively. Using such a simple feeding approach and asymmetrical antenna layout, there are no requirements for connecting cables or additional external couplers which significantly simplifies the antenna system.

Frequency-Scanned Leaky-Wave Antenna Topologies for Two-Dimensional Direction of Arrival Estimation in IoT Wireless Networks

Miguel Poveda-Garcia, Eloy Andreu-Garcia and Joaquin Garcia-Fernandez (Technical University of Cartagena, Spain); David Cañete Rebenaque and Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain)

Two different leaky-wave antenna topologies are proposed for 2D Direction-of-Arrival (DoA) estimation in the frame of Internet of Things (IoT). The theoretical and simulated results are obtained for the Bluetooth Low Energy (BLE) advertising channels frequencies (i.e. channels #37, #38 and #39 at 2.402, 2.426 and 2.48 GHz, respectively). The synthesized frequency-scanned beams are presented for the two designs, one using four ports and the other using only a single port. The localization performances of each topology are also compared.

On the Arbitrary Control of Passive Magnetic Metasurfaces Response

Danilo Brizi (University of Pisa, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)

In this paper, an analytic circuital approach to manipulate the response of magnetic metasurfaces is introduced. In particular, we show that the control over the current flowing in each array element can be arbitrary, thus allowing exotic properties accomplishment. For instance, we prove that beam-steering capability can be easily achieved. The reliability of the proposed analytical model is proved performing full-wave simulations over a test-case configuration. The accurate control on the overall metasurface response can be extremely significant in a number of applications, such as resonant inductive Wireless Power Transfer, reconfigurable antennas and Magnetic Resonance Imaging.

Design and Experimental Characterization of a Two-Dimensional Reconfigurable Metasurface

Rui Feng (Xidian University, China); Badreddine Ratni (Univ Paris Nanterre, France); Jianjia Yi (Key Laboratory of Integrated Services Networks, Xidian University, China); Hailin Zhang (Xidian University, China); André de Lustrac (Institut d'Electronique Fondamentale - Université Paris-Sud, France); Shah Nawaz Burokur (LEME, France)

Due to the multiple possibilities in wavefront manipulation, reconfigurable metasurfaces have attracted considerable interests. In this work, a two-dimensional reconfigurable reflective metasurface integrating varactor diodes is proposed for an operation in the microwave domain. The reconfigurability mechanism enables to control the electromagnetic response of each meta-atom individually by an elaborately designed voltage bias system. Both simulations and measurements are carried out to evaluate and validate the design of the tunable metasurface. Owing to the individual control and high-efficiency characteristics, the reconfigurable metasurface can easily pave the way to applications in multi-frequency and/or multi-functional wireless power transmission, lenses, complex beam generation and smart antennas.

Analytical Models of Reflection and Scattering by Finite-Size Anomalously Reflecting Metasurfaces

Ana Diaz-Rubio, Svetlana Tcvetkova and Sergei Tretyakov (Aalto University, Finland)

The use of tunable metasurfaces for engineering and optimizing propagation environment is actively considered by the telecommunications community. These metasurfaces serve as anomalous reflectors that redirect incident waves into the desired direction. Known models of anomalous reflectors assume that each metasurface element (meta-atom) acts as an independent relay, reflecting the incident waves with a desired phase shift, realizing the phased-array functionality. This assumption, however, is not valid for vast majority of anomalously reflecting metasurfaces. Moreover, the known theories of metasurface reflectors is limited to infinite planar reflectors. In this talk, we will present an approximate analytical model of far-field scattering from anomalously reflecting metasurfaces of a finite size and discuss the features of reflected fields that cannot be found using the known models.

Dual-Purpose Metasurface for Background Insensitive UWB Tag

Shobit Agarwal (Alma Mater Studiorum - Universita di Bologna, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy); Diego Masotti (University of Bologna, Italy)

A circularly polarised metasurface is proposed in this paper. The design of the surface aims at improving the performance of a hybrid radiating structure made of one dipole and an Archimedean spiral antenna designed on the same surface. The antennas operate in UHF and lower European UWB bands, respectively, and realize a compact single-port antenna for future generation autonomous RFID tags. A High Impedance Surface (HIS) is employed as the ground plane to serve as a Perfect Magnetic Conductor (PMC), with the double purpose to maintain both the circular polarization in the UWB band and the low-profile stack-up, while assuring an insensitive behaviour to the background material.

Gaussian Process Regression Modeling Based on Landmark Isometric Feature Mapping for Antennas

Zhen Zhang (Harbin Institute of Technology & Southern University of Science and Technology, China); Yang Yu (University of Birmingham, United Kingdom (Great Britain)); Fan Jiang (Hong Kong University of Science and Technology, China); Qingsha Cheng (Southern University of Science and Technology, Shenzhen, China)

Efficient modeling method accelerates computer-aided antenna design. In this paper, a novel Gaussian process regression (GPR) modeling based on landmark isometric feature mapping (LISOMAP) for antennas is proposed to improve the accuracy of modeling. In the GPR-LISOMAP method, LISOMAP, a dimension reduction method, is used to reduce the dimension of data for eliminating useless information. GPR is utilized as the modeling method to establish the relationship between antenna design space (multiple inputs) and response space (multiple outputs). The proposed modeling method is demonstrated by a circularly polarized antenna. Numerical results show that the GPR-LISOMAP method improves the accuracy of antenna modeling.

Robust Design of Antenna Structures by Means of Domain-Confined Metamodels

Slawomir Koziel and Anna Pietrenko-Dabrowska (Gdansk University of Technology, Poland); Muath Al-Hasan (Al Ain University, United Arab Emirates)

Statistical analysis is of practical importance for high-frequency engineering when it comes to estimating the effects of manufacturing tolerances. One of its bottlenecks, in the case of antenna structures, is a high computational cost of full-wave electromagnetic (EM) analysis normally utilized for reliable performance evaluation. This paper capitalizes on the recently introduced concept of surrogate modeling in constrained domains and delivers a simple yet computationally-efficient procedure for statistical analysis and yield optimization of multi-band antennas. The foundation of our methodology is an appropriate definition of the parameter space region selected for a construction of the fast surrogate model replacing EM analysis for the purpose of Monte Carlo simulations. It has a small volume, which translates to reduced cost of the yield optimization process. Our approach is validated using a triple-band antenna with the yield-optimum design identified at the cost of only a few dozens of EM simulations of the antenna.

Accurate Modeling of Antenna Structures by Means of Domain Confinement and Gradient-Enhanced Kriging

Anna Pietrenko-Dabrowska and Slawomir Koziel (Gdansk University of Technology, Poland); Muath Al-Hasan (Al Ain University, United Arab Emirates)

High cost of EM-based antenna design fosters the incorporation of surrogate modeling techniques to expedite the procedures such as parametric optimization. Data-driven models are popular but their construction is hindered by the curse of dimensionality. A possible workaround are performance-driven modeling methods. The idea it to restrict the construction of the surrogate to small parts of the parameter space containing high quality designs. This leads to a significant reduction of the required training data sets and improvement of the model accuracy. The model domain is established using the sets of reference designs that are pre-optimized beforehand. Their acquisition adds to the overall expenses of model setup and may undermine the computational benefits of the performance-driven modeling paradigm. This paper proposes an alternative approach, where gradient-enhanced kriging is employed to reduce the number of required reference points, thus leading to lowering the cost of the model setup without compromising its

accuracy.

Microwave Tomography for Moisture Level Estimation Using Bayesian Framework

Rahul Yadav (University of Eastern Finland, Finland); Adel Omrani, Hamzekalaei (Karlsruhe Institute of Technology, Germany); Marko Vauhkonen (University of Eastern Finland, Finland); Guido Link (Karlsruhe Institute of Technology, Germany); Timo Lähivaara (University of Eastern Finland, Finland)

In this work, Bayesian inversion framework is tested on synthetic microwave tomography data at a single frequency in X-band (8 GHz to 12 GHz). The imaging modality is applied to estimate the moisture content distribution in a polymer foam. Such estimations are imperative to develop intelligent and efficient industrial drying systems. Three test cases of low, high, and homogeneous wet basis moisture distribution scenarios are considered. In addition, the generalization capabilities of the Bayesian inversion framework for non-smooth moisture distribution case is discussed. Good estimation results are obtained for the given moisture scenarios.

Polynomial Chaos Yield Analysis of Quad-Mode Antennas

Dieter Gert Klink and Petrie Meyer (Stellenbosch University, South Africa)

Polynomial Chaos Expansion (PCE) based yield analysis of a conical Quad-Mode Antenna (QMA) is performed, as an alternative to computationally very expensive Monte-Carlo based methods. A PCE surrogate is constructed using the most appropriate coefficient calculation technique and sub-sampling method based on structure limitations and computational cost. The QMA is shown to be well-behaved in terms of yield. Possible design improvements are discussed.

Development of H-Slotted DGS Based Dual Band Antenna Using ANN for 5G Applications

Nakmouche Farouk (Ege University, Turkey); Abdelmegid Allam (German University in Cairo, Egypt); Diaa Fawzy (Izmir University of Economics, Turkey); Ding-Bing Lin (National Taiwan University of Science and Technology, Taiwan); Mohamed Fathy Abo sree (Arab Academy For Science and Technology Engineering Faculty & AASTMT Company, Egypt)

In the aim of efficient dual band antenna design with gain and optimal impedance matching, the Artificial Neural Networks technique (ANN) is used for the development process. This work presents a modeling for H-slotted Defected Ground Structure (DGS) based dual band antenna using ANN for 5G Sub-6 GHz applications. The designed antenna operates at 3.76 GHz and 6.1 GHz. The antenna gain is 2.18 dB and 2.75 dB at both frequencies, respectively. Firstly, a simulation is performed using CST EM simulator, then the predicted results in term of return losses and frequencies are fed into the ANN model. Secondly using a hybrid algorithm based on both feed-forward back-propagation and Levenberg-Marquart (LM) learning algorithm, the optimal position of the H-Slotted DGS in terms of 5G Sub-6 GHz band is extracted. Finally, the experimental validation is conducted and compared with the simulation results, a good agreement is obtained.

On the Inverse Design of Dielectric Resonator Antenna Structures for Beam-Steering

Mohammed Nassor (University of Ottawa, Canada); Hamad Alroughani (Kuwait University, Kuwait); E'qab Almajali (University of Sharjah, UAE, United Arab Emirates); Derek McNamara and Mustapha C.E. Yagoub (University of Ottawa, Canada)

An existing dielectric resonator antenna (DRA) shape synthesis technique is substantially extended to the multiple-port case in order to realize pattern reconfigurable (beam-steered) versions of such antennas. The shaping procedure is described through reference to a specific class of problem, namely the satisfaction of certain statistical coverage area requirements through pattern reconfigurability. The procedure delivers a shaped DRA that, given the size and location constraints set at the start of the shaping process, has the potential to provide the best coverage possible. At the conclusion of the shaping, which utilizes characteristic mode analysis as a facilitator, a post-shaping step is used to locate the actual feedpoint ports. How closely the best coverage performance can be realized depends on restrictions placed on the beam-steering circuitry by the designer.

Artificial Neural Network Application in Prediction of Concrete Embedded Antenna Performance

Ju Tan (The University of Sheffield, United Kingdom (Great Britain)); Yu Shao (Chongqing University of Posts and Telecommunications, China); Jiliang Zhang (The University of Sheffield, United Kingdom (Great Britain)); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

Artificial Neural Network (ANN) has been extensively applied to microwave device modeling, design and simulations. In the present paper, the prediction of concrete embedded antenna performance using ANN is presented. The ANN model takes antenna embedded depth and concrete dielectric constant as inputs and gives antenna radiation efficiency, gain and input impedance as outputs. The Particle Swarm Optimisation (PSO) is employed to search the global optimal weights and bias for ANN, then Bayesian Regularisation (BR) is used to train the ANN for overcoming the overfitting issue. It is found that the PSO computation iteration for optimal network weights and bias searching is less than gradient descent algorithm. A PSO-BR neural network (PSO-BRNN) and back-propagation neural network (BPNN) are trained to compute and predict the antenna performance. The PSO-BRNN performance is better than BPNN in terms of accuracy and generalisation.

Heating Effect of the Electromagnetic Interaction with Metallic Microparticles

Mohammed Saad Shaikh (Queen Mary University of London, United Kingdom (Great Britain)); Robert Donnan and Rostyslav Dubrovka (Queen Mary, University of London, United Kingdom (Great Britain))

The heating effect of electromagnetic radiation is of practical interests because of the possibility of heating small particles like metallic microparticles, e.g. metallic microparticles, opening prospects for many applications such as drug delivery and remote triggering of electromagnetic microsystems. In this work, the interaction of electromagnetic waves with metallic microparticles has been investigated using numerical simulations. COMSOL Multiphysics is used to demonstrate the thermal effects of the electromagnetic radiation at 2.4 GHz on metallic microparticles of iron powder, iron, aluminum, copper and silver. The results demonstrated that the rise in temperature around the microparticles is proportional to the input power. The total rise in maximum temperature was 33.83 K near the iron powder microparticles at 1W power in 30 minutes. Further investigation also revealed the contribution of both the electric and magnetic field components of the electromagnetic field towards the total heating effect.

Matching Medium Design for In-Body Communications Using Artificial Neural Networks

Cemre Cadir, Omer A. Kati and Sema Dumanli (Bogazici University, Turkey)

Matching media are located between wearable antennas and the human body to enhance implant communications. The selection of the matching medium is a complicated problem and there is yet no well-established approach. The simulations are computationally expensive and the theoretical work is limited, hence this work proposes a novel approach by using artificial neural networks for determining the effect of various matching media. For this aim, a wearable repeater antenna, human tissue blocks with varying relative permittivities, and matching medium layer with varying relative permittivities and thicknesses are utilized. Employing more than 200 simulated designs, optimum matching medium designs are proposed, and the matching medium concept has been shown to increase the average transmitted power by 17.6%. Moreover, it is shown that the trained neural network model can predict the test cases with 4.5% mean error and the computational cost has been decreased by 96-97% compared to the empirical method.

Room: Posters2

High Efficiency, Wideband, Multi-Mode Leaky-Wave Feed for Scanning Lens Phased Array

Sjoerd Bosma and Maria Alonso-delPino (Delft University of Technology, The Netherlands); Cecile Jung-Kubiak (NASA-JPL, Caltech, USA); Goutam Chattopadhyay (NASA-JPL/Caltech, USA); Nuria LLombart (Delft University of Technology, The Netherlands)

Recently, we have proposed a hybrid electro-mechanical scanning antenna array architecture suitable for highly directive phased arrays at submillimeter wavelengths with field-of-views (FoV) of +/- 25 degrees. The concept relies on combining electrical phase shifting of a sparse array with a mechanical translation of an array of lenses. The use of a sparse phased array significantly simplifies the RF front-end, while the translation of a fly's eye lens array steers the element patterns to angles off-broadside, reducing the impact of grating lobes over a wide FoV. The mechanical movement of the lens array can be done using a low-weight, low-power piezo-actuators. In this contribution, we present an analysis of the high efficiency wideband multi-mode leaky-wave feed for the array's lens elements that enables large-angle steering and present measurements of an embedded element prototype at 550 GHz that demonstrate the validity of this analysis.

Efficient Aperture Illumination and Beamforming with Huygens' Metasurfaces Exciting Surface Waves

Vasileios G. Ataloglou and George V. Eleftheriades (University of Toronto, Canada)

Huygens' metasurfaces allow for extreme wave manipulation of the incident fields. Their ability to shape the electromagnetic wavefronts have made them a promising platform to build antenna systems without complicated feeding networks. However, for conventional passive and lossless Huygens' metasurfaces, the power density of the incident and output fields should be locally conserved. This requirement poses limitations to the amplitude of the output fields, especially if the radiating source is placed close to the metasurface. In this paper, a method is proposed to bypass these limitations and design Huygens' metasurfaces with nonlocal response. The method relies on surface waves that redistribute the power in the input side of the metasurface. The usefulness is demonstrated through the design of a radiating aperture with directivity beyond that of conventional metasurfaces. Furthermore, a physical Huygens' metasurface is designed to realize a singly-fed Taylor aperture antenna, verifying the potential of accurate and efficient beamforming.

Low-Profile CTS Array in PCB Technology for K/Ka-Band Applications

Michele Del Mastro (University of Rennes 1, France); Adham Mahmoud (Institut d'Électronique et de Télécommunications de Rennes, France); Thomas Potelon (IETR - University of Rennes 1, France); Ronan Sauleau (University of Rennes 1, France); Gilles Quagliaro (Thales Communications, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

In this paper, an ultra-low-profile wideband continuous transverse stub (CTS) array is presented. The antenna module is fully realized in multilayer printed circuit board (PCB) technology, comprising 9 dielectric substrates. Particularly, the radiating part consists of long slots etched on the top of the eighth dielectric substrate. The slots are parallel-fed by a corporate feed network made of vertical parallel-plate waveguides (PPW), using via-fences. A pillbox system, embedded into two substrates, is employed to feed the slots with a line source. The antenna module is low cost and presents a very low form factor. A prototype was fabricated and measured in the K/Ka-band. The antenna array provides pencil-beam radiation for angles of scanning as far as 24° along the azimuth plane parallel to the slots. The input reflection coefficient is below -10 dB in the frequency range 19-31 GHz (48%). The maximum realized gain is 21 dB at 29 GHz.

Topology Optimization of Electrically Small Antennas with Shape Regularity Constraints

Miloslav Capek, Vojtech Neuman, Jonas Tucek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Mats Gustafsson (Lund University, Sweden)

The existent framework for shape optimization of electrically small antennas is extended by a new set of geometrical operators. They are capable of operating over shapes directly, controlling their regularity, amount of used material, etc. The formulation is compatible with existent physical fitness functions and known fundamental bounds. A simple example of Q-factor minimization is presented.

Direct Synthesis of Accurate Angular Filtering Patterns Using Holographic Leaky-Wave Antennas

Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Miguel Poveda-Garcia and Paula Vivo-Vera (Technical University of Cartagena, Spain); Rafael Verdú-Monedero (Universidad Politécnica de Cartagena, Spain)

We propose a new synthesis technique of angular filtering radiation patterns, using holographic leaky-wave antennas. The synthesis is based on the association of a set of N leaky waves with the response of a passband filter of order N. Compared to previous broad-beam synthesis techniques, the novel method provides accurate angular filtering specifications with demanding restrictions (ripple and rejection levels), and without numerical optimization.

Posters_E: Best Paper Awards - Poster Session - Electromagnetics

Room: Posters3

Fast Direct Error-Controlled Solution of Scattering Problems via H-Matrix Acceleration of Locally Corrected Nystrom Method

Reza Gholami (University of Toronto & University of Manitoba, Canada); Zhuotong Chen (University of California at Santa Barbara, USA); Mohammad Shafieipour (Safe Engineering Services and Technologies, Canada); Vladimir Okhmatovski (University of Manitoba, Canada)

The fast direct high-order solution of radiation problems in the presence of perfect electrically conducting (PEC) sphere with the Locally Corrected Nystrom (LCN) method is presented. Accelerated solution is obtained using error-controlled hierarchical H-matrix framework. Matrix fill time and direct solution time are shown to be substantially reduced compared to those needed by conventional LCN. The error of solution is computed via comparison against the analytical Mie series solution. Developed computational framework is shown to produce the higher order solution while preserving high compressibility of the corresponding H-matrix blocks. The memory cost and CPU time complexity scaling with the size of the problem is analyzed.

The Interpath Relation for Spatially-Discrete Traveling-Wave Modulated Structures

Cody Scarborough (University of Michigan, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

Traveling-wave modulation has been employed since the 1950s for amplification and frequency conversion, and more recently for beam-steering and breaking reciprocity. Typically, traveling-wave modulation is realized by applying a staggered bias/pump signal to an array of discrete unit cells. This is referred to as spatially-discrete traveling-wave modulation (SD-TWM). SD-TWM structures can prove challenging to simulate due to their often complex geometry and extreme temporal variation. Here, we examine a relation established within SD-TWM structures referred to as the interpath relation. The interpath relation reveals that the solution within a single unit cell (as opposed to an entire spatial period) is sufficient to determine the entire problem. The interpath relation is then

incorporated into a method of moments solver to compute the scattered field produced by a representative SD-TWM metasurface. The presented method simplifies the computation of both physical patterned designs, as well as nearly continuous idealized structures.

Reflecting Luneburg Lens: Analytical Solution and Applications

Jorge Ruiz-García (Université de Rennes, France); Enrica Martini (University of Siena, Italy); Cristian Della Giovampaola (Wave Up srl, Italy); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Stefano Maci (University of Siena, Italy)

This paper presents the closed-form solution for a new type of lens beamformer, which consists of two stacked parallel plate waveguides (PPWs) of circular shape. The rays launched by a source at the rim of the bottom PPW are collimated in the top PPW after being reflected at a cylindrical metallic wall that surrounds both layers. Since it reproduces the behavior of the Luneburg lens for reflected rays, this lens is hereinafter referred to as Reflecting Luneburg lens (RLL). The refractive index profile for the azimuthally symmetric circular domain is found by solving the non-linear integral equation of ray-congruence through a truncated Abel transform method. The validity of the derived exact formula is verified by full-wave simulations, practical implementation and possible applications of RLLs in antenna systems are also briefly discussed.

Investigation of Direction of Arrival Estimation Using Characteristic Modes

Lukas Grundmann and Nikolai Peitzmeier (Leibniz University Hannover, Germany); Dirk Manteuffel (University of Hannover, Germany)

A method is proposed to estimate the direction of arrival (DoA) of a traveling wave from characteristic mode weighting coefficients. These are obtained from the currents through the ports positioned on an antenna structure. The additional insight into the behavior of the antenna structure gained by the modal analysis is utilized to create a set of ports that allows to use a single conducting structure for the direction finding. It is shown that the proposed method works for a cubic antenna structure with 20 uncorrelated ports with good accuracy for any DoA.

The Number of Independent Wireless Links on a Given Volume Platform

Riccardo Ozzola and Daniele Cavallo (Delft University of Technology, The Netherlands); Angelo Freni (Università degli studi Firenze, Italy); Nuria LLombart and Andrea Neto (Delft University of Technology, The Netherlands)

The number of independent links that can be hosted by an antenna platform for wireless communication is limited by the mutual coupling between the corresponding beams. These beam coupling can be minimized if the space available for the antennas is electrically large. For these large platforms, a good first order estimation for the number of independent links is the degrees of freedom of the field associated with the sphere enclosing the platform. However, when the antenna volume is moderate or small, the degrees of freedom of the field are not neatly defined and the aperture efficiency becomes larger than one, stopping to be a useful parameter. We resort instead to the concept of observable field, introducing a new coupling coefficient between incident field and antennas in reception. This coefficient allows a trade-off between beam coupling and platform size, to define the maximum number of independent links also for small volumes.

Tuesday, March 23 13:10 - 13:40

IW06: Multiphysic Analysis for 5G Devices (Ansys)

Room: virtual 14

Domenico Loricchio, Ansys

Tuesday, March 23 13:40 - 14:25

Inv1a: Invited Speaker Session:

New antenna measurement setups for non-accessible and on-board antennas.
Fernando Las Heras

Room: virtual 1

Chairs: Amedeo Capozzoli (Università di Napoli Federico II, Italy), Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain)

13:40 ***New Antenna Measurement Setups for Non-Accessible and On-Board Antennas***

Fernando Las-Heras (University of Oviedo, Spain)

In this contribution, an overview of the last advances for challenging antenna measurements is introduced. In particular, two different scenarios are considered. In the first one, antennas are placed at hardly accessible locations. In order to characterize these antennas, UAV-based approaches are introduced. The second case handles the characterization of on-board antennas where conventional approaches, based on mechanical positioners, cannot be easily deployed. In both cases, several challenges must be addressed. First, accurate non-conventional positioning systems with capability to track the probe must be deployed and synchronized. Second, algorithms for irregular scanning trajectories must be implemented in order to achieve antenna characterization data from nonequally-spaced grids. Finally, due to difficulty to access the antenna under test in some realistic scenarios or for fast evaluation, only amplitude data measurements are available and, consequently, further modifications in the procedures and algorithms must be implemented. Several approaches and use cases will be presented, illustrating the possibility of this kind of antenna measurements.

Inv2a: Invited Speaker Session:

Computational electromagnetics in space
Erik Jorgensen

Room: virtual 2

Chairs: Conor Brennan (Dublin City University, Ireland), Peter Knott (Fraunhofer FHR, Germany)

13:40 ***Computational Electromagnetics in Space***

Erik Jørgensen (TICRA, Denmark)

Computational Electromagnetics (CEM) provides an indispensable toolset for antenna design and performance verification. In this talk, we focus on the modelling challenges arising when designing satellite antennas and platforms, with typical application areas within high-throughput telecommunication systems or Earth observation. Antenna design for space applications imposes very stringent requirements on the CEM algorithms, e.g., a predicted gain accuracy better than a few hundreds of a dB and a dynamic range exceeding 100 dB. Further, the accuracy must be maintained for antennas that are electrically large, e.g., several hundred wavelengths, or platforms exceeding 1000 wavelengths in size. Such extreme accuracy requirements are typically not encountered outside the space segment, implying that specialized algorithms must be developed. We present a review of several CEM algorithms developed particularly for space applications. This includes multiple integral equation methods based on higher-order discretisation schemes, as well as an efficient acceleration method providing a dramatic reduction of the memory and CPU requirements. The special requirements relevant for space applications also imply that extremely fast algorithms are needed for specific classes of antenna problems. Such dedicated algorithms are needed to allow numerical optimization of a very large number of degrees of freedom, necessitating that the antenna performance can be evaluated in seconds without compromising the accuracy. We discuss multiple dedicated solvers, hybridization of solvers, and large-scale optimisation problems. Finally, we apply techniques for quantification of uncertainties when realising antennas with finite manufacturing tolerances. The capabilities of the algorithms are illustrated with practical examples.

Tuesday, March 23 14:25 - 15:10

Inv1b: Invited Speaker Session:

Modern Antenna Near-Field Measurements Help Understanding Electromagnetic Theorems, Sampling Techniques, FFT and Instrumentations
Yahya Rahmat-Samii

Room: virtual 1

Chairs: Amedeo Capozzoli (Università di Napoli Federico II, Italy), Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain)

14:25 ***Modern Antenna Near-Field Measurements Help Understanding Electromagnetic Theorems, Sampling Techniques, FFT and Instrumentations***

Yahya Rahmat-Samii (University of California Los Angeles (UCLA) & UCLA, USA)

How can we more effectively engage young engineering students about electromagnetic fundamentals and practices? It is becoming clear that the new generation of students like to see in practice the applications of fundamental concepts that they learn as early as possible as they get exposed to them. I have found that by properly discussing the topic of antenna near-field measurement techniques in my courses, it is possible to link many fundamental concepts in electrical engineering in a unified and elegant fashion. In this invited talk I utilize planar near- field antenna measurements modality as an educational paradigm linking electromagnetic theorems, sampling techniques, FFT, instrumentations, etc. Representative examples will be presented to demonstrate the effectiveness of this approach in making sure that students fully appreciate the power and utilization of those fundamental concepts. This I am pretty confident that will also excite them about the topic of modern antenna measurements.

Inv2b: Invited Speaker Session:

5 Generations of Higher Order Bases: General Approach for Highly Accurate and Efficient EM Modeling
Branko Kolundzija

Room: virtual 2

Chair: Peter Knott (Fraunhofer FHR, Germany)

14:25 ***5 Generations of Higher Order Bases: General Approach for Highly Accurate and Efficient EM Modeling***

Branko Kolundzija (University of Belgrade, Serbia)

Full-wave simulation of arbitrary structures, whose parts are made of homogenous, linear and isotropic materials, can be performed by MoM/SIE (Method of Moments solution of Surface Integral Equations). From the very beginning of MoM/SIE development researchers have explored the possibilities to reduce the resources needed for simulation, to enhance the accuracy of results, and to expand the limits of the maximum electrical size and complexity of the solvable problem. Using HOBFs (Higher Order Basis Functions) of polynomial type instead of low order ones, the number of unknowns required along wires, metallic plates, and dielectric surfaces is reduced from 10/λ, 200/ λ2, and 400/ λ2 to 4/λ, 30/ λ2, and 60/ λ2, respectively (1st Generation of HOBFs). Development of algorithms suitable for out-of-core solution and parallelization on CPUs and GPUs enables acceleration of simulation up to two orders of magnitude, so that dense matrix equation of 100,000 unknowns (1 million unknowns) can be directly solved in a few minutes (during the day) on the desktop PC (2nd Generation of HOBFs). Combination of novel singularity extraction and singularity cancellation techniques gives the possibility to evaluate the MoM matrix elements up to machine precision. Balancing source/field quantities in SIEs and basis/test functions in such MoM matrix extends the limits related to: a) low frequency breakdown, b) very low/high contrast materials, and c) multiscale problems (3rd Generation of HOBFs). Maximal orthogonalization of HOBFs, using two-step

Gramm-Schmidt procedure, results in low condition number of the MoM matrix, practically independent on the HOBFs order. If such max-ortho bases and corresponding matrix elements are evaluated using recurrent formulas based on Legendre polynomials, the maximum applicable HOBF's order can be extended for an order of magnitude, e.g. from 8 to 64. In this way, practically unlimited p-refinement is enabled (4th Generation of HOBFs). So, what is the next step? What is the 5th generation? We are currently working on it, and the results will be presented in the end of this invited presentation.

Tuesday, March 23 15:10 - 15:30

Coffee Break / Exhibition

Rooms: virtual 1, virtual 2, virtual 3, virtual 4, virtual 5, virtual 6, virtual 7, virtual 8, virtual 9, virtual 10, virtual 11, virtual 12, virtual 13, virtual 14, Posters

Tuesday, March 23 15:30 - 17:10

T01-M01: MIMO and OTA testing

T01 LTE and Sub-6GHz 5G / / Measurements

Room: virtual 1

15:30 ***On the Keyhole Effect in Over-The-Air Testing of Higher Order MIMO Systems***

Kristian Karlsson, Martin Wersäll and Fredrik Harrysson (RISE Research Institutes of Sweden, Sweden); Christian Lötbäck (Bluetest AB, Sweden)

In this paper, the influence of a limited number of radio frequency connections between two Rayleigh fading environments, also known as the keyhole effect, is theoretically investigated for higher-order MIMO systems. It is shown that the effect of a limited number of keyholes is kept stable or is even reduced as the number of keyholes is equal to or larger than the MIMO system order. The results are relevant for over-the-air testing with connected Rayleigh fading systems, such as a channel emulator connected to a reverberation chamber, or a reverberation chamber connected to another reverberation chamber (nested reverberation chambers).

15:50 ***Evaluation of Complete Vehicle Over-The-Air Verification Methods for Multiple-Input Multiple-Output Communication Systems***

Christian Lötbäck (Volvo Car Corporation); Kristian Karlsson (RISE Research Institutes of Sweden, Sweden); Madeleine Schilliger Kildal (RanLOS AB & Chalmers University of Technology, Sweden); Argjent Haliti (Volvo Cars, Sweden); Mikael Nilsson (Lund University & Volvo Car Corporation, Sweden); Roman Iustin (Volvo Technology, Sweden)

As more and more advanced wireless technologies are incorporated into vehicles, there is a need to refine the test methods used for assessing the performance. Traditional test setups for multiple-input multiple-output (MIMO) communication systems have been developed for relatively small devices such as handsets and tablets. At the same time, there is a desire to replace vehicular field tests with lab testing, for more efficient and accurate testing. This paper evaluates over-the-air verification methods for MIMO communication systems, which may incorporate vehicle-sized antenna systems and that can be implemented in a lab. Different methods are compared by means of a round robin campaign. The results from the campaign indicate that performance assessment representative to real-world operation can be achieved.

16:10 ***Polarimetric Scattering with Discrete Raytracing for OTA Analysis***

Timothy Pelham, Alberto Loaiza Freire, Geoffrey Hilton and Mark Beach (University of Bristol, United Kingdom (Great Britain))

The use of millimetre waves (mmWave) requires the development of novel, robust over the air (OTA) test methods. One low-cost OTA method is based upon an elliptical arrangement of reflectors, to allow conformance testing of devices at mmWave. A discrete ray model is used to predict the influence of reflector shape and arrangement on scattering at 24GHz for two reference surfaces of differing size and a substrate reflector. The model shows a correlation of 0.99 between the predicted and measured scattering for the larger reference surface, and root mean square (RMS) error of -69dB, while for the smaller reference surface the model achieved a correlation of 0.98 between the predicted and measured scattering, and an RMS error of -69dB.

16:30 ***Realistic Emulation of GNSS Testing Scenarios Using 3D Wave Field Synthesis in an OTA Testbed***

Renato Zea (Fraunhofer IIS, Germany); Mario Lorenz and Wim A. Th. Kotterman (Technische Universität Ilmenau, Germany); Ramona Schwind (Fraunhofer IIS, Germany); Markus Landmann (Fraunhofer Institute for Integrated Circuits IIS, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

While traditional testing methods as conducted and open field tests have their limitations in terms of realism and repeatability of the scenario's conditions, Over-the-Air (OTA) testing enhances the way that GNSS and mobile communications systems with integrated antennas are tested, since it provides the freedom to accurately emulate an impinging wave with arbitrary polarization and direction radiated from any source/reflection such as GNSS satellites and terrestrial base stations. Therefore, real world scenarios can be precisely reproduced with total control of the environment's conditions. In this context, this paper describes the process to implement full polarimetric 3D Wave Field Synthesis (WFS) in an OTA testbed, from the principle to characterize the electromagnetic (EM) field in three dimensions to the system calibration and correspondent verification measurements inside the anechoic chamber, which will provide a deeper insight on the quality and reliability of the EM field for testing purposes.

16:50 ***Projection-OTA, Over-The-Air Testing by Reconfigurable Reflecting Structures***

Wim A. Th. Kotterman (Technische Universität Ilmenau, Germany); Markus Landmann (Fraunhofer Institute for Integrated Circuits IIS, Germany); Reiner S. Thomä (Ilmenau University of Technology, Germany)

The paper presents a new OTA concept that uses passively radiating reconfigurable structures and is inherently bi-directional. It is called Projection-OTA, accommodates test objects that are electrically large to very large in FR1, and shows good prospects for emulating beam dynamics for testing 5G NR in FR2. Prospects and limitations of this concept are discussed.

T02-A04: Lens Antennas

T02 Millimetre wave 5G / / Antennas

Room: virtual 2

Chair: Kimmo Rasilainen (University of Oulu, Finland)

15:30 ***In-Lens Dielectric Gratings Wedge Enhancing the Beam Steering in Low Dielectric Permittivity Lenses***

Marta Arias Campo (IMST GmbH, Germany); Giorgio Carluccio (Delft University of Technology, The Netherlands); Simona Bruni (IMST GmbH, Germany); Nuria LLombart (Delft University of Technology, The Netherlands)

The availability of low relative permittivity plastic materials with moderate loss, light weight, and cost-effective manufacturing enable the low-cost production of plastic elliptical lenses to be used in the future mm- and sub-mm wave systems. However, the low permittivity implies a reduction in the beam steering range achieved when displacing the lens feeder within the focal plane. In this contribution, dielectric gratings with modulated height are integrated inside an elliptical lens with low permittivity, increasing the steering angle reached. A wideband prototype in G-band (140-220GHz) has been fabricated, achieving a Field-of-View of ±25° with gain >30dB.

15:50 ***Dielectric Lens Antennas for 300-GHz Applications***

Kimmo Rasilainen and Jiangcheng Chen (University of Oulu, Finland); Markus Berg (University of Oulu & Excellant LTd., Finland); Aarno Pärssinen (University of Oulu, Finland)

Implementation of proper wireless links at submillimetre-wave and terahertz (THz) frequencies requires high-gain antennas. This simulation-based study investigates the performance of dielectric lenses and their feed antennas at 300 GHz. Parametric studies and electromagnetic simulations are used to determine the general lens properties, and the use of waveguide and on-chip antenna feeds is considered. The results show that the studied lens and feed structures can provide good, directive radiation patterns also with beam scanning.

16:10 ***Ray-Tracing in Dielectric Inhomogeneous Metalenses***

Francesca Maggiorelli and Anastasios Paraskevopoulos (University of Siena, Italy); Roberto Giusto (Huawei Technologies, Italy); Matteo Albani and Stefano Maci (University of Siena, Italy)

We present a fast and efficient analysis of inhomogeneous dielectric lenses based on Geometrical-Optics (GO). To this end, a ray-tracing algorithm has been implemented in a Matlab code in order to overcome time-consuming full-wave simulations in the analysis and synthesis of inhomogeneous lens-antennas. Field amplitude and phase distributions at the output interface of a generic inhomogeneous dielectric lens can be obtained by numerically solving the eikonal and the energy transport equations, respectively. Once the field distribution at the lens-antenna aperture has been achieved, the radiation pattern is derived through an aperture type radiation integral. The developed algorithm has been validated a full-wave analysis, after predetermining the feed source, the lens dimensions and the refractive index profile. Thus, the source incident field in absence of the lens is supposed to be known by simulation or by measurements. Results achieved with the in-house algorithm and the full-wave analysis are in good agreement.

16:30 ***A Compact Transformation Optics-Based Luneburg Lens Antenna Using Curved Reactive Impedance Surface***

Yuanyan Su (EPFL, Switzerland); Zhi Ning Chen (National University of Singapore, Singapore); Anja K. Skrivervik (EPFL, Switzerland)

This paper is to investigate the pattern distortion that happens in the extremely low incidence for a flat TM-polarized half Luneburg lens antenna (HLLA) by using a purely reactive impedance surface (RIS). For the scenario of a radar mounted on unmanned aerial vehicle, a curved RIS is further examined to verify that the proposed conformal HLLA would be able to work for a non-flat RIS-coated object. The simulation results of the proposed antenna show that the right-hand 1st sidelobe at the lowest incidence of y = 15 mm is suppressed to -14.9 dB at 10 GHz and the single-side scanning range is broadened to -20 ~ -57 degree, while the antenna gain of ~13.5 dBi is as smooth as the original one. Therefore, a miniaturized Luneburg lens antenna with the wide-scanning capability is successfully achieved.

16:50 ***3D-Printed Dielectric GRIN Planar Wideband Lens Antenna for 5G Applications***

Jose M Poyanco and Francisco Pizarro (Pontificia Universidad Catolica de Valparaiso, Chile); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

This article presents the design of a 3D-printed wideband planar graded index (GRIN) lens operating on the Ka band from 25 to 40 GHz. The frequency band was chosen to cover candidate frequencies for the new 5G technology such as 28 and 38 GHz bands. The designed lens is composed of ten concentric rings. The lens shows a good wideband behavior, with a maximum gain on the broadside above 25 dB on the whole band. For the construction, the lens will be manufactured using 3D-printing with low-loss dielectric filaments. The different permittivity values of each ring are obtained by varying the infill percentage of the sections on the 3D-printing process.

T02-P02: Propagation for mm-wave 5G

T02 Millimetre wave 5G / / Propagation

Room: virtual 3

Chairs: Khalid A Al Mallak (University of Bristol (UoB) & National Physical Laboratory (NPL), United Kingdom (Great Britain)), Reiner S. Thomä (Ilmenau University of Technology, Germany)

15:30 ***Urban Line-Of-Sight Probability for mmWave Mobile Access and Fronthaul Transmission Hubs***

Dave Townend (BT Labs, United Kingdom); Stuart D Walker (University of Essex, United Kingdom (Great Britain)); Adrian Sharples (BT Labs, United Kingdom); Andy Sutton (BT Technology, United Kingdom)

The line-of-sight (LOS) probability model is a fundamental tool in evaluating high frequency (mmWave) mobile network deployments. This paper utilises a large scale 1875 sq km, high resolution environmental model of representative UK cities to analyse the statistical LOS properties of urban macro (UMa) base stations. The digital environment results are used to evaluate the accuracy of analytical probability models such as those published in industry standard guidelines. A LOS probability distribution for UK street lamp posts is presented to quantify the feasibility of wireless fronthaul connectivity from macro cell hub sites to new street level small cells. In addition, generalised LOS results are presented at a range of end point heights permitting a new UMa model to be proposed. The new model addresses shortcomings of existing models whilst describing the likelihood for LOS conditions between macro sites and street canyon end points at heights of up to 10 m.

15:50 ***Level of Detail of the Physical Environment and Its Impact on Propagation Prediction for a 60-GHz Fixed Radio Link***

Cesar A Amaya, Marcel LeClair, Vincent Picard, Reza Chaharmir, Ming Li and Simon Perras (Communications Research Centre Canada, Canada)

3D models that capture the characteristics of a physical environment in downtown Ottawa with three different levels of detail (LOD) have been developed. This paper investigates the impact of using different LODs of a downtown street canyon on multipath power predicted by ray tracing on a 60-GHz fixed radio link. The 60-GHz radios are equipped with high-gain directional antennas placed at street level below building rooftops. Results are produced and analyzed for two link configurations: with the transmitter and receiver

placed on the same sidewalk of the street canyon and, with transmitter and receiver placed on opposite sidewalks.

16:10 ***Amplitude Distributions of Measured 21.5 GHz Indoor Channels for a Handheld Array***

Jesper Ø Nielsen and Gert Pedersen (Aalborg University, Denmark)

This work investigates 21.5 GHz channel amplitude distributions for a smartphone-like mockup device used in an indoor corridor environment. Channels between an access point (AP) and the mockup were measured for different scenarios and with different users holding the mockup. In addition the mockup was measured without any user nearby in the same conditions. This allows the study of amplitude cumulative distribution functions (CDFs) both when a user is present close to the antennas of the mockup, as well as when no interaction happens. Large variations in the CDF were found both for line of sight (LOS) and non-line of sight (NLOS) scenarios. The presence of a user generally reduced the 1st percentile of the fading amplitude by 2.9 dB and 4.9 dB in median, respectively, for vertical and horizontal polarization at the AP.

16:30 ***Practical Aspects on the Noise Floor Estimation and Cut-Off Margin in Channel Sounding Applications***

Diego Dupleich (Technische Universität Ilmenau, Germany); Robert Müller (TU Ilmenau, Germany); Reiner S. Thomä (Ilmenau University of Technology, Germany)

The characterization of propagation at mm-waves and THz is obtaining relevance since they are expected to be the frequency bands of the future wireless generations. Hence, measurements conducted all around the world with different equipments need to be comparable by establishing common practices. As an example, all measurements are affected by noise, but its estimation and removal are not standardize. Therefore, in the present paper we define a methodology on the estimation of the noise floor and the cut-off margin for its subsequent removal. We firstly analyse the influence of the measurement noise floor on the estimation of different propagation parameters directly from the measured channel impulse response, showing the need of removing the noise floor before any processing of the measurements. Later, we introduce an algorithm to estimate the noise floor in the presence of signal, and the cut-off margin. Finally, we evaluate its performance empirically with measurements.

16:50 ***Characterisation of Human Body Shadowing in Millimetre Wave Systems***

Khalid A Al Mallak (University of Bristol (UoB) & National Physical Laboratory (NPL), United Kingdom (Great Britain)); Manish Nair and Geoffrey Hilton (University of Bristol, United Kingdom (Great Britain)); Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)); Mark Beach (University of Bristol, United Kingdom (Great Britain))

One of the main challenges for millimetre wave (mm-wave) communication for fifth-generation (5G) and beyond systems is the shadowing of received signals. A mobile device in proximity to the human body can result in the shadowing of the received mm-wave signal. By investigating different antenna heights, it is possible to model shadowing based on which, the channel capacity and the resulting average attenuation in the shadow region of the human body is derived. It is proven that the attenuation in the body's shadow for a mm-wave signal at 26GHz can be reduced when the transmit and receive antenna heights are adjusted. Forwards and backwards movement of the body causes positive and negative Doppler Shift correspondingly producing delay-dispersion in the channel. It is also demonstrated that a steerable beam reduces the signal attenuation in the shadow region significantly, as the delay-dispersion of the channel reduces.

T05-M02: Microwave Imaging and Dossimetry

T05 Biomedical and health / / Measurements

Room: virtual 5

Chair: Imke Busboom (Hochschule Düsseldorf, Germany)

15:30 ***Design of a High Selectivity Filter for MRI Guided RF Hyperthermia Therapy***

Kemal Sumser (Erasmus MC Cancer Institute, The Netherlands); L. A. (Sander) Bronckers, Marjolijn Kleijer and Margarethus M. Paulides (Eindhoven University of Technology, The Netherlands)

Hyperthermia devices have been integrated with MR scanners to exploit MR thermometry. Integrating two RF systems require the filtering of high-power RF heating signal from MR system for simultaneous heating and imaging. Currently, a filter that suppresses 100MHz and its harmonics is in use. Development of a MR-compatible hyperthermia applicator for head and neck requires a filter that can suppress also the 433.92MHz signal. A unique new filter which has high power handling, extremely high suppression, and selectivity has been designed that attenuates 100MHz and 433.92MHz signals with low insertion loss (<0.25dB) at 63.89MHz. 0.14dB insertion loss at 63.89MHz, 112dB, 88dB and 93dB signal attenuation were achieved at 100MHz, 200MHz and 433.92MHz, respectively, with the new filter design using model of LM-500 cable. A proof of concept filter was constructed to validate the design. Our investigation shows that filter requirements can be satisfied, but high-power low-loss coaxial cables are necessary.

15:50 ***Numerical Assessment of Microwave Imaging for Axillary Lymph Nodes Screening Using Anthropomorphic Phantom***

Matteo Savazzi (Universidade de Lisboa, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal)

We numerically assess the potential of microwave imaging (MWI) for the detection of axillary lymph nodes (ALNs). The proposed MWI system is radar-based, in which a broad-band signal (2-6 GHz) is transmitted by a single probing antenna to scan the axillary region. The full-wave simulations include a realistic phantom of the underarm region which was previously developed by the authors. The phantom includes the main tissues of the axillary region and the corresponding dielectric properties. We show that the proposed system can successfully detect an ALN embedded in a homogeneous fatty medium. Additionally, we show that despite the strong reflection of the muscle - caused by the high dielectric contrast between fat and muscle - we are able to distinguish an ALN from the background. To the best of our knowledge, this is the first study in literature which employs an anatomically realistic phantom to study ALN MWI.

16:10 ***A Study on the Sensitivity of Microwave Imaging for Detecting Small-Width Bone Fractures***

Kesia Santos (Instituto Federal de Educação, Ciência e Tecnologia da Paraíba, Brazil); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal)

Microwave imaging (MWI) could be a first-responder alternative to X-Rays for detecting fractures in superficial bones like the tibia. However, the low resolution of MWI might be a handicap, therefore it needs to be quantified. A monostatic radar-type configuration is adopted in this study, where a Vivaldi antenna operating in the 8.3-11.1 GHz frequency range is used to scan the bone in the near-field. The study uses full-wave simulations to acquire the antenna s11 vs frequency at all scanning points. The bone is modeled as a multilayer dielectric structure with appropriate permittivity values to represent the bone structures and covering tissues. The image is reconstructed using a matched filter technique. Results show that the proposed system can detect transversal bone fractures as thin as 0.25 mm in superficial bones.

16:30 ***SAR Evaluation for an Inductive Wireless Low Power Charger by a Worst-Case Approach***

Gregory Siguier, Juvenal Alarcon Ramos and Brahim Aloui (Continental Automotive, France); Guillaume Vigneau (Davidson Midi Pyrenees, France); Saïd Bouguern (Continental Automotive, France)

In this paper, a proposition for Specific Absorption Rate (SAR) calculations by electromagnetic simulations (EM) is presented. A worst-case analysis is proposed to demonstrate the health inoffensiveness of Wireless Power Chargers (WPC) embedded in a vehicle. This analysis is intended for low power wireless chargers (up to 15 W) operating at 127 kHz but could be extended to every type of chargers. In addition, this method is applied for demonstrating RF exposure compliance during the radio homologation process.

16:50 ***Terahertz Imaging of 3D Print Infill Structures***

Imke Busboom, Thanh Tung Nguyen, Simon Christmann, Volker Feige and Hartmut Haehnel (Hochschule Düsseldorf, Germany); Bernd Tibken (University of Wuppertal, Germany)

3D printed objects are usually not completely filled to reduce weight, printing time and costs. Instead, infill structures are used. These infill structures have a major influence on the strength of 3D prints. To non-destructively investigate such infill structures, our approach is the use of terahertz time-domain spectroscopy. This paper studies possible evaluation parameters for imaging an exemplary infill structure by using both transmission and reflection measurements. Thus, a non-destructive visualization of 3D print infill structures is enabled.

CS41: (AMTA Session): Unmanned Aerial Vehicle (UAV) - Based Antenna Measurements

T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / Convened Session / Measurements

Room: virtual 6

Chairs: Zhong Chen (ETS-Lindgren, USA), Janet O'Neil (ETS-Lindgren, USA)

15:30 ***Exploration of Anechoic Chamber Characterization with Autonomous Unmanned Aerial Systems***

Anoop Adhyapak (ETS-Lindgren, USA); Mithun Diddi (Northeastern University, USA); Matthew Kling and Adam Colby (KRI at Northeastern University, LLC, USA); Hanumant Singh (Northeastern University, USA)

A novel system for chamber characterization by Fourier Analysis technique is explored. The system consists of a probe antenna mounted on top of an Unmanned Autonomous Vehicle (UAV) equipped with precise positioning, multi-camera tracking system, ground control station along with the fixed transmit antenna and vector network analyzer. The vector measurements are conducted in the ECUAS lab at Northeastern University wherein the probe antenna is scanned across a planar region in the quiet zone of the chamber. Multiple control techniques for UAV navigation are analyzed and the parameters are tuned to optimize the flight trajectory. The Fourier Analysis technique is applied to the scan results from the optimum trajectory for both polarizations to yield the reflectivity of the chamber and locate the reflections' hotspots.

15:50 ***Propagation Research with Drones: Examples and Lessons Learned***

Jerry Hampton, Steve Yao and Trevor Kroeger (Johns Hopkins University Applied Physics Laboratory, USA); Candace V Carducci (The Johns Hopkins University Applied Physics Lab, USA)

This paper provides a practical description on how to conduct propagation research using drones. The paper discusses commercial drone options appropriate for propagation research and describes readily available commercial products that can be used as payloads to make propagation measurements. The paper describes examples of drone-based research we have conducted and concludes with a discussion of lessons we have learned from this research that can be helpful to investigators considering the use of drones to study propagation.

16:10 ***Plane-Wave Spectrum Methods for the Near-Field Characterization of Very Large Structures Using UAVs: The SKA Radio Telescope Case***

Quentin Gueuning (University of Cambridge, United Kingdom (Great Britain)); Jean Cavillot (Université Catholique de Louvain (UCL), Belgium); Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)); Christophe Craeye (Université Catholique de Louvain, Belgium); Eloy de Lera Acedo (University of Cambridge, United Kingdom (Great Britain)); Anthony Keith Brown (University of Manchester, United Kingdom (Great Britain)); Clive Parini (Queen Mary University of London, United Kingdom (Great Britain))

The reconstruction of embedded element patterns is analyzed in physically and electrically large aperture arrays from near-field measurements taken with a source carried by a drone. This is a very challenging metrology problem, especially when the arrays are composed of wide-band wide field-of-view antenna elements in a highly coupled environment, as is the case for the SKA-low radio telescope stations. We study the use of both a direct near- to far-field transformation and a model-based approach to overcome the limitations imposed by this type of complex electromagnetic structures. Both methods are explained using a decomposition of the antenna voltages in terms of a spectrum of incoming plane waves. A numerical example with an irregular array of 16 log-periodic elements and a hemispherical path shows their abilities to capture the mutual coupling effects.

16:30 ***An Improved Forecast Method for the Interaction of Wind Turbines with Doppler VOR***

Thorsten Schrader (Physikalisch-Technische Bundesanstalt, Germany); Jochen Bredemeyer (FCS Flight Calibration Services GmbH, Germany); Thomas Kleine-Ostmann (Physikalisch-Technische Bundesanstalt, Germany); Marius Mihalachi (Physikalisch-Technische Bundesanstalt (PTB), Germany)

The installation of wind turbines leads to bearing errors of Doppler Very High Frequency Omni-Directional Ranges used for terrestrial navigation. The German air navigation service provider uses a simple model to calculate bearing errors. Here, the results of an improved forecast tool are compared to the results from the original tool, full wave simulations and measurements for a distinct trajectory close to the DVOR Hehlingen.

16:50 ***Experimental Campaign to Evaluate the Fundamental Capabilities and Limitations of Synthetic DOA Using Swarming UAVs***

Zhong Chen (Texas A&M University, USA); Wenbo Liu (The Pennsylvania State University, USA); Gregory H Huff (Pennsylvania State University, USA)

A system performance analysis for Direction of Arrival (DOA) estimation using UAV swarms in the presence of small sensor gain, phase, and position errors has been derived analytically. It's analysis accounts for pragmatic errors and uncertainties when the UAVs fly in practice. This includes the signal model with deterministic unknown location errors, which is extended to cases when the location error is stochastic. The Cramer-Rao Bound (CRB) is derived for the joint estimation of DOAs, accounting for variation in sensor gain, sensor phase, and sensor location errors for the swarm. This work examines the results from the first experimental campaign to study the behavior of these systems in a laboratory setting. Both numerical simulations and practical experiments have been obtained to verify the theoretical results. The focus of this manuscript is on the latter.

T09-A04: Reflector Analysis and Design

T09 Space (incl. cubesat) / / Antennas

Room: virtual 8

Chairs: A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands), Jian Yang (Chalmers University of Technology, Sweden)

15:30 ***Calculation of Aperture Efficiency of Reflector Antenna with the Measured Far-Field Function of Its Feed in Ludwig's Third Definition***

Jian Yang (Chalmers University of Technology, Sweden)

Formulas for calculation of aperture efficiency of a primarily-focused parabolic reflector with a rotationally symmetric feed, or so-called Body-of-Revolution (BOR) feed, can be found in literature and many textbooks. Recently, many ultra-wideband (UWB) feeds have been developed for reflectors in radio telescopes, such as the square kilometer array (SKA) project. It has been noticed that all developed UWB feeds are of the non-BOR type. Therefore, it needs to clarify how to calculate the aperture efficiency of a parabolic reflector with the measured far-field function of its feed when the feed is a non-BOR antenna. The purpose of this paper is to derive and document the formulas for calculating aperture efficiency when the far-field function of the non-BOR feed is available by measurements under the Ludwig's third definition. One example of aperture efficiency calculation using the derived formulas based on measurement is presented in this paper.

15:50 ***A Design Concept of Power Efficient, High Gain Antenna System for Mm-Waves Base Stations***

Amr Elsakka and Ulf Johannsen (Eindhoven University of Technology, The Netherlands); Oleg Iupikov (Chalmers University of Technology, Sweden); Martin Johansson (Ericsson Research, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden); A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

A design concept for a phased-array-fed reflector antenna system intended for millimeter-wave base stations is presented. This concept is motivated by the need for efficient beamforming antenna systems with reduced power consumption as compared to the presently considered fully-populated large-scale MIMO arrays. The main idea is to use a high-gain reflector antenna to maximize the effective isotropic radiated power. That in turn, allows minimizing the number of active antenna elements of the phased-array feed, and hence limit the total supplied power. The proposed reflector antenna system is based on a torus reflector which is illuminated by an offset phased-array feed. We show how to determine the antenna design parameters to achieve the desired cell coverage.

16:10 ***Design of a Modulated FSS Subreflector for a Dual-Reflector System***

Michael F. Palvig and Min Zhou (TICRA, Denmark)

This paper describes the design of a modulated FSS subreflector for a S/Ka-band Cassegrain dual-reflector system. The FSS subreflector separates the radiation from the S-band (2.0-2.3 GHz) and Ka-band (25.5-2.7.5 GHz). To simplify the manufacturing of the subreflector, a conical FSS subreflector is considered. Instead of using a periodic FSS where all array elements are identical, a modulated FSS subreflector with varying sized array elements is considered. The FSS elements are optimized to emulate an axial displaced hyperboloid surface, thereby compensating for the non-optimal conical subreflector surface. In Ka-band, the optimized modulated FSS subreflector improves the peak gain of the antenna system with more 6 dBs compared to the use of a periodic FSS.

16:30 ***A New "X-Words like" Approach to Two Dimensional Phase Retrieval Problems***

Giada Battaglia (Università Mediterranea di Reggio Calabria, Italy); Roberta Palmeri (IREA-CNR, Napoli, Italy); Andrea Francesco Morabito (University Mediterranea of Reggio Calabria, Italy); Tommaso Isernia (University of Reggio Calabria, Italy)

A new approach to Phase Retrieval (PR) problem, which is of interest in antenna testing and synthesis, is introduced and discussed. The proposed strategy can be interpreted as a proper combination of solutions of simpler problems, which are herein 1-D PR problems. In particular, the 2-D PR problem is split into a number of 1-D PR problems (along diameters and circumferences) solved through the Spectral Factorization technique, and a subsequent crosswords-like selection scheme. It is worth to note that in the possible applications to antenna testing, opposite to the most widespread existing techniques, the approach just requires a single measurement surface plus the knowledge of the source's support and of the field's phase in a couple of sampling points.

16:50 ***Full-Wave Scattering from Reflector Antennas on Electrically Large Platforms Using Low-Memory Computers***

Oscar Borries, Peter Demeyer and Erik Jørgensen (TICRA, Denmark)

We consider the use of full-wave integral equation techniques on scattering problems involving electrically large structures, and consider how an implementation of such techniques could use an inexpensive solid-state drive (SSD) rather than costly random access memory (RAM). We begin by showing how a Multi-level Fast Multipole Method code based on Higher-Order basis functions has fundamental properties that make it feasible to use disk storage for the less frequently used algorithm data. Then, we show how the use of the SSD allows us to solve larger problems than the RAM of the computing platform makes room for. Finally we consider how this implementation has only a modest impact on the computational time, particularly when compared to the reduction in financial cost of SSD storage rather than RAM.

CS19: LMS Propagation Channel - a Focus on Multipath and Antenna Effects

T09 Space (incl. cubesat) / Convened Session / Propagation

Room: virtual 9

Chairs: Alexandre Chabory (ENAC, France), Fernando Pérez-Fontán (University of Vigo, Spain)

15:30 ***Investigating GNSS Multipath in Aeronautic Applications Through Antenna Installed Performance***

Stefano Caizzone (German Aerospace Center (DLR), Germany); Veenu Tripathi and Simon P Hehenberger (DLR- German Aerospace Center, Germany)

Satellite navigation is a fundamental asset in today's mobile platforms to determine position, velocity and time. In mobile applications, however, the available footprint to place the navigation antenna is often chosen a priori, taking into consideration mechanical/esthetic reasons. This leads often to not-optimal placement, causing multipath and hence impacting on the achievable performance of the antenna and therefore on the achievable navigation accuracy. Proper knowledge of the antenna performance once installed on the platform is therefore of paramount importance to achieve high-precision navigation: methods and tools to assess such performance will be discussed in this work. It will be shown how to characterize the performance in a fully simulative way and then also in a hybrid way, combining anechoic chamber measurement of the antenna with simulation of the platform. It will be shown that, through installed performance analysis, information about the multipath-induced pseudorange error can be obtained.

15:50 ***Dynamic Dual Polarized GNSS Reflectometry Using UAV***

Ankit Regmi, Tuomo Hänninen, Marko E Leinonen and Aarno Pärssinen (University of Oulu, Finland); Markus Berg (University of Oulu & Excellant LTd., Finland)

In this paper, GNSS-Reflectometry is performed using Unmanned Aerial Vehicle (UAV). Received GNSS multipath signal is utilized to perform environment remote sensing in dynamic and static flight modes. Right-Hand Circular Polarized (RHCP) multipath signal is recorded and its interference frequency is used to estimate the height of UAV above the ground surface. In the dynamic flight mode, the C/N0 level of the reflected Left-Hand Circular Polarized (LHCP) signal is used to indicate the presence of different ground surfaces. In comparison with the ground measurement systems, UAV provides a dynamic and flexible measurement platform, potentially significantly reducing the measurement time. At the same time, measurement signal quality is influenced due to the variation of the UAV altitude. The results presented strongly indicate the possibility of utilizing UAVs as measurement platform for remote sensing using GNSS multipath signal.

16:10 ***A Model for the Maritime Satellite Channel as a Function of Sea State***

Fernando Pérez-Fontán, Vicente Pastoriza-Santos and Fernando Machado (University of Vigo, Spain); Norbert Witternigg and Roman Lesjak (Joanneum Research, Austria)

In this paper we present a statistical narrowband mobile satellite maritime propagation channel model at L-band based on empirical observations using GPS C/N 0 measurements from a receiver onboard of a vessel in different sea conditions. The model is fully parameterized for all possible elevation angles. In the measurements, we have used a low gain, 6.2 dBi, hemispherical antenna. The parameters provided, thus, are valid for this and similar antenna gains.

16:30 ***Aeronautical GNSS Channel Model for Spurious Signals Arriving from Below the Horizon***

Alexandre Chabory, Maxandre Coulon and Axel Garcia-Pena (ENAC, France)

This article presents models and results for simulating the aeronautical GNSS channel when a spurious signal is arriving from below the horizon. The proposed models concern the source, the multipath channel and the airborne receiver antenna. For this latter, two solutions are proposed: a simple one with constant below-the-horizon characteristics, and a more realistic that uses a far-field simulation in the presence of the airframe structure. Simulation results on a comprehensive test-case are discussed.

16:50 ***Land Mobile Propagation Satellite Model Based on 360° Images***

Jonathan Israel (ONERA - The French Aerospace Lab, France); Sebastien Rougerie (CNES, France)

This paper presents a new concept of Land Mobile Propagation Satellite model. The main idea is to predict the propagation channel based on the analysis of 360° images. To do so, concurrent RF / optic measurements have been done in the past and this paper will present the correlation study between the images and RF signal. Finally, a coupling model RF / images is proposed here, which allows a LMS channel prediction between 1 to 30 GHz.

T10-E04: EM Modelling and Numerical Techniques

T10 EM modelling and simulation tools / / Electromagnetics

Room: virtual 10

Chair: Giuseppe Vecchi (Politecnico di Torino, Italy)

15:30 ***Realistic Feed Modeling for Metasurface Antennas***

Francesco Vernì (Politecnico di Torino, Italy); Andrea Scarabosio and Marco Righero (LINKS Foundation, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

State-of-the-art metasurface antenna modeling still relies on an approximated feeding scheme which aims to either reproduce experimental or ideal theoretical results. We have developed a three-dimensional full-wave numerical approach based on electric field integral equation (EFIE) to accurately describe the feed and to gain access to the related figure of merit (e.g. return loss). Here we show a good agreement between our solution and already established methodology.

15:50 ***Design Strategy and Considerations to Improve Corona Discharge Breakdown in Groove Gap Waveguides***

Aitor Morales-Hernandez (University of Alicante, Spain); Miguel Ferrando-Rocher (Universidad de Alicante & Universitat Politècnica de València, Spain); Miguel Angel Sanchez-Soriano (University of Alicante, Spain); Stephan Marini (Universidad de Alicante, Spain); Vicente Boria (Universidad Politécnica de Valencia, Spain)

This paper studies the corona discharge breakdown thresholds in groove gap waveguides, and proposes a design strategy to enhance its peak power handling capability (PPHC). The theoretical analysis is focused on the study of the quasi-TE10 mode, and on the PPHC at different frequencies and multiple arrangements of the pin dimensions of the bed of nails. Next, the geometrical parameters width, length and separation of such pins are optimized for improving peak power limits. Finally, the simulated results show reasonably good performance with respect to the equivalent rectangular waveguide power limit.

16:10 ***Accelerating the Full-Wave Simulation of Pyramidal Absorbers Using the Structure Symmetries***

Arya Fallahi (IT'IS Foundation, Switzerland); Amin Enayati (Emersun and Cumming Anechoic Chambers, Belgium)

The problem of plane wave diffraction from pyramidal absorbers is considered. In a previous study, we have developed a hybrid method based on the R-matrix Fourier modal method (RFMM) and the mode-matching (MM) of fields for an efficient and robust analysis of this class of absorbers. The proposed technique benefits from the intrinsic discrete spectrum of the periodic structure in transverse directions and consequently avoids spatial discretization along the periodicity axes, thereby simulating the device with minimal computation cost. Nonetheless, the method suffers from the requirement for solving a full system of linear equations, which leads to large computation costs when the performance of the absorbers at high-frequency bands is modeled. In this paper, we present the methodology for taking advantage of the structure symmetries and the consequent modes parity to drastically reduce the computation costs. The example of VHP pyramidal absorbers is outlined and convergence analysis is performed.

16:30 ***Ray-Tracing-Integral-Equation Hybrid Method for RF Propagation in Complex Media***

Andrea Scarabosio (LINKS Foundation, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Marco Righero (LINKS Foundation, Italy); Jorge A. Tobon Vasquez and Giuseppe Vecchi (Politecnico di Torino, Italy)

We present a hybrid scheme for radio frequency propagation in complex media as a plasma. The physical domain is divided into a homogeneous and a inhomogeneous part, with this latter surrounded by a surface of arbitrary shape. Electromagnetic wave

propagation inside the inhomogeneous part is computed with a classical ray-tracing algorithm, whereas in the homogeneous part the integral equation formulation for radiation is used. Equivalent currents living on the surface surrounding the inhomogeneous part act as a bridge between the two formulation: currents are computed from the ray-tracing electric field and used as sources in the integral equations. We test the accuracy of this hybrid scheme by comparing its results with those obtained with the well established Method of Moment (MoM) and with semi-analytic Mie solutions for various scattering problems. The effect of a high density plasma on the scattered field is illustrated as an example of application.

16:50 ***Finite Array Decomposition Domain Method Applied to Large Low Profile Metasurface-Based Antenna***

Céline Ha (CEA-LETI & Université Grenoble Alpes, France); Jean-François Pintos (CEA-LETI, France); Priscillia Daquin (CNES, France); Serge Bories (CEA, France)

This paper examines the accuracy, the time and memory consumption of the Finite Array Domain Decomposition Method (FA-DDM) applied for a large and complex low-profile metasurface-based antenna, with High-Performance Computing (HPC) for parallel processing. A validation step is performed as the technique is used for non-identical unit cells in the lattice array. Three canonical and simple structures are simulated for validation: the half-wave dipole, the half-wave dipole over a Perfect Electric Conductor (PEC) and the half-wave flat dipole over a mushroom-like Artificial Magnetic Conductor (AMC). To conclude, a large antenna system (9 x 19 cells) with high complexity is proposed to investigate the performance of the FA-DDM.

CS38: Surface Wave and Metasurface Engineering: Recent Developments and Applications

T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics

Room: virtual 11

Chairs: Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)), Okan Yurduseven (Queen's University Belfast & Duke University, United Kingdom (Great Britain))

15:30 ***Ghost Image Removal Using Physical Layer Spatial Asymmetry in Frequency-Diverse Computational Imaging***

The Viet Hoang (Queen's University of Belfast, United Kingdom (Great Britain)); Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast & Duke University, United Kingdom (Great Britain))

Ghost images are one of the undesired artifacts in an imaging system besides a real image. It also happens in frequency-diverse computational imaging used to reduce the complexity of traditional imaging systems using a mechanical scan or active circuits. We present that by breaking the symmetric structure of frequency-diverse wave-chaotic metasurface antennas, the ghost image artifacts in reconstructions retrieved using frequency-diverse computational imaging can be eliminated.

15:50 ***Efficient Conversion of TM Surface Wave into TM Leaky Wave by Metasurface***

Svetlana Tcvetkova (Aalto University, Finland); Enrica Martini (University of Siena, Italy); Sergei Tretyakov (Aalto University, Finland); Stefano Maci (University of Siena, Italy)

In this paper we discuss possible practical implementations of exact solutions for a lossless and reciprocal penetrable metasurface which ensures full conversion of a single-mode surface wave to an arbitrarily directed single plane leaky wave of the same polarization. In contrast to known leaky-wave antennas, we have found the optimal surface reactance modulation which ensures the absence of higher-order modes of the Floquet wave expansion. Therefore, there is no accumulation of reactive energy in higher order modes and all the energy carried by the surface wave is used for launching the single plane wave into space.

16:10 ***The Interpath Relation for Spatially-Discrete Traveling-Wave Modulated Structures***

Cody Scarborough (University of Michigan, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

Traveling-wave modulation has been employed since the 1950s for amplification and frequency conversion, and more recently for beam-steering and breaking reciprocity. Typically, traveling-wave modulation is realized by applying a staggered bias/pump signal to an array of discrete unit cells. This is referred to as spatially-discrete traveling-wave modulation (SD-TWM). SD-TWM structures can prove challenging to simulate due to their often complex geometry and extreme temporal variation. Here, we examine a relation established within SD-TWM structures referred to as the interpath relation. The interpath relation reveals that the solution within a single unit cell (as opposed to an entire spatial period) is sufficient to determine the entire problem. The interpath relation is then incorporated into a method of moments solver to compute the scattered field produced by a representative SD-TWM metasurface. The presented method simplifies the computation of both physical patterned designs, as well as nearly continuous idealized structures.

16:30 ***Efficient Aperture Illumination and Beamforming with Huygens' Metasurfaces Exciting Surface Waves***

Vasileios G. Ataloglou and George V. Eleftheriades (University of Toronto, Canada)

Huygens' metasurfaces allow for extreme wave manipulation of the incident fields. Their ability to shape the electromagnetic wavefronts have made them a promising platform to build antenna systems without complicated feeding networks. However, for conventional passive and lossless Huygens' metasurfaces, the power density of the incident and output fields should be locally conserved. This requirement poses limitations to the amplitude of the output fields, especially if the radiating source is placed close to the metasurface. In this paper, a method is proposed to bypass these limitations and design Huygens' metasurfaces with nonlocal response. The method relies on surface waves that redistribute the power in the input side of the metasurface. The usefulness is demonstrated through the design of a radiating aperture with directivity beyond that of conventional metasurfaces. Furthermore, a physical Huygens' metasurface is designed to realize a singly-fed Taylor aperture antenna, verifying the potential of accurate and efficient beamforming.

16:50 ***Low-Cost Inkjet Printed Paper Poster FSS for 5G Applications***

Anshuman Shastri, Peter M. Njogu, Benito Sanz-Izquierdo and Steven Gao (University of Kent, United Kingdom (Great Britain)); Zhijiao Chen (Beijing University of Posts and Telecommunications, China)

Low-cost inkjet printing of a Frequency Selective Surface (FSS) paper poster to reduce the drop of 5G signals within an indoor environment is introduced in this paper. An array of square loop elements is employed for this application. This low-cost FSS operates at a central frequency of 25.2 GHz while covering the 24 GHz band used in 5G systems. CST Microwave StudioTM was employed to simulate the FSS. The array structure was fabricated using a household Inkjet Printer on a photo paper using nanoparticle silver ink filled in refillable ink cartridges. Simulation transmission responses compared well with measurements. Inkjet printing could print tracks with fine details required for the mm-wave applications and offered reliable conductivity for the filtering performance. Printing of low-cost posters can help in improving the strength of 5G signals.

CS5: Antennas for Harsh Environment

T11 Fundamental research and emerging technologies / Convened Session / Antennas

Room: virtual 12

Chairs: Loic Bernard (ISL, France), Maxime Romier (Anywaves, France)

15:30 ***Design and Verification of an On-Body Antenna in the Harsh Environment of a Horse Hoof***

Jasper Goethals (Ghent University & IMEC, Belgium); Denys Nikolayev (Institut d'Électronique et des Technologies du Numérique (IETR) - UMR CNRS 6164, France); Arno Thielens and Gunter Vermeeren (Ghent University, Belgium); Leen Verloock (UGent, Belgium); Margot Deruyck (Ghent University - IMEC, Belgium); Luc Martens (Ghent University-IMEC, Belgium); Wout Joseph (Ghent University/IMEC, Belgium)

This paper describes the design of an antenna embedded in a hoof pad. The operating frequencies are within the GSM900 band. The dimensions are 40 mm x 25 mm x 1.55 mm. During the characterization of the antenna, the dynamic and harsh environment of a horse hoof is taken into account. The antenna impedance is validated numerically and experimentally to be robust to these changes.

15:50 ***Additional Lens for TEM Horn Antenna and Transient High-Power Application: Design and Characterization in Time Domain***

Philippe Delmote (French-German Research Institute of Saint-Louis - ISL, France); Francois Bieth (ISL, France)

This paper presents the design of a dielectric lens dedicated to transient HPM radiation. The proposed lens has been developed as an optional component that could be used to increase the directivity and the range of a mobile HPM source. The emitter consists in a TEM horn powered by a Marx generator and a dedicated pulse forming line (400kV-50 Ohms, total duration of 1.5ns). The emission high amplitude nanosecond signals covers an ultra-wideband of frequencies, so the design of the lens was carried out in time domain. Once manufactured, the near fields and the far fields have been measured with and without the lens. The maximum gain increases by at least 6 dB beyond 1.3 GHz and can reach 12 dB for higher frequencies. In time domain, the peak amplitude has been multiplied by a factor 2.65 allowing to reach a figure of merit of 2 MV/m.

16:10 ***Snow on Polar Radomes and Performance Deterioration at 26 GHz for a Receiving Ground Station: The SNOWBEAR Project***

Matteo Marchetti and Davide Arenare (University of Pavia, Italy); Filippo Concaro (European Space Agency, Germany); Marco Pasian (University of Pavia, Italy)

Future Earth observation satellites at Polar orbits will use radio links at around 26 GHz to download their scientific data to ground stations at Polar latitudes. However, this use of such frequencies has few previous examples, and the precise link budget modelling and experimental validation of such links is still open. This is especially true for the effects caused by the presence of the snow on the radome. This paper presents a general overview of a dedicated project (SNOWBEAR), developed under European Space Agency coordination, where the performance degradation due to the snow is addressed, identifying two major contributions, absorption and de-pointing. Preliminary results are presented.

16:30 ***Uncertainty Estimation of Achievable Radiation Efficiency of Implantable Antennas***

Zvonimir Sipus (University of Zagreb, Croatia); Anna Susnjara (University of Split, Croatia); Anja K. Skrivervik (EPFL, Switzerland); Dragan Poljak (University of Split, Croatia); Marko Bosiljevac (University of Zagreb, Croatia)

Designing antennas for implanted medical devices is a very complex task where one needs to tackle inherently large EM absorption in the human tissue and very limited available space for the antenna. In addition, designers need to carefully limit the power output of the devices due to health safety regulations and small battery volume. Furthermore, the initial designs assume that permittivity and conductivity of different types of human tissues are known. Unfortunately, these values have a significant variation depending on the age, sex and health conditions of the actual patient. Such variations need to be taken into account in initial designs and in this paper we analyze the influence which the uncertainty of the tissues dielectric parameters have on the predictable power density in implanted antenna scenarios.

16:50 ***GNSS Antenna Design for Underwater Mine-Disposal-Vehicles***

Ulf Johannsen, Robbert Schulpen and Lester Manders (Eindhoven University of Technology, The Netherlands); Robert Engel (Atlas Elektronik GmbH, Germany)

Sea mines are one of the most cost-effective weapons of naval warfare. Underwater mine-disposal vehicles are used to identify and neutralise this threat. In order to localise the position of the vehicle in a shallow water scenario, it needs to surface and update its internal navigation system using a global navigation satellite system. This paper presents the design and prototype of an antenna that can be integrated in the mine-disposal vehicle SeaFox. Simulation and measurement results suggest that the antenna design can cover all major GNSS bands. However, the radiation pattern strongly depends on the water level.

T11-E04: Optimisation Techniques and Applications

T11 Fundamental research and emerging technologies / / Electromagnetics

Room: virtual 13

15:30 ***A Comparison Between Two Different Techniques for Beam-Scanning Reflectarray Antennas Design***

Alessandro Niccolai and Riccardo Enrico Zich (Politecnico di Milano, Italy); Michele Beccaria, Andrea Massaccesi and Paola Pirinoli (Politecnico di Torino, Italy)

The possibility of introducing beam-scanning capabilities in reflectarray (RA) antennas is becoming more and more important and several solutions have been proposed. Among them, a possible approach consists in using a passive RA and acting on the feed to achieve the beam-scanning. However, the fulfillment of the desired high gain constraints over the entire scanning range is still a challenging issue. Here, two different design techniques are considered and compared: a more conventional one, i.e. the bifocal design technique, and a more innovative approach, based on the use of an efficient evolutionary algorithm, the Social Network Optimization technique. The obtained results show the effectiveness of this last method, enabling the design of a RA with scanning capability over a wide angular range, outperforming the bifocal configuration.

15:50 ***SLL Reduction in Planar Dielectric Waveguide with Graphene Strips Using Genetic Algorithm***

Mstyslav Kaliberda and Sergey Pogarsky (Karazin National University of Kharkiv, Ukraine); Lubov Kaliberda (Kharkiv Petro Vasylenko National Technical University of Agriculture, Ukraine)

In this paper, we use genetic algorithm to reduce the side lobe level of the radiation pattern of the H-polarized dielectric waveguide eigenmodes scattered by a finite periodic system of graphene strips at THz. Every individual graphene strip can have its own value of chemical potential and it can be controlled dynamically. In our optimization procedure, the strip width and period are fixed. Only the values of chemical potential are varied for each frequency point. Rigorous solution of the scattering problem is obtained by the method of singular integral equation. Optimized radiation patterns are presented.

16:10 ***A Deep-Learning Classifier for Object Tracking from Through-The-Wall Radar Data***

Gabriele Incorvaia (The University of Manchester, United Kingdom (Great Britain)); Oliver Dorn (University of Manchester, United Kingdom (Great Britain))

In this work, a novel data driven object tracking scheme from through-the-wall radar data is presented. The localization task is firstly rewritten in terms of a classification problem which is addressed by using a deep learning approach. This localization and tracking task is assisted by standard inverse problems techniques which are used in order to recover the stationary background and to enhance the performance of the learning method. Together it yields a combined classifier network which is able to estimate very efficiently an almost arbitrary trajectory described by a target moving inside a building. No prior assumption on the dynamical model of the object is needed, which is a big advantage of the proposed scheme compared to standard Bayesian tracking filters. A 2D proof-of-concept study is discussed here which prepares more realistic 3D extensions to be addressed in our future research.

16:30 ***Automated Synthesis of Metasurface Antennas***

Marcello Zucchi and Francesco Vernì (Politecnico di Torino, Italy); Marco Righero (LINKS Foundation, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

In this paper we propose an algorithm for the automated design of metasurface antennas. From the knowledge of an objective radiation field and of an incident field, it allows to synthesize the required surface impedance on the radiating aperture. A scalar impedance boundary condition is employed in the integral equation formulation of the electromagnetic problem. The approach is entirely numerical, based on an iterative algorithm able to enforce both physical and feasibility constraints. The procedure was applied to the design of a leaky-wave antenna at 30 GHz and the final result showed a good performance compared to a reference analytical design.

16:50 ***Graphene-Based Terahertz Absorber Design Using Artificial Intelligence Approaches***

Behnaz Bakhtiari and Homayoon Oraizi (Iran University of Science and Technology, Iran); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain))

In this paper, a tunable terahertz (THz) absorber is designed by the neural networks, providing the possibility to inverse design a tunable THz absorber. The proposed structure of the absorber contains graphene as an advanced electromagnetic material with tunable properties. By applying an electrical bias to the designed structure, a tunable absorber can be achieved in the THz spectrum. The artificial intelligence (AI) method, is applied to inverse design the structural geometry based on the specified frequency response. Employing a 3D electromagnetic software to simulate various structures to generate a dataset for training forward neural network and using the resultant weights to the inverse neural network to design the structure.

Wednesday, March 24

Wednesday, March 24 10:00 - 11:40

T01-A03: Classic multi band antennas

T01 LTE and Sub-6GHz 5G / / Antennas

Room: virtual 1

Chair: Jaime Molins-Benlliure (Universitat Politècnica de València & ITEAM, Spain)

10:00 ***Metal Rim Antenna with Small Clearance Based on TCM for Smartphone Applications***

Lyuwei Chen and Yi Huang (University of Liverpool, United Kingdom (Great Britain)); Hanyang Wang (Huawei Technologies, United Kingdom (Great Britain)); Hai Zhou (Huawei Technology (UK), United Kingdom (Great Britain))

A metal rim antenna with small clearance for smartphone applications is proposed. The proposed antenna mainly consists of a system ground plane, a metal rim with two slots and two shorting grounded patches. The theory of characteristic modes is used to analyze the entire structure. With the aid of a simulation tool, two resonant characteristic modes (CMs) in the low-frequency band are identified, and its eigen-current distributions are also analyzed to obtain an optimized design. Finally, the bands of 0.85-0.96 and 1.71- 2.69 GHz, are covered. The measured result agrees well with the simulated one, demonstrating the application potential for smartphone applications.

10:20 ***Dual S- and X-Band Shared Aperture Antenna for Nano-Satellite Applications***

Daniel E. Serup, Robin Williams, Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)

This paper presents a dual S- and X-band antenna structure and gives a detailed performance evaluation of the antenna design. The main benefit of the presented antenna is its high frequency-ratio and its low cross-coupling. The antenna measures 82x82mm and has a total thickness of 5.65mm. The antenna is fabricated using Rogers-RT5870 substrate material. The small footprint of the presented antenna makes it very suited for nano-satellite applications. The desired S-band frequency range is from 2.00 to 2.12GHz. The desired X-band frequency range is from 8.2 to 9.0GHz. The Fabricated antenna prototype is measured to have a sufficient impedance bandwidth and a low axial ratio. The cross-coupling is both simulated and measured to be below -40dB in the desired frequency range. The antenna has a realized right hand circularly polarized gain of more than 6.0dBi and more than 12.0dBi in the desired frequency ranges of the S-band and X-band, respectively.

10:40 ***Design of Multi-Wideband Automotive Cell Antenna for LTE and 5G Applications***

Ahmad Yacoub, Mohamed Abbadi and Daniel N Aloi (Oakland University, USA)

This paper will present a multi-wide band monopole antenna for automotive application in the Long-Term Evolution (LTE) and 5G systems that covers the frequency range from 617MHz to 5GHz with reasonable rejection on the L1/L2/L5 GNSS bands. The antenna is

suitable to be placed on the car roof inside a Shark-Fin radome due to its physical dimensions and performance. The design is simulated using FEKO software then fabricated and measured on a one-meter ground plane (GND) and on vehicle's roof. The measurement results of the fabricated prototype are presented and plotted in terms of VSWR, radiation patterns, and efficiency. The proposed antenna shows a very good properties that makes it suitable for the automotive industry.

11:00 ***Design Procedure for 5G/IoT Multiple-Port Cavity-Backed Antennas***

Jaime Molins-Benlliure (Universitat Politècnica de València & ITEAM, Spain); Eva Antonino-Daviu (Universitat Politècnica de València, Spain); Marta Cabedo-Fabrés (Universidad Politécnica de Valencia, Spain); Miguel Ferrando-Bataller (Universitat Politècnica de València, Spain)

The design procedure of a multiple-port cavity-backed antenna is presented using characteristic modes analysis (CMA). This methodology ease the design process, starting from the modes of a squared ground plane with length a, and then analyzing how they change when the plane is reshaped into a (a-2b) x (a-2b) x b cavity. Characteristic modes analysis gives a visual insight establishing some constrains for setting the optimum height (b) of the cavity and the optimum feeding configuration of the ports. A complementary full-wave analysis is also introduced for obtaining additional information regarding the input impedance and isolation between the ports. A 2-port cavity-backed antenna with 4.1 GHz (2.9-7 GHz) impedance bandwidth and 15 dB isolation has been optimized with the proposed procedure.

11:20 ***A Dual-Wideband Circular Polarized Shared-Aperture Antenna for CubeSat Applications***

Salvatore Liberto and George Goussetis (Heriot-Watt University, United Kingdom (Great Britain))

A dual-wideband circular polarized shared aperture antenna for CubeSat applications is presented in this paper. The antenna exploits two distinct components operating at separate bands. The S-band antenna is based on a stacked patch structure. Circular polarization with a single feeding point is achieved by truncating the corners of both patches. The X-band antenna adopts an S-inverted printed dipole where the upper patch of the S-band antenna acts as a ground plane. An alternative technique to feed the printed dipole with a compact and simple balun is then proposed. The shared aperture antenna shows a -10dB impedance bandwidth from 1.92 to 2.16 GHz and from 7.2 to 10 GHz in S- and X- band respectively. These performances are able to cover the downlink and uplink frequencies for the Earth Exploration Satellite. An AR below 3dB in the S-band and below 1.5dB in the X-band within the EESS bandwidths is achieved.

CS32: Recent Advances on Electronically Steerable Antenna Arrays at mmWave and sub-THz Frequencies

T02 Millimetre wave 5G / Convened Session / Antennas

Room: virtual 2

Chairs: Antonio Clemente (CEA-LETI Minatec, France), Ronan Sauleau (University of Rennes 1, France)

10:00 ***Modulated Geodesic Lens Antenna Array***

Pilar Castillo-Tapia and Qingbi Liao (KTH Royal Institute of Technology, Sweden); Nelson Fonseca (European Space Agency, The Netherlands); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

We present the design of a geodesic Luneburg lens array antenna. The water drop lens is a compact and highly-efficient alternative to the planar Luneburg lens. Our proposed lens antenna is able to steer 110 deg in azimuth with negligible scan losses. On the other hand, the linear array of four elements increases 6 dB of directivity in elevation. A feeding network composed by a 1:4 power splitter and four different phase shifters allows to steer 60 deg in elevation.

10:20 ***Reflecting Luneburg Lens: Analytical Solution and Applications***

Jorge Ruiz-García (Université de Rennes, France); Enrica Martini (University of Siena, Italy); Cristian Della Giovampaola (Wave Up srl, Italy); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Stefano Maci (University of Siena, Italy)

This paper presents the closed-form solution for a new type of lens beamformer, which consists of two stacked parallel plate waveguides (PPWs) of circular shape. The rays launched by a source at the rim of the bottom PPW are collimated in the top PPW after being reflected at a cylindrical metallic wall that surrounds both layers. Since it reproduces the behavior of the Luneburg lens for reflected rays, this lens is hereinafter referred to as Reflecting Luneburg lens (RLL). The refractive index profile for the azimuthally symmetric circular domain is found by solving the non-linear integral equation of ray-congruence through a truncated Abel transform method. The validity of the derived exact formula is verified by full-wave simulations, practical implementation and possible applications of RLLs in antenna systems are also briefly discussed.

10:40 ***UWB Millimeter-Wave 1D MIMO Array for Non-Destructive Testing***

Enrico Tolin (IMST GmbH, Germany & Politecnico di Torino, Italy); Marta Arias Campo (IMST GmbH, Germany); Harun Cetinkaya (Fraunhofer-FHR, Germany); Reinhold Herschel and Sabine Guetgemann (Fraunhofer FHR, Germany); Christian Krebs (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Simona Bruni (IMST GmbH, Germany)

A sparse, UWB, multi-module 1D MIMO array atD-band (110-160 GHz) is proposed for 2D imaging of hot steel slabs during the hot rolling process in steelworks. The MIMO array consists of 22 transmitting and 175 receiving antennas. Results illustrate that the MIMO array provides significantly low level of side lobes and high resolution capability. Besides the MIMO concept and first simulations, this paper describes the wide band antenna concept which will be integrated in the system. Full-wave simulation results for the antenna show 37% bandwidth with more than 85% radiation efficiency, and stable -3 dB beamwidth over the whole frequency band.

11:00 ***Pattern Diversity and Scan Loss Reduction for Millimeter Wave Phased Array Applications***

Ralph van Schelven (Delft University of Technology, The Netherlands); Waqas Syed, Giorgio Carluccio, Kostas Doris and Anton Graauw (NXP Semiconductors, The Netherlands); Andrea Neto and Daniele Cavallo (Delft University of Technology, The Netherlands)

In this work, we investigate antenna concepts to enhance the scan range in phased array design. Planar slot antenna elements are used as isolated radiators or in array configurations, in combination with artificial dielectrics layers located in the close proximity to achieve pattern shaping. Spectral domain representations are used for the analysis of the leaky waves propagating within the stratification. The artificial dielectric superstrate supports leaky waves that can be optimized to enhance the gain in a specific angular region or to enlarge the array field-of-view. By controlling the amplitude and phase of the antenna elements, the proposed concepts can be used to realize adaptive arrays, which can change their combined radiation pattern in different operating conditions.

11:20 ***Feed Network Optimization for Currents in Amplitude Based Beam Steerable Arrays***

Siva Sai Krishna Puranam and Robert Sainati (University of Minnesota, Twin Cities, USA); Anand Gopinath (University of Minnesota, USA)

Beam steering which is achieved conventionally using phase shifters can also be achieved by using attenuators in the feed network in Amplitude Steerable arrays. These attenuators provide the necessary weights to the signals entering the antenna elements. The effect of mutual coupling is much more pronounced in the amplitude steerable arrays due to closer spacing which manifests as currents to the elements being changed. This paper addresses a method to compensate for the effect of mutual coupling on the currents by designing an algorithm that optimizes the characteristics of the attenuators in the feed network in order to ensure proper currents are delivered to the antennas.

T04-A02: Antennas for wireless power transfer

T04 IoT and M2M / / Antennas

Room: virtual 4

Chair: Miguel Ferrando-Bataller (Universitat Politècnica de València, Spain)

10:00 ***A Comparative Study Between Different Loop Antennas Topologies for Wireless Power Transmission Based on Modal Analysis***

Ferdaous Abderrazak (ITEAM-UPV, Spain); Eva Antonino-Daviu and Miguel Ferrando-Bataller (Universitat Politècnica de València, Spain); Larbi Talbi (University of Quebec - Outaouais, Canada); Ali Al Qaraghuli (Northeastern University, Boston, MA, USA)

Wireless power transfer (WPT) using magnetic coupling between loop antennas is an emerging technology, which could solve difficulties and hazardous technical problems of wired power transmission. From several millimeters to several hundred millimeters, WPT technology has reached kilowatts power level with high grid load of efficiency, which has brought significant benefits to medical applications, automation systems, consumer electronics, etc. Yet, WPT systems are extremely sensitive to the alignment between the transmitting and the receiving coils. A dual transmitter topology has been proposed to overcome the misalignment problems and maintain high power transfer efficiency. Nevertheless, the misalignment sensitivity between the transmitters was not considered. A comparative study based on the Theory of Characteristic Modes between three different topologies of the transmitting systems in MHz level is conducted in this paper. To enhance the comparison, the power transfer efficiencies of the three models are calculated regarding the same positions of the receiver.

10:20 ***Optimal Design of Microstrip Reflectarray Antenna to Maximize Transmission Distance for Microwave Wireless Power Transmission***

Hao Jiang (Southeast University, China); Wenbin Dou (Southeast University & State Key Of MMW, Southeast University, China)

Transmission distance is a more important index in specific wireless power transmission applications. The design method to obtain the optimal aperture distribution to achieve the maximum transmission distance with a given beam collection efficiency (BCE) is proposed in this work. A 125 by 125 microstrip reflectarray antenna is designed and simulated based on maximization of transmission distance for microwave wireless power transmission applications. The result shows the good performance of reflectarray antenna in achieving maximum transmission distance with a given BCE and aperture size.

10:40 ***Origami Boat Sensing Antenna***

Peter M. Njogu (University of Kent, United Kingdom (Great Britain)); Paul Jablonski (Imperium, United Kingdom (Great Britain)); Anshuman Shastri and Benito Sanz-Izquierdo (University of Kent, United Kingdom (Great Britain))

A monopole antenna for controlling an unmanned surface vehicle (USV), an origami boat, with a built-in sensing function for surface detection is proposed. The design is proof-of-concept for detecting the surface on which the USV sits. The USV model is a Mylar sheet, folded into an origami boat with the antenna on its mast. A quadrilateral structure with piece cut-off from its longest side extends from the monopole antenna's ground plane. This structure provides the surface detection function. The antenna design targets commercial drones' wireless communication and control frequency bands (2.4 GHz and 5.2 GHz). The design viability was assessed using reflection coefficient and radiation pattern performance parameters. A good agreement was observed between the simulated and measured parameters. This work is investigates an antenna sensor solution for future amphibious origami robots with integrated smart sensors. The antenna design and studies were simulated using CST Microwave StudioTM.

11:00 ***A Rectenna Design Based on Circularly Polarized Differential Antenna and Class-F Rectifier***

Sandhya Chandravanshi (Queen's University Belfast, United Kingdom (Great Britain)); Dmitry E Zelenchuk (Queen's University of Belfast, United Kingdom (Great Britain)); Neil Buchanan (Queens University Belfast, United Kingdom (Great Britain))

A rectenna design based on truncated corner circularly polarized patch antenna with a dual out-of-phase feed is proposed in the presented work. Moreover, the axial ratio and realization of other fundamental characteristics of the antenna are studied using parametric analysis and optimized for 2.45 GHz. The proposed rectenna design utilizes a dual port differential feed rectifier that is connected directly to differential antenna minimising loss in interconnects. The designed rectifier here is chosen as a class-F rectifier due to its inherent harmonic suppression property, its efficiency and converted power are simulated and analysed. Finally, proposed dual feed antenna has been simulated with the designed rectifier circuit using circuit simulation method and obtained results are presented. The study concluded that the proposed rectenna arrangement is suitable for a medium power range WPT system.

11:20 ***Cross-Talk Mitigation Using Band-Stop Filters for Multiple-Frequency One-To-Multiple Inductive Power Transfer***

QuocTrinh Vo, Quang-Thang Duong and Minoru Okada (Nara Institute of Science and Technology, Japan)

Multiple-frequency inductive power transfer (IPT) system is able to independently charge multiple receivers with separated operating frequencies by using only one transmitting platform. Unfortunately, when the operating frequencies are close to each other, the system suffers from cross-talk among adjacent frequency signals. To mitigate the cross-talk, this work proposes using band-stop filters with isolation enhancement design in compensation circuit of the charging platform. Effectiveness of the proposed scheme is verified by circuit simulations and experiments with two-receiver IPT system operating at two adjacent frequencies of 170kHz and 200kHz.

T05-P01: Propagation in biological tissues

T05 Biomedical and health / / Propagation

Room: virtual 5

Chair: Esraa Elsayed Mansour (Egypt-Japan University of Science and Technology (E-JUST), Egypt)

10:00 ***An Antipodal Vivaldi Antenna Design for Torso Imaging in a Coupling Medium***

Sulayman Joof and Semih Dogu (Istanbul Technical University, Turkey); Egemen Bilgin (MEF University, Turkey); Mehmet Çayören (Istanbul Technical University, Turkey)

An antipodal Vivaldi antenna designed to operate in a coupling medium with a relative dielectric constant of er = 25 for microwave imaging of torso is presented in this paper. The proposed antenna is similar to the conventional antipodal Vivaldi antenna but with optimized parameters to radiate in the desired coupling medium. The antenna has a size of 120x70 mm2 and operating over 230-1000 MHz frequency bandwidth with a peak gain of 5.42 dBi and peak front-to-back ratio of 14.3 dB. The designed antenna shows a better performance compared to other antennas used for microwave torso imaging. To assess the actual performance, a realistic human torso phantom is implemented to detect the accumulation of water in the lungs, and the linear sampling method is used as the inversion technique. The 3-D reconstruction results show that the proposed antenna can be a candidate for microwave torso imaging applications.

10:20 ***Interpreting Mueller Matrix of Anisotropic Material***

Sidra Batool, Mehwish Nisar, Fabio Mangini and Fabrizio Frezza (Sapienza University of Rome, Italy); Eugenio Fazio (Sapienza Università di Roma & OptSensor srl, Italy)

The polarization imaging methodology has evolved to accept increasingly complex parametric measurements. The Mueller matrix is now generally calculated using a polarimetry technique. In our manuscript, we study the anisotropic wood sample using polarization imaging techniques. Herein, We attempt to study the difference between wood horizontal and vertical fibers. We calculated 3×3 Mueller matrix elements, which can be used to described an intuitive overview of the anisotropic material characteristics. We interpreted experimental results of Mueller matrix coefficients in terms of a graphical representation.

10:40 ***A Novel Approach to Non-Invasive Blood Glucose Sensing Based on A Defected Ground Structure***

Esraa Elsayed Mansour and Ahmed Sayed Ahmed Abdelhamid Allam (Egypt-Japan University of Science and Technology (E-JUST), Egypt); Adel Bedair (Egypt-Japan University of Science and Technology, Egypt)

In this study, we explore a novel approach to measure blood glucose concentration in a non-invasive way using a compact defect ground structure (DGS) filter. This proposed approach is cost-effective, compact, and convenient. The sensor was designed using CST Microwave Studio. The size of the fabricated sensor is 40×40× .883 mm3, which is suitable for hand-held use. The proposed sensor operates at 1.88 GHz and was able to achieve a good sensitivity relative to the change of glucose concentration. The proposed sensor is a potential candidate for non-invasive blood glucose monitoring applications.

11:00 ***Combining Target Coverage and Hot-Spot Suppression into One Cost Function: The Hot-To-Cold Spot Quotient***

Massimiliano Zanoli and Hana Dobšíček Trefná (Chalmers University of Technology, Sweden)

Microwave hyperthermia treatment planning (HTP) is a multi-objective task for which several cost functions have been suggested over the years. The power distribution inside the patient, achieved by amplitude and phase steering of the applicator array, must fulfill diverse requirements. On the one hand, high and homogeneous target power deposition is required for temperature elevation. On the other, healthy tissues should not be subjected to excessive heating and hot-spots outside the target should be suppressed. To these ends, two major SAR-based indicators are currently used as cost functions in clinical HTP, albeit with slightly different meanings: the HTQ and the TC. We propose a novel cost function, termed the hot-to-cold spot quotient (HCQ), aiming at simultaneous target coverage and hot-spot suppression. We show that the HCQ yields HTP solutions that represent a good compromise between the HTQ- and TC-optimal ones for two realistic cases in both single- and multi-frequency settings.

11:20 ***Circularly Polarized Patch Antenna Matched to Liver Tissue with Optimum Placement Positions***

Muhammad Saad Khan (RheinMain University of Applied Sciences, Germany); Georg Rose (OVGU, Germany); Bernd Schweizer (RheinMain University of Applied Sciences, Germany); Andreas Brensing (Hochschule RheinMain, Germany)

In this paper, a circularly polarized microstrip patch antenna matched for propagation in microwave liver tissue is designed at 2.45 GHz. The reflection loss of the antenna is less than 10 dB from 1.8-2.6 GHz. The antenna is circularly polarized in elevation plane cut at azimuth angle (ϕ) of 90◦, for elevation angles(θ) from -14◦ to -7◦ and from 11◦ to 17◦. The axial ratio is below 3 dB in this range of angles from 2.2-2.7 GHz. So considering any reference antenna inserted in the liver tissue, the designed antenna can be placed in any orientation on the liver surface at one of these angles which hold the circular polarization.

T06-A01: Antennas for Aircraft and Automotive

T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / / Antennas

Room: virtual 6

Chair: Jian Yang (Chalmers University of Technology, Sweden)

10:00 ***Insight in Upcoming Applications and Radio Standards Used by the Automotive Industry [INDUSTRIAL KEYNOTE]***

Lars Reichardt (Audi, Germany)

Upcoming services like 5G, Cv2X and UWB allow for a wide offer on connectivity. With this driving becomes safer, faster, more comfortable and more energy efficient. The talk introduces the use of several standards within Audi vehicles and gives an insight in upcoming costumer functions.

10:20 ***Single Layer Dual Circularly Polarized Antenna Elements for Automotive Radar at 77 GHz***

Zhaorui Zang, Ashraf Uz Zaman and Jian Yang (Chalmers University of Technology, Sweden); Carlo Bencivenni (Gapwaves AB, Sweden); Konstantinos Konstantinidis (Veoneer Germany GmbH, Germany)

In this paper, two different configurations of dual circularly polarized antenna elements in single layer gap waveguide (GW) are presented for 77GHz automotive radar systems. Both of the antenna configurations utilize slot element to radiate and generate circular polarizations. The right-hand circular polarization (RHCP) and the left-hand circular polarization (LHCP) are generated at the same working frequency with different input ports. The simulated results show that both two antenna elements could cover the proposed impedance bandwidth (75-80 GHz) with an axial ratio lower than 2 dB.

10:40 ***Multiple-Open-Ended-Slot Antenna for Integrated 4G/5G Mobile Application***

Nghia Nguyen-Trong (University of Adelaide, Australia); Muhammad Ikram (The University of Queensland, Australia)

This paper demonstrates how multiple open-ended slot structures can be employed to design an integrated antenna that simultaneously covers the lower 4G/LTE band (800 MHz), upper 4G/LTE band (2 GHz), sub 6-GHz 5G band (3.5 GHz) and millimeter-wave 5G

band (28 GHz). In this configuration, three open-ended slots with different sizes operating at the low frequencies range and an array of four Vivaldi antennas are placed altogether in a compact footprint of only 73 mm by 8.5 mm. The design is suitable for mobile application and can also be adapted for different devices.

11:00 ***Compact Broadband 4G/5G MIMO Array with Matching and Decoupling Network for Automotive Wireless Communication***

Simon Senega and Zafer Toprak (Universität der Bundeswehr München, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany)

A compact MIMO antenna array for 4G/5G automotive applications is presented. The antenna array has a total size of 185 mm by 40 mm by 80 mm and features four individual radiators. The antennas are printed on a thin flexible foil and are impedance matched and decoupled in two frequency bands in the overall range from 617 MHz to 5 GHz. Three of the antennas support the lower frequency band between 617 MHz and 960 MHz, while all four antennas support the higher frequency band between 1710 MHz and 5 GHz. A coupling of less than −10 dB in the low band and less than −12 dB in the high band is achieved.

11:20 ***Compact Broadband Electromagnetically Coupled Stacked Patch Monopulse Antenna Array at X-Band***

Dovari Nagaraju (Research Center Imarat & DRDO, India); Bivin Mathew and Yogesh Verma (Research Center Imarat, India)

This paper presents a compact, broadband, electromagnetically coupled stacked patch monopulse antenna array at X-band. The antenna element consists of a microstrip line, radiating patch, and parasitic patch in three different layers without air-gap. The antenna array is designed within the diameter of 9 λ with the corporate feed network, which aids the sidelobe level of < -24 dB. The monopulse comparator is designed with the combination of rat-race and double section branch-line hybrids. The impedance bandwidth of the antenna array is 10 % for VSWR < 2. The measured results show a sum pattern peak gain of 24.5 dBi, beamwidth is about 8 deg. in both E-and H-planes. The difference pattern shows a null-depth of better than -30 dB over the bandwidth with a maximum null-depth of about -48 dB.

T07-A01: Array antennas 2

T07 Defence and security / / Antennas

Room: virtual 7

Chairs: Diego Betancourt (Fraunhofer FHR, Germany), Frank Weinmann (Fraunhofer FHR, Germany)

10:00 ***Development and Characterization of a Plastic 3D-Printed Only External-Layer Metal-Coated Waveguide Antenna Array***

Diego Betancourt (Fraunhofer FHR, Germany); Carlos Salzburg (Fraunhofer, Germany); Frank Weinmann (Fraunhofer FHR, Germany)

In this work, the design, fabrication, and experimental verification of a plastic 3D printed metal-coated double-ridged waveguide antenna array is presented. The antenna array consists of four dielectric-loaded square input to circular aperture double-ridged horns arranged in a diamond pattern. A feeding network of one input port to four output ports made on dielectric-loaded double-ridged waveguides is also designed. A novel design methodology to simplify the metal-coating of complex monolithic antenna array structures made on plastic is introduced. A proof-of-concept was fabricated using SLA 3D plastic printing technology and metal-coated only on the external layer using galvanization with Copper and Nickel. The behavior of the antenna array is experimentally verified in the anechoic chamber where a maximum directivity of 17.5 dBi in the frequency bandwidth from 8 to 21 GHz is obtained.

10:20 ***Multiport Compact Stacked Patch Antenna for Multichannel Dynamic Directional Modulation***

Edith Annette Cabrera-Hernández (Universitat Autònoma de Barcelona, Spain)

In this contribution, we investigate a multiport compact stacked patch antenna with 360° beam steering when transmitting multichannel dynamic directional modulation. Two secure observation angles that can be chosen freely in XY plane will be considered. The antenna behavior in the main beam and the side lobes is assessed through bit error rate simulations for different observation angle pairs. Trade-offs between security and power efficiency are also discussed.

10:40 ***High-Efficiency Harmonic Beamforming with Multi-Branch Time-Modulated Array***

Gang Ni, Lening Zhang, Yanchang Gao, Chong He, Jingfeng Chen and Ronghong Jin (Shanghai Jiao Tong University, China)

A novel high-efficiency time modulation (TM) module and harmonic beamforming system are proposed and verified. Aiming to mitigate the power loss in time modulation, single-pole M-throw (SPMT) radio frequency (RF) switches and multiple fixed delay lines are introduced to form the high-efficiency modulation module. Theoretical derivation indicates that the proposed TM module and corresponding beamforming array can realize a significant improvement on overall efficiency. Simulation results are provided to show that the overall efficiency and the gain of the beam can increase with the increase of the fixed delay lines.

11:00 ***Offset-Meandering Line Fed-Patch Periodic-Leaky Wave Antenna for Scanning Through Broadside and Consistent Gain***

Ayaz Ahmad, Busineni Kumar and Jayanta Mukherjee (Indian Institute of Technology Bombay, India)

In this work, a meandering line fed-patch periodic-leaky wave antenna (P-LWA) is designed to achieve broadside beam scanning and consistent gain response. The meandering line is provided a vertical offset (s) away from the longitudinal axis of the unit cell (UC). The combine effect of meandering in the feeding line and its offset acts as a self matching network that enables open stop-band (OSB) elimination at broadside. Consequently, there is no extra matching circuit used in the unit cell which facilitates easy analysis and optimization. The optimized broadside frequency (fB) for the P-LWA is 7.7 GHz. To verify the proposed concept, a prototype of the proposed P-LWA is fabricated and measured. The measured value of impedance bandwidth and maximum realized gain are 36% and 15.4 dBi, respectively.

11:20 ***Iterative Construction of Antenna Array Based on Full-Wave Simulation***

Károly Marák and Jan Kracek (Czech Technical University in Prague, Czech Republic)

A method for the construction of an antenna array based on the iterative addition of its elements is presented. Mutual interactions of the elements are taken into account through a full-wave simulation using the Method of Moments. After adding the desired number of elements, the algorithm of the method can continue by iterative repositioning the already added elements. Some numerical examples are shown to illustrate the scope and convergence of the method.

T09-A01: Antennas for Satellite Communications

T09 Space (incl. cubesat) / / Antennas

Room: virtual 8

10:00 ***SATCOM Antennas in Application and Theatre - Overview, Requirements and Needs [INDUSTRIAL KEYNOTE]***

Jürgen Letschnik (Airbus DS, Willy-Messerschmidt-Strasse1, Germany)

This keynote lecture will give the audience an insight into the applications of SATCOM antenna in military theatre. Application scenarios and according used antenna types will be shown. In addition to the presentation of application scenarios, associated requirements for a SATCOM system and especially those for antennas are explained. In the final part, future perspectives are presented and the corresponding requirements for future antenna systems will be discussed

10:20 ***Three Dimensional Phased Array Antenna for Communications with Satellite Constellations***

Nobuyuki Kaya (WaveArrays, inc., Japan)

Many companies have the projects to launch a lot of small satellites into the low Earth orbit in order to build the worldwide internet services. The ground stations are required to communicate simultaneously with several satellites. It is impossible for the parabolic antenna to track simultaneously several satellites. Therefore, we are newly developing a ground receiving station using the 3-dimensional Phased Array Antenna and the Digital Beam Forming technologies. The purpose of this study is to realize a worldwide receiving antenna network to communicate simultaneously with several satellites and to get information in real-time through the internet anytime and anywhere. We already built the pilot models of the receiving antenna at the frequencies of X-band and S-band, and succeeded in receiving the signal from the satellites.

10:40 ***Reflectarray Antenna Design for LEO Satellite Communications in Ka-Band***

Sara Anguix and Ali Araghi (University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

This paper presents the design of a Ka-band reflectarray antenna, intended for LEO-satellite communications, which operates at 27 GHz. The phase tuning mechanism relies on variable size patches capable of achieving a 360 degrees phase range, which enables the incoming wave to be scattered in any specific direction. In particular, the reflectarray antenna, which has a squared-shape of 30 cm each side, is constituted by a 50 x 50 radiating-patch elements, printed on a planar substrate of "Rogers TMM4" material. With a 27.41 dBi directivity, this configuration is able to generate a pencil-beam in perpendicular direction to the reflecting plane.

11:00 ***Structurally Integrated Phased Array Antennas for Aeronautical SatCom Applications***

Marta Martínez-Vázquez (IMST GmbH, Germany); Jaco Verpoorte (National Aerospace Laboratory NLR, The Netherlands); Jens Leiß (IMST GmbH, Germany); Maren Willemsen (IMST GmbH & Germany, Germany); Adriaan Hulzinga (National Aerospace Laboratory NLR, The Netherlands); Zdeněk Řezníček (Design and Engineering, Czech Republic)

This paper presents a complex antenna tile to be integrated in the fuselage of an aircraft for satellite applications in Ku-band. The different parts of the antenna and the interaction with the structural parts are discussed.

11:20 ***Transmit-Array Antenna with Aberration-Free Wide-Angle Scanning Using Mechanical In-Plane Movements***

Sergio Matos (Instituto Universitário de Lisboa, Portugal); Artur A. Alves (Instituto de Telecomunicações, Instituto Superior Técnico, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Nelson Fonseca (European Space Agency, The Netherlands)

Mechanical steering is the most affordable solution for scanning antennas. The challenge is to balance the trade-offs between high-gain, low profile and wide beam steering. We previously showed that for a Transmit-Array (TA) antenna wide elevation scanning can be achieved by moving the primary source along a line parallel to the aperture. However, aberrations build up as the displacement relative to the lens focus increases, limiting the overall scanning performance. In this work, a new approach to minimize these aberrations is presented. The design of the TA usually assumes an incident spherical wave front. Herein, instead of acting only on the phase correction of the TA, the feed illumination of the aperture is co-designed to minimize the aberrations for all feed positions. The adjustment of the feed illumination is achieved by placing a tailored dielectric lens in front of a standard horn antenna (primary feed). A 28 dBi TA antenna operating at Ka-band uplink [29.5, 30GHz] with F/D=0.7 and elevation scanning up to 50 degrees is designed. Full-wave simulations show an effective reduction of SLL (<-20 dB) when compared with a conventional spherical illumination (<-12dB).

CS10a: (AMTA Session) Computational Modelling of Test Ranges Part 1

T10 EM modelling and simulation tools / Convened Session / Measurements

Room: virtual 9

Chairs: Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)), Vince Rodriguez (NSI-MI Technologies, LLC. & University of Mississippi, USA)

10:00 ***Full-Wave Three-Dimensional EM Simulation of a Spherical Range to Examine and Optimise the Effectiveness of Mode Filtering Based Post Processing Techniques***

Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)); Zhengrong Tian (National Physical Laboratory & NPL, United Kingdom (Great Britain))

This paper extends the authors' prior studies into the use of a very general digital twin of a spherical near-field antenna test system for the careful validation and further optimization of mode filtering-based post processing techniques for scattering suppression. This paper compares and contrasts various measurement configurations and several mode filtering strategies using the results thereof to make recommendations regarding the optimum acquisition strategy and preferred processing methodology. Results are presented and discussed with this paper being the first time that such an extensive and rigorous full-wave three-dimensional computational electromagnetic simulation campaign has been harnessed in this way. This has enabled cylindrical and spherical mode filtering-based scattering suppression techniques to be quantitatively compared, contrasted, and examined.

10:20 ***Scenario Modelling in Echo Generators Design***

Amedeo Capozzoli, Claudio Curcio and Angelo Liseno (Università di Napoli Federico II, Italy)

We deal with the modelling a radiator/scatterer using an equivalent radiator. It requires determining the shape and the dimensions of a radiating surface generating, in a certain region of space D, an electromagnetic field close to that produced by the radiator/scatterer of interest. We propose, for a fixed equivalent radiator's shape, an approach for the solution of the dimensioning issue. The approach uses the Singular Value Decomposition (SVDs) of the operators linking the radiator/scatterer to the field on D and the equivalent radiating panel to the field on D, again. The approach determines the dimensions of the equivalent radiator minimizing the error arising by approximating the primary radiated/scattered field with that radiated using D'. The error is expressed as a Hermitian, positive semi-definite quadratic form so that the problem amounts at the maximization of its minimum eigenvalue. Numerical results are presented for a planar radiator of rectangular shape.

10:40 ***Quiet Zone Quality of a Plane Wave Generator Inside an Over-Moded Waveguide Chamber Emulating a Variable Angle of Incidence***

Pavlo Krasov and Oleg Iupikov (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Andrés Alayón Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden); Robert Rehammar (Bluetest AB & Chalmers University of Technology, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden)

We investigate the use of a hybrid over-the-air (OTA) measurement chamber to emulate far-field testing conditions. The focus has been on the generation of a plane wave arriving at an arbitrary angle-of-arrival (AoA) to the device-under-test (DUT) without mechanical steering. The chamber consists of an oversized waveguide (WG) and a planar array antenna with adaptive beamforming. A modified linear constrained minimum variance (LCMV) beamforming algorithm is used to form a quiet zone (QZ) in the DUT region by using the reflections from the WG's metal walls. The LCMV beamformer formulation has been extended to achieve a volumetric QZ with the desired amplitude and phase uniformity. Numerical studies for the QZ size corresponding to an FR1 base station demonstrate promising results with the low levels of amplitude and phase variation. The AoA coverage of this chamber meets 3GPP specification requirements for OTA conformance testing of base stations with active antenna systems.

11:00 ***Improving Measurement Results by Applying Hybrid Compact Range Modelling Methods***

Bernd Gabler (German Aerospace Center (DLR), Germany); Leopold G. T. van de Coevering (March Microwave Systems B. V., The Netherlands); Björn Möhring (Technical University of Munich (TUM), Germany)

The compact antenna test range (CATR) principle generates pseudo far-field conditions in a limited test-zone volume of an anechoic chamber. Considering the stringent requirements on measurement accuracy for present needs, direct application of a CATR is sometimes questionable. To reduce the errors, related to the CATR principle, prior knowledge of amplitude and phase characteristics across the test-zone are required for performing an accurate calibration of the measurements. Both, measurement and simulation methods have been presented in the past to characterize the test-zone, but have specific advantages and drawbacks. This paper shows how to overcome their limitations with using hybrid Compact Range modelling methods. Existing measurement techniques and simulations approaches are presented. Each of them can be used stand alone or combined in a subsequent hybrid modelling step to evaluate the current system status. Methods are applied to a measured dataset of a corrugated X-band horn antenna to proof the concept.

11:20 ***Low Computational Cost Modelling of Anechoic Chambers and Probe Effect in Antenna Measurement***

Maria Alberica Saporetti and Francesco Saccardi (Microwave Vision Italy, Italy); Francesca Mioc (Consultant, Switzerland); Lars Foged (Microwave Vision Italy, Italy); Emidio Di Giampaolo (University of L'Aquila, Italy)

Full wave and ray tracing solvers are used to evaluate the behavior of anechoic chamber to allow a trade-off between computational costs and performances. Full wave results are extremely accurate in case of well-defined absorbers modelling which is not straightforward due to not available detailed information from absorbers suppliers. High computational times added to time needed to set up the model are not acceptable in case of several iterations. Ray tracer modelling is less demanding and take only seconds. Although not as accurate as full wave, a combination can be envisaged where ray tracer gives a fast insight on different models, leaving the full wave to check few selected ones. In this paper a ray-tracing and an image theory-based tool for fast modelling of anechoic chambers including the probe effect will be presented and compared.

T10-E02: EM Theory and Analytical Techniques

T10 EM modelling and simulation tools / / Electromagnetics

Room: virtual 10

Chairs: Matthys M. Botha (Stellenbosch University, South Africa), Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

10:00 ***Polarizability of Dielectric Prolate Half Ellipse***

Sidra Batool, Mehwish Nisar, Fabio Mangini and Fabrizio Frezza (Sapienza University of Rome, Italy)

his article presents a method for solving the polarizability of a dielectric prolate half ellipse as a function of its relative electric permittivity. The considered geometry consists of two conjoined half ellipses with different permittivities. The polarizability depends on the excitation field direction, therefore can be presented in the form of dyadic consisting of two components that are series and parallel polarizabilities. The method is based on analytical series expansions with coefficients obtained as a numerical solution of a matrix equation.

10:20 ***Ferrite Isolator Based on Dual Non-Reciprocal Mode Converting in Rectangular Waveguide***

Mahmoud Gadelrab Ahmed (The German University in Cairo, Egypt); Mohamed Ali (Concordia University, Egypt); Shoukry Shams (University of Concordia, Canada); Mahmoud Elsaadany (Ecole de Technologie Superieure (ETS), Canada); Abdelmegid Allam (German University in Cairo, Egypt)

Among the most significant devices are isolators, which are considered as essential protection elements in high power applications. It prevents the RF signal from reflecting to the source, and provide the required protection. It depends mainly on the non-reciprocity to allow the power flow in one direction only. In this work, we have designed an isolator based on the non-reciprocal mode conversion in the mm-wave band. This isolator is realized using rectangular waveguide loaded with horizontal ferrite slab in one path. As a result the wave maintain dominant mode operation in one direction, while the mode is converted to the higher order one on the other direction. Afterwards, the second order mode is collected and terminated to a load to protect the source and realize isolation. The proposed design is modeled and simulated to show the objective performance in the operating bandwidth 27-32 GHz.

10:40 ***Generation of Waveform-Controlled Optical Pulses of Arbitrary Width in a Linear, Causal Dielectric: An Approach Based on Asymptotic Analysis***

Constantinos Balictsis (Hellenic Telecommunications and Post Commission - EETT, Greece); Theodoros T. Zygiridis (University of Western Macedonia, Greece)

The unified asymptotic approach is employed herein and yields an analytic description of the input pulse wave, which is required in order to generate a desired waveform-controlled Gaussian pulse envelope chirped harmonic optical wave of arbitrary width at a fixed, arbitrary propagation distance in a linear, dispersive and absorptive dielectric. The dependence of this analytic approach on the input field, medium parameters, and propagation distance is elaborated and its accuracy is verified upon comparison with depicted results of numerical experiments.

11:00 ***Electromagnetic Plane Wave Scattering by Multilayered Biaxial Cylinders via a Volume Integral Equation Method***

Konstantinos Katsinos and Grigorios Zouros (National Technical University of Athens, Greece)

The electromagnetic scattering by multilayered biaxial circular cylinders is considered in this work. The incident plane wave impinges normally on the cylinder, with respect to cylinder's axis. The method of solution is based on a volume integral equation technique, solved by expanding the electric field and the electric displacement in cylindrical vector wave functions of Dini-type which constitute an orthogonal vectorial basis in the transversal circular cross section of the cylinder. Our formalism allows for an easy and direct incorporation of multilayered biaxial permittivity profiles, thru the constitutive relation between the electric field and the matrix-vector product of the inverse permittivity tensor and the electric displacement. To validate our method, we employ the HFSS commercial software and compare the normalized scattering cross section for homogeneous and inhomogeneous biaxial profiles. In addition, we also employ the exact solution for the special case of uniaxial anisotropy.

11:20 ***Space-Time Metasurfaces: Analysis, Design and Applications***

Sajjad Taravati and George V. Eleftheriades (University of Toronto, Canada)

We review the recent progress on wave transformation by space-time metasurfaces. Firstly, analysis of wave incidence to various space and time interfaces, and periodic space-time metasurfaces is provided. Then, design, full-wave simulation and experimental demonstration of space-time metasurfaces are presented. Some of the exotic applications of metasurfaces are also introduced.

T11-M01: Material Measurements

T11 Fundamental research and emerging technologies / / Measurements

Room: virtual 11

10:00 ***Refraction Compensation in Non-Destructive Testing***

André Froehly and Reinhold Herschel (Fraunhofer FHR, Germany)

SAR radar imaging methods are presented, which are able to treat highly refractive fibre composite materials. The methods are based on a previous surface extraction and a subsequent refraction compensation relying on the calculation of a corresponding correction factor. Due to an efficient implementation we achieve a computational effort comparable to the standard back-projection algorithm. We demonstrate the method with examples from simulation and fibre composite materials.

10:20 ***Damage Detection in Metallic Plates Using Guided Electromagnetic Waves***

Vittorio Memmolo (University of Naples Federico II, Italy); Jochen Moll (Goethe University Frankfurt am Main, Germany); Duy Hai Nguyen (Goethe University Frankfurt, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany)

Guided electromagnetic wave (GEMW) propagation using ultra-wideband signals is a novel approach for damage detection. Wave transmission and reflection can be used to warn the presence of such a defect within the waveguides. The present work proposes a feasibility analysis for a structural health monitoring system employing permanently integrated GEMW sensors. This setup allows to interrogate the structure continuously using multiple transmitters and multiple receivers when the electromagnetic waveguide is established. To this end, a metallic plate is equipped with a dielectric waveguide patch attached to the structures' surface. To validate the detectability of damage, a reversible defect is modeled through removable bolts accessible from the other surface of the plate. The experiments are carried out considering different bottom holes at different spatial locations of the plate. The characteristic changes of GEMW signals are adopted in a damage index approach employed to show that defect can be detected sensitively.

10:40 ***Millimeter Wave Material Measurements for Building Entry Loss Models Above 100 GHz***

Jochen Jebramcik and Jonas Wagner (Ruhr-Universität Bochum, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany); Ilona Rolfes and Jan Barowski (Ruhr-Universität Bochum, Germany)

In this paper typical building material transmission measurement results up to 300 GHz are presented. This research is done, in order to further advance building entry loss models and estimations for frequency ranges beyond the current ITU recommendations, which are limited to 100 GHz. For this purpose, a quasi-optical measurement setup is provided to investigate on reflection and transmission properties of e.g. bricks, concrete, drywall, and wooden materials. A special focus is laid on window glass panels, since it is expected that free apertures contribute the most to the total transmission into and out of buildings in this range. The setup is based on a vector network analyzer with millimeterwave extensions and is fully calibrated. The transmission attenuation is measured and an attenuation coefficient is extracted from the measurement.

11:00 ***Accuracy of Fill Level Measurement by an M-Sequence UWB Guided Wave Radar***

Tim Erich Wegner (Technische Universität Ilmenau, Germany); Giovanni Del Galdo (Technische Universität Ilmenau); Stefan Gebhardt (RECHNER Industrie-Elektronik GmbH, Germany)

Due to increasingly complex and automated manufacturing processes of producing companies, the demands on the control parameters of these processes are also increasing. An important parameter is the fill quantity, whose precise determination is becoming of growing importance. It is of additional interest to be able to automatically determine what filling material is currently being used to ensure that the correct material is in the container. This paper shows with which accuracy an M-sequence UWB guided wave radar can determine levels in metallic and non-metallic containers and which possibilities exist to determine the filling material. First, the principle of level measurement using guided wave radar is explained and the measurement setup is described. Afterward, the measurement results are shown and discussed. The measurements show that the level can be measured with an accuracy of less than 0.5mm. In addition, level fluctuations can be detected with an accuracy of 3µm.

11:20 ***Evaluation of the Feasibility of Three Custom-Made Tetrapolar Probes for Electrical Characterization of Cardiac Tissue***

Hamza Benchakroun (National University of Ireland Galway, Ireland); Declan O'Loughlin (Trinity College Dublin, Ireland); Niko Ištuk (National University of Ireland, Galway & Translational Medical Device Lab, Ireland); Martin O'Halloran (National University of Ireland, Galway, Ireland); Alessandra La Gioia (National University of Ireland Galway, Ireland)

Non-thermal cardiac ablation can be used to treat atrial fibrillation and consists in applying a pattern of electrical pulses to the targeted tissue. Knowing the conductivity of the tissue gives an extent of the pulse parameters needed for the ablation. However, there is a lack of conductivity data for cardiac tissues in the range of frequencies of non-thermal ablation. To this extent, this paper presents a feasibility study for the use of three tetrapolar probes, a planar probe, a needle probe and a pin probe, for cardiac tissue electrical characterization. Probe performance was evaluated across the range of 0.1-100 kHz. The planar probe was the most accurate in reference liquid measurements. Thus, it was used to characterize ovine ex vivo cardiac tissue, which measured conductivity is lower than that from the literature. These results suggest the need for a probe design optimization to improve the contact with the tissue.

T11-A03: Reflector feeds

T11 Fundamental research and emerging technologies / / Antennas

Room: virtual 12

Chairs: Daniele Cavallo (Delft University of Technology, The Netherlands), Christophe Granet (Lyrebird Antenna Research Pty Ltd, Australia)

10:00 ***Hexagonal CORPS-BFN to Feed OLAF SAR Instrument***

Carlos Biurrun-Quel (Universidad Publica de Navarra & Institute of Smart Cities, Spain); JuanCarlos Iriarte (Public University of Navarra & Antenna Group, Spain); Iñigo Ederra (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain); Carlos del-Río (Universidad Publica de Navarra & Institute of Smart Cities, Spain)

The concept of Coherently Radiating Periodic Structures-based Beam Forming Networks is applied to feed OLAF (OverLapped SubArray Fed) antenna for SAR Instrument at L-Band. The proper feeding of this system requires the multiple beams to be highly overlapped, and that is generated by a CORPS-BFN using a new 4-port Gysel power combiner/divider implemented in a suspended stripline technology. The network provides high isolation between inputs/outputs, low insertion loss, great return loss and the desired ovelapping of the different beams.

10:20 ***Miniaturized Conical Waveguide Filtenna for 5G Millimeter Wave Base Stations***

Elmine Meyer, Thomas A. H. Bressner, A. B. (Bart) Smolders and Ulf Johannsen (Eindhoven University of Technology, The Netherlands)

This paper presents the design, manufacturing, and measurement of a novel miniaturized 3D printed conical waveguide filtenna concept for use in the 5G New Radio n257 band. Field tests, for the band 26.5 to 27.5 GHz, motivates the desire to add a filtering functionality to the wideband horn antenna. Miniaturization is achieved by adding a lens to the antenna and exploiting the symmetrical resonance properties of a cylindrical resonator for dual-mode operation. Therefore, the manufactured concept filtenna consists of a miniaturized lens-fitted conical horn antenna with an integrated 4 th order 3D printed dual-mode cylindrical waveguide filter. Tuning screws in the filter enable mechanical control over the filtenna centre frequency and bandwidth. The manufactured filtenna achieves a 10 dB return loss bandwidth of 2 % about a centre frequency of 27 GHz, and a gain of 14.8 dBi.

10:40 ***A 3.5 - 12.3 GHz Bullet-Horn Feed Concept***

Christophe Granet (Lyrebird Antenna Research Pty Ltd, Australia); John Kot (Young & Kot Engineering Research, Australia)

The "bullet-horn" concept is applied to an application that requires a feed covering a 3.5 GHz to 12.3 GHz bandwidth.

11:00 ***Comparative Study on the Design of Dichroic Mirrors for the Upgrade to the K-Band Uplink Channel for the ESA Deep Space Antennas***

Matteo Marchetti (University of Pavia, Italy); Fabio Pelorossi (ESOC, ESA, Germany); Filippo Concaro (European Space Agency, Germany); Luca Perregrini and Marco Pasian (University of Pavia, Italy)

Future manned missions to the Moon would require an uplink channel significantly broader in frequency than the ones presently used in S and X band. For this reason, the European Space Agency is considering to upgrade its 35-m deep space antennas to include an uplink channel also in K-Band (22.55-23.15 GHz). This paper addresses a solution where dichroic mirrors are used to accomplish this task. In particular, two solutions based on different manufacturing technologies are thoroughly compared taking into account different perspectives. Mirror designs and simulated results, for both the BWG optics and the dichroic mirrors, are presented.

11:20 ***Focused Connected Array as a Wideband Beam-Steering Feed for Quasi-Optical Systems***

Alejandro Pascual Laguna (Delft University of Technology & SRON, The Netherlands); Daniele Cavallo (Delft University of Technology, The Netherlands); Jochem Baselmans (SRON, The Netherlands); Nuria LLombart (Delft University of Technology, The Netherlands)

In this paper we propose an efficient integrated focal plane array solution based on a near-field focused connected array of slots on a membrane. The focused aperture provides a (1) broadband and highly efficient illumination of the quasi-optical system and (2) scanning capabilities inside a focusing system. The connected array antenna in turn allows for a fully planar solution that can synthesize a focused aperture while providing broadband matching performance and low levels of cross-polarization. We present a low frequency printed circuit board (PCB) prototype to demonstrate the concept operating in the band 3-6 GHz. The feasibility of scaling this concept up to terahertz frequencies, based on a superconducting chip implementation, is also discussed.

Wednesday, March 24 10:00 - 12:30

SW04: EurAAP Women In Antennas and Propagation

Francesca Vipiana

Room: virtual 14

Wednesday, March 24 11:40 - 12:10

IW08: Working together with Fast Antenna Measurements and Numerical Simulation in Antenna Placement Scenarios (MVG)

Room: virtual 13

Lucia Scialacqua, MVG

Wednesday, March 24 11:40 - 13:40

P2: Wednesday Interactive Posters

Room: Posters

Chair: Christoph Herold (Technische Universität Braunschweig, Germany)

5G Wideband Stacked Patch Antennas

Marco Simone, Alessandro Fanti and Giuseppe Mazzarella (University of Cagliari, Italy)

Wide bandwidth requirement is one of the main challenging issues in 5G antenna technology. To satisfy this, the design of a stacked low-profile patch antenna is proposed. The design has been optimized via an optimization tool based on Particle Swarm Optimization integrated with the finite integration technique (FIT). A bandwidth larger than 5 GHz has been obtained in the desired range.

A Compact Dual Frequency SICL Based Cavity Backed Slot Antenna with High Front to Back Ratio for Millimetre Wave Application

Naman Baghel and Soumava Mukherjee (Indian Institute of Technology Jodhpur, India)

This paper presents a compact dual frequency Substrate Integrated Coaxial Line (SICL) based Cavity Backed Slot Antenna (CBSA). A primary slot along with secondary slot is etched on the bottom plate of SICL cavity to generate two non-adjacent resonant frequencies. The primary slot is placed such that it is excited by TE$^z_110(even) mode of the SICL cavity. The secondary slot is placed near the primary slot and excited by the SICL feed line. At second resonance, SICL cavity acts as the reflector for the back radiation and significantly improves front to back ratio (FTBR). The antenna resonates at 24 GHz and 38 GHz with gain of 5.1 dBi and 4.8 dBi, exhibiting high FTBR of 14 dB and 28 dB with co to cross polarization ratio of -22 dB and -32 dB respectively. This antenna finds its application in millimetre wave band 5G spectrum coverage for customer premises equipments (CPE).

Millimeter-Wave Multimode Circular Array for Spatially Encoded Beamforming in a Wide Coverage Area

Stylianos D. Assimonis (Queen's University Belfast, United Kingdom (Great Britain)); Muhammad Ali Babar Abbasi (Queen's University Belfast & The Institute of Electronics, Communications and Information Technology (ECIT), United Kingdom (Great Britain)); Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain))

This paper summarizes an investigation around millimeter-wave (mmWave) multimode circular antenna array based beamformer capable of specially encoded data transmission in a wide coverage area. The circular antenna array is capable of an entire 360 degree azimuth sector coverage where broadcast, uni-cast and multi-cast radio transmissions are possible. Orbital angular momentum (OAM) mode transmission along the elevation axis, i.e., perpendicular to the azimuth plane, can also be achieved. These two types of spatially encoded beamforming makes coverage in almost an entire hemisphere possible. The circular array is developed using twelve multilayer patch antennas with unique radiation performance aiding in both azimuth and elevation radiation. The proposed array architecture and its radiation performance makes it a good candidate for spatially encoded beamforming for mmWave 5G.

Low-Profile CTS Array in PCB Technology for K/Ka-Band Applications

Michele Del Mastro (University of Rennes 1, France); Adham Mahmoud (Institut d'Électronique et de Télécommunications de Rennes, France); Thomas Potelon (IETR - University of Rennes 1, France); Ronan Sauleau (University of Rennes 1, France); Gilles Quagliaro (Thales Communications, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

In this paper, an ultra-low-profile wideband continuous transverse stub (CTS) array is presented. The antenna module is fully realized in multilayer printed circuit board (PCB) technology, comprising 9 dielectric substrates. Particularly, the radiating part consists of long slots etched on the top of the eighth dielectric substrate. The slots are parallel-fed by a corporate feed network made of vertical parallel-plate waveguides (PPW), using via-fences. A pillbox system, embedded into two substrates, is employed to feed the slots with a line source. The antenna module is low cost and presents a very low form factor. A prototype was fabricated and measured in the K/Ka-band. The antenna array provides pencil-beam radiation for angles of scanning as far as 24° along the azimuth plane parallel to the slots. The input reflection coefficient is below -10 dB in the frequency range 19-31 GHz (48%). The maximum realized gain is 21 dB at 29 GHz.

A Low Profile Highly Isolated Phased Array MIMO Antenna System for 5G Applications at 28 GHz

Enis Kobal and Muhammad Usman (University College Dublin, Ireland); Teerachot Siriburanon (University Dublin, Ireland); Robert Bogdan Staszewski and Anding Zhu (University College Dublin, Ireland)

This paper presents a highly isolated phased array antenna system for 5G applications at 28 GHz. The antenna array is formed by 1x8 microstrip antipodal exponential tapered slot antennas each connected to CMOS phase shifters with wire bonds for electrical beam steering. At 28 GHz, the mutual coupling between the antenna elements are lower than -30 dB while the envelope correlation between the ports is less than 0.1. The single antenna array element was fabricated on 20 mil thick Rogers 4003 substrate and the phase shifter was fabricated in 22 nm FD-SOI CMOS. The simulated and measured results of the single antenna element along with the integrated phase shifter are presented together with the simulation results of the overall system.

V2X Large Vehicle Shadowing at 3.5 GHz Compared to 5.9 GHz

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This paper presents a measurement-based comparison of large vehicle shadowing at 3.5 and 5.9 GHz. Obstructed line-of-sight measurements were performed for both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) scenarios in a controlled environment. The results show how the V2I scenarios with elevated transmit antenna positions can benefit from a 2-6 dB smaller shadow loss as compared to the V2V scenarios. Due to the smaller diffraction loss experienced at 3.5 GHz, the maximum shadow levels can be up to 2-3 dB smaller than at 5.9 GHz. The absolute numbers and empirical distributions provided can be used in system level evaluations of vehicle-to-everything (V2X) and vehicle-to-network (V2N) vehicular communication scenarios.

Foliage Modeling for Urban Ray-Tracing Simulations Using Satellite Images

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A foliage modeling approach for urban environments based on the use of satellite images is introduced. Foliage blocks are added into a 3D urban model, which originally consists of only building data. The vegetation blocks, which are considered in the simulation, are mainly large clusters located in the vicinity of the base station, and are surrounding it. Relevant comparisons are made with measurement data and the advantages of the proposed method are demonstrated.

Initial Investigation of D-Band Small-Scale Fading Statistics

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This paper investigates small-scale fading statistics of D-band channels, based on recent measurements performed in a shopping mall. The measurements include both line-of-sight and obstructed-line-of-sight inks. From a limited number of measured data sets of plane waves we synthesize many small-scale fading fading realizations by applying uniformly distributed phases to each plane wave. The results show that small-scale fading of the line-of-sight and obstructed line-of-sight channels in the studied environment is statistically described by Weibull and Nakagami-m distributions, respectively.

Analytical Studies of Refractive Index Variation in Pine Needles Media Under Wildfire Conditions

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In this paper, a range of refractive indexes found in simulations of fire scenarios, considering the Cold Plasma Model, is explored. The Fire Dynamics Simulator (FDS) was used to model a Pinus Pinaster fuel bed burning in a linear burner. The effects of maximum and minimum refractive index values were analysed using the Finite-Difference Time-Domain (FDTD) method, aiming to understand how electric characteristics of a plasma may affect the electromagnetic wave propagation. Results clearly indicate the need to further investigate the propagation phenomena under wildfire conditions.

Hybrid Switchable Phased Array with p-i-n Diodes for 5G Mobile Terminals

Carla Di Paola (Aalborg University, Denmark); Kun Zhao (Sony Research Center Lund, Sweden & Aalborg University, Denmark); Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)

This article proposes a hybrid beam-switchable phased array for 5G mobile handsets. Four reconfigurable antennas are selected as array elements, consisting of two monopoles, placed on both sides of the clearance, fed by SIW. Each element has three p-i-n diodes controlled working modes, which generate three switchable radiation patterns, two broadside and one endfire. While the beam-switching is realized in the phi-plane, the beam-scanning is achieved in the theta-plane through progressive phase shifts. The array has -10 dB impedance bandwidth from 27 to 30 GHz, which is a portion of the 5G spectrum. Simulations including the proposed hybrid antenna system, placed on the top left corner of a mobile phone PCB, prove that the three switchable beams cover the angle range of +/-75° in elevation, while the scan angle of +/-30° in azimuth is covered by beam-scanning, obtaining 3D coverage with realized gain higher than 7 dBi at 28 GHz.

A Novel Linearly Polarized Metal-Only Beam Reconfigurable Magneto-Electric Dipole Antenna

Min Wang, Huifeng Yang, Yuxin Mo, Jijie Deng, Dongsheng Mo, Kunyang Shan and Zhongyuan Liu (Chongqing University of Posts and Telecommunications, China)

A novel beam reconfigurable magneto-electric dipole antenna is presented. The electric dipole is designed with two H-shaped patches and the E-shaped strip is designed as feeding structure to achieve wide impedance bandwidth. The upper ground etched with two symmetric slots is used to connect the magnetic dipole to reduce the profile. And the lower ground act as reflector to suppress the back radiation. Four binary switches are loaded on the stubs of the electric dipole. By controlling the state of each switch to ON or OFF, the antenna has the ability of beam reconfiguration. Finally, a set of prototype antenna with three configurations is simulated to verify the feasibility of design method. The -10 dB impedance bandwidth is 63 %. At 2.7 GHz, the beam directions of three states point to -22°, 16° and 33°, respectively in E-plane. The maximum gain at three states is 9.4 dBi.

Beam Steering MIMO Antenna for Mobile Handsets

Ahmad Abdelgwad and Mohammod Ali (University of South Carolina, USA)

A new two-element pattern-reconfigurable printed dipole MIMO antenna for handheld devices is presented. Beam steering is achieved with the help of RF switches that are placed at the center of parasitic dipole elements that are employed to direct the patterns. The antenna operates in the 2.4 GHz WLAN frequency band with the pattern steering occurring in the 0° and 180° in the azimuth plane.

Design of A 4 × 4-Element High-Integrated Planar Pattern Reconfigurable Array Antenna

Min Wang, Yuxin Mo, Zhenghan Chen, Kunyang Shan, Zhongyuan Liu, Jianlin Feng, Qiang Liu and Jingyu Li (Chongqing University of Posts and Telecommunications, China)

A 4 × 4 Ku-band high-integrated planar pattern reconfigurable array antenna is proposed. It consists of active radiating elements, and 16-way stripline feeding network. A probe-fed O-slot patch, with a compact stripline feeding line is proposed as element. Two PIN diodes are symmetrically integrated on the O-slot. By activating these diodes, each element can generate 1-bit phase resolution (0°/180°). Thus, the array can generate different patterns with linear polarization, including a single beam, two side beams, four beams, and fan beam, etc. Finally, a 1-bit 16-element pattern reconfigurable array antenna with a compact stripline feeding network are simulated. The -10 dB simulated impedance bandwidth of the single beam is 10.4%, the peak gain at 12.5 GHz is 15.3 dBi while the aperture efficiency is 67.4%. These results demonstrate that the proposed design the ability to achieve pattern reconfigurable to be a promising candidate for wireless communication systems.

Multiple Time-Variant Targets Detection Using MIMO Radar Framework for Cerebrovascular Monitoring

Mohammad Ojaroudi (University of Limoges/CNRS, France); Stéphane Bila (XLIM UMR 7252 Université de Limoges/CNRS, France)

This paper presents a multi-input multi-output (MIMO) radar framework to detect the activated brain regions as a multiple target scenario for cerebrovascular monitoring applications. For this purpose, a setup of microwave brain monitoring system is designed to extract cerebrovascular information from the simulated full head phantom. The proposed setup includes multilayer brain phantom with varying blood vessel and bowtie antenna with precisely realized matching medium, which provides a fractional bandwidth from 0.5 to 5 GHz. In order to extract dynamic information from the blood vessel dilation, first, a single vessel with dilation properties, second two vessels located in different ranges and third two targets with different dilation rates are considered. The spectrogram and CFAR methods are used to show the vessel dilation and extract doppler information. Simulated results from all scenarios are presented to demonstrate the fruitfulness of the proposed method for precisely detecting the time-dependent characteristics of cerebrovascular targets.

A Novel Design of Ultrathin Metasurface Structure for Terahertz Time-Domain Spectroscopy (THz-TDS) Applications

Mohammad Ojaroudi (University of Limoges/CNRS, France); Valeria Loscrí (Inria Lille-Nord Europe, France)

In this paper, an ultrathin metasurface structure is proposed for terahertz time-domain spectroscopy (THz-TDS) applications. The proposed structure consists of an inverted T-shaped strip surrounded by a rectangular-shaped split ring resonator (SRR) structure on a high-resistance silicon substrate. By inserting an inverted T-shaped strip inside the SRR, the coupling between the strip and SRR is improved and the sensitivity (refractive index unit (RIU)) of the proposed unit cell is increased. The proposed unit cell can provide an acceptable transmission characteristic around 0.6 THz. In addition, by using biological analyte, in this study brain Glioma, we are able to detect this material's concentrations by calculating the sensitivity in the range of 65 GHz/RIU. The proposed metasurface

structure has small size and high sensitivity characteristics. Simulation results of the transmission coefficients and radiation characteristics show the effectiveness of the proposed design for biomedical applications.

Development and Validation of a Finite Periodic Transmission Line Model for Body Channel Communication

Matteo Lodi (University of Cagliari, Italy); Claudia Cuccu (Politecnico di Torino, Italy); Alessandro Fanti and Giuseppe Mazzarella (University of Cagliari, Italy)

Body channel communication (BCC) is a data transmission technique which uses the human body as communication channel. The availability of mathematical and physical models which can cope with the channel description is an open issue in the literature. In this work, a finite periodic transmission line model to describe the human body as transmission medium is proposed. Bio-impedentiometric measurements from 1 kHz and 1 MHz are carried out to estimate model parameters. The developed model has been validated with measurements carried out with a ground-referred and low-complexity system called Live Wire. A ±3% error for communication distances ranging from 20 to 150 cm was found. This contribution proposes a distributed model which can be used as framework for the design and for enhancing the performances of body channel communication systems.

Fault Diagnosis by Excitation Engineering in a Phased Array with Cosine Squared Element Patterns

Kp Prajosh (Indian Institute of Technology Madras, India); Uday Khankhoje (IIT Madras, India); Francesco Ferranti (IMT Atlantique, France)

Detecting element failure in a phased array antenna plays a crucial role in ensuring a communication system's efficiency since faulty elements lead to a significant deviation in the array pattern. Under the assumption that only a few antenna elements are faulty, fault diagnosis can be accomplished by applying compressive sensing techniques to solve the resulting system of equations. We present a fault diagnosis method of a linear antenna array, where the measurements are taken at a fixed location, and excitations are optimized. We solve the compressive sensing problem that leads to a reduction in the number of measurements required for successful diagnosis using the optimized excitations. We show how the excitations can be optimized for fault detection in the presence of cosine squared field pattern of an antenna element in a linear array.

Antenna Array Design Based on Kaiser-Hamming Polynomials

Goran Molnar (Ericsson Nikola Tesla d. d. & Research and Development Centre, Croatia); Dorian Ljubenko and Andrea Jelavić-Šako (Ericsson Nikola Tesla d. d., Croatia)

Antenna arrays with constrained dynamic range ratio of excitation coefficients have received much attention in recent years. This is because the coefficients with a low ratio allow diminishing of the mutual coupling between the array elements, reduction of the output power loss, and simplification of the feeding network design. In the design of such arrays, the dynamic range ratio can be specified, limited, or minimized. In this paper, we propose a class of symmetrical linear arrays with specified dynamic range ratio. The excitation coefficients are obtained by discretization of a partially flat function which is expressed by the Kaiser-Hamming polynomial. Since this polynomial offers adjustable orders of flatness of the excitation function, we present a straightforward method for finding the orders yielding the pencil beam with a minimum sidelobe level. In comparison with other analytically based methods providing low dynamic range ratios, the proposed technique brings the lowest sidelobe level.

A New Unit-Cell Architecture Applied to Active Wide-Angle Scanning Phased Array

Ahmad Emadeddin and Lars Jonsson (KTH Royal Institute of Technology, Sweden)

we propose a unit-cell element suitable designed for wide-angle scanning active phased array antennas. The design method utilizes the sub-array factor theory inside the unit-cell. The generalization shows that the unit-cell architecture can be applied to different elements to improve their embedded radiation pattern. The presented unit-cell is comprised of three similar radiating elements. It consists of one excited element and two unloaded/open passive parasitic ones. The 1 dB beamwidth of the embedded radiation pattern of the designed unit-cell with a miniaturized vivaldi element is around 130 in the E-plane. It results in a gain reduction of -1.2 dB over 60 scan angles for a linear array. The total array factor of the proposed architecture is similar to the dense arrays with half-wavelength interelement distances and smaller (high density array), with the same physical size.The active impedance variation per scan angles has improved in comparison with half wavelength arrays unit-cell.

Compact UWB Antipodal Vivaldi Array for Beam Steering Applications

Callum J Hodgkinson (University of Edinburgh & Heriot Watt University, United Kingdom (Great Britain)); Dimitris E. Anagnostou (Heriot Watt University, United Kingdom (Great Britain)); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

A novel 6 x 1 antipodal Vivaldi antenna array (AVAA) is presented that can beam steer in the E-plane. The array is matched from 1.66-16.6GHz and can steer, at end-fire, in the range up to 11GHz due to the element spacing being only 13.6mm. This compact ultra-wideband (UWB) design measures only 118.6x81mm, has a gain of 13.5dBi and has low side-lobe levels across its operational bandwidth (BW). Applications of the AVAA include novel beam steering systems, UWB radar, and other communication systems where wideband operation, low side-lobe levels, and antenna beam steering is of interest.

Gridded Square-Ring Frequency Selective Surface for Angular-Stable Response on Chipless Indoor Location Tag Landmarks

Jesús Sánchez-Pastor and Alejandro Jiménez-Sáez (Technische Universität Darmstadt, Germany); Martin Schüßler (TU Darmstadt, Germany); Rolf Jakoby (Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany)

This paper studies the use of gridded square-ring FSSs to encode the backscattered response of trihedral corner reflectors, acting as passive landmarks in a mm-wave indoor self localization system. Previous tags presented low resonance stability under oblique incidence of the incoming wave, which limits the system performance under real operating conditions. The designed FSS uses a miniaturized unit cell to minimize phase differences between its elements, which are responsible for the fluctuating resonance response. The smaller these phase differences, the less varies the response. The new design presents a more stable response than a previous work at W-band (65 - 110 GHz), at the cost of lower frequency selectivity and range. But, the operating angular region of the tag is ±35°, which allows to encode 45 notches, which means 5.5 bits, under transverse magnetic planar wave excitation for identification of tags in indoor self-localizing applications.

An Accurate De-Embedding and Characterization Methodology for Dual-Band HF/UHF RFID Chips and Antennas

Hossein Sarbandi Farahani, Behrooz Rezaee and Michael Gadringer (Graz University of Technology, Austria); Lukas Zöscher (NXP Semiconductors, Austria); Franz Amtmann (NXP Semiconductors Austria GmbH, Gratkorn, Austria); Wolfgang Bosch (Graz University of Technology & Institute of Microwave and Photonic Engineering, Austria)

In this paper, we describe two characterization methodologies for dual-band HF/UHF RFIC chips and antennas with single and differential-ended port configurations. Test fixtures and de-embedding techniques are used to achieve an accurate and robust impedance characterization of an RFID chip and a corresponding antenna. The multiline TRL (thru-reflect-line) de-embedding technique is employed to eliminate the unwanted behavior of the test fixtures from the measured response. In addition, a new mode transition from differential ground-less coupled line to single-ended line is introduced to characterizing the input impedance of the UHF antenna. The simulation and measurement results are in good agreement and demonstrate the accuracy of the proposed method.

Cost-Effective Measurement Methods to Investigate RF Leakages in UHF RFID e-Kanban Racks

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Andrich (Technische Universität Ilmenau, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

In this paper, we present cost-effective techniques to assess shielding performance of RFID Kanban racks equipped with UHF RFID readers. This includes a self-developed positioner, made from roof battens and stepper motors, which positions a tag in a vertical area around each side of the rack to sense the radio frequency (RF) distribution emitted from the reader. For the measurements on the shelves, we sticked 30 tags on a foam board in a 20 cm grid to detect leakages on the horizontal planes. The overall material cost is less than 50 Euro and we made the documentation and control software publicly available.

Performance Improvement of a Water-Based Transparent and Flexible Unidirectional Antenna

Abu Sadat Md. Sayem (Macquarie University, Australia); Roy B. V. B. Simorangkir (Tyndall National Institute, Ireland); Karu Esselle (University of Technology Sydney, Australia); Raheel M Hashmi (Macquarie University & IEEE, Australia)

In this paper, a study has been devoted to design a water-based flexible, robust and transparent antenna having unidirectional radiation pattern. Simulation analysis is presented to exhibit the determining factors affecting antenna performance and further a method is demonstrated to improve the performance. The proposed antenna is designed by utilizing pure water, polymer and transparent-flexible e-textile sheet. The design concept of the antenna is based on the utilization of a reflector surface on one side of a dipole radiator to transform the omnidirectional radiation of the dipole to unidirectional pattern. The reflector is constructed from pure water enclosed inside a rectangular hollow cavity made from polydimethylsiloxane (PDMS) and the dipole radiator is made from transparent-flexible e-textile sheet. The impacts of the reflector's properties on antenna performance are investigated in this research to identify the optimum design parameters for performance improvement.

Design of an Offset Multi-Faceted Reflectarray Antenna

Borja Imaz-Lueje (Universidad de Oviedo, Spain); Daniel R. Prado (Universidad de Oviedo & Signal Theory and Communications, Spain); Manuel Arrebola and Marcos R. Pino (Universidad de Oviedo, Spain)

This paper describes the analysis and design of an offset multi-faceted reflectarray structure composed of three identical panels distributed following a parabolic cylinder. Working in Ka-band, the antenna is designed to generate a pencil beam in the broadside direction of the structure. Its performance is compared with a flat reflectarray of similar aperture size. The multi-faceted reflectarray design achieves a significant improvement in band performance compared to its classic single panel version.

A Single-Layer Reflectarray Using Hexagonal Phoenix Cells for Ka-Band Applications

Aurélie Bornot, Baptiste Palacin, Maxime Romier, Lise Feat and Daniel Belot (CNES, France)

The paper presents a straightforward design method for a single-layer reflectarray with high aperture efficiency, based on a finite database of hexagonal phoenix cells. Two offset fed microstrip reflectarray antennas for Ka-band satellite applications are designed, manufactured and measured in order to validate the method. The first reflectarray is designed to operate between 25.5GHz and 27GHz, the second one to operate between 35.5GHz and 36GHz. Both antennas have a square-shaped aperture of 300x300mm and are designed in linear polarization. The measurements results are in good agreement with those predicted by the simulations. They show that the maximum gain at the central frequency of 26.25GHz for the first antenna is about 37.65dBi with a total efficiency of 70% in linear polarization. The maximum gain in linear polarization at the central frequency of 35.75GHz for the second antenna is about 39.5dBi with a total efficiency of 58%.

Parabolic Reflectarray Antenna to Generate Multiple Beams in Dual-Frequency and Dual-Circular Polarization

Daniel Martinez-de-Rioja (Universidad Politécnica de Madrid, Spain); Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain); Yolanda Rodriguez-Vaqueiro (University of Vigo, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain); Antonio Pino and Marcos Arias (University of Vigo, Spain); Manuel Arrebola (Universidad de Oviedo, Spain); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

This contribution presents the design and simulations of a 1.8-m parabolic reflectarray to generate a multi-spot coverage from a geostationary satellite. The antenna has been designed to generate two spaced beams per feed in orthogonal circular polarizations (CP) simultaneously at transmission and reception frequencies in Ka-band. The parabolic reflectarray operates by the variable rotation technique independently applied at 19.7 GHz and 29.5 GHz to split the orthogonal CP beams focused by the parabolic surface. The proposed design technique and the simulated results have been experimentally validated by the manufacturing and testing of a 0.9-m parabolic reflectarray with the same operating principle. The proposed antenna technology can be used to provide multi-spot coverages in Ka-band from geostationary satellites, with the advantage of reducing to one-half the number of antennas and feed-chains commonly required using conventional reflectors.

Multifocal Approach for Reflectarray Antenna for DTH Applications

Paola Pirinoli (Politecnico di Torino, Italy); Thomas Lohrey (Eutelsat S.A., France); Mario Orefice, Michele Beccaria and Gianluca Dassano (Politecnico di Torino, Italy)

In this paper, numerical and experimental results on the design of a multifocal, planar Reflectarray with scanning capabilities in both elevation and azimuth, are presented. The antenna is a possible alternative to the conventional parabolic reflectors in Direct-To-Home (DTH) receiving systems, with the planar reflector fixed to a building wall and the pointing obtained mechanically moving the feed to steer the main beam of the reflectarray.

Design of Inverted Microstrip Gap-Waveguide Filters in the Ka-Band

Nelson Mario Castro (Pontifcia Universidad Catolica de Valparaiso, Chile); Francisco Pizarro (Pontificia Universidad Catolica de Valparaiso, Chile); Luis Fernando Herran (University of Oviedo, Spain); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

In this article the design of three band-pass filters for Ka-band in inverted microstrip gap waveguide technology is proposed. The three topologies under study correspond to an end coupled band-pass filter, a parallel coupled lines band-pass filter and a split ring resonator band-pass filter. The designed structures exhibit good results in terms of insertion losses (lower than 1.5 dB) and fractional bandwidth. In addition a sensitivity study of the filter position with respect the metasurface (the bed of nails) is presented. These designs can be useful for circuit developers as an alternative cost-effective solution for implementations in this frequency band.

Perfect Power Splitting in Waveguide Junctions Using a Metagrating-Inspired Methodology

Liran Biniashvili (Technion, Israel Institute of Technology, Israel); Ariel Epstein (Technion - Israel Institute of Technology, Israel)

We propose a semi-analytical, metagrating-inspired technique to eliminate reflection loss in a symmetrical three-channel H-plane waveguide junction, achieving seamless power splitting. As in metagratings, sparse periodic arrays of subwavelength scatterers (meta-atoms), the solution is devised by judicious engineering of the meta-atom distribution, relying on modal analysis and systematic formulation of constraints. Herein, we use a mode-matching-based technique to calculate the structure's power scattering coefficients and find an appropriate location at which a passive polarizable element may be placed to suppress spurious reflections. Subsequently, a proper geometry for this scatterer is found using a simple parametric sweep in a full-wave solver. The presented methodology is demonstrated and verified via full-wave simulations, using a metallic post to realize the meta-atom. This reliable scheme, yielding a simple solution based on a semi-analytical model, serves as an appealing alternative to current design procedures, which commonly require intricate formations or a specific split angle.

An Efficient Anisotropic Metasurface for Polarization Conversion Applications

Syed Muhammad Qasim Ali Shah (National University of Sciences and Technology, Pakistan); Fahad Ahmed (National University Of Science and Technology & School of Electrical Engineering and Computer Sciences, Pakistan); Nosherwan Shoaib (Research Institute for Microwave and Millimeter-Wave Studies (RIMMS) & National University of Sciences and Technology (NUST), Pakistan); Abdul Quddious (KIOS Research and Innovation Center of Excellence, University of Cyprus, Cyprus); Symeon Nikolaou (Frederick Research Center, Cyprus); Qammer H Abbasi (University of Glasgow, United Kingdom (Great Britain))

This paper presents an anisotropic metasurface that can work as linear and circular polarizer simultaneously. The proposed design has the ability to achieve linear-to-linear polarization (LTL) within two frequency bands ranging from 7.2-10.51 GHz and 15.81-17.48 GHz. The linear-to-circular (LTC) polarization is also accomplished within the frequency ranges between 6.78-6.89 GHz, 12.54-13.76 GHz and 18.39-18.82 GHz. The proposed design provides stable response against incidence angles up to 30°. The investigated metasurface with the multi-band and multi-polarization capabilities, the compact size and the angular stability can be suitable for several applications related to satellite communications.

New Coplanar Waveguide Based on the Gap Waveguide Technology

Carlos Biurrun-Quel (Universidad Publica de Navarra & Institute of Smart Cities, Spain); Jorge Teniente-Vallinas (Public University of Navarra & Institute of Smart Cities, Spain); Carlos del-Río (Universidad Publica de Navarra & Institute of Smart Cities, Spain)

A new planar waveguide, coined "Inverted Coplanar Gap Waveguide" is presented. The concept of Gap Waveguides and parallel plate suppression between Perfect Magnetic and a Perfect Electric Conductors is applied to Coplanar Waveguides in order to create a low-dispersion, low-loss transmission line. The combination of an Artificial Magnetic Conductor and channelized top cover allow the propagation of an even coplanar mode with a strong component propagating over the air while solving encapsulation matters without the use of metallic vias. The main theory behind this new concept is presented and supported by FEM simulations on a commercial software package.

Dual-Functional Tunable Terahertz Polarization Converter Based on Graphene-VO2 Metasurfaces

Behnaz Bakhtiari and Homayoon Oraizi (Iran University of Science and Technology, Iran); Sajjad Taravati (University of Toronto, Canada)

We propose a dual-functional broadband tunable terahertz polarization converter metasurfaces. The designed structure is composed of hybrid electromagnetic materials and provides tunable polarization conversion in the reflection and transmission states. Not only does the polarization converter provide a wide range of polarization conversion from 5.34 to 7.80 THz with a high polarization conversion ratio (more than 0.97), but also is tunable and controllable.

Angle of Arrival and Angle of Departure Estimation Using Compressed Sensing for Terahertz Communications

Tobias Doeker (Technische Universität Braunschweig, Germany); Pranay Reddy Samala (IIT Bombay, India); Pranshu S Negi (Indian Institute of Technology Bombay, India); Ajit Rajwade (IIT Bombay, India); Thomas Kürner (Technische Universität Braunschweig, Germany)

In this paper, an approach to optimize a device discovery process using highly directive antennas for Terahertz communications is introduced. An algorithm using compressed sensing and some first results based on simulation data are presented. The simulation environment and scenarios as well as the compressed sensing theory are explained and the concept is evaluated considering different propagation scenarios as well as different frequencies and angular resolutions. Finally, the results show that the number of directions of the considered device discovery process can be reduced by up to 61 % on average.

UHF Propagation Measurements Through the Antarctic Firn at Concordia Station

Alberto Toccafondi, Federico Puggelli and Matteo Albani (University of Siena, Italy); Francesco Montomoli (IFAC-CNR, Italy); Marco Brogioni (IFAC & CNR, Italy); Giovanni Macelloni (IFAC-CNR Firenze, Italy)

In this paper we present and discuss the first series of results obtained during a propagation measurement campaign carried out at the French-Italian Concordia research station during last (2019/2020) summer campaign in Antarctica. Specific instrumentation has been designed and assembled, essentially consisting of a transmitting unit and a receiving one, to be let down into two boreholes in the firn. Preliminary measurement results are presented and discussed.

Range-Doppler Imaging Approach for the Wireless Reading of Mechanical Sensors

Dominique Henry and Patrick Pons (LAAS-CNRS); Hervé Aubert (LAAS-CNRS, Toulouse University)

We investigate in this paper the wireless interrogation of chipless and passive mechanical sensors using a range-Doppler imaging algorithm. As an example, a Crookes radiometer illuminated by a light of controlled illuminance is interrogated by using a 24GHz FM-CW radar. A remote detection algorithm is proposed to estimate the reading range and Doppler harmonics embedded in the electromagnetic signal backscattered by the radiometer. From these harmonics the accurate estimation of illuminance is achieved for long reading ranges of at least 3.5m in a cluttered environment.

On the BEP Analysis of M-QAM in a Frequency Non-Selective Beaulieu-Xie Fading Channels

Hugerles Silva (Instituto de Telecomunicações, IT, Brazil); Danilo Almeida (UFCG, Brazil); Wamberto Queiroz (Universidade Federal de Campina Grande, Brazil); Iguatemi E. Fonseca (Federal University of Paraíba, Brazil); Arnaldo Oliveira (Universidade de Aveiro - DETI / Instituto de Telecomunicações - Aveiro, Portugal); Francisco Madeiro (University of Pernambuco, Brazil)

In this paper, new and exact expressions are presented for the bit error probability (BEP) of M-ary quadrature amplitude modulation (M-QAM), considering a frequency non-selective Beaulieu-Xie fading channels, with and without spatial diversity. Special cases for the BX distribution, such as generalized Rice, non-central Chi and κ-μ distribution, are also analyzed in this work. The new BEP expressions are obtained by a method in which the division of the received signal by fading is performed, making the communication channel under fading corresponding to a channel subject to an additive noise. A new expression for the generalized moment generating function (MGF) for the signal-to-noise ratio (SNR) of the BX fading model is determined in this work. Several BEP curves as a function of SNR, corroborated by Monte Carlo simulations, are presented under different parameters that characterize the channel, considering perfect or imperfect channel state information (CSI).

Comparison of Diffuse Roughness Scattering from Material Reflections at 500-750GHz

Demos Serghiou (University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Susan Johny (NPL, United Kingdom (Great Britain)); Manoj Stanley (National Physical Laboratory, Teddington, United Kingdom (Great Britain)); Irshaad Fatadin (National Physical Laboratory, United Kingdom (Great Britain)); Tim Brown (University of Surrey, United Kingdom (Great Britain)); Nick Ridler (National Physical Laboratory, United Kingdom (Great Britain)); Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

In this paper, an ultra-wideband Terahertz (THz) channel measurement campaign in the 500-750 GHz frequency band is presented. Power levels received from signal transmission by reflections off 14 different materials were measured in an indoor environment at Non-Line-of-Sight (NLoS) between the Transmitter (Tx) and Receiver (Rx), and compared to power levels received at Line-of-Sight (LoS) transmission. Frequency up-converters were used to transmit the signal using 26 dBi horn antennas at the Tx and Rx side and the signal was measured using a Vector Network Analyzer (VNA). From the data collected, the signal losses due to absorption and diffuse scattering from the rough surface of each Material Under Test (MUT) are calculated. The power delay profile (PDP) is

presented, where multipath clustering due to diffuse scattering is observed for materials which have a high frequency selectivity, while less scattering and mostly specular reflection is shown for materials with low frequency selectivity.

Multi-Path Component Parameter Estimation Using Millimeter-Wave Beamforming Channel Sounder

Minseok Kim, Shuaiqin Tang and Keiichiro Kumakura (Niigata University, Japan)

This paper proposed a multi-path component (MPC) parameter estimation method which is developed for a novel double-directional channel sounding system in the WiGig millimeter-wave bands, where beamforming RF transceivers realizes a fast double-directional channel acquisition by analog beamformers incorporating16-patch antenna element uniform linear array. The proposed method extracts MPCs from the multi-dimensional power spectra obtained by beam-steering in high-resolution using Sub-Grid CLEAN algorithm. This paper described the channel sounding system configuration and the signal processing, then showed some measurement results conducted for a validation.

X-Band Planar Monopulse Microstrip Antenna Array with Improved Null-Depth

Anil Chepala (Defence Research and Development Organization, India); RamaKoteswara Ghali (Research Centre Imarat, India); Rajender Daggula (Scientist, India)

Here we design a low profile mono-pulse antenna array on micro-strip substrate with improved null depth in X-band. The design includes mono-pulse comparator using 90 hybrids to generate one sum and two difference excitations. The fabricated array has a circular aperture of 300 mm diameter with rectangular patch elements. Antenna gain of 20 dB with beam width of 8 and an excellent null depth of 26.6 dB is achieved. The simulations and the measured results on the hardware are presented in this paper. This is used for airborne applications where high angular accuracy for target tracking using mono-pulse operation is required.

Statistical Models of Antenna Efficiency Measured Using Non-Reference Antenna Methods with Hybrid Stirring

Wei Xue (Xi'an Jiaotong University, China); Xiaoming Chen (Xi'an Jiaotong University, China); Yi Huang (University of Liverpool, United Kingdom (Great Britain))

Owning to the particular properties of the reverberation chamber (RC), it has been widely applied to antenna efficiency measurements. The non-reference antenna methods can determine antenna efficiency without the need of a reference antenna. Therefore, they are more convenient to use than the conventional RC-based method. Very recently, statistical models of the one- and three-antenna methods were derived. However, frequency stirring (i.e., an important stirring mechanism) was not considered in the statistical models. In this work, the improved statistical models with combined mechanical and frequency stirring techniques are proposed. RC measurements are performed to verify the improved models, corresponding results are in accordance with expectation. The improved statistical models allow further analyses of the measured antenna efficiencies using the one- and three-antenna methods when frequency stirring is adopted.

Antenna Radar Cross Section Measurement Within Mode-Stirred Reverberation Chamber

Ariston Reis (Université Paris-Est Marne-la-Vallée, France); Francois Sarrazin (University of Paris-Est-Marne-la-Vallée & ESYCOM, France); Philippe Besnier (IETR, France); Pouliguen Philippe (DGA, France); Elodie Richalot (Université Paris-Est (Marne-la-Vallée), France)

This communication deals with radar cross section (RCS) measurement of a horn antenna within a reverberation chamber (RC). RCs recently became a viable alternative to anechoic chamber to perform RCS measurement. Indeed, one can benefit from the RC statistical properties to retrieve the line of sight wave among the multiple reflections that occur within the cavity. It is the first time that this RC setup is used to measure the RCS of an antenna. More specifically, it is shown that it is possible to distinguish the antenna RCS measured for two different load conditions (short and match). As a consequence, it enables retrieving the antenna gain from RCS measurement performed in RC.

A Single-Aperture 0°-120°-240° Triple-Polarized Planar Compact Circular Monopole Array with a Single-Stage Decoupling and Matching Network

Debapratim Dhara (National Chiao Tung University & Indian Institute of Technology Kanpur, Taiwan); Payel Mondal and A. r. Harish (Indian Institute of Technology Kanpur, India); Yen-Cheng Kuan (National Chiao Tung University, Taiwan)

This paper proposes a compact circular monopole array (CCMA) that can emit 0°-120°-240° linearly polarized beams at the boresight direction with a single aperture. This CCMA consists of three printed monopole antennas azimuthally separated by 120° and backed by a reflector located at a quarter-wavelength distance apart. At 2.42 GHz, the mutual coupling induced by the non-orthogonal beams is canceled by 25 dB through a shunt connected single-stage decoupling and matching network (DMN). Moreover, this CCMA achieves a stable broadside gain of 5.4 dBi for all three polarizations and a combined 10-dB-return-loss and 15- dB-isolation bandwidth of 200 MHz while retaining 78% efficiency and an envelope correlation coefficient (ECC) less than 0.06.

Load Optimization in Reverberation Chambers

Robert Rehammar (Bluetest AB & Chalmers University of Technology, Sweden)

Optimal loading conditions of a reverberation chamber were investigated. The relevant figure of merit is discussed and defined. Multiple loading configurations were tested and results are reported. A simple model of how loading affects measurement uncertainty was developed and used to find a loading configuration that vastly improve results with regards to the defined figure of merit compared to other configurations.

Posters_M: Best Paper Awards - Poster Session - Measurements

Room: Posters2

Millimeter Wave Material Measurements for Building Entry Loss Models Above 100 GHz

Jochen Jebramcik and Jonas Wagner (Ruhr-Universität Bochum, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany); Ilona Rolfes and Jan Barowski (Ruhr-Universität Bochum, Germany)

In this paper typical building material transmission measurement results up to 300 GHz are presented. This research is done, in order to further advance building entry loss models and estimations for frequency ranges beyond the current ITU recommendations, which are limited to 100 GHz. For this purpose, a quasi-optical measurement setup is provided to investigate on reflection and transmission properties of e.g. bricks, concrete, drywall, and wooden materials. A special focus is laid on window glass panels, since it is expected that free apertures contribute the most to the total transmission into and out of buildings in this range. The setup is based on a vector network analyzer with millimeterwave extensions and is fully calibrated. The transmission attenuation is measured and an attenuation coefficient is extracted from the measurement.

Preliminary Assesment of Millimeter Wave Plane Wave Generator for 5G Device Testing

Francesco Scattone (Microwave Vision Group (MVG), Italy); Darko Sekuljica (MVG, Italy); Andrea Giacomini, Francesco Saccardi and Alessandro Scannavini (Microwave Vision Italy, Italy); Evgueni Kaverine (MVG

Industries, France); Shoaib Anwar (Microwave Vision Group, Satimo Industries, France); Nicolas Gross (MVG Industries, France); Per Iversen (Orbit/FR, USA); Lars Foged (Microwave Vision Italy, Italy)

In this paper, early performance assessments on a newly developed plane wave generator (PWG) at millimeter wave frequencies are reported for the first time. The PWG is integrated in an automated system suitable for 5G testing. Far-field radiation from devices such as pattern, beam pointing, and typical over-the-air (OTA) parameters can be measured in 3D space. Devices are positioned in the quiet zone (QZ) using a RF transparent positioner. Live person testing is feasible, using a chair placed in the system such that the device including head and upper torso of the test person is within the QZ. The PWG based system is described in this paper, including a preliminary evaluation of measurement performance and accuracy at system level. The assessment is based on system simulation, measurement post-processing, and actual test on a pilot system. The PWG technology discussed in this paper is currently being integrated as a standard product.

Higher-Order Spectral Analysis of Radio Pulsar Bursts Using MeerKAT

Alexander Faustmann and Jacki Gilmore (Stellenbosch University, South Africa); Vereese van Tonder and Maciej Serylak (SARAO, South Africa)

The discovery of new radio pulsars is a key science goal for many next generation radio telescopes. The achievement of this objective relies both on the use of improved instrumental sensitivity and also on novel signal processing techniques. The MeerKAT is an example of a next generation radio telescope, emissions from a pulsar are recorded using one of its receivers and are tested for activity in the bispectrum. The test confirms bispectral activity and serves as a proof of concept for future pulsar detection algorithms based on non-Gaussian statistics.

Quiet Zone Quality of a Plane Wave Generator Inside an Over-Moded Waveguide Chamber Emulating a Variable Angle of Incidence

Pavlo Krasov and Oleg Iupikov (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Andrés Alayón Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden); Robert Rehammar (Bluetest AB & Chalmers University of Technology, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden)

We investigate the use of a hybrid over-the-air (OTA) measurement chamber to emulate far-field testing conditions. The focus has been on the generation of a plane wave arriving at an arbitrary angle-of-arrival (AoA) to the device-under-test (DUT) without mechanical steering. The chamber consists of an oversized waveguide (WG) and a planar array antenna with adaptive beamforming. A modified linear constrained minimum variance (LCMV) beamforming algorithm is used to form a quiet zone (QZ) in the DUT region by using the reflections from the WG's metal walls. The LCMV beamformer formulation has been extended to achieve a volumetric QZ with the desired amplitude and phase uniformity. Numerical studies for the QZ size corresponding to an FR1 base station demonstrate promising results with the low levels of amplitude and phase variation. The AoA coverage of this chamber meets 3GPP specification requirements for OTA conformance testing of base stations with active antenna systems.

Towards a Crowdsourcing-Based EMF Exposure Monitoring: Evaluation of Smartphone Measurements Using Kriging

Sascha Schießl, Thomas Kopacz and Dirk Heberling (RWTH Aachen University, Germany)

Conventional methods for exposure assessment cannot provide comprehensive and continuous monitoring. A crowdsourcing-based approach relying on the signal strength measurements of common smartphones could be a potential solution. This paper deals with the evaluation of measurement data collected with smartphones under conditions similar to crowdsourcing. Kriging is used to interpolate and smooth the noisy measurement data. The smartphone measurement data is analyzed for three LTE cells and compared with code-selective measurements of a field strength meter. It is shown that areas with high and low exposure can be distinguished and that local hot spots can also be detected. Furthermore, it becomes clear that at least a rough estimate of the electric field strength can be derived from the signal strength measurements, provided that enough smartphone readings are available for this area.

Posters_P: Best Paper Awards - Poster Session - Propagation

Room: Posters3

Bayesian Approaches to Multipath-Enhanced Device-Free Localization

Martin Schmidhammer, Benjamin Siebler, Christian Gentner, Stephan Sand and Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany)

Device-free localization (DFL) systems infer presence and location of moving users by measuring user-induced perturbations in the signal power between wireless network nodes. Thereby, users not only induce perturbations to the power of the line-of-sight, but also to the power of reflected signals observed in the received signal as multipath components. Since the propagation paths of multipath components differ inherently from the line-of-sight path, these propagation paths can be considered as additional network links. This extended network determines the multipath-enhanced device-free localization (MDFL) system. Based on empirical models that relate perturbations in the power of multipath components to the user location, the localization problem can be solved by nonlinear Bayesian filtering. In this work, we therefore investigate the point mass filter and the particle filter as possible solutions. Using simulations, we demonstrate the applicability of these filter solutions for MDFL. The overall localization performance is comparable for both filters.

Terahertz Propagation Characteristics for 6G Mobile Communication Systems

Minoru Inomata, Wataru Yamada, Nobuaki Kuno and Motoharu Sasaki (NTT, Japan); Koshiro Kitao, Mitsuki Nakamura, Hironori Ishikawa and Yasuhiro Oda (NTT DOCOMO, INC., Japan)

The 6th generation (6G) mobile communication system is being actively pursued worldwide. To satisfy extreme-high-speed-communication, one solution is to utilize terahertz bands above 100 GHz because a remarkably wider frequency bandwidth can be utilized than in 5G. To determine the service frequency bands on the basis of system performance for 6G, frequency dependency of path loss and channel properties needs to be understood. In this paper, we introduce our concept of a new network topology for 6G and then show the frequency dependency of human blockage, building shadowing, and scattering effects from a rough building surface up to 150 GHz.

On the Parametrization and Statistics of Propagation Graphs

Richard Prüller (TU Wien, Austria); Thomas Blazek (Silicon Austria Labs GmbH, Austria); Stefan Pratschner and Markus Rupp (TU Wien, Austria)

Propagation graphs (PGs) serve as a frequency-selective, spatially consistent channel model suitable for fast channel simulations in a scattering environment. In this contribution, we propose a new parametrization for PGs that adheres to the doubly exponentially decaying cluster structure of the Saleh-Valenzuela (SV) model. We show how to compute the newly proposed internal model parameters based on an approximation of the K-factor and the two decay rates from the SV model. Furthermore, via the singular values of multiple-input multiple-output (MIMO) channels, we compare the degrees of freedom (DoF) between our new and another frequently used parametrization. Specifically, we compare the DoF loss when the distance between antennas within the transmitter and receiver arrays or the average distance between scatterers decreases. It is shown that, in contrast to the typical parametrization, our newly proposed parametrization loses DoF in both scenarios, as one would expect from a spatially consistent channel model.

Measured Blockage Effect of a Finger and Similar Small Objects at 300 GHz

Pekka Kyösti (Keysight Technologies & University of Oulu, Finland); Nuutti Tervo (University of Oulu, Finland); Markus Berg (University of Oulu & Excellant LTd., Finland); Marko E Leinonen, Klaus Nevala and Aarno

Pärssinen (University of Oulu, Finland)

We study the effect of a finger, and other objects with similar shape, on the channel gain in short distance propagation measurements at 220-330 GHz. Channel impulse responses and channel gains of six objects are analyzed on different positions obstructing a 35 cm LOS link. The intention is to evaluate potential user effects on portable devices supporting the future 6G system. Very short wavelength and link distance cause strong fluctuation of channel gain even on millimetre scale movement of obstacles. The finger phantom causes 44 dB attenuation on close vicinity, 5 mm, of transmitter antenna and has similar attenuation pattern with corresponding metallic stripes. On the contrary, it is observed that some objects, such as the measured Teflon rod, may even increase the signal strength. These impacts are important when studying the wave propagation and network aspects of high frequencies systems.

Weather-Forecast Based RMOP Link-Budget Approach Experimentation: Data-Transfer Optimization at Ka-Band with Hayabusa-2 Satellite Mission Support

Marianna Biscarini (Sapienza University of Rome, Italy); Saverio Di Fabio (CETEMPS, Italy); Klaide De Sanctis (HIMET, Italy); Maria Montagna (VisionSpace Technology GmbH @ ESA Germany); Luca Milani (LSE Space GmbH @ ESA Germany); Yuichi Tsuda (Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan); Frank S. Marzano (Sapienza University of Rome, Italy)

This work describes the operative experimentation of a weather-forecast-based satellite link-budget approach at Ka-band (RMOP) during 6 months of collaboration with JAXA and ESA within Hayabusa-2 deep-space mission. Operative link-budget design was performed 24 hours before each scheduled transmission window providing JAXA and ESA with optimized symbol-rates to adopt during the transmission and the corresponding expected signal-to-noise ratio values allowing a real-time monitoring of the predicted atmospheric channel status. The comparison between simulations and measurements proves the accuracy of the RMOP tool with correlation values higher than 0.9, bias lower than 0.8dB and error standard deviation lower than 0.7dB. The optimization analysis confirms the strong potential of the RMOP approach providing gain values higher than 5 dB in terms of signal-to-noise ratio and higher than 100% in terms of transmitted data-volume. These results pave the way to an operative scheduling of a weather-forecast based link-budget approach for future satellite missions.

Wednesday, March 24 12:10 - 13:40

IW05: Virtual road testing: advanced electromagnetic simulation of radar systems for autonomous vehicle (Ansys)

Room: virtual 13

Bahram Sanadgol, Ansys

Wednesday, March 24 13:40 - 14:25

Inv3a: Invited Speaker Session:

Channel Measurements and Models for 6G: Views and Progress
Jianhua Zhang

Room: virtual 1

13:40 ***Channel Measurements and Models for 6G: Views and Progress***

Jianhua Zhang (Beijing University of Posts and Telecommunications, China)

With the commercialization of fifth generation (5G) worldwide, sixth generation (6G) research has been launched to meet demands for higher system capacity, higher data rate, lower latency, ubiquitous 3D coverage, heterogeneous connections and so on for future services. Channel properties determine the ultimate performance limit of wireless communication systems. Thus, conducting channel research is a prerequisite to designing wireless communication systems, which plays an essential role in fairly and equally evaluating the candidate radio interface technologies. In this paper, several prospective technologies for 6G, such as terahertz (THz) communication, industrial internet of things (IIoT), space-air-ground integrated network (SAGIN), and machine learning are introduced. Then, we present some of our channel measurements and models for 6G. This paper aims to provide enlightening guidance for subsequent research of 6G channel modeling.

Inv4a: Invited Speaker Session:

Metasurface antennas: from fundamentals to practical applications
Enrica Martini

Room: virtual 2

13:40 ***Metasurface Antennas: From Fundamentals to Practical Applications***

Enrica Martini (University of Siena, Italy)

Metasurface (MTS) antennas have emerged in the last decade as a flexible and innovative solution for the design of high-performance planar antennas with pencil beam or shaped radiation pattern. They operate on an interaction between a cylindrical surface wave (SW) excited by an isotropic radiator and an MTS having a spatially modulated equivalent impedance. The periodic modulation of the boundary conditions transforms the SW launched by the feed into a leaky wave, thus, generating a radiating aperture. This results in a lightweight and low-profile structure, characterized by low losses, simple feeding structure, low-cost manufacturing and versatile radiation characteristics. In fact, by acting on the impedance pattern it is possible to obtain a unique control of the phase, amplitude and polarization of the aperture field, thus, molding the radiation pattern with a single point excitation. This talk will provide an overview of this technology, starting from the basic working principles to arrive at practical designs and realization. It will be shown how

the latest developments in analytical and numerical models and design procedures allows today for an extreme control of the pattern shape, field polarization and amplitude tapering. Several realizations of antennas designed for different applications (including very high gain pencil beams with low side lobes and isoflux-shaped pattern) will be presented. The application of this technology for beam scanning and pattern reconfigurability will be also discussed.

Wednesday, March 24 14:25 - 15:10

Inv3b: Invited Speaker Session:

Propagation Models for Inclusive Radio Communication Networks
Claude Oestges

Room: virtual 1

Chair: Ke Guan (Beijing Jiaotong University, China)

14:25 ***Propagation Models for Inclusive Radio Communication Networks***

Claude Oestges (Université Catholique de Louvain, Belgium)

The demand for mobile connectivity is continuously increasing and mobile and wireless communications serve not only very dense populations of mobile phones and nomadic computers, but also the expected multiplicity of devices and sensors located in machines, vehicles, health systems and city infrastructures. The future generations of radio communication networks are expected to implement technologies for supporting wireless connectivity for any rates, type of communicating units, and scenario. Whereas spectral and spatial efficiency are key challenges, in addition to constraints such as energy consumption, latency, mobility, adaptability, heterogeneity, coverage and reliability, the multi-dimensional radio channel remains central in such contexts. Multiple antenna systems (MIMO), interference recognition and management as well as cooperation among separate network nodes are inherently multi-dimensional techniques and should always be designed with a proper knowledge not only of the channel, but also of the interference. In addition, the use of higher frequency ranges (cm- and mm-waves) is investigated to address the spectrum shortage. Finally, new environments have emerged with the application of the wireless Internet of Things (IoT) in several areas. This communication aims to provide an overview of the latest trends in radio propagation, in particular in the context of inclusive radio communication networks. Going from recent radio channel measurements to current modeling techniques, the communication will include an overview of channel modelling results achieved within COST CA15104 Action (IRACON). Recent results in peer-to-peer, multi-link, vehicular and millimeter wave propagation will be described. Future research topics will eventually be briefly outlined.

Inv4b: Invited Speaker Session:

Millimeter Wave Radar Networks
Christian Waldschmidt

Room: virtual 2

14:25 ***Millimeter Wave Radar Networks***

Christian Waldschmidt (University of Ulm, Germany)

Radar sensors in the millimeter wave range have become a standard sensor today for many applications like automotive or industrial sensing due to the high maturity of millimeter wave technology. Such sensors are available as single-chip solutions e.g. at 60, 77 and 122 GHz and are often set up as MIMO (multiple input multiple output) systems with several transmitters and receivers. The bandwidth and number of channels of the MIMO system determine the imaging quality of the sensors, whereby today's sensors achieve an angular separability typically in the range of a few degrees. The next big leap in innovation regarding image quality is the transition to radar networks in which several sensors cooperate. In this talk different approaches for the realization of such networks are presented. Incoherent networks, which are very easy to set up, are primarily more robust than individual sensor systems, have a larger field of view and allow e.g. to capture the full velocity vector of the targets. Coherent networks, on the other hand, with their sparse apertures, which can encompass the entire network, make it possible to significantly improve the angular separability. The key question here is how coherence can be created in the network without having to set up hardware connections between the sensors. The talk shows approaches for the generation of coherence and presents the image quality that can be achieved with them.

Wednesday, March 24 15:10 - 15:30

Coffee Break / Exhibition

Rooms: virtual 1, virtual 2, virtual 3, virtual 4, virtual 5, virtual 6, virtual 7, virtual 8, virtual 9, virtual 10, virtual 11, virtual 12, virtual 13, virtual 14, Posters, Posters2, Posters3

Wednesday, March 24 15:30 - 17:10

T01-A05: Adaptive and Reconfigurable Antennas

T01 LTE and Sub-6GHz 5G / / Antennas
Room: virtual 1

Chairs: Thomas Capelli-Mouvand (University of Bordeaux & STMicroelectronics, France), Anja K. Skrivervik (EPFL, Switzerland)

15:30 ***Polarization and Frequency Agile RFID Reader Antenna via a Reconfigurable Feeding Network***

Enrico Tolin (IMST GmbH, Germany & Politecnico di Torino, Italy); Achim Bahr and Simona Bruni (IMST GmbH, Germany); Francesca Vipiana (Politecnico di Torino, Italy)

This paper presents a patch antenna designed for Ultra High Frequency (UHF) Radio Frequency IDentification (RFID) reader achieving polarization and frequency agility by employing a reconfigurable feeding network inspired by stub theory. The switchable polarization improves the polarization efficiency in comparison with standard circular polarized antennas, while the frequency reconfigurability allows to use the same design to cover the European and US frequency bands. As further optimization, the patch antenna, has reduced size, for improving system integration. The combination of antenna and reconfigurable feeding network has been tested through simulations, showing a good matching over the two RFID frequency bands, while switching among four linear polarizations. The simulated results have shown a good polarization purity, however, the total efficiency is limited by the switching elements. Nevertheless, being a compact and low-cost solution, the proposed frequency and polarization reconfigurable feeding network is a good alternative to standard circular polarized designs.

15:50 ***A Frequency Tunable MIMO Antenna Cluster with Transmitter IC***

Ali Raza Saleem, Rasmus Luomaniemi, Anu Lehtovuori, Kari Stadius, Marko Kosunen, Ville Viikari and Jussi Ryynänen (Aalto University, Finland)

This paper demonstrates the feasibility of an trans-mitter system where a handset MIMO antenna is fed by a 0.5-4.5 GHz integrated transmitter front-end to implement a frequency-tunable antenna cluster. The transmitter implemen-tation performs on-chip amplitude and phase tuning to provide compatible MIMO performance over a wide frequency range in the low bands (700 MHz-960 MHz) and the high bands (1.5 GHz-4.5 GHz). The antenna is built with 8 elements comprising 4 clusters, two for low-band frequencies and two for higher frequencies. The transmitter-IC driving the antenna cluster is implemented in a 28-nm CMOS process with an active chip area of only 0.2 mm2. The proof-of-concept implementation demonstrates enhanced antenna efficiencies from -6.5 dB to -1.5 dB across the frequency bands, and envelope correlation coefficient below 0.4. The measurement results indicate that the antenna cluster technique can be applied with a real integrated transmitter to enhance MIMO operation of mobile antennas.

16:10 ***Assessment of the Electromagnetic Field Exposure Due to 5G Base Stations Using a Monte-Carlo Method: Initial Results***

Jiang Tingyong (National Key Laboratory of High Power Microwave Technology, China); Anja K. Skrivervik (EPFL, Switzerland)

The realistic assessment of the Electromagnetic Field exposure due to wireless telecommunication base stations is critical to protect the population from harm due to excessive exposure, and allow wireless service providers to use the available technology in the most rational way. The classic approach based on the worst-case scenario used up to 4G leads to overs conservative results in the 5G base stations, due to the use of massive MIMO and dynamic pattern beamforming. A statistical approach is required to lead to a more realistic assessment. In this contribution, we propose first results obtained using a Monte Carlo simulation method to assess electromagnetic field exposure levels for different scenarios.

16:30 ***5G Millimeter Wave Active Phased-Array Antenna Active Load Pulling Evaluation on Power Amplifiers***

Thomas Capelli-Mouvand (University of Bordeaux & STMicroelectronics, France); Anthony Ghiotto (University of Bordeaux, France); Philippe Cathelin (STMicroelectronics, France); Nathalie Deltimple (Bordeaux INP & IMS Lab, France)

Phased-array antennas, such as the ones presently developed for 5G millimeter wave (mmW) applications, are concentrating a high density of radiating elements to provide high gain, high directivity, and beam forming capabilities to efficiently address the user equipments (UE). The proximity of a large number of radiating elements creates mutual couplings (MC) responsible for undesirable active load pulling (ALP) that affects the single element power amplifiers (PA) performances. This paper proposes an analysis of the mutual coupling effects that occurs in the context of 5G mmW base station phased array antennas. Active load-pulling and its variation versus the beam steering angle are evaluated. The introduced methodology can be used to determine the exact perturbation the PAs will experience to yield to a phased array antenna / PA co-design.

16:50 ***Frequency/Pattern Reconfigurable Printed Monopole MIMO Antenna for Handheld Devices***

Ahmad Abdelgwad and Mohammod Ali (University of South Carolina, USA)

A two-port four-element varactor diode reconfigurable antenna is presented for MIMO applications. The antenna has the ability to reconfigure either its operating frequency or radiation pattern depending on the capacitance values of the varactor diodes integrated on the constituting monopole arms. Pattern reconfiguration in the azimuth plane at four distinct angles is demonstrated within the frequency range of 3.4-3.9 GHz. System level performance demonstrates excellent MIMO performance such as capacity.

T01-A04: Coupling Suppression

T01 LTE and Sub-6GHz 5G / / Antennas

Room: virtual 2

Chair: Jan Kracek (Czech Technical University in Prague, Czech Republic)

15:30 ***Interaction Suppression Technique for High-Density Antenna Arrays for Mm-Wave 5G MIMO Systems***

Mohammad Alibakhshikenari (Università degli Studi di Roma "Tor Vergata", Roma - ITALY, Italy); Bal Virdee (London Metropolitan University, United Kingdom (Great Britain)); Ayman A. Althuwayb (Jouf University, Saudi Arabia); Francisco Falcone (Universidad Publica de Navarra, Spain); Ernesto Limiti (University of Rome Tor Vergata, Italy)

This paper presents the feasibility study of applying a combination of two suppression-techniques to improve isolation between the radiation elements in high-density antenna arrays and thereby improve the arrays bandwidth and radiation performance. High-isolation between adjacent-radiation elements was achieved by embedding a criss-crossed decoupling-structure comprising slotted microstrip-lines and locating in the ground-plane under each slot a dielectric-ring. The proposed periodic-array behaves as artificial magnetic conductor surfaces as incident waves in the substrate are fully reflected with a near-zero degrees reflection phase. Proof of concept was verified by applying the technique to a 2×4 linear-array of triangular radiation patches. Measurement confirm improvement is the array's bandwidth, fractional bandwidth, average isolation, gain, and efficiency by 2GHz, 6.15%, >10dB, 6.6dBi, and 29%. The array with dimensions of 40×20×0.8mm3 operates across 30-35GHz with average isolation, gain, and efficiency of >23dB, 12dBi, and 85%. The techniques can be applied to mm-Wave 5G MIMO systems.

15:50 ***Experimental Verification of an Approximate Admittance Equation for Center-Fed Dipoles Arranged Parallel Beside Each Other and Estimation of Its Effective Frequency Range***

Kyoichi Iigusa and Hirokazu Sawada (National Institute of Information and Communications Technology, Japan); Takeshi Matsumura (National Institute of Information and Communications Technology (NICT) & Kyoto

University, Japan); Fumihide Kojima (National Institute of Information and Communications Technology, Japan); Hiroshi Harada (National Institute of Information & Communications Technology (NICT), Japan)

A proposed approximate equation between admittance of a set of dipoles and that of the same set of dipoles with one removed is experimentally examined in the case of three or more elements using a multiport network analyzer. Experiment is performed for monopole arrays on a finite ground plate. It is shown that the equation is effective in the fractional band width of approximately 120 percent. The approximation error, validity of an introduced parameter α, and the size condition with which the approximation is effective are clarified.

16:10 ***A Cascaded Power Dividing Decoupling Network for Antennas with Distinct Frequency Bands***

Min Li (The University of Hong Kong, Hong Kong); Lijun Jiang (University of Hong Kong, Hong Kong); Lawrence K. Yeung (the University of Hong Kong, Hong Kong)

This paper proposes a novel decoupling method for two antennas operating in adjacent/contiguous frequency bands using a cascaded power dividing decoupling network (C-PDDN). An n-order C-PDDN can be designed to increase antenna isolation at n desired frequency points. Each PDDN is composed of two power dividers, two transmission lines, and one reactive component. Explicit design formulas are founded for determining design parameters. For illustration, a two-order C-PDDN is applied to a testing array. Results show that it could increase isolation by over 20 dB, verifying the effectiveness.

16:30 ***Dual Port MIMO Antenna with Low Mutual Coupling Based on Asymmetric EBG Decoupling Structure***

Asmaa Ibrahim Afifi (EJUST, Egypt); Anwer Sayed Abd El-Hameed (41 Kawauchi, Aoba Ward, Sendai, Miyagi, Japan); Ahmed Sayed Ahmed Abdelhamid Allam (Egypt-Japan University of Science and Technology (E-JUST), Egypt); Sabah Ahmed (Egypt-Japan University of Science and Technology, Egypt); Adel B. Abdel-Rahman (EJUST, Egypt)

A MIMO CPW-Fed slot antenna is presented for sub-6 GHz 5G applications. This antenna operates at the lower band which extended from 4.2 to 5.2 GHz. The overall MIMO dimensions are 21.6 × 42.2 mm2. The proposed MIMO consists of two identical antennas; each one is a rectangular slot excited with rectangular tuner. A triangle shape and two shunt stubs are connected to the rectangular slot to reduce the antenna size. A unique asymmetric electromagnetic bandgap (EBG) structure is utilized beside polarization diversity for coupling reduction. The element to element isolation is improved to vary from (-26 dB to -50 dB) in case of 0.1 λ0 edge to edge spacing. The simulated and measured results confirm that the proposed antenna is suitable for sub-6 GHz 5G applications. The envelop correlation coefficient is less than 0.025 over the operating band and the diversity gain is almost 10 dB showing satisfactory performance.

16:50 ***24-28 GHz Waveguide Antenna Array***

Tomas Lonsky (RFspin, Czech Republic); Jan Kracek and Pavel Hazdra (Czech Technical University in Prague, Czech Republic)

A design of a compact three-element waveguideantenna array for the microwave frequency band 24-28 GHz ispresented. The array is intended for 5G telecommunication sys-tems where beamforming is necessary. Careful attention is paidon the design of its feeding lines to be of equal physical lengths.Therefore, beamforming phasing is significantly simplified. Theproposed array is made using CNC machining and measured.

T02-A06: Active integrated antennas

T02 Millimetre wave 5G / / Antennas

Room: virtual 3

Chairs: Rob Maaskant (CHALMERS, Sweden), Alicia E. Torres-García (Public University of Navarra, Spain)

15:30 ***Design of a Planar Antenna on a Photonic-Crystal Silicon Cavity for a Submillimetre Wave Receiver***

Alicia E. Torres-García (Public University of Navarra, Spain); Jose M. Perez (Universidad Publica de Navarra, Spain); Jorge Teniente-Vallinas (Public University of Navarra & Institute of Smart Cities, Spain); Ramon Gonzalo (Public University of Navarra, Spain); Iñigo Ederra (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain)

Traditional terahertz mixers face constraints providing compactness and integrability. The integration of the electronic non-linear devices with dielectric photonic crystal platforms arises as a new promising option to perform efficient heterodyne detector arrays in a fully planar approach. This work presents the trade-off carried out for the design of the planar antenna to be integrated in this mixer. This antenna must serve a double purpose: efficiently couple the LO signal and be matched at RF frequencies. A double bow-tie has been found to be the best alternative and has been integrated in a submillimetre wave receiver.

15:50 ***Power Efficiency and Linearity of Highly Integrated Transmitting Array Antennas***

Wan-Chun Liao (Chalmers University of Technology, Sweden); Thomas Emanuelsson (Gapwaves AB, Sweden); Rob Maaskant (CHALMERS, Sweden); Artem Vilenskiy, Thomas Eriksson and Marianna Ivashina (Chalmers University of Technology, Sweden)

Energy efficiency of 5G communication networks and beyond is a major challenge that is yet solved due to high power consumption and low linearity of massive array transmitters. This paper contributes to the existing framework of research in this area by investigating various possible design trade-offs for highly-integrated active antenna elements as employed in such array transmitters. We demonstrate how to exploit antenna element design to synthesize the optimal loading conditions of a given power amplifier (PA) to e.g. maximize power-added efficiency (PAE), minimize nonlinear behavior, or find the desired trade-off between both. The numerical example with a K-band PA-integrated antenna element illustrates that moderate nonlinear effects of the PA can be significantly reduced by tuning the antenna design, with a relatively small PAE loss. The effects of antenna array mutual coupling and corresponding cross-talk between PAs when beamsteering are discussed for a small-scale linear array of such elements.

16:10 ***Performance Analysis of an Integrated Multi-Channel Power Amplifier Incorporating an IC-To-Waveguide Transition***

Alhassan Aljarosha (Eindhoven University of Technology & Chalmers University of Technology, The Netherlands); Piyush Kaul, A. B. (Bart) Smolders and Marion Matters-Kammerer (Eindhoven University of Technology, The Netherlands); Rob Maaskant (CHALMERS, Sweden)

This paper studies the power combiner efficiency of multiple Power Amplifier output signals that are combined within a low-loss contactless transition, intrinsically having low isolation characteristics. Since the PA performance is sensitive to load impedance variations, poor isolation may affect each PA performance, thereby reducing the overall power combiner efficiency. Load impedance variations can e.g. be due to process, supply-voltage and temperature variations. A four-way spatial power combiner (SPC) design is compared to an on-chip Wilkinson Power Combiner (WPC) implemented in 0.13-um SiGe BiCMOS technology incorporating a 50-Ohm impedance matching network. The WPC occupies 84% more area than the non-isolating SPC. Moreover, the non-isolating SPC has an average efficiency 14% larger than the WPC. Simulated results show sigma-variation of 2.81 mW in Pout and 0.87 % in PAE for the non-isolating SPC, and 2.34 mW in Pout and 0.45 % in PAE for the WPC (at 1 dB compression).

16:30 ***Antenna-Mixer-Amplifier Transceiver Based on Space-Time Surface Waves***

Sajjad Taravati and George V. Eleftheriades (University of Toronto, Canada)

We propose a front-end transceiver, i.e., an antenna-mixer-amplifier, by leveraging unique properties of space-wave to surface wave transformation in a space-time periodic medium. Such functionality is offered by space-time surface waves corresponding to complex space-time wave vectors in a subluminal space-time medium. The proposed structure provides pure frequency up/down-conversions supported by weak undesired higher order time harmonics. In contrast to other recently proposed space-time mixers, a large frequency up-/down conversion ratio and amplification is achievable. In addition, the structure does not require progressive energy transition between the space-time modulation and the incident wave, and thus, possesses a subwavelength thickness.

16:50 ***Parallel Plate Waveguide Doherty Power Combiner at Mm-Wave Frequencies***

Ralph van Schelven, Marco Spirito and Daniele Cavallo (Delft University of Technology, The Netherlands)

In this work, an efficient power combiner for mmwave frequency transmitters is investigated. The combiner is based on a parallel plate waveguide (PPW) excited with multiple parallel feeds and can be realized using standard PCB technology. The Doherty power combiner scheme can also be integrated in the proposed concept, to increase the efficiency of the amplifiers for implementing amplitude modulation. The advantage of the proposed PPW combiner with respect to other concepts, e.g. the ones based on substrate integrated waveguide (SIW), is the wider bandwidth and the scalability to arbitrarily large number of inputs. A demonstrator is fabricated using standard PCB technology and measurement results are presented.

T05-E02: Medical Diagnosis and Treatment Methods

T05 Biomedical and health / / Electromagnetics

Room: virtual 5

Chairs: Raquel A. Martins (Instituto de Telecomunicações/Instituto Superior Técnico, Portugal), Giuseppe Vecchi (Politecnico di Torino, Italy)

15:30 ***Empirical Assessment of Breast Lesion Detection Capability Through an Innovative Microwave Imaging Device***

Lorenzo Sani (UBT - Umbria Bioengineering Technologies); Alessandro Vispa (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Navid Ghavami (UBT - Umbria Bioengineering Technologies); Riccardo Loretoni (Breast Unit, Foligno Hospital, Italy); Michele Duranti (Perugia Hospital, Italy); Daniel Álvarez Sánchez-Bayuela and Stefano Caschera (UBT - Umbria Bioengineering Technologies, Italy); Martina Paoli and Alessandra Bigotti (UBT - Umbria Bioengineering Technologies, Perugia, Italy); Mario Badia and Michele Scorsipa (UBT - Umbria Bioengineering Technologies, Italy); Giovanni Raspa (UBT – Umbria Bioengineering Technologies, Italy); Mohammad Ghavami (London South Bank University, United Kingdom (Great Britain)); Gianluigi Tiberi (London South Bank University, United Kingdom (Great Britain) & UBT - Umbria Bioengineering Technologies, Italy)

This paper investigates the effect of conductivity weighting on microwave images obtained through a dedicated imaging device. MammoWave is a microwave imaging device for detection of breast lesions, operating using only two azimuthally rotating antennas without the use of matching liquids. For each breast, a set of conductivity weighted images are generated through modifying our algorithm based on Huygens principle, producing intensity maps representing the homogeneity of tissues' dielectric properties. Subsequently, we introduce several imaging parameters to quantify the non-homogenous behavior of the image. Through empirical investigation on 103 breasts, we can verify that a selection of these features could allow distinction between breasts with radiological findings (WF), and breasts with no radiological findings (NF). Statistical significance was set at $p<0.05$. We obtained single features Area Under the receiver operating characteristic Curves spanning from 0.65 to 0.68. Significantly, we achieve AUCs of up to 0.77 when considering dense breasts only.

15:50 ***SAR Focusing via APA Optimization in Microwave Hyperthermia Treatments***

Rossella Gaffoglio (Fondazione LINKS, Italy); Marco Righero (LINKS Foundation, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

Optimal focus of the temperature increase is crucial for the effectiveness of a hyperthermia treatment and to minimize the collateral damages to the tissues surrounding the region to be heated. For internal tumors, this is currently achieved by means of global optimizations of the feeding of the antennas providing the power to heat the region of interest. In this paper, we consider the use of an array synthesis method based on the Alternating Projections Algorithm (APA) to constraint the power transfer inside a properly-defined mask. Application of this strategy to optimize the power deposition in the delicate case of a tumor in the head and neck region shows satisfactory results when compared to those obtained when the power deposition is optimized with a particle swarm optimization (PSO).

16:10 ***Non-Invasive Thermometry During Hyperthermia Using Differential Microwave Imaging Approach***

Jan Tesarik and Jan Vrba (Faculty of Biomedical Engineering, Czech Technical University in Prague, Czech Republic); Hana Dobšíček Trefná (Chalmers University of Technology, Sweden)

The evaluation of non-invasive microwave thermometry using differential microwave imaging approach is investigated in an experimental setup. The setup consists of a monopole microwave tomographic system, muscle phantom and circulation/heating system. The saline solution is used as the heated medium inside the muscle phantom. Based on Born Approximation and regularization by TSVD we reconstructed the distribution of both dielectric parameters, relative permittivity and electrical conductivity inside the investigation area. A promising agreement between measured and reconstructed electrical conductivity was achieved and some specifics for future improvement of microwave thermometry were identified.

16:30 ***Comparison of Slot-Based and Vivaldi Antennas for Breast Tumor Detection Using Machine Learning and Microwave Imaging Algorithms***

Raquel A. Martins (Instituto de Telecomunicações/Instituto Superior Técnico, Portugal); Joao M. Felicio (Instituto de Telecomunicações, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal)

We compare the performance accuracy of a slot-based antenna and a Vivaldi antenna for breast tumor detection using machine learning (ML) algorithms jointly with microwave imaging (MWI) processing. MWI is known for having low resolution. Therefore, we here study the conjoint use of ML and MWI, in order to enable accurate detection of breast tumors and evaluate how the probing antenna affects the overall system performance. To this end, we perform measurements in the frequency range of 2-6 GHz on anthropomorphic breasts of different volumes and shapes, where we placed two types of tumors. The slot-based antenna provides better imaging results (i.e. good detection of the tumor), but the accuracy of ML techniques is only 60%. Concerning the Vivaldi antenna, the images present clutter, but the accuracy of ML techniques is as high as 85%. These results show that ML and MWI can be complementary to each other.

16:50 ***Pattern-Reconfigurable Metasurface-Antenna Array for Functional Brain Imaging Applications***

Mohammad Ojaroudi (University of Limoges/CNRS, France); Stéphane Bila (XLIM UMR 7252 Université de Limoges/CNRS, France)

In this paper, a compact bow-tie dipole antenna with the pattern reconfigurability characteristics is presented for cerebrovascular monitoring. In order to create a pattern reconfigurable characteristic a balun-matched bow-tie antenna is equipped with a pentagonal shaped metasurface structure with five triangular meta-atoms. The proposed structure with a multi-layer phantom of the human head inside a designed matching medium are simulated in CST medium. To enhance the frequency range to have return loss less than 10 in 0.5-5 GHz, a matching medium is used. In addition, by using these metasurface structure the realized gain is increased from 1.29 dBi to 2.38 dBi at 3 GHz. The inserted pin-diodes on the triangular corners can provide the desired pattern reconfigurability. Hence the main beam direction can be controlled. Simulated reflection and radiation results demonstrate that the proposed meta-antenna and its pattern reconfigurability property effectively applicable for functional brain imaging applications.

T09-A02: Reflect Arrays

T09 Space (incl. cubesat) / / Antennas

Room: virtual 8

Chairs: Jose A. Encinar (Universidad Politecnica de Madrid, Spain), Ronan Sauleau (University of Rennes 1, France)

15:30 ***High-Gain Transmitarray Antenna for Backhauling at D-Band***

Wassim Saleh (Université de Nantes, France); Yoann Letestu (Radio Frequency Systems (RFS), France); Ronan Sauleau (University of Rennes 1, France); Eduardo Motta Cruz (Université de Nantes IETR, France)

This paper presents the design, simulation and prototyping of a 2-bit dual linearly-polarized transmitarray antenna (TA) for 5G millimeter-wave point-to-point backhauling radio links at D-band (130 - 174.8 GHz). The flat lens consists of a square array with 1600 unit cells arranged on a 40×40 element regular grid. This array is based on a printed circuit board structure with only three metal layers and no via connection in order to minimize the insertion loss, the fabrication complexity and the overall cost of the system. The full-array has been optimized using array theory; these results are compared to full-wave simulations performed with Ansys HFSS. The 1-dB and 3-dB gain bandwidth equal 11.9% and 19.7% respectively, with a peak gain of 34.1 dBi and aperture efficiency of 51% at the center frequency. The unit cell configuration is fully symmetric to operate in dual polarization operation.

15:50 ***Passive Dual-Polarized Shaped-Beam Reflectarrays to Improve Coverage in Millimeter-Wave 5G Networks***

Eduardo Martinez-de-Rioja (Universidad Rey Juan Carlos, Spain); Álvaro F. Vaquero and Manuel Arrebola (Universidad de Oviedo, Spain); Eduardo Carrasco and Jose A. Encinar (Universidad Politecnica de Madrid, Spain); Maha Achour (Meta Wave Corporation, USA)

This contribution presents the design of a passive shaped-beam reflectarray to improve coverage in 5G cellular networks. The reflectarray has been designed to produce a broadened and deflected beam in dual-linear polarization at 27.7 GHz. The unit cell provides more than 360º range of phase variation and a robust performance under large angles of incidence (around 50º). Phase-only synthesis has been applied to obtain the required phase distribution on the reflectarray to fulfill the scenario requirements in terms of beam pointing and HPBW. The designed reflectarray exhibits a stable behavior within the 27.2-28.2 GHz band, showing the potential of this technology for millimeter-wave 5G communications.

16:10 ***Evaluation of a Ka-Band Reflectarray Capability to Generate a Uniform Plane Wave in near Field Region***

Álvaro F. Vaquero, Manuel Arrebola and Marcos R. Pino (Universidad de Oviedo, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain)

In this work, a reflectarray is proposed to be used as a plane wave generator (PWG) at 28 GHz and produces a uniform plane wave within the Fresnel region of the antenna in an ultra-compact structure. In a first approach, a far-field focused reflectarray is analyzed to create the plane wave. However, the size of the plane wave is not large enough for its use in compact antenna test ranges (CATR). The generalized Intersection Approach is used to improve the plane wave performances. Simulations of the plane wave generated by the antenna before and after the optimization process are compared, showing an important enhancement on the uniformity of the wave. The obtained phase distribution is used to design and manufacture a reflectarray. The prototype is measured in a planar range facility obtaining a low ripple, both amplitude and phase, in the uniform plane wave created.

16:30 ***W-Band Confocal Antenna System Based on Liquid Crystal Reflectarray for Beam Scanning Applications***

Patricia Fratilescu (Universidad Politécnica de Madrid, Spain); Sergio García-Ruano (Universidad Politécnica de Madrid, Spain); Gerardo Perez-Palomino (Universidad Politécnica de Madrid, Spain); Eduardo Carrasco (Universidad Politecnica de Madrid, Spain)

A confocal antenna system is designed and simulated to demonstrate beam scanning capabilities at W-band. The steering component is a reconfigurable reflectarray based on liquid crystal (LC) technology. Full-wave analysis is performed to obtain the frequency response of the reflectarray cells while Physical Theory of Diffraction (PTD) and Physical Optics (PO) are used to calculate reflected fields and radiation patterns. The simulated results give a maximum gain of 30 dB and a scanning range of 20º in both planes ϕ = 0º and ϕ=90º.

16:50 ***A Ka-Band Beam-Steering Transmitarray Achieving Dual-Circular Polarization***

Francesco Foglia Manzillo (CEA-LETI, France); Maciej Smierzchalski and Jacques Reverdy (CEA, France); Antonio Clemente (CEA-LETI Minatec, France)

This contribution describes a versatile and technologically simple approach for the design of polarization-agile beam-steering transmitarray antennas. The array interleaves two types of electronically reconfigurable unit cells which receive the same linear polarization but radiate horizontally and vertically polarized waves, respectively. The phase shift introduced by each cell can be varied with a resolution of about 90° (2-bit phase quantization) controlling the bias state of two pairs of p-i-n diodes. Dual-circular polarization can be obtained by enforcing the proper phase shift among orthogonally polarized cells. As a proof of concept, a 24×24 transmitarray for Ka-band satellite communications is designed and tested. The experimental results demonstrate beam-steering up to 60° and polarization switching capability. For broadside steering, an axial ratio lower than 1 dB is measured over the entire operating band (29.5-31 GHz).

CS10b: (AMTA Session) Computational Modelling of Test Ranges Part 2

T10 EM modelling and simulation tools / Convened Session / Measurements

Room: virtual 9

15:30 ***Optimisation of the Serration Outline Shape of a Single Offset-Fed Compact Antenna Test Range Reflector Using A Genetic Evolution of the Superformula***

Marc Dirix (Antenna System Solutions, Spain); Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain))

While the size of the reflector in general determines the usable area of the quiet zone inside which plane wave conditions are found, the edge treatment also plays a significant role in terms of overall quality and electromagnetic field distribution. Using modern fast simulation technology in combination with genetic optimisation, the edge treatment can be optimised specifically for a compact antenna test range as part of the design process. This is crucial as it maximises the efficiency with which the available space is used and therefore minimises the costs of implementation of a new facility. This is particularly important in 5G applications where multiple systems are typically required with any economies becoming multiplicative. Several commonly encountered reflector edge treatments are examined with the quiet-zone performances compared against that of an alternative genetically optimised serration design.

15:50 ***Reflector Analysis for Novel OTA Test Method***

Alberto Loaiza Freire, Timothy Pelham, Geoffrey Hilton and Mark Beach (University of Bristol, United Kingdom (Great Britain))

The use of millimetre waves (mmWaves) have required the design of novel OTA test methods. A low-cost OTA methodology based on elliptical cylindrical reflector takes advantage of the reflective properties of the ellipse to perform conformance test of devices operating at mmWaves. Two types of flat reflectors have been compared to quantify the effect that deformations in their surfaces, in the order of millimetres, produce in the reflected signal at 24 GHz. The signal amplitude reflected from a copper substrate reflector, with a total height variation (THV) in its surface of 2.73 mm, is 3.2 dB lower than the signal amplitude reflected by a rigid certified (reference) aluminium cast tooling plate with a THV of 0.46 mm under the same conditions. In addition, the half power beamwidth (HPBW) of the reference reflector is 1° smaller than the HPBW produced by the substrate plate.

16:10 ***Efficient and Accurate Modeling of EMC Anechoic Chambers Using a Combined Discrete Complex Image and Raytracing Method***

Zhong Chen and Yibo Wang (ETS-Lindgren, USA)

The traditional approach to simulate an EMC chamber is by using Geometric Optics (GO) and raytracing. Full wave methods are impractical because of the large amount of computer resources needed. Extending the asymptotic method such as GO to low frequency and in near field, as is required to model an EMC chamber, has long been questioned. In this paper, we describe an improved algorithm by combining GO with the Discrete Complex Image Method (DCIM). We treat the absorbers as multilayered media so that DCIM can be applied to solve for the first order reflections in a more rigorous manner. For higher order reflections where the GO model is adequate, we adopt a visibility tree approach for the raytracing. This approach allows raytracing in an arbitrarily shaped chamber. Several real world case studies are presented to show the accuracy, speed, and flexibility of this method.

16:30 ***The Cost of Accuracy - Throughput Considerations***

Marion C Baggett (NSI-MI Technologies & Baggett Engineering Services, USA); Vince Rodriguez (NSI-MI Technologies, LLC. & University of Mississippi, USA)

Accuracy in a measurement campaign is dependent on many factors. Some of these factors are in the physical components used, the requirements of the electromagnetics involved and the procedural requirements of the campaign. This paper will focus on how the accuracy of the equipment and test environment can impact total cost, specifically range throughput. The current stage in the life cycle of the AUT (design, production, repair) also impacts total cost. The affordability of the accuracy in terms of more costly equipment, calibration processes and operator and test range time may be the determining factor. Throughput needs may limit the accuracy that can be obtained. The accuracies required for each metric must then be evaluated against the accuracy of the available test range(s), the renovation of an existing range, or construction of a new range to meet the accuracy requirements. Two case studies included in this paper are: 1) a rapid near-field data collection that can provide significant throughput improvement over standard near-field data collections at the cost of some accuracy, and 2) the various techniques for improving side lobe measurement accuracy and their impacts on throughput.

16:50 ***Simple Approaches to Range Performance Estimation***

Vince Rodriguez (NSI-MI Technologies, LLC. & University of Mississippi, USA)

Numerical methods in electromagnetics, coupled with faster computers have led to more complex and complex models. However, it must be remembered that these are models, and as models, they are purely representations of reality. In many cases these complex approaches can take several days to solve and, while really accurate, they fail to model the extremely complex components of an anechoic range. RF absorber it the most important of these components and it can be shown that it is in itself a very complex material that is not easily modeled without approximations. A simple approach that effectively "models" an anechoic room was presented in the past and while its results may not be accurate like some of the other numerical method they provide the designer with a quick result that can help in making design decisions.

T10-P01: Propagation modelling and simulation

T10 EM modelling and simulation tools / / Propagation

Room: virtual 10

Chair: Alain Sibille (Telecom Paris, France)

15:30 ***Split-Step Wavelet with Local Operators for the 3D Long-Range Propagation***

Thomas Bonnafont, Rémi Douvenot and Alexandre Chabory (ENAC, France)

Modeling the long-range propagation in the low troposphere is a topic of major concern for many systems such as radar. In 3D, split-step Fourier methods are limited by both computation time and memory size. Therefore, the N times 2D split-step Fourier method is usually used to model the propagation even if 3D effects are not taken into account. To overcome this, we propose a 3D wavelet-based split-step method that is memory and time efficient. This method is based on the use of the fast wavelet transform, which is of low complexity and allows efficient sparse representations. From numerical experiments, we show that the 3D proposed split-step wavelet method is efficient in terms of precision, time, and memory.

15:50 ***Ray Tracing Channel Modeling for Optical Wireless Networks On-Chip***

Franco Fuschini, Marina Barbiroli and Jacopo Nanni (University of Bologna, Italy); Gaetano Bellanca (University of Ferrara, Italy); Velio Tralli (University of Ferrara - Italy, Italy); Giovanna Calo and Vincenzo Petruzzelli (Politecnico di Bari, Italy)

Optical Wireless Networks on Chip have become an ambitious but attractive solution to increase computing performances in multi-core/multi-chip architectures. To assess the benefit of the wireless optical solution a truthful characterization of the wireless channel at the chip scale has to be carried out. Propagation in Optical Wireless Network on Chip occurs in a layered environment, where the layer thickness is often very small compared to the link distance: a high order of multiple reflections/refraction bounces is therefore necessary, triggering strong multipath effect. In this paper the reliability of an "ad hoc" Ray Tracing tool, developed for the specific on chip environment, is described and tested with measurements. Prediction of the average path gain dependence is quite reliable, whereas fast fading tracking accuracy is hampered by unavoidable imprecision in the digital description of the antennas and/or of the propagation environment.

16:10 ***Numerical Analysis of Two MIMO Channels Carrying Orbital Angular Momentum (OAM)***

Lei Wang (Heriot-Watt University, United Kingdom (Great Britain)); Michael Wulff and Cheng Yang (Hamburg University of Technology, Germany); Christian Schuster (Hamburg University of Technology (TUHH), Germany)

This paper presents a numerical analysis of the communication performance of two aligned channel with uniform circular arrays carrying orbital angular momentum (OAM). The direct communication of different OAM modes between the transmitting and receiving OAM arrays is calculated by using full-wave simulation in the method of moments. Moreover, due to the close location of such two OAM channels, the noise signals are increased because of the cross talks from the adjacent channel. The signals of the transmitted modes are not affected significantly. The effects of the communication distance and the gap distance between two channels are also interpreted in this paper.

16:30 ***A Multiscale Parametrization for Refractivity Estimation in the Troposphere***

Uygar Karabaş (ENAC & ISAE-SUPAERO, France); Youssef Diouane (ISAE-SUPAERO, France); Rémi Douvenot (ENAC, France)

This paper presents the idea of multiscale parametrization for tropospheric refractivity inversion using gradient-based optimization method. Our motivation is to improve the accuracy of inversion without the use of apriori information. We retrieve the details of the refractivity distribution progressively from large to smaller scales using hierarchical multiscale strategies in the admissible parameter space. The proposed formulation for multiscale adjoint tomography is validated and is confronted to a numerical test. This study shows that such strategies can potentially resolve complex ducting conditions which would otherwise fail a plain gradient-based inversion.

16:50 ***MIMO Links Mediated by Reconfigurable Intelligent Surfaces***

Alain Sibille (Telecom Paris, France)

In this work we investigate the possibility to realize a true MIMO communication scheme when the propagation between the transmitting and receiving arrays are mediated by a "Reconfigurable Intelligent Surfaces (RIS)", i.e. a surface containing many antenna-like devices, able to change the phase of the reflected wave. The analysis is based on a simple model already employed in a previous work highlighting the mirror vs. scatterer action of a RIS, depending on its size and on the distance to the transmitter and the receiver.

T11-A02: THz Antennas

T11 Fundamental research and emerging technologies / / Antennas

Room: virtual 11

15:30 ***Measurements of H-Band Quartz-Silicon Leaky-Wave Lens with Off-Chip Air-Bridge Interconnect***

Marta Arias Campo (IMST GmbH, Germany); Katarzyna Holc (Fraunhofer Institute for Applied Solid Physics IAF, Freiburg, Germany); Rainer Weber (Fraunhofer IAF, Germany); Carmine De Martino and Marco Spirito (Delft University of Technology, The Netherlands); Arnulf Leuther (Fraunhofer Institute for Applied Solid State Physics, Germany); Simona Bruni (IMST GmbH, Germany); Nuria LLombart (Delft University of Technology, The Netherlands)

The growing emergence of new applications requiring large bandwidth availability has raised the interest in wideband systems at sub-THz frequencies. In this contribution, a wideband H-band (220-320GHz) integrated lens antenna concept fed by a quartz-cavity leaky-wave antenna is presented. A novel air-bridge chip interconnect technology, based on spray coating and laser lithography, is introduced. This interconnection acts as a wideband, low loss transition between the GaAs front-end and the quartz antenna, avoiding the use of expensive waveguide split-blocks. An antenna prototype including the interconnect has been manufactured and characterized, validating the potential performance for an integrated H-band leaky-wave with aperture efficiency higher than 74% over 34% bandwidth, and radiation efficiency higher than 70% over 37% of bandwidth.

15:50 ***High Efficiency, Wideband, Multi-Mode Leaky-Wave Feed for Scanning Lens Phased Array***

Sjoerd Bosma and Maria Alonso-delPino (Delft University of Technology, The Netherlands); Cecile Jung-Kubiak (NASA-JPL, Caltech, USA); Goutam Chattopadhyay (NASA-JPL/Caltech, USA); Nuria LLombart (Delft University of Technology, The Netherlands)

Recently, we have proposed a hybrid electro-mechanical scanning antenna array architecture suitable for highly directive phased arrays at submillimeter wavelengths with field-of-views (FoV) of +/- 25 degrees. The concept relies on combining electrical phase shifting of a sparse array with a mechanical translation of an array of lenses. The use of a sparse phased array significantly simplifies the RF front-end, while the translation of a fly's eye lens array steers the element patterns to angles off-broadside, reducing the impact of grating lobes over a wide FoV. The mechanical movement of the lens array can be done using a low-weight, low-power piezo-actuators. In this contribution, we present an analysis of the high efficiency wideband multi-mode leaky-wave feed for the array's lens elements that enables large-angle steering and present measurements of an embedded element prototype at 550 GHz that demonstrate the validity of this analysis.

16:10 ***Leaky Lens Photo-Conductive Antennas on Low Temperature GaAs Membranes***

Paolo Sberna and Arturo Fiorellini Bernardis (Delft University of Technology, The Netherlands); Alessandro Garufo (TNO, The Netherlands); Juan Bueno (SRON Netherlands Institute for Space Research, The Netherlands); Nuria LLombart and Andrea Neto (Delft University of Technology, The Netherlands)

Laser pumped photo-conductive lens antennas (PCAs) exploit the ultra-short photoconductivity phenomenon of specific semiconductors in order to generate pulsed radiation in the THz regime. State of the art PCAs suffer from high dispersion and low radiation efficiency over the large generated bandwidth due to the poor coupling between the antenna and the dielectric lens. In this work a leaky lens PCA is proposed in order to overcome these issues. The presented structure, indeed, aims at a 1:15 bandwidth (0.1 THz - 1.5 THz). The design, assembly and manufacture of a LT-GaAs membrane-based leaky lens PCA are shown and discussed together with the measurement of the radiated power.

16:30 ***On the Accurate Characterization of Pulsed Photo Conductive Sources: Theory Vs Measurements***

Arturo Fiorellini Bernardis and Paolo Sberna (Delft University of Technology, The Netherlands); Juan Bueno (SRON Netherlands Institute for Space Research, The Netherlands); Nuria LLombart and Andrea Neto (Delft University of Technology, The Netherlands)

The time evolution of voltages and currents in a pulsed photo conductive antenna (PCA) source is evaluated resorting to a rigorous procedure that starts from semiconductor physics to define the phenomena involved in generation of the photocurrent, and then relies on a Norton equivalent circuit in time domain, providing a direct estimation of the power generated by the PCA. The circuit model is validated via a campaign of measurements of a standard PCA source. The saturation phenomena in the THz radiated power occurring at large optical excitation levels, previously observed by the scientific community and associated to different phenomena, are accurately predicted by the present method, which ascribe their main cause to the feedback from the antenna: indeed, the

electromagnetic field generated by the device tend to reduce the strength of the forcing field used to accelerate the photo-carriers.

16:50 ***An Efficient Plasmonic Photoconductive Antenna for Terahertz Continuous-Wave Applications***

Salman Behboudi Amlashi (University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Tim Brown, Pei Xiao and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

An efficient terahertz (THz) photoconductive antenna (PCA) are proposed in this paper. The antenna is designed for continuous wave (CW) applications in the frequency range of 0.5-3 THz. The overall optical-to-THz efficiency of the proposed PCA is improved by enhancing the optical-to-electrical and radiation efficiencies. For the presented PCA, three types of excitation gap are investigated numerically and are compared. To enhance the excited photocurrent, plasmonic excitation is applied to amplify the electric field distribution in the structure. Owing to plasmonic excitation, the optical-to-electrical efficiency of photomixer is increased by a factor of 100. Moreover, the substrates of the proposed PCA is reshaped to improve the radiation efficiency, directivity and side lobe level (SLL). Finally, the radiation characteristics of the proposed PCA is compared with conventional extended-hemispherical lens antenna. The comparison shows a 4-fold reduction in size achieved by the proposed antenna compared to those with similar radiation features.

T11-E01: Imaging Techniques and Applications

T11 Fundamental research and emerging technologies / / Electromagnetics

Room: virtual 12

Chair: Tommaso Isernia (University of Reggio Calabria, Italy)

15:30 ***Perturbation Decay Constant Effects of Power-Law Errors on Refraction Autofocus***

David A. Garren (Naval Postgraduate School, USA)

Recent investigations have yielded techniques for estimating and compensating for the deleterious atmospheric refraction effects in synthetic aperture radar (SAR) image data. The defocused imagery are due to the bending and delay of the each radar pulse as it is refracted by the intervening atmosphere. One advantage of these recent methods is that they are robust to the bending and delay effects that can be different for each individual radar pulse along the synthetic aperture, since local atmospheric parameters can vary along the trajectory of the radar. Robust analysis of the performance of this refraction-based autofocus can be performed by using radar pulse bending and delay that are modeled as power-law spectra. The present analysis considers the effects of varying the value of the decay constants of the power-law spectra upon the overall focus quality of the imagery.

15:50 ***Rewriting Scattering Equations for Faithful Inversion: The Degree of Non-Linearity of the Strong Permittivity Fluctuation Model***

Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy); Tommaso Isernia (University of Reggio Calabria, Italy)

In this contribution some considerations about the degree of non-linearity of the Strong Permittivity Fluctuation model is given in bidimensional geometries. Moreover, a comparison is performed with respect to the traditional TE scattering model. Quantifying the degree of non-linearity represents a fundamental step in order to understand (and possibly overcome) some of the difficulties of inverse scattering problem as well as the validity of approximation-based solution methods.

16:10 ***Broadband Electromagnetic Sensing for Food Quality Control: A Preliminary Experimental Study***

Rosa Scapaticci (CNR-National Research Council of Italy, Italy); Sonia Zappia (IREA - CNR, Italy); Ilaria Catapano (IREA-CNR, Italy); Giuseppe Ruello (University of Naples, Italy); Gennaro Bellizzi and Nicola Pasquino (University of Naples Federico II, Italy); Marta Cavagnaro, Stefano Pisa, Emanuele Piuzzi and Fabrizio Frezza (Sapienza University of Rome, Italy); Francesca Vipiana, Jorge A. Tobon Vasquez and Marco Ricci (Politecnico di Torino, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy)

Quality control is of great importance in food industry, both for the evaluation of product characteristics and to avoid the occurrence of foreign bodies contamination in packaged items. With respect to the inspections against possible contaminants inside the product, different technologies are currently adopted along production chain lines. However, the number of accidents involving low density objects remains very large. To overcome this limitation, the use of electromagnetic technologies has been recently proposed. In this work, the synergic use of terahertz and microwaves technologies is proposed, so to provide high resolution images and in-depth inspections of different scenarios, including low density materials. A focus study on sugar samples is considered, reporting both its broadband characterization at microwaves and preliminary terahertz imaging to evaluate the integrity of the packaging. Ongoing research is devoted to the development and validation of a microwave device for monitoring food products along the production line.

16:30 ***Hybrid Simulation-Measurement Calibration Technique for Microwave Imaging Systems***

David O. Rodriguez-Duarte, Jorge Alberto Tobon Vasquez and Francesca Vipiana (Politecnico di Torino, Italy)

This paper proposes an innovative technique to calibrate microwave imaging (MWI) systems combining available measured data with simulated synthetic ones. The introduced technique aims to compensate the variations of the antenna array due to unavoidable manufacturing tolerances and placement, in comparison to the nominal electromagnetic (EM) scenario. The scheme is tested virtually and experimentally for the MWI of the adult human head tissues. The virtual EM analysis uses a realistic 3-D CAD model working together with a full-wave software, based on the finite element method. Meanwhile, the real implementation employs a single-cavity anthropomorphic head phantom and a custom brick-shaped antenna array working at around 1 GHz.

16:50 ***A Combined Microwave Imaging Algorithm for Localization and Moisture Level Estimation in Multilayered Media***

Adel Omrani, Hamzekalaei (Karlsruhe Institute of Technology, Germany); Rahul Yadav (University of Eastern Finland, Finland); Guido Link (Karlsruhe Institute of Technology, Germany); Marko Vauhkonen and Timo Lähivaara (University of Eastern Finland, Finland); John Jelonnek (Karlsruhe Institute of Technology, Germany)

In this work, a multistatic uniform diffraction tomography (MUDT) method, that was proposed by the authors as a new qualitative imaging method just recently, is combined with the quantitative Bayesian inversion framework. In this combined approach, MUDT is applied to find the location of the moisture and this localization is employed as a pre-knowledge for the Bayesian framework to estimate the moisture levels in a polymer foam. The proposed combined algorithm might become a major part of the development of a new kind of intelligent industrial microwave drying systems. The imaging algorithm is tested with simulated measurement data. The frequency band from 8 GHz to 12 GHz (X-band) is used for the MUDT algorithm whereas a single frequency of 8.2 GHz is assumed for the Bayesian framework. The first results demonstrate the ability of the developed combined algorithm for optimizing the computational load unlike seen in the quantitative inversion approaches.

T11-M03: Measurements of material properties

T11 Fundamental research and emerging technologies / / Measurements

Room: virtual 13

15:30 ***High Resolution SAR Imaging Using a 240 GHz FMCW Radar System with Integrated On-Chip Antennas***

Sven Thomas, André Froehly, Christian Bredendiek and Reinhold Herschel (Fraunhofer FHR, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany)

In this paper high resolution SAR imaging techniques are presented, recorded with a compact 240 GHz radar sensor. The sensor is based on an fully integrated SiGe MMIC, allowing an ultra-compact, lightweight, and low energy sensor solution. The use of a modern SiGe technology allows high operation frequency of up to 250 GHz. The high FMCW modulation bandwidth of up to 52 GHz leads to an ultra-fine imaging resolution for SAR applications. While the power consumption of the whole sensor is 3.5 W, the size is given by 58x46x18 mm³, resulting in an remarkable small and energy efficient sensor solution. Additionally, a calibration technique is shown to compensate the imperfections of the system. The large antenna beam width allows a large synthetic aperture for SAR processing, resulting in a high resolution in cross-range direction. Combined with the high range resolution an ultra fine imaging quality is demonstrated.

15:50 ***Novel Reflection-Only Method for Electromagnetic Characterization of Isotropic Dispersive Material***

Mohammad Baharian (University of Tehran, Iran); Maryam Hasheminasab (Iran University of Science and Technology, Iran); Jalil A. Rashed-Mohassel (School of Electrical and Computer Engineerimg College of Engineering & University of Tehran, Iran); Ahmed Kishk (Concordia University, Canada)

A new reflection only method for electromagnetic characterization of PEC-backed material is proposed. By exploiting waveguide high-order modes, this method can retrieve permittivity and permeability of dispersive and lossy materials. In contrast to similar researches, this method is mathematically simple and easy to implement. An example of retrieving/retrieval electromagnetic parameters of a dispersive material is carried out to show the applicability of the method.

16:10 ***A Comparison of Measurements of the Permittivity and Loss Angle of Polymers in the Frequency Range 10 GHz to 90 GHz***

Brad Givot (3M Company, USA); Andrew P Gregory (National Physical Laboratory, United Kingdom (Great Britain)); Bartek Salski (Warsaw University of Technology, Poland); Fee Zentis (3M Company, USA); Nicole Pettit (Pace Analytical, USA); Tomasz Karpisz and Pawel Kopyt (Warsaw University of Technology, Poland)

The permittivity and loss angle of disc-shaped polymer specimens were measured by using three Split-Post Dielectric Resonators (9.5 GHz, 25 GHz & 34 GHz), a plano-concave open resonator (36 GHz), a bi-concave open resonator (20 GHz to 50 GHz), a helical cavity (10 GHz), and two free-space Gaussian-beam transmission systems (22 - 33 GHz & 60 - 90 GHz). The measured materials were PMMA, polycarbonate, THV 500GZ fluoropolymer, and two grades of PTFE. The work supports the need for materials for manufacture of components for 5G applications.

16:30 ***Electromagnetic Characterization of Materials Through High Accuracy Free Space Measurements***

David Poyatos Martínez, David Ramos Somolinos and Borja Plaza Gallardo (INTA, Spain)

Aerospace or automotive industries employ novel composite or 3D printed materials in their manufacturing processes to improve performance and reduce costs. Obtaining the electromagnetic (EM) characterization of these materials or a combination of them is essential to ensure safety and EM compatibility. In this paper, the development of a test bench with rod antennas for measurements in free space is presented. A complete design is described, from simulation analysis to validation measurements. The aim is to achieve robust measurements which allow the EM characterization of very diverse samples and materials, and high accuracy results that make possible to know the exact EM behaviour of these materials.

16:50 ***Microwave Spectroscopy of Breast Biopsies: Clinical Results from Nine Patients***

Jochen Moll (Goethe University Frankfurt am Main, Germany); Frank Hübner (Goethe University Hospital Frankfurt am Main, Germany); Stefanie M Goram (Goethe-University Frankfurt, Germany); Hai Duy Nguyen (Goethe University Frankfurt, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany); Babak Bazrafshan (Goethe University Frankfurt, Germany); Lukas Lenga and Thomas Vogl (Goethe University Hospital Frankfurt am Main, Germany)

Microwave spectroscopy using open-ended coaxial probes is widely used for the characterization of biological tissues. In this work, we use this technique for the analysis of breast biopsies in the frequency band up to 20GHz. In total, we studied 77 independent measurements from nine patients. The analysis contains X-Ray images as well as the histology finding in terms of BIRADS classification (B2, B3 and B5). The variability of dielectric properties even in small tissue samples is demonstrated and quantified.

T11-A06: High Frequency antennas and components

T11 Fundamental research and emerging technologies / / Antennas

Room: virtual 14

Chairs: Antonio Clemente (CEA-LETI Minatec, France), Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France)

15:30 ***Analysis and Efficient Design of Sub-THz Transmitarrays with Three Anisotropic Layers***

Orestis Koutsos (IETR & CEA Leti, France); Francesco Foglia Manzillo (CEA-LETI, France); Antonio Clemente (CEA-LETI Minatec, France); Ronan Sauleau (University of Rennes 1, France)

In this paper, we study the transmission behavior of a three-layer architecture comprising anisotropic FSS layers with applications to the optimal design of transmitarray (TA) antennas. We employ a theoretical analysis considering the depolarizing properties of the middle layer. We derive a condition showing that we can cover the full phase of transmission achieving at the same time zero insertion loss (IL). Lastly, a 3-bit 40×40 TA is realized at 300 GHz, based on the previous analysis. The antenna is able to attain a maximum gain of 35.1 dBi with an aperture efficiency of 64.8%, which is only 0.5 dB less than the ideal case of a TA with full transmission and perfect phase compensation.

15:50 ***CRLH-Based Low Insertion Loss Phase Shifter for Submillimeter-Waves***

Lucas de Oliveira Veiga (Inatel, Brazil); Andreia Aparecida de Castro Alves (Federal University of Itajubá, Brazil); Raj Mittra (Penn State University, USA); Arismar Cerqueira S. Jr. (INATEL, Brazil)

This paper proposes an analog tunable phase shifter based on composite right/left-handed (CRLH) unit cells. The proposed phase shifter operates in the sub-millimeter band and exhibits a wide bandwidth together with a low insertion loss. The phase incursion of the input signal is obtained by changing the voltage of the varactor mounted on the fingers of the CRLH. The phase shifter layout has a compact size of 20 mm × 15 mm. Numerical simulation results demonstrate phase shifter achieves a phase range of 44.11-degrees, with a 10-degrees step, and an insertion loss 4.27 dB, when operating in the frequency range from 24 to 25.5 GHz. Our approach could be useful for developing beam-steering antenna arrays applied to the fifth-generation mobile network new radio (5G NR) systems.

16:10 ***140 GHz Broadband Antenna in Embedded Wafer-Level Ball Grid Array Technology***

Akanksha Bhutani, Elizabeth Bekker, Lucas Giroto de Oliveira and Mario Pauli (Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)

This paper presents a 140 GHz corner-fed coplanar waveguide (CPW) square patch antenna and a three-element antenna array in embedded wafer level ball grid array (eWLB) technology. In both cases, the feed is provided by a 50 ohm CPW to one of the corners of a CPW square patch element. In addition, a ground plane reflector, realized on a separate Rogers 4003C based printed circuit board, is integrated with the eWLB antenna array using a ball grid array concept. This results in a planar superstrate antenna, whose bandwidth is several orders of magnitude larger than a usual edge-fed CPW patch antenna. The antenna characteristics are measured in D-Band using a probe-based measurement setup and compared with the electromagnetic simulation result. The antenna array shows a reflection coefficient of less than -10 dB and a realized gain of around 10 dBi over a broad bandwidth of 130 to 150 GHz.

16:30 ***Terahertz X-Wave Launchers by Metallic Spline-Profiled Horns***

Srđan Paković (Université de Rennes 1, France); Nicola Bartolomei (University of Rennes 1, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France); Ronan Sauleau (University of Rennes 1, France); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

This paper describes the design of a novel X-wave launcher in the terahertz frequency range. The theoretical background of X-waves and the basic design rules for synthesizing X-wave launchers are presented. The proposed launcher consists of a spline profiled metal horn, it is solely made of metal and can thus be easily scaled for operation in different frequency bands. The performance of the launcher has been analyzed by an in-house mode-matching based tool and validated using full-wave simulations. Finally, the performance of the launcher are compared to other solutions present in the literature.

16:50 ***Frequency Coded Retroreflective Landmark for 230 GHz Indoor Self-Localization Systems***

Petr Kadera (Brno University of Technology, Czech Republic); Alejandro Jiménez-Sáez (Technische Universität Darmstadt, Germany); Lisa Schmitt (Ruhr-Universität Bochum, Germany); Martin Schüßler (TU Darmstadt, Germany); Martin Hoffmann (Ruhr-Universität Bochum, Germany); Jaroslav Lacik (Brno University of Technology, Czech Republic); Rolf Jakoby (Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany)

This paper presents a planar Luneburg lens frequency-coded retroreflector based on a high-resistive silicon (HR-Si) photonic-crystal (PhC) high-Q tag with two resonators working at 237 GHz and 243 GHz. A characterization of the retroreflector, including the readout of the resonance frequency of the resonators, is performed at 30 cm over 130-degree angular range in azimuthal plane. The measured gain of the lens antenna is 15.9 dBi at a frequency of 240 GHz and the radar-cross section (RCS) of the frequency-coded tag landmark achieves -40 dBm2 at 237 GHz

Thursday, March 25

Thursday, March 25 10:00 - 11:40

T01-P01: Machine Learning for Propagation

T01 LTE and Sub-6GHz 5G / / Propagation

Room: virtual 1

Chair: Domenico Spina (Ghent University - imec, Belgium)

10:00 ***Genetic Algorithm Combined with Ray Tracer for Optimizing Cell-Free mMIMO Topology in a Confined Environment***

Ke Shen (University of Gent, Belgium); Toon De Pessemier (University of Ghent, Belgium); Luc Martens (Ghent University - imec, Belgium); Wout Joseph (Ghent University/IMEC, Belgium); Yang Miao (University of Twente, The Netherlands)

This paper proposes a customized genetic algorithm (GA) to generate the optimal cell-free topology for multi-user massive MIMO (mMIMO) in a confined environment. As far as we know, it is beyond the literature and is the first attempt to apply GA in optimizing the base station (BS) antenna placement for cell-free mMIMO. The BS antennas' placement is encoded with an adjusted binary matrix representation, which is straightforward for the subsequent genetic operations. The explored candidates by GA can evolve beyond the parents, where the fitness of individuals is evaluated dynamically via a ray tracer channel simulator. Accelerated by a warm start strategy and elitist replacement, the proposed customized GA provides near-optimal results in experiments, applicable to generic environment with multiple mobile users and different signal-to-noise ratios.

10:20 ***A Study on Urban Structure Map Extraction for Radio Propagation Prediction Using XGBoost***

Tatsuya Nagao and Takahiro Hayashi (KDDI Research, Inc., Japan)

Recently, the rapid increase in mobile data traffic and the diversification of wireless communication have led to demand for the development of high-quality mobile service areas. Therefore, the modeling of complex radio propagation characteristics in the practical environment is an important issue. Radio propagation prediction methods based on machine learning have been proposed, but no study on the appropriate range of urban structure maps as features has been conducted. In this paper, we clarify the appropriate extraction range of map data, applying XGBoost to the machine learning algorithm. Moreover, since XGBoost can output the feature importance, we can extract only those features that are useful for training and input them to machine learning. This approach is expected to improve both accuracy and speed. The evaluation using measurement data obtained in urban areas showed that the computation time for learning can be reduced by about 80% while improving the prediction error.

10:40 ***Radio Propagation Estimation in a Long-Range Environment Using a Deep Neural Network***

Satoshi Ito and Takahiro Hayashi (KDDI Research, Inc., Japan)

Expectations for dynamic spectrum access (DSA) systems that can increase spectrum usage efficiency are growing because network traffic and the number of devices are increasing dramatically. Although the transmission power of a secondary system is controlled by detecting radio waves emitted from the primary system measured by sensors, it is assumed that sensors cannot be placed with sufficient density in the real environment. For this reason, an estimation model in areas where there are no sensors is needed. In addition, when a large number of sensors are used, the sensitivity of the sensors is expected to be limited, hence a highly accurate propagation loss estimation model is required to detect the weak power at long distances from the transmission point. In this paper, the authors have developed a model for estimating propagation loss over the long-range by using a free space path loss map and a building occupancy map.

11:00 ***Machine Learning-Based Characterization of SNR in Digital Satellite Communication Links***

Brecht Dhuyvetters (Ghent University, Belgium); Daniel Delaruelle (Project Manager, Belgium); Hendrik Rogier (Ghent University, Belgium); Tom Dhaene (Ghent University & IMEC, Belgium); Dries Vande Ginste (Ghent University, Belgium); Domenico Spina (Ghent University - imec, Belgium)

Signals traveling through a Satellite Communication (SatCom) channel are subject to noise and interference effects, impacting their Signal-to-Noise ratio (SNR). Furthermore, nonlinear distortion arising from the nonlinear characteristic of the amplifiers in the system also adversely impacts performance. Current state-of-the-art techniques estimate these effects by including a sequence of known pilot symbols in the transmitted signals. While robust, a downside of these approaches is that pilot symbols do not include useful information, thus introducing overhead. This paper presents a Machine Learning (ML) approach to characterize the SNR, using the received signal in the return link of SatCom systems, independent of the signal's distortion level and without relying on pilot symbols. The proposed technique is validated through a suitable application example: the characterization of SNR in a SatCom system using a 16-APSK modulation scheme.

11:20 ***Deep Learning Based Channel Prediction at 2-26 GHz Band Using Long Short-Term Memory Network***

Motoharu Sasaki and Nobuaki Kuno (NTT, Japan); Toshiro Nakahira (NTT Access Network Service Systems Laboratories, Japan); Minoru Inomata, Wataru Yamada and Takatsune Moriyama (NTT, Japan)

We report a method of predicting variations in path loss using long short-term memory (LSTM) as deep learning. The training data and validation data are path loss data measured in Kanagawa, Japan, and the measurement frequencies are in the 2.2 GHz, 4.7 GHz, and 26.4 GHz frequency bands. The median data of the path loss after 1 second was predicted using 100 points of fast fading data obtained about every 0.1 seconds. The median data was derived using fast fading data of 100 points (about 10 seconds). Utilizing the prediction method using LSTM, the root-mean-square error (RMSE) for the validation data was about 2.2 dB at 2.2 GHz, about 2.1 dB at 4.7 GHz, and about 2.4 dB at 26.4 GHz. The prediction errors were improved by 1 dB or more than predictions using the latest observed values.

CS30a: Propagation of Smart Mobility Empowered by 5G and Beyond (Part 1)

T01 LTE and Sub-6GHz 5G / Convened Session / Propagation

Room: virtual 2

Chairs: Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany), Ke Guan (Beijing Jiaotong University, China)

10:00 ***Large- and Small-Scale Fading Characteristics of mmWave HST Propagation Channel Based on 28-GHz Measurements***

Jae-Joon Park, Juyul Lee, Kyung-Won Kim and Myung-Don Kim (ETRI, Korea (South))

Considering a linear cell layout, millimeter-wave (mmWave) high-speed train (HST) measurements were conducted at 28 GHz with a speed up to 170 km/h in two different HST scenarios: viaduct and tunnel scenarios. In this paper, large- and small-scale fading characteristics, such as path loss (PL), K- factor, and etc., were investigated based on the measurements. Since there were significantly different patterns of measured PL for the two scenarios, we proposed multi-slope PL models to cover the characteristics. By observing the measurement data, we characterize multipath components (MPCs) caused by railway structures such as overhead line equipment which were installed along the railway.

10:20 ***Channel Modeling Based on 3D Scenario Information for V2I Communications***

Pan Qi (Beijing University of Posts and Telecommunications, China); Yuxiang Zhang (Beijing University Of Posts And Telecommunications, China); Yuan Zhiqiang, Li Yu, Pan Tang and Jianhua Zhang (Beijing University of Posts and Telecommunications, China)

In this paper, we propose a novel 3D scenario information based channel modeling method with deep learning for Vehicular-to-infrastructure (V2I) communications. Specifically, the vehicular scanning sensors are utilized to capture the point cloud information of 3D scenario directly, and then the channel characteristics are generated and mapped with the 3D scenario information by deep learning network. Benefited from the above modeling framework, the complexity of environment reconstruction and geometric calculation can be reduced greatly. The simulation results show that the prediction precision of reflection point by deep learning has significant impact on the modeling accuracy. By some efficient scenario information extraction operations, the proposed method can realize more than 95% channel modeling accuracy with much lower complexity.

10:40 ***Connectivity Analysis of V2V Channel at Intersections***

Ailin Jia and Suying Jiang (Chang'an University, China); Yue Lv (Chang'an University, China); Xu Zhang and Tiantian Chang (Chang'an University, China); Ibrahim Rashdan and Paul Unterhuber (German Aerospace Center (DLR), Germany); Wei Wang (Chang'an University, China)

The research on the connectivity characteristics of wireless vehicle network is of great significance to the realization of vehicle-to-vehicle (V2V) communication. However, vehicles on the road are dynamically changing, and V2V communication is greatly affected by transmission distance and road environment, it's difficult to analyze the connectivity between vehicles. In this paper, firstly, we establish the single slope path loss model, and analyze the connectivity probability of V2V in urban intersection scenarios. Secondly, we analyze the relationship between connectivity probability and transmission distance and threshold. It is found that radio environment and transmission distance have significant effects on the probability of connectivity.

11:00 ***Diffuse Multipath Analysis of Vehicle-To-Vulnerable Road User Channel in Urban Environment***

Ibrahim Rashdan and Paul Unterhuber (German Aerospace Center (DLR), Germany); Fabian de Ponte Müller (German Aerospace Center DLR, Germany); Stephan Sand (German Aerospace Center (DLR), Germany); Giuseppe Caire (Technische Universität Berlin, Germany)

The impulse response of the radio channel can typically be decomposed into a specular part and diffuse part. Neglecting the diffuse multipath components (DMC) in the channel model may result in underestimating the received power and the channel capacity.

Therefore, it is important to analyze the power contribution of the DMC. This work presents an analysis of the fractional DMC power. A wideband channel measurement campaign was conducted at 5.2 GHz. The Kalman enhanced super resolution tracking (KEST) algorithm is used to estimate the parameters of the specular multipath components (SMC). The results show that the value of the fractional DMC power depends on the shadowing condition. While the DMC contributes as low as 5 % in line-of-sight (LoS) situation prior to the collision, it varies between 15 % and 40 % in obstructed-LoS (OLoS), and it can reach up to 90 % in non-LoS (NLoS) situation.

11:20 ***Modeling of Transitions in Received Power for an Urban V2I Scenario***

Daniel Czaniera, Vimukthi Herath, Christian Schneider and Martin Käske (Ilmenau University of Technology, Germany); Gerd Sommerkorn (Technische Universität Ilmenau, Germany); Reiner S. Thomä (Ilmenau University of Technology, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

In this contribution, we investigate how changes in received power for a vehicle to infrastructure (V2I) communication scenario in an urban environment can be modeled. Significant changes are not only observed for line of sight (LoS) to none line of sight (NLoS) transitions but also when the mobile station travels from a narrow street onto a crossroad and other maneuvers, even with no LoS being present. To model these transitions, in terms of received power, we propose a variant of an arctangent function. We fit the model to different exemplary transitions, which were found in channel sounding data collected in a V2I measurement campaign. We discuss the results in terms of quality of fit and the estimated parameters.

T02-A02: 5G communication architectures: Part 2 handheld arrays

T02 Millimetre wave 5G / / Antennas

Room: virtual 3

Chair: David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

10:00 ***An Antenna Array for Photonic Beam Switching in Mm-Wave Wireless Communications***

Alvaro J Pascual (University of Rennes 1 & IETR, France); Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France); Laurent Brochier (Université de Nice-Sophia Antipolis, France); Thomas Batté (Institut FOTON, INSA, France); Olivier De Sagazan (University Rennes 1, France); Guillermo Carpintero (Universidad Carlos III de Madrid, Spain); Ronan Sauleau (University of Rennes 1, France); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

We present a photonic transmitter at E-band for beam switching in mm-wave wireless links. First, we discuss the trade-offs between beam switching and beam steering with arrays of photonic transmitters. Then, the designed transmitter is presented; it includes two 2×2 sub-arrays of stacked patches fed independently by two photodiodes. The transmitter is placed at the focal plane of a PTFE lens to increase the overall gain. Excitation of either sub-array allows 1D beam witching between ±2.7° for accurate beam alignment or reconfigurable links.

10:20 ***5G mmWave Low-Profile 2 × 2 Planar Array of Tightly Coupled Dipole Subarray Covering FR2***

Seoungjung Kim and Sangwook Nam (Seoul National University, Korea (South))

This paper presents a 5G millimeter wave (mmwave) low-profile 2 × 2 planar tightly coupled dipole subarray (TCDS) covering the bandwidth of 24.25 - 40 GHz which is the frequency range 2 (FR2) designated by 3rd Generation Partnership Project (3GPP). The element antenna of 2 × 2 array is a subarray consisting of 4 × 4 Tightly Coupled Dipole Array (TCDA) unit elements. Total thickness of the proposed antenna is 0.9 mm (0.07 λlow at 24.25 GHz), and the maximum realized gain is 8.3 dBi at the frequency and 12.4 dBi at 40 GHz. This realized gains satisfy the specification of the peak effective isotropic radiated power (EIRP) at 24.25 GHz, 30 GHz, 37 GHz and 40 GHz which are 23.3 dBm, 24.3 dBm, 26.6 dBm and 27.4 dBm, respectively, with transmitter power of 8.1 dBm per a channel.

10:40 ***Heterogeneous Phased Array Architecture Consisting of AoD and AiP to Enhance Spherical Beamforming Coverage for 5G/6G Cellular Handsets***

Junho Park (Pohang University of Science & Technology, Korea (South)); Bumhyun Kim and Jonghyun Kim (POSTECH, Korea (South)); Jaehyun Choi (Pohang University of Science and Technology, Korea (South)); Ahmed Abdelmottaleb Omar and Wonbin Hong (Pohang University of Science and Technology (POSTECH), Korea (South))

This paper presents a first-of-the-kind heterogeneous phased array architecture to enhance spherical beamforming coverage while maintaining present-day device design trends. The proposed architecture symmetrically arranges both antenna-on-display (AoD) and antenna-in-package (AiP) modules in the foreside direction to achieve three independent multi-beamsteering radiation in two opposing broadside and one-endfire directions. The proof-of-concept (POC) model is designed to prove the feasibility of the proposed phased array configuration and architecture. The phased array AoD and AiP modules of the POC model achieve more than 1.7 GHz impedance bandwidth across the 3GPP's licensed n261 (27.5 - 28.35 GHz) bands. The POC model improves EIRP at CDF = 50% by more than 2.8 dB compared to that of each independent AoD and AiP module.

11:00 ***A Compact 5G Antenna Array with Ultra-Wide Bandwidth for MM-Wave Smartphone Applications***

Naser Ojaroudi Parchin (University of Bradford, United Kingdom, United Kingdom (Great Britain)); Yasir Ismael Abdulraheem Al-Yasir and Raed A Abd-Alhameed (University of Bradford, United Kingdom (Great Britain))

In this study, a compact 5G antenna array with ultra-wide impedance bandwidth is proposed for mm-Wave 5G cellular beam-steering. Its structure consists of eight compact folded-dipole antennas with 1×8 linear form placed at top portion of the mobile-phone PCB. The design substrate is a Rogers 0.5 mm RT5880 dielectric. The elements of the design have been etched on the same layer of the ground. The introduced phased array design offers a broad bandwidth of 26-43 GHz covering different 5G candidate bands such as 26, 28, 36, 38, and 40 GHz. Besides, the maximum coupling of the elements is less than -14 dB. Highly compact profile, end-fire beam-steering function, high efficiency, sufficient gain, and wide bandwidth are some of the features for the proposed array antenna which make it suitable for future 5G mobile communications.

11:20 ***A Compact 28GHz-Band 4x4 Butler Matrix Based Beamforming Antenna Module in Broadside Coupled Stripline***

Jean Temga (Tohoku University & RIEC, Japan); Koki Edamatsu, Mizuki Motoyoshi and Noriharu Suematsu (Tohoku University, Japan)

A compact and wideband 4x4BM based four directions beamforming antenna is proposed and designed in 3-layers substrate. A broadside coupled stripline structure is used in the lower layers to design a high performance 3dB/900 coupler as the basic element of the BM. A compact size, wideband and low loss 4x4BM is realized at mmWave frequencies. The upper layer is used to design the antenna array. The simulated return loss at all ports is below-10dB. The simulated four directional beams 12.50, -380, 370, -130 and the second lobe levels -12, -10, -10.5, -12.2dB are respectively achieved when ports 1,2,3, and 4 are excited. The beamforming system exhibits an average gain of 9.6dBi. The measurement of the beamforming antenna module confirms the simulation results.

T02-A09: mm-wave antennas

T02 Millimetre wave 5G / / Antennas

Room: virtual 4

Chair: Jose Manuel Fernández González (Universidad Politécnica de Madrid, Spain)

10:00 ***Design of Triangular-Latticed Sub-Array Antenna Fed by Hexagonal Radial Line for K-Band Applications***

Alfonso-Tomás Muriel-Barrado, Óscar-Alberto Pla-Terrada, Manuel Sierra-Pérez and Jose Manuel Fernández González (Universidad Politécnica de Madrid, Spain)

A circularly polarized double-stacked patch sub-array antenna fed by a hexagonal radial line with internal circular coupling patches is proposed. The antenna works at K band (19.7 GHz - 20.2 GHz) with LHCP. On the one hand, the design approach consists of a coupling study based on the simulation of a periodic parallel-plate waveguide as a first approximation of the radial line. On the other hand, a phase compensation method by rotation is applied to adjust the radiating phase of each element of the sub-array, which are separated 0.7λ0. Thus, the sub-array is uniformly fed in terms of amplitude and phase. An axial ratio below 1 dB is achieved for the entire frequency band, with a gain of 24 dB and a total efficiency of 87%. The radial line has been modelled as a hexagon to perform this analysis in larger arrays in future design steps.

10:20 ***A Simplified Circular Polarized Rectangular Horn Antenna in the 77 GHz Band***

Niels Koch (Audi AG, Germany); Adam Weber (University of Applied Sciences Ingolstadt, Germany)

In this paper we present a very easy and effortless method to transform a standard-gain waveguide horn antenna into a circular polarized rectangular gain horn antenna. For this, a bar-rod separator is inserted into the horn's mouth. By modifying only three different design parameters, the S11 reflection coefficient and axial ratio frequency response can be tuned. The method has been simulated and verified on 3D-printed models in the 77 GHz automotive radar band.

10:40 ***Wideband Coffee-Bean Shaped Radiating Element for Circularly-Polarized Waveguide Slot Arrays***

Miguel Ferrando-Rocher (Universidad de Alicante & Universitat Politècnica de València, Spain); José Ignacio Herranz-Herruzo and Alejandro Valero-Nogueira (Universidad Politécnica de Valencia, Spain)

A wideband coffee-bean shaped radiating element for circularly polarized waveguide slot arrays is presented. The proposed solution is based on a very simple polarizer aimed to be integrated into flat panel antennas in the millimeter-wave band. For validation purposes, a slot array fed by a groove gap waveguide network at 30 GHz is taken as a feeder. Simulated results using periodic boundary conditions in a 2 x 2 unit cell are presented in this work. Preliminary results show a frequency bandwidth of 4 GHz with input reflection coefficient better than -10 dB. It is worth stressing the good polarization purity achieved, being below 1.5 dB from 29 GHz to 31 GHz and below 3 dB in the whole band of interest (28 to 32 GHz).

11:00 ***8 X 4 Mm-Wave 3D Printed MIMO Antenna for 5G Wireless Communication***

Shaker Alkaraki (Queen Mary University Of London, United Kingdom (Great Britain)); Syeda Fizzah Jilani (Aberystwyth University & Queen Mary University of London, United Kingdom (Great Britain)); James Kelly (Queen Mary University of London, United Kingdom (Great Britain)); Yue Gao (University of Surrey, United Kingdom (Great Britain)); Samuel Stremsdoerfer (Jet Metal Technologies, France); Edouard des Gayets (Jet Metal Technologies, Belgium)

A 3D printed 8 ×4 mm-wave multiple input multiple output (MIMO) antenna is presented in this paper. The proposed MIMO has an overall dimensions of 106.3 mm x 75.7 mm and it operates at 28 GHz mm-wave band. The proposed MIMO consists of 32 single elements where, each of the MIMO element consists of two structures. The first structure of each element is a feeding layer and the second is a radiating structure which is the 3D printed antenna. The radiating structure consists of a slot antenna surrounded by cavity and corrugations that improve the gain of the antenna. Furthermore, the proposed MIMO has 16 elements radiate in the boresight direction and 16 elements with side wall that radiates in different directions covers the elevation plane. Hence, the proposed MIMO provides beam switching functionalities up to ∓30° in the elevation by switching between different element that have different wall heights.

11:20 ***Ultra Wide-Band PRGW Based Magneto-Electric Dipole Antenna***

Abdelmegid Allam (German University in Cairo, Egypt); Ahmad Ossama Mahmoud, Aoss (German University in Cairo & None, Egypt); Diaa Fawzy and Murat Askar (Izmir University of Economics, Turkey)

In this paper, a Circularly Polarized (CP) Magneto-Electric (ME) dipole antenna excited by low loss Printed Ridge Gap Waveguide (PRGW) feed network is proposed. The PRGW design consists of substrate filled periodic mushrooms arranged around the ridge of the transmission line. An air gap layer is added above the ridge structure covered with a top metallic layer. The PRGW excites the ME dipole antenna through a transverse radiating slot above the air gap. A ME dipole antenna is designed in the form of horizontal trapezoidal metallic patches supported with vertical pins. It is operating over the frequency band from 54 GHz to 68 GHz where the reflection coefficient is below -10 dB. The maximum gain is 8 dB and the axial ratio bandwidth with maximum value 2.5 dB is achieved all over the band.

T05-E01: Scattering and Imaging Techniques for Medical Applications

T05 Biomedical and health / / Electromagnetics

Room: virtual 5

Chair: Sandra Costanzo (University of Calabria, Italy)

10:00 ***Smart Simplification of Anthropomorphic Head Phantom Aimed for Microwave Imaging***

Tushar Singh (University of Belgrade & WIPL-D, Serbia); Soroush Abedi (Sorbonne University, CNRS, France); Branislav Ninkovic (WIPL-D, Serbia); Marija Stevanovic (University of Belgrade, Serbia); Nadine Joachimowicz (Group of Electrical Engineering - Paris / CentraleSupelec, France); Hélène Roussel (Sorbonne Université, France); Branko Kolundzija (University of Belgrade, Serbia)

In this paper we study the numerical modeling of the complex anthropomorphic human phantoms, aimed for microwave imaging, using the WIPL-D software. By comparing various models, we investigate the influence of the geometrical simplification of the phantom on the accuracy of the electromagnetic response of the antennas in the vicinity of the phantom. By controlling the geometrical deviation of the simplified model with respect to the original model, we show that it is possible to reduce the simulation resources for one to two orders of magnitude while preserving the precision of the electromagnetic analysis.

10:20 ***Feasibility Study of Detection of Coronavirus Disease 2019 with Microwave Medical Imaging***

Xiaoyou Lin (The University of Auckland, New Zealand); Zheng Gong (University of Waikato & South University of Science and Technology of China, New Zealand); Yahui Ding (University of Electronic Science and Technology of China, China); Yifan Chen (University of Waikato & University of Electronic Science and Technology of China, New Zealand); Pedro Antonio Valdes Sosa (University of Electronic Science and Technology of China, New Zealand); Mitchel Joseph Valdes Sosa (Cuban Neuroscience Centre, New Zealand)

This paper studies the feasibility of detecting the pneumonia due to the COVID-19 with microwave medical imaging. One challenge while formulating such a problem is to identify the disease in lungs whose dielectric permittivity is dynamically fluctuating with the respiration. In this paper, we utilize this feature by assuming that the permittivity of the disease has minor variation at microwave frequencies during the respiration, and thus the dielectric variance of the pixels at the diseased site over a number of consecutive images significantly differs from those of the other tissues in the thorax. Based on this assumption, we propose two approaches that make use of the a priori information (API) on the position of the heart and the symmetry of the thorax, respectively, to identify a diseased lung. Finally, these two approaches are numerically validated on a thorax phantom, and their performance is compared.

10:40 ***Comparison of 2-D and 3-D DBIM-TwIST for Brain Stroke Detection and Differentiation***

Olympia Karadima, Pan Lu and Panagiotis Kosmas (King's College London, United Kingdom (Great Britain))

This work presents preliminary results from a three-dimensional (3-D) iterative microwave imaging algorithm vs. its previous two-dimensional (2-D) implementation for detecting brain stroke. The imaging algorithm is based on the distorted Born iterative method (DBIM) combined with the two-step iterative shrinkage thresholding (TwIST) method. Our test scenarios are based on simplified phantoms with hemorrhagic and ischemic stroke targets, which are placed inside our previously developed microwave imaging prototype and are simulated using CST Microwave Studio. Our results demonstrate that both 2-D and 3-D implementations can detect and differentiate a stroke target placed at the same height (but off-centre) with the antenna array. Moreover, the target's dielectric properties are estimated more accurately with the 3-D algorithm.

11:00 ***Fourier Analysis of Submillimeter-Wave Scattering from the Human Cornea***

Faezeh Zarrinkhat (Universitat Politècnica de Catalunya, Spain); Joel Lamberg, Aleksi Tamminen, Mariangela Baggio and Juha Ala-Laurinaho (Aalto University, Finland); Elsayed Esam M. Khaled (Assiut University & Engineering Faculty, Egypt); Juan M. Rius and Jordi Romeu (Universitat Politècnica de Catalunya, Spain); Zachary D Taylor (Aalto University, Finland)

Wave scattering from a human cornea illuminated with a submillimeter-wave Gaussian beam is explored with Fourier analysis. This new approach enabled us to investigate the cornea as a coated sphere rather than a homogenized one. The cornea was modeled as an aqueous spherical shell using effective medium theory, with 60 percent water, enclosing a sphere of pure water. The corneal model was illuminated at 220 GHz - 330 GHz. The interaction of the incident and back-reflected beam, back-scattered field, and back-scattering from one usual beam-cornea alignment scheme were evaluated; beam waist collocated with the surface apex. The result indicates the amount of difference between the reflection from planar stratified and back-scattering from the cornea in the case of focusing the beam waist at the corneal apex.

11:20 ***Fast Jacobian Matrix Formulation for Microwave Tomography Applications***

Samar Hosseinzadegan (Chalmers University of Technology, Sweden); Shireen Geimer (Dartmouth College, USA); Andreas Fhager and Mikael Persson (Chalmers University of Technology, Sweden); Paul M Meaney (Dartmouth College, USA)

We have developed a new technique for computing the Jacobian matrix for microwave tomography systems which is orders of magnitude faster than conventional approaches. It exploits concepts from the nodal adjoint method and previous observations that rows of the matrix can be plotted over the imaging domain to produce sensitivity maps associated with specific transmit/receive antenna pairs. It also requires that the forward solutions and parameter reconstruction distributions be represented on the same grid or mesh. In this way, it computes full rows of the matrix simultaneously via a simple vector-vector multiplication of the forward solutions associated with sources broadcasting from both the designated transmit and receive antennas times a scalar constant. The time savings is substantial and is viable for both 2D and 3D applications.

T08-P01: Propagation for Positioning, Localisation and tracking

T08 Positioning, localization & tracking / / Propagation

Room: virtual 7

Chair: Fernando Pérez-Fontán (University of Vigo, Spain)

10:00 ***Approach for Localizing Scatterers in Urban Drone-To-Drone Propagation Environments***

Dennis Becker, Uwe-Carsten G. Fiebig and Lukas Marcel Schalk (German Aerospace Center (DLR), Germany)

Direct Drone-to-Drone communication is a promising approach for sharing information in order to prevent mid-air collisions in urban airspace . For a reliable and efficient communication, the fundamental propagation mechanisms must be understood and specific channel models be developed. In previous work we identified the origin of some multipath components in first wideband channel measurements by applying a geometrical signal path. But the performance of this approach depends on the degree of simulated details and can easily get computationally expensive. Therefore, in this work we enhance the identification by jointly estimating the delay and doppler frequency for each scatterer and localize their origin by transforming the estimation into the 3D Cartesian domain and intersecting the results with known objects. We show the feasibility of this approach by investigating the parameter dependency on the results under simulated conditions and then compare the results when being applied on real measurement data.

10:20 ***Feasibility Study on the Acquisition of Automotive Radar Data of Urban Traffic Scenarios in Bangkok***

Sreejith Nair and Yeshaswini Palaksha (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Tiwat Pongthavornkamol (National Science and Technology Development Agency, Thailand); Thomas Dallmann (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Nuksit Noomwongs (Chulalongkorn University, Thailand); Suramate Chalermwisutkul (King Mongkut's University of Technology North Bangkok & The Sirindhorn International Thai-German Graduate School of Engineering, Thailand)

This paper summarizes the planned acquisition of radar data of dense urban traffic scenarios seen in one of the metropolitan cities in Asia: Bangkok, Thailand. Thailand, among other ASEAN states, holds the highest share of the number of fatal accidents involving motorbikes; a two wheeled motorcycle with the largest ridership in Thailand. With an aim to developing a low cost radar sensor to enhance safer driving, a commercially available automotive radar evaluation module is used. Experimental measurements are conducted to validate the operability of this module with the scenarios of interest. The real measurements are conducted for selected scenarios that are vulnerable to fatal accidents in Bangkok. The data are later used to study towards developing intelligent safety systems based on radar capable of operating in all visual and weather conditions.

10:40 ***Solving the Phase Dispersion Issue in FMCW Photonic Time Multiplexed Radar Imaging***

Fabien Berland (University of Limoges, France); Hamza Hallak Elwan (Foton Lab, France); Damien Boudescoque, Cyril Decroze, Philippe Di Bin and Christelle Aupetit-Berthelemot (XLIM, France); Thomas Fromenteze (University of Limoges, France)

The frequency-modulated continuous-wave architectures are increasingly used in 3D imaging systems to reduce the constraints linked to the receptive components. For short-range applications, the phase dispersion term that appears when de-chirping these signals is generally considered negligible due to the relatively low propagation delays. However, in this paper, the frequency-modulated continuous-wave architecture is implemented into a short-range radio frequency imaging system which uses a time-division multiplexer in reception. Under these conditions, even if the scanned scene range is small, the received signals are subject to significant delays and the undesirable phase dispersion term becomes non-negligible. Its impact on the reconstructed image is studied here using simulations that consider different delay for the multiplexing and using the measurement of a scene with a multiple-input multiple-output antenna array.

11:00 ***Experimental Results on the Influence of Temperature and Humidity on FMCW Radar Signals at 60 GHz***

Jonas Simon (Goethe-University Frankfurt, Germany); Thomas Maetz (Goethe University Frankfurt, Germany); Jochen Moll (Goethe University Frankfurt am Main, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany); Stefan Krause (Fraunhofer Institute for Wind Energy Systems, Germany)

This paper presents experimental studies on the influence of temperature and humidity on radar signals reflected by a glass-fibre reinforced plastic (GFRP) plate. These ambient conditions have great impact on structural health monitoring applications in changing environments. In this work, we focus on structural health monitoring of wind turbine blades. To estimate these impacts, common weather conditions are simulated inside a climate chamber and measured with two different Frequency Modulated Continuous Wave (FMCW) radar systems. The resulting varying signals will be shown and considerations on compensation methods will be presented.

11:20 ***Multiple-Target Vital Signs Sensing Using 77GHz FMCW Radar***

Weichu Chen (Harbin Institute of Technology, Japan); Shengchang Lan and Guiyuan Zhang (Harbin Institute of Technology, China)

In this paper, a commercial FMCW radar sensor working at 76 to 81GHz is used on single objects and multiple objects to obtain the IF signal containing vital signs information. Heartbeat and respiratory raw waveform are obtained after a series of digital signal preprocessing methods including Fast Fourier transform (FFT) and differential denoising. Later, three classical spectral estimation algorithms for extracting heart and respiration rate and period are used, including peak interval method, autocorrelation function, and Discrete Fourier transformation algorithm. We then implemented simultaneous measurements and calculations for multiple individuals, which is based on analyzing the range and angle information using MIMO antennas. Heartbeats and respiration movement of the target can be estimated by analyzing the frequency distribution of the extracted phase signals over the bands of 0.2-0.8Hz and 1-2 Hz. and experimental results show that this method can better identify the respiration and heartbeat information of multiple targets.

CS9a: Characteristic Mode Analysis for Emerging Applications and New Structures Part 1

T10 EM modelling and simulation tools / Convened Session / Antennas

Room: virtual 9

Chairs: Kalyan C Durbhakula (University of Missouri-Kansas City & Missouri Institute of Defense and Energy, USA), Feng Han Lin (ShanghaiTech University, China)

10:00 ***Wideband Microstrip Patch Antenna with Low RCS Using Multi-Mode Resonance***

Mei-Jiao Sun (Xidian University, China); Neng-Wu Liu (Xidian University & University of Macau, China); Lei Zhu (University of Macau, Macao); Guang Fu (Xidian University, China)

A wideband microstrip patch antenna with low radar cross section (RCS) using multi-mode resonance is proposed in this letter. Initially, a wideband shorted patch antenna (SPA) by utilizing the TM0,1/2 and TM0,3/2 modes is designed as the reference antenna. Then, the in-band RCS reduction can be obtained by introducing microstrip resonators. Finally, the proposed SPA is simulated and discussed. The result shows the antenna has generated the bandwidth for |S11|<-10dB of about 12.7% ranging from 3.67 to 4.17 GHz. Meanwhile, RCS reduction in the operation band of the proposed antenna in TM and TE polarization is as much as 5 and 8 dB independently as compared with the reference counterpart.

10:20 ***A Broadband, Dual-Linear Polarization-Reconfigurable Metasurface Antenna with Characteristic Mode Analysis***

Xiaoming Chen, Mei Li and Ming-Chun Tang (Chongqing University, China)

A low-profile, broadband metasurface antenna (MSA) with reconfigurable dual-polarization diversity is developed. The developed MSA comprises a 4×4 grid-slotted patch array, two pairs of orthogonally feeding dipole strips, two vertically grounded and orthogonally placed microstrip Γ- shaped feeding strips, a reconfigurable feeding network, and an intact ground plane. It is demonstrated that the strip-excited MSA excites three resonant modes to provide a wide operational bandwidth based on the characteristic mode analysis. The simulated results indicate that three modes with broadside radiation patterns are simultaneously excited to create a wide impedance bandwidth of 32 % with an average gain value of 9.5 dBi at both polarization states.

10:40 ***Compact Stacked Impedance-Sheet Resonator Antenna Using Characteristic Mode Analysis for 5G and 6G Networks***

Jia Fan Gao, Si Yu Miao and Feng Han Lin (ShanghaiTech University, China)

Ultra-massive multiple-in-multiple-out (UM-MIMO) antenna has been listed as one of the key technologies in recently released 6G white papers, which requires a massive number of compact antenna of high performance to coexist in a limited aperture. Metasurface antenna of controllable modes is a promising candidate but suffers from aperture size greater than half a wavelength. To address this challenge, the concept of stacked impedance-sheet resonator antenna is proposed, allowing for significant size reduction of metasurface antennas without losing the ability of mode manipulation. Characteristic mode analysis is used for feeding guidance and insightful understanding of the proposed antenna, which is prototype-earths at the 3.5-GHz bands for 5G applications.

11:00 ***Characteristic Mode Analysis of Split-Dipole for Dual-Layer Metasurface Lens Design***

Teng Li (Southeast University, China & Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)

A split-dipole-based unit cell is modeled with characteristic mode analysis for the dual-layer metasurface lens at Ka-band. The split-dipole is first analyzed to show the modal behaviors over the operating band. Then the first two modes are selected for reflectionless incidence by rotating the split-dipole with a certain angle. After that, a planar unit cell is developed for substrate implementation with a magnitude of transmission coefficient better than 0.72 and a phase shift range of 360°. As an example, a dual-layer metasurface lens with an aperture size of 162 mm × 162 mm and a focal length of 135 mm is designed at 30 GHz. The achieved results show the peak gain of 31.6 dBi at 30 GHz with an aperture efficiency of 45% which well verified the proposed method. The metasurface lens can be realized on a single-layer substrate which shows great potential for low-cost communication and radar applications.

CS14: (EuMA / EurAAP Session) EM and Active Electronics Modelling in Antenna Systems for 5G

T10 EM modelling and simulation tools / Convened Session / Antennas

Room: virtual 10

Chairs: Roberto Flamini (Huawei Technologies, Italy), Renato Lombardi (Milan Microwave Competence Center, Italy)

10:00 ***WAIM Design for 5G mmWave Phased Array and Its Effect on Power Amplifiers***

Roberto Flamini and Angelo Milani (Huawei Technologies, Italy); Valentina Verri (Huawei Technologies Italia S. R. L., Italy); Christian Mazzucco (Huawei Technologies, European Research Center, Italy); Claudio Massagrande (HUAWEI Technologies, Italy)

A metamaterial WAIM (Wide Angle Impedance Matching) layer for 5G mmWave phased array is proposed demonstrating its beneficial role not only for the improved Active Impedance matching that reflects on the Realized Gain when steering to large angles, but also for the improved efficiency of the Power Amplifier (PA) that is capable to deliver higher power due to the better matching of the load (i.e. sub-array). The combination of these two improvements has been measured to provide more than 2dB increment in the radiated power when steering to large angles.

10:20 ***Design of ME-Dipole Antennas for 5G Phased Array Applications at 28 GHz***

Giuseppe Scalise, Luigi Boccia and Emilio Arnieri (University of Calabria, Italy); G. Amendola (Universita della Calabria, Italy); Mohadig Rousstia, Alireza Shamsafar, Junlei Zhao, Domenico Calzona and Sergio Pires (Ampleon Netherlands BV, The Netherlands)

Phased arrays are one of the most critical blocks in 5G networks. In the case of the point-to-multipoint link, they have to provide beam reconfigurability over a large scanning range while maintaining a low profile and a limited cost. Moreover, operation at millimeter wave frequencies poses several critical challenges especially in terms of integration and, in turn, analysis. This work provides an introduction to the different simulation challenges involved in the design of a phased array differentiating them into two categories: i) cross-domain effects due to the different integration and packaging technologies present in the array along its vertical dimension and ii) mutual coupling effects taking place across the array horizontal dimension. As a design example, an ultra-low profile Magneto Electric (ME) dipole antenna design for 5 G applications is reported.

10:40 ***Experimental Verification of a 5G Active Metasurface Antenna with Beam Steering Capabilities***

Cristian Della Giovampaola (Wave Up srl, Italy); Francesco Caminita (Wave-Up SRL, Italy); Giuseppe Labate (Wave Up S. R. L., Italy); Enrica Martini and Stefano Maci (University of Siena, Italy)

This work describes the experimental validation of a reconfigurable leaky-wave antenna based on an array of periodically modulated metasurface channels for 5G applications. A representative reduced version of the full antenna was fabricated using standard PCB techniques and tested in the anechoic chamber. The results show a good agreement between simulation and measurements in terms of both beam steering and active element modeling.

11:00 ***Improving the Spectral Efficiency of Array for 5G Massive MIMO by Exploiting a Triangular Lattice***

Francesco Dicandia (IDS - Ingegneria dei Sistemi SpA, Italy); Simone Genovesi (University of Pisa, Italy)

The benefits of exploiting a triangular-lattice arrays employed in massive MIMO systems is addressed. Performance comparison with respect to a square lattice planar array has been carried out within 5G NR n257 and n258 frequency band. Particular attention is paid to illustrate the effect of the array lattice at the system level by evaluating significant figure of merits such as the Sum Spectral Efficiency (SSE), Signal to Interference Ratio (SIR) and array gain. The observed advantages offered by the triangular arrangement of antenna elements in terms of improved gain and SSE as well as the thermal aspect make it appealing for massive MIMO 5G applications.

11:20 ***Millimeter-Wave Vertical Transitions Between Ridge Gap Waveguides and Microstrip Lines for Integration of MMIC with Slot Array***

Qiannan Ren, Ashraf Uz Zaman, Jian Yang and Vessen Vassilev (Chalmers University of Technology, Sweden); Carlo Bencivenni (Gapwaves AB, Sweden)

This paper presents two low-loss vertical transitions between ridge gap waveguides and microstrip lines. The transitions can be utilized as packaging techniques for system level integration of MMICs with waveguide components such as slot array antennas. Both vertical transitions feature microstrip lines being the bottom layer but facing opposite directions. The first vertical transition consists of a microstrip line facing upwards with a patch in the end. Simulation results show that the reflection coefficient is better than -15 dB from 74 to 82 GHz. The second transition of microstrip line facing downwards features E-plane probe with back-short cavity surrounded by periodic pins. Simulation results show that the reflection coefficient is better than -15 dB from 71 to 86 GHz. Comparing with other same layer transitions, the vertical solutions provide more flexibility for the routing of antenna feeding line and have the ability of implementing a more compact design.

T11-M02: NearField & FarField Antenna Measurements

T11 Fundamental research and emerging technologies / / Measurements

Room: virtual 11

Chairs: Zhichao Chen (Volkswagen AG, Germany), Francesco Saccardi (Microwave Vision Italy, Italy)

10:00 ***Sampling Effect on Radiation Characteristics of Automotive 5G Antenna in Spherical-Near-Field Test Range***

Zhichao Chen (Volkswagen AG, Germany)

Since integrated antennas are strongly coupled with the vehicle body structures, antenna measurements on vehicle level are necessary to accurately characterize the antenna performance. Due to large Fraunhofer regions of typical vehicles, especially at higher frequencies for mobile communications, near field measurement ranges are in many cases implemented. This contribution addresses a sampling requirement issue during the spherical near-field measurement of automobile integrated antennas. The measurement results demonstrate a significant deviation on measured radiation patterns and total radiated power (TRP) value of an integrated automobile antenna by using 1° and 10° sampling step in spherical near field measurements. Therefore, a sufficiently fine sampling step is necessary to guarantee a correct measurement results of radiation characteristics in spherical-near-field test range. In this paper a 5G antenna integrated on vehicle roof is taken as an example, but note that the phenomenon mentioned here is not limited to a specific antenna type.

10:20 ***Fast Multi-Probe Planar near Field Measurements with Full Probe Compensation***

Francesco Saccardi (Microwave Vision Italy, Italy); Nicolas Gross (MVG Industries, France); Per Iversen (Orbit/FR, USA); Kim Hassett and Joel Hartzell (MVG Orbit/FR, USA); Tim Schellenberg (MVG Orbit/FR, Italy); Gennady Pinchuk (MVG, Israel); Roni Braun and Lior Shmidov (Orbit/FR, USA); Shai Solomon (MVG Orbit/FR, Israel); Meng He and Xavier Bland (MVG, Hong Kong); Lars Foged (Microwave Vision Italy, Italy)

The measurement needs for space and military industries are constantly evolving, and more often require the characterization of electrically large and multi-port antennas. Planar Near-Field systems (PNF) offer advantages over other test solutions, at the cost of longer acquisition time. The use of multi-probe technology to partially replace slow mechanical scanning is a proven solution to reduce the measurement time. In PNF systems, the effect of the probe must be compensated to achieve sufficient measurement accuracy. The standard calibration used in multi-probe systems provides equalized on-axis probe responses in amplitude/phase and polarization. The probe pattern is approximated from a separate calibration of the probe array elements before installation. Unfortunately, this approach can be time consuming and expensive. A novel technique to determine the multi-probe pattern for accurate PNF compensation is presented. The calibration process is explained and validated by experiment using measurements conducted in a recently installed planar multi-probe system.

10:40 ***Robustness Analysis of the Planar Wide-Mesh Scanning Technique Against Measurement Errors***

Francesco Saccardi and Maria Alberica Saporetti (Microwave Vision Italy, Italy); Ruben Tena Sanchez (Technical University of Madrid, Spain); Lars Foged (Microwave Vision Italy, Italy); Francesco D'Agostino, Flaminio Ferrara, Claudio Gennarelli and Rocco Guerriero (University of Salerno, Italy); Damiano Trenta (European Space Agency, ESTEC, Italy)

Non-redundant near-field scanning methodologies are based on optimal sampling interpolation expansions to reconstruct the field at any point in space. The Planar Wide-Mesh Scanning (PWMS) methodology allows faster measurements than standard Nyquist-compliant acquisitions. The methodology has no accuracy loss and has been validated at different bands and with different antennas in error-free scenarios. In this paper, the robustness of the PWMS methodology is tested against four error sources: probe XY position errors, multiple reflections, cable errors, and room scattering. The errors are included in the 18-terms lists considered by the measurement community as an exhaustive list of the NF errors. These errors are typically unknown and dependent on the mechanical uncertainties and particular setup. The validation has been done considering real measurements with different setups in combination with errors added in post-processing. The good agreement of the results in comparison with standard scanning demonstrates the robustness of this methodology.

11:00 ***Measurement of the Rotational Speed of Industrial Wind Turbine Blades Using a Low Cost 24GHz Doppler Radar***

Youngjae Choi, Yongbin Kim and In-Sik Choi (Hannam University, Korea (South))

The 24 GHz Doppler radar is widely used in various industrial sites to implement a measurement system for the rotational speed of wind turbine blades at a low cost. In this study, a method for measuring the rotational speed of industrial wind turbine blades using a 24 GHz Doppler radar was proposed. Synthetic and measurement data were used to verify the accuracy of the proposed algorithm. The output power (EIRP) of the radar is 19 dBm, the IF-amplifier gain is 40 dB, the 3 dB beam width is 33 degrees, the antenna gain is 15 dBi, and the time sampling rate is 40 ksps. The measured target is an industrial wind turbine with an output of 1,650 kW, a diameter of 82 m, and a rated rotation speed of 14.4 rpm. Experimental results show that the proposed method accurately estimates the rotational speed from both composite and measurement data.

11:20 ***Development of Closed-Form Formula for Quick Estimation of Antenna Factor***

Mohammad G. H. Alijani (Ferdowsi University of Mashhad, Iran); Shahin Sheikh and Ahmed Kishk (Concordia University, Canada)

In this paper, a novel method is introduced to compute the antenna factor parameter. The proposed approach is based on the equivalence concept of electric field radiation source and the receiver antennas in which the response at the antenna terminal is calculated efficiently with a simple equivalent circuit model. The most significant parameters affecting the antenna factor, such as polarization mismatch, reflection coefficient, antenna impedance, and the ground effect are considered. To verify the accuracy of the introduced method, four antennas are examined, and the obtained results are compared.

T11-E02: FSS and Metasurface Modelling and Design

T11 Fundamental research and emerging technologies / / Electromagnetics

Room: virtual 12

10:00 ***A Rotationally Symmetric Miniaturized and Stable Frequency Selective Surface Structure***

Zhangjian He, Yu Shao and Changhong Zhang (Chongqing University of Posts and Telecommunications, China); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

A rotationally symmetric miniaturized low profile frequency selective surface (FSS) is proposed in this paper. The FSS unit is composed of convoluted dipoles, and the hexagonal elements are arranged obliquely to form a compact FSS. An equivalent circuit model is presented to demonstrate the working mechanism of the FSS. To further reduce the size, the similar patterns are etched on both sides of the substrate, and the two metallic layers are connected by vias. By iteratively increasing the layers and metallic vias, the resonant frequency will be greatly reduced. The proposed miniaturized FSS attains good stability for different polarization angles and incident angles.

10:20 ***An Innovative and Simple Impedance Matching Network Using Stacks of Metasurface Sheets to Suppress the Mismatch Between Antennas and RF-Front-End Transceivers Circuits***

Mohammad Alibakhshikenari (Università degli Studi di Roma "Tor Vergata", Roma - ITALY, Italy); Bal Virdee (London Metropolitan University, United Kingdom (Great Britain)); Ayman A. Althuwayb (Jouf University, Saudi Arabia); Francisco Falcone (Universidad Publica de Navarra, Spain); Ernesto Limiti (University of Rome Tor Vergata, Italy)

A innovative and simple LC impedance matching-network implemented by stacks of metasurface (MTS) impedance-sheets is proposed which exhibits reduction of the mismatch between two media with different characteristics. The MTS-based matching-network with cascaded impedance-sheets is modeled as a transmission-line loaded with shunt and series capacitances and inductances. The proposed MTS-sheets can be employed as impedance matching-network between antennas and RF-front-end transceivers circuits to optimize their transmission properties such as maximize efficiency and reduce wastage of power. Each impedance-sheet has designed by a 2-D periodic-array of dielectric-resonator unit-cells based on MTS. The MTS-based unit-cells on the sheets are constructed of square-patches including etched cross-shaped slots and via-holes connecting the top surface to the bottom ground-plane throughout the FR-4 substrate layer. When taking into account the MTS-properties, performances such as bandwidth, gain and efficiency have substantially improved, which confirm the validity of the proposed impedance matching-network for application in RF-front-end transceivers circuits.

10:40 ***A Uniplanar Substrate Integrated Waveguide Based on Edge-Coupled Complementary Split-Ring Resonators for Millimeter-Wave Components***

Maria - Thaleia Passia and Traianos Yioultsis (Aristotle University of Thessaloniki, Greece)

We propose a novel uniplanar substrate integrated waveguide (SIW), based on edge-coupled complementary split-ring resonators (EC-CSRRs) for designing mm-Wave components. A different metamaterial-inspired SIW, utilizing broadside-coupled CSRRs (BC-CSRRs), has already been presented in our previous work, exhibiting low losses, comparable to those of the SIW, a fully-planar form and a relatively simple fabrication process. Our new version of the SIW, the EC-CSRR SIW, is accompanied by a significantly simpler manufacturing process, as the EC-CSRRs are etched only on the top plane of the substrate, avoiding possible misalignments of the upper and lower CSRRs. The EC-CSRR SIW is uniplanar, with losses comparable to those of the BC-CSRR SIW and conventional SIW, provides the potential of using thicker substrates, and yields a promising platform for realizing mmWave components, such as periodic leaky-wave antennas.

11:00 ***Broadband Artificial Magnetic Conductors Constructed of Magnetically Coupled Elements***

Pavel Petrov, Alastair Hibbins and John Sambles (University of Exeter, United Kingdom (Great Britain))

An Artificial Magnetic Conductor (AMC) is a type of metamaterial that can be used to enhance the performance in several antenna and microwave design applications. In this work we propose an analytical approach for size and bandwidth optimization of AMCs constructed of magnetically coupled elements Numerical results (obtained using COMSOL) for the optimized structure demonstrate performance close to the theoretical limit.

11:20 ***Perfect Non Specular Reflection with Polarization Inversion by Using Anisotropic Metasurface Sheet on a Grounded Dielectric Slab***

Cristina Yepes, Camilla Tondi, Marco Faenzi, Enrica Martini and Stefano Maci (University of Siena, Italy)

This paper presents and exact solution for a perfect conversion of a TE-polarized plane wave into a TM-polarized plane wave using a reciprocal and lossless penetrable metasurface reactance on top of a grounded dielectric slab. The incident plane wave has an arbitrary angle of incidence and is redirected towards a non specular direction, providing a reflected plane wave at an arbitrary angle. The exact solution is found by considering the TE0 and TM-1 Floquet wave (FW) only in the FW expansion associated to the periodic problem, whose periodicity is associated with the interference between the two modes along the direction of propagation. The coefficients of all the other modes in the FW expansion vanish, still respecting the conservation of power and the boundary conditions.

CS7: Assessment and Modeling of Antennas and Radio Channels Jointly

T11 Fundamental research and emerging technologies / Convened Session / Propagation

Room: virtual 13

Chairs: Ke Guan (Beijing Jiaotong University, China), Alain Sibille (Telecom Paris, France)

10:00 ***Directional Sub-THz Antenna-Channel Modelling for Indoor Scenarios***

Brecht De Beelde, David Plets, Emmeric Tanghe and Wout Joseph (Ghent University & IMEC, Belgium)

In this paper, sub-THz channel sounding is discussed for indoor scenarios. A directional D-band channel sounder, operational in the full band ranging from 110 to 170 GHz, is presented. We examine the influence of the antenna characteristics on the channel sounder. The channel sounder is used for Line-of-Sight path loss (PL) modelling at sub-THz frequencies for distances up to 4 m. Validation measurements confirm the small beamwidth of the antenna, ranging from 12 degrees for 110 GHz to 11 degrees for 170 GHz. An antenna de-embedding methodology is presented. Fitting Line-of-Sight PL at center frequency 140 GHz to a one-slope model gives a reference PL of 76.0 dB at 1 m and a PL exponent of 1.9. The reference PL is slightly higher than free space PL, whereas the PL exponent is slightly lower.

10:20 ***The Equivalence and Realization of Neural Network and Finite Differences Time Domain***

Yuhang Zhao, Danping He, Ke Guan, Bo Ai and Zhangdui Zhong (Beijing Jiaotong University, China)

Finite Differences-Time Domain (FDTD) is a proven method for numerical calculation and simulation of the electromagnetic field. However, the speed of FDTD slows down dramatically as the size of the simulation space increases. To tackle this problem, two convolutional neural networks, with explainable weights (CNN-A) and unexplainable weights (CNN-B), are proposed in this paper. Numerical examples and comprehensive analysis are provided to benchmark these two networks. The results and analysis demonstrate that CNN-A can reduce the time cost by 20.8% with 100% accuracy compared to the traditional FDTD method. After training with a few samples, CNN-B can reach satisfying accuracy with average 19.8% decrement of time cost comparing with the traditional FDTD method.

10:40 ***Statistical Modeling of WBAN Channels in Indoor Environments Based on Measurements and Ray Tracing***

Badre Youssef (Télécom ParisTech-Institut Mines-Télécom & LTCI, France); Christophe Roblin (Telecom ParisTech & LTCI - Institut Mines-Télécom, France)

In this article, we assess the influence of the indoor environment on the on-body channel for three radio links of Wireless Body Area Networks (WBAN). The purpose is to realize an analysis and statistical modeling with a large number of samples of premises and locations of subject within rooms. To avoid time consuming with experimentations, the adopted approach is to combine measurements, electromagnetic simulations and data (Channel Transfer Functions) from a simplified Ray Tracing code. The measurements realized in Anechoic Chamber enable to validate the EM simulations which are also complementary data considering the limitations of the experimentations (i.e. antenna measurements for elevations far from the azimuth). The code allows to sample with a large flexibility a huge number of environment and subject positions inside the rooms with significant Experimental Designs.

11:00 ***Statistical Modeling of the Human Body as an Extended Antenna***

Thomas Wilding and Erik Leitinger (Graz University of Technology, Austria); Ulrich Muehlmann (NXP Semiconductors, Austria); Klaus Witrisal (Graz University of Technology, Austria)

In this paper we investigate the possibility of modeling a single antenna alone and in close proximity to a physical object by means of discrete point source scatterers. The scatter point model allows joint modeling of a physical antenna and the human body as a single extended object with direction dependent scattering coefficients for the scatter points. We introduce the term extended antenna describing antenna and human body together. To investigate the identifiability of the model parameters we make use of ultrawideband channel measurements and accurate ground truth position and orientation measurements obtained with an optical tracking system. By comparing measurements of the antenna attached directly to the user with measurements for the antenna without the user nearby, we show the shadowing and scattering effects of the human body and the antenna.

11:20 ***Measurement of the V2I Massive Radio Channel with the MaMIMOSA Sounder in a Suburban Environment***

Davy P Gaillot, Pierre Laly, Nor El Islam Dahmouni and Gauthier Delbarre (University of Lille, France); Matthias Van den Bossche (University of Ghent, Belgium); Gunter Vermeeren and Emmeric Tanghe (Ghent University, Belgium); Eric P. Simon (IEMN CNRS UMR8520, France); Wout Joseph (Ghent University/IMEC, Belgium); Luc Martens (Ghent University, Belgium); Martine Liénard (University of Lille, France)

This paper presents the first V2I channel sounding campaign with the real-time MaMIMOSA massive radio channel sounder. This equipment has been jointly developed by ULille (FR) and UGhent (BE) for 5G V2X applications. The system is equipped with a massive 64-antenna array for Tx whereas up to 8 individual antennas can be deployed for Rx. The MaMIMOSA hardware and software capabilities allow to freely adapting the sounding parameters to the investigated scenario demonstrating its versatility and flexibility. Radio channels were measured at 5.89 GHz with 80 MHz bandwidth at the ULille campus using with a vehicle speed up to 60 km/h. In addition to this suburban mobility scenario, Obstructed Line-Of-Sight static radio channels were collected for a roadside to parking setup to study the influence of vegetation. Very preliminary Doppler characteristics are reported from the measured radio channels. A deeper analysis will be included in the final paper.

SW02: Challenges of Modern Material Measurements

Amedeo Capazzoli

Room: virtual 14

Thursday, March 25 11:40 - 12:10

IW09: Efficient full wave EM simulation of automotive radar and communication systems (IMST)

Room: virtual 14

Winfried Simon, IMST

Thursday, March 25 11:40 - 13:40

P3: Thursday Interactive Posters

Room: Posters

Chair: Christoph Herold (Technische Universität Braunschweig, Germany)

Design of Wide-Scan Lens Based Focal Plane Arrays for Sub-Millimeter Imaging Systems

Huasheng Zhang, Shahab Oddin Dabironezare, Muhan Zhang and Nuria LLombart (Delft University of Technology, The Netherlands)

Large format focal plane arrays (FPAs) of lenses are candidates for wide field of view sub-millimeter imagers. Recently, a spectral technique based on Coherent Fourier Optics has been proposed for analyzing such lens based FPAs in reception in order to facilitate the optimization via a field matching with the lens feed pattern. Based on this theoretical frame work, two practical lens antenna geometries based on silicon and plastic lenses combined with leaky-wave feeds are proposed and compared here. The synthesized lens based FPAs achieved scan losses much lower than the ones predicted by standard formulas related to the direct field coming from the reflector. In particular, the proposed silicon and plastic lens based FPAs achieved scan loss of about 1.7 and 3.4 dB, respectively, while scanning up to 20 degree with directivity of 52 dBi. The technique is validated via full-wave simulations and Physical Optics codes with an excellent agreement.

Imaging System Trade-Offs for Lens Based Focal Plane Arrays with Distributed Absorbers

Shahab Oddin Dabironezare (Delft University of Technology, The Netherlands); Juho Luomahaara (VTT Technical Research Centre of Finland, Finland); Nuria LLombart (Delft University of Technology, The Netherlands)

In this paper, the system trade-offs for imagers with focal plane array of lenses coupled to distributed absorbers are derived. Coherent Fourier Optics methodology is employed to characterize the coupling between the lens array and the Quasi-Optical system. An existing absorber based imager is considered here as a reference and its performance is compared to the one of the proposed lens absorber. It is shown that the performance of the two imagers are comparable in terms of aperture efficiency, point spread function, and normalized throughput while the plane wave response of the lens absorber is significantly narrower. As a result, lens absorbers are much less sensitive to the thermal noise of their surroundings. Moreover, the proposed lens absorber design achieves 5 times better sensitivity to distributed incoherent sources due to its smaller physical size. The results shown here are validated using full wave simulation with excellent agreement.

3D Luneburg Lens Antenna with Layered Structure for High-Gain Communication Systems

Maral Ansari (Level 6, Building 11, UTS, 81 Broadway & University of Technology Sydney, Australia); Bevan Jones (Level 6, Building 11, UTS, 81 Broadway, Australia); Negin Shariati and Y. Jay Guo (University of Technology Sydney, Australia)

A novel spherical Luneburg lens antenna is presented providing high efficiency, multiple beams and dual polarization. The lens is constructed of planar layers of light-weight foam with conducting cubic inclusions of different sizes located on an equally spaced three-dimensional (3D) orthogonal grid. This structure makes for simple manufacture of the lens and reduces the cost and weight which have been major problems with Luneburg lenses in the lower frequency microwave bands. A dual +- 45 degree-polarized square waveguide is used as the lens source to demonstrate the dual-polarization beam scanning capability of the lens. A prototype lens antenna operating in the 3:3 to 3:8 GHz band has been designed, fabricated and tested. Measured results show that the lens can achieve multiple beams in both planes with a scanning loss of less than 0.8 dB, a peak gain of 23 dBi, and a radiation efficiency of better than 90%.

A New Solution for GRIN Lenses

Anastasios Paraskevopoulos and Francesca Maggiorelli (University of Siena, Italy); Shiyu Zhang and J (Yiannis) Vardaxoglou (Loughborough University, United Kingdom (Great Britain)); Matteo Albani and Stefano Maci

(University of Siena, Italy)

In this paper, a new solution for the design of GRIN lenses is proposed based on geometrical optics. The expression of the refractive index profile n(ρ) is extracted in closed form, which is valid for a very large range of GRIN lens parameters (focal distance F, the thickness d, and the maximum refractive index n(0)). The maximum path error from the equalization of all the ray paths using the new design formulas is compared with the literature and it is found to be one order of magnitude smaller. The explicit formula for the refractive index can lead to the calculation of the aperture efficiency of the lens, which allows an automatic optimal design for a standard feed pattern without the need for optimization algorithms.

Modeling of Path Loss Characteristics in a Waveguide-Like Structure Scenario at 28 GHz

Qidu Song, Pan Tang and Tao Jiang (Beijing University of Posts and Telecommunications, China); Lei Tian (Beijing University of Posts and Telecommunications & Wireless Technology Innovation Institute, China); Jianhua Zhang (Beijing University of Posts and Telecommunications, China); Jianwu Dou (ZTE Corporation, China)

Radio wave propagation in a waveguide-like structure scenario performs a specific path loss characteristic which is termed as waveguide effect. In this paper, we analyze the path loss characteristics in a waveguide-like structure scenario based on channel measurements at 28 GHz. First, three different modeling methods, including the waveguide approach, ray-tracing approach, and empirical approach, are compared and validated with the measurement results. This study suggests that the empirical dual-slope channel model can give a more accurate prediction of path loss with minimum root mean square error (RMSE). Secondly, the influence of the geometry position of antennas on path loss is investigated by using the dual-slope path loss model. Comparative analysis results reveal that a stronger waveguide effect exists when placing the antenna close to the wall and when having antenna height difference, horizontal measurements at different line-of-sight distances confirm the analysis that waveguide effect exists after the breakpoint.

Measurement of Millimeter-Wave 3D MIMO Channel in Large Indoor Environment

Qiongyang Guo, Yang Wang and Xi Liao (Chongqing University of Posts and Telecommunications, China); Chun Jin (Chongqing University of Posts and Telecommunications, United Kingdom (Great Britain)); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain)); Jiliang Zhang (The University of Sheffield, United Kingdom (Great Britain))

Three-dimensional (3D) multiple-input multiple-output (MIMO) and millimeter wave (mm-wave) are key technologies for the future wireless communication. This paper proposes a channel measurement method for millimeter wave 3D MIMO channel. Using the uniform rectangular array (URA) and vector network analyzer (VNA), measurement of 3D MIMO channel is carried out in a large conference hall. Subsequently, the power angle delay profile (PADP) of line-of sight (LOS) and non-line of sight (NLOS) is extracted from the measured data. The analysis is extended to a multi-user scenario in which virtual URA is used as the base station to work with users at different altitudes under LOS and NLOS conditions. Measurement results shows that the multipath resolution can be improved when the antenna height is close to each other. These findings can provide valuable experimental basis for 3D MIMO channel modeling of massive antenna elements.

RIS-Enabled mmWave Channel Sounding Based on Electronically Reconfigurable Transmitarrays

Alfred Mudonhi (CEA Leti and Universite Catholique de Louvain & Universite Grenoble-Alpes, France); Marina Lotti (CEA-LETI, France); Antonio Clemente (CEA-LETI Minatec, France); Raffaele D'Errico (CEA, LETI, Minatec Campus & Univ\. Grenoble-Alpes, France); Claude Oestges (Université Catholique de Louvain, Belgium)

In this paper we present a millimeter wave radio channel sounding campaign, enabled by Reconfigurable Intelligent Surfaces (RISs). The measurement setup is based on electronically reconfigurable transmitarray (TA) composed by 400 unit-cells. Optimal phase distributions were implemented in order to operate a beam scan over 120 degrees. Two indoor scenarios were investigated in the Ka Band, exploiting the beam scanning capabilities of the antenna. The results in terms of path loss and delay spread are presented and discussed.

XBee Latency Analysis for the Drones Mounted Machine Control over the Wireless Communication Channel

Da Si, Robert Michael Edwards and Yu Geng (Loughborough University, United Kingdom (Great Britain))

In this paper, a method for the study XBee latency is researched. Study of an XBee radio link is important when considering machine control over wireless. Furthermore, knowledge of an XBee latency probability distribution is useful in the simulation of machine control over wireless. In this research, a camera gimble, typical of those used by expert observers with drones was proposed as the machine control activity. The test bed used was created using two XBee IEEE 802.15.4 MaxStream modules in a point to point configuration. In drone mounted machine control over an XBee channel a controller sends command messages to a flying drone. Lower latency in camera control yields shorter reaction times for camera operators and a more comfortable operation experience for untrained expert observers.

Implementation of Optimal Transmitting Sources for Radiative-Wireless Power Transmission Using Practical Antenna Arrays

Joon-Hong Kim (Seoul National University, Korea (South)); Taewoo Yu (Seoul National University & INMC, Korea (South)); Sangwook Nam (Seoul National University, Korea (South))

In this study, research on the methodology that effectively implement theoretical current distributions as practical antenna arrays is described. An optimization technique using genetic algorithm is applied to sample the theoretical current distribution. As a results, the proposed thinned arrays show improved performance compared to the same number of densely arranged regular arrays. It is revealed that the use of optimization technique has advantages in cost, weight, efficiency than the same number of the regular array.

Textile Rectenna for RF Energy Harvesting

Fábio Silva and Rita Almeida (Instituto Superior de Engenharia de Lisboa, Portugal); Carolina T. S. Gouveia (Instituto de Telecomunicações, Aveiro & University of Aveiro, Portugal); Caroline Loss (Universidade da Beira Interior, Portugal); Pedro Pinho (IT - Instituto de Telecomunicações & ISEL - Instituto Superior de Engenharia de Lisboa, Portugal); Daniel Belo (Universidade de Aveiro & Instituto de Telecomunicações, Portugal)

Wearable devices are part of many people's lives, however the batteries they need are a major limitation. In order to solve this problem, an energy harvesting system was studied and implemented, to replace the battery usage and thus enhance the device portability. It is composed by two antennas, one for transmitting and the other for receiving, and a rectifier circuit. The system was completely developed in textile, allowing the integration into the user's clothing.

Analyzing and Maximizing the Power Harvesting Efficiency of a Textile Rectenna Through Reflector-Based Shielding

Mahmoud Wagih, Alex S Weddell and Stephen Beeby (University of Southampton, United Kingdom (Great Britain))

Wearable rectennas harvest power from off-body sources; shielding mechanisms such as microstrip antennas' ground planes are typically used to reduce absorption by the body. This work investigates the use of unconnected reflectors to improve textile rectennas' harvesting capabilities. A high-efficiency rectenna using a textile-based rectifier, achieving over 40% RF-DC efficiency from −20 dBm power, and a monopole is investigated with different clothing layers in the presence and absence of a reflector. It is shown that a textile reflector can improve the DC output of a rectenna, on an external clothing layer, by over 100% through improving the measured gain by 2.4 dB. However, for rectennas with less than 2.0 mm clearance from the body, a reflector can have detrimental effect on the rectenna. The proposed reflector-backed rectenna achieves a wearable harvesting efficiency of 40%, from an ultra-low power density of 0.3 μW/cm 2, demonstrating significant sensitivity improvement over state-of-the-art rectennas.

Performance Evaluation of Automotive Radar in the Presence of Bumper with Multiple Paint Layers Using Bidirectional Loss Model

Jogesh Chandra Dash, Mihir Parikh, Nancy Modi and Jayanta Mukherjee (Indian Institute of Technology Bombay, India); Sajitha Vr and Tejomurtula SaiDeepak (Daimler-Mercedes Benz Research and Development India, India); Vivek Dhoot (Daimler-Mercedes Benz Research & Development India, India)

In this paper, we propose a mathematical model to compute the bi-directional loss of an automotive radar in the presence of a bumper with multi-layered paint. The proposed model uses a physical optics (PO) based approximation for the reflective and dielectric losses. The model takes into account the shape of the bumper and compares it with a proprietary algorithm. The model is applied on a six-element microstrip array antenna placed behind a curved bumper, with and without the presence of multiple paint layers. The bidirectional loss, in the broad-side direction, as obtained from the model is 4.6 dB due to the presence of the bumper with a single paint layer and 8.8 dB when the number of paint layers is five.

MIMO-TDL Model Parameter Estimation from V2I Channel Sounding

Nina Hassan (Ilmenau University of Technology, Germany); Diego Dupleich (Technische Universität Ilmenau, Germany); Christian Schneider and Reiner S. Thomä (Ilmenau University of Technology, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

This contribution proposes modeling methods for MIMO-TDL channel models under new evaluation method, which is non-WSSUS. V2X channels cannot be assumed to follow the WSSUS assumption due to high inherent mobility. It can be extended to non-WSSUS by employing an ON/OFF process (persistence process). An algorithm to select taps and estimate their parameters from measured data is illustrated. Meanwhile, the slow and fast fading is separated from received signal to assess the fading distribution of taps. The analysis investigates correlation coefficient among taps persistence process, as well as, among taps amplitude. Additionally, an approach is discussed to develop a time varying MIMO-TDL model, whose parameters are varying over time.

Wave-Physical Factors Determining the Link Quality in ITS-G5 Studied with Field-Operational Tests

Berk Altinel (Technische Universitat Ilmenau, Germany); Christian Bornkessel (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

Even though vehicular communication systems have been rolled out in road, they remain a prominent field of research and development. The functional and operational safety of vehicle-to-X system demands reliable and efficient methods for verification and validation, based on their functional principles and underlying wave-physical phenomena. To test such systems in virtual environment, we have undertaken empirical studies of the communication channel, to analyze parameters like distance and sight conditions in a rich multipath environment. This paper describes the results and conclusions derived from a set of field-operational tests along a track, with modules operating with ITS-G5. While the results confirm the expectation that field-operational tests aren't reproducible on a quantitative level, we have gained insight into fundamental constraints on the channel parameters and approaches towards emulation in virtual environment. Employing omni-directional roof-mounted antennas, we have observed reliable communication links for ranges up to 250 meters, independent of sight conditions.

On the End-To-End Latency of Cellular-Connected UAV Communications

Hong Zhu and José Rodríguez-Piñeiro (Tongji University, China); Zeyu Huang (Vienna University of Technology (TU Wien), Austria); Tomás Domínguez-Bolaño (University of A Coruña, Spain); Xuesong Cai (Aalborg University, Denmark); Xuefeng Yin (Tongji University, China); Juyul Lee (ETRI, Korea (South)); David W Matolak (University of South Carolina, USA)

Unmanned Aerial Vehicles (UAVs) have been widely used in military and civilian fields in the recent years. In order to give support to the vast amount of added value services, UAV communications have become a hot spot for the fifth generation (5G) and have a very broad development prospect. In this paper, based on the channel modeling results obtained by actual measurements, we evaluate the end-to-end delay of Long Term Evolution (LTE) for air-to-ground (A2G) communications in suburban environments. The results show that, in order to satisfy the reliability and latency requirements of the critical communications, the base stations (BSs) deployment and the flight routes need to be carefully considered since small increments on the flight distance can have great influence on the packet success rate and the end-to-end delay. The obtained results are of great importance to evaluate if current LTE deployments can support critical communications for cellular-connected UAVs.

Broadband and Wide-Angle Microwave Metamaterial Absorber with Effective EM Wave Absorption in the S-, C-, X- and Ku-Band

Yixian Fang and Zhirun Hu (University of Manchester, United Kingdom (Great Britain))

A broadband microwave metamaterial absorber with wide-angle property is introduced in this paper. The bandwidth of effective absorption (over 90% absorptivity) of the proposed absorber is from 2.2 GHz to 18.4 GHz, covering almost the whole S-, C-, X-, and Ku-band, with relative absorption bandwidth of 157%. The total thickness of the proposed absorber is 15 mm, which corresponds to 0.11λ at the lowest operating frequency. To provide wide-angle and broadband frequency matching, a wide-angle impedance matching layer is used in the unit cell design. The proposed absorber can realize more than 80% absorptivity for TE polarization and more than 90% absorptivity for TM polarization from S-band to Ku-band when the incident angle is less than 50°. Equivalent circuit method is used to analyze the proposed absorber and the circuit model analysis results agree quite well with the numerical full-wave simulation.

Ku-Band Dual-Mode Filter Designed in Microstrip Gap Waveguide Technology

Luis Inclan-Sanchez (University Carlos III of Madrid, Spain)

A new version of a dual-mode filter based on microstrip gap waveguide technology is proposed in this paper. The analyzed filter consists of a square ring with a perturbation that produces the coupling of two degenerate modes. In this new configuration, the effect that some of the main parameters have on the filter's bandpass response is studied. This work shows by means of some examples the possibility of designing filters of reduced size in inverted microstrip gap waveguide technology. Two filters have been implemented in the Ku band with a 3 dB fractional bandwidth of 9.3% and 8.6%. The minimum simulated insertion losses for the filters have been 0.4 dB and 0.5 dB respectively. This novel proposal presents an inherent packaging capability and also allows the implementation of bandpass filters with very low losses and increased selectivity.

Radar Cross Section Reduction Using Intertwined Structures

Juan Andrés Vásquez Peralvo and Jose Manuel Fernández González (Universidad Politécnica de Madrid, Spain); Jonathan Michael Rigelsford (The University of Sheffield, United Kingdom (Great Britain))

A thin Non-absorptive Radar Cross Section Reducer (NARR) surface capable of redirect the scattered energy to different directions is presented. The NARR surface is composed of interwoven Unit Cells, which have the main characteristic of allowing ultra-miniaturized structures. This feature allows more Unit Cells to be placed in a given area, thus improving frequency response over flat, curved or small areas. To generate the interweave, two Brigid's Cross and two hexagonal cross interwoven structures are used for square and rhombus surfaces, respectively. These structures, disposed in a checkerboard arrangement, are used to generate a destructive phase difference in a bandwidth range of 180 +/- 37-degree, which allows to obtain a Radar Cross Section (RCS) Reduction below -10 dB. The simulation results for monostatic and bistatic RCS are analyzed and compared with the case of a PEC surface.

Rapid Alignment of High-Accuracy Reflector Panels Used in Compact Antenna Test Ranges Based on Laser Tracker and Dial Indicator

Wang Mingming, Ye Mengxue and Li Dongsheng (Beihang University, China); Cheng Xin (23th Institute of China Aerospace Science and Industry Corporation, China)

The assembly and alignment of large-scale and high-accuracy reflector used in compact antenna test ranges (CATR) face great challenges. To address these challenges, a closed-loop alignment system is established based on 6-DOF adjustment mechanism, laser

tracker and digital dial indicator. Under the cooperation of the three components, the adjusting and positioning resolution of the system can reach 1μm. A large-scale reflector used in the CATR with 5m quiet-zone is quickly aligned using the alignment system within two weeks, and the RMS of profile deviation of the reflector with 11.7m width and 10.32m height reached to 27μm. Compared with the manufacturing accuracy of 24 microns, the panel profile accuracy loss caused by the assembly and alignment process is only 3 microns. Compared with 24μm manufacturing deviation of the whole reflector, the accuracy loss caused by the assembly and alignment process is only 3μm.

A Dual-Band Deployable Cassegrain Reflector Antenna for Space Applications

Keyur K Mistry and Manisha Kushwaha (Oxford Space Systems, United Kingdom (Great Britain)); Debbie Fellows (Wave RF, United Kingdom (Great Britain)); Tao Huang, Juan Reveles and Steve Hamer (Oxford Space Systems, United Kingdom (Great Britain)); Paul Greenway (European Space Agency, United Kingdom (Great Britain)); Arturo Martin Polegre (European Space Agency, The Netherlands)

This paper presents a dual-band deployable Cassegrain reflector antenna, that operates in K-band for reception and Ka-band for transmission. The antenna achieves gain of approximately 38 dBi in K-band and 42 dBi in Ka-band. The antenna fits into a stowed volume of 2.15U CubeSat and weigh approximately 2.6 kg. The paper also demonstrates different design stages that were involved in achieving the proposed antenna system. Furthermore, the simulated system level performance calculated in CST as well as in HFSS are compared and presented in this paper.

Theoretical Design of a Holography Horn for the Surface Accuracy Testing of a Large Cassegrain Antenna at Ku-Band

Christophe Granet (Lyrebird Antenna Research Pty Ltd, Australia)

The theoretical design of two optimized horn options to test the surface accuracy of a large Cassegrain reflector antenna through the use of the holography technique is presented. Two different horn concepts are actually considered: a smooth-walled spline-profile horn and a spline profile corrugated horn.

Compact and Highly Efficient Single and Dual Polarized Aperture Antennas with Integrated Multiport Overmoded Excitation

Charalampos Stoumpos (Thales Alenia Space & Heriot-Watt University, France); Jean Philippe Fraysse (Thales Alenia Space, France); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Ronan Sauleau (University of Rennes 1, France); Cebrian Gonzalez (Idonial, Spain); Hervé Legay (Thalès Alenia Space, France)

This paper presents a new type of radiating horn-like radiating element which exploits a two- or four-port integrated overmoded power division depending on the aperture type and the requirement for single- or dual-polarization. The general concept is illustrated by two design examples which are proposed in this paper at Ku-Tx band (10.7 - 12.75 GHz); a single-polarized two-access rectangular aperture pyramidal horn and a dual-polarized four-access square aperture horn feed antenna. The operational principles address a power divider which feeds two or four flared waveguide sections which are further connected to a bi- or quad-furcated surface discontinuity for the combination of the incoming fields. Finally, a common waveguide region on top completes the total topology. This type of radiating elements exhibits a compact profile, while at the same time achieves high aperture efficiency (over 90%) due to robust materialization of the desired aperture modal content over a bandwidth of 20%.

On the Link Between Leaky-Wave Mechanism and Parasitic Resonances Observed in a Reflecting Periodic Surface Made of Phoenix Cells

Guillaume Courtin (Université Rennes, INSA Rennes & IETR, France); Raphael Gillard and Renaud Loison (IETR & INSA, France); Hervé Legay (Thalès Alenia Space, France); Priscillia Daquin (CNES, France)

This communication investigates a parasitic resonance with strong losses that is exhibited by a periodic structure composed of 4 th order Phoenix cells on top of a metal-backed dielectric slab. The physical origin of the phenomenon is examined through simulations. This study shows that this parasitic resonance is linked to a trapped wave propagating in the structure. It corresponds to a leaky-wave mechanism occurring under certain conditions. In order to avoid such undesired resonances, a design rule is derived which defines a new constraint on the cell periodicity.

Performance Evaluation of 2D Vs 4D Surrogate Models of Reflectarray Unit Cells Based on Support Vector Regression

Daniel R. Prado (Universidad de Oviedo & Signal Theory and Communications, Spain); Jesús López-Fernández and Manuel Arrebola (Universidad de Oviedo, Spain)

Surrogate models of reflectarray unit cells are usually generated employing a number of input variables such as geometrical features of the cell, frequency and angles of incidence. Here we show how surrogate models based on support vector regression can be improved by removing their dependence on the angle of incidence. This is done by grouping the reflectarray elements under a relatively small set of incidence angles. Thus, instead of generating models with the angles of incidence as input variables, models are obtained per angle of incidence pair, reducing dimensionality to improve their performance without significant impact on the reflectarray analysis accuracy.

Comparative Study of Different Approaches to Analyze Unit Cells of Reflectarray Antennas

Andrés Gómez-Álvarez and Borja Imaz-Lueje (Universidad de Oviedo, Spain); Daniel R. Prado (Universidad de Oviedo & Signal Theory and Communications, Spain); Manuel Arrebola and Marcos R. Pino (Universidad de Oviedo, Spain)

We present a comparative study of reflectarray antenna analysis using two different techniques. Two different reflectarrays are simulated, with an isoflux pattern and with a squared-cosecant pattern in elevation and sectored-beam in azimuth. Each antenna is analysed using two techniques to obtain the reflection coefficients matrix. Both techniques are based on the Floquet theorem assuming local periodicity. First, we use the commercial software HFSS to analyze reflectarray cells based on two stacked rectangular patches. The finite element method of HFSS is employed. The second method is an in-house ad hoc method of moments (MoM). In all cases, each reflectarray element is analyzed considering the real angle of incidence instead of the common approach of using normal incidence curves. Results show good agreement between the two approaches for the computation of the reflection coefficients as well as for the prediction of both the copolar and crosspolar components of the radiation patterns.

Simple Analytical Model of Pixel for Reflectarray Antennas

Shahin Sheikh and Ahmed Kishk (Concordia University, Canada)

A simple analytical model is provided for fast analysis of reflectarray (RA) antennas. The RA pixels are analytically modeled to generate the frequency response against the angle of incidences; thereby, the RA performance can be better predicted with respect to the frequency and feed positions. The analytically computed solutions are compared with the exact solutions of the periodic pixels. The model shows an acceptable performance. Then, some analytical models are provided for 1D, and 2D RAs and radiation patterns are calculated for different feed positions within a frequency band.

Spiral Antenna with a Miniaturized Circular HIS Reflector

Masahiro Tanabe (Toshiba Infrastructure Systems & Solutions Corporation, Japan)

This paper presents the radiation characteristics of a spiral antenna backed by a miniaturized circular HIS reflector (CirHISR), consisting of a circular dielectric substrate printed on fan-shaped patch elements and perfect electric conductor (PEC). The CirHISR size reduction of 20% is realized, compared to the reference CirHISR. The analysis is performed using the method of moment. It is found that constant input impedance and lower axial ratio are obtained across the frequency range of 3 - 10 GHz.

Time Domain Analysis of Compact, High Gain UWB Cavity-Backed Monopole Antenna

Mahrukh Khan (The College of New Jersey, USA); Benjamin Bissen (University of Missouri-Kansas City, USA); Anthony Caruso (University of Missouri - Kansas City, USA)

A compact (115 x 115 mm2) cavity-backed monopole unidirectional ultrawideband (UWB) antenna is proposed. The proposed antenna's impedance bandwidth is around 90 % from 1.5-4 GHz. A prototype has been fabricated, and measurement results were obtained. The measured gain of the cavity backed antenna is 10 dBi at 2.4 GHz, which shows an improvement of 6dB (approx) compared to a traditional monopole antenna. The effect of the cavity in the antenna's structure has been discussed. Monopole antennas are known for showing good time domain behavior. It has been demonstrated that the cavity backed UWB antenna is capable of sending narrow Gaussian pulses in the face to face configuration with acceptable (,i.e., > 0.8) fidelity factor and uniform group delay with variations less than 2 ns. The proposed UWB antenna is suitable for many wireless applications because of its good radiation characteristics and reasonable performance in time domain.

Multi-Layer Multi-Dielectric Lens Loaded SIW Horn Antenna for Ku-Band Applications

Sunil Kumar Sahoo (IIT Kanpur, India); Moitreya Adhikary (Indian Institute of Technology Kanpur & IIT Kanpur, India); Animesh Biswas (IIT Kanpur, India); Mohammad Jaleel Akhtar (Indian Institute of Technology Kanpur, India)

This paper presents a wide-band substrate integrated waveguide (SIW) horn antenna with enhanced gain and front to back ratio (FTBR) for Ku-band applications. The proposed antenna is realized by placing an elliptical multi-layer multi-dielectric lens (EMLMDL) at the radiating aperture of a probe-fed thin (h1 = λ0/13) SIW H-plane horn antenna. The top and bottom layers of the EMLMDL are realized by high-k dielectric material having relative permittivity 10.2, where as the middle layer is the extension of SIW horn aperture. This three layer arrangement reduces the aperture mismatch over a wide frequency band and improve gain and FTBR while maintaining the overall thickness of EMLMDL to 0.2λ0. The proposed antenna exhibits measured impedance bandwidth of 34% (12.9-18 GHz). The end-fire radiation pattern is fairly stable over the entire Ku-band with FTBR better than 12 dB. The peak gain variation over the operating band is 8.5-11.0 dBi.

Dual-Polarized Filtering Antenna for Mm-Wave 5G Base Station Antenna Array

Zeeshan Siddiqui (University of Oulu & Centre for Wireless Communications, Finland); Marko Sonkki (Private Sector, Finland); Kimmo Rasilainen and Jiangcheng Chen (University of Oulu, Finland); Markus Berg (University of Oulu & Excellant LTd., Finland); Marko E Leinonen and Aarno Pärssinen (University of Oulu, Finland)

This paper presents a dual-polarized filtering antenna designed for a 5G mm-Wave base station phased array. The out-of-band radiation of a stacked patch antenna is suppressed by embedding filtering structures along with radiating patches and feed network. Four radiation nulls can be tuned by introducing a combination of open-loop and hairpin resonators at appropriate locations, and a bandpass filtering response can be achieved. The antenna design principles and simulated performance are discussed. The antenna operates in n257 and n258 mm-Wave bands, demonstrating -10 dB impedance bandwidth at 24.25-29.5 GHz. The realized gain remains stable between 5 and 6 dBi at all the operating frequencies. The isolation between the ports and cross-polar discrimination remain better than 20 dB in all the covered frequency range.

Design and Characterization of an Open-Ended Cavity-Backed Quasi-Yagi Antenna

Sander J Verdiesen, Ulf Johannsen and Ad Reniers (Eindhoven University of Technology, The Netherlands)

In the near future, lightweight racing bicycles will be equipped with wireless cameras. These wireless cameras will communicate with the control vehicle via an aircraft flying at an altitude of up to seven kilometers. With the current antenna, a monopole, it is not possible to bridge the distance to the aircraft with sufficient signal strength. The new antenna must achieve more gain over a specific opening angle, which places demands on the half-power beamwidth. Furthermore, the antenna must be dual-polarized, small and lightweight. It is shown that a quasi-Yagi antenna is a particularly suitable antenna type. The final antenna design exhibits a half-power beamwidth of 77° in the E-plane and the H-plane and a gain of 7.5 dBi. The realized antenna weighs 33 grams.

Printed Ridge Gap Waveguide Based Radome Antenna for K-Ka Applications

Abdelrahman Taha and Abdelmegid Allam (German University in Cairo, Egypt); Mohamed Fathy Abo sree (Arab Academy For Science and Technology Engineering Faculty & AASTMT Company, Egypt); Walaa Wahba (Military Technical College, Egypt)

In this paper, PRGW based bow-tie aperture antenna loaded with radome structure is presented for K-KA applications. Five different radome configurations with different sizes are proposed, including single bow-tie shape, three layers of bow-tie, rectangular and hemispherical geometrical shapes. Three different substrate materials with relative dielectric constants of 2.94, 3.3 and 6.45 are implemented. Different thicknesses are used for different configurations for the sake of optimising the antenna gain. The structure is simulated based on Finite Difference Time Domain (FDTD) analysis; CST Microwave Studio and Finite Element Method(FEM); Ansoft HFSS for validation of the results. It is found that the radome structure of hemispherical geometrical shape with total radius 18.4 mm equally divided over the three layers; achieves maximum overall gain. It enhances the gain by 52\% relative to the structure without radome. It operates from 26.5 GHz up to 33.4 GHz.

Design of Compact SIW Cavity Backed Self-Triplexing Planar Slot Antenna for Triple Band Application

Soumava Mukherjee (Indian Institute of Technology Jodhpur, India); Sourav Ghosh (Indian Institute of Technology, Jodhpur, India); Animesh Biswas (IIT Kanpur, India)

A novel design technique of planar triple band self-triplexing Substrate Integrated Waveguide (SIW) cavity backed slot antenna is presented. The proposed antenna uses three separate feeding ports to excite three SIW cavity modes into the proposed design. A dumbbell shaped slot antenna placed at top metallic plate is excited by these modes to radiate at corresponding resonant frequencies in C, X and Ku band. The behaviour of the proposed SIW cavity modes are analyzed with the help of half mode theory to predict the resonant frequencies of the proposed antenna. The fabricated prototype of the antenna resonates at 6.76 GHz, 8.62 GHz and 13.33 GHz and exhibits unidirectional radiation pattern with a gain of 3.78 dBi, 4.46 dBi, 5.6 dBi at three resonant frequencies respectively. The proposed antenna maintains a high isolation of better than 15 dB between its three excitation ports while retaining its compact configuration.

Off-Centre Fed Dipole Suppressing the Radiation of the Feed-Line by a Load Impedance at an Arbitrary Point

Serafin Benedikt Fischer (University of Stuttgart, Germany); Jan Hesselbarth (University of Stuttgart & IHF -- Institute of Radio Frequency Technology, Germany)

When feeding a straight dipole radiator asymmetrically with a differential line, not only the two unequal dipole arms radiate, but also the feed-line itself radiates together with all possible components connected to it. This is because of the partially non-balanced currents on the two feed-line conductors. Therefore, the feed-line contributes significantly to the radiation and its length changes the antenna input impedance. In this work it is shown, that an asymmetrically driven dipole can be neutralized in terms of feed-line radiation by loading the dipole with a suitable impedance at an arbitrarily chosen position.

3D Printed and Metallized Ka-Band Orthomode Transducer for Polarimetric Radar Applications

Tim Freialdenhoven (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Patrick Witte (Fraunhofer FHR, Germany); Thomas Dallmann (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany)

An orthomode transducer allows the combination or separation of orthogonal waveguide modes. This paper presents a stepped orthomode transducer (OMT) for Ka-band, developed for polarimetric radar applications to reduce the number of antenna elements. The

OMT is produced by stereolithography 3D printing and then manually metallized with conductive paint. A CST simulation model is presented, which considers mechanical and manufacturing related constraints such as electrical conductivity and surface roughness. For applying the conductive paint, a split block design with two halves and a constructive gap, which was also accounted in the simulation, is developed. The impact on the performance compared to a lossless and monolithic structure is analyzed. A sample of the 3-port OMT is fabricated and measurements are performed. The comparison of the simulated and measured S-parameters shows that the designed structure works as intended and the correspondence of the model with reality is sufficient.

Novel GNSS 3D-Printed Ceramic Antenna Qualified for Smallsat Applications

Gautier Mazingue (Anywaves, France); Louis Mangenot and Stephane Roy (ANYWAVES, France); Nicolas Capet (ANYWAVES FRANCE, France); Maxime Romier (Anywaves, France)

This paper reports the design and qualification of a novel GNSS antenna for SmallSat applications. The antenna features a 3D-printed structured ceramic substrate, enabling to achieve a compact and efficient RF design. Harsh mechanical and thermal tests are set to demonstrate its robustness to space environment. This is an important milestone for the 3D-printed ceramic technology with various applications foreseen for space antennas.

Chipless Frequency-Coded RFID Tags Integrating High-Q Resonators and Dielectric Rod Antennas

Tom Burmeister and Alejandro Jiménez-Sáez (Technische Universität Darmstadt, Germany); Masoud Sakaki (University of Duisburg-Essen, Germany); Martin Schüßler (TU Darmstadt, Germany); Jesús Sánchez-Pastor (Technische Universität Darmstadt, Germany); Niels Benson (Institute for Nanostructures and Technology (NST), University of Duisburg-Essen, Germany); Rolf Jakoby (Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany)

A possible passive infrastructure for mm-wave self localization systems is proposed in this paper. W-band photonic crystal based high-Q resonators coupled to free space by a dielectric rod antenna are employed. Q-factors of approximately 300 and wireless tag readout over 10 cm can be achieved using Rogers RT/duroid RO 6010.2LM. The maximum readout range increases to 40 cm when lower-loss additively manufactured Alumina tags are used. Development of a 3 bit prototype tag is successful, demonstrating the possibility to increase the number of resonators per tag using the presented approach.

Graphene Inkjet-Printed Ultrawideband Tapered Coplanar-Waveguide Antenna on Kapton Substrate

Isidoro Ibanez-Labiano, Shohreh Nourinovin and Akram Alomainy (Queen Mary University of London, United Kingdom (Great Britain))

This paper presents an ultra-wideband graphene antenna with tapered coplanar-waveguide feed. The proposed antenna covers the 2.7-8.2 GHz bandwidth (2.6-10 GHz measured), with two main resonance frequencies at 3.1 and 5.5 gigahertz (3.1 and 5.8 measured). Simulations show a radiation pattern that looks quasi-omnidirectional with a maximum gain limited to 3.15 dBi and efficiency above 84.7%. In order to post-process the graphene ink and to provide flexibility, Kapton Polyimide is used as a substrate. The flexibility, as well as the lightweight and ease in the fabrication of accurate designs, turns this antenna into a suitable candidate for wearable and flexible wireless applications.

Small Antenna with Stable Impedance and Circular Polarization

Soheyl Soodmand, Mark Beach and Kevin A Morris (University of Bristol, United Kingdom (Great Britain))

Variations in antenna impedance with respect to frequency significantly reduces the isolation bandwidth in some modern 5G communication systems like In-Band Full Duplex (IBFD) transceivers. A frequency independent antenna with a core structure of equiangular Archimedean spiral is designed to achieve impedance stability in frequency domain. The antenna impedance at an ultra-wideband (UWB) frequency range of 1.5GHz to 4GHz is more smoothened in some design steps to achieve an stable impedance using electromagnetic absorbers, capacitive impedance tuning and modification techniques whilst this small antenna also has circular polarization, electromagnetic compatibility, and suitable radiation efficiency.

Small Antenna at 5.4 GHz for 11 mm Telemetry-Unit in Harsh Environment

Loic Bernard and Nelda Etienne-Baroun (ISL, France); Façal Saada (ISL, USA)

The design of a small patch antenna in C-band is presented; it is dedicated to the instrumentation of a 20 mm caliber projectile with a telemetry unit. The antenna diameter is 0.2 λ at 5.4 GHz. This antenna includes some metallized vias through the whole antenna, to be used also as a connector for the onboard electronics. Their presence don't degrade the radiation properties neither the polarization. This antenna was used in a few firings, endorsing accelerations of 45 000 g and spin rate of 900 Hz. Its survival and its good function during the projectile flight were demonstrated.

Optimization Approach to Reduce the Emission Signal to the Vehicle Antenna of an 100BASE-T1 ECU

Emanuel Panholzer (University of the Federal Armed Forces Munich & Mercedes-Benz AG, Germany)

In automotive industry the interaction from novel technical features like new communication systems (e.g. 100BASE-T1) leads to undesired interaction with the vehicles antennas. The reason is the increasing packaging density of the electrical components while also the used frequency increases. In this work easy to determine parameters for critical cable routings and cable length considering the undesired interaction with the vehicle antenna are analyzed. Furthermore, the application is shown for the example of an Automotive Ethernet ECU, which interacts with the vehicle antenna.

Posters_S: Best Paper Awards - Poster Session - Student

Room: Posters2

Efficient Aperture Illumination and Beamforming with Huygens' Metasurfaces Exciting Surface Waves

Vasileios G. Ataloglou and George V. Eleftheriades (University of Toronto, Canada)

Huygens' metasurfaces allow for extreme wave manipulation of the incident fields. Their ability to shape the electromagnetic wavefronts have made them a promising platform to build antenna systems without complicated feeding networks. However, for conventional passive and lossless Huygens' metasurfaces, the power density of the incident and output fields should be locally conserved. This requirement poses limitations to the amplitude of the output fields, especially if the radiating source is placed close to the metasurface. In this paper, a method is proposed to bypass these limitations and design Huygens' metasurfaces with nonlocal response. The method relies on surface waves that redistribute the power in the input side of the metasurface. The usefulness is demonstrated through the design of a radiating aperture with directivity beyond that of conventional metasurfaces. Furthermore, a physical Huygens' metasurface is designed to realize a singly-fed Taylor aperture antenna, verifying the potential of accurate and efficient beamforming.

Analysis and Efficient Design of Sub-THz Transmitarrays with Three Anisotropic Layers

Orestis Koutsos (IETR & CEA Leti, France); Francesco Foglia Manzillo (CEA-LETI, France); Antonio Clemente (CEA-LETI Minatec, France); Ronan Sauleau (University of Rennes 1, France)

In this paper, we study the transmission behavior of a three-layer architecture comprising anisotropic FSS layers with applications to the optimal design of transmitarray (TA) antennas. We employ a theoretical analysis considering the depolarizing properties of the middle layer. We derive a condition showing that we can cover the full phase of transmission achieving at the same time zero insertion loss (IL). Lastly, a 3-bit 40×40 TA is realized at 300 GHz, based on the previous analysis. The antenna is able to attain a maximum gain of 35.1 dBi with an aperture efficiency of 64.8%, which is only 0.5 dB less than the ideal case of a TA with full transmission and perfect phase compensation.

Millimeter Wave Material Measurements for Building Entry Loss Models Above 100 GHz

Jochen Jebramcik and Jonas Wagner (Ruhr-Universität Bochum, Germany); Nils Pohl (Ruhr-University Bochum & Fraunhofer FHR, Germany); Ilona Rolfes and Jan Barowski (Ruhr-Universität Bochum, Germany)

In this paper typical building material transmission measurement results up to 300 GHz are presented. This research is done, in order to further advance building entry loss models and estimations for frequency ranges beyond the current ITU recommendations, which are limited to 100 GHz. For this purpose, a quasi-optical measurement setup is provided to investigate on reflection and transmission properties of e.g. bricks, concrete, drywall, and wooden materials. A special focus is laid on window glass panels, since it is expected that free apertures contribute the most to the total transmission into and out of buildings in this range. The setup is based on a vector network analyzer with millimeterwave extensions and is fully calibrated. The transmission attenuation is measured and an attenuation coefficient is extracted from the measurement.

The Interpath Relation for Spatially-Discrete Traveling-Wave Modulated Structures

Cody Scarborough (University of Michigan, USA); Anthony Grbic (University of Michigan, Ann Arbor, USA)

Traveling-wave modulation has been employed since the 1950s for amplification and frequency conversion, and more recently for beam-steering and breaking reciprocity. Typically, traveling-wave modulation is realized by applying a staggered bias/pump signal to an array of discrete unit cells. This is referred to as spatially-discrete traveling-wave modulation (SD-TWM). SD-TWM structures can prove challenging to simulate due to their often complex geometry and extreme temporal variation. Here, we examine a relation established within SD-TWM structures referred to as the interpath relation. The interpath relation reveals that the solution within a single unit cell (as opposed to an entire spatial period) is sufficient to determine the entire problem. The interpath relation is then incorporated into a method of moments solver to compute the scattered field produced by a representative SD-TWM metasurface. The presented method simplifies the computation of both physical patterned designs, as well as nearly continuous idealized structures.

Investigation of Direction of Arrival Estimation Using Characteristic Modes

Lukas Grundmann and Nikolai Peitzmeier (Leibniz University Hannover, Germany); Dirk Manteuffel (University of Hannover, Germany)

A method is proposed to estimate the direction of arrival (DoA) of a traveling wave from characteristic mode weighting coefficients. These are obtained from the currents through the ports positioned on an antenna structure. The additional insight into the behavior of the antenna structure gained by the modal analysis is utilized to create a set of ports that allows to use a single conducting structure for the direction finding. It is shown that the proposed method works for a cubic antenna structure with 20 uncorrelated ports with good accuracy for any DoA.

Thursday, March 25 12:10 - 13:40

IW03: Efficiently Simulating Connected Systems in Complex Environments: From Antenna Design & Placement on Sub-System Level to Communication between Systems of Systems (Altair)

Room: virtual 14

Dr. Markus Schick, Altair

Thursday, March 25 13:10 - 13:40

IW11: State-of-the-Art Test Methods for the Comprehensive Evaluation of Module and Vehicle Mounted Antenna-Dependent ADAS Features (ETS Lindgren)

Room: virtual 13

Janet O'Neil:; Garth D'Abreu; Ram Mirwani (ETS Lindgren)

Thursday, March 25 13:40 - 14:25

Inv5a: Invited Speaker Session:

Characteristic Modes for Antenna Analysis and Synthesis

Miloslav Capek

Room: virtual 1

Chairs: Stefania Monni (TNO Defence Security and Safety, The Netherlands), Andrea Neto (Delft University of Technology, The Netherlands)

13:40 *Characteristic Modes for Antenna Analysis and Synthesis*

Miloslav Capek (Czech Technical University in Prague, Czech Republic)

From its humble beginning featuring only a few applications in scattering theory, characteristic mode decomposition has evolved into a well-established paradigm implemented as a powerful numerical method in contemporary EM simulation packages. The theory has attracted significant attention over the last 20 years and established itself as a unique tool providing additional physical insights into radiation mechanism. In recent years, there has been rapid progress in research related to the use of characteristic modes for the design, modeling and optimization of advanced and novel antenna systems. Systematic procedures using characteristic modes have been proposed for antenna design in a wide range of applications (MIMO, RFID, 4G/5G and beyond, IoT, body area networks, array antennas, etc.). The talk will review the properties of the characteristic modes and their advantages, as well as discuss recent breakthroughs, especially those focusing on novel features. Special emphasis will be placed on the extensions of the theory and its generalization. The talk will conclude with a discussion of open problems and future challenges.

Inv6a: Invited Speaker Session:

Antenna-in-Package (AiP) Technology

Zhang Yue Ping

Room: virtual 2

13:40 *Antenna-In-Package (AiP) Technology*

Yue Ping Zhang (Nanyang Technological University, Singapore)

Antenna-in-package technology integrates an antenna or antennas with a radio or radar transceiver die (or dies) into a standard surface mount package. AiP technology well balances performance, size, and cost. Hence, it has been widely adopted by chip makers for highly integrated radios and radars. It is the antenna and packaging technology for the fifth generation (5G) cellular networks and beyond operating in the millimetre-wave (mmWave) bands. This talk will provide an overview of the development of AiP technology. It will consider antennas, packages, and interconnects for AiP technology. It will show that the antenna choice is usually based on those popular antennas that can be easily designed for the application and that the materials and processes choices involve tradeoffs among constraints, such as electrical performance, thermal-mechanical reliability, compactness, manufacturability, and cost. This talk will also show a probe-based setup to measure mmWave AiP impedance and radiation characteristics. It goes on to highlight flip-chip AiP (FC-AiP) and fan-out AiP (FO-AiP) with examples.

Thursday, March 25 14:25 - 15:10

Inv5b: Invited Speaker Session:

Over-the-Air EVM measurements with a VNA

Joel Dunsmore

Room: virtual 1

Chair: Stefania Monni (TNO Defence Security and Safety, The Netherlands)

14:25 *Over-The-Air EVM Measurements with a VNA*

Joel Dunsmore (1400 Fountaingrove Parkway & Keysight Technologies, USA)

This talk will present latest results in over-the-air (OTA) measurements of an active phased-array antenna's performance, focusing on the precision EVM measurement method introduced in 2020 at the German Microwave Conference (GeMic 2020), but now applied in an OTA environment. This method, using a wideband modulated source, and VNA as a receiver, provides a precisely calibrated input signal to the antenna-under-test and can characterize its performance for EVM and other non-linear attributes. Of particular interest is the ability to extend the dynamic range of the measurement through coherent time averaging, allowing the EVM of individual phase-array elements to be characterized in a situation where the signal would normally be lost in the noise floor using traditional methods. The paper will present measurements of a 64-element electronically steerable antenna in the 37-40 GHz band, measured on boresight, at various beam angles, and characterized also element by element, with comparison to traditional methods.

Inv6b: Invited Speaker Session:

Backscattering-based wireless communication and power transfer to small biomedical implants

Leena Ukkonen

Room: virtual 2

14:25 *Backscattering-Based Wireless Communication and Power Transfer to Small Biomedical Implants*

Leena Ukkonen (Tampere University, Finland)

In this presentation, we will focus on different aspects of backscattering based wireless communication and power transfer to small biomedical implants. We will present different antenna topologies for data and power transfer through tissue, in vitro and in vivo studies on implantable intracranial pressure (ICP) sensors and give insight and analysis on wireless link reliability in tissue environment. We will also present radio frequency identification (RFID) -based implant platform and communication method. Moreover, we will focus on differences and challenges of in vivo environment compared to laboratory phantoms and tissue models. In our studies, different types of implantable antennas have been tested to investigate reliability, accuracy and sensitivity of the brain implants: a hybrid near field-far field system with a piezoresistive sensor for ICP monitoring, a UHF band spilt-ring resonator system and LC tank based miniature implantable antenna. This presentation will explain these implant antennas and wireless power transfer in tissue environment present in human head.

Thursday, March 25 15:10 - 15:30

Coffee Break / Exhibition

Rooms: virtual 1, virtual 2, virtual 3, virtual 4, virtual 5, virtual 6, virtual 7, virtual 8, virtual 9, virtual 10, virtual 11, virtual 12, virtual 13, virtual 14, Posters

Thursday, March 25 15:30 - 17:10

T01-A01: 5G Antennas

T01 LTE and Sub-6GHz 5G / / Antennas

Room: virtual 1

Chair: Mohammad S. Sharawi (Polytechnique Montreal, Canada)

15:30 ***Future Antenna Requirements from a Network Operator's Perspective [INDUSTRIAL KEYNOTE]***

Ingo Willimowski (Vodafone, Germany)

The future antenna requirements from the perspective of a network operator's focused on passive and active antennas as well as technologies, like MIMO and beamforming, will be explained shortly. Some insights into the evolving area of Mobile Private Networks requiring indoor coverage and an outlook to Open RAN will be given.

15:50 ***A Wideband Polarization Grid Loaded Circularly Polarized Laminated Resonator Antenna***

Yaowei Hou, Yao-ping Zhang and Junfa Mao (Shanghai Jiao Tong University, China)

A novel wideband circularly polarized (CP) Laminated Resonator Antenna (LRA) is presented in this paper. First, a differential pair of L-probes is inserted into the LRA to excite the dominant mode TE x 011 of LRA for wide impedance bandwidth. Then, a frequency-insensitive dielectric polarization grid is placed in front of the LRA to obtain broadband CP radiation. The inhomogeneous property of the adopted grid can realize two orthogonal linearly polarized waves with a 90° phase difference and equal amplitudes within a wide operating band. Simulation results show that the proposed LRA achieves a CP bandwidth from 4.42 GHz to 5.75 GHz (26.16%) and a peak gain of 9.82 dBi. Featuring simple, low-cost structure and wideband characteristics, the proposed LRA is a promising candidate for the future fifth-generation (5G) communication systems.

16:10 ***Phased Array 5G Antenna Design with Petal-Shaped Beams and Improved Radiation Coverage***

Naser Ojaroudi Parchin (University of Bradford, United Kingdom, United Kingdom (Great Britain)); Yasir Ismael Abdulraheem Al-Yasir and Raed A Abd-Alhameed (University of Bradford, United Kingdom (Great Britain))

The focus of this study is to introduce a new technique to increase the radiation coverage of a phased array 5G antenna. The structure of the phased array design contains eight compact T-shaped slots with single directors, discrete feeding, and 1×8 linear arrangement on the edge of the mobile-phone PCB. By modifying the size of the employed radiators, the antenna is capable to provide petal-shaped beams at different scanning angles, which improves the radiation coverage of the 5G mobile-phone phased array. The elements of the design are etched on the same layer of the ground plane. The proposed array is highly compact which occupies less than 5 mm (clearance) of the PCB plane. The critical properties of the introduced phased array are investigated. The designed antenna exhibits wide beam-steering, high efficiencies, and sufficient gain levels at 28 GHz, the main 5G band.

16:30 ***Embedded Electronically Steerable SATCOM Aero Antenna Development for Clean Sky 2 Project***

Vesselin Peshlov (RaySat Bulgaria Ltd, Bulgaria)

This paper presents electronically steerable SATCOM aero antenna (E2S2A2) developed under Clean Sky 2 project (717164 - E2S2A2 - H2020-CS2-CFP02-2015-01). The Antenna is designed as embedded structure into the Wing to Fuselage Fairing (WFF) structure of the airframe of Airbus C295 aircraft. Custom designed multi-functional RFIC devices enable beam and polarization control in the antenna. The design is proven by successfully completed flight tests of the antenna prototype.

16:50 ***Multi-Function Pattern Reconfigurable Antenna for 5G Small Cell Base-Stations***

Saeed A. Haydhah (Concordia University, Canada & University of Cote d'Azur, France); Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France); Leonardo Lizzi (University Côte d'Azur, CNRS, LEAT, France); Mohammad S. Sharawi (Polytechnique Montreal, Canada); Ahmed A. Kishk and John Xiupu Zhang (Concordia University, Canada)

A new pattern reconfigurable 2×2 array antenna is proposed. The antenna has two modes of operation, Array Mode and Multiple-Input-Multiple-Output (MIMO) Mode. The single-element antenna used is a pattern reconfigurable U-slot antenna with four pattern configurations. An average efficiency of 80%, a peak gain of 9.4 dB, and an overlapped −10 dB impedance-bandwidth of 200 MHz around the resonant frequency 3.65 GHz are achieved. The size of the proposed antenna is 140×140×21 mm3, which is suitable for small cell base-stations. For the MIMO Mode, the antenna has a maximum ECC of 0.06 between the four patterns and a minimum isolation of 12.9 dB between the four ports. For the array Mode, the antenna has a peak gain of 12.5 dB, and steering angles for $0^\circ \le \theta \le 30^\circ$ in the planes at $\phi = 0^\circ$ and $\phi = 90^\circ$. Pattern reconfigurability is achieved using electrical switching. The used substrate is FR-4.

CS30b: Propagation of Smart Mobility Empowered by 5G and Beyond (Part 2)

T01 LTE and Sub-6GHz 5G / Convened Session / Propagation

Room: virtual 2

Chairs: Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany), Ke Guan (Beijing Jiaotong University, China)

15:30 ***Influence of Railway Infrastructure on Train-To-Train Communications***

Paul Unterhuber and Michael Walter (German Aerospace Center (DLR), Germany); Thomas Kürner (Technische Universität Braunschweig, Germany)

The future of railway operation will rely on train-to-train (T2T) communications. Hence, we investigate the propagation mechanisms based on channel sounding measurements and derive channel models for T2T communications. For every wireless communication, the environment significantly influences the wireless propagation. For railway environments, especially regular installed objects along track like overhead line masts cause pronounced multipath components (MPCs). In this paper, we analyze the MPCs from a T2T propagation measurement with two high speed trains. In detail, we extract the MPCs, identify the ones caused by overhead line masts and derive a distance-variant fading statistic for this kind of objects. Furthermore, we provide an outline on a T2T geometry-based stochastic channel model (GSCM) and how we incorporate the statistics of overhead line masts in the GSCM.

15:50 ***On-Campus Over-The-Air Millimeter-Wave Channel Evaluation for Connected and Automated Mobility***

Erik Kampert (WMG, University of Warwick, United Kingdom (Great Britain)); Elijah Adegoke (University of Warwick, United Kingdom (Great Britain)); Reiner Stuhlfauth (Rohde&Schwarz, Germany); Matthew D Higgins (University of Warwick, United Kingdom (Great Britain))

Highest throughput wireless communication between vehicles and infrastructure will rely on millimeter-wave carriers and technology, which provide access to large bandwidths whilst still being able to establish stable links over distances of hundreds of meters. The work presented here, evaluates the quality of such signals in a mini-urban campus environment, by comparing detailed channel sounding results with signal quality parameters such as the error vector magnitude and the established data throughput. This provides insights into the relationships between fundamental parameters used to establish channel models and the quality of service parameters used in applications and standards. For the environment investigated, a strong threshold dependence of the signal quality on the received power is observed and explained in detail.

16:10 ***Applicability of 5G Technology for a Wireless Train Backbone***

Pedro Aljama (Ikerlan, Spain); Aitor Arriola (IKERLAN, Spain); Imanol Martinez (IKERLAN-IK4 RESEARCH ALLIANCE, Spain); Iñaki Val (IKERLAN, Spain); Igor Lopez (Construcciones y Auxiliar de Ferrocarriles (CAF), Spain); Julio Manco and Jérôme Härri (EURECOM, France)

The migration of TCMS communications to a Wireless Train Backbone (WLTB) is one of the main goals of CONNECTA-2 and Safe4RAIL-2 projects of Shift2Rail initiative. In this paper the suitability of 5G technology for a WLTB is analyzed, both for infrastructure-based and V2X networks. Obtained results indicate that 5G technology is suitable for a WLTB, but in order to cover a large number of consists either high-end 5G configurations need to be used (e.g. 4x4 MIMO in millimeter waves) or the requirements for the WLTB need to be scaled down.

16:30 ***Bayesian Approaches to Multipath-Enhanced Device-Free Localization***

Martin Schmidhammer, Benjamin Siebler, Christian Gentner, Stephan Sand and Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany)

Device-free localization (DFL) systems infer presence and location of moving users by measuring user-induced perturbations in the signal power between wireless network nodes. Thereby, users not only induce perturbations to the power of the line-of-sight, but also to the power of reflected signals observed in the received signal as multipath components. Since the propagation paths of multipath components differ inherently from the line-of-sight path, these propagation paths can be considered as additional network links. This extended network determines the multipath-enhanced device-free localization (MDFL) system. Based on empirical models that relate perturbations in the power of multipath components to the user location, the localization problem can be solved by nonlinear Bayesian filtering. In this work, we therefore investigate the point mass filter and the particle filter as possible solutions. Using simulations, we demonstrate the applicability of these filter solutions for MDFL. The overall localization performance is comparable for both filters.

16:50 ***Measurement of Pathloss for Train Passengers in an Antenna Corridor***

Nima Jamaly and Daniel Wenger (Swisscom, Switzerland); Reto Schoch (Schoch Technik GmbH, Switzerland); Matthias Rohrer and Roger Jegerlehner (Swisscom AG, Switzerland)

In this paper, the measured median pathloss between the ports of a pencil-beam antenna as a base station antenna near the railway track (i.e., antenna corridor), and a dipole antenna onboard a train wagon is presented. The dipole antenna which represents a typical user equipment e.g., a laptop, a smart phone, tablet etc., was placed at a common passenger position. The selected wagon is an ordinary Swiss inter-city double-deck wagon recently equipped with RF-friendly windowpanes. Here our focus is the port-to-port median pathloss at around 3600 MHz band. The results highlight that the excess pathloss into the wagon compared to the line-of-sight free space pathloss with similar antennas is within the range 15-38 dB. We further address the polarisation pathloss imbalance present inside the wagon and quantify it. This imbalance is an outcome of the presence of non-rich multipath inside the wagons equipped with RF-friendly windowpanes. In the end, we show that the paths through the closest windowpane to the user equipment are likely the dominant ones and thus determining the pathloss.

T02-A07: mm wave integrated and planar antennas

T02 Millimetre wave 5G / / Antennas

Room: virtual 3

Chair: Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

15:30 ***A Cylindrical Coaxial-Fed Resonant Cavity Antenna with Off-Axis Beaming for 5G Applications***

Azita Goudarzi, Mohammad Mahdi Honari, Alireza Gharaati and Rashid Mirzavand (University of Alberta, Canada)

This paper presents a resonant cavity antenna (RCA) with a directive tilted beam at 28 GHz. A cylindrical waveguide fed by a coaxial probe is used as the main radiator to make a tilted beam. Besides, a proper single-layer partially reflective surface (PRS) is used to enhance the performance of the RCA structure in terms of making a directive pencil beam. A tilted beam at the angle of θ = 30 0 with a high gain feature is achieved over the desired bandwidth from 27.8 GHz to 28.5 GHz. The maximum gain is 15.8 dBi at 28 GHz. The proposed antenna is suitable for the millimeter wave wireless communications, radar systems and tracking technologies.

15:50 ***A Wideband Corrugated Leaky-Wave Feed with Low Cross-Pol for High Efficiency Lens Illumination***

Maria Alonso-delPino, Nick van Rooijen, Sjoerd Bosma and Nuria LLombart (Delft University of Technology, The Netherlands)

In this conference abstract we present a novel leaky-wave lens antenna feed that is suitable for wideband array applications at millimeter and submillimeter wavelengths. The antenna geometry consists of a waveguide with concentric corrugated rings on its aperture plane that illuminate an air-cavity and a low permittivity dielectric lens. The concentric rings on the waveguide aperture reduce the radiation of the non-desired TM0 mode which is usually present unless it is suppressed with a double-slot iris. With the TM0 reduction, this antenna feed presents highly axially symmetric radiated patterns, high aperture efficiency and very low cross polarization level over a band larger than 1:2 (67%). In this contribution we will present the design of a prototype that operates over the entire WR5 waveguide band.

16:10 ***Leaky-Wave Antenna with Beam Steering Capability Based on a Meandered Metallic Waveguide***

Constantin Constantinides (Alba Orbital, United Kingdom (Great Britain)); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain)); Samuel Rotenberg (Heriot-Watt University, United Kingdom (Great Britain)); Carolina Mateo-Segura (Heriot Watt University, United Kingdom (Great Britain)); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

We present a new concept for beam steering from the backward to the forward quadrant, at a fixed frequency, that minimizes the need for active, reconfigurable RF components. The compact structure may enable significant cost reductions and improved antenna efficiency when compared to more conventional beam steering approaches. The proposed 1-D leaky-wave antenna is a meandered metallic waveguide, embedded within a cavity exploiting the radiation from higher order Floquet space harmonics. This frequency scanning principle is adapted for fixed frequency operation at 20 GHz by mechanically modifying simultaneously all the lengths of the waveguide meanders. A scan range of 100° in the elevation plane is achieved by adjusting the height of the cavity. Realized gain values higher than 10 dBi are observed. We present here the theoretical principles for the design of such a fixed frequency, beam steering antenna and the corresponding results are validated by a commercial full-wave simulator.

16:30 ***Numerical Analysis of Huygens-Like On-Chip Antennas for Mm-Wave Applications***

Dmitrii Kruglov, Marianna Ivashina and Oleg Iupikov (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden)

Silicon technologies are preferred when it comes to en masse user equipment production, but the antennas in silicon suffer from high dielectric losses and strong substrate waves coupling. The use of a Huygens source as the antenna element has a potential of decreasing these negative effects, as was demonstrated in several non-silicon PCB designs. In this paper, we investigate if a similar performance enhancement can be achieved in thin back-gated silicon antenna chips. We present a numerical comparison of an electric dipole, a magnetic dipole and a Huygens source antenna at 120 GHz on a lossy silicon substrate sitting on a ground plane. Antennas are defined in MATLAB as distributed currents and imported as near-field sources into CST Microwave Studio. This way we treat the problem in a very general way without regards for any particular physical antenna implementations. Radiation efficiency and gain are shown as functions of substrate thickness.

16:50 ***RF Modeling and Measurement of a Novel Aperture-Coupled Hybrid Glass-Silicon 5G Antenna Array***

Thi Huyen Le, Marco Rossi, Ivan Ndip, Michael Kaiser, Charles-Alix Manier, Robert Gernhardt, Hermann Oppermann and Klaus-Dieter Lang (Fraunhofer IZM, Germany); Herbert Reichl (Fraunhofer Institute for Reliability and Microintegration, Germany)

In this work, the electromagnetic modelling and measurement of a novel aperture- coupled hybrid glass-silicon 1x2 antenna array is presented. Very good correlation is obtained between simulation and measurement.

T06-M01: UAV Measurements

T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / / Measurements

Room: virtual 6

Chairs: Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany), Simon Henault (Defence Research and Development Canada, Canada)

15:30 ***Conformal Sparse Image Reconstruction on Singly Curved Surfaces***

Niklas Wingren, Daniel Sjöberg and Mats Gustafsson (Lund University, Sweden)

This paper presents a mm-wave image reconstruction method designed for nondestructive testing of singly curved, thin composite panels. It extends a previously demonstrated imaging method from planar imaging to imaging conformed to a known singly curved geometry. The imaging algorithm allows for a reference-free measurement process and exploits sparsity in the specific imaging problem for performance benefits like high resolution and dynamic range. The method is tested on synthetically generated data and its performance is compared to a more lightweight time reversal based method. In this comparison, the images provided by our method have higher resolution, higher dynamic range and are influenced less by the curvature and medium of the device under test.

15:50 ***Post-Integration Antenna Characterisation for a V-Band Drone-Detection Radar***

Riana H. Geschke, Alex Shoykhetbrod, Ralf Brauns, Christopher Schwäbig, Stefan Wickmann and Sven Leuchs (Fraunhofer FHR, Germany); Christian Krebs (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Andries Küter (Fraunhofer FHR, Germany); Dirk Nüßler (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany)

A drone detection FMCW radar operating from 57 to 64 GHz band has one transmit and two receiving antennas with fan beams. Aspects related to board layout such as direct TX to RX coupling due to the close integration of the system and enclosure and packaging effects reduce the antenna beamwidths and may reduce antenna efficiency, as we demonstrate in this paper. Post-integration diagnostic methods to test the system performance related to the antenna system are presented. The concept of a combined or cumulative transmit-receive radiation pattern is introduced and used to determine the success of design measures to reduce antenna coupling. Radomes and enclosure options are compared using the system as a network analyser.

16:10 ***Compression Analysis and Measurement of Active Receiving Antennas***

Timothee Le Gall and Anthony Ghiotto (University of Bordeaux, France); Gwenael Morvan, Stefan Varault and Bruno Louis (THALES Defence Mission Systems, France); Gregoire Pillet (Thales Research and Technology, France)

Active antennas are of high interest for the emerging radar and telecommunication applications, including 5G and satellite megaconstellations. On the one hand, the non-linear analysis and measurement of active transmitting antennas are crucial, mainly due to the non-linear operation of the power amplifiers. Numerous papers addressing this topic can be found in the literature. On the other hand, to the authors' best knowledge, the non-linear analysis and measurement of active receiving antennas are scarcely reported in the literature. Likewise, they are of interest, specifically, to characterize such antennas under high-power unintentional or intentional spurious signals or to validate limiting circuit operations. Therefore, this paper is providing a theoretical analysis and measurement methodology to characterize the compression of active receiving antennas. For validation purpose, a demonstrator, operating at 2.45 GHz, was fabricated and measured using the proposed approach.

16:30 ***Antenna Measurement Drone for Over-The-Horizon Radar***

Simon Henault (Defence Research and Development Canada, Canada)

An antenna measurement drone was recently integrated by Defence Research and Development Canada to verify the performance of an over-the-horizon radar (OTHR) transmit array. This solution only uses off-the-shelf components and is very economical compared to alternative options. A calibration technique is also proposed and verified, making it possible for the drone to measure the phase of the OTHR array element patterns. These phase measurements are also useful to identify issues with individual array elements. Very accurate measured beampatterns are presented and are compared with theoretical predictions.

16:50 ***Setup and Error Analysis of a Fully Coherent UAV-Based Near-Field Measurement System***

Fabian T. Faul and Thomas F. Eibert (Technical University of Munich, Germany)

A UAV-based near-field measurement system for fully coherent and very flexible in-situ antenna measurements is presented. A laser tracker is utilized in order to determine the measurement locations with high precision and to overcome the existing limitations of real-time kinematic GPS positioning systems. In combination with a vector network analyzer, good measurement results can be achieved and are presented in the paper. Furthermore, two methods for the analysis of the measurement data are described.

T07-A02: Slotted Waveguide and leaky wave antennas

T07 Defence and security / / Antennas

Room: virtual 7

15:30 ***Direct Synthesis of Accurate Angular Filtering Patterns Using Holographic Leaky-Wave Antennas***

Jose-Luis Gómez-Tornero (Polytechnic University of Cartagena, Spain); Miguel Poveda-Garcia and Paula Vivo-Vera (Technical University of Cartagena, Spain); Rafael Verdú-Monedero (Universidad Politécnica de Cartagena, Spain)

We propose a new synthesis technique of angular filtering radiation patterns, using holographic leaky-wave antennas. The synthesis is based on the association of a set of N leaky waves with the response of a passband filter of order N. Compared to previous broad-beam synthesis techniques, the novel method provides accurate angular filtering specifications with demanding restrictions (ripple and rejection levels), and without numerical optimization.

15:50 ***A Short Channel Waveguide Stub-Loaded Leaky-Wave Antenna at Ku-Band***

Dovari Nagaraju (Research Center Imarat & DRDO, India); Yogesh Verma and Bivin Mathew (Research Center Imarat, India)

This paper presents a flush-mounted, short channel waveguide, stub-loaded, leaky-wave antenna at Ku-band. The antenna is designed with a slot length of 1.33 λ at the design frequency. The antenna can be synthesized for a given beam tilt by controlling the width of the waveguide and for a given beamwidth by controlling the length and width of the slot. The radiation efficiency and cross-polarization levels of the antenna are 97 % and -48 dB respectively. A thin dielectric of RT5880, with 31 mils thickness is used as the radome. The antenna is fed by waveguide to coaxial transition for realization and testing of the antenna. The comparisons of the simulation, measured results, and dispersion characteristics of the antenna have been reported. The beam tilt of 30 deg., the gain of 8.1 dBi, the beamwidth of 42 deg. in the longitudinal direction, and 160 deg. in transverse direction have been reported.

16:10 ***A Circularly-Polarized Zero Beam-Squinting Leaky-Wave Antenna Using NRI-TL Metamaterials with Increased Gain***

Kyriakos Neophytou, Kypros Kossifos and Marco A. Antoniades (University of Cyprus, Cyprus)

A circularly-polarized metamaterial leaky-wave antenna (LWA) at 5.5 GHz is presented, which exhibits zero beam-squinting (ZBS) at broadside with an increased gain. It consists of two oppositely-directed negative-refractive-index transmission-line (NRI-TL) LWAs. The two LWAs radiate their main beams in opposite directions, and the combination of the two beams results in a broadside beam. The two LWAs are fed through a NRI-TL balun that adds a 180 ◦ phase difference between the two output signals. The addition of the balun doubles the gain of the metamaterial LWA, and makes it circularly polarized. The gain of the antenna is 11.75 dBi at 5.5 GHz, 3.35 dBi higher compared to the antenna without the balun. The ZBS bandwidth of the antenna is 0.9 GHz, the axial ratio ranges from 1.1 to 1.4, and the average radiation efficiency is 80%.

16:30 ***Grating Lobe Reduction Using Tilted Beam Unit Cell in Series-Fed Patch Periodic Leaky-Wave Antennas***

Wasim Alshrafi, Amar Al-Bassam and Dirk Heberling (RWTH Aachen University, Germany)

It is known that series-fed patch (SFP) periodic leaky-wave antennas (P-LWAs) suffer from the grating-lobe issue, which appears at the higher frequencies as the main beam scans towards the forward direction. Here, we propose a novel solution using beam tilting of the unit-cell radiation pattern to mitigate this issue. This solution is realized by modifying the unit-cell structure using parasitic monopoles placed close to the patch element in the H-plane, where the combined radiation pattern of the patch and the two monopoles results into a tilted beam in the E-plane direction. Finally, a design of a SFP P-LWA with monopoles at 6.1 GHz to validate the proposed structure is presented and its results are discussed. The full-wave simulation shows a significant reduction of the grating lobes of the seven unit-cell array at higher frequencies, at which the grating lobes appear.

16:50 ***On the Design of SIW Dual Circularly-Polarized Leaky Wave Antenna for Mm-Wave Applications***

Mahmoud Elsaadany (Ecole de Technologie Superieure (ETS), Canada); Mohamed Ali (Assiut University); Shoukry Shams (University of Concordia, Canada); Ghyslain Gagnon (ETS, Canada)

Circularly-polarized antennas are considered among the most effective antenna types due to their high penetration capability. Further, dual circularly-polarized can double the physical channel capacity over the same frequency through sending different messages over two orthogonal polarization. In this article, a low profile, compact design is proposed for dual-circularly polarized antenna. The proposed structure consists of a hybrid coupler feeding two guided channels, where each channel is loaded with a leaky-wave slot antenna. The entire configuration is designed using Substrate Integrated Waveguide (SIW) technology to provide a low profile and reduce the implementation cost. The proposed design covers a wide band of operation from 27 to 32 GHz, with a matching level below -15 dB. The final structure is simulated with two different numerical packages to provide a sufficient validation for the proposed design.

T08-A02: Dielectric resonator antennas

T08 Positioning, localization & tracking / / Antennas

Room: virtual 8

Chair: Cyrille Menudier (XLIM UMR 7252, Université de Limoges/CNRS, France)

15:30 ***A Novel Dual Band-Notched UWB Printed Monopole Loaded with Dielectric Resonators***

Mohammad Abediankasgari (University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Shadi Danesh (Babol Noshirvani University of Technology, Iran); Pei Xiao and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

A novel dual band-notched printed monopole for ultra-wideband (UWB) applications is presented. The antenna element consists of a microstrip line-fed metal patch loaded with three dielectric resonators (DRs) to achieve impedance matching and bandwidth enhancement. To realize dual band-notched characteristics, a slot etched in the patch, two L-shaped parasitic strips connected to the DRs, and slots in the ground plane, are used. The two key issues in the antenna concern the loading DRs which are in very close proximity to the slots in the ground plane, and the introduction of the two notch-bands. Measurements demonstrate a good radiation performance with an ultra-wide impedance bandwidth from 2.54 GHz to 13.64 GHz with two band-notches at 3.22-4.06 GHz and 5.04-6.04 GHz. Outside the notches, the antenna reaches a quite high and stable gain over the rest of the UWB band, about 5 dBi in between ca. 6 and 14 GHz.

15:50 ***A Wideband Cylindrical Dielectric Resonator Antenna with a New Material***

Qiang Hua, Yi Huang, Tianyuan Jia, Chaoyun Song and Lyuwei Chen (University of Liverpool, United Kingdom (Great Britain))

A wideband cylindrical dielectric resonator antenna (CDRA) is presented in this paper, which has a simple structure and is fed by the aperture coupling feeding method. Both the substrate and the dielectric resonator (DR) are made of new material whose relative permittivity is inversely proportional to the frequency square. Since the size of the dielectric resonator antenna (DRA) is proportional to the wavelength (at the resonant frequency) over square root of the permittivity. Therefore, the size of the DRA will not change with the resonant frequency. The resonant frequency will be determined and controlled by the feeding structure. During this process, the mode excited will keep the same. In addition, compared with the traditional DRA, the proposed DRA has a compact size and

wider impedance bandwidth by employing the new material.

16:10 ***Multi-Permittivity 3D-Printed Ceramic Dual-Band Circularly Polarized Dielectric Resonator Antenna for Space Applications***

Quentin Lamotte, Gautier Mazingue, Jacek Bhatker and Maxime Romier (Anywaves, France); Nicolas Capet (ANYWAVES FRANCE, France); Nicolas Delhote (XLIM - UMR CNRS, University of Limoges, France); Cyrille Menudier (XLIM UMR 7252, Université de Limoges/CNRS, France); Olivier Tantot (XLIM - University of Limoges, France); Marc Thevenot (XLIM-UMR CNRS 7252, University of Limoges, France); Kevin Elis (CNES, France)

This document presents a Dielectric Resonator Antenna (DRA) developed by ANYWAVES with the support of the French Space Agency (CNES) and the help of an academic partner XLIM. This antenna is circularly-polarized, dual-band (Upper-L-Band [1.559 - 1.61 GHz] and TTC S-Band [2.025 - 2.29 GHz]) and designed to be integrated on a CubeSat or Nanosatellite. The particularity of this DRA is that the dielectric part is a structured 3D-printed block of Zirconia with two different permittivities. Two different feeding lines have been designed: with and without an integrated diplexer.

16:30 ***Analysis and Modelling of the Antenna Mode and Structural Mode Scattering of a Dielectric Resonator***

Ali Alhaj Abbas (Duisburg-Essen University, Germany); Maher Khaliel (Universität Duisburg-Essen, Germany & Benha Faculty of Engineering, Benha University, Egypt); Ashraf Abuelhaija (Applied Science Private University, Jordan); Mohammed El-Absi (University of Duisburg-Essen, Germany); MD Jahangir Alam (University of Duisburg-Essen & Institute of Digital Signal Processing, Germany); Klaus Solbach (UDE, Germany); Thomas Kaiser (Universität Duisburg-Essen, Germany)

This paper presents an analysis of the backscattering of a dielectric resonator (DR) due to the antenna mode and the structural mode. More specifically, we focus on the structural mode scattering since the discussion of the RCS of DRs in the past has concentrated on analyzing the ``Eigenmodes'' only. Therefore, we present evidence for its existence and provide a qualitative and quantitative approximation. It is found that the structural scattering of a DR with high rel. permittivity can be approximated by the scattering of a metal body of the same dimensions as the DR. Furthermore, a mathematical model of the antenna mode scattering is provided using the multipole expansion and with the aid of filter theory. As a result of the superposition of both scattering modes, it is found that the structural mode scattering slightly alters the appearance of the ``Eigenmodes'' in frequency position, scattering level, quality factor, and shape.

16:50 ***High-Permittivity Ceramic Tags Miniaturization for Long-Range RFID Applications***

Dmitry Dobrykh (ITMO University, Russia & Tel Aviv University, Israel); Ildar Yusupov, Anna Mikhailovskaya, Sergey Krasikov, Diana Shakirova and Andrey Bogdanov (ITMO University, Russia); Alexey P. Slobozhanyuk (ITMO University & Australian National University, Russia); Dmitry Filonov (Moscow Institute of Physics and Technology, Russia); Pavel Ginzburg (Tel Aviv University, Israel)

Radio frequency identification (RFID) allows performing a remote readout of data from passive battery-free tags, interrogated with an active reader. Quite a few efforts, concentrating on antennas design, have been explored, pushing integrating distances to tens of meters. Here we develop a new concept of miniature high-permittivity ceramic tags, capable to extend reading ranges quite substantially. Instead of using conduction currents in metallic wires to drive electronic chips and provide electromagnetic radiation, our approach relies on excitation of displacement currents in high-permittivity resonators. Practical aspects of this approach include improved robustness to environmental fluctuations, footprint reduction, and readout range extension. Our architecture is shown to perform reading range up to 19 meters, if state of the art electronic components is in use, having the smallest size among long-range RFID passive tags. Miniature RFID tags, capable to establish long-range communication channels, can find use in numerous applications.

CS9b: Characteristic Mode Analysis for Emerging Applications and New Structures Part 2

T10 EM modelling and simulation tools / Convened Session / Antennas

Room: virtual 9

Chairs: Kalyan C Durbhakula (University of Missouri-Kansas City & Missouri Institute of Defense and Energy, USA), Feng Han Lin (ShanghaiTech University, China)

15:30 ***Analysis of an Annular Coupled Patch Using CMA and CMT***

John Borchardt and Tyler LaPointe (Sandia National Labs, USA)

This work analyses a low-profile, broadband monopole patch antenna (which we call the Annular Coupled Patch) using Characteristic Mode Analysis. The full structure is divided into two resonators: a cylindrical cavity and annular PIFA, which are electromagnetically coupled by the fringing fields about the annular ring of vias separating the two resonators. The analysis shows that Coupled Mode Theory accurately models the resonances of the full, coupled structure. The modal behavior is compared and contrasted with several other antennas that are also well-modeled by Coupled Mode Theory.

15:50 ***Investigation of Direction of Arrival Estimation Using Characteristic Modes***

Lukas Grundmann and Nikolai Peitzmeier (Leibniz University Hannover, Germany); Dirk Manteuffel (University of Hannover, Germany)

A method is proposed to estimate the direction of arrival (DoA) of a traveling wave from characteristic mode weighting coefficients. These are obtained from the currents through the ports positioned on an antenna structure. The additional insight into the behavior of the antenna structure gained by the modal analysis is utilized to create a set of ports that allows to use a single conducting structure for the direction finding. It is shown that the proposed method works for a cubic antenna structure with 20 uncorrelated ports with good accuracy for any DoA.

16:10 ***Base Station Antenna Array Design with Characteristic Mode Analysis***

Philipp Gentner and Mathias Pietzka (Ericsson Antenna Technology Germany GmbH, Germany)

This paper revisits the history of Characteristic Mode Analysis (CMA) and describes thereby the fundamental differences between the antenna element design for handheld terminals and array applications, such as base station antenna design. With this knowledge in mind, open research topics are highlighted. A mutual coupling investigation with CMA is performed on a typical multiband array arrangement, to show the influence of mutual coupling on the individual array modes, respectively the modal significance.

16:30 ***Characteristic Mode Analysis for the Design of Metasurface-Based Space Antennas***

Simone Genovesi (University of Pisa, Italy); Francesco Dicandia (IDS - Ingegneria dei Sistemi SpA, Italy)

A novel metasurface is proposed as a superstrate for the design of circularly polarized antennas. A square loop is considered as the unit cell of the metasurface that has to be excited by a linearly polarized source. The use of stubs is investigated toward the excitation of orthogonal radiated fields with the necessary 90-degree phase shift without resorting to a different periodicity of the employed metasurface.

16:50 ***Characteristic Mode Analysis and Optimization of Meandering Probe Fed Patch Antenna for Wide-Bandwidth in UHF Band***

Kalyan C Durbhakula (University of Missouri-Kansas City & Missouri Institute of Defense and Energy, USA); Anthony Caruso (University of Missouri - Kansas City, USA)

Patch antennas operating in ultra-high frequency band (especially between 500 MHz and 1.5 GHz center frequency) have been seldom used in practical applications due to its narrow bandwidth limitations. The goal of this work is to enhance the bandwidth of a conventional patch antenna in the ultra-high frequency band by varying the location of meandering shaped probe. The -10 dB return loss (or S11) impedance bandwidth has been improved from 23.5% (before optimization) to 35.86% (after optimization). Characteristic mode analysis has been used to identify and understand the differences in impedance bandwidth before and after optimization. In addition, a rectangular shaped slot has been introduced to create a low-frequency resonance which expands our future scope for bandwidth improvement.

T10-E03: Computational EM Modellling and Numerical Techniques

T10 EM modelling and simulation tools / / Electromagnetics

Room: virtual 10

15:30 ***A Macro Basis Function Formulation for Thick Wires in the Method of Moments***

Jacques T du Plessis and Matthys M. Botha (Stellenbosch University, South Africa)

A new method is developed to accurately and efficiently simulate cylindrical conductors in the method of moments (MoM). Conventionally, wire currents are approximated as line currents using node-associated rooftop basis functions, for sufficiently electrically thin wires. The new method uses macro basis functions on quadrilateral cells to model the wire surface current density, allowing for accurate resolution of wire geometry and surface currents. This extends the range of the traditional thin-wire method to include wires with electrically larger radii. The method keeps the amount of unknowns on the same order as a conventional thin-wire solver. Preliminary results are presented and further extensions are discussed.

15:50 ***Comparison of Split-Ring Resonator Composite Periodic Media Based on Numerical Eigensolutions***

Michalis Nitas and Traianos Yioultsis (Aristotle University of Thessaloniki, Greece)

In this work we study the behavior of composite periodic media consisting of split-ring resonators by means of the solution of eigenvalue problems. Initially, we compare the dispersion diagrams of Edge-Coupled Split-Ring Resonator (ECSRR) and Broadside-Coupled Split-Ring Resonator (BC-SRR) media for the case of in plane propagation. Subsequently, we present the comparison results between the BC-SRR and its complementary counterpart which exhibit magnetic and electric resonances, respectively, at the same frequency zones. Field distributions of the returned modes are illustrated and their characteristics are studied with respect to their expected behavior extracted from analytical models in literature.

16:10 ***Scattering-Reduction of a Parasitic Dielectric Object via Metasurface-Tuning***

Riccardo Cacocciola (Paris Nanterre University & Saint-Gobain Research, France); Badreddine Ratni (Univ Paris Nanterre, France); Shah Nawaz Burokur (LEME, France)

We present metasurface-tuning as a solution to reduce spurious scattering from a parasitic dielectric object. By burying metasurfaces in the dielectric volume it is possible to control the scattering behavior of the parasitic object and camouflage it with respect to a given dielectric reference. A transmission line model is proposed to evaluate the metasurface's surface impedance retrieval. Near-field and far-field full-wave simulation results validate the scattering reduction of the dielectric parasitic object at 10 GHz for both TE and TM incident polarized waves. This study suggests that metasurface-tuning can be an alternative solution to conventional metallic-strip-tuning to reduce the scattering induced by mechanical dielectric seams in ground-based radomes.

16:30 ***Interpolation of Impedance Matrices for Varying Quasi-Periodic Boundary Conditions in 2D Periodic Method of Moments***

Denis Tihon (Cavendish Laboratory, University of Cambridge, UK); Christophe Craeye (Université Catholique de Louvain, Belgium); Nilufer Ozdemir (Universite Catholique de Louvain, Belgium); Stafford Withington (Cavendish Laboratory, United Kingdom (Great Britain))

Periodic structures can be simulated using the periodic Method of Moments. The quasi-periodicity, i.e. periodicity within a linear phase-shift, is implemented through the use of the periodic Green's function. In this paper, we propose a technique to interpolate the impedance matrix for varying phase-shifts. To improve the accuracy, the contribution of the dominant Floquet modes and a linear phase-shift are first extracted. The technique is applied to planar geometries, but can be extended to non-planar configurations.

16:50 ***Absorption and Invisibility of a Transparent Radial Anisotropy (TRA) Cylinder***

Sidra Batool, Mehwish Nisar, Fabio Mangini and Fabrizio Frezza (Sapienza University of Rome, Italy)

This article presents the inspection of a Transparent Radially Anisotropic (TRA) cylinder with permittivity dyadic, in the electrostatic settings. The quasistatic polarizability of the TRA cylinder with the values and signs of permittivity components offering different interesting features, involving, absorbance, anomalous losses, resonant singularities, invisibility. In this manuscript, we have a special focus on the electrostatic response of a circular cylinder with a certain condition of anisotropic parameters. We study the stimulating behaviour of polarizability of a TRA cylinder in quadrant (plane geometry). We have also computed the TRA cylinder behaves as a cloak using suitable choices of the anisotropic parameters

T11-A07: Additive manufacturing of antennas

T11 Fundamental research and emerging technologies / / Antennas

Room: virtual 11

15:30 ***3D Printed Slotted Waveguide Array Antenna for D-Band Applications***

Konstantin Lomakin and Mark Sippel (Friedrich-Alexander University, Germany); Klaus Helmreich (Universität Erlangen- Nürnberg, Germany); Gerald Gold (FAU Erlangen-Nürnberg, Germany)

This work presents an additively manufactured 12 elements slotted waveguide array antenna for D-Band applications incorporating a Dolph-Chebyshev taper for side lobe suppression. The specimen is printed by digital light processing from UV-curable photopolymer resin and is subsequently metal coated using an electroless silver plating process. A bandwidth B10 dB of about 19 GHz is achieved at 140 GHz with a realized side lobe level of 17dB, hence, highlighting the prospects of additive manufacturing towards D-Band frequency range and future automotive radar sensors.

15:50 ***Ultralight Wideband Open Boundary Quad-Ridged Antenna Manufactured Using 3D Printing Technology***

Julien Haumant (Elliptika & Université de Bretagne Occidentale, France); Pierre Massaloux (CESTA, France); Daouda Diedhiou and Alexandre Manchec (Elliptika, France); Rozenn Allanic and Cedric Quendo (Lab-STICC - UBO Brest, France); Christian Person (IMT Atlantique, France); Rose-Marie Sauvage (DGA, France)

In this paper, authors propose to manufacture an ultra-wideband open boundary quad-ridged antenna using a 3D printing manufacturing method followed by a chemical metallization process. The lowest operating frequency has been decreased from 550 MHz to 300 MHz using dielectric slots. Furthermore, the structure of the antenna is optimized in term of weight and reached only 1100 g for an overall size of 442x442x442 mm3. Finally, measurements show good performances over the frequency band from 300 MHz to 6 GHz.

16:10 ***Additive Manufactured Matching Medium Design for Implant Communications***

Ozum Habiboglu (Bogazici University, Turkey); Sila Akgun (Middle East Techical University, Turkey); Erdem Cil (Bogazici University, Turkey); Ozlem Aydin Civi (Middle East Technical University, Turkey); Sema Dumanli (Bogazici University, Turkey)

The design of matching media with different dielectric constants for the use in implant communications is presented in this paper. Each medium consists of a 3D printed honeycomb structure filled with a high dielectric lossless semi-liquid. The dielectric constant of the media is determined by the infill percentage of the honeycomb structure as well as the dielectric constant of both the semi-liquid and the material of the structure. An algorithm is developed that can specify values for the infill percentage to reach a target dielectric constant value from a given material and semi-liquid. For the measurements, several structures with different infills are fabricated with polylactic acid using additive manufacturing. Water-based semi-liquids are developed to fill the structures. The dielectric constants of the fabricated media are measured with a half-filled rectangular resonant cavity. The practical results agree with numerical ones with an error of less than 9% for all different cases.

16:30 ***Four-Way Orthomode Waveguide Power Dividers: Subtractive and Additive Manufacturing***

Charalampos Stoumpos (Thales Alenia Space & Heriot-Watt University, France); Jean Philippe Fraysse (Thales Alenia Space, France); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Ronan Sauleau (University of Rennes 1, France); Cebrian Gonzalez (Idonial, Spain); Thierry Pierre (Thales Alenia Space, France); Hervé Legay (Thalès Alenia Space, France)

This paper presents two waveguide power dividers in a planar 4-way equiphasic dual-polarization power division configuration operating in the transmit Ku-band (10.7-12.75 GHz). Both concepts are primarily targeted as excitation networks for multiple accesses radiating elements or antenna arrays. The presented solutions are characterized by two different variants that accommodate for different manufacturing processes, namely subtractive manufacturing (SM) and additive manufacturing (AM). Their principal operations are described and finally their RF performance is presented and compared experimentally inter alia. The principal objective is to demonstrate the mechanical complexity of this type of microwave components and how 3D-printing enables its efficient realization via co-design.

16:50 ***Experimental Validation of a Compact 3D-Printed Subreflector Subsystem for Cassegrain Antenna in X-Band***

Alejandro Rebollo, Álvaro F. Vaquero, Manuel Arrebola and Marcos R. Pino (Universidad de Oviedo, Spain)

In this work, a dual-reflector antenna based on a Cassegrain optics with a compact self-supported subreflector is presented to operate at X-band. The feeding subsystem is composed of a subreflector surface, the primary feed and a supporting structure in a single dielectric piece, providing a smart solution. The antenna is fed by a metallic rectangular waveguide with a H-plane transition to a Dielectric Rectangular Waveguide (DRW) finished on a hyperboloid. The designing process presented is based on optical geometrics and it is validated through the manufacture of the Cassegrain antenna. The prototype is fabricated using a 3-D printed technique and the subreflector and main parabolic reflector are metalized by a coating technique. The antenna is simulated and measured obtaining a high agreement on both. The prototype shows good performances in the whole band, validating both the designing technique and the proposed subreflector.

CS27: (AMTA/EurAAP Session): Post Processing Techniques in Antenna Measurements

T11 Fundamental research and emerging technologies / Convened Session / Measurements

Room: virtual 12

Chairs: Jeffrey Guerrieri (National Institute of Standards and Technology, USA), Francesco Saccardi (Microwave Vision Italy, Italy)

15:30 ***Inverse Surface-Source Solutions for Very Large Antennas - the One Thousand Wavelength Aperture***

Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany); Josef Migl (Airbus DS GmbH, Germany)

Inverse source and in particular inverse surface-source solutions can rather easily be obtained for irregularly sampled observation data collected with arbitrary measurement probes. This gives the opportunity to perform near-field (NF) far-field (FF) transformations for a wide collection of measurement setups if the related computational effort can be afforded. It is shown that inverse source solvers with multilevel fast multipole method (MLFMM) acceleration and normal-error (NE) arrangement of the normal equation system can provide reliable inverse source solutions of very large aperture antennas with very good error control.

15:50 ***Practical Feasibility of a NF-FF Transformation with Uniform Planar Spiral Scan for Quasi-Spherical AUTs***

Francesco D'Agostino, Flaminio Ferrara, Claudio Gennarelli, Rocco Guerriero, Massimo Migliozzi and Giovanni Riccio (University of Salerno, Italy)

This communication deals with the experimental validation of an effective near-field-far-field (NF-FF) transformation with planar spiral scanning. Such a technique, suitable for volumetric antennas, uses a reduced number of NF samples, which are collected along a planar spiral whose step is uniform to make easier the control of the velocity of the involved linear positioner. The NF data needed by the standard plane-rectangular NF-FF transformation are accurately reconstructed from the acquired spiral samples by employing an efficient two-dimensional optimal sampling interpolation (OSI) algorithm, which has been developed, by choosing the spiral step coincident with the sampling spacing needed to interpolate along a radial line, according to the spatial band-limitation properties of electromagnetic fields, and by arranging a proper non-redundant representation along such a spiral. Some experimental tests results are reported to assess the effectiveness of the FF reconstruction process.

16:10 ***Spherical Near-Field Measurements for Offset-Mounted Antennas***

Fernando Rodríguez Varela (Universidad Politécnica de Madrid, Spain); Belen Galocha (Universidad Politecnica de Madrid, Spain); Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain)

Spherical near-field measurements of offset mounted antennas lead to increased scanning times with respect to a standard centered measurement. Such offset increases the effective electrical dimensions of the antenna under test (AUT) so a higher number of samples is required for the far-field transformation. This paper presents a near-field to far-field transformation technique for offset mounted antennas which avoids the increased measurement times, with improved computational efficiency and full probe correction. Numerical and measurement examples are given to demonstrate its performance in various scenarios.

16:30 ***SVO and Singular Functions Quadrature in Near-Field Antenna Measurements***

Amedeo Capozzoli, Claudio Curcio and Angelo Liseno (Università di Napoli Federico II, Italy)

We show that the sampling approach provided by the Singular Value Optimization (SVO) technique defines quadrature rules of the singular functions arising from the application of the Singular Value Decomposition (SVD) approach. In other words, by the information collected by the elementary antennas defined by the SVO, it is possible to accurately determine the open circuit voltages received by the "virtual" antennas defined by the singular functions. The discussion is led in a 2D, scalar setting. The theoretical arguments are supported by numerical results referring to a full 3D Near-Field/Far-Field (NFFF) transformation problem.

16:50 ***On the Antenna Positioning for a Faster and Better Radiation Pattern Characterization***

Nicolas Mezieres (University of Rennes 1 & CNES, LNE, France); Benjamin Fuchs (University of Rennes 1 - IETR, France); Laurent Le Coq (University of Rennes 1 & IETR, France); Jean-Marie Lerat (LNE, France); Romain Contreres and Gwenn Le Fur (CNES, France)

The positioning of the antenna under test in the measurement coordinate system is a crucial part in antenna measurements. When the antenna is properly centered and oriented with respect to the measurement system, its radiation pattern can be faster and better characterized. The vector spherical harmonic expansion of the antenna pattern enables to modify by post-processing both the antenna position and orientation. This feature can be harnessed to help finding the best antenna positioning efficiently. Validations on simulated and measured near and far-field data are shown.

T11-E05: Metamaterial-enhanced antenna design

T11 Fundamental research and emerging technologies / / Electromagnetics

Room: virtual 13

Chairs: Shah Nawaz Burokur (LEME, France), Cristina Yepes (University of Siena, Italy)

15:30 ***Metasurface Antennas: Efficiency Versus Bandwidth***

Modeste Bodehou (Université Catholique de Louvain, Belgium); Marco Faenzi (University of Siena, Italy); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Stefano Maci (University of Siena, Italy); Christophe Craeye (Université Catholique de Louvain, Belgium); Enrica Martini (University of Siena, Italy)

Two methods are proposed for the accurate and fast analysis of the efficiency of arbitrarily modulated metasurface (MTS) antennas. The surface current on the MTS is expanded into entire-domain basis functions. The first method uses a Fourier-Bessel basis and relies on the Poynting theorem, while the second approach is based on the calculation of the surface-wave residue with a Gaussian-Ring expansion for the current. Both methods allow one to compute the efficiency of MTS antennas in a few minutes, which represents a drastic reduction of the computation time in comparison with any commercial software. The algorithms are then used to analyze the frequency dependence of the efficiency of MTS antennas in two different cases: 1) anisotropic MTS with uniform periodicity, 2) anisotropic MTS with non-uniform periodicity. The latter case corresponds to an active region MTS and provides a larger bandwidth. Validation with commercial software and measurements data is provided.

15:50 ***Mutual Coupling Reduction of Dielectric Resonator Antennas by Metamaterial Inspired Diverter Elements***

Muhammad F Bashir and Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

Mutual coupling (MC) of dielectric resonator antennas is investigated and decoupling is accomplished by metamaterial inspired diverter elements. The diverter elements consist of unit cells of metallic crosses surrounded by four L-shaped copper strips each, printed on both sides of a substrate. A one-unit cell diverter element brings about 3.8 dB reduction in MC and a 2-by-2 unit cell diverter element reduces MC by 3 dB at 25.4 GHz.

16:10 ***Influence of End-Launch Position over a Textile Wave-Guide Surface for BAN Applications***

Maria El Bacha (University of cote d'Azur, CNRS, LEAT, France); Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France); Leonardo Lizzi (University Côte d'Azur, CNRS, LEAT, France)

This paper represents a study of dipoles' position sensibility above a wave-guide meta-surface targeting Wireless Body Area Network(WBAN). Its importance is displayed through the fact that connected clothes are hard to implement in real life despite the fast evolution of technology that have witnessed this field in the last decade.

16:30 ***A Low Profile Antenna with Ultra-Wideband Low Radar Cross Section Characteristic Based on Coding Metasurface***

Enez Furkan Cihan, Mehmet Kopar and Ersel Ercek (ASELSAN Inc., Turkey); Cumali Sabah (Middle East Technical University - Northern Cyprus Campus, Turkey)

In this article, we propose a design of aperture coupled antenna with ultra-wideband low radar cross section (RCS) characteristics for X band applications. The RCS reduction ranging from 8 to 24 GHz has been realized with two novel artificial magnetic conductor (AMC) unit cells that are placed around the patch antenna. The AMCs have been designed with a 180±38° phase difference within a frequency range in order to provide an effective phase cancellation. The proposed antenna's operating bandwidth is 8.9-9.8 GHz, corresponding to an impedance bandwidth of 9.6%, and the RCS reduction is mainly in the Ku band. The maximum out-of-band RCS reduction is 37 dB at 12.7 GHz, while the maximum in-band RCS reduction is 27 dB at 9.2 GHz. The monostatic RCS results of the reference antenna and proposed antenna have been investigated under both θ and ϕ-polarized plane wave incidence.

16:50 ***Four Square Metaloop-Based Antennas Using C-, N-, and P-Metaatoms***

Hisamatsu Nakano, Tomoki Abe and Junji Yamauchi (Hosei University, Japan)

Four metaloop antennas (MLAs) are compared to a reference antenna composed of C-type metaatoms. A 2FD-MLA consists of two concentrically arrayed MLAs composed of C-type metaatoms. It is found that the 2FD-MLA has almost the same gain as the

reference antenna. A 1FD-MLA, where the two MLAs of the 2FD-MLA are connected and a single feed point is used, is found to have a larger gain than the reference antenna. A 1FD-MLAN, where the C-type metaatoms constituting the outer metaloop of the 1FD-MLA are replaced with N-type metaatoms, has a gain that is larger for a left-handed circularly polarized wave. In contrast, a 1FD-MLAP, where C-type metaatoms constituting the inner metaloop of the 1FD-MLA are replaced with P-type metaatoms, has a gain that is larger for a right-handed circularly polarized wave. Some comments are made about the radiation pattern, axial ratio, and VSWR of the antennas.

Friday, March 26

Friday, March 26 9:00 - 10:40

CS13: Disruptive Antenna Technologies Making 5G a Reality

T01 LTE and Sub-6GHz 5G / Convened Session / Antennas

Room: virtual 1

Chairs: Syed Muzahir Abbas (Macquarie University, Australia), Muhammad Ali Babar Abbasi (Queen's University Belfast & The Institute of Electronics, Communications and Information Technology (ECIT), United Kingdom (Great Britain))

9:00 ***Co-Aperture Concentric Square Slots-Based Sub-6 GHz and Mm-Wave 5G Antenna Design***

Rifaqat Hussain (KFUPM, Saudi Arabia)

In this paper, a square concentric slots-based antenna is presented for sub-6 GHz and millimeter wave (mm-wave) bands for Internet of Things (IoT) applications. The proposed antenna design exhibits an octa-band operation for sub-6GHz spectrum while it is resonating at 28 GHz for mm-wave band. The unique features of the proposed design are using the same radiating structure for both sub-6 GHz and mm-wave bands. The antenna consists of a three concentric square slots with ground (GND) plane dimensions of 50×50×0.508 mm 3 . For the sub-6 GHz band, the antenna is excited by a single open-end microstrip transmission-line, while eight transmission lines are used to excite the slots array at mm-wave band. The antenna covers most of 5G bands at sub-6 GHz as well as at mm-wave band at 28 GHz. Thus, the proposed antenna is a potential candidate for 5G enabled IoT applications.

9:20 ***Millimeter-Wave Channel Sounding Technique Using Oversized Lens-Loaded Cavity***

Muhammad Ali Babar Abbasi (Queen's University Belfast & The Institute of Electronics, Communications and Information Technology (ECIT), United Kingdom (Great Britain)); Vincent Fusco (Queen's University Belfast, United Kingdom (Great Britain)); Okan Yurduseven (Queen's University Belfast & Duke University, United Kingdom (Great Britain))

This paper briefly summarizes an ongoing investigation on millimetre-wave (mmWave) channel sounding using a low complexity single RF chain mode mixing lens--loaded cavity. The main advantage of using the mode-mixing technique is to be able to process the information required to estimate the direction-of-arrival (DoA) of the incoming signal just by reading the signal at the single RF-chain output. This massively reduces the system complexity compared to a standard N-element array antenna that requires around N times RF chains. Specifically, this paper presents a way by which signal directivity towards the coverage area can be enhanced by placing a lens in-front of an oversized cavity. This provides an extra channel gain to the incoming wave, consequently enhancing the DoA estimation resolution. This ongoing investigation can substantially simplify the physical hardware layer of the mmWave channel sounder, offering a great potential for the forthcoming mmWave 5G.

9:40 ***Cross-Band Interaction Mitigation in Dual-Band Antenna Arrays for 4G/5G and Beyond***

Yingjian Xiong (Hangzhou Dianzi University, China); Can Ding (University of Technology Sydney (UTS), Australia); Zhiqun Cheng (Hangzhou Dianzi University, China); Jay Guo (UTS, Australia)

Collocating antennas for different purposes on a single communication platform is a big trend as it can improve space efficiency. However, strong interactions happen among the antennas working at different bands due to the close proximity, leading to deteriorated antenna performance. This paper proposes a simple yet effective method to alleviate this issue by developing new array topology. The proposed method is used on a typical 3G/4G dual-band dual-polarized base station antenna array as an example to illustrate its effectiveness. By relocating the positions of the antennas in such array, the antenna performance can be substantially enhanced. Although this simple technique cannot eliminate the interaction solely, it can be used as a supplementary with other techniques to achieve optimal performance. At last, the proposed array topology is used together with a low-scattering spiral antenna designed for cross-band scattering mitigation, which leads to an outstanding array performance with a compact size.

10:00 ***ASIC-Enabled Reprogrammable Metasurfaces for 5G Applications***

Kypros Kossifos, Marco A. Antoniades and Julius Georgiou (University of Cyprus, Cyprus)

The multibeam capabilities of a metasurface design that is enabled by an application-specific integrated circuit (ASIC) are presented in this work. The ASIC loads the metasurface with multi-bit discrete states, which translate into a finely tuned amplitude and phase response. We demonstrate multiple pencil beam patterns utilizing the multi-bit amplitude and phase response. The proposed metasurface design, which was designed at 3.6 GHz, has the potential to be used in multiple-user mobile communication systems, including next-generation 5G networks.

10:20 ***Reduction of Correlation Coefficient Using Frequency Selective Surface for Multiband MIMO Antenna***

Muhammad Nouman Ashraf and Muhammad Umar Khan (National University of Sciences and Technology (NUST), Pakistan); Tayyab Hassan (1RIMMS, National University of Science and Technology (NUST), Pakistan); Rifaqat Hussain (KFUPM, Saudi Arabia); Mohammad S. Sharawi (Polytechnique Montreal, Canada)

In this work, a dual band multiple-input-multiple-output (MIMO) antenna system based on Fabry-Perot (FP) cavity is proposed. Partially Reflective Surface (PRS) with phase gradient was placed over a 2-elements dual-band MIMO antenna to reduce the Envelope Correlation Coefficient (ECC). The design operates at the sub 6-GHz 5G frequency bands of 2.8GHz and 5.6-GHz. The maximum achieved reduction in ECC is 73.4% while 1.3 dB increase in the gain is also obtained at both the frequencies.

10:40 Coffee Break

11:10 ***Optically Controlled Reconfigurable NRI-TL Phase Shifter for 5G Antenna Applications***

Asif Bilal (EMPHASIS Research Center, University of Cyprus, Cyprus); Abdul Quddious (KIOS Research and Innovation Center of Excellence, University of Cyprus, Cyprus); Haris Votsi (EMPHASIS Research Center, University of Cyprus, Cyprus); Atsushi Kanno (National Institute of Information and Communications Technology, Japan); Tetsuya Kawanishi (Waseda University & National Institute of Information and Communications Technology, Japan); Stavros Iezekiel and Marco A. Antoniades (University of Cyprus, Cyprus)

An optically controlled reconfigurable NRI-TL metamaterial phase shifter operating at 3.6 GHz is proposed. A host TL with a fixed length loaded with series capacitors and shunt inductors is used to achieve reconfigurability, while the optical control is introduced by integrating highly resistive silicon dies with the shunt branches of the NRI-TL design. The insertion phases of the phase shifter's two states are ±60°, leading to a differential phase shift of 120°, with insertion losses of 1.3~dB and 1.8~dB, respectively. The operational bandwidth of the phase shifter is between 3.45--3.75 GHz. The versatile optical control and good RF performance make the proposed NRI-TL phase shifter well suited for 5G antenna array applications.

11:30 ***Low-Cost Radial Line Slot Array Antenna for Millimeter-Wave Backhaul Links***

Muhammad Usman Afzal (University of Technology Sydney, Australia); Mst Nishat Yasmin Koli (Macquarie University, Australia); Karu Esselle (University of Technology Sydney, Australia)

The front-end antennas with a directed narrow beam are essential to establish a robust backhaul network for 5G network. The cost and profile of the antenna is imperative due to a large number of smaller cells envisaged for a millimeter-based 5G communication network. Radial-line slot array (RLSA) antennas are suitable due to their planar and thin height profile and single feed point. A low-cost RLSA is investigated for the millimeter-wave backhaul network without using dielectric materials. The lack of dielectric substantially reduces the fabrication cost of the antenna. The RLSA is made of two metal plates where radiating slots are on a thin-plate at the top. The results predicted through numerical simulations indicate antenna can create a narrow broadside beam without any excessive grating or side lobes.

11:50 ***Additive Manufacturing Techniques for 5G IoT Antennas and Sensors***

David Chatzichristodoulou (RF AND MICROWAVE SOLUTIONS LTD & Frederick Research Center, Nicosia, Cyprus); Abdul Quddious (KIOS Research and Innovation Center of Excellence, University of Cyprus, Cyprus); Loukia Vassiliou (Agricultural Research Institute, Nicosia, Cyprus); Nosherwan Shoaib (Research Institute for Microwave and Millimeter-Wave Studies (RIMMS) & National University of Sciences and Technology (NUST), Pakistan); Photos Vryonides (Frederick University Cyprus, Cyprus); Symeon Nikolaou (Frederick Research Center, Cyprus)

This paper demonstrates the use of additive manufacturing techniques through two examples of 5G internet of things (IoT) soil humidity sensors. A combination of inkjet-printing and 3D printing is used for the implementation of sub-1GHz planar antenna that can be used with an RFID reader for soil humidity sensing. A second 3.5 GHz dipole antenna loaded with humidity sensitive PEDOT:PSS is mainly 3D printed using a resin 3D printer. The implemented prototypes are presented, and their performance and potential improvements are discussed.

12:10 ***Access Point Selection Strategies for Indoor 5G Millimeter-Wave Distributed Antenna Systems***

Lei Zhang (Queen's University Belfast, United Kingdom (Great Britain)); Simon Cotton (Queen's University, Belfast, United Kingdom (Great Britain)); Seong Ki Yoo (Coventry University, United Kingdom (Great Britain)); Marta Fernandez (University of the Basque Country, Spain); William G. Scanlon (Tyndall National Institute, Ireland)

In this paper, we study the use of three candidate Access Point (AP) selection mechanisms for use with indoor millimetre-wave (mmWave) Distributed Antenna Systems (DASs). These are per-sample random AP selection, one-shot AP selection and per-sample optimal AP selection. To facilitate our analysis, we used a customized measurement system operating at 60 GHz, to record the signal power time series simultaneously received at 9 ceiling mounted AP locations while a mobile user imitating a voice call application. Using the time series data, the localized cross correlation coefficient (CCC) was estimated from the received signal strength (RSS) using the Spearman's rank-order correlation. It was found that the resultant time series of the localized CCCs was well-described by the Gaussian distribution across all of the considered measurement scenarios. Moreover, it was observed that the LOS and quasi-LOS paths typically led to higher CCC values with broader spreads than the NLOS scenarios.

12:30 ***Miniaturized 5G Module of Wideband Dual-Polarized Mm-Wave Antennas-In-Package Integrating Non-Mm-Wave Antennas (AiPiA) for MIMO in Cellular Phones***

Huan-Chu Huang (Etheta Communication Technology Co., Ltd., Taiwan); Zhixing Qi and Dasong Gao (Etheta Communication Technologies Co., China); Junyong Liu (East China Research Institute of Microelectronics, China); Yanchao Zhou (Etheta Communication Technologies Co., China); Jingwei Li (East China Research Institute of Microelectronics, China); Hong Lin (Etheta Communication Technologies Co., China)

A miniaturized 5G module of wideband dual-polarized mm-Wave antennas-in-package integrating non-mm-Wave antennas (AiPiA) for the multiple-input and multiple-output (MIMO) operations in both the 5G mm-Wave bands and non-mm-Wave band n78 for cellular phones is presented. In terms of the 10-dB return losses, this module can cover not only the 3GPP 5G mm-Wave bands (n257, n261, and n260) but also the planned 5G mm-Wave band (24.75-27.50 GHz) in China. Besides, by the dual polarizations (pol.), the MIMO operations in the mentioned mm-Wave bands can be realized. Moreover, for the lower limits of 6-dB return loss and -4-dB antenna efficiency, the two non-mm-Wave antennas in the module can support the 5G band n78 for the MIMO function with the in-band isolation higher than 15.12 dB and ECCs lower than 0.054. Thus, this miniaturized AiPiA module can innovatively serve as an appealing one-stop MIMO antenna total solution for the 5th generation mobile communications (5G) to greatly contribute to developments of cellular phones.

CS29: (IET/IRACON Session): Propagation Measurements and Modelling for 5G and beyond

T02 Millimetre wave 5G / Convened Session / Propagation

Room: virtual 2

Chairs: Sana Salous (Durham University, United Kingdom (Great Britain)), Enrico M. Vitucci (University of Bologna, Italy)

9:00 ***A Trajectory-Driven SIMO Mm-Wave Channel Model for a Moving Point Scatterer***

Nurilla Avazov, Rym Hicheri and Matthias Pätzold (University of Agder, Norway)

In this paper, we propose a trajectory-based three-dimensional (3D) non-stationary channel model for a millimeter wave (mm-Wave) single-input multiple-output (SIMO) system. The proposed channel model is designed to capture the mobility of a moving point scatterer in an indoor environment. We derive the expression of the time-variant (TV) channel transfer function (CTF). We study the TV Doppler characteristics of the channel, such as the TV Doppler power spectrum and the TV mean Doppler shift. To validate the proposed channel model, we performed a measurement campaign in an indoor environment using a software defined radar operating at 24 GHz. As a moving object, we consider a single swinging pendulum. The findings demonstrate an excellent agreement between the developed channel model and the real-world measured data. This can serve as a basis for developments of future non-stationary trajectory-driven channel models in the presence of moving objects modelled by multiple point scatterers.

9:20 ***Auto-Generated Summaries for Stochastic Radio Channel Models***

Ayush Bharti (Aalborg University, Denmark); Ramoni O. Adeogun (AAU, Denmark); Troels Pedersen (Aalborg University, Denmark)

Recently, a calibration method has been proposed for estimating the parameters of stochastic radio channel models using summaries of channel impulse response measurements without multipath extraction. In this paper, we attempt to automatically generate summaries using an autoencoder for calibration of channel models. This approach avoids the need for explicitly designing informative summaries about the model parameters, which can be tedious. We test the method by calibrating the stochastic polarized propagation graph model on simulated as well as measured data. The autoencoder is found to generate summaries that give reasonably accurate results while calibrating the considered model.

9:40 ***Near-Ground Propagation Measurements for Vehicular Deployments***

Dmitrii Solomitckii (Tampere University, Finland); Vasilii Semkin (VTT Technical Research Centre of Finland, Finland); Matias Turunen (Tampere University of Technology, Finland); Markus Allén (Tampere University, Finland); Claude Oestges (Université Catholique de Louvain, Belgium); Mikko Valkama (Tampere University, Finland)

In the nearest future, connected vehicles will be widely spread due to ongoing standardization activities of vehicle-to-everything communications. However, exchanging real-time traffic information is challenging in urban environments with dense traffic where the line-of-sight might be blocked. In this paper, we present the measurement results of the automotive communication and radar sensing through the obstructing vehicle, when the transmitting and receiving antennas are located very close to the ground, and the radio waves propagate near-ground, i.e. between the bottom of the car and the road pavement. It is shown that communication between two vehicles is undoubtedly feasible at distances 1.5 m and antenna heights of 0.3 m with 16 dB loss. Almost the same losses are observed in a radar sensing for distances longer than 2 m.

10:00 ***Millimeter-Wave Indoor Directional Propagation Measurements***

Amar Al-Jzari and Sana Salous (Durham University, United Kingdom (Great Britain))

The millimeter wave (mmWave) band around 60 GHz has been identified as one of the ISM bands for wireless indoor communication systems. In this paper, we present wideband channel measurements conducted at 60 GHz in a seminar room and office environment using state of art Durham University's channel sounder. The statistical channel parameters of power angle profile, root mean square delay spread, and angular spread are presented for different orientations which include line of sight, obstructed line of sight and non-line of sight with the smallest delay spreads and angular spreads values being observed for the line of sight case.

10:20 ***Terahertz Propagation Characteristics for 6G Mobile Communication Systems***

Minoru Inomata, Wataru Yamada, Nobuaki Kuno and Motoharu Sasaki (NTT, Japan); Koshiro Kitao, Mitsuki Nakamura, Hironori Ishikawa and Yasuhiro Oda (NTT DOCOMO, INC., Japan)

The 6th generation (6G) mobile communication system is being actively pursued worldwide. To satisfy extreme-high-speed-communication, one solution is to utilize terahertz bands above 100 GHz because a remarkably wider frequency bandwidth can be utilized than in 5G. To determine the service frequency bands on the basis of system performance for 6G, frequency dependency of path loss and channel properties needs to be understood. In this paper, we introduce our concept of a new network topology for 6G and then show the frequency dependency of human blockage, building shadowing, and scattering effects from a rough building surface up to 150 GHz.

10:40 Coffee Break

11:10 ***Millimeter-Wave Large Cubicle Office Propagation Characteristics Based on Measurements at 28, 38 and 71 GHz***

Juyul Lee, Kyung-Won Kim, Myung-Don Kim and Jae-Joon Park (ETRI, Korea (South))

In this paper, we investigate the millimeter-wave (mmWave) propagation characteristics of large office environments based on measurement data analysis. The measurement campaign was conducted at 28, 38 and 71 GHz with a 500 MHz measurement bandwidth, which frequency bands were chosen considering the WRC-19 mmWave 5G frequencies. In particular, we focus on an open-space type office furnished with cubicle partitions. Unlike regular classical offices, cubicle partitions and pillars are major clutter sources in this office type. Compared with the existing 3GPP model, a larger path loss exponent (PLE) was observed in our LOS measurements, while a smaller PLE was observed in our NLOS measurements. This seems due to a larger hall effect rather than a wave-guiding effect. We also investigate the shadow fading statistics and the excess loss from the free space loss. In addition, we examine the delay spread statistics from the 500-MHz bandwidth measurement data.

11:30 ***Radio Propagation in an Office Environment at 140 GHz and 28 GHz***

Bengt-Erik Olsson (Ericsson AB, Sweden); Christina Larsson (Ericsson Research & Ericsson AB, Sweden); Martin Johansson and Sinh Nguyen (Ericsson Research, Sweden)

In this paper, we compare the radio propagation channel characteristics between the 28 and 140 GHz bands in an open office environment and provide reflection/penetration losses of several common materials in the office obtained from measurements at these two frequencies. The paper concludes that the excess loss, i.e. the loss additional to Friis free space path loss, is very similar between 28 and 140 GHz as long as the measurements are conducted in open areas. In closed meeting rooms the excess loss is drastically increased due to the noticeably higher wall penetration losses at 140 GHz.

11:50 ***Near Field Modeling for THz Wireless Channel in Nettop Size Metal Enclosures***

Jinbang Fu, Prateek Juyal and Alenka Zajic (Georgia Institute of Technology, USA)

This paper proposes a path loss model and a geometry-based statistical model for Terahertz (THz) chip-to-chip wireless communication in nettop size metal enclosures. The proposed path loss model captures the attenuation of traveling wave and the gain of the electromagnetic horn in near-field region, also the resonant modes in the metal enclosure. The proposed geometric channel model describes the propagation of the traveling wave and the wave generated from the excited walls as a superposition of line of sight (LoS) and multi-bounced (MB) rays. Measurements for LoS propagation in near-field region have been performed in the indoor environment and in a nettop size empty metal enclosure. A good agreement between the measured and model predicted results has been observed, which proves the validity of the proposed models.

12:10 ***Propagation Modeling for Expansion of Communication Coverage to the Sky***

Wataru Yamada, Nobuaki Kuno, Minoru Inomata and Motoharu Sasaki (NTT, Japan); Kentaro Nishimori (Niigata University, Japan)

The newly proposed theory based model could be used to estimate propagation loss from the ground to sky area. Propagation loss from the ground to the sky were measured in 26 GHz band by measurement system powered by drone. Through the comparison of measurement and prediction results, it was found that RMSE was around 3 dB. Therefore, the model can estimate propagation loss continuously and accurately from the ground to the sky level. Moreover, fast fading characteristics from the ground to the sky are investigated.

12:30 ***The Analysis of Cross-Polarisation Discrimination for Body Area Networks in Cylindrical Metallic Environment***

Sławomir J. Ambroziak (Gdańsk University of Technology, Poland); Krzysztof K. Cwalina (Gdansk University of Technology, Poland); Piotr Rajchowski (Gdańsk University of Technology, Poland)

The analysis of cross-polarisation discrimination for Body Area Networks in an untypical environment of cylindrical metallic room has been performed in the paper. This analysis was done based on the measurements carried out for dynamic narrowband off-body channels operating at the frequency of 2.45 GHz. The results have shown that there is a strong dependence of the depolarisation effect on the existence of direct component in the radio channel.

T02-A03: MIMO Antenna Systems

T02 Millimetre wave 5G / / Antennas

Room: virtual 3

Chair: Olha Voitsun (Universität der Bundeswehr München, Germany)

9:00 ***Ka-Band Programmable Metasurface Demonstrations in Wireless Communication Scenarios***

Yueheng Li and Joerg Eisenbeis (Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany); Lucas Giroto de Oliveira (Karlsruhe Institute of Technology, Germany)

A programmable metasurface (PM) is a promising antenna array concept that can realize flexible electronically steerable beamforming. This property enables implementations of PM in wireless communication measurements. In this paper, by utilizing the steerable single beam and double beams generated from a PM at 28 GHz, communication systems regarding channel estimation, multipath single-input and single-output (SISO), as well as single-input and multiple-output (SIMO) systems are demonstrated and analyzed. The measurement results show system performances that prove the feasibility of PM wireless communication concepts.

9:20 ***A Varactor-Based Phaseshifting Network for Maximum-Ratio Combining of Antennas***

Olha Voitsun (Universität der Bundeswehr München, Germany); Stefan Lindenmeier (Universität der Bundeswehr, Germany)

A new antenna diversity circuit is presented for maximum ratio combining of C2X antennas at 5.9 GHz. The circuit allows phase alignment in a range between 0° and 360° as well as soft switching between the antennas with a variable weighting factor between 0% and 100%. Phase shifting is performed via variable varactor based phase shifters where one analog voltage steers the phase between 0° and 200°. A further discrete phase shifter adds 180° when higher angles are required. Also the soft switching between the antennas is steered by one voltage which defines the ratio between the power transmission of the two connected antenna paths. The circuit is realized on a Rogers substrate by discrete SMD-elements. Parasitic effects at 5.9 GHz are compensated in the network. Simulated and measured results of the circuits are presented showing low losses and functioning in the desired ranges of values.

9:40 ***Feasibility Study of a Near-Field Quasi-Optical MIMO Antenna for 270GHz Point to Point Wireless Links***

Nuria LLombart and Shahab Oddin Dabironezare (Delft University of Technology, The Netherlands)

This paper presents a feasibility study of a single feed per beam Quasi-Optical Antennas for enabling incoherent MIMO array front-end architecture in the 220-320GHz spectral bandwidth. For this purpose, we present theoretical curves of the level of co-coupling and interference between the multiple wireless channels versus the link distance in a Point to Point configuration. A specific and new MIMO array architecture operating at 270GHz based on a 2x2 array of parabolic reflectors combined with 2x2 focal plane arrays is proposed for a link distance of 100m. The proposed 16x16 MIMO implementation is capable of generating 16 dual-polarized channels in a 70GHz bandwidth with SIR>17dBs and a co-channel power coupling of -3dBs. Combining this architecture with wideband front-ends could potentially lead to an unprecedented aggregated data rate larger than Tbps in a Point to Point wireless LoS link.

10:00 ***Ka Band Far Field Radio Link System Based on OAM Multiplexed Vortex Beams Collimated by a Paraboloidal Reflector***

Altunkan Hizal (ASELSAN, Turkey); Hayrullah Yildiz (Baskent University, Turkey)

Orbital angular momentum OAM carrying mmw vortex wave VW beams generated by uniform circular array with microstrip patch elements are collimated by a paraboloidal reflector. OAM modes designated by plus/minus eight topological charges p are tightly collimated into a narrow radiation cone. Each OAM mode is modulated by 16QAM symbol vectors SV and multiplexed. Eight non-vortex dual polarized paraboloidal receiver antennas are positioned on a small arc on the rim of radiation cone. Antennas are designed by electromagnetic simulations. The received signals are demultiplexed by a novel algorithm based on orthogonality of OAM modes using IDFT. Orthogonal polarizations are assigned to plus/minus p are used to cover 16SV simultaneously. Effects of impairments and noise are simulated by Monte Carlo method. The signal to noise ratio is very high and far-field VW radio link is feasible. The symbol error rate free bit rate of link is 16 times more than 16QAM

10:20 ***High-Resolution DOA Estimation Using Compressive Sensing with Deterministic Sensing Matrices and Compact Generalized Coprime Arrays***

Said E. El-Khamy (Alexandria University, Egypt); Ahmed El-Shazly and Ahmed Eltrass (Faculty of Engineering, Alexandria University, Egypt)

This paper proposes a new high-resolution Direction Of Arrival (DOA) estimation approach for generalized coprime antenna arrays using Compressive Sensing (CS) with chaotic deterministic sensing matrices. The performance is investigated for different antenna array configurations with and without CS using both Multiple Signal Classification (MUSIC) and Capon DOA estimation techniques. The performance is evaluated in terms of the spatial spectrum, the computational time, and the Root Mean Square Error (RMSE) between estimated and actual DOAs when changing the Signal to Noise Ratio (SNR), the number of snapshots, and the number of antenna array elements. Theoretical analysis and simulation results show that the use of CS with chaotic deterministic sensing matrices not only allows resolving very closed signal sources well with comparable performance when using the actual measurement vector, but also reduces significantly the computational time for high-resolution DOA estimation of generalized coprime antenna arrays.

CS1: (AMTA Session): 5G & mm-wave Antenna Testing

T02 Millimetre wave 5G / Convened Session / Measurements

Room: virtual 4

Chairs: Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)), Kim Hassett (MVG Orbit/FR, United States)

9:00 ***Impact of Manufacturing Tolerances of Waveguide Power Dividers on the Quiet Zone Quality of a Plane Wave Generator***

Rutger van Boeijen (University of Twente & Bluetest a. b., The Netherlands); Andrés Alayón Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden); Robert Rehammar (Bluetest AB & Chalmers University of Technology, Sweden)

The effects of manufacturing tolerances on the quiet zone quality of a plane wave generator have been investigated. Waveguide power dividers required in the passive power distribution network of a plane wave generator have been designed. Monte Carlo simulations of the S-parameters of the designed power splitters have been performed by varying the power dividers' dimensions within manufacturing tolerances assuming a normal distribution. Furthermore, the splitting ratios resulting from the randomization are assumed to be uniformly distributed as the input for evaluating the quiet zone by means of Monte Carlo simulations. Assuming a 20 by 20 squared cm quiet zone, it has been found that for the considered setup that: (i) the phase deviation in the quiet zone never exceeds +/- 4.79 degrees, and (ii) for the amplitude deviation, never exceeds +/- 0.91 dB within a single simulated quiet zone.

9:20 ***Towards Testing of 5G Millimeter Wave Devices Using Plane Wave Generators***

Francesco Scattone (Microwave Vision Group (MVG), Italy); Darko Sekuljica (MVG, Italy); Andrea Giacomini, Francesco Saccardi and Alessandro Scannavini (Microwave Vision Italy, Italy); Evgueni Kaverine (MVG Industries, France); Shoaib Anwar (Microwave Vision Group, Satimo Industries, France); Nicolas Gross (MVG Industries, France); Per Iversen (Orbit/FR, USA); Lars Foged (Microwave Vision Italy, Italy)

The development and validation of a Plane Wave Generator (PWG) suitable for 5G testing at frequencies below 6 GHz have been reported in recent publications. There is an obvious interest to further develop the successful PWG technology for testing at higher frequencies employed by 5G and other communication systems. In this paper, we report on the technology development of a dual polarized PWG at millimeter wave frequencies. A representative technology demonstrator has been manufactured and tested. The demonstrator consists of twelve identical dual polarized elements distributed on two concentric rings using a corporate feed network to ensure the correct amplitude and phase distribution. The spatial allocation of the elements is determined from the geometry of the PWG system with the full-size test zone. The demonstrator has been manufactured and validated successfully. The validated technology is currently being implemented in the full-size PWG system.

9:40 ***Experimental Evaluation of a Millimeter-Wave Fully-Connected Hybrid Beamformer with a Large Antenna Array***

Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)); David Cheadle (National Physical Laboratory, United Kingdom (Great Britain)); Sohail Payami (University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Konstantinos Nikitopoulos and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

Current trends in developing cost-effective and energy-efficient wireless systems operating at millimeter-wave (mm-wave) frequencies and with large-scale phased array antennas for fulfilling the high data-rate demands of 5G and beyond has driven the needs to explore the use of hybrid beamforming technologies. This paper presents an experimental study of a wide-bandwidth millimeter-wave fully-connected hybrid beamformer system that operates at 26 GHz with 128 antenna elements arranged in a 16 × 8 planar array, 6-bit phase shifter, 6-bit attenuators and two separate radio frequency (RF) channels each capable of fully independent beamforming. The linearity, phase, and attenuation performance of the beamformer system between 25.5 GHz and 26.5 GHz are evaluated as well as the beamforming performance of a 128-element planar phased array at 26 GHz where the measured radiation patterns with and without amplitude tapering are compared.

10:00 ***Assessment of Combined SAR for Low Power Radio Base Stations with Multiple Antennas***

Fatemeh Ghasemifard, Bo Xu, Davide Colombi, Paramananda Joshi and Christer Törnevik (Ericsson AB, Sweden)

In this paper, we investigate when the phase shift between the elements in an array of two dipole antennas can be disregarded for Specific Absorption Rate (SAR) assessments. It is found that at a short assessment distance (one tenth of wavelength from the phantom), the antennas behave like individual electromagnetic sources. Thus, the maximum of combined SAR when both antennas transmitting simultaneously is well-approximated by the maximum SAR of individual antennas. In addition, for antenna separation distances of half a wavelength or larger, the variation of SAR with the phase shift among the antennas is small. Therefore, measuring SAR with antennas operating simultaneously disregarding the phase shift provides an accurate estimate of the exposure leading to a significant reduction in the measurement time. The results obtained for the array of dipole antennas are verified by analyzing a low power Ericsson 5G radio base station product with four antenna branches.

10:20 ***Validation of CATRs for 5G mmWave OTA Testing Applications***

Michael D. Foegelle (ETS-Lindgren, USA)

The 3GPP and CTIA have chosen CATRs as the default test system for over-the-air conformance and performance testing of the 5G New Radio (NR) at mmWave frequencies. However, the requirements for evaluating the DUT within these systems and the methods for validating system performance differ considerably from what the established antenna measurement industry would typically do to test antennas or validate the performance of a CATR. This paper will provide a brief overview of the current methodologies and investigate how well they work for the target application. It will also make some suggestions for possible improvements to the methodologies used.

10:40 Coffee Break

11:10 ***Multipath Rician Channel Simulation in the Test Zone of a Hybrid OTA Chamber***

Andrés Alayón Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden); Pavlo Krasov and Oleg Iupikov (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Robert Rehammar (Bluetest AB & Chalmers University of Technology, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden)

Multipath fields with ascribed Rician distribution parameters have been simulated in a novel hybrid chamber for over the air characterization of antenna systems and wireless devices. Simulations are based on waveguide mode summations representing a combination of the half-space rich isotropic multipath component and the on-axis line-of-sight component. It has been shown that the Rician distributed channels can be emulated without the use of additional static or moving scatterers.

11:30 ***Positioning of Orthogonally-Polarized Waveguide Probes for Near-Field Antenna Measurement***

Sabin Kumar Karki and Juha Ala-Laurinaho (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland); Ari Alanne (DA-Design Oy, Finland); Paul Moseley (European Space Agency, Switzerland); Massimiliano Simeoni (European Space Agency, The Netherlands)

In planar near-field antenna measurement, the full polarization characterization time of an antenna-under-test can be shortened by simultaneously using orthogonally-polarized probes. This paper discusses the positioning of two orthogonally-polarized probes in a near-field scanning system. The studies are conducted through full-wave simulations of tapered open-ended WR-75 waveguides operating at Ku-band. The studied probe characteristics are the mutual coupling between the orthogonally-polarized probes and the radiation pattern. The simulation studies concluded that the positioning along the major axes of the probe affects the radiation pattern more whereas the positioning along the diagonal direction increases the mutual coupling between orthogonal polarizations. Thus, the appropriate positioning is a tradeoff between these two parameters. For example, in order to maintain the ripples in the radiation pattern below 0.3dB within ±60° and port-to-port isolation below -35dB, the orthogonally-polarized probes are recommended to be

separated by more than 2-λ distance and aligned along the diagonal direction.

11:50 ***Spherical Antenna Measurements Performed in a Robot-Based Mm-Wave Test Range***

Roland Moch, Thomas M Gemmer and Dirk Heberling (RWTH Aachen University, Germany)

The robot-based antenna measurement system at the Institute of High Frequency Technology at RWTH Aachen University is put into operation and its measuring capability is proven by preliminary spherical measurement data. For this purpose, near- and far-field measurement data of a standard gain horn antenna are shown and compared with measurement data of the institute's compact antenna test range. The influence of the scalar feed horn used as the probe is compensated by a full high-order probe correction. It is shown that the deviation in the E-plane of the antenna is mainly < 40 dB in wide parts of the angular range of the radiation pattern. In view of the fact that the construction of the measurement range is not yet completed and no absorbers are mounted, the deviations are, thus, within the range of the expected tolerance.

12:10 ***High Front to Back Ratio Dual-Polarized Antenna-Coupled Electrode Electro-Optic Modulator for 28 GHz Band near Field Antenna Measurement***

Satoru Kurokawa (National Institute of Advanced Industrial Science and Technology, Japan)

We have developed a simultaneously receiving type dual (orthogonally) polarized antenna-coupled-electrode electro-optic (EO) modulator for 28 GHz-band 5th generation mobile communication as a receiving antenna. Our developed EO modulator can measure the orthogonally polarized microwave signal simultaneously. Cross-polarization discrimination ratio for E-plane of the EO modulator is more than 18 dB, and Front to back ratio is more than 33 dB for the frequency range from 27 to 29.5 GHz, respectively. Further, we show a near field radiation patter measurement result for a WR-28 standard gain horn antenna using our developed EO modulator.

12:30 ***A Novel Design of Compact Antenna Test Range for Ultra-Precise Antenna Test***

Chung-Huan Li (WavePro Inc., Taiwan)

A novel compact antenna test range (CATR) design is presented in this study. Conventionally, the edges of the reflector are parallel to the chamber walls. Instead, a diamond-shape reflector (DSR) is proposed in this design. The reflector is rotated for 45 degrees, so the corners of DSR point to the walls (patent pending). This design suppresses the scattering from the absorbers on the walls, which improves quiet-zone (QZ) performance accordingly. This is important for some applications, such as angle-of-arrival (AoA), which are sensitive to clutters. In addition, the chamber size can be more compact as the new design allows shorter distance between the reflector and the walls. The design has been realized and validated with QZ measurement.

CS18: (EurAAP Session) IoT Antenna Modelling and Design

T04 IoT and M2M / Convened Session / Antennas

Room: virtual 5

Chairs: Jaume Anguera (Fractus Antennas & Universitat Ramon Llull, Spain), Miloslav Capek (Czech Technical University in Prague, Czech Republic)

9:00 ***Design of a Compact Textile Crown Antenna Integrated with AMC for Wearable IoT Applications***

Bashar Bahaa Qas Elias (Universiti Malaysia Perlis (UniMAP), Malaysia); Ping Jack Soh (Universiti Malaysia Perlis (UniMAP) & Katholieke Universiteit Leuven, Malaysia); Azremi Abdullah Al-Hadi (University Malaysia Perlis, Malaysia); Callum J Hodgkinson (University of Edinburgh & Heriot Watt University, United Kingdom (Great Britain)); Symon K. Podilchak (University of Edinburgh, United Kingdom (Great Britain))

A compact crown-shaped planar antenna integrated with a 3 × 3 artificial magnetic conductor ground (AMC) is presented for the wearable internet of things (IoT) communications. Simulation is performed using FEKO software based on two approaches: characteristic mode analysis and the method of moments. This paper aims to optimize and understand the operation of the AMC reflector by studying its mode behavior. Results show that the proposed antennas operate at 5.8 GHz with acceptable radiation characteristics in terms of a reflection coefficients, realized gain of 8 dBi, and a front-to-back ratio (FBR) of 17.33 dB. Moreover, the flexible features of the antenna make it suitable for wearable IoT applications.

9:20 ***Miniature Sub-GHz Antenna for IoT from Space Applications: Challenges and First Results***

Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France); Le Huy Trinh (University of Information and Technology & Vietnam National University, Vietnam); Thomas Telkamp (Lacuna Space, The Netherlands)

This paper discusses the sub-GHz antenna design using for the communication between the terrestrial Internet of Things (IoT) to Low-Earth Orbit (LEO) satellites. In the first part, we will focus on the LEO constraints and the antenna characteristics that are suitable for this application. Then, first results using a compact tri-fillar configuration are presented with in-field testing and the EIRP limits. In the second part, a new solution to improve the radiation characteristics is proposed and analyzed.

9:40 ***NFC Sensing of Tear Fluid for Animal Health Monitoring***

Mélusine Pigeon and Nadeem Rather (Tyndall National Institute, Ireland); John Laurence Buckley (Tyndall National Institute & University College Cork, Ireland); Brendan O'Flynn (Tyndall National Institude, Ireland)

This article describes the state-of-the-art and preliminary simulations related to the design of a contact lens for health monitoring of cattle or other animals. This project is part of the SFI center Vistamilk as part of the work program associated with the Cow cluster. In this article, we propose to use NFC (near-Field communication) technology integrated in a contact lens to measure biomarkers in the tear fluid of a cow's eye. The feasibility of such an approach is described and documented. The simulations described show that the design of a contact lens for cows, with integrated sensing capability, is feasible and will inform future research in this area in the implementation of such a system.

10:00 ***A Compact Sub-1 GHz IoT Antenna Design with Wide Tuning Capabilities***

Rifaqat Hussain (KFUPM, Saudi Arabia); Mohamed A Abou-Khousa (Khalifa University of Science and Technology, United Arab Emirates); Muhammad Umar Khan (National University of Sciences and Technology (NUST), Pakistan); Mohammad S. Sharawi (Polytechnique Montreal, Canada)

In this work, an Internet of Things (IoT) antenna design is presented for low power and long-range communications within 5G sub-1 GHz applications. The antenna design is optimized to operate in sub-1 GHz bands using a simple meandered loop slot-line structure reactively loaded with a varactor diode. The varactor diode helps in achieving frequency reconfigurability (FR) over a wide-band in sub-1 GHz range. The proposed antenna covers frequency bands from 758 to 1034 MHz. The antenna is realized on RO-4350 board with dimensions 60×27 mm 2 . The distinguishing features of the proposed antenna design are simple biasing circuitry, compact low profile antenna design with wide tuning capabilities

10:20 ***In-Body Antennas Design Based on Fundamental Limits of Obtainable Power Density***

Marko Bosiljevac (University of Zagreb, Croatia); Anja K. Skrivervik (EPFL, Switzerland); Zvonimir Sipus (University of Zagreb, Croatia)

In-body medical implants are one of the most promising solutions for increasing patient healthcare in the future. Many such devices already exist, however, each new design is a challenge due to size constraints and communication issues which arise due to significant dielectric losses in the body. Therefore, antenna design and placement of antennas in the body is one of key factors for ensuring full functionality of such devices. We address this influence by observing the maximum power density that can be obtained in several in-body scenarios. These results are obtained using simplified spherical body phantom, however, the extracted guidelines can be used in much more complex scenarios and help in achieving efficient antenna design.

10:40 Coffee Break

11:10 ***Antenna Boosters: Easy Design of IoT Devices***

Jaume Anguera (Fractus Antennas & Universitat Ramon Llull, Spain); Aurora Andújar (Fractus, Spain); José Leiva (Fractus Antennas, Spain); Rosa Mateos (Fractus, Spain)

The continuous increase of wireless devices boosts RF/microwave and wireless engineers to design in a simple, quick, and effective way. For this purpose, a method for designing multiband antenna systems from a very simple antenna element is proposed. This results in a procedure where the antenna is seen as an impedance box where the number of bands is fixed by the design of a multi-band matching network with lumped elements. The design of said multiband matching network is addressed by a computerized procedure giving as a result the matching network topology and the values of each lumped element. To validate the procedure, a multiband antenna system operating at 824MHz-960MMHz and 1710-2690MHz is built. The matching network has been obtained using a fully automated method without human intervention and without any adjustment. This procedure opens the window to facilitate the design of multiband antenna system to IoT designers.

11:30 ***Miniaturized Omnidirectional Circularly Polarized Antenna for IoT Applications***

Verdiana Mastrosimini (Politecnico di Bari, Italy); Luca Santamaria (University Côte d'Azur, CNRS, LEAT, France); Marco Grande (Politecnico di Bari, Italy); Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France); Robert Staraj (University Cote d'Azur, CNRS, LEAT, France); Leonardo Lizzi (University Côte d'Azur, CNRS, LEAT, France)

In this paper, a miniaturized omnidirectional circularly polarized (OCP) antenna for Internet-of-Things (IoT) applications is presented. The CP waveform is synthesized by combining two linearly polarized antenna elements which act as electric and magnetic dipole, respectively. The vertical and the horizontally polarized elements are integrated and fed by a single port. The OCP antenna achieves a CP bandwidth covering 80 MHz from 2.4 to 2.48 GHz. The results show that the antenna can provide at 2.44 GHz an axial ratio lower than 3 dB and gain variations of less than 1.1 dB over all azimuth angles. The OCP antenna is printed on two cost-effective FR-4 PCBs and it is very low profile. Thanks to its radiation and geometric properties, the proposed antenna solution fits well in specific IoT use cases where a monopole-type radiation pattern is required.

11:50 ***A Large Frequency Ratio Dual-Band Microstrip Antenna with Consistent Radiation Pattern for Internet of Sea Applications***

Hanguang Liao, Rana Bilal and Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia)

Sensing and retrieving data from ocean to land are challenging tasks, while the Internet of Sea concept provides a realistic solution to that. A large frequency ratio dual-band microstrip antenna design working at GSM, LoRa, and BLE bands with consistent radiation pattern is proposed for Internet of Sea applications. The antenna is based on a modified Split Ring Antenna which provides two radiating modes, where the frequency ratio is close to 3. The proposed microstrip antenna is optimized for a better radiation efficiency and consistent radiation pattern at both bands. The method to control the H-plane HPBW of the proposed antenna is provided. The antenna prototype is fabricated and measured, which shows the radiation pattern at both bands are consistent and the H-plane HPBWs are 94°and 78°, at the lower and higher bands respectively.

12:10 ***Plastronics Development of Low-Profile Conformal Antenna for IoT Sensors***

Gildas Bengloan (University of Nantes IETR & LACROIX Electronics Solutions, France); Bruno Froppier (University of Nantes, France); Anne Chousseaud (unkown, France); Jacques Girard (LACROIX Electronics Solutions, France); Eduardo Motta Cruz (Université de Nantes IETR, France)

A compact and conformal cylindrical antenna for IoT sensor applications is presented. Plastronics development using Laser Direct Structuring (LDS) process is carried on to optimize the space occupied by the antenna. Specific LDS-compatible polycarbonate (PC) thermoplastic is used as a substrate. The dipole antenna stands on the outer surface of a 17 mm high cylinder with a diameter of 48 mm. The antenna operates in the European ISM band (868 MHz), which implies a very low profile length dimension of $\lambda/7 \times \lambda/7 \times \lambda/20$. The cylindrical holder is mounted in an industrial light fixture in order to be connected to a compact sensor board. Good agreement between simulations and measurements is found with a dipole-like radiation pattern and a maximum of 1 dBi measured gain. The 22 MHz bandwidth (S11 < -10 dB) satisfies the European ISM band IoT protocols LoRa and SigFox.

12:30 ***UHF RFID Tag Performance Measurements for SLCs Applications Using DIY-Positioners***

Niklas Beuster and Kurt Gerd Blau (Technische Universität Ilmenau, Germany); Johannes Trabert (MetraLabs GmbH, Germany); Alexander Ihlow (Ilmenau University of Technology, Germany); Julia Bauer and Carsten Andrich (Technische Universität Ilmenau, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

With this paper, we present cost-effective techniques to characterize UHF RFID performance with regards to small load carriers (SLC). A self-developed turntable-positioner is used to measure the antenna pattern of tags attached to empty SLCs, as well as SLCs filled with scrap metal. With the tag-positioner we presented in a recent publication, read range degradation of various tags near dissipative and conductive electro static discharge (ESD) protective material was investigated. We also measured the sensitivity of around 80 different tags in front of an SLC made of ESD protective material and compared their performance to operation in free-space propagation. To conduct the measurements themselves, we use commercial off-the-shelf readers like the R420 from Impinj, which we control via LLRP commands, implemented in Python.

CS33: (EurAAP Session) Recent Advances on Propagation Research and Its Impact on Localizations

T08 Positioning, localization & tracking / Convened Session / Propagation

Room: virtual 7

Chairs: Christian Gentner (German Aerospace Center (DLR), Germany), Wei Wang (Chang'an University, China)

9:00 ***Convolutional Neural Network Powered Identification of the Location and Orientation of Human Body via Human Form Point Cloud***

Min Chen (South University of Science and Technology of China, China); Yang Miao (University of Twente, The Netherlands); Yi Gong (Southern University of Science and Technology, Shenzhen, China); Xing-peng Mao (Harbin Institute of Technology, China)

This paper proposes a Convolutional Neural Network (CNN) based scheme using the point cloud of human body to identify its location and posture. The point cloud is randomly generated but confined within a human form. The CNN-based model is fed with point cloud for predicting mass center location and orientation of the body with help of high end graphical processing units. We propose to project the point cloud in two vertical planes to exploit the image recognition capability of CNN. The proposed method is tested with a single person for three primary postures: standing, sitting and lying, to evaluate the prediction capability. Effects of the number of points indicating point cloud density and the distance between the observation station and the target are investigated. Simulation results show a body part dependent localization accuracy smaller than 8 cm, and posture dependent success rate above 93%, validating the functionality of proposed scheme.

9:20 ***On Simplification of Ray Tracing Channels in Radio Channel Emulators for Device Testing***

Allan Mbugua and Yun Chen (Huawei Technologies Duesseldorf GmbH, Munich Research Center, Germany); Wei Fan (Aalborg University, Denmark)

Emulation of ray tracing (RT) simulated and measured channels in radio channel emulators is seen as a key enabler for virtual drive testing (VDT). Limitations in emulator hardware resources require that RT simulated or measured channels are simplified. In this preliminary study, the impact of channel simplification is investigated with a target of minimizing the error of the mean delay. The increase in the number of taps in the channel model caused by tap splitting in the conventional constant mean delay method proposed in the literature is addressed by considering the radio frequency (RF) bandwidth of the channel emulator. Although this approach is not optimal, for an average mean delay of 444 ns, it minimizes the mean error to 11 ns using on average 9 taps compared to 24 taps and 34 taps in the original and the tap aligned channels with a constant mean delay, respectively.

9:40 ***Multipath-Based SLAM Using Belief Propagation with Interacting Multiple Dynamic Models***

Erik Leitinger, Stefan Grebien and Klaus Witrisal (Graz University of Technology, Austria)

In this paper, we present a Bayesian multipath-based simultaneous localization and mapping (SLAM) algorithm that continuously adapts interacting multiple models (IMM) parameters to describe the mobile agent state dynamics. The time-evolution of the interacting multiple models (IMM) parameters is described by a Markov chain and the parameters are incorporated into the factor graph structure that represents the statistical structure of the SLAM problem. The proposed belief propagation (BP)-based algorithm adapts in an online manner to time-varying system models by jointly inferring the model parameters along with the agent and map feature states. The performance of the proposed algorithm is finally evaluatedin a simulated scenario. Our numerical simulation results show that the proposed multipath-based SLM algorithm is able to cope with strongly changing agent state dynamics.

10:00 ***In-Field Calibration of a Multi-Mode Antenna for DoA Estimation***

Robert Pöhlmann, Emanuel Staudinger, Siwei Zhang, Stefano Caizzone and Armin Dammann (German Aerospace Center (DLR), Germany); Peter A. Hoeher (University of Kiel, Germany)

State-of-the-art radio localization methods often rely on estimating the signal direction-of-arrival (DoA) or direction-of-departure (DoD). This requires careful calibration of the antenna, including surrounding structure, in a measurement chamber. Alternatively, auto-calibration algorithms can be used for certain types of phased arrays. However, they cannot correct all model errors and cannot be applied to other types of multiport antennas like multi-mode antennas (MMAs) or collocated antennas. In this paper, we present a maximum a posteriori (MAP) in-field calibration algorithm based on wavefield modeling and manifold separation for arbitrary multiport antennas. The algorithm is evaluated using measurements of a four-port MMA mounted on a rover. A significant performance gain for DoA estimation using in-field calibration is achieved compared to calibration in a chamber.

10:20 ***A Study on Vehicle Connectivity and Its Impact on Positioning***

Suying Jiang, Tiantian Chang, Ailin Jia and Wei Wang (Chang'an University, China)

Vehicular Ad-hoc network (VANET) is one of the fundamental parts in the intelligent transport system (ITS). Researches on the connectivity probability and vehicle positioning of VANET have remarkable significance on VANET security and system optimization. This paper presents a study on the vehicle connectivity and its impact on positioning. Firstly, we investigate the research on vehicle connectivity in the past years. Secondly, based on dual-slope path loss model, we study the connectivity probability. Based on the assumption that the distribution of vehicle nodes follows a Gaussian distribution in a dense traffic network, we present the Cramer-Rao lower bound (CRLB) for positioning error in VANET. Finally, through simulation, we analyze the influence of the path loss exponents on CRLB.

10:40 Coffee Break

11:10 ***Gaussian Mixture Model Learning for Multipath Assisted Positioning***

Rostislav Karasek (German Aerospace Center (DLR), Germany & Czech Technical University in Prague, Czech Republic); Christian Gentner (German Aerospace Center (DLR), Germany)

The wireless signal distortion decreases the precision of the estimated position. However, the distortion caused by the multipath propagation was recently shown not to decrease but even improve the precision when utilized correctly. This approach is called mutipath assisted positioning. In this paper, we propose a particle filter resampling algorithm for multipath assisted positioning exploring high likelihood areas allowing a better approximation of the posterior probability density function. Thanks to the posterior probability density function modeled as a Gaussian mixture model, we can perform the exploration with the same computational load as a regularized particle filter. The proposed algorithm allows decreasing the number of particles orderly while preserving the state of the art approach's precision. We show a comparison of the state of the art Channel-SLAM algorithm with the proposed Gaussian mixture model-based method demonstrating the significance of the achieved improvement.

11:30 ***Multi-Bandwidth NLOS Identification Based on Deep Learning Method***

Tiantian Chang and Suying Jiang (Chang'an University, China); Yuzhe Sun (Chang'an University, China); Ailin Jia and Wei Wang (Chang'an University, China)

The identification of the propagation conditions of the wireless system, i.e., line-of-sight (LOS) and non-line-of-sight (NLOS), has a significant impact on radio based positioning performance and channel modeling. Traditional methods to identify LOS/NLOS are usually based on extracting features of the channel impulse response (CIR), based on which a decision threshold is used to distinguish between LOS and NLOS conditions. However, channel features of LOS and NLOS are sometimes similar with each other, which usually results in low accuracy of LOS/NLOS identification. In this paper, we use the combined channel feature that is consist of channel state information (CSI) and four characteristics of the channel impulse response as input, and use Long Short-Term Memory (LSTM) to train the learning method to identify LOS/NLOS condition. The proposed method is evaluated based on measured data. The results show that the proposed method achieves an accuracy of 95.477% for LOS/NLOS channel identification.

11:50 ***5G SLAM with Low-Complexity Channel Estimation***

Yu Ge and Fan Jiang (Chalmers University of Technology, Sweden); Meifang Zhu (Lund University, Sweden); Fuxi Wen (Chalmers University of Technology, Sweden); Lennart Svensson (Chalmers University, Sweden); Henk Wymeersch (Chalmers University of Technology, Sweden)

5G millimeter-wave signals are beneficial for simultaneous localization and mapping (SLAM), due to their inherent geometric connection to the propagation environment. Channel estimators can exploit received signals to estimate multipath components in terms of

delays and angles, which can be used in localization and mapping. Thus, a good channel estimator is essential for 5G SLAM. This paper presents a novel low-complexity multidimensional ESPRIT-based channel estimator and applies it to a 5G SLAM framework. Simulation results demonstrate that the proposed channel estimator can accurately estimate channel information with low computational cost, with limited impact on mapping performance, compared to a tensor-ESPRIT benchmark.

12:10 ***Radar-Based Detection of Birds at Wind Turbines: Numerical Analysis for Optimum Coverage***

Ashkan Taremi Zadeh and Moritz Mälzer (Goethe University Frankfurt am Main, Germany); Duy Hai Nguyen (Goethe University Frankfurt, Germany); Jochen Moll (Goethe University Frankfurt am Main, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany)

The use of radar systems for monitoring and adaptive wind turbine control can reduce bird and bat mortality at wind turbines. For such projects many challenges such as range, coverage, resolution, position and reaction speed of the radar system have to be overcome. With suitable simulations, many of these obstacles are easier to overcome and many errors in the construction and installation of the radar systems can be avoided in advance. In this paper, we present a simulation environment to find a suitable position for radar systems used for bird monitoring at wind turbine installations. In this paper we present a simulation for five frequency modulated continuous wave (FMCW) radar system operating in the Ka-band from 33.4 GHz to 36.0 GHz. The aim of this paper is to find a suitable position for an optimal coverage around the wind turbine using five FMCW radars.

12:30 ***Evaluation and Comparison of Different Motion Models for Flight Navigation***

Dennis Kulemann (Leibniz Universität Hannover, Germany); Ankit Jain (Institut für Erdmessung, Leibniz Universität Hannover, Germany); Steffen Schön (Leibniz Universität Hannover, Germany)

Navigation performance of a flight has to be maintained with a certain level of accuracy in civilian or military operations. Global navigation satellite system (GNSS) based devices in flights act as primary source of navigation. In order to improve the accuracy and robustness of the navigation, information from other systems are fused together. The accuracy is further enhanced when adequate motion models are used. In this paper, we present results of multiple motion models in association with aircraft navigation and evaluate their performances. GNSS and inertial measurement unit (IMU) data are recorded in an aerial flight for about three hours. In order to highlight the impact of different motion models, data captured is processed post flight and position estimates are computed with a linearized Kalman filter (LKF). For different flight segments, the estimated position RMSE varies up to a maximum of about 4 decimeters with different motion models.

CS4: Antennas and Arrays for Radio Astronomy

T09 Space (incl. cubesat) / Convened Session / Antennas

Room: virtual 8

Chairs: Eloy de Lera Acedo (University of Cambridge, United Kingdom (Great Britain)), David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands)

9:00 ***Using Shape Memory Alloy for CubeSat Antenna Design in Space***

Niels Vertegaal (Eindhoven University of Technology, The Netherlands); Mark Bentum (Eindhoven University of Technology & ASTRON, The Netherlands); Hamid Pourshaghaghi (Eindhoven University of Technology, The Netherlands)

In this paper, a novel method on designing and deploying an antenna using Shape Memory Alloy (SMA) is presented. SMA, such as NiTinol, has the ability to be trained when heating the material to a certain temperature (e.g. 500C) in a certain shape. After cooling, it can be deformed after which it will return to its previously trained shape when heated towards transition temperature. Using this property, two antennas are designed using wires and sheets, respectively to show the possibilities and to determine the future feasibility for a design for Radio Astronomy. These antennas are simulated and show promising results to continue research and development. The horn antenna achieves a gain of 17.48~dBi at 15~GHz when deployed and 10~dBi when folded. The S-Parameters shows good matching across the Ku-band. The Yagi-uda antenna, when fully deployed, achieves 11~dBi at 1420~MHz, making it suitable for looking at the 21-cm hydrogen line.

9:20 ***Wideband Coaxial to QRWG Transition for the ngVLA Band 2 Horn Feed, Using a Quadraxial Transition***

Jacobus M Kotzé and Petrie Meyer (Stellenbosch University, South Africa)

Wideband feeding networks for QRFH antennas typically compromise on either return loss, or modal purity. This paper presents a new wideband transition from coaxial lines to QRWG, to enable a wideband feed for the ngVLA Band 2 QRFH which obviates this compromise. The transition presented in this paper introduces a new ridge design and transition to coaxial cables, and uses modal suppression techniques to achieve high performance over a 3.5:1 bandwidth. The designed transition has a reflection coefficient peaking at -10.5 dB, and measures lower than -25dB over 83% of the 3.5 - 12.3 GHz band. Higher order modes measure below -47 dB relative to the fundamental TE 11 mode over the entire band. This transition will allow future QRFH feeds to be designed based on the assumption of a pure mode excitation, accelerating the optimisation of high sensitivity reflector feeds for radio astronomy.

9:40 ***Effect of Conductive Propellers on VHF UAV-Based Antenna Measurements: Simulated Results***

Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy); Fabio Paonessa (National Research Council of Italy (CNR - IEIIT), Italy); Lorenzo Ciorba (Institute of Electronics, Computer and Telecommunication Engineering (IEIIT-CNR), Torino & Politecnico di Torino, Torino, Italy); Mauro Lumia (CNR, Italy); Giuseppe Addamo (Istituto di Elettr. e di Ingegneria dell'Inform. e delle Telecom. (IEIIT-CNR), Italy); Oscar A. Peverini (Istituto di Elettr. e di Ingegneria dell'Inform. e delle Telecom. (IEIIT- CNR), Italy); Pietro Bolli (INAF - Osservatorio Astrofisico di Arcetri, Italy)

The majority of commercial heavy-lift Unmanned Aerial Vehicles (UAVs) is equipped with carbon fiber propellers. This paper analyzes the impact of such conductive rotating parts on UAV-based antenna measurements in the VHF band. The simulated results show a significant increase of both measurement noise and systematics.

10:00 ***The Most Sensitive Radio Telescope to Deliver Unprecedented and Global Open Science: The Square Kilometer Array (50 MHz - 15.3 GHz)***

Maria Grazia Labate, Jeff Wagg, Bassem Alachkar, Shari Breen, Gerhard Swart and Andre van Es (SKA Organisation, United Kingdom (Great Britain))

The Square Kilometer Array (SKA), with its unprecedented large radio wave collecting area, will be 50 times more sensitive than any imaging radio telescope array previously built and be able to survey the sky 10000 times faster. The SKA project is now moving towards the start of procurement phase and construction activities. Verification Systems and Precursors on the SKA sites are already showing promising results. This paper will focus on the high sensitivity goals and how these are achieved by the SKA design.

10:20 ***Wideband Metamaterial Absorbing Antenna Ground Planes for 21cm Radio Cosmology Applications***

Nafsika Memeletzoglou (University Carlos III of Madrid, Spain); Eloy de Lera Acedo (University of Cambridge, United Kingdom (Great Britain)); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

This paper presents the design of an absorbing ground plane as a solution for ground reflections in 21cm radio cosmology applications. The proposed ground plane is formed by a metamaterial, specially designed to achieve high absorption at a large frequency band. The metamaterial consists of a periodic array of hybrid unit cells, that are based on split ring resonators. The frequency band under investigation is 50 MHz to 200 MHz. The proposed absorber covers 77% of the band, achieving more than 95% of absorption.

10:40 Coffee Break

11:10 ***A Novel UAV Beam Measurement System for the SKA1-LOW Telescope***

Iman Farhat, Alessio Magro and Mark Bezzina (University of Malta, Malta); Kristian Zarb Adami (University of Oxford, United Kingdom (Great Britain)); Eloy de Lera Acedo (University of Cambridge, United Kingdom (Great Britain)); Livia Massa (University of Malta, Malta); Alec Josaitis (University of Cambridge, Malta); Quentin Gueuning (University of Cambridge, United Kingdom (Great Britain)); Alexander Pettett (University of Oxford, Malta); Anthony Keith Brown (University of Manchester, United Kingdom (Great Britain)); Christophe Craeye (Université Catholique de Louvain, Belgium)

A verification system to characterize the far-field beam map for SKALA4 antenna using a customized drone referred to as FOX is presented in this paper. Apart from describing the FOX drone used in Ghajn tuffieha measurements campaign, Malta, the paper discusses the de-embedding algorithm that is used to extract the radiation pattern from the sampled data. The measured radiation pattern of SKALA4 antenna operating at 50 MHz are found to be in good agreement with the fullwave predictions. The results show that this technique is very promising for ongoing and future radio experiments.

11:30 ***Commissioning of a Per-Element Beam Model for the LOFAR Radio Telescope***

Michel Arts (ASTRON, the Netherlands Institute for Radio Astronomy, The Netherlands); David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands); Sebastiaan Van der Tol, Marco Iacobelli and Bram Veenboer (ASTRON, The Netherlands)

Until now the LOFAR radio telescope in the Netherlands used a simple beam model with identical element patterns to calibrate the array. To improve the accuracy of the calibration, work has been set in motion to improve the beam model by full-wave electromagnetic simulations. This paper reports the initial commissioning results.

11:50 ***Strategy and Overview for Development of Beyond-Decade-Bandwidth Quad-Ridge Flared Horns for Radio Astronomy***

Jonas Flygare and Jian Yang (Chalmers University of Technology, Sweden)

This paper considers the potential of the dielectrically loaded Quad-ridge Flared Horn (QRFH) feed to provide continuous beyond-decade bandwidth in reflector telescopes for radio astronomy. An overview of the beam pattern evolution over frequency in a recent ultra-wideband feed designed for 1.5-15.5 GHz is presented.

CS25: COST Action CA18223 (SyMat): Periodic Structures with Higher Symmetries

T10 EM modelling and simulation tools / Convened Session / Electromagnetics

Room: virtual 9

Chairs: Eva Rajo-Iglesias (University Carlos III of Madrid, Spain), Francesca Vipiana (Politecnico di Torino, Italy)

9:00 ***Ultra-Wideband Homogenization of a Glide-Symmetric Parallel-Plate Waveguide***

Boris Fischer and Guido Valerio (Sorbonne Université, France)

Glide-symmetric metasurfaces present the low-dispersive and low-loss characteristics required by modern communication devices in the millimeter-wave frequency band. Simple changes of their characteristic dimensions allow for a smooth variation of their effective refractive index. However, the lack of analytical models for these structures makes it difficult to foresee the effect of these changes on the effective index, requiring cumbersome numerical studies to properly size them. Here, a glide-symmetric corrugated parallel-plate waveguide is homogenized at low-frequencies, yielding an analytical expression of its effective refractive index. Numerical results show that this leads to a wide-band characterization of the glide-symmetric structure, due to its low-dispersive behavior.

9:20 ***Reconfigurable Phase Shifter in Waveguide Technology Based on Glide-Symmetric Holey Structures***

Angel Palomares-Caballero (Universidad de Granada, Spain); Antonio Alex-Amor (Technical University of Madrid, Spain); Pablo Padilla (University of Granada, Spain); Juan Valenzuela-Valdés (Universidad de Granada, Spain)

A reconfigurable phase shifter in waveguide composed by glide-symmetric holey unit cells is presented in this paper. The hole depths of this kind of holey unit cell are modified to allow a phase shift variation in the waveguide. The adjustment of the hole depths in the unit cell is achieved by the insertion of screws in the holes that are implemented as through holes. This advantage in implementation of reconfigurable elements inside the holes is added to the low-dispersive behaviour of the holey glide-symmetric unit cells. Both features make possible the design of a reconfigurable phase shifter in waveguide with flat phase shift responses. The phase shifter design proposed in this work provides a maximum phase shift of 90 degrees with good impedance matching from 50 GHz to 75 GHz.

9:40 ***Numerical Modelling of Glide Periodic Structures via Integral Equations***

Javier Rivero and Jorge A. Tobon Vasquez (Politecnico di Torino, Italy); Guido Valerio (Sorbonne Université, France); Francesca Vipiana (Politecnico di Torino, Italy)

In this paper we propose to study the dispersion diagram of non-canonical glide-symmetric unit cells via integral equations with the use of the periodic Green's function and discretized via the method of moment. The proposed approach is validated with a fully metallic implementation of a Luneburg lens operating at Ka-band with potential use for 5G communications. The promising preliminary numerical results highlight the potentialities of this approach.

10:00 ***OAM Beams via Higher Order Cylindrical Leaky Waves***

Paolo Burghignoli (Sapienza University of Rome, Italy); Walter Fuscaldo (Consiglio Nazionale delle Ricerche (CNR), Italy); Davide Comite (Sapienza University of Rome, Italy); Francesco Mancini (Leonardo S.p.A., Italy); Giancarlo Merola (Sapienza University of Rome, Italy); Paolo Baccarelli (Roma Tre University, Italy); Alessandro Galli (Sapienza University of Rome, Italy)

The use of higher order cylindrical leaky waves for producing electromagnetic waves carrying orbital angular momentum is illustrated for both far- and near-field applications. As concerns the first, Fabry-Perot cavity antennas fed by a single uniform circular array are shown to be capable of producing twisted conical patterns with consistent beam angle and different azimuthal orders, operating on forward cylindrical leaky waves. As concerns the latter, a printed radially periodic structure supporting backward cylindrical leaky waves, also fed by a single circular phased array, is shown to be capable of radiating twisted Bessel beams in the near-field region, in addition to twisted conical far-field patterns.

10:20 ***Characterization of Twist-Symmetric Dielectric Waveguides***

Pilar Castillo-Tapia and Kwinten Van Gassen (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Zvonimir Sipus (University of Zagreb, Croatia); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

Here, we study the propagation of a twist-symmetric dielectric rod with three different methods: eigenmode solver, multimode Bloch analysis, and scattering parameters of a truncated structure. With the eigenmode analysis, we demonstrate that these structures permit the propagation of circularly polarized modes, and only one of the modes has a stopband in the first Brillouin zone. These results are corroborated with the simulation of a truncated structure, demonstrating that the propagation is only possible for one of the modes at a given frequency band. Finally, the multimode Bloch analysis is used to also characterize the attenuation constant in the stopband.

10:40 Coffee Break

11:10 ***Dispersion Analysis of Glide-Symmetric Holey Metasurface Based on Multimodal Transfer-Matrix Approach***

Qiao Chen (KTH Royal Institute of Technology, Sweden & State Key Laboratory of Millimeter Wave, Southeast University, China); Francisco Mesa (University of Seville, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

The dispersion behaviors of a glide-symmetric holey metasurface is investigated, with special interest in its stopband attenuation. The unit cell of the periodic surface is described by its multimodal transfer matrix in order to account for the higher-order modal couplings between adjacent cells. This multimodal transfer matrix is obtained from the generalized scattering matrix (simulated by CST) that relates multiple modes on each cell boundary. Then, the complex modal wavenumbers are calculated from a generalized eigenproblem. This simulation-aided approach proves to be a highly efficient and very accurate tool for the Bloch analysis of glide-symmetric metasurfaces. Additionally, it enables the study of some unnoticed phenomena that cannot be captured by a commercial eigenmode simulator; among them, the existence of complex modes and the anisotropy in the stopbands. The reported findings can be beneficially employed for the design of such glide-symmetric holey surface as an EBG for gap-waveguide technology.

11:30 ***A Parallel-Plate Lens for Mechanical Wide-Angle Beam Scanning***

Thomas Ströber (Univ Rennes 1, IETR, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Hervé Legay (Thalès Alenia Space, France); Ségolène Tubau (Thales Alenia Space, France)

This paper presents a parallel-plate waveguide lens for wide-angle mechanical beam steering. A previously developed ray-tracing procedure is used for designing the quasi-optical system. The feed system is based on gap waveguide technology enabling a simple and rapid mechanical actuation. Validation of the proposed concept is given by numerical results for a Ka-band lens design. A high scanning performance over an angular range of +/-50° with a worst-case scan loss of about 3 dB is achieved. The simulated return loss is greater than 15 dB in the 27.5-31 GHz band. The proposed lens beamformer is an attractive ground-segment solution for future Satcom applications.

11:50 ***Active Impedance of PTD-Symmetric Checker-Board Type Open Ended Waveguide Array***

Iram Nadeem (University of Siena, Italy); Valentina Verri (Huawei Technologies Italia S. R. L., Italy); Enrica Martini, Alberto Toccafondi and Stefano Maci (University of Siena, Italy)

We analyze here the active impedance properties of an infinite array constituted by TEM waveguides open ended in a checker-board PEC-PMC ground plane. With the latter terminology we denote an alternance of PEC and PMC boundary condition squares. This array structure exhibits a property of parity time-reversal duality (PTD) symmetry along two axes. The TEM waveguides are constituted by two electric and two magnetic walls, and the contiguous ones are rotated of 90° to get dual polarization. This waveguide supports the propagation of a mode protected against backscattering which is consequence of the PTD symmetry. The waveguide has been designed to operate at the 5G frequency range (3 - 4) GHz. Due to the PTD properties, the proposed waveguide array exhibits wide angle (0°-60°) active impedance matching over a large bandwidth together with a good isolation between the cross-polarized ports.

12:10 ***Challenges in Using Glide-Symmetric Holey EBG Structures for Gap Waveguide Technology***

Zvonimir Sipus and Marko Bosiljevac (University of Zagreb, Croatia); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

Recently, there has been an increased interest in exploring periodic structures with higher symmetries due to the development of new types of microwave components with enhanced properties. Significant potential of this new approach can also be exploited in the design of electromagnetic band-gap (EBG) structures, in particular since manufacturing of the components in gap waveguide technology can be notably simplified. However, at the same time it is necessary to respect some limitations and challenging design aspects which this new technology is introducing. The aim of this paper is to discuss design issues related to the implementation of holey glide-symmetric periodic structures in gap waveguide-based components.

12:30 ***Broadband Dispersionless Glide-Symmetric Parallel-Plate Waveguide with Small Corrugations***

Boris Fischer and Guido Valerio (Sorbonne Université, France)

Glide-symmetric metasurfaces are a low-loss, conformable and cheap solution for the design of wide-band microwave devices, notably lens antennas. However, existing models do not explain why glide symmetry decreases the dispersion over a large spectrum. Here, the dispersion equation of a glide-symmetric corrugated parallel-plate waveguide is linearized under certain geometrical restrictions, notably the size of the corrugations, proving that the effective refractive index of this structure is frequency-independent over the first Brillouin zone.

CS40: Unconventional Techniques and Applications for Inverse Scattering Problems

T10 EM modelling and simulation tools / Convened Session / Electromagnetics

Room: virtual 10

Chairs: Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy), Rosa Scapaticci (CNR-National Research Council of Italy, Italy)

9:00 ***Nonlinear Inverse-Scattering in Variable-Exponent Spaces for Multifrequency Subsurface Imaging***

Alessandro Fedeli, Valentina Schenone, Claudio Estatico, Matteo Pastorino and Andrea Randazzo (University of Genoa, Italy)

In this paper, a subsurface imaging configuration is considered, with the goal of retrieving the quantitative dielectric properties of buried targets from scattered electric field measurements performed by a set of antennas above the soil. The acquired scattered-field data are processed by a nonlinear inverse-scattering approach in variable-exponent Lebesgue spaces able to jointly exploit multifrequency data, which is extended here for the first time to subsurface imaging problems. Numerical simulations are presented as a preliminary assessment of the proposed inverse-scattering technique, where a multistatic ground penetrating radar configuration is adopted.

9:20 ***Electromagnetic Field Prediction - Scattered and Total Field Approaches***

Chandan Bhat, Uday Khankhoje and Karteekeya Sastry (IIT Madras, India); Raffaele Solimene (Università degli studi della Campania Luigi Vanvitelli, Italy)

We summarize recent approaches to estimate electromagnetic fields in an arbitrary two-dimensional scattering domain. Only an estimate of the objects' spatial support in the scattering environment is required in our approach. Using the Huygens' principle and compressive sensing, the tangential electromagnetic fields on the scatterers' surface are estimated by making few field measurements in the scattering domain. Based on the field measurements, two inverse formulations are discussed in the paper: (a) scattered field inverse (SFI) and (b) total field inverse (TFI). For an indoor scattering domain with three scattering objects, the total electric field is recovered with an accuracy of 92%, and the incident field is recovered with an accuracy of 96% when the number of measurements is 0.3 times the number of unknowns in which the problem is formulated.

9:40 ***Single Data Set Calibration and Imaging with Uncooperative Electromagnetic Inversion Systems***

Eungjoo Kim, Joe LoVetri, Ian Jeffrey and Colin Gilmore (University of Manitoba, Canada)

Working with a multi-static grain-bin Electromagnetic Imaging (EMI) system, we propose a novel calibration procedure where we calibrate out the measurement system effects and image on a single set of S-parameters. Unlike most EMI systems, which require two measurements, only one set of S parameters are used for both calibration and imaging. The procedure relies on performing a parametric inversion to estimate the bulk contents of the grain bin, followed by an optimization to obtain per-channel calibration coefficients. The core assumption of the calibration procedure is that cross-talk between channels is small enough to ignore. A proof-of-concept of the calibration and imaging procedure is given with a simple synthetic example of an existing grain bin. The synthetic example shows that under highly favorable assumptions the single-data set procedure can give results of similar quality to the traditional (two data set based) calibration and imaging procedure.

10:00 ***Deep Learning-Enhanced Qualitative Microwave Imaging: Rationale and Initial Assessment***

Alvaro Yago (CNR, National Research Council, Italy); Marta Cavagnaro (Sapienza University of Rome, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy)

In this paper, an innovative approach to microwave imaging that combines qualitative imaging and deep learning is presented. The goal is to set a framework for a reliable and user-independent retrieval of the shapes of unknown targets. To this end, the proposed approach exploits an inversion technique known as orthogonality sampling method, which is capable of providing a qualitative estimation of the shape of targets in real-time. The output of the qualitive inversion is processed by a deep learning fully convolutional network called U-Net. U-Net automatically generates binary masks depicting the geometrical properties of the targets, i.e., separates the scattering objects (foreground) from the background. A quantitative assessment of the performance of the processing framework is provided with simulated data to demonstrate the capabilities of the proposed approach.

10:20 ***Microwave Imaging via a Migration Algorithm and Effective Spatial Sampling***

Maria Antonia Maisto and Raffaele Solimene (Università degli studi della Campania Luigi Vanvitelli, Italy); Rocco Pierri (Università della Campania Luigi Vanvitelli, Italy)

In this paper, subsurface imaging problem is addressed. In particular, the focus is on reducing the spatial measurement without degrading the the performance achievable in the reconstruction.

10:40 Coffee Break

11:10 ***Inverse Scattering of Metallic Objects Through Bessel Beams***

Santi Concetto Pavone (Università degli Studi di Catania, Italy); Gino Sorbello and Loreto Di Donato (University of Catania, Italy)

Scattering of Bessel beams can be matter of great interest in many practical areas such as near-field radar cross section (RCS) measurement, ground penetrating radar (GPR) and optical microscopy. In this contribution, we explore the advantages of performing inverse scattering through Bessel beams to obtain better results when compared to standard inversion approaches dealt with standard incident fields such as plane waves, current filaments or fields radiated by dipoles/loops in tridimensional imaging. Preliminary numerical assessments are given towards metallic scatterers by exploiting the well-known standard back-propagation technique.

11:30 ***Neural Networks for Inverse Problems: The Microwave Imaging Case***

Stefano Franceschini and Michele Ambrosanio (University of Naples Parthenope, Italy); Fabio Baselice (Università di Napoli Parthenope Italy); Vito Pascazio (Università di Napoli Parthenope, Italy)

In the framework of inverse scattering problems, this paper investigates the use of different artificial-neural network architectures for imaging purposes by processing the data collected at receivers locations in a multiview-multistatic fashion. Generally, this type of problems is strongly non-linear and ill-posed, thus the development of fast and reliable approaches is paramount for practical implementations. In the last years, machine learning approaches have proved to be very promising to recover quantitatively the electromagnetic features of objects located in an investigation domain, but at the expense of large data sets required for the training procedure. More in detail, this communication tries to explore the role of the network topology by exploiting three different scenarios with an increasingly higher degree of non-linearity.

11:50 ***Physics Embedded Iterative Neural Network for Solving Integral Equations***

Rui Guo and Zhichao Lin (Tsinghua University, China); Tao Shan (University of Tsinghua, China); Xiaoqian Song, Maokun Li, Fan Yang and Shenheng Xu (Tsinghua University, China); Aria Abubakar (Schlumberger-Doll Research, USA)

The integral equations describing forward scattering problems are generally solved numerically by iterative methods. In this work, we apply iterative deep neural network to solve both surface integral equation (SIE) and volume integral equation (VIE). The Green's function describing wave physics is involved in both training and prediction stage. The trained neural network can predict either the surface current density on conducting targets from SIE, or the total electromagnetic (EM) field in dielectric volume from VIE. We validate this method with two numerical examples, one for SIE and the other for VIE. This work may provide us a new perspective of incorporating wave physics into neural networks for fast EM computation.

12:10 ***Microwave Tomography for Food Contamination Monitoring***

Marco Ricci (Politecnico di Torino, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Francesca Vipiana (Politecnico di Torino, Italy)

The security of packaged food needs to be guaranteed to safeguard customers health. A raise of complaints of physical contaminations into food products pushes for the development of additional monitoring techniques to prevent any kind of hazards, but also to protect brands from customers trust loss. In this work, a prototype working at microwave frequencies is assessed and tested in a significant environment. It exploits the dielectric contrast between contaminants and food content, and it is it is mainly focused on two classes of intrusions matters, i.e. plastic and glass fragments of few mm size, that have limited detection by the existing in-line technologies, such as X-rays systems. The measurements and the resulting 3-D image reconstructions are encouraging and allow to aim at the development of an industrial prototype, monitoring packaged food in real-time along a production line.

12:30 ***Discretization Error Analysis in the Contrast Source Inversion Algorithm***

Valeria Mariano, Jorge A. Tobon Vasquez and Francesca Vipiana (Politecnico di Torino, Italy)

This paper describes the use of the contrast source inversion method combined with the finite element method for the numerical solution of 3-D microwave inversion problems. In particular, this work is focused on the discretization of the involved physical vector quantities, analyzing the impact of the chosen discretization on the solution process with the goal of optimizing the implemented algorithm in terms of accuracy, memory requirements and computational cost.

CS3: Antenna Design and Fundamental Bounds with External Constraints

T11 Fundamental research and emerging technologies / Convened Session / Antennas

Room: virtual 11

Chairs: Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France), Lars Jonsson (KTH Royal Institute of Technology, Sweden)

9:00 ***Upper Bounds on the Performance of Cross-Polarized Backscatterers Integrated with a Ground Plane***

Osmery Hernández (Public University of Navarre, Spain); Iñigo Ederra (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain); Richard Ziolkowski (University of Technology Sydney, Australia & University of Arizona, USA); Iñigo Liberal (Public University of Navarre, Spain)

Several technologies, including chipless RFIDs, sensing and ambient backscattering communications, benefit from the use of cross-polarized backscattering systems integrated with a ground plane. Despite its relatively weak intensity, encoding the information within the cross-polarized backscattering enables isolating the signal of interest from the co-polarized ground plane reflection. In previous works, we have derived upper bounds on the performance of different scattering processes by using the optical theorem, emphasizing the superior performance of highly directive systems. Here, we take advantage of this theory to investigate the cross-polarized backscattering performance that can be obtained with different (uniform and non-uniform) endfire arrays of magnetic dipole antennas in front of a ground plane.

9:20 ***Q-Factor Studies for Multiport Antennas***

Rasmus Luomaniemi, Pasi Ylä-Oijala and Anu Lehtovuori (Aalto University, Finland)

In this paper, we study the quality factor Q for multiport antennas. We demonstrate that determining the feeding signals of the ports has an essential role when aiming at minimizing the Q-factor. A simple example is used to illustrate the connection of the bandwidth and Q factor.

9:40 ***On the Range of Input Impedances for a Small Embedded Antenna***

Lars Jonsson (KTH Royal Institute of Technology, Sweden); Cem Kesici (Ohio State University, USA)

In this paper, we investigate the range of input impedances that are available for a small embedded antenna using stochastic antenna design methods. The trade-off parameters include the feed position, the embedded position, and the granularity of the antenna representation. The embedded antenna is 2 x 2 cm, and the device is approximated with a 5 x 5 cm planar metal structure. From the investigations, it is clear that the center-edge embedded antenna has a wider range of available impedances than a corner embedded antenna. Furthermore, for the considered case, a reduction of the antenna-representation granularity increases the range of available impedances. Elements of a port-specific dual bound are also presented.

10:00 ***A Decoupling and Matching Network with Harmonic Suppression for MIMO Antennas***

Yiming Zhang and Shuai Zhang (Aalborg University, Denmark)

This article presents a decoupling and impedance matching network with harmonic suppression for two-element antenna arrays, including a resistor-loaded decoupling part and a slotline-based impedance matching and harmonic suppression part. By integrating with the proposed network, the mutual coupling between the elements at the center frequency can be well suppressed. Moreover, the second-order harmonic is also suppressed to a low level. For verification purposes, a 2×2 dual-polarized antenna array centered at 3.5 GHz is employed and integrated with the proposed networks. A 3-D model is constructed and full-wave simulations are carried out. The results denote that the strongest in-band mutual coupling is suppressed from -16.6 dB to less than -25 dB, and a good out-of-band rejection level up to 10 GHz is obtained.

10:20 ***Fundamental Bounds for Multi-Port Antennas***

Miloslav Capek, Lukas Jelinek and Michal Masek (Czech Technical University in Prague, Czech Republic)

Current-density fundamental bounds are formulated for N-port radiators utilizing a port mode basis. A prescription is given for the transformation of full-wave method-of-moments matrix operators into port matrices. Fundamental bound on the total active reflection coefficient is presented as an example. Significant reduction of size of underlying matrices allows for simultaneous optimization of ports' placement and excitation amplitudes.

10:40 Coffee Break

11:10 ***Optimal Absorption and Scattering in Embedded Design Problems***

Kurt Schab and Austin Rothschild (Santa Clara University, USA); Miloslav Capek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Mats Gustafsson (Lund University, Sweden)

A multi-objective optimization problem is constructed to determine bounds on absorption and scattering characteristics of structures confined to regions of arbitrary shape and material characteristics. The problem takes the form of a quadratically constrained quadratic program and is solvable by deterministic means. The method is extended to incorporate the effects of arbitrary proximity-coupled objects through numerical Green's function methods, allowing for the calculation of bounds on embedded design performance.

11:30 ***Huygens Dipole Array with High Aperture Efficiency and Suppressed Sidelobes***

Wei Lin (University of Technology Sydney, Australia); Richard Ziolkowski (University of Technology Sydney, Australia & University of Arizona, USA)

A sidelobe suppressed, high aperture efficiency X-band Huygens dipole array is reported. The Huygens array consists of four magnetic and four electric dipole radiators. A collinear set of magnetic dipoles (MDs) is formed from a TE0.5,0 mode open waveguide integrated with phase inverters. The electric dipoles (EDs) are produced by connecting two metallic plates to the aperture of the waveguide, one on each side of it and orthogonal to that vertical wall of the waveguide. The overlapped -10-dB impedance and 3-dB realized gain bandwidth is 800 MHz, covering 9.45 to 10.25 GHz. The sidelobe levels of the 1x4 array are significantly reduced to -23.3 dB thanks to the natural tapering of the amplitude distributions of the MDs and EDs from the center of the array to both of its ends. The peak realized gain value is 12 dBi. The aperture efficiency is 74%.

11:50 ***Dual-Band Antenna with AMC for Wearable Applications***

Carlos Alexander Chuquitarco-Jiménez, Eva Antonino-Daviu and Miguel Ferrando-Bataller (Universitat Politècnica de València, Spain)

A dual-band antenna with AMC screen is proposed for wrist worn applications. The antenna is aimed to operate at 0.86 and 2.4 GHz, so a dual-band AMC structure is designed and integrated with the antenna in order to overcome the effect of the human arm. Results show a satisfactory performance in the bands of interest.

12:10 ***On Limitation of Impedance Bandwidth for Integrated Antennas in Mobile Terminals with Narrow Clearance***

Tran Quang Khai Nguyen (Université Cote d'Azur, CNRS, France); Lars Jonsson (KTH Royal Institute of Technology, Sweden); Fabien Ferrero (Université Cote d'Azur, CNRS, LEAT & CREMANT, France); Leonardo Lizzi (University Côte d'Azur, CNRS, LEAT, France)

This paper studies the reduction of frequency bandwidth in a modern full-screen mobile terminal as a function of the clearance area reserved for the antenna. This can be quantified for a given antenna structure in terms of the Q-factor. The realized Q-factor is here calculated using either the surface currents or the frequency derivative of the input impedance ratio. Both work well as a figure of merit to evaluate some most important geometrical parameters of a mobile terminal. It is also possible to estimate a lower-bound Q-factor of a terminal by using the stored energy approach. The low-bound Q-factor is used to illustrate the Q-factor for a terminal with 2% and 4% clearance to the total size for any possible antenna design. Improvement in bandwidth by using a 3D structure is also studied.

12:30 ***Elementwise Constraints for Tighter Antenna Bounds***

Ben A. P. Nel and Mats Gustafsson (Lund University, Sweden)

Many antenna design problems do not yet have feasible methods with which to determine the best possible design and heuristic methods are commonly used in optimization. Although antenna current optimization is able to produce physical bounds on many antenna parameters, these methods have so far not accounted for a given excitation, which is crucial in many designs. In this paper optimizing currents through a feed constraint formulation is presented as an approach that can bring antenna bounds closer to designs. Further tightening bounds through an elementwise power constraint formulation is presented and the challenge of constraining power over every current element is discussed.

CS34: Recent Challenges in Small Antenna Design

T11 Fundamental research and emerging technologies / Convened Session / Antennas

Room: virtual 12

Chairs: Anu Lehtovuori (Aalto University, Finland), Adam Narbudowicz (Trinity College Dublin, Ireland & Wroclaw University of Science and Technology, Poland)

9:00 ***Wideband Reduction of the Metal-Frame Blockage to Mm-Wave Antennas***

Rocio Rodriguez-Cano (Aalborg University, Denmark); Kun Zhao (Sony Research Center Lund, Sweden & Aalborg University, Denmark); Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)

In this paper, a method to reduce the metal-frame obstruction to the radiation of endfire mm-wave arrays with wideband operation is presented. A 7 mm-wide frame is chosen to emulate the current commercial bezel thickness. Slots of three different sizes are etched on the frame to ensure the wideband endfire behavior. The proposed solution allows the mm-wave array to radiate through the metal frame from 27.27 GHz to 37.43 GHz, which corresponds to a fractional bandwidth of 31.4 %. The presented design is compared with the free space mm-array and with the array with a normal unmodified frame. The results show that the proposed solution provides similar performance to the free space counterpart, while a 15 dBi gain improvement of the antenna array comparing to a normal frame is obtained. A good beam-steering performance can also be supported with the proposed slotted-frame structure of the mm-wave array.

9:20 ***On Package Connected Array with Beam Steering Capabilities at Millimeter-Waves***

Md Rasheduzzaman Al-Amin (Ecloe Polytechnique Montreal, Canada); Mohammad S. Sharawi (Polytechnique Montreal, Canada)

In this work, we present a small, compact, beam steerable on package connected array antenna (CAA) for millimeter-wave (mm-wave) applications. A single slot-based CAA (SCAA) is designed at 28 GHz with a bandwidth of 2.67 GHz. A backing reflector (BR) representing the lower layer is included beneath the CAA with an air separation to make it unidirectional. 11.9 dBi of far-field gain is obtained having 2.5 GHz bandwidth at broadside direction with only 4 antenna elements. The designed SCAA can be steered upto ± 41 and ± 38 degrees for without and with BR respectively. Then, the single SCAA is placed on a package stack-up with small dimension (18. 2 mm x 4.3 mm x 1 mm) which resulted in having 2 GHz of bandwidth. The comparative results between the proposed and other available designs show that the proposed on package SCAA provides wider bandwidth and a smaller form factor.

9:40 ***Feasibility Study of an Industrial Moisture Content Sensor Based on Wheeler Cap***

Prakorn Pratoomma (King Mongkut's University of Technology North Bangkok, Thailand); Abel Abdul Zandamela (Trinity College Dublin, Ireland); Suramate Chalermwisutkul (King Mongkut's University of Technology North Bangkok & The Sirindhorn International Thai-German Graduate School of Engineering, Thailand); Adam Narbudowicz (Trinity College Dublin, Ireland & Wroclaw University of Science and Technology, Poland)

The paper proposes a technique for sensing of moisture content of a waste paper block based on Wheeler Cap measurement method. The technique allows sufficient penetration into the sample due to relatively low frequencies in the VHF band. Water blocks within the sample can be detected due to the increased loss compared to a dry sample. The simulation setup comprises a cylindrical Wheeler Cap structure and an electrically small antenna which is located in the same enclosure as the Material Under Test (MUT). The moisture content can be detected due to frequency shift and amplitude change of the reflected signal. The study demonstrates that varying moisture content from 5% to 50% results in the change of the frequency from 276.35 MHz to 264.35 MHz, and simultaneous change in the level of reflected signal from -4.51 to -6.64 dB. Other factors, such as misplacement of the sample, are also discussed.

10:00 ***Wireless Power Transfer (WPT) Enabled IoT Sensors Based on Ultra-Thin Electrically Small Antennas***

Wei Lin (University of Technology Sydney, Australia); Richard Ziolkowski (University of Technology Sydney, Australia & University of Arizona, USA)

Wireless power transfer (WPT) enabled Internet-of-Things (IoT) temperature and light sensors based on two ultra-thin electrically small antennas are reported. Two distinctive wireless power capture capabilities are realized with metamaterial-inspired electrically small antennas. The near-field resonant parasitic (NFRP) element-based Egyptian Axe Dipole (EAD) antenna realizes an omnidirectional pattern. The Huygens dipole antenna, which combines a balanced pair of EAD and capacitively loaded loop (CLL) NFRP elements, realizes a unidirectional pattern. A sensor-augmented rectifier circuit is developed and seamlessly integrated with these antennas. Both of these systems are ultra-thin, being printed on a single piece of PCB substrate. The compact IoT temperature and light detection sensors were successfully implemented and tested. Since these high performance WPT-powered sensors are battery-free, they are very attractive for a variety of IoT applications.

10:20 ***Low-Band LTE Antenna Integrated into Mm-Wave Handset Antenna***

Joni Kurvinen (Aalto University School of Electrical Engineering, Finland); Resti Montoya, Anu Lehtovuori and Juha Ala-Laurinaho (Aalto University, Finland); Janne Ilvonen (Huawei Technologies Oy (Finland) Co. Ltd, Finland); Alexander Khripkov (Huawei Technologies LTD, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

Integration of small antennas is emphasized when more and more antennas should be placed to the limited volume of handsets. This paper shows a mm-wave antenna array and a low-band LTE antenna, which are designed to share the same metal frame section in a smartphone. The results show that two antennas can be integrated together without additional volume and without remarkable degradation in their performance.

10:40 Coffee Break

11:10 ***On Effects of a Finite Ground Plane on the Antenna Q-Factor***

Jari-Matti Hannula and Lars Jonsson (KTH Royal Institute of Technology, Sweden)

The ground plane is an important part of many antennas, either as a tool to improve the antenna characteristics, or as a necessity for antennas operating near a metallic device. Due to its prevalence in antenna design, it is important to be able to identify how it affects the optimal antenna performance and consequently how it should be included in the antenna design. In this work we investigate how the antenna Q-factor, a quantity inversely proportional to the Q-factor, is affected by the presence of a finite ground plane, and the location of the antenna relative to it.

11:30 ***Rules of Thumb to Assess Losses of Implanted Antennas***

Mingxiang Gao (Swiss Federal Institute of Technology in Lausanne, Switzerland); Denys Nikolayev (Institut d'Électronique et des Technologies du Numérique (IETR) - UMR CNRS 6164, France); Marko Bosiljevac and Zvonimir Sipus (University of Zagreb, Croatia); Anja K. Skrivervik (EPFL, Switzerland)

Fundamental limits for implanted antennas should be able to evaluate the bounds on losses with the knowledge of physical limitations from antenna and tissue parameters. In this work, rules of thumb to assess losses of deeply implanted antennas are presented toward improving the radiation efficiency. By means of rigorous and approximate approaches, the radiation efficiency of an elementary antenna within a spherical phantom is calculated as a function of multiple variables. According to the rules summarized subsequently, losses from different contributions may play a key role in specific situations, such as changes in the antenna type, phantom size, implant location and operating frequency.

11:50 ***Topology Optimization of Electrically Small Antennas with Shape Regularity Constraints***

Miloslav Capek, Vojtech Neuman, Jonas Tucek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Mats Gustafsson (Lund University, Sweden)

The existent framework for shape optimization of electrically small antennas is extended by a new set of geometrical operators. They are capable of operating over shapes directly, controlling their regularity, amount of used material, etc. The formulation is compatible with existent physical fitness functions and known fundamental bounds. A simple example of Q-factor minimization is presented.

12:10 ***MACKEY II Model with Reduced Thickness***

Keisuke Miyashita (Kanazawa-institute-of-technology, Japan); Toshiki Tamura, Shigeru Makino and Kenji Itoh (Kanazawa Institute of Technology, Japan)

The Meta-surface inspired Antenna Chip developed by the KIT EOE Laboratory (MACKEY, Wi-Fi 2.4GHz band), is an electrically small antenna that is sufficiently robust to metal objects. However, there has been a demand to make the basic model even thinner because it is 4mm thick. Therefore, a new model, named MACKEY II (Wi-Fi 2.4 GHz band), with broadband characteristics and reduced thickness is proposed. It is adapted to create a new structure where in the antenna substrate is placed inside the AMC substrate to create a thinner dimension than the basic model. In this paper, the characteristics and feeding method of MACKEY II are presented, along with, the measurement results.

12:30 ***Miniaturized Meander-Line Dipole Antenna for Short-Range Wireless Communication Networks***

Syeda Fizzah Jilani (Department of Physics, Physical Sciences Building, Aberystwyth University, Aberystwyth, UK, SY23 3BZ); Anin Maskay (Independent Researcher, USA); Shaker Alkaraki (Queen Mary University Of London, United Kingdom (Great Britain)); Qammer H Abbasi (University of Glasgow, United Kingdom (Great Britain)); Akram Alomainy (Queen Mary University of London, United Kingdom (Great Britain))

This paper presents the design and performance analysis of a planar, miniaturized meander-line dipole antenna designed for short-range wireless communication links. The proposed compact antenna has a size of 0.08λo × 0.03λo (at fo = 288 MHz) and designed on a sapphire substrate with optimized dimensions of 80.75 × 31.3 × 1.5 mm3. This electrically small antenna design is comprised of symmetric C-shaped resonators with meandered lines and gaps to perform frequency tuning. Simulated results show that the antenna can be effectively tuned to 288 MHz, 298 MHz and 310 MHz by applying structural reconfigurations. The radiation pattern in all the suggested frequency bands is perfectly omnidirectional. The proposed antenna due to highly compact size is a potential candidate for the short-range wireless networks.

SW03: Antennas and Propagation Aspects for THz Communications

Thomas Kürner

Room: virtual 13

SW01a: Integration challenges for mm-wave phased arrays Part 1

Stefania Monni

Room: virtual 14

Friday, March 26 10:40 - 11:10

Coffee Break / Exhibition

Rooms: virtual 1, virtual 2, virtual 3, virtual 4, virtual 5, virtual 6, virtual 7, virtual 8, virtual 9, virtual 10, virtual 11, virtual 12, virtual 13, virtual 14, Posters

Friday, March 26 11:10 - 12:50

CS13 continued

T01 LTE and Sub-6GHz 5G / Convened Session / Antennas
Room: virtual 1

CS29 continued

T02 Millimetre wave 5G / Convened Session / Propagation
Room: virtual 2

CS1 continued

T02 Millimetre wave 5G / Convened Session / Measurements
Room: virtual 4

CS18 continued

T04 IoT and M2M / Convened Session / Antennas
Room: virtual 5

T05-A01: Antennas for medical applications

T05 Biomedical and health / / Antennas
Room: virtual 6

Chairs: Stephen Pistorius (University of Manitoba, Canada), Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)

11:10 ***A Compact Design for Dual-Band Implantable Antenna Applications***

Abdenasser Lamkaddem (Carlos III University of Madrid, Madrid, Spain); Ahmed El Yousfi (Universidad Carlos III De Madrid, Spain); Kerlos Atia Abdalmalak (Universidad Carlos III de Madrid, Spain); Vicente González Posadas (Polytechnic University of Madrid, Spain); Luis Enrique García Muñoz and Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)

This paper presents the development of a dual-band antenna working in the Industrial, Scientific, and Medical (ISM) band (902 - 928 MHz, 2.4 - 2.5 GHz). The proposed antenna is compact, has a frequency-independent response between the lowest and the highest frequency, has a small size of 6 mm x 6 mm x 2.54 mm, and exhibits a high gain for implantable application of -13.14 dBi at 915 MHz and -28 dBi at 2.45 GHz. This design does not use any via or defected ground plane making the antenna very useful for this kind of application. The miniaturized dualband antenna has been tested in the presence of salmon fish and chicken meat to replicate the behavior of the antenna in the human body

11:30 ***Capacitively Coupled Electrode Antenna: A Practical Solution for Biomedical Implants***

Ali Khaleghi (Norwegian University of Science and Technology (NTNU) & Oslo University Hospital, Norway); Ilangko Balasingham (Norwegian Institute of Science and Technology, Norway)

A capacitively coupled electrode antenna is proposed for use in medical implants. The antenna involves the conductivity of the biological medium and extends the applied RF electric signal to the conductive biological medium, thus the antenna virtual size increase that results in higher radiation efficiency compared to the similar size physical antennas. The antenna is self-matched or can be easily matched to a 50-ohm source impedance and provides ultra-wideband impedance matching that makes it less sensitive to the

variations of the surrounded biological tissues. The proposed antenna occupies a minimal volume, which is a requirement for the implants. The physical structure of the antenna is similar to the contact electrodes but uses a capacitive coupling gap to the medium to increase radiation efficiency and reduce the specific absorption rate (SAR). A sample antenna at 403 MHz is designed and compared to the ideal conventional dipole and loop geometries.

11:50 ***A Dual-Band Microstrip Patch Antenna for Brain-Machine Interface Applications***

Mahdi Salimitorkamani and Hayrettin Odabasi (Eskisehir Osmangazi University, Turkey); Atabak Najafi (Gazi, Turkey)

In this paper, a novel dual-band printed monopole antenna (PMA) is studied for Brain-Machine Interface (BMI) applications. The PMA has a square radiating patch with one L-shaped sleet and two L-shaped slots, and two more L-shaped slots on its ground plane. The antenna works at two different frequency range: WLAN/UWB (2.3-2.5 GHz and 4.1-11.5 GHz). The WLAN resonance is obtained via L-shaped sleet inserted on the patch's side, by which the resonance frequency can be altered via its length. The bandwidth of the antenna patch is further improved via the addition of double L-shaped slots on the patch and ground plane. Furthermore, the antenna characteristics inside the brain phantom have been studied for the BMI purpose. The proposed antenna has a stable gain over the radiating frequency and transmitted power between 1.1-4.6 mW inside the brain phantom. Far-Field and Near-Field of the antenna have been analyzed for BMI purposes. The designed antenna with a small size of 15×20×1.6mm is suitable for BMI applications, not only with the aim of lower power consumption but also for the purpose of implanting.

12:10 ***Design of an Uncooled Microwave Monopole Antenna for Tissue Ablation at 2.45 GHz***

Federico Cilia, Lourdes Farrugia, Julian Bonello, Iman Farhat and Charles Sammut (University of Malta, Malta); Evan Dimech (University of Malta & University of York, Malta)

This study investigates the use of microwave electric fields for treating tumours, as an alternative to surgical therapies, potentially reducing morbidity and invasiveness. An uncooled coaxial-based monopole antenna was designed, for percutaneous microwave ablation cancer treatment. The antenna was optimised to provide an optimal match with liver tissue, at 2.45GHz. The diameter of the designed antenna was kept at a minimum by using an RG405 coaxial cable, thus keeping the treatment minimally invasive. A simulation model of the antenna using Computer Simulation Technology (CST) Studio software was developed and validated methodologically by experiments. During the latter, the designed coaxial based monopole antenna was excited with a power signal of between 30W and 50W while immersed in a liver specimen. The performance of the proposed antenna, under power conditions, while immersed in the liver specimen, showed promising results considering the utilisation of an uncooled monopole without added impedance-matching networks.

12:30 ***Antipodal Vivaldi Antenna with Ceramic Cone Lens for Biomedical Microwave Imaging Systems***

Mengchu Wang (National Research Council-Institute for Electromagnetic Sensing of the Environment, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Marta Cavagnaro (Sapienza University of Rome, Italy)

Microwave imaging (MWI) for biomedical applications has drawn great attention in recent decades owing to its attractive features such as low cost, portability, and use of non-ionizing radiation. In the microwave imaging system, the antenna plays the most crucial role because it dictates the amount of electromagnetic power transmitted to the human body. In this contribution, an ultra-wideband antipodal Vivaldi antenna was designed for a biomedical MWI system. The antenna is immersed in a coupling medium of permittivity 23 and operates in the frequency band 0.5 - 5 GHz. The radiation of the antenna was improved by removing a piece of substrate from the aperture and replacing it with a high permittivity ceramic cone lens. Such a ceramic lens was capable to increase antenna radiation without changing the antenna impedance. This study paves the way for the assessment of a biomedical microwave imaging system.

CS33 continued

T08 Positioning, localization & tracking / Convened Session / Propagation

Room: virtual 7

CS4 continued

T09 Space (incl. cubesat) / Convened Session / Antennas

Room: virtual 8

CS25 continued

T10 EM modelling and simulation tools / Convened Session / Electromagnetics

Room: virtual 9

CS40 continued

T10 EM modelling and simulation tools / Convened Session / Electromagnetics

Room: virtual 10

CS3 continued

T11 Fundamental research and emerging technologies / Convened Session / Antennas

Room: virtual 11

CS34 continued

T11 Fundamental research and emerging technologies / Convened Session / Antennas

Room: virtual 12

SW03 continued

Room: virtual 13

SW01a continued

Room: virtual 14

Friday, March 26 12:50 - 13:50

Closing Ceremony

Room: virtual 1

Chairs: Thomas Kürner (Technische Universität Braunschweig, Germany), Cyril Mangenot (Api-Space, France)

Friday, March 26 14:00 - 18:00

SC01: Short Course: Multibeam Antennas and Beamforming Networks

Multibeam Antennas and Beamforming Networks

Giovanni Toso and Piero Angeletti

Room: virtual 1

The objective of this course consists in presenting the state of the art and the on-going developments in Multi-Beam Antennas (MBAs) and Beam-Forming Networks (BFNs). They find application in several fields including communications, remote sensing (e.g. radars, radiometers, etc.), electronic surveillance and defense systems, science (e.g. multibeam radio telescopes), RF navigation systems, etc. They may be installed on board satellites, airplanes, trains, buses, buildings, cars etc. MBAs and BFNs are becoming also fundamental elements in emerging MIMO and 5G communications. The course content is regularly updated by the organizers who are involved since more than twenty years in this domain.

SC02: Short Course: Gap waveguides for mmWave antenna systems and electronic packaging

Gap waveguides for mmWave antenna systems and electronic packaging

Ashraf Uz Zaman & Eva Rajo-Iglesias

Room: virtual 2

There is an emergent need for higher data rate related to upcoming wireless applications. Given the data rate, capacity and quality of service (QoS) requirements, this can only be possible if the vast unlicensed bandwidth available at mmWave frequencies can be utilised and all the technical hurdles at mmWave frequencies (above 30GHz) are solved in a cost effective way. In terms of available bandwidth world-wide, flexible transmission rules, 60GHz is a boon from a system perspective. But RF designers have faced enormous challenges in simulation, design, integration, physical realisation, packaging and test of the complete systems. The technical challenges are literally orders of magnitude more complex than 2.4GHz or 5GHz WiFi systems of today. In future, the industrial winners will be the companies that can provide the mmwave hardware at the lowest cost. This requires new waveguide and mmWave packaging technologies that are more cost effective than normal rectangular waveguide technology, and is more power-efficient (lower losses) than PCB-based microstrip and coplanar waveguides. The gap waveguide technology has this potential. Also for medium to high mmWave frequencies, antennas need to be located very close to their on-chip RF active components. Thus, the packaging of the complete RF module also plays a very important role for good performance mmWave modules. The gap waveguide technology presented in this short course is also a potential candidate which can be explored and utilised at mmWave frequency range for antenna and RF subsystem design. This short course will cover an overview of the gap waveguide technology, the parallel-plate stop band design, some mmWave antenna designs based on gap waveguide technology and some RF subsystem design such as filters, packaging of RF electronics etc.

SC03: Short Course: User antennas for internet everywhere

User antennas for internet everywhere

Gerard Caille & Nelson J. G. Fonseca

Room: virtual 3

Internet access everywhere is a fundamental need nowadays, and satellite systems play a specific role in all cases where terrestrial networks cannot offer a reliable connectivity. Efficient while low-cost terminals for users connected to satellites are compulsory, and this is finally one of the main condition for the viability of such systems. In the user terminal, its antenna front-end is the most critical sub-system, as in most cases it requires that a directive beam tracks one (or 2) satellite(s) over a very wide field-of-view, because either the user or the satellite is moving or even both simultaneously. Trading the best solutions, building innovative efficient designs is a stringent challenge for antenna engineers. We will review designs based on electronic or mechanical steering, hybrid solutions (combining mechanical and electronic steering), and new concepts applied to these missions.

SC07: Short Course: THz Technology and Instrumentation

Miguel Navarro-Cía

Room: virtual 7

Wireless communications are irremediably moving into millimetre-waves and THz; evidence of this is the IEEE 802.15.3d-2017 standard. THz is also becoming key for security screening, quality control and medical imaging because of its excellent balance between spatial resolution and material penetration. Unquestionably, THz will play a major role in coming years and this has been noticed by EurAAP and IEEE, among other entities, which are taken action accordingly. In this context, engineers need to be well aware of the current technology and the challenges related to THz in order to wangle the next generation of THz components and systems.

Friday, March 26 14:00 - 14:30

IW10: Recent advances in antenna measurement systems in response to current and future test challenges (Asysol)

Room: virtual 13

Dr. Sergiy Pivnenko, Asysol

Friday, March 26 14:00 - 16:00

SW01b: Integration challenges for mm-wave phased arrays Part 2

Stefania Monni

Room: virtual 14