ConTEL 2019

WISDOM

Wideband Low-Cost Smart Passive and Active Integrated Antennas for THz Wireless Communications

Focused Workshop

July 4th, 2019

Inffeldgasse 12, 8010 Graz

Free admission

Please register via email to:
michael.gadringer@tugraz.at

WISDOM ConTEL 2019

Thursday, 4th July 2019

08:00 – 09:00		**Registration**
09:00 – 10:30		**ConTEL & WISDOM Joint Workshop**
	9:00 - 9:15	**Welcome Address: Dr. Wolfgang Bösch**
	9:15 - 10:00	**Keynote Talk: Dr. Steven Gao** **Compact MIMO Antennas for Mobile Terminals in 5G**
	10:00 - 10:30	**Dr. Benito Sanz-Izquierdo:** **3D Printing of Antennas and FSS for mm-Wave and THz Applications**
10:30 – 11:00		**Coffee break**
11:00 – 13:10		**WISDOM Session I**
	11:00 – 11:45	**Keynote Talk: Dr. Patrick Reynaert** **THz in CMOS: Dream, Nightmare or Reality?**
	11:45 – 12:15	**Dr. Rui Xu:** **Low-Cost and High-Gain mm-Wave and THz Antenna Based on 3D-Printing Technique**
	12:15 – 12:45	**MSc. Jan Köhler:** **Planar Lenses for micro- and mm-Wave Applications**
	12:45 – 13:10	**MSc. Alexander Standaert:** **Co-Design of THz Transmitters and 3D Printed Antennas**
13:10 – 14:00		**Lunch break**
14:00 – 15:00		**WISDOM Session II**
	14:00 – 14:45	**Keynote Talk: Dr. Dmitry Isakov** **Application of high dielectric permittivity feedstock for 3D printing of electromagnetic devices**
	14:45 – 15:00	**Workshop Closing**

Provided by:

chist-era · EPSRC Pioneering research and skills · fwo · FWF Der Wissenschaftsfonds. · KU LEUVEN · TU Graz · University of Kent · WARWICK THE UNIVERSITY OF WARWICK

9:00 - 9:15	**Welcome Address: Dr. Wolfgang Bösch**

ConTEL & WISDOM Joint Workshop Opening

Welcome address by Dr. Wolfgang Bösch
Institute of Microwave and Photonic Engineering
Graz University of Technology, Austria

9:15 - 10:00	**Keynote Talk: Dr. Steven Gao** **Compact MIMO Antennas for Mobile Terminals in 5G**

Director of Graduate Studies at the School of Engineering and Digital Arts
University of Kent, United Kingdom

***Abstract* — Multiple Inputs and Multiple Outputs (MIMO) antennas are required for mobile phones in 5G and beyond. One of the biggest challenges is: How to achieve high isolation between antennas closely packed? This talk gives a brief overview of various techniques proposed in recent years, such as the use of parasitic elements, neutral lines, metamaterials, electromagnetic band gap (EBG), etc. It is shown that these techniques could achieve good isolation up to about 20 dB when antenna elements have a distance of about half wavelength, but the performance deteriorates quickly when the antenna elements distance is reduced further. A technique called Common-Mode/Differential-Mode (CM/DM) antenna design is then presented. The CM/DM technique is shown to be able to achieve high isolation over 20 dB when the antenna elements have zero distance between them. The technique is promising for achieve compact-size highly integrated MIMO antenna systems for smart phones in 5G and beyond.**

Bio: Steven Gao is a Full Professor and Chair in RF and Microwave Engineering, and the Director of Graduate Studies at the School of Engineering and Digital Arts, University of Kent, UK. His research covers smart antennas, phased arrays, MIMO, reconfigurable antennas, wideband/multiband antennas, antennas for mobile communications/satellite communications/IOT, RF/microwave/mm-wave/THz circuits, UWB radars, synthetic-aperture radars, and sensors for healthcare. He co-authored/co-edited three books (Space Antenna Handbook, Wiley, 2012; Circularly Polarized Antennas, IEEE-Wiley, 2014; Low-Cost Smart Antennas, Wiley, 2019), over 300 papers and 10 patents. He is an Associate Editor of IEEE Transactions on Antennas and Propagation and several other international Journals (Radio Science, IEEE Access, Electronics Letters, IET Circuits, Devices and Systems, etc), and the Editor-in-Chief for John Wiley & Sons Book Series on "Microwave and Wireless Technologies". He was a Distinguished Lecturer of IEEE Antennas and Propagation Society (2014-2016), and General Chair of LAPC 2013, UK. He was an Invited Speaker at many conferences. He was named a Fellow of IEEE due to his contributions to reconfigurable antennas and broadband printed antennas. He is also a Fellow of Royal Aeronautical Society, UK, and a Fellow of IET.

10:00 - 10:30	**Dr. Benito Sanz-Izquierdo:** **3D Printing of Antennas and FSS for mm-Wave and THz Applications**

Former Member of Graduate Studies at the School of Engineering and Digital Arts
University of Kent, United Kingdom

***Abstract* — 3D additive manufacturing is an attractive solution for millimeter wave and terahertz device fabrication. The layer-by-layer layer fabrication technology, also known as 3D printing (3DP), offers the production of complex devices directly from a digital model. 3D fractal antennas and frequency selective structures (FSS) are examples of the potential applicability of AM to the development of novel microwave devices. These structures can be fully fabricated using metal layers or, alternatively, by fully or partially metalizing polymers. Partially metalizing polymers has been demonstrated to offer significant performance improvements and unit cell size reduction in the development of FSS at microwave frequencies. At millimeter wave and terahertz frequencies, the resolution of the current 3D printing equipment is a key issue. From the design perspective, this can be overcome by selecting specific designs and using high-end tools. This talk reviews some of our previous work on 3D printing of electromagnetic structures at microwave and millimeter wave frequencies and presents new results on FSS for terahertz applications.**

Bio: Dr. Sanz is a Senior Lecturer at the University of Kent, U.K. He received the B.Sc. from the ULPGC, Spain, and the M.Sc. and Ph.D. degrees from the University of Kent, U.K. He holds an MBA from CCCU, UK. Prior to becoming a lecturer in 2013, he was a Research Associate at Kent where he worked on EPSRC funded projects. In 2012, he worked for Harada Industries Ltd on the development of novel antennas for the automotive industry. In 2017, he was a visiting fellow at Selex E.S. where he worked on reconfigurable antennas for the defense industry. From 2015 to 2019, he was an EPSRC HVMC fellow which involved working with the CPI on the development of Innovative 3D printing solutions for antenna applications. His main research interests are multiband antennas, wearable microwave devices, sensors, electromagnetic band-gap structures and frequency selective surfaces. Currently, he is involved in projects in the area of 3D printing for electromagnetic device fabrication. He has authored more than 100 peer-reviewed journal publications and international conference papers and has h-index of over 27. He has received awards and special mentions for his work on wearable antennas (best paper at IEEE IWAT, mention in the House of Lords), reconfigurable antennas (Best CST Microwave Studio paper in 2017), 3D printed antennas (front cover on IEEE Trans. on Components, Packing and Manufacturing Technology Dec.2017) and FSS (best paper award at the 4th IET Enterprise Workshop: RF technology for Aerospace, 2015).

11:00 – 11:45	Keynote Talk: Dr. Patrick Reynaert THz in CMOS: Dream, Nightmare or Reality?

Department of Electrical Engineering (ESAT-MICAS)
University of Leuven (KU Leuven), Belgium

***Abstract* — The maximum operating frequency of CMOS has steadily increased over the past thirty years and extrapolations would predict THz circuits in CMOS soon. Compared to other technologies, CMOS does offer integration complexity paving the road for entire THz systems. As such, potential applications such as near-field scanning, quality control, spectroscopy and imaging could be pushed to the consumer market.**
However, CMOS scaling also resulted into thinner interconnects with higher intrinsic resistance which in turn limits the maximum operating frequency. On the other hand, one could go beyond the f_{max}-limit by exploiting the non-linear behaviour of a transistor. This concept is used already in frequency-doubler and -triplers and can be extended to entire transmitters and receivers. This talk will highlight some of these challenges when designing circuits in CMOS in the THz (300GHz-3THz) frequency band. Several examples in 40nm and 28nm CMOS at a frequency range from 200 to 620GHz will be discussed.

Bio: Patrick Reynaert was born in Wilrijk, Belgium, in 1976. He received the Master of Industrial Sciences in Electronics (ing.) from the Karel de Grote Hogeschool, Antwerpen, Belgium in 1998 and both the Master of Electrical Engineering (ir.) and the Ph.D. in Engineering Science (dr.) from the University of Leuven (KU Leuven), Belgium in 2001 and 2006 respectively.
During 2006-2007, he was a post-doctoral researcher at the Department of Electrical Engineering and Computer Sciences of the University of California at Berkeley, with the support of a BAEF Francqui Fellowship. During the summer of 2007, he was a visiting researcher at Infineon, Villach, Austria.
Since October 2007, he is a Professor at the University of Leuven (KU Leuven), department of Electrical Engineering (ESAT-MICAS). His main research interests include mm-wave and THz CMOS circuit design, high-speed circuits and RF power amplifiers.
Patrick Reynaert is a Senior Member of the IEEE and chair of the IEEE SSCS Benelux Chapter. He serves or has served on the technical program committees of several international conferences including ISSCC, IEDM, ESSCIRC, RFIC, ICECS and PRIME. He has served as Associate Editor for Transactions on Circuits and Systems – I, and as Guest Editor for the Journal of Solid-State Circuits.
He received the 2011 TSMC-Europractice Innovation Award, the ESSCIRC-2011 Best Paper award and the 2014 2nd Bell Labs Prize.

11:45 – 12:15 **Dr. Rui Xu:**
Low-Cost and High-Gain mm-Wave and THz Antenna Based on 3D-Printing Technique

Member of Graduate Studies at the School of Engineering and Digital Arts
University of Kent, United Kingdom

***Abstract* — Recently, Terahertz (THz) has been paid more and more attention because of its useful applications, such as noninvasive biomedical imaging, defect detection in semi-conductors, stand-off detection of hidden explosives and weapons. Among THz systems, antennas are important. The antenna gain directly determines the output equivalent isotopically radiated power (EIRP) of a transmitter and how much power a receiver can receive, that is, it has great influence on the dynamic range of a THz system or the maximum transmission distance. In general, the systems can use many antenna elements to form an array to achieve high gain. However, it needs a complex feed network and will make a high-cost. This talk gives a brief overview of various techniques proposed in recent years to achieve low-cost and high-gain radiation at mm-wave wave. However, there are few works have been done at THz wave. Then, a low-cost and high-gain antenna with Partially-Reflective Surface (PRS) and 3D-printing technique is presented in this talk. This antenna is shown to be able to achieve 24.0 dB high-gain radiation. Also, a 1×4 antenna array is designed for higher-gain and beam-switching. The PRS and 3D-printing technology can make sure this antenna with low-cost and high-gain performance.**

Bio: RUI XU received the degrees of B.Sc, M.Sc and Ph.D in Electronic Engineering in Northwestern Polytechnical University Xi'an, China in 2013, 2015 and 2019 respectively. From 2019, he is with the School of Engineering and Digital Arts as a Postdoctoral Research Associate at University of Kent, UK. His recent research interests include wideband and multi-band antennas, waveguide slot antennas, circularly polarized antennas, low-cost high-gain mm-wave and THz antenna, reconfigurable antenna and EM Periodic Structure.

12:15 – 12:45

MSc. Jan Köhler:
Planar Lenses for micro- and mm-Wave Applications

Institute of Microwave and Photonic Engineering
Graz University of Technology, Austria

***Abstract*— Despite the trivial concept of 3D printing supporting structures to enhance radiating electromagnetic field waves, the practicability is limited due to achievable fabrication quality. Nowadays CMOS technology is being able to operate in the THz range. The associated wavelength corresponds to the need for smaller sizes of the considered components and a higher level of precision in production. Driven by promising research and test results we saw the opportunity of focusing electromagnetic radiation using metamaterials and incorporate intelligent passive filter design into these structures. At the same time the structures can be optimized to cope with the limits imposed by 3D printing.**
Radiating the electromagnetic field wave, antennas oscillate energy into space. Due to parasitic coupling some of it will propagate into the electrical circuit. To minimize such effects, we combine the antenna with an additional layer of metamaterial, creating a dome to focus the energy away from the PCB and preventing it from radiating to undesired directions.

Bio: Jan Köhler (born in Potsdam, Germany) received the B.Eng. at the THB Brandenburg (Germany) University of Applied Sciences and M.Sc. at the TU Berlin (Germany) in electrical engineering in 2012 and 2017, respectively. From 2010 to 2016 he has been also a research assistant at the Fraunhofer Institut IZM Berlin, RF & Smart Sensor Systems (R3S), developing new methods and tools for RFID, HF antenna design and passive components. From November 2016 to March 2017 he has been working as an engineer at the Toll Collect GmbH (Germany) developing an interactive UR5 (Universal Robots) robot. Since 2017 he is a research assistant at the IHF, TU Graz (Austria) and working towards the Ph.D. degree on passive RF filter structures based on metamaterials through 3D printing.

12:45 – 13:10	**MSc. Alexander Standaert:** **Co-Design of THz Transmitters and 3D Printed Antennas**

Department of Electrical Engineering (ESAT-MICAS)
University of Leuven (KU Leuven), Belgium

***Abstract*— With the scaling of CMOS technology, transistors become faster and it has become possible to generate (harmonic) frequency sources in the THz range. Bringing these THz signals off chip efficiently is however a major design challenge. The most convenient way to extract these THz signals by radiating them out with on-chip antennas. Due to the high frequencies these antennas have become small enough that this is economical, but due to lossy substrates and thin metal layers, the gain and efficiency of these antennas becomes very bad. In this talk, different techniques are presented to improve the antenna performance of on-chip antennas by 3D printing dielectric or metallic structures on top of the chip. The techniques are then validated with prototypes in the 400-600GHz range.**

Bio: Alexander Standaert was born in Belgium in 1991. He received the B.Sc and M.Sc degrees in electronics engineering from KU Leuven, Belgium, in 2012 and 2014, respectively. Since 2014 he is as a research assistant at MICAS, KU Leuven, Belgium, and working towards the Ph.D. degree on data communications through polymer waveguides.

14:00 – 14:45	<u>Keynote Talk</u>: Dr. Dmitry Isakov **Application of high dielectric permittivity feedstock for 3D printing of electromagnetic devices.**

WMG
University of Warwick, United Kingdom

***Abstract* — The development and use of composite materials with a wide range of electromagnetic properties for three-dimensional printing (3DP) will open up new possibilities for novel functional structures utilising the principles of transformation optics, smart microwave devices, and systems possessing meta-material features.**
Recently it was shown that bespoke feedstock filaments for Material Extrusion (ME) - a.k.a. Fused Deposition Modelling, are successfully used for 3DP of RF devices [1,2]. However, due to the limitation of the resolution of ME 3DP, the use of this method for the manufacturing of devices operating in the terahertz range is extremely difficult. At the same time, Vat Polymerisation (VP) - e.g Stereolithography – SLA, makes it possible to manufacture three-dimensional structures with characteristic elements less than 20 micrometers that makes this method attractive for fabrication of functional THz devices.
We will discuss in detail the approaches and problems of making composite feedstock materials for 3DP through both ME and VP 3DP approaches. Particular attention will be given to bespoke photo-curable composite resins with high refractive index and manufacturing devices using VP for high-frequency applications. The application of using high permittivity materials will be demonstrated on the examples of RF gradient refractive lens and spiral phase plate. Other approaches for the 3D printing of THz reflection surface and omnidirectional antennas will also be discussed.

Bio: Dr Isakov graduated in 2003 from the Institute of Crystallography (Russia) with a PhD dissertation on studies of switching processes in ferroelectrics. After PhD he studies on semiorganic crystals with the scope on developing applications for electro-optical and piezoelectric devices. Since 2008 Dr Isakov developed an independent research effort for studying nanomaterials with the potential to be used as functional elements in molecular electronics and integrated optics. He implemented state of the art setup for fabrication low-dimensional structures and several advanced experimental techniques to perform a variety of different nonlinear optical measurements as well as systems to characterise and evaluate the piezoelectric and pyroelectric properties in the fabricated 1D structures. Since 2014 he was a research fellow at the University of Oxford with interest in graded permittivity materials for novel electromagnetic applications and exploring challenges emerging in the area of spatial transformations and electromagnetism. Currently he is an Assistant Professor at the WMG, University of Warwick with research interests in multi-material 3D printing, active materials and sensing technologies, dielectrics oxides, polymers, functional composites and their applications.