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GeMiC 2022 ULM

German Microwave Conference 2022

May 16-18 Ulm|Germany

Conference Program

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Monday, May 16th

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Exhibition opens from 9:00 until 17:40.

Tuesday, May 17th

	Foyer	Großer Saal	Kleiner Saal	Studio München	Studio Stuttgart
08:00					
08:30		Radar Modelling and Signal Processing 08:30 - 10:10	Millimeter-Wave Circuits 08:30 - 10:10	ITG Workshop on Antennas 08:30 - 10:10	Workshop SIMUSERV Antenna, Antenna Array and Microwave Filter Design with SIMULIA CST Studio Suite® 08:30 - 10:10
09:00					
10:00					
10:10	Poster Session 2 *with Coffee* 10:10 - 12:20	*Coffee Break* | Foyer 10:10 - 10:40			
10:40		Localization Systems 10:40 - 12:20	Passive Components 10:40 - 12:20	ITG Workshop on Antennas 10:40 - 12:20	Workshop IHP IHP Photonic SiGe BiCMOS Technology for Broadband Integrated Communication Circuits 10:40 - 12:20
11:00					
12:00					
12:20	*Lunch Break* | Foyer 12:20 - 13:20				
13:00					
13:20		Plenary Session (Keynote 1: Andrea Neto) (Keynote 2: Goutam Chattopadhyay) 13:20 - 15:30			
14:00					
15:00					
15:30	*Coffee Break* | Foyer 15:30 - 16:00				
16:00		Antennas and Antenna Arrays 16:00 - 17:40	Transmitters and Receivers 16:00 - 17:40		Workshop Anritsu 16:00 - 17:40
17:00					
17:40	**Dinner Event** *Note:* Please bring a jacket, we will bring food! from 17:40				
18:00					

Exhibition opens from 8:00 until 16:00.

Program Overview

Wednesday, May 18th

	Foyer	Großer Saal	Kleiner Saal	Studio München	Studio Stuttgart
08:00					
08:30		Communication Systems 08:30 - 10:10	Calibration and Material Characte-rization 08:30 - 10:10		Workshop Infineon - SiGe BiCMOS Technology and Circuits for mm-Wave Applications like Future High-Resolution Radar 08:30 - 10:10
09:00					
10:00					
10:10	*Coffee Break* | Foyer 10:10 - 10:40				
10:40		Closing Session (Keynote: James Hwang) 10:40 - 12:20			
11:00					
12:00					
12:20	*Lunch Break* | Foyer 12:20 - 13:20				
13:00					
13:20					

Exhibition closed.

Welcome Message

German Microwave Conference, GeMiC 2022
Edwin-Scharff-Haus, Neu-Ulm, May 16-18

Pictures of the committee (up left to down right)**:** Christian Waldschmidt, Christian Damm, Dietmar Kissinger, Hermann Schumacher, Tobias Chaloun, Martin Hitzler, Yvonne Kufner

Dear Gemic 2022 Delegate,

on behalf of

- The German Institute for Microwave and Antenna Technologies (IMA)
- The German Association for Electrical, Electronic & Information Technologies (VDE) and its Information Technology Society (ITG)
- The Institute of Electrical and Electronics Engineers (IEEE), represented through its Germany Section MTT/AP Joint Chapter
- The European Microwave Association (EuMA)
- And Ulm University

it is our great pleasure to welcome you to the 14th German Microwave Conference - GeMiC 2022, which is held from May 16 to 18, 2022 in Ulm! This year is special from different points of view. For the first time since 17 years, GeMiC is held again in a city where it took place before: 2005 the first GeMiC was held in Ulm, organized by our former colleague Prof. Dr.-Ing. Wolfgang Menzel. This was the start of the very successful GeMiC conference series: Ulm (2005), Karlsruhe (2006), Hamburg (2008), München (2009), Berlin (2010), Darmstadt (2011), Ilmenau (2012), Aachen (2014), Nürnberg (2015), Bochum (2016), Freiburg (2018), Stuttgart (2019) and Cottbus (2020).

So we are proud to say

Welcome Back to Ulm!

Welcome Message

The second fact making this GeMiC special was caused by the global Corona pandemic, which forced us to postpone the 14th GeMiC from the originally scheduled date in 2021 by one year: For the first time, we unfortunately had a year without either GeMiC or the European Microwave Conference to be held in Germany. Therefore, we are very happy to welcome you all here in Ulm and its “twin-city” Neu-Ulm after this involuntary break and wish to recover from a difficult year with a fresh start of successful networking and technical discussions.

To further enrich the excellent technical program, GeMiC presents four keynote talks:

Monday – Opening Session

- **Prof. Gerhard Kahmen**

IHP – Leibniz-Institut für innovative Mikroelektronik
More than Moore or CMOS +X – Complementing CMOS to overcome the limits of scaling for future electronic systems

Tuesday – Plenary Session

- **Prof. Andrea Neto**

Technical University of Delft, The Netherlands
Toward THz Pulsed Radars

- **Prof. Goutam Chattopadhyay**

NASA-Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA
Terahertz Space Instruments and Technologies

Wednesday – Closing Session

- **Prof. James C. M. Hwang**

Cornell University, Ithaca, USA
Microwaving a Biological Cell Alive – Broadband Label-free Noninvasive Electrical Characterization of a Live Cell

The conference is complemented by academic and industry workshops, short courses, and the industry exhibition. At this exhibition, you can get in touch with cutting edge instrumentation systems, simulation tools, components, and subsystems in the area of microwaves. We hope that during the breaks and the social events accompanying the conference, you will find numerous opportunities for discussions and face to face exchange of latest research results.

The Welcome Reception on Monday, May 16, will be held in the Foyer of Edwin-Scharff-Haus right next to the exhibition.

The Conference Dinner Event will take place on Tuesday, May 17, outside of Edwin-Scharff-Haus right next to the Danube river with a beautiful view to the old town of Ulm on the other side of the river, food, drinks and entertainment. Please bring a jacket, evenings can be chilly next to the Danube.

Finally, we want to express our thanks to all **authors, reviewers and the Awards Team** for their contributions.

We would like to thank the **Local Team** Maximilian Döring, Ines Dorsch, Timo Grebner, Philipp Hinz, Martin Sander, Felix Wiedenmann for their invaluable work.

We highly appreciate the financial support by our sponsors and exhibitors:

■ ANRITSU ■ bsw TestSystems & Consuftihg ■ HENSOLDT Sensors ■ IHP
■ Infineon Technologies ■ Keysight Technologies Deutschland
■ MBDA Deutschland ■ Mercedes-Benz AG ■ Nokia Solutions and Networks
■ Rohde & Schwarz ■ SIMUSERV GmbH ■ Thales

without their support, GeMiC 2022 would not have been possible.

Equally, we acknowledge the support of our technical co-sponsors:

- IEEE
- EuMA

Further, we would like to express our thanks to the sponsors of the awards for the categories:

- Best Student Paper Award - EuMA
- Best Student Paper Award - Daimler
- Best Paper Award - Daimler
- Best Paper Award – IMA

Finally, we wish you all a successful and interesting conference, and

“Welcome Back to Ulm”

Committees and Boards

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Dietmar Kissinger, Hermann Schumacher,
Tobias Chaloun, Martin Hitzler, Yvonne Kufner
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Keynote Talks

Terahertz Space Instruments and Technologies

Prof. Goutam Chattopadhyay

NASA's Jet Propulsion Laboratory, which completed eighty years of its existence in 2016, builds spacecraft and instruments for NASA missions. Exploring the universe and our own planet Earth from the space has been the mission of NASA. Robotics missions such as Voyager, which continues to go beyond our solar system, missions to Mars and other planets, exploring the stars and galaxies for astrophysics missions, exploring and answering the question, "are we alone in this universe?" has been the driving force for NASA exploration since its inception. Fundamental science questions drive the selection of NASA missions. We develop new technologies and innovative instruments to make measurements that can answer these science questions. In this presentation, we will present an overview of the state-of-the-art radar, spectrometers, radiometers, and other instruments that we are currently developing and layout the details of the science questions they will try to answer. Rapid progress in multiple fronts, such as commercial software for component and device modeling, low-loss circuits and interconnect technologies, cell phone technologies, and submicron scale lithographic techniques are making it possible for us to design and develop smart, low-power yet very powerful instruments that can even fit in a SmallSat or CubeSat. We will also discuss the challenges of the future generation instruments in addressing the needs for critical scientific applications. The research described herein was carried out at the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, under contract with National Aeronautics and Space Administration.

Goutam Chattopadhyay is a Senior Research Scientist at the NASA's Jet Propulsion Laboratory, California Institute of Technology, a Visiting Associate at the Division of Physics, Mathematics, and Astronomy at the California Institute of Technology, Pasadena, USA, a BEL Distinguished Chair Professor at the Indian Institute of Science, Bangalore, India, and an Adjunct Professor at the Indian Institute of Technology, Kharagpur, India. He received the Ph.D. degree in electrical engineering from the California Institute of Technology (Caltech), Pasadena, in 2000. He is a Fellow of IEEE (USA) and IETE (India) and an IEEE Distinguished Lecturer.
His research interests include microwave, millimeter-wave, and terahertz receiver systems and radars, and development of space instruments for the search for life beyond Earth.

He has more than 300 publications in international journals and conferences and holds more than fifteen patents. He also received more than 35 NASA technical achievement and new technology invention awards. He received the IEEE Region 6 Engineer of the Year Award in 2018, Distinguished Alumni Award from the Indian Institute of Engineering Science and Technology (IIEST), India in 2017. He was the recipient of the best journal paper award in 2013 by IEEE Transactions on Terahertz Science and Technology, best paper award for antenna design and applications at the European Antennas and Propagation conference (EuCAP) in 2017, the best journal paper award in 2020 by IEEE Transactions on Terahertz Science and Technology, and IETE Prof. S. N. Mitra Memorial Award in 2014.

Keynote Talks

Microwaving a Biological Cell Alive – Broadband Label-free Noninvasive Electrical Characterization of a Live Cell

Prof. James C. M. Hwang

Microwave is not just for cooking, smart cars, or mobile phones. We can take advantage of the wide electromagnetic spectrum to do wonderful things that are more vital to our lives. For example, microwave ablation of cancer tumor is already in wide use, and microwave remote monitoring of vital signs is becoming more important as the population ages. This talk will focus on a biomedical use of microwave at the single-cell level. At low power, microwave can readily penetrate a cell membrane to interrogate what is inside a cell, without cooking it or otherwise hurting it. It is currently the fastest, most compact, and least costly way to tell whether a cell is alive or dead. On the other hand, at higher power but lower frequency, the electromagnetic signal can interact strongly with the cell membrane to drill temporary holes of nanometer size. The nanopores allow drugs to diffuse into the cell and, based on the reaction of the cell, individualized medicine can be developed and drug development can be sped up in general. Conversely, the nanopores allow strands of DNA molecules to be pulled out of the cell without killing it, which can speed up genetic engineering. Lastly, by changing both the power and frequency of the signal, we can have either positive or negative dielectrophoresis effects, which we have used to coerce a live cell to the examination table of Dr. Microwave, then usher it out after examination. These interesting uses of microwave and the resulted fundamental knowledge about biological cells will be explored in the talk.

James Hwang is Professor in the Department of Materials Science and Engineering at Cornell University. He graduated from the same department with a Ph.D. degree. After years of industrial experience at IBM, Bell Labs, GE, and GAIN, he spent most of his academic career at Lehigh University. He cofounded GAIN and QED; the latter became the public company IQE. He was a Program Officer at the U.S. Air Force Office of Scientific Research for GHz-THz Electronics. He has been a visiting professor at Cornell University in the US, Marche Polytechnic University in Italy, Nanyang Technological University in Singapore, National Chiao Tung University in Taiwan, Shanghai Jiao Tong University, East China Normal University, and University of Science and Technology in China. He is an IEEE Life Fellow and a Distinguished Microwave Lecturer. He is also a Track Editor for the IEEE Transactions on Microwave Theory and Techniques. He has published approximately 400 refereed technical papers and been granted eight U.S. patents. He has researched the design, modeling and characterization of optical, electronic, and micro-electromechanical devices and circuits. His current research interest includes electromagnetic sensors for individual biological cells, scanning microwave microscopy, and two-dimensional atomic-layered materials and devices.

More than Moore or CMOS +X – Complementing CMOS to Overcome the Limits of Scaling for Future Electronic Systems

Prof. Gerhard Kahmen

While pure CMOS scaling according to Moore's law is approaching its physical and economical limits orthogonal technologies following the More than Moore approach and combined with scaled CMOS are the key to meet the requirements for future electronic systems.
Future systems such as intelligent autonomous vehicles or communication networks will require a complex combination of powerful computation capabilities, signal processing, sensor technology and artificial intelligence to meet performance, functionality and energy efficiency requirements at the same time. After a brief overview and limitations of state of the art CMOS technology Si-BiCMOS based technologies complementing highly scaled CMOS to CMOS + X as enabler for future electronic systems are presented and discussed.

Gerhard Kahmen received his Diploma (Dipl-Ing.) in Electrical Engineering (Diplom) at the technical university of Aachen (RWTH) in 1997 and the Dr.-Ing. degree in electrical engineering from Ulm University in 2016. From 1998 to 2000 he worked for Philips Semiconductors in Nimegen / The Netherlands on Power Amplifier Modules for handsets. In 2001 he joined the Test & Measurement division of Rohde & Schwarz in Munich where he developed high dynamic range broadband mixed signal ASICs for test & measurement equipment. From 2008 to 2010 he was responsible for a mixed-signal ASIC R&D team as a director of engineering. From 2011 to 2019 Gerhard Kahmen was responsible for the worldwide mixed signal ASIC R&D activities of Rohde & Schwarz in a Vice President position. Since 2020 he is in the position of the scientific director at the IHP / Frankfurt (Oder) and holds a full professorship for semiconductor technology at Brandenburg Technical University (BTU). His research interests are broadband RF / Mixed-Signal ASICs with high dynamic range and ultra-high speed digital to analog converters for direct digital RF signal generation.

Keynote Talks

Toward THz Pulsed Radars

Prof. Andrea Neto

A THz radar can realize images with fine lateral resolutions even with moderate antenna sizes. However, exploiting only limited absolute Bandwidth (BW), state of the art THz radars provide at most a moderate centi-metric range resolutions. Within this paper I will describe the strategy of the Tera Hertz Sensing group to break the mm range resolution limit, by developing radar front ends capable of producing images with extreme resolutions, with refresh rates in the tenths of a second, at a fraction of the complexity of existing THz radar architectures. This could be achieved by exploiting pulsed Optical-to-THz up/down conversions via Photoconductive Antennas (PCA). PCA's have never been proposed as Radars yet, mostly because the power available from reliable sources was only sufficient for localized spectroscopy. This bottle neck, has now been cleared by the TS Group: reproducible m-watt power sources in the THz spectrum have been demonstrated which are 50 times more powerful than what has been commercially available. The remaining bottle necks are mostly associated to pulse conditioning. In a Radar, one cannot resort to differential measurements as in spectroscopy. The spreading of the pulses in the unknown channels must be separated from the spreading in the Tx and Rx front ends.

Andrea Neto (M'00–SM'10–F'16) received the Laurea degree (summa cum laude) in electronic engineering from the University of Florence, Italy, in 1994, and the Ph.D. degree in electromagnetics from the University of Siena, Italy, in 2000. Part of his Ph.D. degree was developed at the European Space Agency Research and Technology Center, Noordwijk (ESTEC), The Netherlands. He was with the Antenna Section, at ESTEC, for over two years. From 2000 to 2001, he was a Post-Doctoral Researcher with the California Institute of Technology, Pasadena, CA, USA, where he was with the Sub-Millimeter-Wave Advanced Technology Group. From 2002 to 2010, he was a Senior Antenna Scientist with TNO Defense, Security, and Safety, The Hague, The Netherlands. In 2010, he became a Full Professor of applied electromagnetism at the Electrical Engineering, Mathematics and Computer Science (EEMCS) Department, Technical University of Delft, Delft, The Netherlands. In 2011, he was a recipient of the European Research Council Starting Grant to perform research on Advanced Antenna Architectures for THz Sensing Systems. This grant jump started the THz Sensing Group which he still leads.

His current research interests include the analysis and design of antennas with an emphasis on arrays, dielectric lens antennas, wideband antennas, electromagnetic band gap (EBG) structures, and terahertz antennas. Dr. Neto is a member of the Technical Board of the European School of Antennas and the organizer of the course on antenna imaging techniques. He served as an Associate Editor for the IEEE Transaction on Antennas and Propagation from 2008 to 2013 and the IEEE Antennas and Wireless Propagation Letters from 2005 to 2013 and then associate Editor of the IEEE Transaction on THz Science and Technology. He was TPC Co-Chair for the EuCAP 2021 Conference in Düsseldorf.

Sessions and Workshops

Monday

Monday, May 16th

10:00 - 10:40	*Coffee Break*	Foyer
10:40 - 12:20	**Waveguide Components**	Kleiner Saal
	Workshop Rohde & Schwarz	Studio Stuttgart
12:20 - 13:20	*Lunch Break*	Foyer
13:20 - 15:30	**Opening Session** Keynote: **Gerhard Kahmen**	Großer Saal
15:30 - 16:00	*Coffee Break*	Foyer
15:30 - 17:40	**Poster Session 1** *with Coffee*	Foyer
16:00 - 17:40	**Radar Systems**	Großer Saal
	Microwave Circuits	Kleiner Saal
	Workshop Keysight	Studio München
	Workshop Keysight	Studio Stuttgart
17:40 -	***Welcome Reception***	Foyer

Coffee Break	*Room:* Foyer	10:10 -10:40

Waveguide Components — 10:40 - 12:20

Chair: Prof. M. Thumm
Room: Kleiner Saal

10:40 Additively Manufactured Broadwall Waveguide Couplers for V-Band Applications

Andreas Hofmann, Konstantin Lomakin, Mark Sippel, Dr. Gerald Gold
FAU Erlangen-Nuremberg | Germany

This work demonstrates the feasibility of monolithic additively manufactured broadwall slotted waveguide couplers from polymer resin in combination with electroless silver plating for V-band applications. Waveguide couplers with two different coupling coefficients were manufactured exploiting conventional desktop DLP printers, opening up new possibilites for complex monolithic additively manufactured waveguide components and systems. The manufactured waveguide couplers are electrically charaterized and their propagation properties compared to EM-field simulations.

11:00 Verification of the 170/204 GHz Quasi-Optical Output Coupler of the 2 MW Coaxial-Cavity Gyrotron using a Mode Generator Setup

Tobias Ruess[1,2], Dr. Gerd Gantenbein[1], Dr. Jianbo Jin[1], Alexander Marek[1], Dr. Tomasz Rzesnick[1], Prof. Manfred Thumm[1,2], Dr. Dietmar Wagner[3], Prof. John Jelonnek[1,2]
[1] IHM, [2] IHE, Karlsruhe Institute of Technology (KIT) | Germany;
[3] Max-Planck-Institute for Plasma Physics | Germany

At KIT, a 2 MW single-frequency 170 GHz coaxial- cavity short-pulse pre-prototype gyrotron has been upgraded towards to dual-frequency operation at 170 GHz and 204 GHz. That upgrade includes a modification of the quasi-optical output coupler system. For validation of the proper design a verification of that sub-system at low power is vital. Therefore, an automated quasi-optical mode generator has been developed for the excitation of the high-order rotating TE34,19 cavity mode excited at 170 GHz and the TE40,23 mode excited at 204 GHz. The TE40,23 mode is the mode with the highest eigenvalue ever excited in cold tests with a high mode purity. The measurements results of the quasi-optical output coupler system shows an excellent agreement with the simulation.

11:20 A Compact Dual Band Polariser for Q/V-Band

Philipp Kohl, Michael Kilian, Dr. Michael Schneider, Christian Hartwanger
Airbus Defence and Space GmbH | Germany

This paper presents a dual septum polariser able to extract or combine two orthogonal circular polarisations in a very compact manner. The component is manufactured with well-known high accuracy manufacturing processes and S-parameters are measured to verify the simulated results. The component looks similar to the well-known septum polariser but contrary to this, two septa are used to expand the operating bandwidth to 31 percent.

11:40 3D Printed Waveguide Transition for 77 GHz Radar Applications

Lukas Engel, Konstantin Lomakin, Dr. Gerald Gold, Tim Pfahler, Dr. Jan Schür, Prof. Martin Vossiek
Friedrich-Alexander University Erlangen-Nuremberg | Germany

A novel approach of a differential microstrip line to a rectangular waveguide realized by an alternative manu- facturing method, based on additive manufacturing, is presented. In comparison with conventional machining, this approach offers an improved behavior regarding weight, costs and uncomplicated alignment with simultaneous high manufacturing accuracy. The transition is designed for applications in the frequency range of 70 – 90 GHz in particular for automotive radar at 77 GHz but yet can easily be adapted for other frequencies. Measurements are carried out stating a return loss of $|S11|^2 < -24$ dB and an insertion loss $|S21|^2$ better than -1.3 dB at 77 GHz for the transition. To demonstrate excellent suitability for hybrid circuits an analysis of manufacturing tolerances and resulting degradation on the performance of the transition have been conducted. The measurements of this analysis prove a high reproducibility and robustness of the promising technology even for precision demanding mmW applications.

12:00 Coupling Matrix Description of WR-3 Waveguide Filter with Multiple Transmission Zeros Created by Source to Load Cross-Coupling

Daniel Miek, Kennet Braasch, Chad Bartlett, Fynn Kamrath, Patrick Boe, Prof. Michael Höft
Christian-Albrechts-Universität zu Kiel | Germany

In this paper, a fourth order source to load (SL) cross-coupled WR-3 band (220-325 GHz) waveguide filter is presented. Due to the dispersive characteristic of the SL cross-coupling, two extra transmission zeros (TZs) are obtained, which

are not predicted by the common coupling matrix theory. One of these TZs can be positioned freely on the frequency axis while the position of the second one depends on the position of the first one, allowing the realization of asymmetric filter responses. It is shown that the SL coupling proposed in this filter set-up reveals a quadratic frequency dependency. Based on this observation, a coupling matrix description which agrees well with an appropriate discrete equivalent circuit as well as the simulation results can be found. A prototype is manufactured with a high precision CNC milling machine as proof of concept.

Workshop Rohde & Schwarz 10:40 - 12:20

Room: Studio Stuttgart

10:40 **The path towards 6G: From Millimeter Waves to THz**
T. Eichler

11:30 **Modern RF Frontend Design and Testing**
M. Lörner

Lunch Break *Room:* Foyer 12:20 -13:20

Opening Session 13:20 - 15:20

Chair: Prof. C. Waldschmidt
Room: Großer Saal

14:30 **Gerhard Kahmen – More than Moore or CMOS +X – Complementing CMOS to Overcome the Limits of Scaling for Future Electronic Systems**

Coffee Break *Room:* Foyer 15:30 -16:00

Poster Session 1 *(with coffee)* 15:30 - 17:40

Chair: Dr. M. Hitzler
Room: Foyer

C-Band MIMO FMCW Radar for Imaging Targets in Dielectric Medium

Maximilian Sundermeier, Prof. Dirk Fischer
University of Applied Sciences Münster | Germany

A frequency modulated continuous wave (FMCW) radar with imaging capability due to a multiple input multiple output (MIMO) antenna array is used to detect metallic objects embedded in chaotic structured dielectric material. The radar operates with frequency chirps over the complete C-band from 4 to 8 GHz with a chirp time of 200 µs. The MIMO array consists of 10 transmit and 12 receive antennas that are linearly arranged and stacked on top of each other. Each Tx-Rx channel is separated in the time domain by using a special antenna switching scheme. This reduces the hardware complexity of the system. Many correlated reflected signals are expected, due to the medium the object of interest is embedded in, therefore, a synthetic aperture radar (SAR) algorithm namely the range migration algorithm (RMA) is used to reconstruct the image.

A Compact Wide Coverage 0.7-1.5 GHz MEMS-based Impedance Tuner

Jonathan Okocha, Prof. Matthias Rudolph
Brandenburg University of Technology (BTU) | Germany

We propose a lumped element re-configurable impedance tuner with wide impedance coverage within the 0.7 - 1.5 GHz frequency band. The fabricated device is compact and the design is centered around 0.9 GHz using 4 BST MEMS varactors for continuous tuning covering a VSWR up to 55:1 on the smith chart.

The Effect of Facet Size on the RCS Simulation of an Automotive Radar Target with Curved Surface

Mohannad Saifo[1], Dr. Alexander Ioffe[2], Dr. Markus Stefer[2], Prof. Markus Clemens[1]
[1] Bergische Universität Wuppertal | Germany;
[2] APTIV Services Deutschland GmbH | Germany

Electromagnetic simulation is increasingly used in automotive industry to generate radar data in virtual scenarios instead of actual measurement campaigns.

Objects in the scenario are usually converted into triangular facets before the simulation. This paper studies the effect of facetization criteria on the RCS accuracy of an object with curved surface.

Investigation of the Influence of LO Leakage in an E-Band Quadrature Transmitter

Dominik Wrana[1], Benjamin Schoch[1], Laura Manoliu[1], Simon Haußmann[1], Axel Tessmann[2] Prof. Ingmar Kallfass[1]
[1] Institute of Robust Power Semiconductor Systems (ILH) University of Stuttgart | Germany;
[2] Fraunhofer IAF, Fraunhofer Institute for Applied Solid State Physics | Germany

This paper discusses the influence of local-oscillator leakage on signal quality based on a homodyne double-balanced quadrature E-band transmitter designed for broadband wireless communication. The varying severeness of the leakage over the local oscillator frequency tuning range from 72 to 88 GHz as well as with changing intermediate frequency input power is measured and evaluated using continuous wave as well as complex modulated signals. With power levels between −22 and 0 dBm at the RF port of the transmitter module, the leaked carrier exceeds the data signal power at some LO frequencies and is also traced back to lead to inherent saturation of the output amplifier. This is identified by evaluation of measured transmitter output spectra and constellation diagrams of the demodulated QPSK signals with baudrates up to 5 GBd.

Evaluation of Range Doppler Processing Algorithms for Tank Level Probing Radar

Dr. Christoph Dahl[1], Dr. Markus Hammes[2], Prof. Michael Vogt[1], Dr. Christian Schulz[1], Prof. Ilona Rolfes[1]
[1] Ruhr University Bochum | Germany; [2] Krohne Messtechnik GmbH | Germany

In this contribution, the performance of different algorithms for range Doppler processing are compared and discussed for application in tank level probing radar. Algorithms using the fast Fourier transform and the keystone transform have been evaluated by simulations and measurements regarding the accuracy and the reliability of measuring the filling level of a liquid inside a tank. In addition the impact of waves on the surface of the liquid has been investigated. It is shown, that the keystone transform is capable to improve the performance of measurements in tank level scenarios.

Radar Systems

16:00 - 17:40

Chair: Prof. P. Knott
Room: Großer Saal

16:00 Loopback Testing of Automotive 77 GHz Antenna-in-Package Radar Transceiver ICs

Abhijit Pal[1], Prof. Martin Schneider[1], Abdellatif Zanati[2]
[1] University of Bremen | Germany; [2] NXP Semiconductors Germany GmbH | Germany

In this contribution, a testing strategy is presented showing how automotive radar transceivers with packaged antennas can be measured in a metrologically reproducible way with regard to their high-frequency properties. The testing concept presented in this work is based on a full loopback from the 3 TX channels to the 4 RX channels of a single chip 77 GHz radar transceiver, TEF810X, manufactured by NXP Semiconductors. The concept uses a Printed Circuit Board (PCB) based structure to facilitate the coupling of the EM waves from the packaged antennas into waveguides. Thereafter, a fan out structure is designed in a metallic block with rectangular waveguides to increase inter-channel spacing of the individual TX and RX channels. Finally, another PCB is designed to facilitate the loopback from TX channels to RX channels using microstrip transmission lines. An insertion loss of roughly 5 dB, a return loss of roughly 19 dB and an inter-channel isolation of › 25 dB is achievable over a frequency range of 76 GHz – 81 GHz.

16:20 A Compact Measurement Setup for the Validation of MIMO arrays in D-band and W-band

Jonas Wagner, Dr. Christoph Dahl, Prof. Ilona Rolfes, Dr. Jan Barowski
Ruhr-University Bochum | Germany

This paper presents a measurement setup for scanning the virtual array of a Multiple Input - Multiple Output (MIMO) system which can be used to validate MIMO array concepts. Two FMCW (Frequency-Modulated Continuous Wave) radar sensors are used for this purpose, mounted on a 2D linear rail. Resulting MIMO images can be matched to corresponding radar cross section (RCS) values using the described calibration method. In order to increase the image quality, averaging is used for a larger signal-to-noise ratio (SNR). Measurements show that the achieved angular resolution matches with theoretically possible values.

16:40 Characteristics of Diode Detectors for Six-Port Radars

Prabhav Manchanda[1], Dr. Sascha Krause[2], Prof. Wolfgang Heinrich[2], Prof. Matthias Rudolph[1]
[1] Brandenburg Technical University Cottbus-Senftenberg | Germany;
[2] Ferdinand-Braun-Institute for High-Frequency Technology | Germany

In recent times, six-port radar technology has been implemented for accurate phase measurements due to its low cost and easy implementation. This work focuses on various design aspects of a six-port radar for vital sign detection. The requirements for the system are derived from its operating conditions. As the diode detector plays a crucial role in the system, a simple yet analytical model is used to predict its behavior. This can help designers optimize the detector's design parameters, calculate link budgets, etc. The effects of Local Oscillator(LO) power level and load impedance are highlighted by studying the conversion gain, signal to noise ratio, and system resolution. The calculations are compared to Harmonic Balance simulations done with Keysight ADS.

17:00 High Accuracy Thickness Measurements of Conducting Material with Single FMCW Radar Sensor

Niklas Muckermann, Lukas Piotrowsky, Prof. Nils Pohl
Ruhr University Bochum | Germany

A novel quasi-optical measurement setup for measuring the thickness of conducting materials, e.g. steel sheets, is presented. It utilizes a single ultra wideband frequency-modulated continuous-wave (FMCW) radar, operating from 68 to 90 GHz. To demonstrate the capabilities of the presented approach, we perform thickness measurements with spring steel sheets with thicknesses from 300 µm to 950 µm. The measurements show accuracies in the micrometer range and a measurement reproducibility of ±3.2 µm is achieved.

Microwave Circuits 16:00 - 17:40

Chair: Prof. M. Rudolph
Room: Kleiner Saal

16:00 A Robust Programmable Static Frequency Divider in Low-Voltage Emitter-Coupled Logic

Dr. Frank Herzel, Thomas Mausolf, Dr. Gunter Fischer
IHP - Leibniz Institut für innovative Mikroelektronik | Germany

A programmable 7-bit frequency divider in SiGe BiCMOS technology is presented. The bipolar divider can divide input frequencies up to 5.6 GHz by any number from 57 to 112. To reduce supply voltage and power consumption, emitter followers at the outputs of the flipflops and the logic gates are avoided and used selectively at their inputs. The circuit is functional for any supply voltage between 2.2 V and 3.3 V for temperatures up to 125°C. It draws 63 mA from a single 2.2 V supply. Using this divider circuit as an exemplary ECL circuit, a flexible ECL cell library is developed and verified by the divider measurements. The absence of MOS devices makes the library suitable for radiation-hard applications. The absence of MOS devices makes the library suitable for radiation-hard applications.

16:20 A Performance Study of 22nm FDSOI CMOS for Wideband 5G Power Amplifier Applications

Quang Huy Le[1], Dang Khoa Huynh[1], Anurag Nayak[1], Dr. Thomas Kämpfe[1], Prof. Matthias Rudolph[2]
[1] Fraunhofer Institute for Photonic Microsystems (IPMS) | Germany;
[2] Ulrich L. Rohde Chair of RF and Microwave Techniques, Brandenburg University of Technology (BTU), Cottbus, Germany | Germany

This paper presents a performance study of the 22nm FDSOI transistor through the design and simulation of a wideband two-stage power amplifier (PA). The PA design flow includes preliminary characterization and modeling of the core active device. The matching networks are designed through 3D electromagnetic (EM) simulation by using Ansys HFSS. The proposed PA is well matched to the 50-Ω system impedance and covers the 5G New Radio (NR) FR1 and FR2 frequency bands with a moderate small-signal gain of 16 ± 1.5 dB. The PA delivers 12 ± 0.2 dBm output power from 12 GHz to 32 GHz with a 3-dB bandwidth of 42 GHz. Moreover, the power-added efficiency (PAE) is maintained above 30% in the 5G FR2 bands and reaches a maximum value of 40%.

16:40 A Novel System for Recovery Time Measurements of GaN-Based Low-Noise Amplifiers

Antonio Tomaz, Dr. Stefan Gerlich, Prof. Matthias Rudolph, Dr. Cristina Andrei
Brandenburg University of Technology Cottbus-Senftenberg | Germany

A novel setup allowing for recovery time measurement of robust GaN LNA is presented in this paper. The setup is based on an PNA-X vector network analyzer and allows for the characterization of the LNA's small-signal gain, while it also monitors overdrive pulse power and reflected pulse power. The system setup and operation is shown in detail. As an example, two different GaN LNAs were measured in order to validate the test setup.

17:00 GaN-HEMT Integrated Switch LNA Module for 5G Mobile Communications

Megha Krishnaji Rao[1], Dr. Andreas Wentzel[2], Dr. Cristina Andrei[1],
Prof. Matthias Rudolph[1]
[1] Brandenburg University of Technology (BTU) Cottbus-Senftenberg | Germany;
[2] Ferdinand-Braun-Institut gGmbH, Berlin | Germany

An integration of a two-stage low noise amplifier along with a single pole double throw switch being part of the transceiver front-end using GaN HEMT technology is presented in this paper. The designed standalone LNA has a high gain of 24.4 dB and a low noise figure of 1.25 dB. The LNA is integrated with a SPDT switch with an insertion loss of 0.7 dB and an isolation of 28 dB. Hybrid integration of the two circuits yields a compact demonstrator. The integrated module achieves promising results with a gain of 20.7 dB and a noise figure of 2.6 dB in the receiving mode.

Workshop Keysight – Modern Methods of Wideband Modulation Test for 5G and 6G Components

16:00 - 17:40

Room: Studio München

Recent requirements for characterizing components such as amplifiers, frequency converters, digital-to-RF transceivers and other components for 5G and 6G systems have pushed test methods to, and beyond, their limits. This workshop introduces modern methods of testing components for wideband modulation; precision source signal-generation and precision measurements using Vector Signal Analysis (VSA) software for demodulation and evaluation of component contributions to channel response, error-vector-magnitude (EVM) and Adjacent Channel Power Ratio (ACPR) are presented. Methods that include test system pre-distortion of signal generators and drive amplifiers, precise and traceable calibration of vector receivers, and the use of advanced noise reduction techniques are presented, with practical applications including digital-pre-distortion (DPD) evaluation of high-efficiency amplifiers, for 5G use. Extension to sub-THz (D-band) frequencies are described with some examples shown.

16:00 **Modern Methods of Wideband Modulation Test for 5G and 6G Components**
J. Dunsmore

Workshop Keysight – Automotive Radar Millimeter Wave Microstrip Patch Array Antenna Simulations

16:00 - 17:40

Room: Studio Stuttgart

This workshop presents a corporate-fed microstrip patch antenna array EM simulation performed in Keysight ADS RFPro for millimeter-wave automotive radar applications. The 4×4 antenna array design is envisioned for operation in the long-range radar (LRR) band of 76-77 GHz. ADS RFPro enables automatic expert setting EM simulations leading to efficient use of computational resources and reduced simulation times. Finite Element Method (FEM) solver is used for simulation of the antenna array. Scalability of design and simulation using RFPro is also demonstrated.

16:00 **Automotive Radar Millimeter Wave Microstrip Patch Array Antenna Simulations**
C. Groetsch

Welcome Reception

17:40-20:00

Chair: Prof. C. Damm
Room: Foyer

Tuesday, May 17th

08:30 - 10:10	**Radar Modelling and Signal Processing**	Großer Saal
	Millimeter-Wave Circuits	Kleiner Saal
	ITG Workshop on Antennas	Studio München
	Workshop SIMUSERV	Studio Stuttgart
10:10 - 10:40	*Coffee Break*	Foyer
10:10 - 12:20	**Poster Session 1** *with Coffee*	Foyer
10:40 - 12:20	**Localization Systems**	Großer Saal
	Passive Components	Kleiner Saal
	ITG Workshop on Antennas	Studio München
	Workshop IHP	Studio Stuttgart
12:20 - 13:20	*Lunch Break*	Foyer
13:20 - 15:30	**Plenary Session** Keynote 1: **Andrea Neto** Keynote 2: **Goutam Chattopadhyay**	Großer Saal
15:30 - 16:00	*Coffee Break*	Foyer
16:00 - 17:40	**Antennas and Antenna Arrays**	Großer Saal
	Transmitters and Receivers	Kleiner Saal
	Workshop Anritsu	Studio Stuttgart
17:40 -	***Dinner Event***	Outside Edwin-Scharff-Haus

Radar Modelling and Signal Processing 8:30-10:30

Chair: Prof. M. Vossiek
Room: Großer Saal

08:30 Near Range Target Generation By Direct Replay of Measurements

Patrick Rippl, Prof. Thomas Walter
Ulm University of Applied Sciences | German

On the path towards higher automation in traffic scenarios, automotive radar sensors provide key information on the vehicles environment and show potential to facilitate the detection of traffic participants even under harsh conditions. Radar target simulators are used to simulate a virtual environment that enables a verification of the radar sensor functionality. This contribution presents the direct replay of measured vulnerable road user scenarios using a radar target simulator, that is designed to evaluate automotive radar sensors that are mounted for the detection of near surroundings of vehicles. For the evaluation, two measurements of a pedestrian and a cyclist that are recorded using a frequency modulated chirp sequence radar are used as input for the scenario replay.

08:50 Influence of Waveform Orthogonality and Array Geometry on Compressed Sensing Algorithms for CDMA MIMO Radar

Saravanan Nagesh, Prof. Joachim Ender, Dr. Marıa A. Gonzalez Huici
Fraunhofer FHR (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR) | Germany

Compressed Sensing (CS) has been proved, as an effective technique to handle computational loads of Multiple Input Multiple Output (MIMO) radar systems, additionally when considering Code Division Multiple Access (CDMA) MIMO radars high sidelobes which are artifacts of the waveform can be mitigated. However, the question as to how the correlation properties of these sequences or the choice of array geometry contribute towards performance of CS algorithms, individually or jointly, has not been analysed. In this paper we present a study investigating, waveform orthogonality and array geometry as parameters influencing the CS algorithms reconstruction performance. The numerical simulations have been carried out for a 2 dimensional range-angle (RA) scene with multiple targets, reconstructed by a CS-CDMA MIMO system, transmitting different code sequences in combination with different array geometries. The results validate, how the right combination of array configuration and transmission waveform leads to lower estimation errors and increased probability of success.

09:10 A Data-driven Approach for Stochastic Modeling of Automotive Radar Detections for Extended Objects

Philip Aust[1], Florian Hau[1], Dr. Jürgen Dickmann[1], Prof. Matthias A. Hein[2]
[1] Mercedes-Benz AG | Germany
[2] Technische Universität Ilmenau | Germany

Radar sensors play an important role in automated driving technologies. However, the rising number of sensors deployed to enable autonomous driving functions leads to enormous validation efforts. While simulations are a possible approach to accelerate the validation process, the development effort for realistic sensor models increases significantly. Data-driven sensor models offer the possibility to replicate sensor data accurately and efficiently. Using real measurement data, the sensor output can be simulated without the detailed parametric modeling of the wave propagation and sensor effects. In this paper, the radar signatures of a passenger vehicle under a constant aspect angle are analyzed in real measurements. Then, a data-driven approach for stochastically modeling the radar target detections is presented. The model is trained with real sensor data to achieve a high degree of realism. A qualitative comparison between the simulated and measured detections reveals promising results.

09:30 A Ground Truth System for Radar Measurements of Humans

Nicolai Kern, Adrian Holzbock, Timo Grebner, Prof. Vasileios Belagiannis, Prof. Klaus Dietmayer, Prof. Christian Waldschmidt
Ulm University | Germany

Radar simulations of human targets can be deployed to reduce the measurement effort linked to dataset generation for tasks such as gesture or activity classification. However, simulations require realistic human motion data in order to capture the dynamics of the simulated activities. For this purpose, this paper proposes a stereo camera-based system that enables simultaneous recording of radar data and the corresponding human pose ground truth. By introducing a camera-radar calibration procedure, the 3D human poses and the radar system are synchronized both in time and space. Thus, the system enables the one-by-one re-simulation of the captured measurements for the investigation of simulation quality or sensor studies. The performance of the calibration procedure and the feasibility of direct re-simulations is shown with measurements of an exemplary gesture. In addition, the straightforward extension of the proposed approach to radar sensor networks is demonstrated.

09:50 Radar Target Simulation Based on Measurement Data

Pirmin Schoeder, Timo Grebner, Vinzenz Janoudi, Prof. Christian Waldschmidt
Ulm University | Germany

The repeatability of radar sensor tests is of high importance, in order to allow for a better comparability. Guaranteeing consistent test conditions is therefore essential. This article describes a radar target simulator able to simulate a traffic scenario for chirp-sequence frequency modulated continuous wave radar sensors, based on measurement data. First, the system setup is briefly presented, that is used to generate the targets, afterwards the major challenges and required signal processing steps are laid out. Finally, a comparison between the original measured scenario data and the replayed version is conducted.

Millimeter-Wave Circuits 8:30-10:10

Chair: Prof. I. Kallfass
Room: Kleiner Saal

08:30 A Broadband Low-Noise Amplifier for D-Band Communications in SiGe BiCMOS Technology

Dr. Mohammed Ali[1], Dr. Goran Panic[2], Prof. Dietmar Kissinger[1]
[1] University of Ulm | Germany;
[2] IHP Microelectronics GmbH | Germany

This paper presents a broadband high-gain and high-linearity four stages cascode Low-Noise Amplifier (LNA) implemented in 0.13 µm SiGe BiCMOS technology. Gain, Noise Figure (NF) and stability have been improved by employing two techniques; shunt-peaking at the intermediate node of the cascode devices, and negative capacitor feedback of the common base device. Wideband flat gain has been achieved by using staggered-tuning technique. The designed LNA has gain and NF of 30 dB and 7.5 dB, respectively. It covers the entire D-Band with a DC power consumption of 100 mW and the total chip area is 0.44 mm2 including PADs.

08:50 An H-Band mHEMT-Based Millimeter-Wave True-Time Delay MMIC

Cristina Elena Maurette Blasini[1], Konstantin Kuliabin[1], Dr. Sébastien Chartier[2]
Prof. Rüdiger Quay[1]
[1] Albert-Ludwigs-University Freiburg | Germany
[2] IAF, Freiburg | Germany

This paper reports the investigation of a monolithic millimeter-wave integrated True-Time Delay (TTD) circuit for H-Band frequencies (220-325 GHz), using Fraunhofer IAF 35-nm mHEMT technology. The circuit is based on a 4-bit-cascaded delay elements architecture, consisting of two single-pole double-throw switches and thin-film microstrip lines as delay and reference paths. A TTD circuit with 16 relative delay states is obtained with a maximum delay of 3.398 ps. It has a resolution of 0.227 ps with an RMS delay error less than 0.09 ps, and a relative bandwidth of 35% of the H-Band. The average insertion loss is 8.1 dB, and the return loss is better than 15 dB at the input and output. The results of this research work allow projecting a 4-bit TTD circuit and its inclusion in broadband transmit/receive applications.

09:10 66 GHz 11.5 mW Low-power SiGe Frequency Quadrupler Operating at 300 K and 4 K

Yaxin Zhang[1] , Xiaodi Jin[1], Dr. Wenfeng Liang[2], Dr. Paulius Sakalas[3],
Prof. Michael Schröter[1]
[1] Technische Universität Dresden, Germany | Germany
[2] Infineon Technologies AG | Germany
[3] MPI AST Division | Germany

A V-band (50-75 GHz) frequency quadrupler operat- ing at both room temperature (300 K) and cryogenic temperature (4 K) is presented. The circuit was realized in a 130-nm SiGe BiC- MOS technology featuring high-speed HBTs with (fT , fmax) = (300, 500) GHz at a base–collector voltage VBC = -0.5 V. For achieving ultra-low DC power dissipation, this quadrupler was designed with the transistor deliberately operating in saturation. At 300 K, the circuit has a peak conversion gain (CG) of -3.6 dB at 66 GHz with a corresponding output power (Pout) of -5 dBm. At 4 K, an enhanced peak CG of 1.6 dB at 66 GHz is observed with a higher Pout of -0.5 dBm. With a supply voltage of 0.7 V, this quadrupler consumes only 11.5 mW DC power (Pdc) in operation and 1.33 mW stand-by Pdc.

09:30 A 0.007 mm² 48 - 53 GHz Low-Noise LC-Oscillator using an Ultra-Compact High-Q Resonator

Patrick Kurth, Kai Misselwitz, Dr. Philipp Scholz, Urs Hecht, Prof. Friedel Gerfers
Technische Universität Berlin | Germany

This paper presents a 50 GHz LC-oscillator uti- lizing an ultra-compact merged resonator design obtaining an outstanding low phase noise of −86.5 dBc/Hz at 1 MHz offset while occupying an area of only 0.007 mm2. The resonator implementation achieves both a high quality factor and metal density error-free design by using a top-metal capacitance structure placed within the 150 pH inductor. This leads to a robust process-tolerant and compact resonator realization. Furthermore, with the inductor and the main capacitor being on the same metal level, the harmful interconnect resistance is eliminated, which further enhances the quality factor. The proposed resonator implementation enables a rapid and reliable LC-oscillator design with improved phase noise in deep nanometer CMOS technologies. Implemented in a 22 nm FDX CMOS technology, the 50 GHz LC- oscillator is tunable between 48 GHz and 53 GHz while consuming only 4.5 mW from a single 1.8 V power supply resulting in an excellent Figure-of-Merit of −175 dBc/Hz.

09:50 A Differential Travelling-Wave Amplifier in a 22nm FD-SOI CMOS Technology

Athanasios Gatzastras[1], Dr. Christian Volmer[2], Prof. Ingmar Kallfass[1]
[1] Institute of Robust Power Semiconductor Systems (ILH) - University of Stuttgart | Germany;
[2] Advantest Europe GmbH | Germany

This work presents a differential travelling-wave amplifier (TWA) fabricated in a 22nm FD-SOI CMOS technology. With a transit frequency (ft) and a maximum frequency of oscillation (fmax) of 353 and 370 GHz for n-channel devices, respectively. The proposed TWA is formed by seven unity gain stages built by differential cascodes with a total power consumption of 230 mW. The paper analyses and discusses the challenges of layout-parasitics influencing the even- and odd-mode performance and proposes an advantageous routing of the drain and gate lines of the differential TWA.

Tuesday

ITG Workshop on Antennas - Innovative Beamforming Antennas, Part 1

8:30-10:10

Room: Studio München

08:30 Radar Antennas with Digital Beamforming
M. Böck

08:40 Digital Beamforming Concepts for Future Airborne Applications
M. Leib

09:10 Design, Manufacturing and Experimental Verification of a Wideband Metamaterial Based RAM Structure for RCS Reduction
F. Weinmann

09:40 Innovative Beamforming Concept Using Multi-Mode Multi-Port Antenna
L. Mörlein

Workshop SIMUSERV - Antenna, Antenna Array and Microwave Filter Design with SIMULIA CST Studio Suite®

8:30-10:10

Room: Studio Stuttgart

Antennas, Antenna Arrays and Microwave Filters are the basic building blocks of any wireless communication network. In this workshop, we will show the dedicated workflows in SIMULIA CST Studio Suite to handle the full complexity of complete antenna systems with the focus on 5G antenna arrays and filter design. In some live demos we will share the latest improvements in CST Studio Suite 2022 for the design and simulation of antenna arrays, antenna placement, mmWave antennas and the 3D model build automation for cavity filters. The latest improvements in CSTs state-of-the art solver technology including time domain, frequency domain, integral equations and asymptotic techniques and supporting solutions like Filter3D and Antenna Magus will be discussed.

08:30 5G – Network Coverage, Antenna Array Design, mmWave Antenna Design
T. Wittig

09:20 Filter Design – 3D Model Build Automation and Workflow Improvements
F. Demming-Janssen

Coffee Break *Room:* Foyer **10:10 -10:40**

Poster Session 2 *(with coffee)* 10:10 -12:20

Chair: Dr. M. Ali
Room: Foyer

Evaluation of Phase Noise Effects on Time of Flight Measurement with Binary Coded Excitation Signals

Gordon Notzon[1], Dr. Robert Storch[2], Prof. Thomas Musch[1], Prof. Michael Vogt[1]
[1] Ruhr University Bochum | Germany;
[2] Krohne Messtechnik GmbH | Germany

In case of time of flight (TOF) measurement using binary coded excitation signals, phase noise (PN) of the clock source and additive PN of the binary signal generator play an important role for signal-to-noise ratio (SNR) and measurement precision. Based on both, theoretical analyses and simulations, the according effects are analyzed in detail. Below, first the average noise power at the output of the correlation receiver of an according measurement system is analytically described for frequency-independent PN. Using these findings, the SNR and the standard deviation (SD) of the TOF measurement are quantified. In a second step, similar analyses are performed for frequency-dependent PN. Finally, simulation results are compared with quantitative data from the theoretical analyses.

Frequency Extension Method for Multirate Radar Target Simulation Systems

Georg Körner, Christoph Birkenhauer, Patrick Stief, Christian Carlowitz, Prof. Martin Vossiek
FAU Erlangen-Nürnberg | Germany

Radar target simulation is an important tool for testing and characterizing radar systems. It was shown before, that multirate radar target simulators allow for highly accurate emulation of moving targets. These multirate systems are a special case of digital radio frequency memory systems. By using different sampling clocks in the ADCs and DACs, moving targets can be simulated with outstanding realistic behavior, since this multirate system mimics the behavior of the continuous target distance changes perfectly. In this paper, we demonstrate for the first time how the frequency range of the multirate digital target emulation can be extended. We want to apply sub-Nyquist sampling techniques combined with the multirate technique and analyze its effect. It is shown that sub-Nyquist sampling

does not change the signal properties; rather, the signals are downconverted via the sampling process, which enables direct coverage of higher frequency bands. This reduces the cost and complexity of hardware designs for multirate radar target simulation compared to previously demonstrated mixer-based down-conversion. We successfully demonstrate a frequency range extension of the baseband system by a factor of more than five.

Determination of Quasi-Coaxial Via Capacitance using Conformal Mapping Technique

Hiroaki Takahashi[1], Ioannis Peppas[1], Erich Schlaffer[2], Helmut Paulitsch[1], Prof. Wolfgang Bösch[1]
[1] Graz University of Technology/ IHF- TU Graz | Austria;
[2] AT&S Austria Technologie & Systemtechnik AG | Austria

This paper presents an analytical investigation on a static capacitance of a quasi-coaxial via, which consists of a signal via and two surrounding ground vias. To determine the capacitance we propose an analytical equation derived from a modified mapping function for parallel circular conductors under the condition of a ground-signal-ground (GSG) symmetrical configuration. The validity of the derived equation as a function of via diameters and the distance between the signal via and the ground vias was examined by comparison of analytical capacitance per unit length with Q2D static numerical simulations, which results in good agreements within a few percentages of the error. Moreover, a 3D model of quasi-coaxial is designed with an existing design rule for a microvia. Its capacitance at 30 GHz is numerically extracted by full-wave electromagnetic simulation and compared to the analytical capacitance. As a result, we have observed that the difference between them is up to a few femtofarads.

Feasibility Study for Dual Septum Polarisers manufactured by Additive Layer Manufacturing

Michael Kilian, Dr. Michael Schneider, Philipp Kohl, Christian Hartwanger
Airbus Defence and Space GmbH | Germany

During the last years, additive manufacturing technologies becomes popular because of new possibilities in developing components used on satellites. However, especially for RF components limited accuracy is an issue because small deviations have negative influences to the RF performance. This paper gives an overview about the sensitivity of dual septum polariser performance values using additive manufacturing techniques. For a representative study, different frequency bands are regarded.

Localization Systems 10:40-12:20

Chair: Prof. R. Jakoby
Room: Großer Saal

10:40 Availability Analysis of PCL Passive Radar Systems for ATC Applications

Christian Erhart[1], Dirk Doser[1], Thomas Janner[2]
[1] Hensoldt Sensors GmbH | Germany;
[2] Rohde & Schwarz GmbH & Co. KG | Germany

Air surveillance sensor systems have to meet a lot of requirements before they can be put into operation. Besides requirements concerning track accuracy and proper operability, the availability of the system is of great significance for all air navigation service providers. This paper will deliver information that allows an assessment of the availability of passive radar systems for civil air traffic control. For this purpose, the architecture and the fundamental functionality of the passive radar system TwInvis, which was developed by Hensoldt Sensors GmbH, will be explained exemplary. Afterwards, relevant figures concerning the availability of the system itself will be stated. Because the TwInvis passive radar system uses broadcasting transmitters as illuminators of aircraft, the availability of a state of the art broadcast transmitter, developed by Rohde und Schwarz will be assessed, too. Most passive radar systems are capable of processing a multiple number of illuminators. To take this into account, the consequences of a transmitter's outage will be described and illustrated at the end of this paper.

11:00 Hybrid Time-Frequency Coded Photonic Crystal-based Chipless Retroreflective Tag Landmarks

Robin Neuder, Jesús Sánchez-Pastor, Dr. Martin Schüßler, Prof. Rolf Jakoby, Dr. Alejandro Jiménez-Sáez
TU Darmstadt, IMP | Germany

This paper studies the implementation of a hybrid time-frequency modulation scheme in the chipless retroreflective tag landmarks of a mm-Wave indoor self-localization system. The fully-passive implementation of the modulation scheme is demonstrated with high-Q cavities working at 78 GHz for frequency coding and different time delays induced by the length of the transmission line for time coding. Both modulations operate within the same bandwidth and are integrated

in a monolithic dielectric slab using a Photonic Crystal (PhC) periodic structure. Three hybrid coded tag landmarks manufactured in Rogers 6010.2LM are evaluated in measurements at 60 cm. While the cavity response is distinctively traceable in frequency domain, time domain analysis shows that implemented delays are correctly read out by the reader with a discrepancy of less than 8% compared with simulations, providing a proof of concept for hybrid time-frequency coding in PhC-based tag landmarks.

11:20 **Impact of Integration Time on Detection Performance Based on Field Trail Results in Passive Radar**

Markus Steck[1] ,Steffen Lutz[1], Prof. Robert Weigel[2]
[1] Hensoldt Sensors GmbH | Germany
[2] Institute for Electronics Engineering, Friedrich-Alexander-University Erlangen-Nürnberg | Germany

This paper provides an overview of the influence of different integration times on the detection performance of a passive radar system. For this purpose, a passive radar processing 16 different FM-transmitters simultaneously was used [1]. The detection performance over the whole airspace as well as a detailed analysis of individual trajectories are examined. Recorded raw-data was processed with different integration times and compared with reference data which was categorized by different airplane-types. A noticeable improvement in the detection performance can be achieved with longer integration times, but it also causes additional challenges for the signal processing [3].

11:40 **Instantaneous Ego-Motion Estimation based on Ambiguous Velocity Information within a Network of Radar Sensors**

Timo Grebner, Pirmin Schoeder, Fabian Konrad, Prof. Christian Waldschmidt
Ulm University | Germany

Accurate ego-motion estimation plays a crucial role in the automotive sector, as well as in the field of robotics for both the representation of the environment, as grid-maps e.g., as well as the estimation of target features. Radar-based ego-motion estimations show great potential but are limited by their maximum detectable unambiguous radial velocity. This limitation becomes even worse with the often used TDM-MIMO multiplexing strategy. The following paper presents a radar-based ego-motion estimation algorithm, which overcomes this limitation. The presented approach is independent of modulation scheme or front-end design and expands the maximum estimable vehicle speed.

Passive Components 10:40-12:20

Chair: Prof. H. Maune
Room: Kleiner Saal

10:40 Validation of a New Fast-Time Scale Code for Advanced Simulations of Gyrotron Cavities

Lukas Feuerstein, Alexander Marek, Dr. Konstantinos A. Avramidis, Dr. Stefan Illy, Dr. Chuanren Wu, Prof. John Jelonnek
Karlsruhe Institut of Technology | Germany

Gyrotrons for fusion applications are microwave vacuum tubes that are capable to produce an output power in the megawatt range at long pulses up to continuous wave (CW) and at frequencies above 100 GHz. That is possible due to the working principle of gyrotrons which allows using cavities with a very large electrical size (in the order of several cm) compared to the operating wavelength (in the order of a few mm). This mandatory requirement for high output power is a challenge in simulating the interaction between the electromagnetic (EM) field and the electron beam in a gyrotron resonator. Due to this, the simulation of the electron interaction in gyrotrons are typically carried out by using computer codes which make use of the very specific properties of the EM problem to simplify the calculations. At KIT, a new code names “SimpleRick” is under development. A fast-time scale Particle-in-Cell (PIC) method is implemented to complement the classical models used for gyrotron simulation. The PIC code introduces significantly fewer assumptions than the classical model and may therefore represent more physical details. For example, in contrast to the classical models, the new model can represent non-symmetric electron beams. In this work, the numerical implementation and the performance of this PIC model are verified and a new method for the calculation of the eigenvalues of coaxial gyrotron resonators is shown in more detail.

11:00 Microstrip Combline Bandpass Filter with Tuning Range Enhancement and Bandwidth Tunability Using Resonator Loaded Series Varactor and SLR

Robert Wünsche[1], Prof. Ralf Collmann[1], Prof. Marco Krondorf[1], Josef Forster[2]
[1] HTWK Leipzig | Germany;
[2] Rohde & Schwarz GmbH & Co. KG | Germany

A new microstrip combline filter with adjustable center frequency and bandwidth is proposed. The design is based on a double sided varactor loaded resonators

and a resonant defected ground structures. Detailed filter design equations are given and explained. To validate the proposed structure, a second-order prototype filter is designed and fabricated with a relative bandwidth of 10 to 15% and a tuning range of 95 %.

11:20 Fully Canonical Dielectric TM-Mode Filters with Frequency Dependent Coupling Matrix Description

Kennet Braasch, Daniel Miek, Patrick Boe, Fynn Kamrath, Prof. Michael Höft
Christian-Albrechts-Universität zu Kiel | Germany

In this paper, two different realizations of a fully canonical filter using dielectric TM-mode resonators are presented. Both proposed filters are of fourth order and reveal two pairs of real frequency axis transmission zeros (TZs). The first pair is realized using a cascaded quadruplet while the second pair is implemented utilizing a coupling between the source and load port. For both cross couplings, different realizations are presented and compared with respect to their implementation. Particular emphasis is placed on the frequency dependence of the cross couplings in order to explain the strong asymmetry of the TZs. With the help of presented calculations, a coupling matrix description is achieved. Both filters are manufactured out of aluminum and their S-Parameters are presented.

11:40 A Broad Band Patch Antenna Used as Auxiliary Load for Measuring Multi-port Device with 2-port VNA at W-band

Dongwei Wang[1], Prof. Rolf Jakoby[1], Prof. Holger Maune[2], Prof. Philippe Ferrari[3], Ariana L. C. Serrano[4], Gustavo P. Rehder[4]
[1] Technische Universität Darmstadt | Germany
[2] University of Magdeburg | Germany
[3] Université Grenoble Alpes | France
[4] University São Paulo | Brazil

This paper presents a simple technique for characterizing multi-port devices. It gives a fast and efficient measurement of the scattering S-parameters of the multi-port device under test (DUT) by measuring 2 of the N ports while other N-2 ports being terminated by broad band antennas as substitution to 50 Ω loads to minimize reflection. This method is applied to the characterization of a 4-port branch-line quadrature hybrid coupler centered at 100 GHz, where direct 4-port measurement are not equipped. Widely available post processing algorithms are then applied which reconstruct the CN 2 sets of 2-port measured S-parameters into a N port S-parameter for testing purpose. The reconstructed S-parameters match the 4-port simulation well especially in terms of amplitude and phase of the transmissions at both output ports.

ITG Workshop on Antennas - Innovative Beamforming Antennas, Part 2

10:40-12:20

Room: Studio München

10:40 **Active Arrays for Satcom and 5G/6G**
M. Geissler

10:50 **Small antennas in huge environments - simulation using hybrid methods**
S. Hipp

11:20 **Sub-Terahertz lens antennas for 6G communications and high-resolution radar applications**
M. Arias Campo

11:50 **Design and manufacturing of customizable phased array for satcom applications based on circular polarized domino tiles in Ka band**
F. Boulos

Workshop IHP - IHP Photonic SiGe BiCMOS Technology for Broadband Integrated Communication Circuits

10:40-12:20

Room: Studio Stuttgart

The Workshop delivers firsthand information and opportunities for discussions about IHP's technologies, services and integrated circuits. IHP`s offerings are very suitable for demanding applications such as wireless and broadband communication, medical technology, aerospace, mobility, wireless security, and industrial automation. Its electronic and photonic-electronic technologies and circuits are among the most advanced in the world. In the speed of silicon-based transistors, IHP holds the world record with 720 GHz maximum oscillation frequency. The institute has a pilot line that manufactures circuits using its high-performance SiGe BiCMOS technologies. These technologies together with additional modules are available as a service offer for MPW and small series for science and industry. The organization of ASIC manufacturing service including available Design Kits, Design Flows and schedules will be presented it the first talk. The second talk will present two different optoelectronic receivers in SG25H5 EPIC technology. The workshop will conclude with live demonstration of a monolithic broadband opto-electronic coherent receiver.

10:40 **SiGe BiCMOS and Si Photonics Technologies for RF and Terahertz Technologies**
R. Scholz

11:15 **Monolithically Integrated Optoelectronic Circuits in SG25H5 EPIC Technology**
M. Inaç

11:50 **Demonstration of a Monolithic Broadband Opto-Electronic Coherent Receiver**
A. Peczek

Lunch Break *Room:* Foyer 12:20 -13:20

Plenary Session 13:20-15:20

Chair: Dr. T. Chaloun, Prof. D. Kissinger
Room: Großer Saal

13:20 **Andrea Neto** – Toward THz Pulsed Radars

14:20 **Goutam Chattopadhyay** – Terahertz Space Instruments and Technologies

Coffee Break *Room:* Foyer 15:30 -16:00

Antennas and Antenna Arrays | 16:00-17:40

Chair: Prof. D. Heberling
Room: Großer Saal

16:00 Model-based Optimization of Fishnet Metamaterial Lenses under Oblique Incidence

Adrian Diepolder, Mario Mueh, Susanne Brandl, Prof. Christian Waldschmidt, Prof. Christian Damm
Ulm University | Germany

In this paper, a design method for obliquely excited artificial gradient-index lenses based on a single-layer fishnet metamaterial is presented. The proposed unit cell design for operation at 60 GHz covers transmission phase values between -180° and +180° at nearly constant magnitude by variation of the geometry parameters. In order to predict the behavior of a specific unit cell geometry under oblique incidence, a model-based approach, accounting for anisotropy and spatial dispersion, was developed. To verify the new method, a lens for collimating a strongly curved wave front is designed. This lens is compared with a design based on the conventional phase compensation approach in terms of simulation and measurement results.

16:20 Effect of the Orientation of the Array Elements of Uniform Circular Antenna Arrays on Orbital Angular Momentum (OAM) Modes

Michael Wulff[1], Dr. Lei Wang[2], Dr. Cheng Yang[1], Prof. Christian Schuster[1]
[1] Hamburg University of Technology(TUHH) | Germany
[2] Heriot-Watt University, Edinburgh | United Kingdom

In this paper, the effect of the orientation of the array elements of a uniform circular antenna array (UCA) on orbital angular momentum (OAM) communication is investigated. For the first time, UCAs are studied in which the elements are rotated in a systematic way around their center by a linearly increasing angle of rotation. It is shown here that these UCAs provide a smaller decrease in transmission over distance for some modes compared to other configurations used, but at the cost of increased mode conversion. For that reason the mode conversion and the decrease of the received mode power over distance are of particular interest. UCAs with dipoles normal and tangential to the array surface are compared. For the latter, the dipoles are rotated around their center with a rotation angle increasing linearly around the UCA. The transmission of the OAM modes is evaluated on a sphere, showing that the direction of the strongest

Tuesday

transmission of the OAM modes varies with the rotation of the array elements. It is shown that the UCAs with radial (or azimuthal) dipoles provide the best mode transmission with little mode conversion. All investigations have been carried out using a tool based on the method of moments (MoM).

16:40 Dielectric Rod Antenna for Glass-Packaged Radar Sensors at G-band

Thomas Galler[1], Dr. Philipp Hügler[2], Dr. Tobias Chaloun[1], Prof. Christian Waldschmidt[1]

[1] University Ulm | Germany
[2] Endress+Hauser SE+Co. KG | Germany

A wideband and robust design of a dielectric rod antenna at G-band (140 GHz–220 GHz) for short range radar applications in harsh environmental conditions is presented. The proposed antenna is based on a simple plug-in solution made of PEEK material ($\varepsilon_{r,PEEK} = 3.2$), which enables the mechanically detachable integration into a glass-encapsulated millimeter wave radar sensor system. To further increase the antenna gain, an optically transparent biconvex lens is presented. The antenna performance has been investigated by full wave simulations and validated through measurements of the fabricated antenna prototype. The experimental results of the realized antenna element show excellent agreement to the simulated values. The rod antenna covers a 3 dB-beam width of 46° and achieves a maximum gain of 12.4 dBi. The additional use of the dielectric lens increases the gain to 30.4 dBi with a stable beam pattern over the entire modulation bandwidth of 20 GHz of the radar sensor. The measured 3D-radiation patterns at various frequencies across the operational band are provided.

17:00 Self-Diplexing, Dual-Polarized Ka-Band SIW Slot Antenna with Integrated K-Band Patch

Noah Sielck, Till Schwiers, Kevin Erkelenz, Prof. Alexander Koelpin, Prof. Arne F. Jacob

Hamburg University of Technology (TUHH) | Germany

This contribution presents a fully self-diplexing and dual linear polarized antenna operating in the K- and Ka-band. The combination of a 30 GHz substrate integrated waveguide (SIW) slot antenna and a 20 GHz microstrip patch antenna (MPA) results in a compact dual-band design. Standard printed circuit board (PCB) technology yields a three layer assembly with a footprint of less than 7.5x7.5mm2 and a height of 0.55 mm. The circuit includes a filter which improves the inter-band isolation in the upper band from 12 dB to more than 45 dB. The -10 dB reflection bandwidth remains above 0.55 GHz and 0.75 GHz in the lower and the upper band, respectively. Because of its compactness, the proposed antenna is well suited for applications in phased arrays.

17:20 High-Gain Holographic Multi-Feed Antenna

Maximilian Döring, Thomas Frey, Prof. Christian Waldschmidt, Dr. Tobias Chaloun
Ulm University | Germany

In this work, a novel multi-feed synthesis for holographic leaky-wave (LW) antennas is presented that considers the angular dependence of each pixel structure. This approach of combining multiple single-beam holograms minimizes the impedance error w.r.t. each individual impedance hologram. A multi-feed antenna with two feeding points at 20 GHz is fabricated and measured using this new design methodology. The simulation and measurement results show a good agreement. The fabricated LW antenna has a gain of 21.7 dBi and 22.1 dBi and a side lobe level (SLL) of 9.0 dB and 9.6 dB for both feeds.

Transmitters and Receivers 16:00-17:40

Chair: Prof. M. Berroth
Room: Kleiner Saal

16:00 An UWB 18.5 GS/s Sampling Front-End with 35 dB SNDR at 39 GHz Input Frequency in 22 nm FDSOI

Nima Lotfi, Dr. Philipp Scholz, Prof. Friedel Gerfers
Technische Universität Berlin | Germany

This paper presents the design and implementation of an ultra-wideband buffered front-end sampler (T&H) operating at 18.5 GS/s with 44 GHz measured signal bandwidth. The highly-linear sampler, intended for a 5-bit 4X time-interleaved (TI) 74 GS/s flash ADC, is realized in a 22 nm FD-SOI (FDX) CMOS process. It comprises an ultra-low jitter limiting clock path and a source-follower based T&H architecture maximizing the overall linearity and isolation as well as enhancing the effective sampling bandwidth. The front-end takes advantage of the flipped-well forward-biasing process option lowing the transistor threshold voltage by approximately 85 mV/V to achieve a differential input range of 600 mVppd while using a dual 1.2 V and 0.9 V supply voltage. Characterization results reveal an SFDR and SNDR of better than 37.2 dBc and 35 dB (ENOB=5.5 bits) respectively using a single-tone sine wave in the fifth Nyquist zone (fin = 39 GHz) and an SFDR of 40.9 dBc with a wideband two-tone input at fin1 = 1.5 GHz and fin2 = 36.1 GHz. The compact front-end design with the input buffer, T&H core, clock

buffer and low jitter sample-phase generator occupies a core are of as small as 0.004 mm2 in the utilized 22 nm FD-SOI process. The total power consumption is only 75 mW of which 10 mW is consumed by the entire clock path operating from the 0.9V supply.

16:20 Real-Time Processing and Delta-Sigma Modulation on FPGA for Switching Mode RF Amplifiers

Julian Tonn, Dr. Thomas Veigel, Dr. Thomas Veigel, Manuel Wittlinger, Dr. Markus Grözing, Prof. Manfred Berroth
Universität Stuttgart | Germany

A real-time digital signal processing chain, implemented on a field-programmable gate array (FPGA) is presented. The processing chain contains a quadrature amplitude modulation (QAM) mapper, an upsampling filter (USF) and a first order delta-sigma modulator. It is used to generate input symbols for a digital pulse-width and pulse- position modulator (DPWPM) integrated circuit (IC) which supports carrier frequencies of up to 2.7 GHz. However, the FPGA design itself has been proven to work up to 5.9 GHz and therefore covers most of the 5G NR FR1 frequency bands. At 900 MHz, a 14 MBd 256-QAM (112 Mb/s) payload signal with an error vector magnitude (EVM) of 1.94 % and a signal-to- noise ratio (SNR) of 34.3 dB is shown. At 2.7 GHz, a 10.5 MBd 256-QAM (84 Mb/s) signal with an EVM of 4.26 % and an SNR of 27.4 dB is presented.

16:40 Polar Transmitter with Pseudo-Differential Inverse Class-E Output Stage in 22 nm FD-SOI

Andres Seidel, Dr. Jens Wagner, Prof. Frank Ellinger
Technische Universität Dresden | Germany

This paper discusses the conceptual approach of a fully integrated polar transmitter for signal transmission in the sub-6 GHz frequency range. It investigates a compact differential inverse class-E topology as power output stage. To enable amplitude modulation without lossy DC-DC converters, a method for generating a pseudo-differential pulse width modulation is presented. A voltage controlled oscillator, phase shifters, a control interface and a current reference are also integrated on the chip. In laboratory measurements, the circuit with a compact chip area of 1.07 mm2 achieves a relative bandwidth of 71%, a maximum output power of 19.3 dBm and a PAE of 27% including bond wire and external balun losses at a low-voltage supply of 1 V.

17:00 Design and Measurements of a Low-power Low-Data-rate Direct-detection Wireless Receiver with Improved Co-channel Interference Robustness

Saed Abughannam, Stephan Kruse, Mohammed Iftekhar, Prof. Christoph Scheytt
Heinz Nixdorf Institute, University of Paderborn | Germany

Direct-detection architecture in RF receivers allows for ultra-low power dissipation. However, it suffers from high sensitivity to co-channel interference and poor receiver sensitivity, which reduces the communication performance and reliability. This paper presents the design and measurements of a novel 2.4 GHz low-power low-data-rate receiver. The receiver is based on direct-detection architecture in combination with a 13-bits Barker-coded Surface Acoustic Wave (SAW) correlator to im- prove co-channel interference. Furthermore, to improve receiver sensitivity, the baseband bandwidth is reduced by means of an innovative Narrowband Correlator (NBC) in conjunction with Pulse Position Modulation (PPM), which allows for scalable receiver sensitivity versus data-rate. The receiver is designed in TSMC65n technology and achieves a power dissipation of 142 µW from a 1.2 V supply source and a receiver sensitivity of –50 dBm at a data-rate of 600 kbps. It can be used as a Wake-up Receiver (WuRx) in Wireless Sensor Networks (WSNs) to minimize the power dissipation and provide asynchronous communication.

17:20 Receiver Synchronization of Ultra-Wideband Phase Modulated Signals with a Fully Analog QPSK Costas Loop

Janis Wörmann[1], Ulrich Jagdhold[2], Eswara Rao Bammidi[1], Prof. Ingmar Kallfass[1]
[1] Institute of Robust Power Semiconductor Systems (ILH) - University of Stuttgart | Germany;
[2] Institute for High Performance Microelectronics (IHP), Frankfurt (Oder) | Germany

A fully analog QPSK Costas loop is verified by measurements and shows long term stability and locking for ultra-wideband signals with bit rates up to 2 Gbit/s of BPSK and QPSK modulated signals. The loop is used for receiver synchronization and tested with carrier frequencies up to 7.5 GHz. The effects of time delay on the locking behavior of the loop are briefly addressed in a theoretical manner and generally confirmed by measurements. To the best of the author's knowledge, this is the first successful QPSK measurement of a long-term stable locked, fully analog QPSK Costas loop.

Workshop Anritsu

16:00-17:40

Room: Studio Stuttgart

Dinner Event

Please bring a jacket, we will bring food!

17:40-20:00

Chair: Prof. H. Schumacher
Room: Outside of Edwin-Scharff-Haus, right next to the Danube rive

Wednesday, May 18th

08:30 - 10:10	■	**Communication Systems**	Großer Saal
	■	**Calibration and Material Characterization**	Kleiner Saal
	■	**Workshop Infineon**	Studio Stuttgart
10:10 - 10:40	■	*Coffee Break*	Foyer
10:40 - 12:20	■	**Closing Session** Keynote: **James Hwang**	Großer Saal
12:20 - 13:20	■	*Lunch Break*	Foyer

Communication Systems 8:30-10:10

Chair: Prof. V. Issakov
Room: Großer Saal

08:30 QAM-4 Dielectric Waveguide Communication Link for Mid-range Distances at W-Band Frequencies

Andre Meyer, Prof. Martin Schneider
Universität Bremen | Germany

Numerical analyses have shown that minimizing the dispersion of dielectric waveguides (DWGs) is essential for high data rate communication links at mm-wave frequencies. In this paper an experimental QAM-4 communication link at 83 GHz is presented that uses DWGs with different dispersion characteristics to demonstrate their impact on data rate and link distance. As a result, a DWG communication link with a data rate of 8 Gbit/s and DWG length of 15 m was realized. The obtained results significantly exceed the maximum data rates at 15 m of recently published works without the need of energy-consuming equalization. In addition, a 4 Gbit/s communication link over 30 m was demonstrated that doubles the maximum transmission distance of previously published DWG communication links in the mm-wave frequency range. The results also indicate that even higher data rates over such long distances are possible, which makes dielectric waveguides competitive to baseband transmission systems like twisted pair and twinaxial cables.

08:50 Investigation of an RF Frontend at 35 GHz for Joint Broadband Radar and Communication Applications

Winfried Johannes[1], Stephan Stanko[1], Prof. Ingmar Kallfass[2],
[1] Fraunhofer FHR (Fraunhofer Institute for High Frequency Physics and Radar Techniques) | Germany;
[2] Institute of Robust Power Semiconductor Systems (ILH) - University of Stuttgart | Germany

The simultaneous processing and transmission of complex synchronisation or communication signals and broadband radar signals is a very important feature of modern RF frontends. Especially for multi-static radars or radar networks this multi-functionality is instrumented. This publication describes the investigation of an RF frontend at 35 GHz with simultaneous operation of Quadrature Phase-Shift Keying communication and broadband frequency modulated continuous wave radar in frequency domain multiplexing. The successful simulation of such a system is described first. After that the adaption and optimization of the radar system MIRAND35 based on measurements is explained. Finally, measurements with the optimized system are presented. Simulation and measurements are analysed and compared regarding communication and radar performance.

09:10 Measurements of Atmospheric Attenuation in an Outdoor Wireless E/W-Band Communication Link

Laura Manoliu[1], Ralf Henneberger[2], Dr. Axel Tessmann[3], Dr. Jochen Seidel[4], Dr. Michael Eppard[5], Dominik Wrana[6], Benjamin Schoch[6], Prof. Ingmar Kallfass[6] ,
[1] Institute of Robust Power Semiconductor Systems (ILH) - University of Stuttgart | Germany;
[2] RPG Radiometer Physics GmbH | Germany;
[3] Fraunhofer IAF, Fraunhofer Institute for Applied Solid State Physics | Germany;
[4] University of Stuttgart | Germany; [5] Max Planck Institute for Solid State Research | Germany;
[6] Institute of Robust Power Semiconductor Systems (ILH) - University of Stuttgart | Germany

This paper is giving a summary about the atmospheric effects affecting millimeter wave communication systems for a point-to-point E-band link. The focus is on attenuation caused by water droplets. Experimental results obtained in Stuttgart, Germany, are presented to confirm the theoretical aspects discussed through this paper. Wideband complex modulated signals with up to 3.3 GBd symbol rate are used to model the atmospheric behavior of electromagnetic radio frequency signals on an E-band link (71-76 GHz), operated over 1.6 km distance. This paper reviews also the availability and fade margin targets of the new radio links by showing the correlation with the ITU models and recommendations.

09:30 Virtual Test Drive for Car2Car Communication and its Application on a Synchronized Switch Diversity

Anton Dobler, Prof. Stefan Lindenmeier
University of the Bundeswehr Munich | Germany

A reproducible semi-virtual test drive for C2C/C2X-communication is applied on a new switch diversity setup. On base of measured characteristics of a set of C2C/C2X-diversity antennas a test drive is performed in a virtual city model, creating channel data which is emulated in a hardware transmission system. By that the performance of C2C/C2X-antennas and connected RF-signal processing circuits can be analysed in a reproducible way. In a new example a switch diversity synchronization method is presented and analysed within the test drive. This setup is able to synchronize to the packets received by a commercial C2C/C2X-receiver. Based on this reproducible analysis it is shown, that the implemented switch diversity algorithm reduces packet error rates significantly compared with a single antenna transmission.

09:50 Performance Optimization of an E-Band Communication Link using Open-Loop Predistortion

Benjamin Schoch[1], Florian Wiewel[1], Dominik Wrana[1], Laura Manoliu[1], Simon Haussmann[1], Dr. Axel Tessmann[2], Prof. Ingmar Kallfass[1],
[1] Institute of Robust Power Semiconductor Systems, University of Stuttgart | Germany;
[2] Fraunhofer IAF, Fraunhofer Institute for Applied Solid State Physics | Germany

This paper demonstrates the performance optimization of a millimeter wave transmit frontend operating in E-band, using a digital predistortion method with an open-loop architecture. The Tx system contains a cascaded amplifier module chain, realized in different technologies, to achieve modulated signals with record output powers of 2 W. An open-loop DPD system with an indirect learning architecture and a Volterra series based nonlinear model has been selected to investigate the improvements in the frequency range from 71 to 76 GHz with bandwidths up to 800 MHz. The transmitter's linearity, signal quality, and spectral regrowth were measured with a modulated signal containing different power levels. Three channels with different sizes, located in the proposed channel arrangements by the ITU, were chosen to exemplarily test the performance of the DPD. An implemented DPD algorithm could demonstrate improvements in signal quality and adjacent channel power.

Calibration and Material Characterization 8:30-10:10

Chair: Prof. I. Rolfes
Room: Kleiner Saal

08:30 Evaluation of Influences of Titanium Dioxide on Radar Sensors Operating at 77 GHz

Christian Winter1, Dr. Stefan Holzknecht[1], Tiziano Fabbri[1], Dr. Ingo Weber[1], Prof. Erwin Biebl[2]
[1] BMW AG | Germany;
[2] Associate Professorship of Microwave Engineering Technical University Munich | Germany

For future driver assistance functions and autonomous driving, radar represents an indispensable technology. Since the functional load on radar sensors is still increasing, the number of radar sensors per vehicle is also increasing. Therefore, from a design perspective, a hidden integration behind painted plastic bumpers is favorable. However, depending on the contents of the coating, the radar performance is decreasing. Especially Titanium Dioxide (TiO2), which is one of the most used pigments in automotive coatings shows an impact on radar depending on its concentration. In this contribution, effects of different TiO2 concentrations on radar sensors operating at 77 GHz are investigated. The Influence is evaluated by determining the relative permittivity and the deviation when estimating angles.

08:50 Efficient Method for Determining Substrate Parameters of Additive Manufactured Spatial Circuit Carriers

Thomas Mager, Dr. Christoph Jürgenhake, Prof. Roman Dumitrescu
Fraunhofer Institut für Entwurfstechnik Mechatronik - IEM | Germany

Electronic devices are taking on an increasingly important function in industrial and private areas. Over the last 40 years, electronics have evolved rapidly, driven by Moore's Law. Now we have reached a point where further downsizing of semiconductors is no longer practicable. Thus, the third dimension is being used to drive integration spatially. This trend is now more and more evident for circuit carriers as well. Technologies such as Molded Interconnect Devices (MID) are being increasingly used in industrial and consumer applications, such as smartphones, tablets, sensors, etc. This technology combines the functions of the Printed Circuit Board (PCB) and the housing in one device. The substrate is usually based on plastic. Depending on the manufacturing process, a wide

variety of plastics and coatings are used. The electrical properties of these materials must be precisely determined in order to correctly dimension for example microstrips, resonators or antennas with regard to their electrical behaviour. These parameters are often not available for the required frequency range. Thus, the circuit designer has to determine these necessary material parameters by himself. For the electrical characterisation of materials, a wide variety of measurement methods exist. Depending on the frequency range, an impedance analyser or a network analyser is required as well as a special fixture for the material specimen. These fixtures in particular are high-precision appliances that are not always available to the designer or are very expensive to purchase. In the following article, a method is presented which enables the characterisation of dielectric material samples without these sophisticated fixtures.

09:10 Temperature Dependent Dielectric Characterization With Partially Loaded Waveguides

Irwin Barengolts, Francesca Schenkel, Dr. Christian Schulz, Dr. Jan Barowski, Prof. Ilona Rolfes
Ruhr-Universität Bochum | Germany

In this paper, a method for the characterization of the dielectric parameters as a function of temperature is presented. The effects of temperature on the polarizability of the materials are measured. To obtain accurate results, the effects of the heating process investigated on the measurement system must be taken into account and be corrected. Correction methods based on the adjustment of the calibration plane or the adaptation of the propagation constant are shown. The impact of the thermal expansion is investigated and the robust functionality of the implemented algorithm is verified in a test setup. The test setup is based on waveguides that enable nearly perfect boundary conditions and a simple correction of different thermal influences. Measurements are carried out in a frequency range from 8.4 GHz to 12.5 GHz with PTFE as the material under test (MUT) in a temperature range from 24°C to 106°C. This frequency range corresponds to the X-band and allows an easy realization of the measurement system.

09:30 Combination of Scattering Matrix Code and Process Model to Optimize a Microwave Applicator Suitable for the Stabilization of PAN Fibers

Julia Hofele, Moritz Engler, Dr. Guido Link, Prof. John Jelonnek
KIT | Germany

Carbon fiber production is an energy intensive process requiring new approaches for energy efficient heating. One possible option might be the dielectric heating. A basic requirement to design an efficient applicator is the knowledge of the variation of dielectric properties during processing. The experience shows strongly increasing dielectric loss of a Polyacrylonitrile (PAN) fiber with increasing temperatures while it decreases during the chemical transformation in the stabilization stage. For the applicator design an electrical field that counteracts the variation of the dielectric loss is a suitable choice. In this presentation the focus is on the combination of the generalized scattering matrix (GSM) code with a process model. It shall allow for the optimization of the geometry of a cylindrical resonator usable during the stabilization stage of the PAN fiber. The scattering matrix code is utilized to calculate the field profile of a cylindrical resonator with step-wise changing diameter that acts as applicator. The number of steps can be varied, depending on the ability of production and spacial requirements.

09:50 Evaluating Error Influences of a Dielectric Waveguide for mm-Wave In Vitro Epithelial Cell Vitality Measurements

Philipp Hinz, Mario Mueh, Jessica Heck, Prof. Christian Damm
Ulm University | Germany

A novel measurement setup for contact-free live monitoring of cell vitality using a G-band dielectric waveguide (DWG) from 140 GHz to 220 GHz is introduced. Static and time-variant error influences caused by temperature expansion and water evaporation are investigated, modeled, and compensated. The resulting measured scattering parameters allow the observation of small changes within the signal reflected by the cell suspension. Through using UV-C radiation, the cells can be influenced within the setup. Finally, an exemplary measurement on yeast cells is presented, which demonstrates the capability of the DWG for contact-free measurements.

Workshop Infineon - SiGe BiCMOS Technology and Circuits for mm-Wave Applications like Future High-Resolution Radar

8:30-10:10

Room: Studio Stuttgart

In this workshop the latest developments of Infineon Technologies in SiGe BiCMOS technology, modeling and design system for mm-wave applications are discussed. Circuit examples suited for high-performance automotive radar systems are shown. The first talk presents Infineon´s next generation SiGe BiCMOS technology B12HFC. By integrating an innovative SiGe HBT device with maximum oscillation frequency of 500 GHz in a 90 nm CMOS platform, B12HFC significantly surpasses the high-frequency performance of technologies available in production today and improves the integration capabilities. In the next presentation the work on device characterization and modelling and the process design kit for the new technology are described. A comprehensive design system supports all important methods and tools needed for complex mm-wave circuit design. The third talk shows the results of the development of a 76-81 GHz power amplifier for automotive radar systems. In combination with existing SiGe or CMOS transceivers, this component enables the realization of scalable high-performance radar systems with superior resolution at low power consumption. The final presentation shows concepts and circuit results for radar systems beyond 100 GHz. Due to the good RF-performance of SiGe BiCMOS and the large bandwidth available in these frequency ranges, radar systems with outstanding performance will be possible in low-cost silicon-based technologies in future supporting the trend towards autonomous driving. Additionally, other application areas in high frequency ranges and with similar requirements, e.g. in communication or industrial sensing, will profit from the availability of such technologies.

08:30 B12HFC: Infineon´s Next Generation 500 GHz fmax SiGe BiCMOS Technology
J. Böck

08:55 Modeling and Design System for mm-Wave Circuit Design
K. Aufinger

09:20 SiGe Power Amplifier for Scalable High-Performance Radar Systems
H. Knapp

09:45 High-Performance SiGe FMCW Radar Demonstrators at 120 GHz and 240 GHz
F. Ahmed

Coffee Break	*Room:* Foyer	10:10 -10:40

Closing Session 10:40-12:20

Chair: Dr. T. Chaloun
Room: Großer Saal

10:40 **James Hwang** – Microwaving a Biological Cell Alive – Broadband Label-free Noninvasive Electrical Characterization of a Live Cell

Lunch Break	*Room:* Foyer	12:20 -13:20

Wednesday

Venue

The conference will be hosted in the conference center Edwin-Scharff-Haus in the city of Neu-Ulm. Ulm and Neu-Ulm share the same public transportation system, enabling convenient seamless travel within both cities.

Venue Address
Edwin-Scharff-Haus
Silcherstraße 40
D-89231 Neu-Ulm

Coordinates 48.3934, 9.99146
Plus Code 9XVR+9C Neu-Ulm

Scan Address

Scan Coordinates

Arriving with the train at Ulm Main Train Station

The venue is located within a walking distance of 15 minutes from Ulm main railway station and can also be reached by bus: Take “Line 7” into direction “Willy-Brandt-Platz” and exit at bus stop “Amtsgericht”.

Arriving with the car

The conference center offers convenient paid parking.
For more detailed information see:
https://nu.neu-ulm.de/de/neu-ulm-erleben/veranstaltungsorte/edwin-scharff-haus/anreisen/ (German version only).

WiFi-Access

The conference center provides complimentary WiFi, just connect to “ESHNU” (open, no encryption) and then use the credentials provided in your conference bag to login at the start page appearing in your browser.

WLAN-SSID: ESHNU

Electronic Proceedings

This year, the proceedings are provided electronically via download. During the conference, go to ***gemic2022.de/proceedings/download/*** and download the ZIP archive using the password provided in your conference bag. Unpack the zip file, and enjoy all technical conference contents locally without the need for an internet connection. For your convenience, we provide a second URL in your conference bag enabling you to browse through the contents without large download. Just open the Live Proceedings URL to browse while at the conference. Please find the details in your bag.

Proceedings

Several weeks after the conference, the proceedings will be published as always in IEEE Xplore. Use your personal or institutional IEEE Xplore account for access.

Please note, the **workshop material is not part of the proceedings**, it is up to the individual workshop organizers if their material will be provided. Please ask them directly for details, we cannot assist you with this.

Welcome Reception

The Welcome Reception will start on Monday at 17:40 in the Foyer of the Edwin-Scharff-Haus, right next to the exhibition. Come, grab a drink and some finger food and enjoy the networking.

Conference Dinner

The outdoor Dinner Event will take place Tuesday at 17:40 in the backyard of Edwin-Scharff-Haus, next to the Danube river with a beautiful view to the old town of Ulm on the other side of the river, food, drinks and entertainment. Please bring a jacket, evenings can be chilly next to the Danube.

Exhibition hours

Exhibition will be open on Monday from 9:00 until 17:40 and Tuesday from 8:00 until 16:00. Wednesday will have no exhibition, so take the opportunity to enjoy the exhibition during the first two conference days.

Imprint

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