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2024 DUISBURG

GeMiC

German
Microwave
Conference

March 11th – 13th

Conference Program

VDE ITG IEEE IMA e.V.

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GeMiC 2024 Duisburg

Program Overview

Monday, 11th of March

	Foyer	Philharmonie	Tiger & Turtle	Zoo Duisburg
09:00	**Registration | Foyer** 09:00 - 12:00			
12:00	**Lunch | Foyer** 12:00 - 13:00			
13:00		**Opening Session** **Keynote 1:** Alwyn Seeds **Keynote 2:** Gerd Hechtfischer 13:00 - 14:20		
14:00				
14:20				
14:40		**Power Amplifier** 14:40 - 15:40	**Communication** 14:40 - 16:00	
15:00				
15:40				
16:00	**Coffee Break | Foyer** 16:00 - 16:20			
16:20		**Devices** 16:20 - 18:00	**(3D)-Printing** 16:20 - 17:40	**Workshop: Rohde & Schwarz** 16:20 - 18:00
17:00				
17:40				
18:00	**Welcome Reception | Foyer** from 18:00			

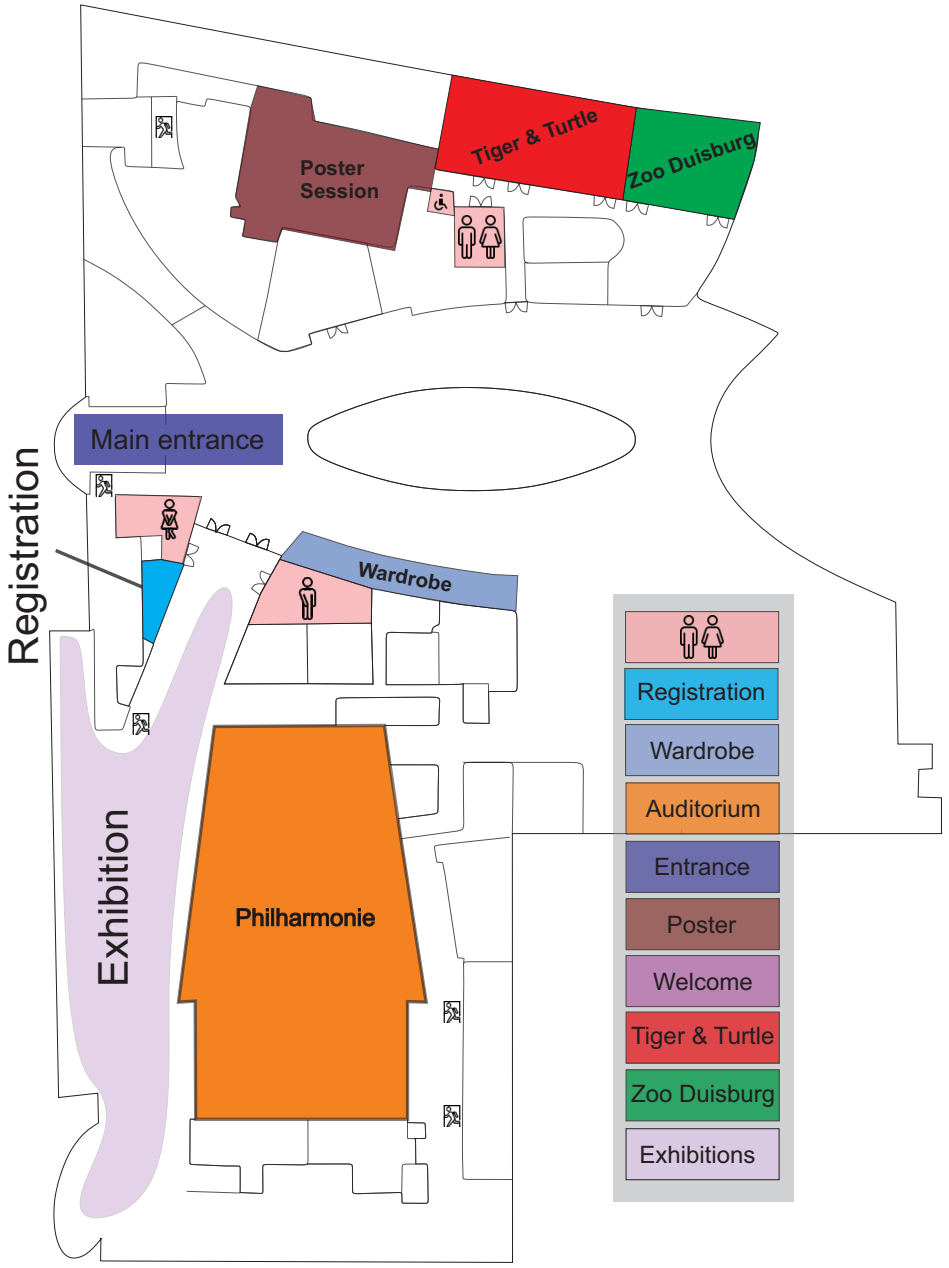
Tuesday, 12th of March

	Foyer	Philharmonie	Tiger & Turtle	Zoo Duisburg
08:00				
08:40	**Registration** 8:40 - 10:20	**Antenna 1** 8:40 - 10:20	**Sources & Transmitters** 8:40 - 10:00	**Workshop DFG Meteracom 1** 8:40 - 10:20
09:00				
10:00				
10:20	**Poster Session** 10:20 - 13:20	**Coffee Break | Foyer** 10:20 - 10:40		
10:40		**Antenna 2** 10:40 - 12:00	**Bio-Medical Applications** 10:40 - 12:20	**Workshop DFG Meteracom 2** 10:40 - 12:20
11:00				
12:00				
12:20		**Lunch | Foyer** 12:20 - 13:20		
13:00				
13:20		**Plenary Talks** **Keynote 3:** Suzuki **Keynote 4:** Huggard 13:20 - 14:20		
14:00				
14:30		**Waveguides 1** 14:30 - 15:30	**Focused Session on mm-Wave and THz Photonics 1** 14:30 - 15:30	**Measurement Techniques 1** 14:30 - 15:30
15:00				
15:30		**Coffee Break | Foyer** 15:30 - 15:50		
16:00	**Poster Session** 15:30 - 17:10	**Waveguides 2** 15:50 - 17:10	**Focused Session on mm-Wave and THz Photonics 2** 15:50 - 16:50	**Measurement Techniques 2** 15:50 - 16:30
16:30				**IMA Meetings** 16:30 - 17:15
17:00				
17:30	**Bus Transfer to the Landschaftspark** 17:30 - 18:00			**MTT/AP Chapter Meetings** 17:15 - 18:00
18:00	**Conference Dinner** 18:00 - 22:00			

Wednesday, 13th March

	Foyer	Philharmonie	Tiger & Turtle	Zoo Duisburg
08:20		**Radar** 8:20 - 10:00	**Filter** 8:20 - 09:40	**Focus Session THz.NRW** 8:20 - 10:00
09:00				
09:40				
10:00		**Keynote 5:** Jonathan Borrill		
10:30	**Coffee Break | Foyer** 10:30 - 10:50			
11:00		**Receivers** 10:50 - 12:10	**Applications** 10:50 - 11:50	
12:00		**Keynote 6:** Joel Dunsmore		
12:40		**Awards & Closing**		
13:00	**Lunch | Foyer** 13:00 - 14:00			
14:00	**Departure**			
14:30	**Lab-Tours** Registration required!			

Overview Conference Location



Sponsor Exhibition

Foyer Philharmonie

Opening Times:

Monday: 11:00 - 20:00
Tuesday: 8:30 - 17:30

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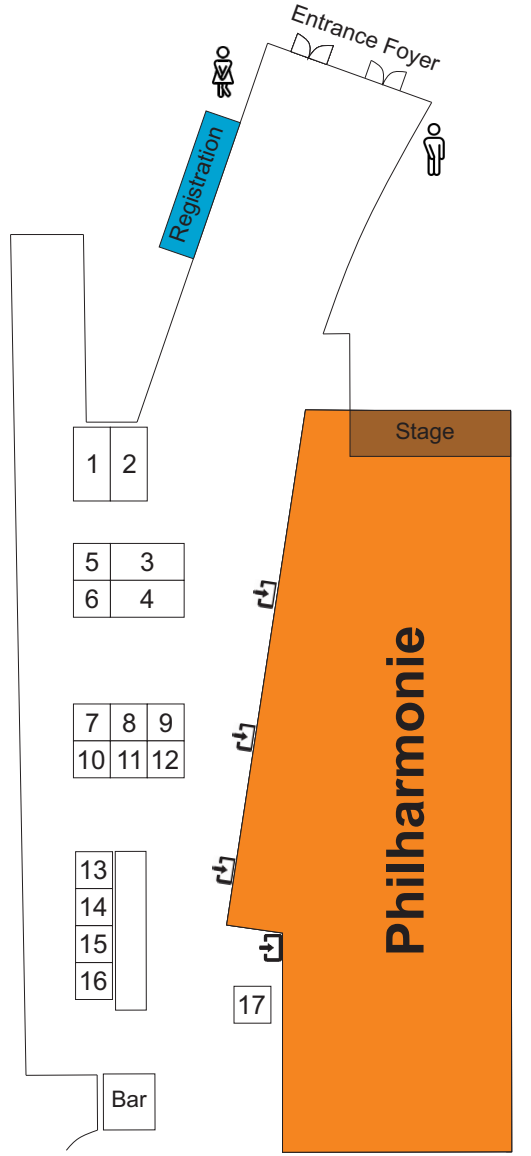
16 Teraoptics
17 6GEM



Welcome Message

Dear GeMiC 2024 participant,

welcome to the 15th German Microwave Conference in Duisburg, March 11-13, 2024!

GeMiC is a very successful conference series, which started in Ulm in 2005. In the following years, Karlsruhe, Hamburg, München, Berlin, Darmstadt, Ilmenau, Aachen, Nürnberg, Bochum, Freiburg, Stuttgart, Cottbus, and again Ulm, were hosts, and now, in 2024, the University of Duisburg-Essen.

GeMiC is supported by

- German Institute for Microwave and Antenna Technologies (IMA)
- German association for Electrical, Electronic & Information Technologies (VDE) and its Information Technology Society (ITG)
- Institute of Electrical and Electronics Engineers (IEEE), through its Microwave Theory and Technology Society (MTT) and the German Section MTT/AP Joint Chapter
- European Microwave Association (EuMA)
- German Research Foundation (DFG)
- University of Duisburg-Essen

The field of Microwave research and industrial engineering keeps evolving at a fast pace, enabling socially relevant developments in the areas of communication, automotive traffic, medical diagnostics and sustainable agriculture, to name just a few. In GeMiC 2024, six keynote talks will be held throughout the technical program, highlighting a focus in this year's conference on sub-mm-wave and THz research.

Monday

- **Alwyn Seeds**
  University College London
  Photonically enabled THz Wireless Technologies
- **Gerd Hechtfischer**
  Rohde & Schwarz GmbH
  Driving the evolution towards 6G

Tuesday

- **Safumi Suzuki**
  Tokyo Institute of Technology
  Terahertz signal sources with milliwatt-class output powers using resonant tunneling diodes

- **Peter Huggard**
  Science and Technology Facilities Council, RAL Space
  Technology for remote sensing applications at W-band and higher frequencies

Wednesday

- **Jonathan Borrill**
  Anritsu Corporation
  Innovations in test tools, enabling fundamental 6G research
- **Joel Dunsmore**
  Keysight Technologies
  Advances in Wideband Modulated Load-pull Measurements for Power, EVM and ACPR

The contributed talks are organized in two parallel tracks. In addition, the program contains poster sessions, industry and academic workshops, and the industrial exposition including live demonstration of newest microwave systems, components, and software. Coffee and Lunch breaks will be held in the foyer, where the industry exhibition and poster sessions take place.

On the evening of Monday, March 11, the Welcome reception will be held in the foyer of the Duisburg Mercatorhalle conference center.

The conference dinner will take place on Tuesday March 12 in the Landschaftspark Duisburg Nord, a former steel works giving unique testimony to the industrial history of the Ruhr area.

The organization team of GeMiC 2024 would like to thank all authors and reviewers, and the awards committee for their contributions.

Two awards will be given at GeMIC 2024, thanks to the sponsors EuMA and IMA:

- Best Student Paper (EuMA)
- Best Conference Paper (IMA)

We would like to sincerely thank our financial sponsors. The conference can only be realized with their support

Gold Sponsors: Rohde & Schwarz, Keysight, Anritsu, Terahertz.NRW,

Silver Sponsors: bsw Test Systems & Consulting, SIMUSERV, 2π-LABS, ACST, Rosenberger, IMST, IHP, KROHNE Messtechnik, FormFactor, EPOS, HITECH RF & Microwave Solutions, Teraoptics, 6GEM

We would like to thank the DFG for the conference grant and support of international traveling guests.

The organization team wishes everyone an interesting GeMiC 2024 in Duisburg!

Committees and Boards

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General Infos

Conference Location

Mercatorhalle Duisburg
within City Palais
König-Heinrich Platz
47051 Duisburg

From the Mainstation

10-minute walk along the Königstraße.
The Mercatorhalle is in the City Palais on the first floor.

By Car

A parking garage is in the direct vicinity of the Mercatorhalle. For Navigation systems: Averdunkstraße 1, 47051 Duisburg. We suggest to use the City Palais or Averdunk garage. Both garages are open 24/7 and costs 2€ per hour with a maximum of 12€ for 24 hours.

For Electric Cars

You can find nearby charging points either at Friedrich-Albert-Lange-Platz 7 or Burgplatz 17, 47051 Duisburg.

Wardrobe

At the conference location a Wardrobe is available for free. You may also temporarily place your luggage here.

WLAN

SSID: GeMiC-2024

Password: Duisburg-2024

Lab Tours

We will offer Lab-Tours at the end of the GeMiC, which require an additional registration. Please travel to the according building on your own. You can of course ask the local team for support. Please keep an eye on the GeMiC Website for additional information and updates.

Dinner Information

Program

17:30 – 18:00 **Bus transfer to Gebläsehalle**

18:00 – 18:30 **Bus transfer to Gebläsehalle***

*Only for members of the last session: IMA and MTT/AP Germany Joint Chapter meetings

18:15 – 18:45 **Reception Drink and Welcoming**

19:00 – 20:30 **Dinner**

20:30 – 21:30 **Program**

21:30 – 21:50 **Bus transfer to Duisburg Hbf**

22:10 – 22:30 **Bus transfer to Duisburg Hbf**

Location

Gebläsehalle
Landschaftspark Nord Duisburg
Emscherstraße 71
47137 Duisburg

Transfer

Organized bus transfer

Meeting Point for the organized bus transfer is Landfermannstraße 6. The busses depart at 17:30. For the members of the IMA and MTT/AP Germany Joint Chapter meetings a special bus will depart at 18:00. Please be there 10 min before departure. The busses will then stay at the Gebläsehalle and make two tours back to the mainstation at 21:30 and 22:10.

Transfer by public transport

Take the tram 903 (direction: Dinslaken Bahnhof) at station "König-Heinrich-Platz" to station „DU-Landschaftspark Nord" (approx. 14 min/ 7 stops). The tram departs every 8 min. From there you have to walk through the Emscherstraße approx. 750m. The last tram from „DU-Landschaftspark Nord" back to "König-Heinrich-Platz" depart usually at 23:10.

Transport by night-express

After 23:10 the public transport system changes to the night-express routes. The first night-bus from „DU-Landschaftspark Nord" back to "König-Heinrich-Platz" departs at 00:38 and then once per hour (until 2:38).

Transport by car

In Duisburg the Emscherstraße exists twice. Make sure to drive to the one in Duisburg-Obermeiderich. The Landschaftspark Duisburg-Nord has a large visitor car park directly opposite the main park entrance. The visitor car park has 1,500 spaces and parking is free.

Transport by taxi

0203 8050915 | www.duisburger-taxi.de
0203 333333 | www.taxi-duisburg.net

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The Rohde & Schwarz technology group is among the trailblazers when it comes to paving the way for a safer and connected world with its leading solutions in test & measurement, technology systems, and networks & cybersecurity. Founded nearly 90 years ago, the group is a reliable partner for industry and government customers around the globe. On June 30, 2022, Rohde & Schwarz had around 13,000 employees worldwide. The independent group achieved a net revenue of EUR 2.53 billion in the 2021/2022 fiscal year (July to June). The company is headquartered in Munich, Germany.

Website: www.rohde-schwarz.com
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KEYSIGHT

At Keysight (NYSE: KEYS), we inspire and empower innovators to bring world-changing technologies to life. As an S&P 500 company, we're delivering market-leading design, emulation, and test solutions to help engineers develop and deploy faster, with less risk, throughout the entire product lifecycle. We're a global innovation partner enabling customers in communications, industrial automation, aerospace and defense, automotive, semiconductor, and general electronics markets to accelerate innovation to connect and secure the world. Learn more at www.keysight.com.

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GeMiC 2024 Duisburg

Anritsu

Anritsu Corporation has been a provider of innovative communications solutions for 125 years. The world leading test and measurement solutions include wireless, optical, microwave/RF and digital instruments, and monitoring systems, that can be used during R&D, manufacturing, installation, and maintenance of Telecom networks. Anritsu supplies a wide range of leading-edge RF and Microwave test solutions operating at frequencies up to 750 GHz. Product lines include Vector Network Analyzers, Spectrum Analyzers, Signal Generators, Power Meters, including benchtop and handheld units. The company develops advanced solutions for 5G, M2M, IoT, as well as other emerging and legacy wireline and wireless communication markets.

Website: www.anritsu.com
Contact: +49 (0) 89-442308-0, E-Mail: Benelux@Anritsu.com

terahertz.NRW

The Network in North Rhine-Westphalia for Excellent Terahertz Research

terahertz.NRW brings together leading minds in terahertz research from NRW and around the world. Together, we create a network to harness the disruptive potential of this technology. Our goal is to develop new mobile applications for communication, localization, material characterization, medical technology, and environmental monitoring. We are making terahertz technology globally visible – made in NRW.

terahertz.NRW is a network supported by the state of North Rhine-Westphalia, consisting of Fraunhofer FHR, Ruhr-University Bochum, University of Duisburg-Essen, Fraunhofer IMS, and Bergische University Wuppertal.

Website: www.terahertz.nrw/

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bsw TestSystems & Consulting: Semiconductor & Electronics & High frequency solutions

bsw TestSystems & Consulting is a measurement solution provider for the semiconductor, electronic and telecom industry as well as research and development institutes. Our emphasis is on RF/µw techniques and high-speed digital, more specific on S-parameters, tuner measurement techniques for noise parameters and load-pull, Signal Integrity applications, DC/CV parameter extraction and contacting/fixturing solutions.

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2π-LABS is a high-tech radar sensor company.

Our 2πSENSE software defined and highly versatile D-band (126 – 182 GHz with 56 GHz bandwidth) radar sensor & technology platform enables fast, cost effective & accurate network analyzer like measurements for a wide variety of industrial and scientific applications.

Some applications examples are:

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For more information visit our website or talk to us during the conference.

Website: https://acst.de/

Contact: +49 (6181) 966 98 00 E-Mail: sales@acst.de

Rosenberger

Rosenberger is one of the world's leading manufacturers of impedance-controlled and optical interconnect solutions in high-frequency, high-voltage and fibre-optic technology.

The product range covers RF coaxial connectors and cable assemblies, test, measurement & calibration products, aerospace, security & defence engineering products, automotive connectors, medical & industrial connectivity solutions as well as M2M / IoT systems. The

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Website: https://www.rosenberger.com

Contact: +49 (8684) 18 – 0 E-Mail: info@rosenberger.com

IMST

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Website: https://imst.com/

Contact: +49 (02842) 981 0 E-Mail: contact@imst.de

IHP

IHP is one of the world`s leading research institutions in the field of silicon-germanium electronics, and its electronic and photonic-electronic technologies and circuits are among the most powerful in the world. IHP offers research partners and customers access to its high-performance SiGe BiCMOS technologies with dedicated integrated RF and silicon photonics modules, as well as development support for dedicated process steps and devices. IHP's portfolio includes the world's fastest integrated SiGe heterobipolar transistors, and moreover special MPW runs with memristor devices for AI, with a graphene module for photonic devices, or with a backside redistribution layer for advanced packaging. The offer also includes support for the development of dedicated processes on single tools, or of process flows for special devices or interposer flows, as well as the adaption of existing standard process flows. Professional Process Design Kits (PDKs) for IHP's SiGe BiCMOS and electronic-photonic technologies are also offered through the MPW service. This is the foundation for developing circuits with the world's fastest bipolar transistors in the sub-terahertz range.

Website: https://www.ihp-microelectronics.com/

Contact: +49 (335) 5625 0 E-Mail: ihp@ihp-microelectronics.com

KROHNE

KROHNE is a world-leading manufacturer and supplier of solutions in industrial process instrumentation. Founded in 1921 and headquartered in Duisburg, Germany, KROHNE offers supporting products and services for one-stop-shopping and in industries as widespread as oil & gas, water & wastewater, chemical & petrochemical, food & beverage, power, minerals & mining and marine.

More than 350 engineers in the worldwide KROHNE Group are continuously engaged in research into promising technologies for the future, in pursuit of improved measurement and further developments. The family-owned enterprise has permanent representation in more than 100 countries and employs more than 4,000 people in order to bring highly innovative products from a single source, and tailor-made technical solutions to measurement requirements.

Website: https://de.krohne.com

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MicroSanj develops solutions for high resolution and high speed thermal imaging based on the thermoreflectance principle. These are used for microelectronic and optoelectronic devices and circuit thermal design and characterization with a focus on spatial, temporal, and temperature resolution. Their solutions are unique for their spatial- and time resolution which is sub-micron and roughly 50ns, allowing thermal characterization of power amplifier IC's. Their solution can be integrated on almost any microscope.

Website: https://hitechbv.nl/

Contact: +31 (30) 307 4420 E-Mail: information@hitechbv.nl

TERAOPTICS – is a European funded research network focusing on Terahertz Photonics for Communications, Space, Security, Radio-Astronomy, and Material Science. It comprises 11 academic and another 12 mostly non-academic industrial partners from around the globe. The focused session will present some of the recent scientific breakthroughs in photonic integrated circuit (PIC) development that have contributed to the advancement of the field. This includes high-power THz photodiodes integrated with ultra-wideband dielectric waveguides for spectroscopic applications, polymer-based hybrid THz PICs, novel photonic THz receiver based upon optically pumped mixers, and broadband and low phase noise radio frequency over fiver (RFoF) technology up to diffractive optics for THz beam control.

Website: https://teraoptics.eu/

Contact: +49 (203) 379 2340 E-Mail: manager@teraoptics.eu

EPOS

EPOS embedded Core & Power Solutions GmbH & Co. KG

EPOS is a subsidiary and development center of Infineon Technologies AG with approximately 60 employees. Together with Infineon Technologies, EPOS engineers develop radar sensors for the automotive market. New radar sensors with fault-tolerant behavior in a modern CMOS technology are needed as a component for the future market of autonomous driving. At the Duisburg location, engineers work on VLSI design and implementation, as well as validation, characterization, and development of test programs for production testing to improve yield and provide automotive quality to customer. Additionally, EPOS also has project responsibility for radar products that are developed with other Infineon locations in Germany and Austria. The engineers at EPOS Duisburg are highly skilled and dedicated to developing advanced radar sensors that meet the highest standards of quality and safety. With their expertise and ongoing collaboration with other Infineon sites, EPOS is committed to driving innovation in the automotive industry.

Website: https://www.infineon.com/cms/en/careers/

Contact: +49 (203) 28080 115 E-Mail: Monika.Arzt@epos-d.com

6GEM

With their application „6GEM open - efficient - secure - safe“, the RWTH Aachen University, the Ruhr-University Bochum, the Dortmund University of Technology and the University of Duisburg-Essen were successful in a call for proposals issued by the German Federal Ministry of Education and Research (BMBF). The four universities will work together with four non-university research institutions on future communication technologies in 6G mobile communications from August 1, 2021. Co-applicants were the Fraunhofer Institute for Material Flow and Logistics, the Fraunhofer Institute for Microelectronic Circuits and Systems, the Fraunhofer Institute for High Frequency Physics and Radar Technology and the Max Planck Institute for Security and Privacy.

The 6GEM consortium combines scientific excellence and mobile communications expertise at the network, material, component/microchip and module levels in North Rhine-Westphalia. Experience in their implementation and worldwide networking is also available. A holistic approach is being pursued, from production and logistics to people with their needs for self-determination, privacy and security in times of climate change.

Website: https://www.6gem.de

Further Sponsors

AIXTRON

AIXTRON is the leading provider of deposition equipment to the compound semiconductor industry. The company was founded in 1983 and is headquartered in Herzogenrath (Aachen City Region), Germany, with subsidiaries and representative offices in Asia, the USA, and Europe. The company's MOCVD systems are used worldwide by a wide range of customers to manufacture high-performance components for power electronic and optoelectronic applications like LED and next generation display technology, data transmission, sensor technology, energy management and conversion, communication, signal and lighting technology, and many other sophisticated high-tech applications.

Website: https://www.aixtron.com/

UNIVERSITÄT DUISBURG ESSEN

Offen im Denken

The University of Duisburg-Essen (UDE) - one of the youngest and largest universities in Germany - is located in the heart of the Ruhr metropolitan region. Its broad spectrum of subjects ranges from the humanities, social sciences and education to economics, engineering, natural sciences and medicine. Since its foundation in 2003, the UDE has developed into a globally recognized research university. This is documented by the top international positions it has now achieved.

Innovative and digitally supported teaching and learning concepts make the UDE an attractive place for research-based teaching. It offers its 41,740 students from over 130 nations 267 degree programs, 127 of which are teacher training programs.

The UDE has a strategic partnership with the Ruhr-Universität Bochum and the Technische Universität Dortmund under the umbrella of the Universitätsallianz Ruhr (UA Ruhr). They cooperate closely in research and teaching and are also jointly present in three continents with their own branch offices. In addition, the UDE maintains partnerships with over 100 universities around the world.

Website: https://www.uni-due.de

GeMiC 2024 Duisburg

Keynote Talks

Joel Dunsmore

Joel Dunsmore is a Keysight R&D Fellow working at the Santa Rosa Site. He received his Ph.D. from Leeds University in 2004. He was a principal contributor to PNA family of network analyzers, with recent work in non-linear test, including differential devices, and mixer measurements, as well as modulated and spectrum measurements. He has received 36 patents and authored the “Handbook of Microwave Component Measurements, 2nd Edition (John Wiley, 2020)”, and has the YouTube Channel @DrJoelVNA.

Peter Huggard

Peter Huggard graduated from Trinity College Dublin, Ireland with an honours degree in experimental physics. This was followed by a PhD on the generation and detection of short pulse terahertz radiation. After post-doctoral research at Universität Regensburg, Germany, and the University of Bath, UK, and lecturing in physics at the University of Bath, he joined the CCLRC Rutherford Appleton Laboratory, Harwell, Oxfordshire, UK in 2000. He is now leader of the 35 strong combined Millimetre Wave Technology and Chilbolton Observatory Group there. The group develops and produces state of the art semiconductor technology for Earth observation and radio astronomy, supporting operational meteorology and scientific research. It also builds and operates a suite of specialised radars, used for studying the atmosphere and tracking near Earth space objects such as satellites and debris. The MMT group’s work is supported by our own specialised in-house machining and semiconductor processing facilities. It has spun off a company, Teratech Components Ltd., and has recently licenced space technology to Spire Global Ltd. Beneficiaries of the group’s work include the UK academic research community, ESO, UKRI, UKSA and ESA, UKMO, Airbus Defence and Space and EUMETSAT.

Dr Huggard has published over 75 peer reviewed journal papers. He is a UK Research Councils’ Individual Merit fellow, a chartered physicist and a senior member of the IEEE. He also holds a visiting professorship at the Department of Electrical and Electronic Engineering, University College London.

Alwyn Seeds

Alwyn Seeds holds the B.Sc, Ph.D. and D.Sc. degrees of the University of London. After working as a Staff Member at Lincoln Laboratory, Massachusetts Institute of Technology and as Lecturer in Telecommunications at Queen Mary College, University of London, he joined University College London in 1986, where he is currently Professor of Opto-electronics, Head of the Photonics Group and Director of the EPSRC National Dark Fibre Facility. He has published more than 500 papers on microwave and opto-electronic devices and their systems applications, of which some 100 have been invited.

Professor Seeds is a Fellow of the Royal Academy of Engineering (UK), an IEEE Life Fellow (USA) and has served as Vice-President for Technical Affairs of the IEEE Photonics Society (USA). He co-founded Zinwave, a manufacturer of wireless over fibre systems, now a unit of Wilson Electronics LLC. There are now over 850 Zinwave systems installed in 26 countries worldwide. Alwyn Seeds was awarded the Gabor Medal and Prize of the Institute of Physics in 2012, the Distinguished Educator Award of the IEEE Microwave Theory and Techniques Society in 2018 and the Engineering Achievement Award of the IEEE Photonics Society in 2023.

Safumi Suzuki

Safumi Suzuki received the B.E. degree in electrical and electronic engineering and M.E. and D.E. degrees in electronics and applied physics from the Tokyo Institute of Technology, Tokyo, Japan, in 2005, 2007, and 2009, respectively. From 2009 to 2014, he was an Assistant Professor with the Department of Electronics and Applied Physics and, from 2014 to 2016, an Associate Professor with the Department of Physical Electronics, Tokyo Institute of Technology, respectively. Since 2016, he has been an Associate Professor with the Department of Electrical and Electronic Engineering, Tokyo Institute of Technology. His research interests include terahertz electronic devices and applications.

Gerd Hechtfischer

Gerd Hechtfischer received the diploma degree in physics from the Technische Universität München, Munich, Germany in 1994 and the Dr. rer.nat. degree in solid state physics from the University of Erlangen, Erlangen, Germany in 1997. His research activities have been focused on microwaves, superconductors and thin film technology. Dr. Hechtfischer holds several patents in this field.

He is currently senior director microwave development at Corporate R&D of Rohde & Schwarz GmbH & Co. KG in Munich, Germany. Gerd Hechtfischer is a senior member of the IEEE.

Jonathan Borrill

Head of Global Market Technology

Anritsu Corporation.

Jonathan has over 30 years' experience in the area of advanced RF and wireless signalling systems. After graduating from Southampton University (UK) in electronic engineering, Jonathan worked for the UK Ministry of Defence (now Qinetiq) developing advanced millimetre wave communications systems. After a stint at Motorola as application engineering manager, in 2001 he moved to Anritsu. There, after performing business development and management roles for the EMEA region, he was appointed as Head of Global Market Technology for the corporate T&M business.

Jonathan is a full member of the Institute of Engineering and Technology and a Chartered Engineer.

Sessions and Workshops

Monday, 11th of March

09:00 – 12:00	Registration	Foyer
12:00 – 13:00	Lunch	Foyer
13:00 – 14:20	**Opening Session**	Philharmonie
	Keynote 1: Alwyn Seeds	
	Keynote 2: Gerd Hechtfischer	
14:40 – 15:40	**Power Amplifier**	Philharmonie
14:40 – 16:00	**Communication**	Tiger & Turtle
16:00 – 16:20	Coffee Break	Foyer
16:20 – 18:00	**Devices**	Philharmonie
	Workshop: Rohde & Schwarz	Zoo Duisburg
16:20 – 17:40	**(3D-) Printing**	Tiger & Turtle
18:00 – 21:00	Welcome Reception	Foyer

GeMiC 2024 Duisburg

Monday

Registration *Room:* Foyer **08:30 – 12:00**

Lunch *Room:* Foyer **12:00 – 13:00**

Opening Session **13:00 – 14:20**

Chair: Prof. N. Weimann & Prof. A. Stöhr
Room: Philharmonie

13:00 **Welcoming by Prof. Barbara Albert, Rector of the University of Duisburg-Essen, and Dr. Sebastian Ritter, Mayor of Duisburg.**

13:20 **Keynote 1: Photonically enabled THz Wireless Technologies**

Alwyn Seeds, University College London

Connections between user devices and the immense bandwidth of the optical fibre network are usually by microwave wireless, limiting the available user bandwidth. The THz spectrum is attracting considerable interest for overcoming this throughput bottle-neck. In this talk, after introducing key system requirements and opportunities for THz communication systems, the use of photonic techniques to generate and distribute the required signals will be presented and some examples of experimental THz communication systems presented.

13:50 **Keynote 2: Driving the evolution towards 6G**

Gerd Hechtfischer, Rohde & Schwarz GmbH

While the rollout of 5G is still ongoing in most parts of the world, the development of 6G, the next level of wireless communication and data transmission, has gained focus in industry and academic research. Increased transmission speed, lower latency and energy efficiency are considered the main objectives of the coming 6G technology. Based on these improvements, 6G is expected to enable new use cases, services, and device forms. To shape the new communication infrastructure, progress in radio hardware is needed as a strong contribution at the physical layer. The talk will give insights how advances in microwave test and measurement instruments are addressing technical challenges on the road to 6G.

Power Amplifier 14:40 – 15:40

Chair: Prof. I. Kallfass
Room: Philharmonie

14:40 General Combiner Initialization Workflow for All Types of Active Load Modulation Power Amplifiers

Alexander Deublein[1], Andreas Illmer[1], Christian Musolff[2], Robert Weigel[1], Georg Fischer[1]
[1] Friedrich-Alexander-Universität Erlangen-Nürnberg | Germany
[2] Infineon Technologies AG | Germany

A highly trackable and computationally efficient combiner initialization workflow is introduced that can be applied to any type of power amplifier (PA) employing active load modulation (ALM), such as Doherty PAs (DPAs), outphasing transmitters, load modulated balanced amplifiers, and circulator load modulated amplifiers. The workflow is based on a tunable combiner and associated boundary conditions derived from single-transistor load-pull. As a result, the PA's topology is fixed in advance, clearly distinguishing this technique from existing analytical algorithms. The ability to transition seamlessly from load-pull to an educated initial design of the desired ALM scheme is demonstrated using a two-way inverted DPA based on compact models of Infineon's GaN-on-Si transistors at 3.6 GHz. Apart from its inherent single-frequency limitation, which can be overcome by sampling the band of interest, the software-aided nature of the novel design workflow allows both non-reciprocal components and measured data to be included in the tunable combiner, resulting in unprecedented versatility.

15:00 Demonstration of a Drain-Bar-Based Supply Concept for H-Band High Power Amplifiers

Thomas Ufschlag[1], Benjamin Schoch[1], Dominik Wrana[1], Lukas Gebert[1], Axel Tessmann[2], Arnulf Leuther[2], Sandrine Wagner[2], Ingmar Kallfass[1]
[1] University of Stuttgart | Germany
[2] Fraunhofer Institute for Applied Solid State Physics IAF | Germany

This paper reports for the first time the demonstration of a drain-bar concept for high power amplifiers operating in H-band (220-325 GHz). The presented design is based on socalled power-cells, which are four-finger-transistors consisting out of two distinct two-finger devices embedded in a passive structure. The novelty is that the presented layout of the four-finger device is adapted for the drain-bar concept. This novel drain-bar powercell can be stacked to build the required parallelization. Stacking of the power-cells forms the drain-bar, which supplies all drains and suppresses odd-mode oscillations. The presented amplifier is fabricated in a 35 nm InGaAs mHEMT technology and operates at a center frequency of 248 GHz with a 3 dB bandwidth of 30 GHz. An OP1 dB of 3 dBm is measured.

15:20 A Method for Improved Phase Characteristics in a GaN PA for Supply Modulation

Anders I. Hagen, Morten Olavsbråten
Norwegian University of Science and Technology (NTNU) | Norway

A method for reduction of phase variance in RF envelope tracked power amplifiers is proposed and demonstrated through simulations and measurements of an implemented GaN on SiC Power Amplifier. Simulations of a traditional one transistor implementation is compared to the proposed solution, using a 2.1 GHz 10 W power amplifier built around the CG2H40010F transistor shows reductions in phase differences of up to 21.5 degrees (from 48 down to 26.5 degrees) over a wide range of supply and gate voltages. Measurements show correspondence with simulations demonstrating improvement in phase difference.

Communication 14:40 – 16:00

Chair: Prof. F. Gerfers
Room: Tiger & Turtle

14:40 Time and Frequency Synchronization for Real-Time Wireless Digital Communication Systems

Roghayeh Ghasemi, Tobias Koegel, Patrick Fenske, Robert Schober, Martin Vossiek
Friedrich-Alexander-Universität Erlangen-Nürnberg, Institute of Microwaves and Photonics (LHFT) | Germany

In this paper, we present a fully field-programmable gate array (FPGA)-based real-time implementation of a wireless time and frequency synchronization scheme for communication and sensor networks. For this purpose, a communication link using frequency division multiplexing is established

between three distributed stations. This allows the simultaneous and continuous transmission of quadrature phase-shift keying-modulated data between the stations with no interference. The time difference between the stations is estimated using the precision time protocol. Due to the deterministic processing time of the FPGA implementation, precise time synchronization is achieved, with a standard deviation of 10 ns per communication cycle. Moreover, in the proposed method, successive estimates of the time offset are used to estimate the frequency difference between the stations, which allows the tuning of the digitally controlled crystal oscillators of the distributed stations to the frequency of the central reference station, with a clock rate deviation of approximately two parts per billion. The structure is robust with respect to multipath interference and is extendable to additional frequency bands and stations. The results demonstrate the excellent performance and robustness of the proposed concept.

15:00 **Investigations of Multi-Beam SCORE Datarates**

Johann Christian Marten, Marwan Younis, Gerhard Krieger
German Aerospace Center (DLR), Microwaves and Radar Institute | Germany

Synthetic Aperture Radar (SAR) instruments equipped with multi-channel capabilities allows the application of digital beam forming techniques facilitating high resolution and wide swath imaging. Moving the digital interface close to the antenna comes at the expense of increased and more complex digital processing. This paper details the on-board data processing steps providing closed expressions for the data rates, memory utilisation and computational complexity.

The reference system is taken to be a radar ground demonstrator based on a reflector with a 32-channel feed array followed by a 3-FPGA digital processing unit. Simulations show that the necessary computational performance can be achieved, although memory constraints remain critical.

15:20 **A Gigabit Wireline Transceiver Using Time-Mode-Circuits in 28nm**

Tim Lauber, Stefan Voigt, Alexander Kronig, Ralf Wunderlich, Stefan Heinen
RWTH Aachen University, Integrated Analog Circuits and RF Systems | Germany

This work presents a 1 Gbps serial wireline transceiver using pulse-width-modulation implemented in a 28 nm technology. The bandwidth efficiency of this time modulation is discussed and a novel system for modulation and demodulation by delay locked loops is introduced. Delay cells for the proposed

architecture are designed and simulation results through all design corners are shown. The theoretical basis for design of pre- and postemphasis in the analog front end is discussed. The system consumes 13.44 mW from a 0.9 V supply voltage.

15:40 **Crosstalk Immune High-Speed Photonic Integrated Transceiver**

Souvaraj De[1], Ranjan Das[1], Karanveer Singh[1], Younus Mandalawi[1], Thomas Kleine-Ostmann[2], Thomas Schneider[1]
[1] Technical University Braunschweig, THz-Photonics Group | Germany
[2] Physikalisch-Technische Bundesanstalt (PTB), Department High Frequency and Electromagnetic Fields | Germany

Optical communication systems show promising results in terms of data transmission in the microwave and terahertz (THz) frequency range. Consequently, photonic integrated circuits (PICs) provide numerous advantages like high transfer rate, minimal loss for long-distance communication, reduced power consumption, etc. Nonetheless, in such densely packed PICs, a large number of photonic components are tightly confined in a small space, resulting in thermal crosstalk, which eventually hampers the system's performance. Deep trench supported designs can alleviate the thermal crosstalk in such systems to a large extent. Here, by simulations, we mitigate thermal crosstalk and enhance the performance in terms of Bit Error Rate and extinction ratio for an optical transmitter-receiver system with back-to-back and 5 km radio over fiber transmission line configuration at a high data rate with a deep trench assisted silicon Mach-Zehnder modulator and a Si-Ge avalanche photodetector at the transmitter and receiver, respectively.

Coffee Break *Room:* Foyer **16:00 – 16:20**

Devices 16:20 – 18:00

Chair: Prof. N. Weimann
Room: Philharmonie

16:20 Determining GaN HEMT Trap Models from MHz Load-line Measurement — A Case Study

Matthias Rudolph[1,2], Petros Beleniotis[1], Christos Zervos[1], Ulrich L. Rohde[1], Cristina Andrei[1]
[1] Brandenburg University of Technology | Germany
[2] Ferdinand-Braun-Institut gGmbH, Leibniz-Institute für Höchstfrequenztechnik | Germany

GaN HEMTs are known to suffer from trapping effects that lead to a reduction in current density depending on previously applied drain voltages. Characterization of the effect currently requires expensive fast-pulsed voltage supplies that can be synchronized with measurement. We propose a method that provides basically the same information based on a dynamic load-line measurement in the lower MHz range, speeding up the measurement process and reducing equipment cost. This paper presents a case study based on simulation of a proven advanced GaN HEMT model in order to explore the general feasibility of the concept.

16:40 Experimental Characterization of Drain Current Transient Effects in 'Buffer-Free' RF GaN HEMTs

Simone Cangini[1], Gian Piero Gibiino[1], Alberto Maria Angelotti[1], Martino Lorenzini[2], Corrado Florian[1], Alberto Santarelli[1]
[1] University of Bologna | Italy
[2] Gallium Semiconductor | the Netherlands

Drain current transient measurements performed on an RF GaN HEMT device manufactured using a 'bufferfree' technology are compared with those from a corresponding device sharing the same layout and processing steps but utilizing a conventional Fe-doped buffer. A substantially different empirical behavior is observed, that is characterized by a significantly reduced drain-lag and non-monotonic current transients with extended relaxation times.

17:00 Bias-dependent Spectrum Analysis of Highly Nonlinear Resonant Tunneling Diode Oscillators

Enes Mutlu[1], Jonas Watermann[1], Jonathan Abts[1], Özgül Tek[1], Christian Preuss[1], Robin Kress[1], Benedikt Sievert[2], Daniel Erni[2], Andreas Rennings[2], Nils Weimann[1]
[1] University of Duisburg-Essen, Dept. Components for High-Frequency Electronics (BHE) | Germany
[2] University of Duisburg-Essen, General and Theoretical Electrical Engineering (ATE) | Germany

Many resonant tunneling diode (RTD) devices employ antenna structures that emit signals towards the backside of the substrate exhibiting high permittivity. Consequently, these devices are prone to coupling into substrate modes. The intended increased nonlinearity of optimized RTDs results in an amplified susceptibility of the oscillator to coupling phenomena with resonant substrate modes. We present small area devices with reduced capacitance that are integrated into antennas with high inductance. This design allows for the creation of highly nonlinear oscillators and enables the investigation of the spectral performance under varying bias conditions. The measurements indicate the occurrence of spurious oscillations which are estimated to be multiples of resonant substrate modes in the extended device structure.

17:20 Investigation of Mutual Injection Locking on Resonant-Tunneling-Diode Oscillators

Robin Kress, Enes Mutlu, Bo Song, Alexander Possberg, Simone Clochiatti, Nils Weimann
University of Duisburg-Essen, Dept. Components for High-Frequency Electronics (BHE) | Germany

An RTD patch oscillator concept is presented based on electroplated patch antennas, supported by Benzocyclobuten as a dielectric. With the utilized double-barrier RTD layer stack, a single pixel output power of -8.7 dBm and a DC-to-RF conversion efficiency of 3.5% are estimated. The design enables the use of mutual injection locking between adjacent oscillator pixels in an arrayed configuration. We investigate the mutual injection locking behaviour based on transient simulations, including 3D EM-simulated S-parameter blocks of the integrated patch antenna. A two- and four-element array is analyzed with respect to locking performance and phase relations. Far-field simulations of arrays with up to 1 × 4 elements were carried out utilizing superposition of fields. The presented design enables for spatial power combining of more than one RTD oscillator via synchronized pixels.

17:40 Segmented Mach-Zehnder Modulator for Orthogonal Sampling Based High Bandwidth THz Transmitters

Younus Mandalawi, Mohamed I. Hosni, Karanveer Singh, Janosch Meier, Souvaraj De, Ranjan Das, Thomas Schneider
Technical University Braunschweig, THz-Photonics Group | Germany

We present the concept for a compact, integrated, photonics-assisted digital-to-analog converter and optical modulator in one single device. The system takes advantage of two ideas namely: A segmented Mach-Zehnder modulator (MZM), and orthogonal sampling. The presented and simulated proof-of-concept device with three segments has a bandwidth of 15 GHz and a sampling rate of 30 GSs. No pulse source is required as it is generated from a single radio frequency oscillator and a properly biased segmented modulator. The system can enable the generation and modulation of high-bandwidth signals within the Terahertz range.

(3D-) Printing 16:20 – 17:40

Chair: Prof. N. Benson
Room: Tiger & Turtle

16:20 Broadband Terahertz Absorber from 3D-Printed Resin

Tobias Kubiczek[1], Benedikt Sievert[2], Daniel Erni[2], Jan C. Balzer[1]
[1] University of Duisburg-Essen, Chair of Communication Systems | Germany
[2] University of Duisburg-Essen, General and Theoretical Electrical Engineering (ATE) | Germany

This paper presents the design, simulation, fabrication, and measurement of a pyramidal absorber for the terahertz frequency range. The fabrication is carried out by 3D-printing with a resin printer enabling high resolution structures with an accuracy of 35 µm. The measurement with a vector network analyzer agrees with the simulation and shows a broadband absorption of 50 dB above 250 GHz.

16:40 Ultra-Precise Deposition – XTPL Technology for 3D Printed Broadband Spiral Inductors

Luca Valenziano, Felix Zeh, Georg Gramlich, Thomas Zwick, Akanksha Bhutani
Karlsruhe Institute of Technology, Institute of Radio Frequency Engineering and Electronics | Germany

This paper presents the first spiral inductor fabricated with the ultra-precise deposition (UPD) printing system by XTPL to the best of our knowledge. Three different designs of printed spiral inductors are designed, fabricated and compared. All inductors are manufactured on a standard substrate material prepared accordingly for the printing process. The small structural sizes that can be achieved allow a reduction of parasitic effects and thereby a increase of the self resonant frequency (SRF) compared to a reference inductor. Overall, this paper demonstrates the potential of the UPD printing system for printing passive circuit components, particularly inductors.

17:00 Ultraprecise Printing of D-Band Interconnects Using Dielectric Ramps

Martin Roemhild[1], Georg Gramlich[2], Jonathan Wendel[2], Holger Baur[1], Thomas Zwick[2], Norbert Fruehauf[1]
[1] University of Stuttgart, Institute for Large Area Microelectronics | Germany
[2] Karlsruhe Institute of Technology, Institute of Radio Frequency Engineering and Electronics | Germany

In this paper, the fabrication of coplanar waveguide (CPW) based interconnects by Ultraprecise Deposition (UPD) and their characterization in the D-band (110-170 GHz) is discussed. UPD was recently introduced by XTPL as an alternative to aerosol jet and ink jet printing technologies. Its most distinguishing feature is that the printing nozzle is in contact with the substrate during printing, allowing for the application of highly viscous inks with a lateral precision of 1-2 µm. The high viscosity of the silver-filled ink is used to print interconnects between a Corning 1737 display glass substrate and a 100 µm thin AF-45 glass die. The interconnects are realized using low-cost dispensed dielectric ramps made of a suspension of alumina particles in an epoxy resin. This approach requires neither highly precise milling of the substrate, nor precise alignment of chip and substrate, nor a complex fabrication process for the dielectric ramps. The interconnects with an air gap of 9 µm show as little as approximately 0.65 dB of insertion loss at 160 GHz, and broadband transmission in the entire D-band.

17:20 A Highly Flexible and Elastic Low-Cost Stencil-Printed Coplanar Waveguide on Rough Airbag Nylon 66 Textile

Björn Möhring[1], Philipp Rinklin[2], Sebastian Schweizer[3], Uwe Siart[1], Bernhard Wolfrum[2], Thomas F. Eibert[1]

[1] Technical University of Munich, Chair of High-Frequency Engineering | Germany

[2] Technical University of Munich, Neuroelectronics - Munich Institute of Biomedical Engineering | Germany

3 AUDI AG, Department or Airbag Development | Germany

A highly flexible, stencil-printed coplanar waveguide (CPW) attached to a rugged nylon 66 substrate for carrying radio frequency (RF) signals up to 6 GHz is presented. In a manual, facile, and cost-effective printing process, this transmission line is applied directly on a car airbag's textile substrate with a highly elastic, strong adhesive, silver-based ink. The design idea, the manufacturing process, and microscope images are presented and discussed. Measured and full-wave simulated scattering parameters of this two-port waveguide demonstrate the effectiveness of the design approach and reveal expected shortcomings primarily due to limited conductivity and considerable surface roughness. Despite the rough, woven, coated, very lossy dielectric nylon substrate, the simple manufacturing process, the limited conductivity of the ink, and the glued-on connectors, a flexible yet stretchable RF planar transmission line is obtained.

Workshop: Rohde & Schwarz 16:20 – 18:00

Room: Zoo Duisburg

16:20 Towards 6G: From THz communications to reconfigurable intelligent surfaces (RIS)

Dr. Taro Eichler[1], Prof. Dr. Wilhelm Keusgen[2]

[1] Rohde & Schwarz GmbH | Germany

[2] Technical University Berlin | Germany

New frequency ranges such as sub-Terahertz (sub-THz) and terahertz (THz) waves have frequencies extending from 0.1 THz up to 3 THz and fall in the spectral region between microwave and optical waves and promise a plethora of applications yet to be explored, ranging from communication to imaging, spectroscopy, and sensing. The prospect of offering large contiguous frequency bands to meet the demand for highest data transfer rates up to the terabit/sec range make this frequency range, in addition to microwave and millimeter bands, a key research area of 6G mobile communication. This tutorial aims to provide a comprehensive overview of the developments in 6G technologies and highlight various research activities dedicated to the role of sub-THz and THz waves in 6G

To fully utilize this potential, it is crucial to understand the propagation characteristics, and channel measurements as well as channel models have become essential for the development of future communication standards. We will introduce essential measurement techniques to characterize the broadband mobile radio channel with respect to pathloss, temporal dispersion, time variance and Doppler, as well as directions of arrival and present typical results of the sub-THz radio cannel. Especially in the microwave and lower millimeter wave range, MIMO and hybrid MIMO will be of significant importance. Thus, we will also address the measurement of MIMO channels. Integrated Sensing and Communication (ISAC) offers new opportunities to save the spectrum and hardware resources by combining communications and radar sensing and therefore also the propagation characteristics with respect to sensing are of increasing interest.

AI will be an integral part of the communication system and we will discuss some applications such as an AI-driven neural receiver.

Future wireless communication systems will exploit large antenna arrays and reconfigurable intelligent surfaces (RIS), to achieve a high degree of freedom in the space domain and enhance coverage. RIS have the potential to dynamically shape the radio environment, which allows the transmission channel to be „programmed". Design and measurements of RIS pose a challenge, which will be discussed.

Besides using electronic MMICs, alternative methods for generating THz radiation based on photonic technologies will play a key role in the future. Especially with the prospect of miniaturizing today's lab setups into photonic integrated circuits (PIC), these approaches could become mainstream. Recently R&S is coordinating a research project, 6G-ADLANTIK, funded by the German ministry for education and research with the objective to develop a novel tunable THz system based on ultra-stable photonic sources and optical frequency comb technology for communication and instrumentation.

Welcome Reception *Room:* Foyer 18:00 – 21:00

Tuesday, 12th of March

08:40 – 10:20	Registration	Foyer
	Antenna 1	Philharmonie
	Sources & Transmitters	Tiger & Turtle
	Workshop DFG Meteracom 1	Zoo Duisburg
10:20 – 10:40	Coffee Break	Foyer
10:40 – 12:20	**Antenna 2**	Philharmonie
	Bio-Medical Applications	Tiger & Turtle
	Workshop DFG Meteracom 2	Zoo Duisburg
	Poster Session	Foyer
12:20 – 13:20	Lunch (with Poster Session)	Foyer
13:20 – 14:20	**Plenary Talk** **Keynote 3: Safumi Suzuki** **Keynote 4: Peter Huggard**	Philharmonie
14:30 – 15:30	**Waveguides 1**	Philharmonie
	Focused Session on mm-Wave and THz Photonics 1	Tiger & Turtle
	Measurement Techniques 1	Zoo Duisburg
15:30 – 15:50	Coffee Break	Foyer
15:50 – 17:10	**Waveguides 2**	Philharmonie
	Focused Session on mm-Wave and THz Photonics 2	Tiger & Turtle
	Measurement Techniques 2	Zoo Duisburg
	Poster Session	Foyer
16:30 – 18:00	**IMA & MTT/AP Chapter Meetings**	Zoo Duisburg
17:30 – 18:00	Bus Transfer to the Landschaftspark	
18:00 – 22:00	Conference Dinner	

Antenna 1 — 08:40 – 10:20

Chair: Prof. D. Heberling
Room: Philharmonie

08:40 Electrically Small Antennas as Probe for UAV-based Antenna Measurements

Abdo Z. Salah, Thomas F. Eibert
Technical University of Munich, School of Computation, Information and Technology | Germany

Uninhabitated Aerial Vehicles (UAVs) are increasingly used in antenna measurements and testing, where in particular one or more receiving probes may be carried by the UAV to evaluate the performance of antennas or radio systems in real-world scenarios. Utilizing electrically small probing antennas offers the advantages of extended flight duration and reduced overall UAV weight, especially for low frequencies. In this study, we investigate the performance of the receiver when employing small loops or dipoles as probes. Additionally, we derive a comprehensive expression for the signal-to-noise ratio (SNR) and the system noise figure, which accounts for factors such as ohmic loss and mismatch loss, aspects that are often ignored when calculating the equivalent noise temperature of an antenna.

09:00 A Dual-Band Dual-Circular Polarised Antenna Array for UAV Detection and Tracking

Wasim Alshrafi[1], Ulrich Engel[2], Burak Cihan[2], Jannik Springer[2], Guillaume François[3], Dirk Heberling[1,3]
[1] Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR | Germany
[2] Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE | Germany
[3] RWTH Aachen University | Germany

An antenna array system was designed for a Fraunhofer FKIE UAV detection system, with the aim of increasing its detection accuracy. The array system consists of two independent uniformly circular arrays operating at the ISM bands 2.4 and 5.8 GHz, where each array comprises 8 dual circularly polarised patch antenna elements. The elements were manufactured and their radiation performance was measured and validated in the laboratory. The full detection system platform was then assembled and the detection accuracy was measured in real outdoor conditions. The detection performance was validated with a 90 % probability of a DOA angle error lower than 5°.

09:20 Design of a 240 GHz Dielectric Resonator Antenna in 130 nm SiGe BiCMOS Process

Muhammad Faisal Bachir, Matthias Wietstruck
Leibniz Institute for High Performance Microelectronics (IHP) | Germany

A 240 GHz dielectric resonator antenna is designed in the back-end-of-line (BEOL) of a 130 nm SiGe BiCMOS process. The radiating structure made up of high-resistivity silicon, is aperture-coupled fed by a microstrip feedline. The antenna operates from 231 GHz to 250 GHz at its fundamental mode TE111 and has a realized gain of 5.1 dBi.

09:40 A Broadband Lens Loaded Vivaldi Antenna for sub-6 GHz/mmWave 5G Applications and Wideband Nondestructive Material Characterization

Berker Colak[1], Zeynep Ertekin[2], **Mustafa Secmen[2]**
[1] Iskenderun Technical University Hatay, Institute of Graduate Studies | Turkey
[2] Yasar University, Department of Electrical and Electronics Engineering | Turkey

This study presents a broadband and compact antipodal Vivaldi antenna design and production having an improved gain characteristic with the addition of a dielectric lens made of PLA. The proposed antenna has measured VSWR of less than 2.1 through the broadband frequency of 3.3-43.5 GHz and has more than 6.5 dBi measured gain above 8.5 GHz (up to 43.5 GHz). The antenna, which can fit in a cube with just 4.8 cm edge, has low-cost and easy manufacturing. It can meet the need of multiple antennas due to its broad frequency range (from S-band to Ka-band), which covers different applications such as wideband nondestructive material characterization and testing. Since the proposed antenna covers sub-6 GHz (3.3 GHz, 5.8 GHz) and mmWave (26, 38, 41 GHz) 5G frequencies, it can be also used in base stations with MIMO or array configuration.

10:00 Power Normalization for Over the Air Augmented Exposure Assessment

David Schaefer[1], Benoit Derat[2], Andreas Lauer[1], Winfried Simon[1], Mert Celik[2], Thorsten Liebig[1]
[1] IMST GmbH, Antennas & EM Modeling | Germany
[2] Rohde & Schwarz GmbH and Co. KG, Test & Measurement Division | Germany

This paper concerns the challenges of power normalization for soft excitation equivalent field sources in reflective environments in the context of exposure assessment. At first, the principle of the over-the-air augmented (OTAA) method and the need for adequate power normalization in exposure assessments is explained. By the example of 1D finite difference time domain (FDTD) simulations and equivalent circuit (EC) considerations it is then discussed how the total power radiated by field sources is affected by reflections from its environment, and how this can be considered in power normalization. Finally, two improvement approaches are addressed.

Sources & Transmitters 08:40 – 10:00

Chair: Prof. A. C. Ulusoy
Room: Philharmonie

08:40 Amplitude versus time resolution trade-off in digital RF transmitter line-ups

Jan Philipp Wiedemann, Georg Fischer, Florian Irnstorfer
Friedrich-Alexander University, Department of Electrical-Electronic-Communication Engineering | Germany

A novel power amplifier (PA) architecture is presented which constitutes a hybrid between the switched capacitor PA (SCPA) and the class-D PA in order to improve the transmitter line-up digitization for high power radio frequency (RF) applications. Instead of using either the amplitude (corresponding to the SCPA) or the temporal (corresponding to the class-D PA) resolution to reconstruct the desired output signal amplitude, a trade-off between the two possibilities is used in order to relax the requirements for both. This work derives the theoretically optimum drive signals needed to realize such an architecture showing that the optimum drive strategy enables high signal integrity and power efficiency at high power RF output signals, while requiring fewer high speed drive signal generation circuits than initially expected.

09:00 Battery Powered Compact and Lightweight RTD THz Oscillator Module

Christian Preuss, Enes Mutlu, Ben Daedler, Jonathan Abts, Jonas Watermann, Nils Weimann
University of Duisburg-Essen, Dept. Components for High-Frequency Electronics (BHE) | Germany

In this work a compact and handheld single resonant tunneling diode (RTD) oscillator module is presented. This module is powered by a standard CR2032 coin cell battery, eliminating the need for an external power supply. The system is build by a stack of two FR4-boards; one consisting of the bias related components and the other used for the RTD integration. With this package a Tx module operating at a frequency of 329.76 GHz with an output power of around

39 µW is shown. The overall system has a dimension of around 3.1 cm x 3.3 cm x 2.45 cm (LxWxH) without housing. For mechanical protection a 3D printed plastic housing is fabricated, resulting in a module dimension of around 8.6 cm x 6.1 cm x 3.8 cm (LxWxH).

09:20 A low phase noise 12 GHz LO generation with quadrature outputs in 0.13 µm SiGe BiCMOS

Meghana Kadam, Yerzhan Kudabay, Vadim Issakov
Technical University Braunschweig | Germany

Local oscillator (LO) signal generation is essential for almost all RF systems. Furthermore, accurate quadrature generation is required for numerous applications, such as radar or communication systems. This paper presents an LO generation chip with an on-chip quadrature generation by means of operating the VCO at a second harmonic and using a 2:1 CML frequency divider. The chip achieves in measurement a phase noise of -118.5 dBc/Hz at 1 MHz offset from 12.19 GHz carrier and a phase deviation of less than 1°. It is realized in 0.13 µm SiGe BiCMOS technology and consumes only 55 mA from a single 1.8 V supply, including VCO, buffers and frequency divider. The chip occupies only 1.13 mm2 including pads. The proposed solution is suitable for backhaul communication transceivers operating around 12 GHz.

09:40 A SiGe Based 60 GHz Signal Source MMIC for MIMO Radar Application

Muhammed Ali Yildirim[1], Jonathan Bott[1], Florian Vogelsang[1], Christian Bredendiek[2], Klaus Aufinger[3], Nils Pohl[1]
[1] Ruhr University Bochum | Germany
[2] Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR | Germany
[3] Infineon Technologies AG | Germany

In this paper, we present an MMIC with two different signal sources for a MIMO radar system. The MMIC is fabricated in a 130 nm SiGe technology with an ft of 240 GHz and a fmax of 380 GHz. The MMIC consists of a Colpitts-Clapp VCO together with a divide-by-8-prescaler as the first signal source, and a bootstrapped gilbert cell frequency doubler, which is driven by an external signal source. With an output frequency of around 60 GHz, one of the two signal sources provides the input signal for multiple MIMO transceiver chips. The signal source can be selected depending on the orientation of the MMIC. The VCO provides two differential output signals from 50.4 GHz to 68.3 GHz and has a phase noise of -94 dBc/Hz at the center frequency with an offset frequency of 1 MHz. By supplying the VCO with 3.3 V, the power consumption is 194.04 mW.

The frequency doubler has a maximum gain of -4.5 dB at the center frequency and consumes 43.56 mW from a 3.3 V power supply.

Workshop DFG Meteracom 1 — 08:40 – 10:20

Chair: Prof. T. Kürner
Room: Zoo Duisburg

08:40 Introduction to DFG FOR 2863 Meteracom

Thomas Kürner
Technical University Braunschweig | Germany

The capability to perform measurements and evaluate these measurements in a proper way are crucial for the advance of THz communication systems. Metrology at THz frequencies is however still in its infancy and as of today it only covers detector calibration to characterization of ultrafast devices and to measurement uncertainty analysis of different spectrometer types available at THz frequencies. The research unit DFG FOR 2863 Meteracom addresses the grand challenge of metrology in THz communication measurements systematically, and in the areas traceability to the International System of Units (SI), characterisation of the measurement equipmenst, metrological characterisation of the RF components and the propagation channel measurements required for enabling the functionality of THz communications. In this workshop some of the key results DFG FOR 2863 Meteracom will be presented and This presentation will give a brief introduction into the research unit.

08:50 External Key Note: Tracing millimeter waves: Unlocking THz Communication's Potential with Accuracy in Basis RF Parameters

Gerhard Rösel
Rohde & Schwarz GmbH

Each new generation of mobile networks brings with it new features and a wealth of new possibilities. While the rollout of 5G NR networks is currently underway, the development of 6G is already taking shape. The development of new high-frequency measurement devices and transmission systems requires the traceability of basic RF parameters such as RF power, S-Parameters, An-

tenna factor and Phase noise. To ensure traceability of RF parameters at high frequencies, the collaboration between electronics and optics is becoming increasingly important and is a game changer in establishing new traceability chains. This presentation highlights various examples of traceability of electronics and optics, including a new method for obtaining traceability of phase relationships between the respective harmonics using an electro-optical comb generator.

09:20 Characterization of RF Impairments in Analog Electronic THz Frontends

Dominik Wrana, Simon Haussmann, Ingmar Kallfass
University of Stuttgart | Germany

The development of electronic transmit and receive frontends for communication and radar applications in the THz frequency range requires a fundamental understanding of frontend non-idealities which impose limitations to the achievable signal quality and data throughput. This talk discusses RF frontend impairments such as unwanted LO harmonics and in-band interference as well as phase noise. Additionally, an innovative measurement platform which combines time and frequency domain analysis at 300 GHz under broadband modulated signal conditions is presented.

09:40 Traceability challenges for sub-THz channel sounding

Mohanad Dawood Al-Dabbagh[1], Diego Dupleich, Tobias Doeker, Thomas Kleine-Ostmann, David Humphreys, Reiner S. Thomä, Thomas Kürner
[1] Physikalisch-Technische Bundesanstalt | Germany

Sub-terahertz (sub-THz) frequency band holds promise for next-generation wireless communication systems due to the high bandwidth availability. The channel sounding systems for this band are specialized equipment used to analyse and characterize the propagation characteristics of electromagnetic signals. However, ensuring traceability in sub-THz channel measurements poses great challenges. This presentation investigates the complexities of traceability in sub-THz channel sounding, particularly addressing the selection and calibration of reference measurements using correlational-based channel sounders. The use of theoretical calculations and repeated measurement scenarios, and the use of Vector Network Analysers (VNAs) as reference measuring devices. It investigates calibration methodologies, instrumentation limitations and their influences on measurement traceability.

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10:00 Channel Sounder Architectures for Performance Evaluation of THz Systems

Giovanni Del Galdo, Reiner S. Thomä, Jonas Gedschold[1], Diego Dupleich, Tobias Doeker, Carla Reinhardt, Thomas Kürner
[1] Technical University Ilmenau | Germany

This presentation deals with channel sounder architectures and focuses on challenges related to the SNR of THz systems. Shrinking antenna apertures and a resulting higher pathloss diminish the power transmission from transmitter to receiver requiring methods to improve SNR. This issue can be addressed in the radio frequency frontends by amplifiers, automatic gain control, or antenna gains, but also in the baseband by waveform design or signal processing. This talk discusses solutions and their impact on channel sounder architectures to measure and characterize the THz propagation channel. In particular, we tackle waveform design, directional sounding, as well as application examples showing real-time measurements.

Tuesday

Coffee Break
Room: Foyer
10:20 – 10:40

Poster Session 1
10:20 – 13:20

Room: Foyer
Abstracts on Page 90

Antenna 2
10:40 – 12:20

Chair: Prof. D. Erni
Room: Philharmonie

10:40 A Compact Description of Directive Antennas in Numerical Microwave Simulations based on Complex Source Beams

Steffen Gerling, Tobias Körner, Jochen Altholz, Christian Schulz, Jan Barowski, Ilona Rolfes
Ruhr University Bochum, Institute of Microwave Systems | Germany

While it is possible for the Physical Optic (PO) to simulate the wave propagation of an antenna in short range scenarios, it becomes more computational inefficient compared to a far-field assumption, because the enclosing surface of the antenna has to be sampled. In order to accelerate a PO in the near-field, in this work the representation of antennas with the Complex Source Beam (CSB) which is a compact method to represent a Gaussian like beam is investigated. Therefore, we present a method to find the parameters for the CSB to represent the emitted wave of an antenna. For this purpose, an optimization procedure is used to obtain the representation with the least deviation from a full wave simulation. A comparison with a full wave simulation shows that this method is highly accurate in the area of the main lobe which makes it fast to simulate measurement scenarios in the terahertz range in which mostly antennas with high directivity are used.

11:00 Empirical Study on the Antenna-Dependent Accuracy of Continuous-Wave Radars

Bartosz Tegowski, Björn Schulz, Alexander Koelpin
Hamburg University of Technology, Institute of High-Frequency Technology | Germany

The impact of antennas on the accuracy of continuous-wave radar systems is examined in this contribution. Due to its own radar cross section (RCS), the radar antenna redirects a fraction of the incident field, originally scattered by the target, towards the latter. This generates virtual targets, which impair the accuracy of relative distance measurements. The associated errors are empirically studied for a selection of horn antennas and patch antenna arrays by measurements with a vector network analyzer in the 24-GHz ISM band. The errors vary with the antenna type and can be up to several hundreds of micrometers. It is shown that a specific reduction of the antenna RCS improves the accuracy.

11:20 Far Field Phase Reconstruction using Planar Near Field Scanning Techniques

Martin Obermaier[1], Thomas Deckert[2], Marc Vanden Bossche[3], Dirk Plettemeier[1]
[1] Technical University Dresden, Chair for RF and Photonics Engineering | Germany
[2] NI, Dresden | Germany
[3] NI, Brussel | Belgium

Planar near field (NF) scanners enable the characterization of antennas in a compact space. Most publications on this topic do not consider the reconstructed far field (FF) phase of the antenna and limit their scope to the FF gain or directivity. In this work we show and discuss how the captured NF can be processed to retain the phase information of the FF. This is essential for capturing the single element patterns of electrically steerable array (ESA) antennas, since it allows to characterise the effects of the element spacings on the phase of the FF patterns.

11:40 A Metal-Only Holographic Leaky-Wave Antenna Based on Spoof Surface Plasmon Polaritons

Mohammad Amin Chaychi Zadeh[1], Sajjad Zohrevand[1], **Ehsan Farokhipour[2]**, Daniel Erni[2], Nader Komjani[1]
[1] Iran University of Science & Technology, School of Electrical Engineering | Iran
[2] University of Duisburg-Essen, General and Theoretical Electrical Engineering (ATE) | Germany

This paper presents a metal-only sinusoidal modulated metasurface (MTS) leaky-wave antenna (LWA) with an operating frequency of 18 GHz. Avoiding dielectric losses at high frequencies and withstanding harsh environmental conditions in space exploration are the advantages of metal-only antennas. In spoof surface plasmon polariton (SSPP) structures, the electromagnetic wave of the dominant TM mode is confined at the boundary of two environments. By utilizing the holographic technique and development of pseudo-periodicity in the SSPP structures and consequently stimulating the Floquet mode harmonics, the dispersion curve of the SSPP mode is located inside the radiation cone, and the leakage and radiation conditions of surface wave are provided. The proposed LWA is composed of cross-shaped unit-cells. The realized gain and efficiency of the LWA are 26.5 dBi and 86%, respectively.

12:00 The Occurrence of Parasitic Radiation in Transmission-Reflection Material Characterization using a Sandwich Antenna-Sample-Antenna Setup

Marvin Degen, Jan Taro Svejda, Mandana Jalali, Andreas Rennings, Daniel Erni
University of Duisburg-Essen, General and Theoretical Electrical Engineering (ATE) | Germany

The occurrence of parasitic radiation through the sample into the free space in a widely used sandwich antenna– sample–antenna (SASA) setup for the transmission-reflection (TR) method based material characterization is investigated for the first time. A simple equivalent circuit (EC) taking into account the losses due to this radiation in order to exclude them as dielectric losses in the measurement procedure is presented. Based on conducted near-field (NF) measurements, the time-averaged Poynting vector has been calculated qualitatively demonstrating the occurrence of the conjectured parasitic radiation. This conclusion is further supported by an independent far-field (FF) measurement.

Bio-Medical Applications 10:40 – 12:20

Chair: Dr. M. Jalali
Room: Tiger & Turtle

10:40 Influence of Heavy Metal Contamination on THz Transmission of Plants

Lisa C. Kreuzer[1], Fabian Brix[2], Petra Düchting[2], Sebastian T. Gassel[1], Niklas Schulz[1], Carsten Brenner[1], Milan Deumer[3], Robert Kohlhaas[3], Martin R. Hofmann[1]
[1] Ruhr University Bochum, Photonics and Terahertz Technology | Germany
[2] Ruhr University Bochum, Molecular Genetics and Physiology of Plants | Germany
[3] Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute | Germany

Mining has led to soil contamination with heavy metals in numerous regions. This contamination not only affects large-scale food cultivation but also concerns individuals who grow food in their gardens. Hence, there is a critical requirement to develop efficient and reliable methods for studying and monitoring plant exposure to these harmful substances.

Currently, researchers rely on complex and time-consuming laboratory procedures that entail destructive sampling to examine plant exposure to heavy metals. This method is expensive and not suitable for extensive monitoring. The capability of continuous wave (CW) Terahertz spectroscopy to differentiate between contaminated and uncontaminated leaves of the plant species Arabidopsis halleri has already been demonstrated. In this study, the varying levels of Cadmium and Zinc concentrations in the leaves of this plant are analyzed.

11:00 Experimental Study on K-band Microwave Monitoring of Laser Ablation in Biological Tissue

Moritz Mälzer[1], Teresa Slanina[1], Sebastian Beck[1], **Jochen Moll[1]**, Viktor Krozer[1], Samir Lamrini[2]
[1] Goethe University Frankfurt am Main, Terahertz-Photonics | Germany
[2] LISA Laser Products GmbH | Germany

Laser ablation is widely used in various oncological applications as a minimally invasive and relatively mild form of cancer therapy. For this purpose, an optical fiber is inserted into the malignant tissue to locally destroy the tumor cells. In this work, a proof of concept for microwave-guided laser ablation in K-band

is demonstrated in a laboratory setting. The experimental setup consists of two ultra-wideband antennas connected to a vector network analyzer that face each other in a one dimensional setup. Sausage meat aligned between the transmitting and receiving antenna is locally destroyed using laser energy on the direct Tx-Rx-path. The reflexion and transmission signals in the frequency band from 15-25 GHz have been analyzed through a trend analysis.

11:20 Radar Based Heartbeat Estimation in Time Domain

Michelle R. Tchameni[1], Christian Schiffer[1], Udo Schroeder[2], Volker Lücken[1], **Andreas R. Diewald[1]**
[1] University of Applied Sciences, Laboratory for Radar Technology and Optical Systems | Germany
[2] Basics & Mathematical Models, IEE S.A. | Luxembourg

Non-contact methods for monitoring vital signs, like the heartbeat, offer convenience and hygiene benefits but face challenges in achieving accurate and reliable results. In this paper, we propose a novel approach for estimating heartbeat peaks in radar signals using a cross-correlation method based on a template function. By applying this correlative method to phase-extracted radar signals recorded from breathing individuals, cardiac information is isolated and heartbeat peaks are identified over time. Experiments using a 24 GHz FMCW radar system have been conducted, comparing the results with synchronized ECG data. Our approach not only demonstrates the effectiveness of non-contact cardiac monitoring but also showcases its potential for providing valuable insights into improved vital signs monitoring. This work showcases the potential of radar technology for real-time vital sign monitoring and healthcare applications.

11:40 Gender-specific Electromagnetic Power Absorption in Human Skin Tissue at 5G/6G Frequencies

Sinan Dogusan, Mandana Jalali, Jan Taro Svejda, Daniel Erni
University of Duisburg-Essen, General and Theoretical Electrical Engineering (ATE) | Germany

In this study, the human skin in six different anatomical regions of the body (abdomen, back, breast, dorsum of foot, dorsum of hand, and scalp) of male and female individuals in a human population of the same ethnicity were ho-mo-ge-neous-ly modeled a in four layers: stratum corneum (SC), epidermis/dermis (E/D), hypodermis (HYP), and muscle tissue (MSC). The mentioned twelve different human skin models were exposed to integrated electromagnetic (EM) waves in the 5G/6G frequency ranges, and the absorbed power in each tissue layers and the penetration depths in the corresponding body regions were calculated, and based on the simulation results, gender-specific in the corresponding the absorbed power and the penetration depths were investigated.

12:00 A sub-terahertz passive wireless Biosensor based on Photonic Crystal

Yixiong Zhao[1], Ali Alhaj Abbas[2], Masoud Sakaki[3], Gero Bramlage[4], Guillaume Delaittre[4], Niels Benson[3], Thomas Kaiser[2], **Jan C. Balzer[1]**
[1] University of Duisburg-Essen, Chair of Communication Systems (NTS) | Germany
[2] University of Duisburg-Essen, Institute of Digital Signal Processing (DSV) | Germany
[3] University of Duisburg-Essen, Institute of Technology for Nanostructures (NST) | Germany
[4] University of Wuppertal, Organic Functional Molecules | Germany

In this work, we demonstrate a 3D printed photonic crystal (PhC) chip including a slot resonator and a dielectric rod antenna for remote biosensing applications. The slot resonator with a high Q factor improves sensitivity and facilitates extracting resonance information from the reflected clutter signals due to the environment. The sensor is fabricated using 3D ceramic printing technique providing high resolution and fast prototyping. The fabricated sensor can detect a thin protein film in a wireless experimental setup.

Workshop DFG Meteracom 2 — 10:40 – 12:20

Chair: Prof. T. Kürner
Room: Zoo Duisburg

10:40 Progress towards traceability for THz communications waveforms and the use of "data enabled analysis" in testing

David Humphreys[1], Heiko Füser Dominik Wrana, Cao Viên Phung, Mohanad Al-Dabbagh, Ingmar Kallfass, Thomas Kleine-Ostmann, Admela Jukan, André Drummond
[1] Mercator Fellow | United Kingdom

Communication systems are designed to meet published specification standards, and measurement traceability is an essential underpinning for these standards. Where measurement traceability applies to THz communication, an enabling technology for 6G, is discussed and the proposed approach is outlined. Communication systems use "Blind" estimation to select the constellation

Tuesday

points. In the presence of noise and impairments this can create errors. The second part of the presentation discusses the use of two “data directed” approaches, based on PRBS sequences or on random data, to Error Vector Magnitude measurement and fault diagnosis.

11:00 **Photonically Assisted Sampling Circuits**

Maxim Weizel, J. Christoph Scheytt
Paderborn University | Germany

The resolution of high-speed ADCs with bandwidths in the tens of gigahertz range is largely limited by the jitter of the used clock sources. Photonically Assisted Sampling Circuits as the front-end of high-speed photonically assisted ADCs have the potential to shift the performance limits of data converters towards yet unprecedented accuracies. This is mainly enabled by using an optical pulse train provided by a Mode-Locked Laser (MLL). MLLs shows a superior jitter performance compared to their electronic counterparts and start to become widely available with gigahertz repetition rates. The talk will include different types of architectures ranging over recent advances and ending with the current research in the Meteracom project and future outlooks.

11:20 **Review of Orthogonal Sampling for Terahertz Signal Processing**

Younus Mandalawi, **Souvaraj De**[1], Thomas Kleine-Ostmann, Thomas Schneider
[1] Physikalisch-Technische Bundesanstalt | Germany

Future communication systems in the Terahertz band shall transmit data rates in access of 1 Tbit/s. Such data rates require the processing of signals with very high bandwidths. Due to the limited bandwidth of the standard CMOS technology, especially the analog-to-digital (ADC) and digital-to-analog (DAC) converters may be a bottleneck for future communication systems. We will review the concept of orthogonal sampling and discuss how very broadband signals can be processed with low bandwidth electronics.

11:40 ***Panel Discussion:*** **What are the big challenges in Metrology to make THz communications happening?**

Thomas Kürner (Moderator), Gerhard Rösel, Thomas Kleine-Ostmann, Ingmar Kallfass, Thomas Schneider, David Humphreys

Lunch — *Room:* Foyer — 12:20 – 13:20

Plenary Talks — 13:20 – 14:20

Chair: Prof. N. Weimann
Room: Philharmonie

13:20 Keynote 3: Terahertz signal sources with milliwatt-class output powers using resonant tunneling diodes

Safumi Suzuki, Tokyo Institute of Technology

Use of Terahertz (THz) waves are expected for high-capacity communications and sensing applications in Beyond 5G/6G system, etc. However, semiconductor THz signal sources face limitations due to their low output power. Studies on semiconductor THz sources include optical devices like quantum cascade lasers (QCLs) and electronic devices like diodes and transistors. Resonant tunneling diodes (RTDs) have negative differential conductance characteristics, which enables formation of oscillators, and are promising for THz sources due to compactness and high-frequency operation. RTD devices also have a problem in low output powers, but efforts for increase in output power have been conducted. Recent work achieved 11.8 mW at 450 GHz with a 36-element coherent array, and 0.7 mW at 700 GHz with strongly coupled two-element array. RTD oscillators with double slotring antennas exhibit >1 mW output power with a good directivity in 400 GHz range. Studies to increase single oscillator power have also been made. We proposed a cavity resonator structure to enhance single oscillator output power in high-frequency range. This resonator, with low loss and low inductance, achieves high output power even with large-area RTDs, but a thermal destruction due to large current became a problem. Using InP with small thermal resistance for the lower electrical conduction layer instead of InGaAs, improved heat dissipation prevents thermal destruction. A device combining a cavity resonator and an array technique achieved 0.24 mW at a very high frequency of 925 GHz.

13:50 Keynote 4: Technology for remote sensing applications at W-band and higher frequencies

Peter Huggard, Science and Technology Facilities Council RAL Space

The Millimetre Technology Group at RAL Space, part of UK Research and Innovation, specialises in the development and supply of waveguide heterodyne technology at frequencies from the W-Band to above 1 THz. I will describe the Group's capabilities, particularly in the areas of precision CNC machining and air-bridged Schottky diode technology, and report on some recent collaborative instrumentation projects for Earth observation, radioastronomy and atmospheric science. The largest of these is the supply of high reliability space flight receivers at frequencies up to 229 GHz for atmospheric remote sensing, part of EUMETSAT's MetOp-Second Generation programme. The heterodyne receivers, some working with low noise amplifiers, will provide global atmospheric data on humidity and temperature, critical inputs to numerical weather prediction. Last year, the Group delivered CARUSO to the Sardinia Radio Telescope. CARUSO (Cryogenic Array Receiver for Users of the Sardinia Observatory) is a 16 pixel, dual polarisation sideband separating receiver covering 75 to 116 GHz. It incorporates cryogenic p-HEMT low noise amplifiers and sideband separating InGaAs sub-harmonic mixers with low local oscillator power requirements. The design and performance of the instrument will be reported. Finally, I will present GRaCE (G-band Radar for Cloud Experiments), a 200 GHz ground based solid state Doppler cloud radar. The zenith looking GRaCE is intended to derisk technology and to build the science case for a high frequency space borne cloud radar. Instrument

Waveguides 1 — 14:30 – 15:30

Chair: Prof. H. Maune
Room: Philharmonie

14:30 Normalized Design Charts for Low-loss Dispersion-Minimized Circular Dielectric Waveguides for Millimeter Waves

Martin Schneider, André Meyer
University of Bremen, RF and Microwave Engineering Laboratory | Germany

This paper presents the design of low-loss and dispersion-minimized dielectric waveguides (DWGs) of circular cross-section. We give easy-to-use, normalized design charts to find the optimum diameters of DWGs with a solid core or with

a hollow core. Based on the introduction of a normalized frequency the charts can be used for a wide range of frequencies (e.g., between 60 and 300 GHz) and a wide range of dielectric materials for the waveguide's core as well as for the waveguide's cladding. Exemplary DWG designs are given and verified by measurements in W band and D band.

14:50 Discrete Tuned Millimeter Wave SIW Resonators in GaAs and on PCB

Edward A. Ball, Sumin David Joseph
The University of Sheffield, Department of Electronic and Electrical Engineering | United Kingdom

A concept to digitally tune Substrate Integrated Waveguide resonators using FET switches is presented. Simulation results are provided for designs at 73 GHz on GaAs. Also, simulation and measured results are provided at 23 GHz for a PCB prototype. The 73 GHz design has a tuning range of 580 MHz and an average unloaded Q of 121. The 23 GHz PCB prototype has a measured tuning range of 260 MHz and average unloaded Q of 72.9.

15:10 Width-Constrained Multilayer SIW Components Based on Adjoined Folded SIW Transitions

Bartosz Tegowski[1], Thomas Jaschke[2], Anton Sieganschin[3], Arne F. Jacob[1], Alexander Koelpin[1]
[1] Hamburg University of Technology, Institute of High-Frequency Technology | Germany
[2] Wärtsilä Voyage GmbH | Germany
[3] NXP Semicondctors Germany GmbH, CTO-IMT / THz-Lab Hamburg | Germany

Stacked, multilayer substrate integrated waveguide (SIW) components are discussed in this contribution. The superordinate design constraint is the limitation of the lateral dimensions determined by the width of the feed SIWs. This is achieved by using a broadband adjoined SIW-to-folded-SIW transition. Based on it, a Riblet-type short-slot quadrature hybrid coupler and a helix-like layer twist of two stacked SIWs are designed, manufactured, and validated in K-/Ka-band by measurements.

Focused Session on Millimeter-Wave and Terahertz Photonics 1 — 14:30 – 15:30

Chair: Prof. A. Stöhr
Room: Tiger & Turtle

14:30 Photonics-Assisted Integrated Devices Enabling Ultra-Wideband Terahertz Systems

Shuya Iwamatsu[1], José Luis Fernández Estévez[1], Marcel Grzeslo[1,2], Muhsin Ali[3], Guillermo Carpintero[3,4], Andreas Stöhr[1,2]
[1] University of Duisburg-Essen, Department of Optoelectronics (OE) | Germany
[2] Microwave Photonics GmbH | Germany
[3] LeapWave Technologies | Spain
[4] University Carlos III of Madrid | Spain

Emerging terahertz (THz) silicon microphotonics is promising due to its potential towards the development of ultra-wideband THz systems on chip. Here, we present recent technologies for ultra-wideband THz integrated circuits enabled by interconnecting between InP-based uni-traveling-carrier photodiode source and Si-based dielectric rod waveguide.

14:50 Optoelectronic Terahertz Receiver based on the Hybrid Integration of Schottky Diodes and UTC Photodiodes in a Rectangular Waveguide Block

Iñigo Belio-Apaolaza[1], Himanshu Gohil[1,2], Hui Wang[2], James Seddon[1], Peter G. Huggard[2], Cyril C. Renaud[1]
[1] University College London | United Kingdom
[2] RAL Space | United Kingdom

Optoelectronic terahertz receivers have the potential of incorporating photonic solutions for local oscillator provision. However, these are typically based on photoconductors with poor conversion efficiency. Here, we present the design of a 300 GHz mixer based on the hybrid integration of InGaAs Schottky diodes and uni travelling carrier photodiodes in the same rectangular waveguide block. This solution combines the efficient down-conversion of Schottky technology and the benefits of photonic local oscillators.

15:10 Low Power Consumption and Low Phase Noise Broadband DC-40 GHz RFoF Links for Antenna Remoting

Yilmaz Ucar[1,2], Vitaly Rymanov[2], Sumer Makhlouf[1,2], Andreas Stöhr[1,2]
[1] University of Duisburg-Essen, Department of Optoelectronics (OE) | Germany
[2] Microwave Photonics GmbH | Germany

Replacing metallic cables by active radio frequency over fiber (RFoF) links is beneficial for various applications including satellite communications, 6G backhaul, antenna remoting or test & measurement. This is because RFoF provides low-loss and ultra-broadband connectivity. Besides low weight optical fibers, another important requirement of RFoF links for space-born applications, is the overall power consumption of a link. In this work we report on low-power consumption RFoF Tx/Rx modules using advanced 1.3µm optical modulators and photoreceivers. Using the fabricated modules, we achieved low power

Measurement Techniques 1 — 14:30 – 15:30

Chair: Prof. A. Kölpin
Room: Zoo Duisburg

14:30 Terahertz Measurements Through Water Enabled by a Compact and Cost-efficient THz-TDS System

Vladyslav Cherniak, Tobias Kubiczek, Kevin Kolpatzeck, Jan C. Balzer
University of Duisburg-Essen, Chair of Communication Systems (NTS) | Germany

Spectroscopy is a widely used tool for material characterization and classification across all frequencies of the electromagnetic spectrum. Depending on the frequency employed, absorption losses become the limiting factor for the penetration depth of the material under test (MUT). Water, in particular, exhibits strong absorption in the terahertz range, necessitating extended averaging times. In this study, we present terahertz time-domain spectroscopy (THz-TDS) measurements conducted across varying thicknesses of water, using our self-built, compact measurement system, which maintains phase stability over prolonged averaging periods achieving a peak dynamic range greater than 130 dB.

14:50 Density-independent measurement of high moisture contents using appropriate frequencies

Florian Stern, Wolfgang Taute, Michael Höft
Kiel University, Chair of Microwave Engineering | Germany

Conventional moisture measurement methods often have problems with accuracy when the material density varies or high moisture ranges are to be determined. This paper addresses density-independent moisture measurement in moving bulk materials using microwave techniques. Four measurement methods are compared, one using a fixed frequency and the other using different frequency ranges. The characteristics, limitations, and material dependencies of these methods are examined, as well as their suitability for continuous moisture measurement in moving bulk materials. These fluctuating bulk materials occur frequently, especially in materials such as wood chips. Using the transmission method of microwave transmission with two antennas, material moisture can also be determined independently of density on the basis of permittivity. By cleverly choosing the frequency and processing attenuation and phase shifts, moisture contents of up to 20% can be measured independently of the material

density. Moisture measurement methods often have problems distinguishing between high and low moisture contents at extreme moisture contents due to signal saturation. By measuring a wide frequency range, much higher moisture contents and ranges can be determined. In addition, a variant is presented that detects high moisture content with a small frequency range. Our approach allows high-resolution measurements to be performed on continuously changing materials at significantly accelerated rates. This accelerated process allows near instantaneous visualization of frequency sweep results. The measurements were performed on moving bulk materials.

15:10 Thermal Isolation in Microcalorimeter Measurements

Windi Kurnia Perangin-Angin, Karsten Kuhlmann, Jürgen Rühaak
Physikalisch-Technische Bundesanstalt, High Frequency and Electromagnetic Fields | Germany

Microcalorimeter measurements must be carried out in a thermally stable environment, e.g. thermally shielded from outside influences. But DC and RF signals still need to pass through such thermal shielding. While the heat conductivity of DC signal lines is usually not critical for the actual measurements, the thermal insulation of the RF transmission line is vital and one of the biggest challenges in many calorimeter experiments. Usually, commercial coaxial lines or rectangular waveguides are good heat conductors, thus the thermal isolation section (TIS) for a microcalorimeter set-up is often custom made. This work is about the design and test of TISs for the waveguide bands R 900 (75-110 GHz), R 1.4k (110-170 GHz), and R 1.8k (140-220 GHz). Scattering parameter measurements of microcalorimeter feeding lines and effective efficiencies of transfer standards as well as thermal simulations are presented, and the results are discussed.

Coffee Break *Room:* Foyer **15:30 – 15:50**

Poster Session 2 **15:30 – 17:10**

Room: Foyer
Abstracts on Page 90

Waveguides 2 **15:50 – 17:10**

Chair: Prof. J. Balzer
Room: Philharmonie

15:50 Contactless Transition for Wideband Double-Ridge Waveguides

Omar Jabi[1], Nico Weiss[1], **Georg Frederik Riemschneider[1]**, Ralf Riedinger[2], Alexander Kölpin[1]
[1] Hamburg University of Technology, Institute of High-Frequency Technology | Germany
[2] University Hamburg (UHH), Institute for Quantum Physics and Centre for Optical Quantum Technology | Germany

As quantum computers require temperatures near absolute zero, cryostats are utilized to deliver such conditions. This necessitates thermal decoupling in the signal feedlines. This paper introduces contactless waveguide transitions as an alternative to the currently used coaxial cables. Specifically, we present a contactless transition for WRD650 waveguides. The structure was optimised for transmission within the frequency range of 10 GHz to 18 GHz and validated by measurement. Additionally, the transition exhibits a relatively low susceptibility to misalignments and a decreased dispersion in contrast to rectangular waveguides.

16:10 S-Parameter Characterization Based on Dielectric Waveguides in D-Band

Kerstin Orend, Thomas Musch
Ruhr University Bochum, Institute of Electronic Circuits | Germany

This paper presents a material characterization S-parameter measurement setup for transmission and reflection measurements in terms of magnitude and phase. Flexible D-band dielectric waveguides enable the direct transmission measurement of the material under test. Furthermore, fundamentals of dielectric waveguides are explained, which form the basis of the measurement system. An FMCW radar calibration concept is presented that can perform complex S-parameter measurements. A dielectric waveguide system including material fixtures was designed and realized by means of a 3D printer within the scope of this work. Finally, measurements were performed and compared with a traditional vector network analyzer measurement setup to demonstrate the functionality of the measurement setup and the potential of the approach.

16:30 Dual-Polarized Polymer Dielectric Rod Waveguide for 60 GHz Band

Yizhang Li, Jan Hesselbarth
University of Stuttgart | Germany

A dielectric rod waveguide in dual-polarized operation is characterized experimentally in the 60 GHz band. The cross-sectional shape of the extruded PTFE rod is chosen to reduce both transmission loss and unwanted coupling to the orthogonal polarization mode. Measurements include the effects of radiation leakage at bends and the cross-coupling due to twists. Measured insertion loss is 2.05 dB/m and 2.27 dB/m at 60 GHz for the two polarizations, respectively. This is based on an extracted material loss tangent of 0.000'4 at 60 GHz.

16:50 Design and Simulation of a Waveguide-to-Microstripline Transition for Planar Slow Wave Structures

G. Ulisse, V. Krozer
Goethe University Frankfurt, Terahertz-Photonics | Germany

Microwave technology stands as a critical cornerstone in numerous modern applications, spanning from telecommunication and radar to high-power amplification. Efficient interfaces between different transmission line technologies have become imperative in the development of microwave devices. In this context, this work introduces a possible transition between waveguide and microstrip line, specifically designed to operate around 30GHz frequency range with a bandwidth of approximately 7 GHz. This adapter was originally conceived to streamline the integration of planar slow wave structures into high-frequency systems, and its straightforward approach not only simplifies the fabrication process but also readily facilitates the extension of its operating frequency range.

Focused Session on Millimeter-Wave and Terahertz Photonics 2 — 16:10 – 16:50

Chair: Prof. A. Stöhr
Room: Tiger & Turtle

15:50 Ten Times Lower Power Requirement Sub-Millimeter Wave Receivers Operating at Room Temperatures

Javier Martinez Gil, Diego Moro Melgar, Oleg Cojocari, Ion Oprea
ACST GmbH | Germany

In this work we report the development and demonstration at ACST of an experimental sub-harmonic full-band WR 3.4 mixer, featuring discrete InGaAs low barrier Schottky diodes. This mixer sets the ground basis at ACST for the development of THz room temperature receivers up to 1.1 THz with 10 times lower local oscillator (LO) power requirement. The mixer presents typical DSB Noise Temperatures of 9000 K varying from 7000 to 10000 K withing the 220-330 GHz radio frequency (RF) band. The reduction in local oscillator input power requirements is as low as 500 µW for optimal operation conditions. The mixer can still perform good results reducing the LO power to 350 µW. Both, the mixer and the diodes have been fully designed and fabricated at ACST GmbH.

16:10 Planar diffractive optical elements for THz beam polarization control

Surya Revanth Ayyagari[1], Simonas Indrišiunas[2], Vytautas Janonis[1], Daniil Pashnev[1], Justinas Jorudas[1], Andreas Kurt Klein-Schuster[3], Andreas Stöhr[3,4], Guillaume Ducournau[5], Irmantas Kašalynas[1]
[1] Terahertz Photonics Laboratory, Center for Physical Sciences and Technology (FTMC) | Lithuania
[2] Laser Microfabrication Laboratory, Center for Physical Sciences and Technology (FTMC) | Lithuania
[3] University of Duisburg-Essen, Department of Optoelectronics (OE) | Germany
[4] Microwave Photonics GmbH | Germany
[5] Lille University | France

We proposed the diffractive optical elements (DOEs) based on planar high-resistivity silicon gratings to perform as quarter waveplate (QWP) and half waveplate (HWP) at selected THz frequency range. As proof of principle QWPs were developed for 0.4 THz frequency demonstrating an operational bandwidth of up to 200 GHz. The Finite Difference Time Domain (FDTD) simulations were found in good agreement with THz Time Domain spectroscopy (THz-TDS) and vector network analyzer (VNA) experiments measuring transmission amplitude and phase spectra in the range of 0.1-1.0 THz.

16:30 Polymer-Based Hybrid-Integrated RF Photonics Transmitter for mm-wave/ THz Applications

Kalliopi Spanidou[1], Tianwen Qian[2], Peer Liebermann[2], David de Felipe[2], Norbert Keil[2], Guillermo Carpintero[1,3]
[1] University Carlos III of Madrid | Spain
[2] Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute (HHI) | Germany
[3] LeapWave Technologies | Spain

Photonic integration plays a key role in revolutionizing and shaping the future of THz communication and sensing applications through high-performance optical sources for photonic-based RF signal generation. However, widely tunable low-phase noise signals remain a challenge, especially when aiming to include the THz range. Hybrid integration, thanks to the integration of different materials with complementary characteristics can offer key advantages over monolithic InP sources to achieve high-performance, extremely wide tuning range and high-spectral signal purity. We report a novel polymer-based hybrid-integrated optical heterodyne signal source including two tunable InP/Polymer distributed Bragg reflector (DBR) laser monolithically with an integrated wavelength-meter based on thin-film filters (TFF) and on-chip photodiodes (PD) for absolute wavelength measurement. Owing to high efficiency of the hybrid platform, wavelength tuning up to 6 nm (~ 0.7 THz) and accurate wavelength monitoring are achieved. This compact optical source aims for reliable, low phase-noise RF signal generation for 5G/6G applications.

Measurement Techniques 2 — 15:50 – 16:30

Chair: Dr. J. Barowski
Room: Zoo Duisburg

15:50 Calibration and Measurements of a Highly Directive Antenna for E-band Satellite Communication

Laura Manoliu[1], Mustafa Efe Erdogan[1], Erfan Amini[1], Axel Tessmann[2], Ralf Henneberger[3], Jens Freese[4], Markus Koller[5], Ingmar Kallfass[1]
[1] University of Stuttgart, Institute of Robust Power Semiconductor Systems (ILH) | Germany
[2] Fraunhofer Institute of Applied Solid State Physics (IAF) | Germany
[3] Radiometer Physics GmbH (RPG) | Germany
[4] Tesat Spacecom GmbH | Germany
[5] University of Stuttgart, Institute of Space Systems (IRS) | Germany

This paper delves into the detailed features and measurements of a novel highly directive antenna designed specifically for E-band satellite communication. We explore the key aspects of its design, construction, and performance. In addition, we provide comprehensive measurements and analyses of the antenna's radiation patterns, gain, and track and scan capabilities to evaluate its practical applicability for 71-76 GHz satellite downlink communication systems.

16:20 Complex Near-field Measurement using On-The-Fly Scan with In-phase and Quadrature Demodulation

Cheng Yang[1], Christian Adam[2], Sebastian Götschel[3]
[1] Hamburg University of Technology, Institut für Theoretische Elektrotechnik | Germany
[2] Hamburg University of Technology, Institute for Integrated Circuits | Germany
[3] Hamburg University of Technology, Chair Computational Mathematics | Germany

Recently, a new near-field measurement technique based on on-the-fly (OTF) scanning and a Hilbert transform (HT) was proposed, allowing for rapid phase retrieval using a single probe. However, because of the required Nyquist rate sampling, this method encounters challenges related to costly data acquisition, storage, and processing demands, thereby restricting its use at MHz and GHz frequencies. In this paper a novel method is proposed, which addresses these issues by introducing in-phase and quadrature (IQ) demodulation in place of the HT. Its inherent frequency down conversion of the measured signal enables sampling at a significantly lower rate. To demonstrate the effectiveness of

the proposed method, it is employed in a near-field scanner to measure the magnetic fields of two distinct devices under test: a wireless power transmitter and a microstrip line, operating at 125 kHz and 1 GHz, respectively. Measurement results, compared to conventional field measurement approaches, show a good correlation, affirming the suitability of this fast and cost-effective solution for antennas, and RF systems.

IMA & MTT/AP Chapter Meetings 16:30 – 18:00

Room: Zoo Duisburg

Bus Transfer to the Landschaftspark 17:30 – 18:00

Conference Dinner 18:00 – 22:00

Further Information Page 14

Wednesday, 13th of March

08:20 – 10:00	**Radar**	Philharmonie
	Filter	Tiger & Turtle
	Focus Session THz.NRW	Zoo Duisburg
10:00 - 10:30	**Plenary Talk**	Philharmonie
	Keynote 5: Jonathan Borrill	
10:30 – 10:50	Coffee Break	Foyer
10:50 – 12:10	**Receivers**	Philharmonie
10:50 – 11:50	**Applications**	Tiger & Turtle
12:10 – 12:40	**Plenary Talk**	Philharmonie
	Keynote 6: Joel Dunsmore	
12:40 – 13:00	**Awards & Closing Ceremony**	Philharmonie
13:00 – 14:00	Lunch	Foyer
14:00	Departure	
14:30	Lab-Tours (Registration required)	

Radar 08:20 – 10:00

Chair: Prof. P. Knott
Room: Philharmonie

08:20 Chipless Tag Identification in Cluttered Environments through mm-Wave SAR Imaging

Ali Alhaj Abbas, Aman Batra, Thomas Kaiser
University of Duisburg-Essen, Institute of Digital Signal Processing (DSV) | Germany

In the realm of self-localization and tracking systems reliant on frequency-coded chipless RFID infrastructure, the effective suppression of clutter is imperative for ensuring reliable tag detection, particularly in challenging and cluttered environments. This paper introduces a novel approach to address this issue by employing Synthetic Aperture Radar (SAR) technique. High-resolution SAR imaging has the potential to distinguish tags from the surrounding clutter. The proposed method relies on extracting the tag position in reference to SAR geometry. Based on the position, a cluttered environment is compressed within the time-domain data, allowing the unique ID of the tag to be extracted from its corresponding frequency-domain response. The proposed methodology is experimentally validated in the W-band (75 GHz - 110 GHz) using a frequency-coded trihedral corner reflector, where the code was designated using a triangle Dielectric Resonator (DR) array. To exemplify a clutter scenario, a large metal reflector was placed directly behind the tag. Contrary to other methods in the literature, the results of this study conclusively demonstrate the efficacy of SAR processing for clutter mitigation in various tracking systems.

08:40 A Synthetic Aperture Imaging Concept for a Sequential Sampling Impulse Radar

Lena Krabbe, Niklas Haberberger, Michael Stelzig, Markus Hehn, Martin Vossiek
Friedrich-Alexander-University Erlangen-Nürnberg, Institute of Microwaves and Photonics (LHFT) | Germany

Sequential sampling impulse radar, which is known for its low complexity and potential energy efficiency, has seen limited exploration of its imaging capabilities, particularly for synthetic aperture radar (SAR) focusing. This paper fills this gap by introducing a phase-based SAR imaging concept for a sequential sampling impulse radar without IQ-mixer. This work outlines a

mathematical model for the received echo signal and processing steps to extract the phase information from the real-valued radar data. Experimental validation is performed in an outdoor scenario. The measurement results demonstrate successful phase-based SAR focusing, overcoming the limitations of amplitude-based reconstruction. The signal processing and imaging concept shown in this paper, combined with the used 1.35 GHz sequential sampling impulse radar systems, is intended for future use in glaciological research for the enhanced monitoring of glacier stratification, but it is also suitable for many other high-resolution ground penetrating radar (GPR) applications.

09:00 An Improved Stepped-Frequency PMCW Waveform for Automotive Radar Applications

Moritz Kahlert[1], Claas Tebruegge[1], Tai Fei[2], Markus Gardill[3]
[1] HELLA GmbH & Co. KGaA | Germany
[2] University of Applied Science and Arts Dortmund | Germany
[3] Brandenburg University of Technology | Germany

In phase-modulated continuous wave (PMCW) radar systems, fine range resolution typically requires high instantaneous bandwidths, necessitating fast-sampling analog-todigital converters (ADCs). However, these ADCs are expensive and power-consuming. Consequently, due to their affordable hardware implementation, today's automotive radar systems still mainly employ analog frequency-modulated continuous wave (FMCW) waveforms. A larger bandwidth without requiring fast-sampling ADCs can also be synthesized by transmitting consecutive pulses in a coherent processing interval (CPI) at incremented carrier frequencies. To enable PMCW with low-data-rate ADCs, this paper proposes an improved stepped-frequency PMCW (SF-PMCW) waveform and evaluates its performance against a stepped-frequency FMCW (SF-FMCW) radar system in a simulated environment. The results indicate that the proposed SFPMCW waveform can yield superior target detection capabilities with comparable system parameters.

09:20 A Range-Doppler Processing based Calibration Method for Short-Range Millimeterwave FMCW Radar Imaging

Jan Barowski, Ilona Rolfes
Ruhr University Bochum | Germany

This contribution presents a novel calibration method for ultra-wideband radar sensors. Calibrated radar measurements can be used to obtain quantitave correct reflection factor measurements in both, magnitude and phase, or to compensate for non-constant envelopes of the transmit signal that may degrade the pulse shape and therefore reduce resolution. The method is especially suited for short range imaging applications when the sample under test is in close proximity to the radiating aperture and is applicable to both, quasi-optical (QO) setups as well as synthetic aperture radar (SAR) imaging configurations. The proposed method utilizes a range-doppler measurement on a reference target to remove disturbing contributions by multiple reflections that are otherwise hardly separable from the target reflection.

09:40 Analysis and Simulation of a Photonic Multiband FMCW Radar Sensor System using Nyquist Pulses

Stephan Kruse[1], Tobias Schwabe[1], Pascal Kneuper[1], Heiko G. Kurz[2], Marc-Michael Meinecke[2], J. Christoph Scheytt[1]
[1] Paderborn University, Institute for Photonic Quantum Systems | Germany
[2] Volkswagen Aktiengesellschaft | Germany

A photonic multiband radio detection and ranging (radar) sensor system is presented. In the proposed approach a single frequency modulated continuous wave (FMCW) local oscillator (LO) drives a Mach Zehnder modulator (MZM), which is biased in the Nyquist point. Due to the nonlinear behavior of the MZM, harmonics of the FMCW LO signal are generated and distributed to the transmitter (TX) and receiver (RX) frontends. Within this paper such a photonic multiband radar system is proposed and analysed analytically. The results of the analysis are validated by means of the proposed hardware model.

It should be noted that all components of the photonic multiband radar sensor system can be integrated monolithically into a single silicon based electronic photonic integrated circuit (EPIC), which will enable low cost, large aperture phased-arrays with or without multiple input and multiple output (MIMO) techniques.

GeMiC 2024 Duisburg

Wednesday

Filter 08:20 – 09:40

Chair: Prof. C. Damm
Room: Tiger & Turtle

08:20 Additive Manufactured Dual-Mode X-shaped Filter Realized by High-Permittivity Ceramics

Daniel Miek, Patrick Boe, Michael Höft
Kiel University | Germany

In this paper, a lithography based additive manufacturing (AM) technique is used for the realization of a ceramic X-shaped dual-mode filter. The fourth order filter consists of two identical ceramics which are mounted in a copper housing and which are coupled by an aperture. Due to the arrangement of the ceramics and the associated coupling scheme, a negative cross-coupling between the first and fourth resonance is realized, leading to two transmission zeros (TZs), one above and one below the passband. The digital light processing process used for fabrication of the ceramics is described and compared to the stereolithography approach. Subsequently, the filter design process is addressed. The measurement results are compared to the simulation and reveal good agreement.

08:40 Compact E-Band SIW Filters Targeting PCB-Based MMIC Hetero-Integration

Dominik Wrana, **Marc Günter**, Simon Haussmann, Ingmar Kallfass
University of Stuttgart | Germany

In this paper we present the design and characterization of a fifth-order fundamental mode and fifth-order higher-order mode substrate integrated waveguide filter in E-band. Low-cost Rogers3003 printed-circuit board technology is used to fabricate the filters designed for a center frequency of 73.5 GHz and a bandwidth of 5 GHz. The simulated as well as the measured and de-embedded insertion loss of both core filter devices is better than 5 dB with matching of better than 15 dB. The measured frequency shift and reduced passband performance of the test structures including SIW-to-WG transitions are traced back to the non-idealities of the used SIW-to-RWG transition based on investigation of manufacturing tolerances and corresponding re-simulation.

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09:00 Compact WR-3 Filter with Improved Rejection Properties by Double Source-Load Cross-Coupling

Daniel Miek, Kennet Braasch, Fynn Kamrath, Patrick Boe, Michael Höft
Kiel University | Germany

This paper describes the realization of a fourth order waveguide filter, which is designed in the WR-3 frequency band (220 GHz - 330 GHz). The filter implements a classical quadruplet topology. A cross-coupling between the first and fourth resonator realizes a pair of transmission zeros (TZs) to improve the near passband rejection properties. A source to load (SL) cross-coupling is added to the topology for the realization of further TZs. In comparison to former investigations, the SL cross-coupling proposed here consists of two individual coupling slots. An SL cross-coupling in waveguide technique can be designed to show a dispersive behaviour, wherefore additional TZs can be introduced to the filter response. A double slot coupling aperture increases the degrees of freedom with respect to placing these additional TZs. As a result, in total seven TZs in the WR-3 frequency band are generated. Six of these TZs can be placed nearly symmetrically above and below the passband. An adapted coupling matrix description as well as a discrete equivalent circuit are proposed as well. Furthermore, parameter studies are carried out and measurement results are compared to simulation.

09:20 Reconfigurable Waveguide Bandpass Filter with Piezoelectric Motors in the W-Band

Fynn Kamrath, Patrick Boe, Kennet Braasch, Daniel Bruhn, Daniel Miek, Michael Höft
Kiel University, Chair of Microwave Engineering | Germany

This paper presents a fully reconfigurable bandpass filter in the W-band. The third-order filter utilizes contactless tuning plungers, which are under the control of piezoelectric motors, to tune its transmission characteristic. This arrangement allows exceptionally precise adjustments, enabling highly accurate tuning options. The tuning element incorporates coupling resonators to change coupling strength between resonators. Notably, both the main resonators and the coupling resonators use identical contactless plungers, simplifying the overall design. The filters' center frequency can be adjusted between 78 GHz and 82 GHz while the bandwidth can be changed independently between 300 MHz and 600 MHz. For most tuning states, an unloaded Q-factor Q0 above 1000 can be measured and the filter is able to realize a return loss of better than 20 dB.

Wednesday

Focus Session THz.NRW 08:20 – 09:50

Chair: Prof. T. Kaiser & Prof. A. Czylwik
Room: Zoo Duisburg

08:20 Introduction to THz.NRW

Dirk Nüßler
Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR) | Germany

08:30 Terahertz-Based Non-Contact Vital Sign Measurements

Svenja Nicola Kobel, Christian Wiede, Karsten Seidl
Fraunhofer Institute for Microelectronic Circuits and Systems (IMS) | Germany

As digital health and wearable technologies become increasingly important in society, the demand for non-invasive and convenient monitoring of vital signs has increased significantly. Vital signs play a crucial role in assessing a person's physiological state and overall health. While traditional contact-based methods have been the norm, recent advances in terahertz technology offer a promising approach for non-contact vital sign measurements. Terahertz technology, situated between microwave and infrared wavelengths, has gained attention due to its ability to penetrate materials such as clothing and biological tissues, making it particularly suitable for contactless measurements. This characteristic positions terahertz technology as an innovative solution for addressing the limitations of traditional vital sign monitoring methods. In this work, terahertz-based reflection measurements are used for the non-contact determination of heart rate and respiratory rate. By utilizing the unique properties of terahertz waves, reflection measurements offer the possibility to precisely measure distances. In this way, the minute movements caused by blood flow during the cardiac cycle and the movements during respiration can be detected. The methodology includes signal processing tailored to the respective vital signs. The measurement points investigated included the finger, wrist, arm bend, and thorax. In an initial pilot study, the method was successfully implemented and demonstrated. The highest accuracy was achieved when measuring the respiratory rate on the thorax, while the arm bend proved most accurate for measuring the heart rate. The results indicate that terahertz waves can accurately detect and monitor changes in heart rate and respiratory rate, representing a promising alternative to conventional methods. This study emphasizes the potential of terahertz technology as a non-invasive and non-contact method of measuring vital signs. The results contribute to the growing body of knowledge that supports the role of terahertz technology in advancing healthcare monitoring modalities.

08:50 MMICs for mm-wave to THz Joint Communication and Sensing (JCS)

Jan Wessel, Till Stephan Ziegler-Bellenberg, Steffen Hansen, Dominic Funke
Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR) | Germany

The increasing demand for smart mobility and a higher degree of automation brings out the strong need for novel concepts on hardware as well as on software and system design site. One promising approach is the combination of sensing and communication to reduce hardware complexity by a higher level of integration and simultaneously maintaining or even increasing functionality. This talk addresses the novel concept of harmonic tag-based joint communication and sensing (JCS) as well as monolithic microwave integrated circuits (MMICs) that provide frequency modulated continuous wave (FMCW) radar functionality and also high data rate communication. A strong focus is set on the ranging accuracy so that the radar key performance is not impaired by the extension with communication features pursuing an assisted radar track. To meet the demands on high resolution ranging as well as high data rate communication, the presented integrated circuits operate in the millimeter to terahertz frequency domain to take advantage of the large bandwidth available. Therefore, the concepts for JCS and their requirements imposed on the MMICs are explored based on three examples operating at 120 GHz, 240 GHz and 300 GHz, respectively. Further aspects regarding sensor fusion for enhanced radar performance or data transmission for identification, status reporting etc. are analyzed.

09:10 A D-Band VNA Frequency Extension Module Based on a Single SiGe MMIC

Justin Romstadt
Ruhr University Bochum | Germany

Current research in the broad academic and industrial communities is enabled by the increasing availability of high-quality measurement technology for the frequency range above 100 GHz. In particular, vector network analysis, which is used to characterize discrete and integrated circuits, systems, antennas, or materials, has an important role. As the frequency range of vector network analyzers (VNAs) is insufficient, vector network analyzer extension modules are needed. Commercially available options consist of discrete components, which increases the size and price of such modules.Therefore, a compact and cost-effective VNA extension module, which combines most of the functions on a single SiGe-MMIC, will be presented in this presentation. The talk will include design considerations of the whole system and single components integrated into the MMIC.To demonstrate the functionality of the module, a comparison with a state-of-the-art extension module based on measurements of different DUTs will also be shown. Here, the focus lies on the dynamic ranges, magnitude- and phase stability and identified problems and limitations of the innovative design approach.

09:30 Mobile Terahertz Spectroscopy Systems Enabled by Mode-Locked Laser Diodes

Kevin Kolpatzek
University of Duisburg-Essen, Chair of Communication Systems (NTS) | Germany

Modern fiber-coupled terahertz time-domain spectroscopy (THz-TDS) systems have found widespread use in fundamental research and are currently finding their way into real-world applications. However, their bulk, weight, and power consumption make them suitable only for stationary applications. One way to overcome this limitation is the replacement of the fiber laser that is at the heart of the THz-TDS system with a suitable semiconductor light source. Although first solutions based on multi-mode laser diodes have been demonstrated as early as 1999, their bandwidth and dynamic range leave a lot to be desired.

More recently, it was shown that monolithic mode-locked laser diodes (MLLDs) can be used for the same application. A key characteristic of a THz-TDS system that is driven by an MLLD is its unusually high pulse repetition rate of several 10 GHz. We now call this approach ultra-high repetition terahertz time-domain spectroscopy (UHRR-THz-TDS). Through careful system analysis, leading to several innovations in system design and signal processing, we are now able to construct mobile shoebox-sized UHRR-THz-TDS systems with a peak dynamic range in excess of 100 dB, and we see first promising results for achieving spectral update rates of several 100 spectra per second.

This talk gives an overview of the state of the art in UHRR-THz-TDS, compares it to other measurement techniques in the terahertz frequency range, and discusses promising new applications.

GeMiC 2024 Duisburg

Wednesday

Plenary Talk 10:00 – 10:30

Chair: Prof. N. Pohl
Room: Philharmonie

10:00 Keynote 5: Innovations in test tools, enabling fundamental 6G research

Jonathan Borrill, Chief Technical Officer Anritsu Group

Industry activity in 6G (also known as IMT2030) is currently in the pre-standards research stage, and there is significant activity to evaluate new frequency bands, new waveforms, and new use cases that can be derived from these. The presentation will introduce innovative new R&D test tools and methods in the area of channel sounding and propagation measurements, together with new testing technologies for sub-THz bands. The measurement challenges, test design concepts and actual measurement results will be presented and discussed, as well as the challenges foreseen to deploy these technologies into 6G networks.

Coffee Break *Room:* Foyer 10:30 – 10:50

Receivers 10:50 – 12:10

Chair: Prof. M. Rudolph
Room: Philharmonie

10:50 THz Near-Field Imaging Sensor Using Integrated Substrateless Silicon Interferometer

Shuya Iwamatsu[1], Daniel Headland[2], Israa Mohammad[1], Masayuki Fujita[3], Andreas Stöhr[1]
[1] University of Duisburg-Essen, Department of Optoelectronics (OE) | Germany
[2] University Carlos III of Madrid, Optoelectronics and Laser Technology Group | Spain
3 Osaka University, Graduate School of Engineering Science | Japan

Terahertz (THz) time-domain spectroscopy (TDS) technology has greatly advanced various THz applications ranging from fundamental science to industrial non-destructive imaging. However, traditional THz-TDS systems rely on complex setups with femtosecond pulse lasers and bulky free-space optical components, hindering their miniaturization. A more practical approach introduces THz frequency domain imaging using semiconductor laser diodes, which replace femtosecond laser and facilitate integration into photonic integrated circuit (PIC) chips. Despite its promise, addressing real-world imaging applications remains challenging due to the need for free-space optics, which also negatively impact resolution due to the diffraction limit. To overcome this limitation, this study explores the use of silicon (Si) microphotonics, focusing on an integrated Y-junction that operates as an interferometer. The Y-junction essentially replaces all free-space components, paving the way towards compact, monolithically integrated all-silicon structures that span just ~1 cm. We demonstrate near-field imaging at 325 GHz employing the Y-junction. The experiments achieve a 500-µm spatial resolution and a 100-µm depth resolution, showcasing potential for handheld THz near-field imaging sensors.

11:10 A Robust High-Linear 76–81 GHz Automotive Radar IQ Receiver Frontend in 22 nm FD-SOI CMOS

Jidan Al-Eryani[1], Miguel Chanca[2], Rainer Blechschmidt[3], Guenter Voge[1]
[1] Robert Bosch GmbH | Germany
[2] Bosch Service Solution | Spain
[3] Bosch Sensortec GmbH | Germany

A 76–81 GHz automotive radar IQ receiver (RX) frontend in a 22 nm FD-SOI CMOS technology is presented. It consists of low-noise amplifiers, mixers, IQ generation, LO amplifiers, and a transimpedance amplifier followed by the baseband blocks. The RX is part of a radar system-on-chip and is packaged in a flip-chip ball grid array then soldered into a printed circuit board. The main parameters are measured while sweeping RF frequency and an extended temperature range from -40°C to 140°C. The measured gain varies by only +/- 0.6 dB across frequency and temperature, showing its robustness. The image rejection ratio stays above 26 dB. The nominal output signal-to-noise ratio (SNR1dB) at the input-referred 1 dB compression point (IP1dB) is 163 dB (SNR1dB = IP1dB + 174 - NF) and stays above 160 dB. This is state of the art for CMOS RXs considering the trade-off between noise figure (NF) and IP1dB.

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Wednesday

11:30 A Multi-mode Direct Conversion Receiver for Joint Communication and Radar Sensing

Sandra George[1], Padmanava Sen[1], Corrado Carta[2]
[1] Barkhausen Institute | Germany
[2] Technical University Berlin, IHP Microelectronics GmbH | Germany

This paper presents a reconfigurable direct conversion receiver in 22 nm FDSOI technology with 25 GHz center frequency, implemented for Joint Communication and Radar Sensing (JC&S) applications. The receiver employs a multi-mode 2-stage cascaded common source Low Noise Amplifier (LNA) and a multi-mode Gilbert cell down-conversion mixer. The receiver can be switched between radar mode and communication mode delivering more linearity in radar mode and higher gain in communication mode. In the communication mode, the receiver consumes a power of 22.4 mW while delivering an overall gain of 24.5 dB and an iP1dB of -28 dBm excluding the baseband buffer. In the radar mode, the receiver consumes a maximum DC power of 11.63 mW delivering a maximum receiver gain of 14.8 dB and an iP1dB of -20 dBm at 25 GHz. The receiver consumes an area of 0.74 mm2 including pads and a core area of 0.15 mm2.

11:50 A Wide Band High Linearity CT-ΣΔ Converter for Receivers Reaching 1.75 Gb/s Using 16384 QAM

Julius Edler, Patrick James Artz, Enne Wittenhagen, Friedel Gerfers
Technical University Berlin, Chair Mixed Signal Circuit Design | Germany

Higher order quadrature amplitude modulation (QAM) schemes enable increased data rates as well as improved spectral efficiency and thereby empower the evolution of future mobile communication standards. A key component in the receive chain is the analog-to-digital converter (ADC). Performance metrics are usually extracted using narrow-band signals such as high-purity single or two-tone sine waves. As an alternative, this paper describes gigabit rate receiver characterizations using complex wide-band signals with modulation depths up to 16384-QAM. This is possible by the use of a wide-band Sigma-Delta ADC with > 60 dB dynamic range with a bandwidth of 250 MHz. The complete digital signal processing chain is described, which features a linear equalizer and a low-pass decimation filter to recover the transmitted symbols. The influence of various transceiver design choices, such as the pulse shaping filter are measured. For the mitigation of interference from of out-of-band signals, high linearity is essential. This is shown by a sine-wave interference test showing RMS error-vector-magnitudes (EVM) under different linearity conditions. Here, EVMs of less than 0.2% are presented with 1.75 Gb/s transmission speed enabling future mobile communications.

GeMiC 2024 Duisburg

Applications 10:50 – 11:50

Chair: Prof. I. Rolfes
Room: Philharmonie

10:50 Analysis of fine building structures using radar

Tobias Karrer, Markus Peichl, Stephan Dill
German Aerospace Center (DLR), Microwaves and Radar Institute | Germany

Knowing the structure of a wall, ceiling or floor, as well as the location of enclosed hollows, cavities or pipes, is very beneficial for various applications. In this paper the potential of radar measurements for the analysis of building structures is outlined by the discussion of wall and floor measurements in an office building from the 1970s. These illustrate that with a suitable radar system it is possible to get information about the individual layers of a floor or wall and, that it is possible to detect and interpret non-visible structures inside of them. A measurement along a large inside wall, that appears to be constructed the same way for the entire corridor, shows that a different paneling, thickness of layers or material is used in different optically non-visible sections. For optimizing the energy consumption or investigating the status prior to any refurbishment, it can be very helpful to know detailed wall structure in order to apply suitable measures. As an interesting detail, a floor measurement shows that an optically non-visible cable canal is not laid as expected. For safety aspects, like in case of a fire or gas attack, it is very helpful to know possible propagation paths for the spread of smoke and gas within the building. For that additional reason, the real location and extent of cable ducts, cavities or hollows inside building structures is of high interest.

11:10 Terahertz Insights Into Fabric Look-Through

Andreas Prokscha[1], Fawad Sheikh[1], Kevin Kolpatzeck[2], Yamen Zantah[1], Dien Lessy[1], Jan C. Balzer[2], Andreas Czylwik[2], Thomas Kaiser[1]
[1] University of Duisburg-Essen, Institute of Digital Signal Processing (DSV) | Germany
[2] University of Duisburg-Essen, Chair of Communication Systems (NTS) | Germany

For centuries, fabrics have been a staple in human life, primarily as clothing materials. However, their role has evolved into versatile materials with innovative applications in textile-based electronics, including fashion technology, smart fabrics, and interactive textiles. Furthermore, fabrics can function as electromagnetic (EM) wave-absorbing, and wave-transparent

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materials. This paper reports findings from transmission measurements using a THz-TDS and THz-FDS setup in the 100 to 1000 GHz frequency range. Diverse fabrics, including natural, synthetic, and blended fibers are examined. Initially, the refractive indices are derived from the THz-TDS and THz-FDS measurements. These data are then used to derive Fresnel transmission coefficients. The results provide valuable insights into the interaction of fabrics with electromagnetic waves, contributing to various technical applications, particularly within the biomedical industry and security checks.

11:30 Steering-Layer: A Hybrid DSP-Machine Learning Layer for Sensor DoA Estimation

Cândido Vieira, Volker Lücken, Andreas R. Diewald, Hans-Peter Beise
Trier University of Applied Sciences, LaROS | Germany

In this paper, we introduce a new hybrid machine learning layer, the Steering-Layer, designed for precise direction of arrival (DoA) estimation of reflected signals. The accuracy of DoA estimation is crucial for a multitude of applications, ranging from radar and sonar systems to communications and healthcare. While the foundation of the Steering-Layer is deeply rooted in the multiple signal classification (MUSIC) algorithm, our method harnesses the power of machine learning to elevate the robustness and performance of DoA estimations. Central to this approach is the integration of the manifold array concept into the weights of the layer, enhancing DoA estimates when multiple receivers are engaged. Our experimental outcomes delineate two distinct advantages: first, compared to Eigendecomposition methods, there is no need to determine the number of observed objects in advance; second, unlike FFT techniques, the resolution is not constrained by the number of samples. Computationally, the Steering-Layer's complexity was evaluated to be between FFT and MUSIC. Recognizing the DoA as a multi-label classification problem, this model utilizes the multichannel signal's covariance matrix as its input. Post-processing through the Steering-Layer, the resulting multiple pseudo spectra are fed into subsequent ML layers, culminating in an output through a sigmoid activation, optimized by binary-cross-entropy loss. Using the Steering-Layer, our model produces accurate estimates with a considerably smaller model size compared to other machine learning models for DoA. We tested our approach with real experimental data from a mmWave MIMO radar. Our approach bridges traditional signal processing and machine learning, promoting DoA estimation advancements.

Plenary Talk 12:10 – 12:40

Chair: Prof. N. Weimann
Room: Philharmonie

12:10 Keynote 6: Advances in Wideband Modulated Load-pull Measurements for Power, EVM and ACPR

Joel Dunsmore, Keysight Technologies

Load-pull measurement using mechanical tuners is the classic way to determine the proper matching impedance of a power amplifier operating under nonlinear conditions. These tuners provided a wide range of impedances, but only over a narrow bandwidth. For the narrow-band modulation conditions of traditional 4G and LTE systems, this seemed sufficient. But for modern 5G and Non-Terrestrial Networks (NTN), bandwidths can be much wider and the narrow-band matching of mechanical tuners is not sufficient.

This paper presents new methods using active sources to present proper loading conditions to amplifiers driven with wideband modulated signals. The active load presents a wideband load to the DUT, through active injection. Further, these methods can extract power, Error-Vector-Magnitude (EVM) and Adjacent Channel Power Ratio (ACPR) as a function of load impedance changes. Active loads over wide bandwidths has been shown in previous work, but this work shows extracting modulation parameters (EVM and ACPR) as wells as power and gain. The load conditions can be single impedance, or present an impedance profile that might match what an antenna would present to the amplifier-under-test. The paper will explore measurement results for an active device under these various conditions.

Detailed Discussion: The amplifier under test will be stimulated with various format modulated signals representative of those used in communications systems such as QPSK, QAM and OFDM. Tests will be done under modulated conditions with bandwidths as wide as 2 GHz. For these tests, the power, gain, EVM and ACPR will be characterized for loads around the Smith chart, plotting the power and EVM as a function of load phase, for a series of load reflections at various magnitudes. We will compare the changes in power and EVM across load positions. EVM will be computed in two ways: using spectral correlation, and with full demodulation, and using two instruments, a Vector Network Analyzer (VNA) and Vector Spectrum Analyzer (VSA), to correlate results. Additionally, we will look at the changes in EVM and power when the load is changed from a

fixed impedance, to one that emulates real non-ideal load such as an antenna matched at the center of a band, but which has impedance that varies with frequency, particularly varies in phase due to length effects.

Awards & Closing Ceremony		12:40 – 13:00
Room: Philharmonie		
Lunch	*Room:* Foyer	13:00 – 14:00
Departure		14:00

Poster Session 10:40 – 12:20

Room: Foyer

PP01 2x2 Tile Usable for Reconfigurable Intelligent Surfaces Operating at 28 GHz

Mehmet Emin Arslan, Ulrich Nordmeyer, Niels Neumann
Technical University Clausthal | Germany

Reconfigurable intelligent surfaces (RIS) have emerged as a promising technology to realize a smart wireless environment in millimeter wave (mmWave) communication systems. The implementation of RIS is considered to be used for 5G/6G technology operating in the mmWave range. However, manufacturing each unit cell of RIS in mmWave bands can be challenging due to the limited space for implementing RIS components with currently available technology. In addition, implementing a RIS as a dense plane on building facades for real-life applications can be unrealistic, and controlling the RIS can be challenging due to the potentially extreme number of unit cells. In this study, a novel 2x2 tile considered for sparse array RIS and operating at 28 GHz is designed and manufactured. Numerical simulations and experimental measurements are performed and the results are compared. Not only is a good agreement between the experimental and the numerical results presented but also a practical tile design for mmWave RIS implementations is proposed.

PP02 A Robust and Cost-Effective Process Control Monitor Concept to Verify Quality Characteristics of Printed Circuit Boards up to 40 GHz

Felix Sepaintner[1], Andreas Scharl[2], Johannes Jakob[1], Franz Röhrl[2], Werner Bogner[1], Stefan Zorn[2]
[1] Deggendorf Institute of Technology | Germany
[2] Rohde & Schwarz GmbH and Co. KG | Germany

This paper presents a concept to examine the dielectric constant, dissipation factor, substrate height and etch quality of printed circuit boards. With a robust probe system, manual millimeter-wave measurements are possible within harsh environments. In combination with on-board sensors, material and processing tolerances can be determined easily with very low precision loss compared to established measurement methods.

PP03 Single Snapshot Array Interpolation for Angular Estimation in Automotive Radar Applications

Alisa Jauch[1], Frank Meinl[1], Holger Blume[2]
[1] Robert Bosch GmbH, Engineering Radar Technology and Modules | Germany
[2] Leibniz University Hannover, Institute of Microelectronic Systems | Germany

A lot of research efforts have been invested to improve angular estimation accuracy and resolution while keeping hardware efforts small. For this reason, techniques to virtually augment antenna apertures became popular. Among these are the employment of multiple-input and multiple-output (MIMO) methods or the utilization of second-order statistics in co-prime arrays. However, since these virtually augmented arrays generally feature holes and thus missing spatial samples, they suffer from an increase of sidelobe levels and performance degradation. This imposes challenges to angular estimation procedures. To face those shortcomings, this paper presents a novel, fast and simple array interpolation technique to reconstruct a uniform linear array (ULA) measurement. The method is furthermore suitable for applications with severely limited snapshot count such as automotive imaging radars. Numerical experiments validate the superiority of the proposed method in terms of resolution ability, estimation accuracy and computation time compared to nuclear norm minimization (NNM) techniques.

PP04 Limitation of Asymptotic RF Simulation Method in Presence of Periodic Structures of Close-to-Wavelength Size

Abdul Rehman Waseem Mir[1], Markus Clemens[1], Alexander Ioffe[2], Markus Stefer2
[1] University of Wuppertal | Germany
[2] Aptiv Services Deutschland GmbH | Germany

Ray Launching Geometrical Optics (RL-GO) technique is known for reliable and accurate results including those in the automotive radar related field. However, the high frequency approximation can be expected to reveal inaccuracies when applied to periodical structures consisting of close-to-wavelength structure sizes. This paper investigates the limitations of RL-GO for objects or arrangements that possess dimensions below or close to the radiation wavelength λ_g inside the material. Here, Multilevel Fast Multipole Method (MLFMM) which is a full wave technique provides the benchmark for accuracy verification. The expected accuracy impact has been investigated in this work for periodic structures with dimensions between 1.5 λ_g and 0.15 λ_g. In the scope of this work for RL-GO, accuracy condition are found and formulated.

Tuesday

PP05 Graphene-based Balanced Nonlinear Transmission-Line Frequency Doubler

Abdelrahman Elgamal[1], Paula Palacios[2], Renato Negra[2], Thomas Dallmann[3]
[1] Integrated Circuits Department Fraunhofer FHR | Germany
[2] RWTH Aachen University, Chair of High Frequency Electronics | Germany
[3] Technical University Ilmenau, Research Group FAVF | Germany

This paper introduces a tunable balanced Nonlinear Transmission-Line (NLTL) frequency doubler topology designed using graphene-based Monolithic Microwave Integrated Circuit (MMIC) technology. The frequency doubler chip, operating at a centre frequency of 1.6 GHz, is presented alongside its validation through a proof-of-concept Printed Circuit Board (PCB). The proposed topology offers significant advantages, including high harmonics suppression and exceptional phase noise performance. We employ two measurement setups to evaluate the PCB's performance, showcasing the practical applicability of the design. The frequency doubler design achieved remarkable performance, featuring a conversion gain of -11 dB with high tunability. The circuit exhibited good fundamental suppression below -25 dB, and third and fourth harmonic suppression lower than -35 dB. Moreover, the circuit showcased low-phase noise with a delta carrier-to-noise ratio (CNR) of 6.33 dB.

PP06 Two-Dimensional Resonant-Tunneling-Diode Oscillator Array for Quasi-Plane Terahertz Radiation

Zhenling Tang, Safumi Suzuki
Tokyo Institute of Technology, Department of Electrical and Electronic Engineering | Japan

We propose a two-dimensional (2D) resonant-tunneling-diode (RTD) oscillator array to generate quasi-plane terahertz (THz) waves. Dual-RTD slot antennas are employed to form the 2D array meshes, where adjacent RTDs are arranged in a reverse configuration to enhance power-combination through anti-phase coupling. Expansive metal pads are introduced to redirect the electric fields, mitigating electric field cancellation and leading to improved radiation efficiency. The 2×2 2D RTD array achieves milliwatt level output power terahertz radiation, exhibiting improved directivity. Moreover, this work demonstrates that further expansion of array elements holds the potential to enable high-power terahertz radiation with a quasi-plane wavefront.

PP07 In-Package Characterization of Dielectrics Using Ring Resonators and Adaptive 3D EM-Simulations Around 77 GHz

Pascal Stadler[1], Tobias T. Braun[1], Christian Geissler[2], Philipp Scheibe[3], Tanja Braun[3], Ole Hölck[3], Justin Romstadt[1], Nils Pohl[1,4]
[1] Ruhr University Bochum, Integrated Systems | Germany
[2] Infineon Technologies AG | Germany
[3] Fraunhofer Institute for Reliability and Microintegration IZM | Germany
[4] Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR | Germany

A method to obtain the permittivity and gauge the loss tangent of packaging materials at frequencies around 77 GHz from a single package is presented in this paper. In-package ring resonators, calibrated with an integrated TRL standard, are measured and their results contrasted with adaptive 3D electromagnetic simulations. By comparing the resonance frequency and peak bandwidth, the characteristics of the RDL separating dielectric and the mold compound were extracted, respectively. The results were validated in Infineons eWLB technology with a minimal deviation of 0.16% / 14.28% in $\varepsilon_{r,DIEL}$ / $\varepsilon_{r,Mold}$ and 0% / 11.11% in $\tan(\delta_{r,DIEL})$ / $\tan(\delta_{r,Mold})$ over all samples. It was further used to deduce the attributes of Fraunhofers RDL-first technology. Under a-priori knowledge of the permittivity, this concept has also been shown feasible to estimate fluctuations in a given technology.

PP08 Investigating a possible shielding behavior of the European honey bee's cuticle at THz frequencies

Mandana Jalali, Jan Taro Svejda, Benedikt Sievert, Daniel Erni
University of Duisburg-Essen, General and Theoretical Electrical Engineering (ATE) | Germany

The current work is focused on a first analysis of high-frequency radiation penetration into a European honey bee (Apis mellifera) using an efficient 2D model of the insect's major part's cross-section, the abdomen. Material properties of the bee's involved body parts – i.e. cuticula, wings, and inner parts – are measured and modelled as corresponding dielectric functions. Afterwards, and based on the established material properties, a possible shielding effect of the cuticle layer e.g. at the abdomen of the bee is numerically analyzed. Our results indicate that the cuticle layer indeed reduces the radiation exposure of the bee's inner organs in particular in the frequency range of 1-130 GHz. However, it is observed that despite this shielding, the electromagnetic (EM) exposure within the bee's abdomen at 95 GHz is enhanced, where the inner

organs such the heart and the stomach may perceive remarkable values of the electric field. The study clearly reveals that a homogeneous model, which assigns a uniform effective permittivity to the bee's body, does not really capture this interaction's complexities. Hence, virtual EM microdosimetry at bees are in a stark need for a heterogeneous as well as anatomically precise 3D full-wave bee model (digital twin).

PP09 RF Characterization of flexible printed circuits up to 40 GHz

Andreas E. Olk, Palak Dave, Pascal Schmalen
IEE S.A. | Luxembourg

Flexible printed circuits show great potential for applications due to additive-type fabrication, ease of integration into devices and cost effectiveness. In the microwave frequency range, they mostly suffer from significant losses and cannot compete with their rigid PCB counterparts. In this work, we assess the performance of transmission lines from two different low cost flexible printed circuit fabrication techniques at frequencies up to 40 GHz. We show that transmission lines from laminated aluminum on PET show significant performance advantages compared to more conventional screen printed lines made using silver ink.

PP10 Evaluation of Control Link Impacts on the IRS Assisted Communication System with Hardware-in-the-Loop Simulation

Xianshi Zeng, Jonas Buehlmeyer, Robert Weigel, Florian Irnstorfer
Friedrich-Alexander-University Erlangen-Nürnberg, Institute for Electronics Engineering | Germany

With the development of Intelligent Reflecting Surface (IRS) technology, the network performance of the control channel has an increasing impact on IRS systems. This paper presents a hardware-in-the-loop (HiL) simulation methodology for the IRS controller using real network devices. We demonstrate the behaviour of a control channel connected to the simulated IRS-based communication platform. This provides test results that correlate with wired and wireless network connection. In addition, previous work has investigated the mobile user tracking (UT) scheme and proposed methods to achieve a higher signal-to-noise ratio (SNR) in the downlink case, which will provide a theoretical upper bound. Our experimental results are analysed and compared with previous simulation methods. The results show that the proposed HiL simulation methodology can validate the functionality of the UT scheme and emphasize the importance of considering the impact of the non-ideal control link on the IRS system.

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PP11 Optimising the Image Rejection in Phase-Only Multilevel LINC Transmitters

Stefan Mueller, Renato Negra
RWTH Aachen University, Chair of High Frequency Electronics | Germany

This work presents a process to optimise the image-rejection in phase-only multilevel LINC transmitters (POMLINC). The image is generated in the IQ-modulator-based phase-modulators. Compared to optimising the image-rejection for each IQ-modulator separately, it can be further optimised for the full system. To do that, the fact that the level-generating amplifiers of the PO-MLINC are operated within a limited range of input phases is exploited. The theory of this process is presented. Furthermore, simulation and measurement results are shown. The measurement results show a 7.7-dB IMRR improvement in the PO-MLINC setup.

PP12 Effect of Soliton Decomposition on Harmonic Levels in a Lumped NLTL Multiplier

Fatih Erdem, Sencer Koç
Middle East Technical University, Department of Electrical-Electronics Engineering | Turkey

A sinusoidal wave entering nonlinear transmission line (NLTL) multipliers undergoes an edge-sharpening effect. As a result, a sharpened waveform with rich harmonic content is obtained. However, the levels of generated harmonics decay monotonically, leading to poor conversion efficiency at higher order harmonics. Another characteristics of NLTL multipliers is the propagation of solitons which can be exploited to generate harmonics more efficiently. Through soliton decomposition, the power transferred to higher-order harmonics can be increased. In this work, we have investigated a capacitive lumped NLTL multiplier through simulations and measurements. The effect of soliton decomposition on harmonic levels has been presented.

PP13 Rectangular Waveguide to Coplanar Waveguide Transition for 110 to 170 GHz

Konrad Mueller, Christian Preuss, Robin Kress, Enes Mutlu, Nils Weimann
University of Duisburg-Essen, Dept. Components for High-Frequency Electronics (BHE) | Germany

In this work a structure is shown to transition from a rectangular waveguide, across a square coaxial section to interface an on-chip coplanar waveguide (CPW) pad in the frequency range of 110 to 170 GHz. The structure allows to transition without the use of a carrier substrate, reducing the total amount of interfaces for the terahertz (THz) transition. It allows close placement of the

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chip to the transition, reducing the impact of parasitic components. A back-to-back structure is simulated including an analysis of manufacturing variations. The proposed structure shows to be robust to manufacturing tolerances and covers the whole D-band. First manufacturing tests are conducted, indicating that low-loss straight waveguide sections can be achieved, based on measured surface roughness much lower than the skin depth.

PP14 THz Optoelectronic 2-D Beam Steering Transmitter for Short-Range Communications

Thomas Haddad[1], Jonas Tebart[1], Carlos Biurrun-Quel[2], Peng Lu[1], Andreas Stöhr[1]
[1] University of Duisburg-Essen, Dept. of Optoelectronics (OE) | Germany
[2] Public University of Navarra | Spain

This paper reports on a THz optoelectronic beam steering transmitter for THz communications in WR3.4 frequency range. The transmitter incorporates two commercially available UTC photodiode modules and an InP-based 2-D beam steering chip. In detail, this chip utilizes an array of three leaky-wave antennas driven by a beamforming network called CORPS to enable the 2-D beam steering using only two tuning elements. Experimentally, by sweeping the frequency between 0.26 and 0.32 THz, the beam steers from -12° to +33° in elevation direction. On the other hand, by tuning an optical delay line between ±0.84 ps, the THz beam changes the azimuth angle between -20° and +19°. Furthermore, data transmission of 2 Gbps over a 15 cm wireless distance is successfully demonstrated using the fabricated optoelectronic transmitter chip at various angles between 10° to 30° in elevation and 0° to 10° in azimuth. At all angles, the BER is below the hard-decision forward error correction limit of 3.8×10-3 when using a 4-QAM modulation. The highest SNR is found to be 14.84 dB at a point equivalent (El., Az.) of (20°, 5°).

PP15 Subharmonically Pumped H-Band Resistive IQ-Mixer with Gate Bias above Threshold Voltage

Lukas Gebert[1], Benjamin Schoch[1], Dominik Wrana[1], Simon Haussmann[1], Thomas Ufschlag[1], Axel Tesmann[2], Sandrine Wagner[2], Ingmar Kallfass[1]
[1] University of Stuttgart, Institute of Robust Power Semiconductor Systems | Germany
[2] Fraunhofer Institute for Applied Solid State Physics IAF | Germany

In this paper a resistive IQ mixer biased at the gate above its threshold region is presented. This bias point allows due to lower resistance for broadband matching and good conversion gain. The mixer is subharmonically pumped to improve the LO to RF isolation and the LO power generation. TandemX coupler is used for the 90° hybrid a. A conversion gain of -25 dB for up and down conversion was measured. An IF bandwidth of 30 GHz and a RF bandwidth of 60 GHz is achievable while the LO is adjustable over a bandwidth of 30 GHz allow for frequency multiplexing. The mixer is realized in a 35 nm mHEMT InGaAs process.

PP16 Channel Measurements in an Industrial Environment for Access Point-to-Sensor Communication at 300 GHz

Carla E. Reinhardt, **Varvara V. Elesina**, Johannes M. Eckhardt, Tobias Doeker, Lucas C. Ribeiro, Thomas Kürner
Technical University Braunschweig | Germany

This paper presents channel measurements for a machine to access point communication scenario at low THz frequencies. The measurements included time-invariant scenarios where an access point communicated with two static sensors as well as a time-variant scenario in which a static access point communicated with a moving sensor node. Recent evaluation results are provided, comprising power delay profiles that simultaneously demonstrate the potential for THz communication in these scenarios and highlight emerging challenges that warrant further research.

PP17 Power-Combined Sources and Compact Economical Source in the mm-Wave Frequency Range (200 - 300 GHz)

V. Lain-Rubio, M. Rickes, R. Lehna, D. Moro-Melgar, Frank Gorski, O. Cojocari
ACST GmbH | Germany

In this work a set of two sources based on Schottky barrier diodes covering the frequency ranges of 200- 235 GHz and 230-265 GHz with more than 23 dBm and 22 dBm output power levels, respectively, are presented. Following the already developed compact sources in the 200-300 GHz, the typical available output power of 16 dBm has been easily increased in more than 5dB by the combination of four tripler chips in one single module. Moreover, a compact commercial source in the frequency range of 270-297 GHz with nominal output power of 10 dBm is presented. The small deviation in measurement results from unit to unit, beside the low production costs, establishes this source as a reliable and reproducible product for high-volume-applications in this frequency range.

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Tuesday

PP18 A 17 mW X-Band LNA for Backhaul Applications in 0.13 µm SiGe BiCMOS

Victor Adam Reig[1],Paulo Oliveira[2], Hans-Dieter Wohlmuth[2], Vadim Issakov[1]
[1] Technical University Braunschweig, Institute for CMOS Design | Germany
[2] Infineon Technologies AG | Germany

This paper presents a low-power X-band single-ended input to differential output, single-stage cascode low-noise amplifier (LNA) in Infineon's Silicon Germanium (SiGe) BiCMOS technology. The circuit operates from a single supply voltage of 1.8 V. At the center frequency of 12 GHz, the amplifier offers a measured gain of 20.9 dB and a noise figure of 2.8 dB including the on-chip input balun. The circuit achieves a linearity of -10.8 dBm input-referred 1 dB compression point at 12 GHz. The chip size including the pads is 0.86 mm2.

PP19 Terahertz Massive MIMO System Evaluation with Virtual Antenna Arrays at 300 GHz

Yamen Zantah, Nidal Zarifeh, Qianlong Xiao, Mai Alissa, Thomas Kaiser
University of Duisburg-Essen, Institute of Digital Signal Processing (DSV) | Germany

This paper presents an experimental study of a THz massive MIMO (M-MIMO) system utilizing virtual antenna arrays in indoor Line-of-Sight (LoS) environment. Using a VNA-based THz measurement system with a 60 GHz bandwidth spanning 240 GHz to 300 GHz, we emulate a 25 × 25 THz M-MIMO system by creating 5 × 5 uniform planar arrays (UPA) at both the transmitter and receiver, with half-wavelength inter-element spacing, similar to scenario-generic on-chip antenna arrays. The system is evaluated by assessing the MIMO channel correlation and capacity while also exploring some sub-arrays configurations towards inter-element spacing optimization. The analysis demonstrates the strongly correlated channels accompanying the employment of the multi-antenna system in LoS environment, which highly decrease the achievable system spectral efficiency compared with the theoretical upper bound. A minor capacity enhancement ratio of about 1.8 is achieved by employing all systems antenna elements with a maximum channel capacity of 1019 Gbps. This study presents a first experimental evaluation of such large-scale MIMO system implementing virtual antenna array concept in the THz band.

PP20 Compact 112 ps Step Recovery Diode based Pulse Generator for Medical Applications

Marco Mütze, Armin Bakkal, Petr Schaffer, Dirk Plettemeier
Technical University Dresden, Chair of Radio Frequency and Photonics Engineering | Germany

This paper presents the design of an ultra-wideband (UWB) sub-nanosecond pulse generator. It has been developed as a part of a novel silent speech radar application working at frequencies between 500 MHz and 5 GHz. The proposed circuit is based on a step recovery diode (SRD) and generates a Gaussian pulse with an amplitude of 4 V and a bandwidth of 4.85 GHz. The circuit has been simulated, a PCB fabricated, optimized and tested. A 3.3 V or 5 V CMOS clock of more than 25 MHz repetition rate with moderate requirements on rise and fall times can be used to trigger the pulse. The output is designed to match to 50 Ohm loads which allows to feed antenna structures directly. Measurement results are presented and show Gaussian pulses with a pulse duration of 112 ps Full-Wave at Half-Maximum (FWHM).

See you next GeMiC!

Notes

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