Tagungsprogramm

Zusammenfassung der Beiträge

Conference Program

Abstracts

U.R.S.I.

Landesausschuss in der Bundesrepublik Deutschland e.V.

Kleinheubacher Tagung 2017

25. – 27. September 2017

Altes Rathaus - Miltenberg

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09:20 – 10:40 Uhr: Mo-C1
Ort: Altes Rathaus, Bürgersaal
C: Radio Communication Systems and Signal Processing
Titel: Modeling of electrical circuits and systems
Sitzungsleiter: Jens Anders

09:20 – 09:40 Uhr: KH2017-Mo-C1-01
Ort: Altes Rathaus, Bürgersaal
Robuste Generierung von Wellendigital-Modellen nichtlinearer elektrischer Bauelemente mit Hilfe einer Wellengrößenbeschreibung
Tim Schwerdtfeger[1], Anton Kummert[1]
([1] Bergische Universität Wuppertal)

Das von Alfred Fettweis eingeführte Konzept der Wellendigitalfilter bietet eine einzigartige Verknüpfung von elektrischen Referenzschaltungen und digitalen Systemen. Hierbei wird jedes elektrische Bauelement unter Beibehaltung der lokalen Passivitätseigenschaften streng modular diskretisiert und anschließend zu einem Digitalsystem verknüpft, das die Referenzschaltung in Topologie und dynamischem Verhalten akkurat widerspiegelt. Die Konstruktionsprinzipien des urspünglichen Wellendigital-Konzeptes schränken hierbei allerdings die Menge der realisierbaren Referenzschaltungen stark ein, um verzögerungsfreie Schleifen im resultierenden Signalflussgraphen zu vermeiden. So war es gemäß der klassischen Literatur im Allgemeinen lediglich möglich, ein einziges eintoriges nichtlineares Bauelement umzusetzen. Realitätsnahe Wellendigitalmodelle mehrtoriger Nichtlinearitäten, etwa von Transistoren, sind aus diesem Grund bisher vollständig unbekannt. Erst mit aktuellen Erweiterungen des Konzeptes sind solche Nichtlinearitäten in beliebiger Anzahl und Topologie als Wellendigitalsimulation umsetzbar geworden. Die Herleitung solcher stark nichtlinearer Wellendigitalbausteine ist somit von großem aktuellen Interesse. Hierfür müssen die gängigen nichtlinearen Bauteilmodelle, die üblicherweise über funktionale Beziehungen der Kirchhoffschen Kenngrößen Strom und Spannung beschrieben werden, in den Wellenbereich transformiert werden. Diese Transformation der elektrischen Kennfelder in eine äquivalente nichtlineare Wellengrößen-Beschreibung ist im Allgemeinen aber nicht geschlossen möglich. Aus diesem Grund muss hier auf numerische Mittel zurückgegriffen werden. Dabei erweisen sich Standardverfahren aber als äußerst wenig robust und benötigen aufwändige Parameter- oder Startwertoptimierung, um überhaupt zu einem brauchbaren Ergebnis zu gelangen. Im Rahmen des Vortrages wird ein neues, problemangepasstes numerisches Verfahren vorgestellt, mit dem sich ein Wellendigitalmodell eines passiven nichtlinearen Mehrtores auf äußerst robuste Weise generieren lässt. Hierbei ist insbesondere auch der residuelle Fehler an jedem Punkt durch die Interpolation aus benachbarten exakten Werten beschränkt. Das Verfahren wird anhand von stark nichtlinearen Transistorschaltungen demonstriert, die bisher nicht als Wellendigitalfilter realisierbar waren.

09:40 – 10:00 Uhr: KH2017-Mo-C1-02
Ort: Altes Rathaus, Bürgersaal
Energy-efficient noise-aware design of CMOS LC tank oscillators
Sebastian Bader[1], Maurits Ortmanns[1], Jens Anders[1] ([1]Universität Ulm)

In this contribution, a new energy efficient noise-aware oscillator design flow is presented. The proposed method is based on closed form expressions for the oscillator amplitude and phase noise derived from perturbation theory and stochastic averaging. Within the variety of possible oscillator types, LC-tank oscillators are a popular choice for the use in CMOS transceivers due to their good performance and robustness. In the proposed talk, we will first discuss a deterministic perturbation theory-based analysis of the oscillator to obtain analytical models for the oscillation frequency and amplitude. Then, we will analyze the influence of the intrinsic oscillator noise sources using the method of stochastic averaging, which was first proposed by Stratonovich [1]. The resulting closed-form expression for the oscillator phase noise is then combined with the previously derived closed-form terms for the oscillator amplitude and frequency to arrive at the newly proposed energy-efficient noise-aware design flow. More specifically, we will discuss how the amplitude strongly depends on the bias current and up to which degree a larger amplitude leads to lower phase noise. This trade-off between phase noise and low power consumption is crucial for the design and the proposed closed-form expressions allow for an optimal choice of both the oscillator bias current and the value of the tank inductance as a starting point for a final performance optimization based on numerical circuit simulations. Finally, the proposed design flow is validated against simulations in a conventional 130 nm CMOS technology.

[1] R. L. Stratonovich, Topics in the Theory of Random Noise. New York: Gordon and Breach, 1967.

10:00 – 10:20 Uhr: KH2017-Mo-C1-03
Ort: Altes Rathaus, Bürgersaal
Ordnungsreduktion hierarchisch gekoppelter dynamischer Systeme
Michael Popp[1], Wolfgang Mathis[1]
([1]Leibniz Universität Hannover)

Die Entwicklung und der Betrieb moderner elektrischer und elektronischer Systeme wird durch leistungsfähige Simulationswerkzeuge unterstützt bzw. erst ermöglicht. Modelle für die Simulation sehr großer Gesamtsysteme werden gewöhnlich aus kleineren und weniger komplexen Teilsystemmodellen hierarchisch zusammengesetzt. Während diese Herangehensweise im Modellierungsprozess zum etablierten Stand der Technik gehört, wird die hierarchische Struktur zur Durchführung der eigentlichen Simulation aufgelöst.
Im Gegensatz hierzu steht der in diesem Beitrag verfolgte Ansatz. Basierend auf einer modifizierten Variante des sogenannten Component Connection Modeling nach DeCarlo und Saeks wird eine Formulierung der zusammengesetzten Gesamtmodellgleichungen verwendet, welche sowohl die hierarchische Struktur selbst als auch die Komponentenverbindungen innerhalb einzelner Teilsysteme über den gesamten Simulationsprozess hinweg bewahrt.
Zum Einen kann mit der vorgeschlagenen Formulierung eine beschleunigte Simulation durch eine parallelisierte Funktionsauswertung des Gesamtgleichungssystems erzielt werden. Darüber hinaus ergibt sich auch die Möglichkeit, den Aspekt der hierarchischen Modellformulierung auf das Gebiet der mathematischen Ordnungsreduktion für dynamische Systeme auszuweiten, um ggf. eine weitere Steigerung der Simulationseffizienz zu erzielen. So kann beispielsweise die Rechenzeit für die Erzeugung eines reduzierten Systems in einem mehrstufigen, an der hierarchischen Systemstruktur orientierten Reduktionsprozess verglichen mit der direkten Reduktion des Gesamtgleichungssystems deutlich gesenkt werden.
Anhand einiger hierarchisch aufgebauter dynamischer Beispielsysteme wird in diesem Beitrag zum Einen das modifizierte Component Connection Modeling (mCCM) veranschaulicht. Zum anderen wird die Verknüpfung des mCCM mit etablierten Methoden zur Ordnungsreduktion demonstriert. Für gekoppelte lineare Systeme wird exemplarisch das auf Hankel-Singulärwerten basierende balancierte Abschneiden (engl. balanced truncation) und für gekoppelte nichtlineare Systeme das TPWL-Verfahren (trajectory piecewise linear) einer anwendungsorientierten Analyse unterzogen. Insbesondere die sich ergebenden praktischen Schwierigkeiten und die systematischen Beschränkungen der jeweiligen Verfahren werden diskutiert.
Schließlich wird auf die hauseigene Simulationsplattform CoSimMA eingegangen. In dieser sind alle in diesem Beitrag vorgestellten Konzepte modular und objektorientiert implementiert, so dass sich eine sehr gute Eignung als experimenteller Simulator zur Entwicklung und Erforschung neuartiger, alternativer Simulationskonzepte ergibt.

10:20 – 10:40 Uhr: KH2017-Mo-C1-04
Ort: Altes Rathaus, Bürgersaal
Self-calibrating Pulse Width Modulator with a very high time resolution for an audio power amplifier using ZePoC
Thomas Vennemann[1], Lars Kreuer[1], Richard Mathis[2], Wolfgang Mathis[1]
([1]Leibniz Universität Hannover, [2]Universität Göttingen)

For an open loop class D audio power amplifier using zero position coding (ZePoC) a pulse width modulator with a very high time resolution is necessary. The complete ZePoC algorithm is implemented on a single digital signal processor (DSP). For generating pulse width modulated (PWM) signals the DSP contains PWM units which can be clocked at a maximal frequency of 200 MHz. The generated PWM signals have a time resolution of 5 ns which is not sufficient for audio applications. To get an audio signal with 16 bit linear bit depth, time steps of 150 ps or less are required. For a time resolution of 150 ps in a synchronous digital circuit the clock frequency must be increased above 6 GHz. This is only an option if a field programmable gate array (FPGA) with high speed serializers will be used. In our contribution we will show an alternative approach without increasing any frequencies.
The PWM unit of the DSP will be extended by a mixed signal circuit containing an integrated circuit (IC) used for skew management of digital signals. To increase the time resolution of the PWM signal generated by the DSP this signal is routed through different paths of cascaded delay lines inside the IC. Each possible path has an individual delay ranging from 3 to 12 ns. Every edge of the PWM signal can be positioned in 10 ps increments which is equivalent to a digital circuit running at 100 GHz. The pulse width modulator consisting of the internal DSP unit and the external mixed signal circuit has to be calibrated at several constant operating temperatures because many parameters are drifting over temperature. Due to the enormous amount of time and the required measurement equipment the circuit can be calibrated inside the system without additional external equipment. A software algorithm compensates the drift over temperature during normal operation.

With the presented circuit the dead time of the power stage can also be adjusted. To reduce the harmonic distortion caused by non ideal switching and the low pass output filter the dead time has to be minimized. Metrological tests with an Audio Precision SYS 2522 will show the resulting spectra and the influence of dead times.

11:10 – 12:30 Uhr: Mo-C2
Ort: Altes Rathaus, Bürgersaal
C: Radio Communication Systems and Signal Processing
Titel: Networks and coding
Sitzungsleiter: N.N.

11:10 – 11:30 Uhr: KH2017-Mo-C2-01
Ort: Altes Rathaus, Bürgersaal
Where to go from Here? New Cross Layer Techniques for LTE Turbo-Code Decoding at High Code Rates
Stefan Weithoffer[1], Norbert Wehn[1]
([1]Universität Kaiserslautern)

Today, the monthly data traffic per smartphone is expected to increase from 2.7 GB per month in 2016 to 18 GB per month in 2021 due to the widespread use of streaming video services, which creates more than 50 % of the annual mobile traffic increase. To satisfy this hunger for higher data rates, sophisiticated wireless baseband signal processing is necessary. Here, we focus on the channel decoder, which is one of the most computationally intensive parts in baseband processing and thus a major source of latency and power comsumption.
Wireless communication standards like the 3GPP Long Term Evolution (LTE) use rate compatible Turbo-Codes as channel code and adjust the transmit data rate (or code rate) r dynamically to achieve a desired Signal-to-Noise-Ratio (SNR) while keeping the transmit power P constant and maximizing the information throughput. As a result, the channel decoder has to be extremely flexible while achieving a very high throughput and a low decoding latency for large code block sizes. From the perspective of the decoder, flexibility means excellent decoding performance across a wide range of code rates and code block sizes.
Highly parallel architectures as presented in literature, achieve LTE Turbo-Code throughput requirements. However, for the high degree of parallelism which is required to fulfill the throughput demands, the individual code blocks have to be split into (small) sub-blocks, which makes additional calculations to compute estimates for the state metrics at the sub-block borders necessary in order to mitigate a degradation of the decoding performance. This, in turn, limits the maximum degree of decoder parallelism that can be achieved for a given target FER. Moreover, this effect is even more pronounced for high code rates, which are mandatory to increase the information throughput.
In this paper, we follow a cross-layer approach to increase the FER performance for a fully LTE-A Pro compatible Turbo-Code decoder hardware architecture without the need to trade off throughput against FER performance. We employ a combination of new techniques developed in our group and use synergies accross different layers of the decoding to improve the FER performance significantly accross a wide range of code block sizes and code rates.
Starting from a fully LTE-A Pro Turbo-Code decoder architecture optimized for high throughput, we demonstrate the negligible hardware overhead of improved algorithms recently proposed by our group. For that, the improved FC algorithm, which makes significant coding gains possible, is combined with a special CRC calculation scheme and hardware architecture. The resulting flexible architecture achieves state-of-the-art throughput and area efficiency numbers while having a communications performance surpassing state-of-the-art for high code rates.
To the best of our knowledge, a most advanced hardware implementation of a complete Turbo-Code decoder with the new TB and CB level techniques, which enable coding gains up to 1.8 dB compared to state-of the-art with negligible overhead, is demonstrated for the first time. Post place & route results, show the architecture to be competetive in terms of throughput (1.375 Gb/s), area (0.55mm2) and energy efficiency (0.04 nJ/bit/iter).

11:30 – 11:50 Uhr: KH2017-Mo-C2-02
Ort: Altes Rathaus, Bürgersaal
Polar Code Decoder Exploration Framework
Claus Kestel[1], Norbert Wehn[1]
([1]Universität Kaiserslautern)

Over the last decades, digital communication systems became an essential part of our lives. We consume, produce and store an ever increasing amount of data. Constantly requiring faster networks and more sophisticated signal processing to handle the growing amount of traffic but also the demand for energy efficient and low latency solutions for todays applications. One of the important parts of this signal processing is Channel Coding or Forward Error Correction (FEC) that copes with transmission errors in noisy environments. In this paper we focus on the decoding, for Polar Codes in particular.
Polar Codes, invented 2008 by Erdal Arikan, are the first codes proven to achieve channel capacity for Binary Symmetric Memoryless Channels (BSMC)[1]. They belong to the class of multilevel concatenated codes, but in contrast to the similar Reed-Muller-Codes they use the phenomenon of channel polarization to maximize coding efficiency. As a candidate for the FEC of the next generation mobile networks (5G) they play an important role in the ongoing standardization process.
A number of hardware implementations for Polar Code Decoders have been proposed in recent years. They cover fully unrolled and pipelined architectures as well as flexible and iterative implementations but are mostly optimized only for one specific target, e.g. throughput, energy efficiency or code rate flexibility. However, a holistic analysis of the available trade-offs is missing in literature.
Therefore, in this paper we propose a framework to systematically explore the design space for Polar Code decoder hardware implementations and to evaluate the various trade-offs. At the same time the flexible framework will allow the adaption to changing requirements ie. change to the code structure during the standardization of 5G.
One of the decoding algorithms for Polar Codes is the Soft Cancellation (SCAN) algorithm [2]. It is a combination of the Successive Cancellation (SC) Algorithm proposed by Arikan in his original publication and the Belief Propagation (BP) Algorithm for Polar Codes. While the SC decodes sequentially and decides bit by bit, the BP works in parallel over several iterations (similar to the LDPC BP) and exchanges soft values between nodes. SCAN and its variations adopt the message passing between nodes and furthermore allow to choose the degree of parallelism.
Additionally, the SCAN decoding algorithm is highly parameterizable in terms of the processing order of the nodes, the memory consumption of the nodes, number of iterations and complete unrolling / pipelining or quantization and therefore well suited for this exploration.
For the SCAN algorithm we evaluate the trade-offs between error correction performance and implementation efficiency (throughput, latency and area usage) based on synthesizable VHDL models.

[1] E. Arikan, "Channel Polarization: A Method for Constructing Capacity- Achieving Codes for Symmetric Binary-Input Memoryless Channels," IEEE Transactions on Information Theory, vol. 55, pp. 3051-3073, July 2009.
[2] J. Lin, Z. Yan, and Z. Wang, "Efficient Soft Cancelation Decoder Architectures for Polar Codes," IEEE Transactions on Very Large Scale Integration (VLSI) Systems, vol. 25, pp. 87-99, Jan 2017.

11:50 – 12:10 Uhr: KH2017-Mo-C2-03
Ort: Altes Rathaus, Bürgersaal
Future integrated communication network architectures enabling heterogeneous service provision
Paul Arnold[1], Dirk V Hugo[2]
([1]Deutsche Telekom AG & DT, [2]Telekom Innovation Laboratories & Deutsche Telekom AG)

This paper summarizes expectations and requirements towards future converged communication systems denoted by 5th Generation (5G). Multiple research and standardization activities globally contribute to the definition and specification of an Information and Communication Technology (ICT) to provide business customers and residential users with both, existing and future upcoming services which demand for higher data rates and granted performance figures in terms of QoS parameters, such as low latency and high reliability. Representative use case families are threefold and represented as enhanced Mobile Broadband (eMBB), massive Internet of Things (mIoT), and Critical Communication, i.e. Ultra-Low Latency (ULL)/Ultra-High Reliability (UHR). To deploy and operate a dedicated network for each service or use case separately would raise the expenses and service costs to an unduly high amount. Instead provision of a commonly shared physical infrastructure offering resources for transport, processing, and storage of data to several separated logical networks (slices) individually managed and configured by potentially multiple service providers is the main concept of this new approach.

Beside a plentitude of other initiatives the EU-funded 5G NORMA project (5G Novel Radio Multiservice adaptive network Architecture) has developed an architecture which enables not only network programmability (configurability in software), but also network slicing and Multi Tenancy (allowing independent 3rd parties to offer an end-to-end service tailored according to their needs) in a mobile network. Major aspects dealt with here are the selectable support of mobility (on-demand) and service-aware QoE/QoS control.
Specifically we will report on the outcome of the analysis of design criteria for Mobility Management schemes and the result of an exemplary application of the modular mobility function to scenarios with variable service requirements (e.g. high-terminal speed vs. on-demand mobility or portability of devices). An efficient sharing of scarce frequency resources in new radio systems demands for tight coordination of orchestration and assignment (scheduling) of resources for the different network slices as per capacity and priority (QoS) demand. Dynamicity aspects in changing algorithms and schemes to manage, configure, and optimize the resources at the radio base stations according to slice specific Service Level Agreements (SLAs) are investigated. It has been shown that architectural issues in terms of hierarchy (centralized vs. distributed) and layering, i.e. separation of control (signaling) and (user) data plane will play an essential role to increase the elasticity of network infrastructures which is in focus of applying SDN (Software Defined Networking) and NFV (Network Function Virtualization) to next generation communication systems.
An outlook towards follow-on standardization and open research questions within different SDOs (Standards Defining Organizations) and recently started cooperative projects concludes the contribution.

- NGMN white paper (2015), http://ngmn.org/5g-white-paper/5g-white-paper.html
- 5G NORMA web site, https://5gnorma.5g-ppp.eu/
- "5G Communication for Automation in Vertical Domains",
- 3GPP 2017, http://www.3gpp.org/news-events/3gpp-news/1839-5g_cc_automation
- "5G and Internet Technology", IETF 2017, https://www.ietf.org/blog/2017/06/5g-and-internet-technology/

12:10 – 12:30 Uhr: KH2017-Mo-C2-04
Ort: Altes Rathaus, Bürgersaal
Design of Plannar Inverted F-Antenna for 4G Wireless Communications
Amin Al-Ka'bi (Australian College of Kuwait)

With the introduction of the fourth generation (4G) of cellular mobile communications, there has been an increase in the frequency bands that a generic mobile phone should be able to operate. This requirement poses some challenges in the design of the transceiver modules of the device as well as the RF front-end and the antenna. In this paper we discuss the effect of Planar Inverted F-Antenna (PIFA) dimensions on its resonance frequency, and we come up an empirical equation for this relationship.

13:30 – 14:30 Uhr: Mo-P1
Ort: Altes Rathaus, Bürgersaal
Sitzungsleiter: Madhu Chandra
Plenary Talk: A Vision for Spaceborne Radar Remote Sensing
Alberto Moreira (Deutsches Zentrum für Luft- und Raumfahrt – DLR)

At the beginning of the 21st century, our society is facing grand challenges of global dimension: Climate change, scarcity of resources, food security, fresh water supply, sustainable development, zero carbon society, mobility and a world changed security situation. Up-to-date geospatial information is essential, for example, to detect changes in the environment and to protect it, to understand climate change and take actions to reduce it, to monitor a sustainable use of natural resources, or to provide information in real time for disaster relief forces in crisis areas. Spaceborne remote sensing with radar satellites plays a vital role in this task because it is the only sensor technology that is able to provide global, high-resolution imaging during day and night and independent from the weather conditions. The vision for the radar remote sensing looks fascinating: An integrated remote sensing system consisting of a constellation of satellites enables continuous, global monitoring of the Earth's surface, as it already exists for weather prediction with a network of geostationary satellites. A constellation of spaceborne radar systems becomes thus the cornerstone of this information system for Earth dynamics and environmental monitoring. This talk provides first an overview of the state of the art and applications of spaceborne synthetic aperture radar (SAR). One prominent example is the TanDEM-X mission, the first bistatic radar in space. It consists of a synthetic aperture radar interferometer with two almost identical satellites flying in a closely controlled formation. With a typical separation between the satellites of 150 to 400 m a global Digital Elevation Model (DEM) with 2 m relative height accuracy at 12 m posting has been generated and is available for scientific and commercial applications since September 2016. All the specifications for the

final DEM product of TanDEM-X have been achieved and even surpassed, confirming the excellent quality of the bi-static radar instruments, the interferometric processing system and the data calibration Second, the talk will describe the paradigm shift that is taking place in spaceborne SAR systems. The fast growing user community poses demanding requirements for higher resolution and shorter revisit time which push the development of new technologies for achieving a wide-swath high-resolution imaging. New antenna concepts with digital beamforming will boost the performance of future SAR systems by at least one order of magnitude. One example is Tandem-L, a highly innovative SAR satellite mission which is based on two bistatic L-band radar satellites using a feed array with digital beamforming in combination with a large deployable reflector. These technological developments will open the door for an integrated remote sensing system for the continuous observation of dynamic processes over the Earth surface with unprecedented accuracy. Ultimate goal of such a system is to provide geospatial information as an essential contribution to solve grand societal challenges of global dimension related to climate change, sustainable development, land and resources use, mobility, environmental protection and security.

15:00 – 16:40 Uhr: Mo-C3
Ort: Altes Rathaus, Bürgersaal
C: Radio Communication Systems and Signal Processing
Titel: Radar and Automotive
Sitzungsleiter: N.N.

15:00 – 15:20 Uhr: KH2017-Mo-C3-01
Ort: Altes Rathaus, Bürgersaal
Methods for Evaluating the Performance of Automotive Radar Target Simulators.
Maximilian Engelhardt[1], Florian Pfeiffer[2], Erwin Biebl[3]
([1]Technische Universität München, [2]Perisens GmbH, [3]Technische Universität München)

As the usage of automotive radar sensors increases there is also a growing demand for testing these sensors. Different designs are available for generating simulated targets. In many applications there is no access to the internals of the sensor or the sensor is even part of a more complex system that needs to be tested in action, so generating simulated targets has to be performed at the high frequency domain, typically at 24 GHz or 77 GHz. The basic concept of a target simulator is receiving the signal of the radar sensor, delaying it by a certain amount of time, which corresponds to the distance of the simulated target, adjusting the amplitude appropriately, optionally adding a frequency shift which simulates a Doppler shift and finally transmitting the signal back to the radar sensor. In the following methods for characterizing important aspects of such a target simulation system will be shown.
For the measurement of static parameters a network analyzer can be used. The measurement of the target simulator under test can be perform either by directly connecting the network analyzer to the high frequency connector of the target simulator or by using an additional antenna at the network analyzer and keeping a well known distance between both systems. Using this method the characteristic properties of a static target can be measured easily by performing the inverse fast Fourier transform of the measured S-parameters. This also yields an easy way to characterize additional unwanted targets that are generated. Such targets can occur from reflections inside the system as well as limited isolation between transmit and receive path.
However, measurement of Doppler shift as well as moving targets is not easy to perform using a network analyzer. A solution is using a radar evaluation platform, which nowadays is available off-the-shelf and low-priced compared to a full network analyzer. Such a radar evaluation platform usually works very similar to a commercial automotive radar system, but offers the possibility to access the complete analog-to-digital converter data as well as specifying predefined frequency-modulated-continuous-wave signals that are being transmitted. By using an appropriate series of modulated ramps and performing a two-dimensional Fourier transformation a Range-Doppler graph can be generated. There it is easily possible to examine the purity of the Doppler shift, for example undesired spurious side peaks caused by the internal phase-locked-loop can be detected. Another advantage of unfiltered access to the analog-to-digital converter data is the ability to have a close look at the effects during the switching operations inside the target simulator. Switching delays, non synchronous switching or undesired behavior during the change in delay, amplitude or Doppler shift can be analyzed using this technique. Due to the similarity to a commercial automotive radar sensor this method allows a similar view of the signal like the sensor internally has and is thus beneficial for understanding certain sensor behavior.

15:20 – 15:40 Uhr: KH2017-Mo-C3-02
Ort: Altes Rathaus, Bürgersaal
Target Recovery from Randomly Distributed Radars using Compressed Sensing Techniques
Torsten Reissland[1], Alexander Koelpin[2], Robert Weigel[1]
([1]Universität Erlangen-Nürnberg, [2]Brandenburgische Technische Universität Cottbus-Senftenberg)

In highly automated industrial applications radar sensor systems already play an important role. For future applications, good knowledge about the three-dimensional environment of physically acting industrial systems will be beneficial, if not necessary. For this reason, the use of distributed radar systems to gain precise knowledge of the systems environment and its work pieces is proposed.
In the literature only few approaches for three-dimensional radar target recovery in the short range can be found. Furthermore, these approaches presume different kinds of regular patterns in which the radar sensors must be placed. This is obviously contrary to the requirements of e.g. industrial robots which can be moved on arbitrary trajectories. The most challenging problem when it comes to target recovery from randomly distributed radar sensors is the high computational effort which has to be spent.
In this work an algorithm is presented which aims at recovering several point targets from as few as possible radar measurements. The whole work is based on simulations and analytical considerations. Each radar uses well-known frequency modulated continuous waveform signals to gain information in range direction. As stated in the title the recovering is carried out by a compressed sensing algorithm. To use this algorithm, the whole problem has to be transformed into a linear system of equations, small enough to be solved by commercially available computers in an amount of time which is suited for the application. This linear equation eventually consists of the received radar signals, a measurement matrix and the reflectivity of assumed targets located in a-priori defined voxels. As the number of voxels which have to be taken into account increases drastically with the desired resolution, an iterative approach had to be developed to limit the algorithms requirements in terms of computational effort. Finally, different suited recovery algorithms were compared in terms of robustness.

15:40 – 16:00 Uhr: KH2017-Mo-C3-03
Ort: Altes Rathaus, Bürgersaal
Radar-Based Road Users Classification with a Convolutional Neural Network
Rodrigo Pérez[1], Falk Schubert[2], Ralph Rasshofer[3], Erwin Biebl[1]
([1]Technische Universität München, [2]BMW AG, [3]BMW Forschung und Technik GmbH)

Road traffic injuries are responsible for a great number of deaths worldwide. A significant part of this number can be traced to the vulnerable road users group, i.e. pedestrians, cyclists and motorcyclists. Modern vehicles are equipped with multiple sensors to increase both driver comfort and road safety. The ability to classify other road users can provide an intelligent system with useful information on how to react on a dangerous situation. Radar sensors are especially attractive, since they are able to measure range, velocity and angle even in adverse environment conditions.
The micro-Doppler effect describes the additional change in frequency induced by the motion of the components of a moving object, e.g. the swinging arms of a pedestrian. A certain pattern, denoted as micro-Doppler signature, can be observed in different subjects and can be used to classify them.
This work presents a method to classify road users based solely on measurements from a 77 GHz radar system with similar parameters to those available in modern automobiles. The radar has eight coherent receive channels and it is operated as a chirp sequence frequency-modulated continuous-wave radar. Each radar measurement frame is processed by means of a 3-dimensional discrete Fourier transform, providing a so-called range-Doppler-angle spectrum, from which targets may be resolved in range, radial velocity and angle. This 3-dimensional spectrum is the basis, on which classification is performed. Since this approach performs the classification on single measurement frames, it makes it possible to give an intelligent system information on a timely manner.
With data gathered in different urban locations, a convolutional neural network is trained to classify targets under three categories: pedestrians, automobiles and cyclists. The training set contains subjects moving both longitudinally and laterally to the radar. At this time, the size of the training set is 2500 frames. A separate test set, which contains only measurement tracks unknown to the network, is used to evaluate the accuracy of the classification.

16:00 – 16:20 Uhr: KH2017-Mo-C3-04
Ort: Altes Rathaus, Bürgersaal
Concept for detecting angles and displacements from a MR-Sensor-Array using an ICP algorithm
Phil Meier[1], Kris Rohrmann[1], Marvin Sandner[1], Marcus Prochaska[1]
([1]Ostfalia Hochschule für angewandte Wissenschaften)

In the area of weak magnetic field measurement challenging requirements have to be fulfilled: Systems for weak field sensing have to have a linear transfer characteristic, high sensitivity, low noise and a negligible hysteresis. Especially in industrial and automotive applications further demands should be considered such as stability, low power consumption, low temperature and life time drift. Since AMR elements possess good temperature stability, high robustness against large magnetic fields and relatively high sensitivity, they are often the first choice for automotive applications. That is why in the following AMR sensors are considered. However, it must be pointed out that the presented methodology is also applicable to other xMR technologies For angular measurement a static field is typical generated by a permanent magnet which position has to be carefully adjusted. One sensor is typically build from four AMR elements which are connected as a Wheatstone-bridge. A rotation of the magnet results in a change of the bridge voltage caused by the dependency on the AMR resistant's of the angle PHI. Such sensor systems reach an acceptable error below one degree over its lifespan. The described sensor system is highly sensitive for a displacement between the sensor and the magnet. Thus, already a shift of tenths of a millimeter causes an unacceptable error in the measured angle of several degrees. Thanks to the advancing miniaturization of electronical components it is possible to place several sensors on one chip resulting in an array of Wheatstone-bridges. Because such an array generates more data in one measurement alternative methods become feasible, for example image processing methods could be used. In this work we use a 3x3 magnetic sensor array an ICP-algorithm is used to process the Data for angular detection. We show the concept for an AMR angular sensor which is able to quantify 360 degree under defined boundary conditions by simulation and measurement. It will be also shown that this concept represents an improvement of the existing sensor systems.

16:20 – 16:40 Uhr: KH2017-Mo-C3-05
Ort: Altes Rathaus, Bürgersaal
A novel readout circuit for magneto-resistive sensors in anti-lock braking systems
Marcus Prochaska[1], Marvin Sandner[1], Kris Rohrmann[1], Phil Meier[1]
([1]Ostfalia Hochschule für angewandte Wissenschaften)

Magneto-resistive sensors are able to meet the challenging requirements of anti-lock braking systems, due to their robustness against harsh environmental conditions, high sensitivity and excellent noise performance. However, new vehicle concepts such as hybrids and electric cars demand a higher stability of the sensor functionality. In this paper a novel CMOS readout circuit is presented, which significantly reduces the dependency of the sensor performance on temperature and lifetime drift. The presented concept based on a magnetic excitation of the magneto-resistive elements. From this follows also a reduction of the sensor size, which enables a system cost reduction as well as the implementation of large sensor arrays. Since anisotropic magneto-resistive (AMR) elements play an important role in the ABS sensor market, in the following we considered AMR elements. However, it must be pointed out, that the presented methodology is also applicable to other xMR technologies such as giant magneto-resistance (GMR) and tunnel magneto-resistance (TMR). For the linearization of AMR elements typically a Barber pole construction is used, where the sensing elements are arranged as a Wheatstone bridge to maximize the sensor output signal and to reduce temperature drift. However, Barber pole sensors need a magnetic field applied along the anisotropic or easy axis to improve their stability, since the internal magnetization of the ferromagnetic sensor element has two stable positions. Otherwise, if for any reason a powerful magnetic field opposing the internal field, the magnetization flips from one into the opposite direction. Unfortunately, this stabilization field given by a bias magnet lowers significantly the sensitivity and increases the size of the sensor system A state of the art ABS sensors consists of xMR sensing elements arranged in a Wheatstone bridge, a pre-amplifier and a Schmitt trigger, which generates a pulse train, where the frequency of the pulse train is proportional to the rotational speed of the car wheel. In contrast to typical AMR wheel speed sensors we use a single AMR element without Barber poles, which is modulated by on-chip coils. Since a Wheatstone bridge as well as a bias magnet is not needed, sensor and sensor system size is reduced. Furthermore, since a bias field is not needed, the modulated sensor possesses a higher sensitivity compared to an AMR sensor with Barber poles. Because of the lower sensor size, modulation of the sensors enables the realization of integrated xMR sensor arrays. Moreover, due to the magnetic excitation we are able to eliminate offset given by the xMR elements. From this follows a significantly reduced drift over lifetime and temperature. Typically, modulation of the sensor leads to higher power consumption or a complex signal processing. On this account we use three-dimensional coils for low power

consumption, where the xMR element represents the spool core. To reduce the complexity of the readout circuit, we developed an efficient sensing methodology, which is based on an auto-zero amplifier concept.

09:20 – 10:40 Uhr: Mo-T1
Ort: Brauerei Keller, Gambrinus – Stube
Special Session Terahertz Technology
Sitzungsleiter: Thomas Kleine-Ostmann

09:20 – 10:00 Uhr: KH2017-Mo-T1-01
Ort: Brauerei Keller, Gambrinus – Stube
Industrial applications of broadband terahertz radiation
Rene Beigang[1], Garik Torosyan[2], Soufiene Krimi[1] ([1]Universität Kaiserslautern, [2]Photonic Center Kaiserslautern)

The state of the art of THz technology will be reviewed and recent developments required for its widespread use will be discussed. This includes results from electronic devices, modern quantum cascade lasers and narrowband tunable cw as well as ultra-broadband pulsed systems based on lasers and nonlinear optics. All systems have their particular properties which make them suitable for specific measuring techniques and applications. These techniques extend from spectroscopy, time resolved measurements and imaging to all possible combinations among these methods.
The applications realized so far are both very fundamental but also very close to industrial use. On the fundamental side THz systems are applied in chemistry, physics, astrophysics and biology. Material sciences use the special properties of materials in the THz spectral range to get information which are otherwise difficult to obtain. Using modern high power systems material properties can be changed and even nonlinear experiments became possible. In biomedicine and biophysics there are additional problems concerning the strong absorption of water in the THz range which require particular smart experimental methods to obtain meaningful results form THz experiments.
In recent years many groups have already demonstrated the potential for industrial use of THz technology, however, it turned out to be a long way from proof of principle to real industrial use. In many cases very simple reasons prevented that THz technology was used routinely for industrial problems, like cost, complexity of the systems, or even a lack of knowledge about the THz technology. So far there are only a few promising industrial applications on the horizon where THz is the only solution for an urgent problem. Just to mention one, the determination of layer thicknesses in multilayer paint coatings on plastic, carbon reinforced plastic or metal seems to perfectly match with the properties of broadband THz systems.
Pros and cons of the individual THz technologies will be shown and required future developments in order to clear the road to industrial use will be discussed.

10:00 – 10:40 Uhr: KH2017-Mo-T1-02
Ort: Brauerei Keller, Gambrinus – Stube
THz channel simulation and measurement
Ke Guan[1, 2], Bile Peng[2], Sebastian Rey[2], Thomas Kuerner[2]
([1]Beijing Jiaotong University, P.R. China, [2]Technische Universität Braunschweig)

Whenever a wireless communication system is applied the first time in either a new environment or in a new frequency band, the propagation channel needs to be subject to detailed investigations. This holds also for millimeter wave (mmWave) and Terahertz (THz) communication systems. In this presentation, we first define several typical application scenarios of the future mmWave and THz communications, then describe ray-launching and ray-tracing simulators, which generate deterministic and detailed channel models. Channel measurement with a channel sounder working at 10~GHz, 60~GHz and 300~GHz are carried out in these scenarios, providing validation of the channel models. Finally, some exemplary mmWave and THz channel sounding measurements and ray-launching/tracing results are analyzed.

11:10 – 12:10 Uhr: Mo-T2
Ort: Brauerei Keller, Gambrinus – Stube
Special Session Terahertz Technology
Sitzungsleiter: Thorsten Schrader

11:10 – 11:50 Uhr: KH2017-Mo-T2-01
Ort: Brauerei Keller, Gambrinus – Stube
THz-sources and systems based on near infrared diode lasers
Martin Hofmann[1], Yinghui Hu[1], Jared Gwaro[1], Nils Surkamp[1], Benjamin Döpke[1], Carsten Brenner[1], Besher Khani[2], Andreas Stöhr[2], Bernd Sumpf[3], Andreas Klehr[3], Jörg Fricke[3]
([1]Ruhr-Universität Bochum, [2]Universität Duisburg-Essen, [3]Ferdinand-Braun-Institut für Höchstfrequenztechnik Berlin)

We give an overview of diode laser based THz systems. First, we review the most common different concepts, namely continuous wave (CW) THz generation by photomixing of two diode lasers or two-color lasers, THz time domain spectroscopy (TDS) based on mode-locked diode lasers, and quasi time domain spectroscopy (Q-TDS) based on spectrally broadband diode lasers. Then, we discuss several schemes to realize particularly compact and cost-effective THz systems: First, we introduce a CW THz system based on cost effective 1.55 µm telecom components and show its use for simple non-destructive testing applications. Then, we demonstrate an even more compact CW system based on a monolithic two-color diode laser. Finally, we show the first diode laser based TDS system based on asynchronous optical sampling (ASOPS).

11:50 – 12:10 Uhr: KH2017-Mo-T2-02
Ort: Brauerei Keller, Gambrinus – Stube
Open Questions in THz Metrology
Thomas Kleine-Ostmann (Physikalisch-Technische Bundesanstalt)

Trust in measurement results, comparability and interoperability are crucial for the development of new technologies. With the advent of THz science and technology new advanced measurement techniques have been developed that allow for insights that cannot be obtained with other methods. By now commercial systems such as spectrometers and scanners making use of THz radiation are appearing on the market and the question of the reliability of measurements becomes increasingly important. Recent intercomparisons on material parameter measurements with THz spectrometers show strong deviations between results from different laboratories. This indicates that proper sample handling and data evaluation techniques are crucial but remain unclear and that many laboratories underestimate their measurement uncertainty and are missing appropriate techniques for uncertainty assessment. A significant measurement quantity for the characterization of THz systems is the radiated power, as it relates to performance but also to safety aspects. Source-based and detector-based radiometry as a prerequisite for traceable detector calibration is still a field of active research as only few national metrology institutes can offer calibration services. Besides THz power, temporal characteristics are relevant when it comes to the characterization of ultrafast devices. Established traceability chains based on electro-optic pulse generation and waveform metrology exist when it comes to measurement of transfer functions of ultra-fast oscilloscopes and photo diodes. New techniques such as synchronous and asynchronous sampling with THz frequency combs have been developed allowing for the spectral characterization of THz sources. In contrast to this, vector network analysis is a long-established technique to measure transfer functions which has been extended to the sub-mm wave regime over the years. However, the traceability of scattering parameters in the higher waveguide bands remains unsolved as precise modeling of calibration standards used for system error correction is difficult. In this review the main approaches to establish traceability including the proper assessment of measurement uncertainties are discussed for the different measurement techniques in the THz frequency range.

15:00 – 16:40 Uhr: Mo-A1
Ort: Brauerei Keller, Gambrinus – Stube
A: Electromagnetic Metrology
Sitzungsleiter: Thorsten Schrader

15:00 – 15:20 Uhr: KH2017-Mo-A1-01
Ort: Brauerei Keller, Gambrinus – Stube
Radarbasiertes Structural Health Monitoring der Rotorblätter von Windkraftanlagen
Christoph Will[1], Michael Sporer[1], Nina Sebald[1], Jonas Fuchs[1], Robert Weigel[1], Alexander Koelpin[2] ([1]Universität Erlangen-Nürnberg, [2]Brandenburgische Technische Universität)

Windkraft ist eine zentrale Stütze beim Umbau der Energieversorgung von konventionellen Technologien hin zu einer nachhaltigen und ressourcenschonenden Erzeugung elektrischer Energie. Die Leistungsfähigkeit von Windkraftanlagen wird immer weiter gesteigert, was nicht zuletzt mit größeren Anlagen, höheren Türmen und längeren Rotorblättern erreicht wird. Die Wartung dieser Anlagen ist gerade im Off-Shore-Bereich, aber auch im Binnenland mit sehr großem Aufwand verbunden. Des Weiteren muss zu jedem Zeitpunkt die Sicherheit der Anlage und der Umgebung garantiert werden, weshalb bereits viele unterschiedliche Systeme für die Überwachung von Teilkomponenten der Anlage im Einsatz sind. Die Überwachung des Betriebszustands der Rotorblätter stellt jedoch ein bisher nur unzureichend gelöstes Problem dar. Je nach Windverhältnissen kann es zu massiven Schwingungen dieser Blätter kommen, die im schlimmsten Fall sogar zur Zerstörung der Anlage führen können. Dieser Beitrag stellt ein frequenzmoduliertes Dauerstrichradar (FMCW-Radar) zur Modalanalyse der einzelnen Rotorblätter vor.
Während vergleichbare Forschungsarbeiten am Turm oder ringförmig um die Anlage verteilte Radarsysteme verwenden, wird hier ein Systemkonzept auf der Gondel vorgeschlagen. Vorteile sind die hochauflösende Erfassung des jeweiligen Blattes bei dessen Vorbeiflug unabhängig von der Ausrichtung der Gondel als auch die Einsetzbarkeit im Off-Shore-Bereich. Das entwickelte System ist ein bistatisches Dauerstrichradar mit einer Sende- und zwei Empfangsantennen, das optional um weitere Empfängersysteme erweitert werden kann. Die Auswertung der beiden Empfangssignale des Hauptsystems kann entweder individuell und unabhängig voneinander erfolgen oder aus der interferometrischen Phase. Es werden im 24-GHz-ISM-Band zulässige Frequenzrampen mit einer Bandbreite von 250 MHz und einer Chirp-Rate von einem Kilohertz generiert. Die resultierende Zieltrennung von 60 cm ermöglicht die simultane Distanzauswertung und damit einhergehende Modalanalyse an mehreren Messpunkten entlang des Rotorblatts.
Neben der Hardware soll vor allem die Messdatenaufbereitung präsentiert werden, aber auch ein Ausblick auf diverse Algorithmen zur Modalanalyse gegeben werden. Die Messungen wurden auf einer Windkraftanlage vom Typ „Vestas V112" mit einer Nabenhöhe von 140 m und einer Rotorblattlänge von etwa 55 m durchgeführt. Im Rahmen eines mehrtätigen Feldtests unter normalen Betriebsbedingungen wurden Messdaten aufgezeichnet und ausgewertet. Die Messdatenaufbereitung zur Extraktion der Nutzdaten gliedert sich in mehrere Schritte. Zunächst müssen die einzelnen Rotorblätter detektiert und segmentiert werden. Anschließend werden mittels der schnellen Fourier-Transformation (FFT) die FMCW-Rohdaten in distanzabhängige Phasenwerte konvertiert. Diese können nun sowohl zur Generierung der interferometrischen Phase als auch durch sogenanntes „Unwrapping" zur Berechnung von Distanzwerten verwendet werden. Diese Distanzwerte weisen für alle Messpunkte entlang des Rotorblatts einen typischen, durch Annäherung und Entfernung verursachten, parabolischen Verlauf auf. Simulationen eines punktförmigen Ziels bestätigen diesen Verlauf und damit die Funktionsfähigkeit des Radarsensors. Aufgrund der Form der Rotorblätter ergeben sich für jeden Messpunkt individuelle Parabelverläufe, weshalb jeder Messpunkt hinsichtlich der Nutzdatenextraktion per Parabelschätzung gesondert betrachtet werden muss. Die extrahierten Nutzdaten können nun mit verschiedenen Algorithmen auf ihre enthaltenen Moden hin analysiert werden.

15:20 – 15:40 Uhr: KH2017-Mo-A1-02
Ort: Brauerei Keller, Gambrinus – Stube
Measurement Uncertainty of Radiated Electromagnetic Emissions in In-Situ Tests of Wind Energy Conversion Systems
Sebastian Koj[1], Axel Hoffmann[1], Heyno Garbe[1] ([1]Leibniz Universität Hannover)

In order to meet the goal of the 2015 Paris agreement, the reduction of carbon dioxide emissions is a movement towards power generation systems with renewable energy sources instead of fossil ones [1]. One approach is to operate wind energy conversion systems (WECS). Like all other industrial, scientific and medical (ISM) devices, WECS must be assessed and evaluated regarding their radiated electromagnetic (EM) emissions based on international standards [2]. Due to their geometrical size, WECS cannot simply be installed and tested at a defined test site, such as an open area test site (OATS). Instead they need to be tested in-situ. The problem is,

that for an equipment under test (EUT), evaluated in-situ only, the compliance with the standards can be proven for this specific EUT, but not for the whole production series. In order to reduce the effort and costs, it is always aimed for a series release. However, a series release is only possible with the knowledge of the measurement uncertainty, determined according to the "Guide to the Expression of Uncertainty in Measurement" (GUM) [3]. The measurement uncertainty for in-situ tests of WECS is not specified yet. One approach to deal with this problem is to analyze the aspects of measurement uncertainty on OATS, given by the international standards, in the first phase, and evaluate them on their transferability to in-situ. This leads to two main emphases: the deflection of the antenna through wind velocity, and the reflection of EM waves on different grounds. In the second phase, simulations are set-up to evaluate these aspects in particular.
For the deflection of the antenna tripod, caused by wind, adapted dipoles will be simulated under different tilting angles in a plain wave field and the antenna foot point voltage, which directly relates to the EM field, will be observed. By calculating the force needed to tilt a common antenna tripod to a certain angle, the relation between wind velocity and the deviation of the EM field will be established. The EM field of the tilted antenna and the not tilted antenna will be compared and the impact on the measurement uncertainty will be discussed. Secondly, the reflection of the EM waves on different grounds will be evaluated. Especially the extremes in texture - sand and clay - and moisture will be taken into account. Therefore, a simple model of a WECS will be simulated above infinite extended ground with different EM characteristics. The observed EM fields will be compared to the EM field of a WECS above infinite perfect electric ground and the impact on the uncertainty will be discussed. Thanks to the achievements made in this contribution it is possible to determine the measurement uncertainty of radiated EM emissions during WECS evaluation.

[1] UN/FCCC/CP/2015/L.9/Rev.1: Adoption of the Paris Agreement, Paris, 30 November to 11 December 2015
[2] IEC/CISPR 11:2015, Industrial, scientific and medical equipment - Radiofrequency disturbance characteristics - Limits and methods of measurement
[3] JCGM 100:2008: Evaluation of measurement data - Guide to the expression of uncertainty in measurement

15:40 – 16:00 Uhr: KH2017-Mo-A1-03
Ort: Brauerei Keller, Gambrinus – Stube
Hochaufgelöste Messungen des Signal-in-Space von Anflugradaren sowie von Windprofilern des DWD
Thorsten Schrader[1], Jochen Bredemeyer[2], Christoph Stupperich[3], Heyno Garbe[4] ([1]Physikalisch-Technische Bundesanstalt, [2]FCS Flight Calibration Services GmbH, [3]steep GmbH, [4]Leibniz Universität Hannover)

Als Folge der politisch beschlossenen Energiewende in der Bundesrepublik Deutschland nimmt der Ausbau regenerativer Energielieferanten wie z.B. der Windenergie on- und off-shore stark zu. Die ausgewiesenen Windvorranggebiete werden bevorzugt entweder für Neubauprojekte von Windenergieanlagen (WEA) oder auch für Repowering (Austausch kleinerer Anlagen durch solche mit höheren Türmen, größeren Rotoren und daher größerer Leistung) genutzt. In vielen Fällen konkurrieren jedoch geplante Bauvorhaben von WEA mit den terrestrischen Navigationsanlagen (Drehfunkfeuer, VOR/D-VOR) sowie Radaranlagen der militärischen Luftraumüberwachung, der zivilen Flugführung sowie des Deutschen Wetterdienstes. Bisher wurden zur Abschätzung der Beeinträchtigung und der Standortanalyse Gutachten beauftragt, die jedoch weitgehend auf numerischen Simulationen beruhen. Die technisch notwendigen Vereinfachungen bei der numerischen Analyse sind dabei jedoch nicht immer zulässig, mindestens jedoch kritisch für eine sichere Aussage. Eine messtechnische Validierung fehlt bisher vollständig. Ziel muss es sein, einerseits sowohl den Ausbau von WEA zu unterstützen, andererseits aber auch die notwendige Funktionalität der sicherheitsrelevanten Anlagen sicherzustellen.
Das Projekt WERAN (Wechselwirkung von Windenergieanlagen mit terrestrischer Navigation/Radar) setzt genau dort an, diese bisher bestehende Lücke zu schließen. Der innovative Ansatz dieses Projektes besteht darin, das komplexe Problem der elektromagnetischen Wechselwirkung von WEA und Radar-/terrestrischen Navigationsanlagen in messtechnisch erfassbare Zwischenschritte aufzuteilen und nur physikalische, objektiv bestimmbare Größen zu vergleichen. Dazu wird zunächst der lineare Übertragungskanal der verschiedenen Systeme durch neuentwickelte Messtechnik charakterisiert. Anhand des veränderten Signalinhaltes lassen sich dann in der nicht-linearen Signalverarbeitung Aussagen über das tatsächliche Störverhalten von WEA treffen. Die Betreiber der Systeme müssen letztlich entscheiden, welche Störungen sie operationell tolerieren können. Nachdem in 2016 über Messungen an Drehfunkfeuern berichtet wurde, werden nun Ergebnisse von Anflugradaren sowie von Windprofilern des Deutschen Wetterdienstes vorgestellt.

16:00 – 16:20 Uhr: KH2017-Mo-A1-04
Ort: Brauerei Keller, Gambrinus – Stube
Kalibrierung eines C-Band FMCW-Radars.
Karsten Schubert[1], Jens Werner[1], Fabian Schwartau[2]
([1]Jade Hochschule, [2]Technische Universität Braunschweig)

Einleitung (Motivation/Problemstellung) Im Zuge der Energiewende werden eine Vielzahl von Windenergieanlagen (WEA) errichtet. Im Rahmen des Genehmigungsverfahrens muss dabei im Vorfeld sichergestellt werden, dass weder Flug- noch Wetterradarsysteme gestört werden, damit die hoheitlichen Aufgaben der deutschen Flugsicherung bzw. des Deutschen Wetterdienstes ordnungsgemäß erfüllt werden können. Die derzeit verwendeten Simulationsmodelle, die für Genehmigungsverfahren eingesetzt werden, beruhen auf zahlreichen Annahmen, die bislang nicht messtechnisch verifiziert wurden. Die potentielle Störwirkung von WEA auf Radarsysteme kann somit nicht exakt vorhergesagt werden. Für Genehmigungsverfahren ist jedoch eine zuverlässige Vorhersage aus o.g. Gründen zwingend erforderlich. Es besteht somit ein erhebliches Interesse, zuverlässige Vorhersagemodelle zu entwickeln, die messtechnisch fundiert untermauert sind.
C-Band Versuchsradar Fernziel ist es, die Auswirkungen von WEA auf C-Band (5,6 GHz) Niederschlagsradare messtechnisch näher zu untersuchen. Hierfür wird an der Jade Hochschule ein experimenteller FMCW-Radar entwickelt. Vorteil dieser Eigenentwicklung sind die flexiblen Anpassmöglichkeiten an die jeweilige Messumgebung. So kann beispielsweise in unmittelbarer Umgebung eines Windparks eine Antenne mit großem Öffnungswinkel (kleiner Gewinn) eingesetzt werden um mehrere WEA gleichzeitig zu untersuchen. Ferner können hierbei auch die Wechselwirkungen zwischen den Anlagen (Abschattung, Mehrfachreflexion) untersucht werden. Genauso ist es allerdings auch möglich, durch den Einsatz einer Antenne mir kleinem Öffnungswinkel (hoher Gewinn) gezielt einzelne Teile einer WEA (beispielsweise nur die Rotorblätter) zu untersuchen.
Um nicht nur eine qualitative Aussage über das Rückstreuverhalten des gewählten Scenarios treffen zu können ist eine Systemkalibrierung erforderlich. Hierfür wird ein Objekt mit definiertem Radarquerschnitt benötigt. Besonders geeignet sind hierfür Objekte, bei denen sich der Radarquerschnitt analytisch bestimmen lässt wie beispielsweise eine perfekt leitende Kugel oder ein Winkelreflektor. Für praktische Kalibrierzwecke wird eine 38 cm große Edelstahlkugel verwendet.
Kalibrieraufbau Der Kalibrieraufbau besteht im wesentlichem aus dem Versuchsradar und der 38 cm Edelstahlkugel. Das Hauptproblem besteht darin, die Kugel in einigen Hundert Metern Entfernung und einigen Zehn Meter Höhe aufzuhängen. Gleichzeitig sollte der Aufhängungspunkt selbst nicht oder nur schwach reflektierend sein. Ferner sollte sich die Position des Referenzobjektes während des Kalibriervorgangs nicht ändern. Die eben genannten Anforderungen machen die Systemkalibrierung zu einem nicht trivialen Problem. Für erste Kalibrierungen werden Messungen in einer Halle durchgeführt. Dieses hat zum einen den Vorteil, dass mechanische Aufhänge Punkte vorhanden sind und zum anderen absolute Windstille herrscht. Durch die Hallenwände ergeben sich wiederum parasitiere reflektierende Flächen. Bei der Wahl der Messanordnung muss von daher darauf geachtet werden, dass alle parasitären Reflationen möglichst schwach sind und räumlich soweit entfernt sind, dass sie vom Radar bedingt durch Laufzeitunterschiede aufgelöst werden können.
Der finale Artikel beschreibt den Messaufbau und die Grenzen dieses Verfahrens. Ferner werden zum Vergleich Messungen mit einem kommerziellen Netzwerkanalysator vorgestellt. Abschließend werden weitere Vergleichsmessungen vorgestellt und die Messunsicherheit diskutiert.
Ausblick Diese Arbeit wird im Rahmen des Jade2Pro Promotionsprogrammes an der Jade Hochschule Wilhelmshaven durchgeführt. Das langfristige Ziel ist, ein statistisches Modell zur Vorhersage der Beeinflussung des Wetterradars durch WEA zu entwickeln. Dabei wird u.a. mit der PTB als Projektkoordinator der WERAN-Studie zusammengearbeitet.

16:20 – 16:40 Uhr: KH2017-Mo-A1-05
Ort: Brauerei Keller, Gambrinus – Stube
Hardware-beschleunigte eingebettete SAR-Prozessoren für Echtzeit FMCW-Radar Anwendungen
Jonas Wagner[1], Jan Barowski[1], Tobias Kalb[1], Diana Goehringer[2], Ilona Rolfes[3]
([1]Ruhr-Universität Bochum, [2]Technische Universität Dresden, [3]Ruhr-Universität Bochum)

Auf Basis des synthetischen Apertur-Radars (SAR) können aus einer Vielzahl von Entfernungsmessungen, die ein Radar zur Verfügung stellt, Informationen über die genaue Position und die geometrische Form betrachteter Ziele errechnet werden. Somit können zwei- oder dreidimensionale Darstellungen der Umgebung erstellt werden. Die bekannteste SAR-Anwendung ist die hochauflösende dreidimensionale Vermessung ganzer Landstriche, die von Satelliten oder Flugzeugen aus erfolgt. Andere Systeme sind auf die Anwendung in kleineren Dimensionen spezialisiert und werden beispielsweise für Sicherheitsüberprüfungen von Briefen, Paketen oder Flugpassagieren eingesetzt. In diesem Beitrag wird für die Implementierung eines

zweidimensionalen Radar-Bildgebungs-Algorithmus ein eingebettetes System genutzt. Derartige Systeme sind einerseits räumlich deutlich kompakter als gewöhnliche Computer, andererseits können Programme meist als gemischte Hardware-Software-Ausführung auf das jeweils verwendete System angepasst und hinsichtlich Durchführungszeit und Leistungsaufnahme optimiert werden. Mit diesen Eigenschaften sind eingebettete Systeme insbesondere für mobile SAR-Systeme (z.B. auf Drohnen oder in Handheld-Geräten) interessant.
Der verwendete Aufbau besteht aus einer Metallschiene, auf der ein Schlitten verfahren werden kann. Zusätzlich zum Radarsensor, welcher die Bilddaten aufnimmt, ist ein weiterer Sensor auf den Schlitten montiert, welcher die Position auf der Schiene jederzeit hochgenau bestimmen kann, indem er den Abstand zu einer Metallwand am Ende der Schiene misst. Dazu wird das Maximum des Betragsspektrums dieses Positionsradars bestimmt. Die hierfür notwendige FFT kann effizient in der Hardware ausgeführt werden. Für eine höhere Genauigkeit wird ein quadratischer Fit angewendet. Diese Positionsbestimmung ermöglicht es, den Bild-Sensor auf der Schiene in einer Dimension frei zu bewegen, da die aufgenommenen Daten bei genau bekannter Position korrekt zu einem Bild verrechnet werden können.
Da der Bildgebungs-Prozess in Echtzeit (≥ 20 Bilder/Sekunde) dargestellt werden soll, wird für die notwendige Kompression in Range-Richtung eine effiziente Hardware-FFT genutzt. Anschließend muss für jeden Bildpunkt der Abstand zwischen diesem und der aktuellen Position des Sensors berechnet und die entsprechende Phasenänderung kompensiert werden, um die Messung auf den Bildbereich zu projizieren. Diese Verarbeitung wird als Rückprojektions-Algorithmus bezeichnet. Da dieser auf ein großes Array angewendet wird (hier wird eine Bildgröße von 140751 Bildpunkten verwendet), kann durch Anwendung einer Befehls-Pipeline eine erhebliche Beschleunigung erzielt werden. Je nach verwendetem Interpolations-Verfahren bei der Projektion sind so 86 bis 107 Messungen pro Sekunde durchführbar. Zur Visualisierung werden die Daten über eine Netzwerkschnittstelle an einen PC gesendet.

09:20 – 10:40 Uhr: Mo-E1
Ort: Brauerei Keller, Tagungsraum
E: Electromagnetic Environment and Interference
Titel: EMV komplexer Systeme
Sitzungsleiter: Sergey Tkachenko

09:20 – 09:40 Uhr: KH2017-Mo-E1-01
Ort: Brauerei Keller, Tagungsraum
Automotive Radar Interference and Protection in Autonomous Driving Applications
Hans-Ludwig Bloecher[1], Juergen Dickmann[1]
([1]Daimler AG)

Radar will be a key component in highly robust and reliable environment sensing systems for highly automated and autonomous driving. Due to the application of automotive radar technology in non-automotive applications and the increasing number of vehicles equipped with radar, the need of protecting automotive radar against these interference sources becomes important. This contribution provides, from the OEMs point-of-view, a brief compilation of the present situation and its boundary conditions, and addresses probable technical and non-technical countermeasures.

09:40 – 10:00 Uhr: KH2017-Mo-E1-02
Ort: Brauerei Keller, Tagungsraum
Using the EMT to Analyze the Coupling Behavior of Transient Signals into Proper Volumes of Real Systems
Sven Fisahn[1], Sebastian Koj[1], Heyno Garbe[1]
([1]Leibniz Universität Hannover)

Modern electronic systems should be highly reliable against various types of electromagnetic interferences in order to avoid malfunctions, which could lead to unexpected consequences if the functionality of such a system is critical to security. Thus, the knowledge of the system reliability is of a great interest. Due to the complexity of a modern electronic system with many individual components and interconnections, it is almost impossible to solve this problem analytically as a whole. The complexity of this task increases further, since the enclosure of the overall system as well as possible existing enclosures or housings of individual subsystems and components have to be taken into account, too. One approach to deal with this problem is the application of the zone concept respectively its formal description called electromagnetic topology (EMT) [1] to a given system, in order to analyze and estimate its reliability. Therefore, the space occupied by the system is divided into individual volumes, which are surrounded by surfaces (volume/surface topology). All interactions between these

volumes are described by an interaction graph (interaction sequence diagram). Both, the volume/surface topology as well as the related interaction graph form a so called topological model. In many cases, this qualitative description is sufficient in order to estimate the reliability of an electronic system against electromagnetic interferences (EMI). However, for a quantitative consideration the interaction graph can be transferred into a general matrix equation, which is a form of the Baum-Liu-Tesche (BLT) equation. Furthermore, a suitable quantitative description for the volume/surface topology has also to be found, but is a more sophisticated task. Since the individual volumes can form unwanted respectively parasitic cavity resonators, especially if they are surrounded by surfaces with a high electric shielding effectiveness (proper surfaces), it seems to be reasonable to characterize these volumes by the typical physical quantities of a cavity resonator. These quantities are the resonant frequencies f and the corresponding quality factors Q.
In this contribution, the coupling behavior of transient signals into a proper volume of real electronic system will be examined by means of a generic microcontroller board [2] within a metallic enclosure of cylindrical and longitudinal shape (hollow cylinder). Therefore, the principles of the EMT will be introduced in order to enable setting up a topological model of the investigated system. By means of this topological model, the resonance behavior of the enclosure will be investigated by analytical and numerical methods as well as by measurements. Particular attention will be paid to the proper volume´s quality factor Q, which includes four different contributions of losses (currents inside the cavity walls, aperture radiation, loading with absorbing materials and antennas/sensors for field monitoring inside the cavity). Since a previous investigation [2] pointed out that the aperture size affects the shielding effectiveness of a cubical metallic enclosure and the reliability of a microcontroller board located inside this enclosure, the influence of the aperture size to the reliability of the given real system is investigated.

[1] C. E. Baum, "Electromagnetic topology: "A formal approach to the analysis and design of complex electronic systems", 4th International Zurich Symposium on Electromagnetic Compatibility, 1981.
[2] S. Fisahn, H. Garbe: "Unterschiedliches Einkoppelverhalten von (N)EMP- und UWB-Impulsen in kurze Leiterbahnen", Internationale Fachmesse und Kongress für Elektromagnetische Verträglichkeit (EMV Düsseldorf), 2010
[3] H. Herlemann, S. Fisahn, M.Koch and H.Garbe: "Effects of Shielding Enclosures on the Breakdown Failure Rate of Electronic Equipment", 8th International Symposium on Electromagnetic Compatibility (EMC Europe), 2008

10:00 – 10:20 Uhr: KH2017-Mo-E1-03
Ort: Brauerei Keller, Tagungsraum
Einfluss eines elektrisch nichtleitenden Kühlkörpers für Leistungshalbleiter auf die Störaussendung
Stephan Chromy[1], Sebastian Fahlbusch[1], Kai Rathjen[1], Klaus Hoffmann[1], Stefan Dickmann[1]
([1]Helmut-Schmidt-Universität Hamburg)

Leistungshalbleiter finden im Zuge der aktuellen technischen Entwicklung immer weitere Verbreitung. Auch werden immer höhere Schaltfrequenzen und steilere Schaltflanken realisiert, sodass Störaussendungen zunehmen und höhere Frequenzen erreichen. Am Beispiel von Siliziumkarbid-Leistungs-MOSFETs (SiC-MOSFETs) mit Schaltflanken von weit über 30 V/ns bei einer Schaltfrequenz von bis zu 1 MHz wird deutlich, dass unter dem Aspekt der EMV Frequenzen bis mindestens 1 GHz berücksichtigt werden müssen. Insbesondere beim Schalten hoher elektrischer Leistungen ist eine Kühlung der Leistungshalbleiter zwingend erforderlich. Die hierzu verwendeten Kühlkörper befinden sich räumlich in unmittelbarer Nähe zum Leistungshalbleiter. Typischerweise werden Kühlkörper aufgrund der guten Wärmeleitung und einfachen Bearbeitbarkeit aus Aluminium gefertigt, die allerdings gut elektrisch leitfähig sind. Trotz einer dünnen elektrischen Isolierung zwischen Leistungshalbleiter und Kühlkörper, häufig „Thermal Interface Material" (TIM) genannt, können über die daraus resultierende kapazitive Kopplung Spannungsflanken vom Leistungshalbleiter auf den Kühlkörper übertragen werden. Auf diese Weise wirkt der Kühlkörper als Antenne und führt zu höheren gestrahlten Störaussendungen. Weiterhin kommt es bei der Verwendung eines geerdeten Kühlkörpers zu Gleichtaktströmen, welche die EMV-Problematik zusätzlich verstärken. Eine potentielle Möglichkeit die Störaussendungen zu verringern und gleichzeitig die Notwendigkeit einer Erdung hinfällig zu machen, ist die Verwendung eines Materials für den Kühlkörper, welches eine gute Wärmeleitfähigkeit aber dabei ebenso einen sehr hohen spezifischen Widerstand besitzt. In dieser Arbeit wird der Einfluss eines Kühlkörpers aus der Sinterkeramik Aluminiumnitrid (AlN) in Verbindung mit einem TO-247-Gehäuse, wie es sehr häufig auch für Leistungshalbleiter eingesetzt wird, auf die Störaussendung untersucht. Das verwendete AlN besitzt eine Wärmeleitfähigkeit von 180 W/(m K) (zum Vergleich: Aluminium 236 W/(m K)) und einen spezifischen Widerstand von mehr als 5E10 Ohm m. Zur Einordnung der Messergebnisse wird neben dem Kühlkörper aus AlN ebenso ein Kühlkörper gleicher Geometrie aus Aluminium betrachtet. Beide Kühlkörper sind für die Verwendung mit einer Wasserkühlung konzipiert. In einer Messung hinsichtlich der thermischen Leistungsfähigkeit konnte zunächst gezeigt werden, dass der thermische Widerstand des AlN-Kühlkörpers auf

dem Niveau des Aluminium-Kühlkörpers liegt. Da bei der Verwendung des AlN-Kühlkörpers zusätzlich keine Notwendigkeit für eine Isolierung zwischen dem TO-Gehäuse und dem Kühlkörper besteht, weist das Gesamtsystem sogar einen leicht niedrigeren Wärmewiderstand im Vergleich zum Aluminium-Kühlkörper mit elektrischer Isolierung auf. Weiterhin wurden Messungen in einer Absorberkammer hinsichtlich der S11- und S21-Parameter durchgeführt. Für die Messung der S21-Parameter wurde einer Log-Per-Antenne verwendet. Zusätzlich zum Experiment wurde eine Simulation des Aufbaus mit der FIT-Methode durchgeführt. Dies ermöglicht die Betrachtung des elektrischen Feldes in weiteren Ausrichtungen von Antenne und DUT, welche in der verfügbaren Absorberkammer nicht realisierbar sind. Der Aluminiumkühlkörper wurde sowohl geerdet als auch ohne Erdung (floating) vermessen. Es konnte gezeigt werden, dass im Frequenzbereich von 30 MHz bis 1 GHz die Verwendung des AlN-Kühlkörpers im Vergleich zu einem nicht geerdeten Aluminium-Kühlkörper zu einer Verringerung der Abstrahlung führt. Im Vergleich zu dem geerdeten Aluminium-Kühlkörper wurde mit dem AlN-Kühlkörper eine leicht höhere Abstrahlung gemessen.

10:20 – 10:40 Uhr: KH2017-Mo-E1-04
Ort: Brauerei Keller, Tagungsraum
Konstruktive Anpassung charakteristischer Größen einer Modenverwirbelungskammer für EMV-Tests und zur Leistungsspektroskopie
Claas Hendrik Schlie[1], Marco Rozgic[1], Michael Dudzinski[1], Ines Barbary[1], Lars Ole Fichte[1], Jens Storjohann[1], Robert Hollan[1], Stefan Potthast[2], Julia Schiffner[3], Martin Schaarschmidt[2], Frank Sabath[2], Marcus Stiemer[1]
([1]Helmut-Schmidt-Universität Hamburg, [2]Wehrwissenschaftliches Institut für Schutztechnologien - ABC-Schutz, [3]Heinrich Heine Universität Düsseldorf)

Dieser Vortrag berichtet über den aktuellen Forschungsstand eines Projektes, welches den Aufbau einer Wissensbasis zum Ziel hat, mit der der Einfluss einzelner konstruktiver Details einer Modenverwirbelungskammer (MVK) auf ihre Leistungsfähigkeit im jeweils gewünschten Einsatzbereich abgeschätzt werden kann. Zu den untersuchten Einsatzbereichen zählen neben den klassischen EMV-Anwendungen (wie Immunitäts-, Emissions- und Schirmdämpfungs-Tests) auch die Verwendung der MVK für leistungsspektroskopische Messungen.
Die mit einer MVK durchgeführten Leistungsspektroskopie-Messungen haben das Ziel, berührungslos elektrotechnische Eigenschaften eines unbekannten Bauteils zu bestimmen, z.B. Resonanzfrequenzen, absorbierte Leistung und zugehörige Dämpfung. Bei dem Verfahren der Leistungsspektroskopie werden in Abhängigkeit von der Anregungsfrequenz die effektiv absorbierten Wirkleistungen einer leeren Kammer und einer mit einem Prüfling (Device Under Test, DUT) beladenen MVK bestimmt und erstere von letzterer subtrahiert. So kann die in dem DUT einkoppelnde frequenzabhängige Leistung ermittelt werden. Mit diesem Verfahren kann bei Untersuchungen auf elektromagnetische Verträglichkeit (EMV) eine erhebliche Zeit- und somit auch Kostenersparnis erzielt werden, denn durch die Identifikation der kritischen Koppelfrequenzen reduziert sich die Anzahl der zu untersuchenden Frequenzen auf die mit dem Verfahren identifizierten Frequenzen.
Im Prüfvolumen der MVK werden Ensembles elektrischer Felder erzeugt, deren statistische Verteilung durch eine Geometrievariation der MVK, z.B. mit einem sich drehenden Stirrer, hervorgerufen wird. Diese sind bezüglich Feldrichtung und Polarisation idealerweise im statistischen Mittel gleichverteilt. Im Idealfall ist zudem die Amplitude des gemittelten Feldes im Prüfvolumen der MVK räumlich konstant. Zudem erhalten die erzeugten Felder alle kritischen Feldparameter, insbesondere auch den den „Worst-Case". Somit ist es nicht notwendig, die Position oder Orientierung eines DUTs zu variieren.
Die Qualität der Approximation einer idealen MVK durch eine reale MVK hängt von einer Vielzahl von Parametern, z.B. Kammermaterial, Wandeigenschaften, Stirrermaterialien und -geometrie, verwendeten Antennen sowie ihrer Position und Ausrichtung, Konstruktion und Materialien des Systems zur Positionierung eines DUTs, der Qualität von HF-Dichtungen und HF-Anschlüssen, aber auch den Betriebsparametern. Im Rahmen des Forschungsprojektes werden unter anderem selbst erstellte Dipole (mit definierten Empfangseigenschaften) und industriell gefertigte RFIDs auf ihre kritischen Koppelfrequenzen hin untersucht. Anhand der Messergebnisse sind dann Rückschlüsse auf konstruktive und messtechnische Verbesserungen des Verfahrens möglich.
Zur Beurteilung konstruktiver Details bedarf es geeigneter Messgrößen, die die anwendungsspezifische Leistungsfähigkeit einer MVK charakterisieren: Von genereller Bedeutung ist z.B. die Feldhomogenität im Testvolumen, quantifiziert durch die räumliche Varianz über alle Stirrerpositionen gemittelter Felder (oder, je nach Anwendung, auch Feldmaxima). Weitere charakteristische Messgrößen sind die absorbierte Wirkleistung der MVK für verschiedene Kammerkonstruktionen und die elektrische Güte der Kammer, die den eingestellten „Trade-off" zwischen hohen Feldstärken und guten Gleichverteilungseigenschaften charakterisiert.
Um diese Parameter zu untersuchen, werden im Rahmen dieses Forschungsprojektes Messtechniken und Messaufbauten entwickelt, die den Einfluss der Variation dieser Parameter erfassen können. Unter anderem wird ein automatisiertes 3D-Positioniersystem entwickelt, welches komplett aus Materialen mit einer niedrigen

Dielektrizitätskonstante gefertigt wird, damit es die im Inneren des Prüfvolumens erzeugten Felder nicht beeinflusst. Dieses 3D-Positioniersystem soll unter anderem zur Untersuchung der Feldhomogenität im Prüfvolumen eingesetzt werden, da es aufgrund der Automatisierung in der Lage ist, eine große Anzahl von Raumpositionen zu vermessen, und so sowohl statistisch valide Verteilungsaussagen als auch einen Vergleich mit Simulationsergebnissen ermöglicht.

11:10 – 12:30 Uhr: Mo-E2
Ort: Brauerei Keller, Tagungsraum
E: Electromagnetic Environment and Interference
Titel: EMV Modellierung und Analyse
Sitzungsleiter: Marcus Stiemer

11:10 – 11:30 Uhr: KH2017-Mo-E2-01
Ort: Brauerei Keller, Tagungsraum
Simulation based analysis of electric field distributions in small reverberation chambers
Ines Barbary[1], Julia Schiffner[2], Marco Rozgic[1], Claas Hendrik Schlie[1], Michael Hagel[1], Marcus Stiemer[1]
([1]Helmut Schmidt Universität Hamburg, [2]Heinrich Heine Universität Düsseldorf)

Small electromagnetic reverberation chambers (ERCs) are used as test environments for electromagnetic compatibility (EMC) tests. Due to their small size and low operational costs compared to other EMC environments such as the open area test side or anechoic chambers, they are interesting for all sorts of tests on smaller devices under test (DUTs), as soon as the frequencies of interest are sufficiently high for an ERC. Using the changes in the chamber's geometry (here with the help of a rotating mode stirrer) the electromagnetic fields inside the chamber are altered with respect to all possible directions and polarizations, thus DUTs need not be moved manually.
The focus of this work is the characterization of statistical properties of electromagnetic fields inside ERCs by means of simulation. Simulations allow for observation of real and imaginary parts of the cartesian field components in their representation of a standing wave, which is difficult or impossible to achieve experimentally. By generating a plethora of simulated field data a very thorough statistical analysis can be performed.
A model ERC was simulated with a boundary element method (BEM) using the software Protheus developed by AIRBUS Defence and Space. Protheus solves the electric field integral equation utilizing a fast multilevel multipole method. To incorporate Ohmic losses at the chamber walls Leontovich type boundary conditions (BCs) have been employed. It is well known that if these BCs are used the conductivity of the chamber material has to be exchanged by a fitted, but not physically realistic, material parameter to adjust the damping of the modelled ERC correctly. Here, we present an alternative method exploiting perfectly electrically conducting (PEC) BCs and a subsequent outlier removal strategy to mimic Ohmic losses. Hence, fields with statistically favorable properties can be reproduced.
Additionally we introduce a statistical analysis framework allowing for the characterization of measured and simulated electromagnetic fields inside ERCs. We focus on the determination of the lowest usable frequency (LUF) via statistical distribution analysis. From a technological point of view it is desirable to identify the frequency at which the fields inside the ERC leave the under-moded state and enter the over-moded state, where the desired field distribution is achieved. Current industrial standards propose several notions to characterize the LUF: via a particular Eigenmode (usually the 60th), as three times the base mode frequency, or as the first frequency, for which field homogeneity can be established to a certain degree in the working volume. However, experimental results suggest that the transition to the over-moded state arises at significantly higher frequencies. In this novel approach the transition from under-moded to over-moded state is analyzed by statistical means. The over-moded state is reached once the distribution of the absolute values of each individual field component has changed from a Weibull distribution with a shape parameter clearly below 2 to a Weibull distribution with a shape parameter of 2. The latter is identical with a Rayleigh distribution.

11:30 – 11:50 Uhr: KH2017-Mo-E2-02
Ort: Brauerei Keller, Tagungsraum
Die Dedekind-Antenne, ein neuer Antennentyp für MVKs
Jens Storjohann[1], Marcus Stiemer[1], Carl Friedrich Rädel[1], Kai Rathjen[1]
([1]Helmut Schmidt Universität Hamburg)

Selbst-komplementäre Antennen haben, wie von Mushiake beschrieben, im Idealfall einen frequenzunabhängigen Fußpunktwiderstand. Man findet in der mathematischen Literatur im Zusammenhang mit doppelt- periodischen Funktionen einer komplexen Variablen Schwarz-Weiß-Einfärbungen ("tesselations") der komplexen oberen Halb-Ebene, die die Eigenschaft der Selbst-Komplementarität haben. Diese Einfärbungen entstehen aus der Betrachtung einer mathematischen Transformationsgruppe (Modulgruppe), die nur zwei erzeugende Elemente hat, nämlich eine Spiegelung am Einheitskreis mit Vorzeichenwechsel und eine Translation. Es werden Teilbereiche der Ebene gewählt und Flach-Antennen definiert, deren leitfähige Bereiche durch Anwendung oben genannter Transformationen eines „Originalbildes" erzeugt werden. Dieses Originalbild ist in der Sprache der Gruppentheorie ein Fundamentalbereich oder ein Teil davon. Die so erzeugten Antennen sind vergleichbar mit Patch-Antennen oder fraktalen Antennen. Die Antennen sind ideal betrachtet periodisch, in Realität aber endlich. Die Begrenzung auf einen endlichen Bereich wird systematisch durchgeführt durch Kombinationen von Transformationen mit endlich vielen Verschiebungen und allen dazu sinnvollen Spiegelungen, deren Anzahl begrenzt ist. Sie werden simuliert, aufgebaut und getestet. Ziel ist, für MVK's geeignete Sende- und Empfangs-Antennen zu erhalten, die einen konstanten Fußpunktwiderstand, d. h. einen geringen Reflexionsfaktor mit einer „chaotischen" Richtcharakteristik, wie sie für den Einsatz in einer Modenverwirbelungskammer zweckmäßig erscheint, vereinen. Hierdurch soll bei gegebener Größe der MVK eine niedrige LUF erhalten werden.

11:50 – 12:10 Uhr: KH2017-Mo-E2-03
Ort: Brauerei Keller, Tagungsraum
A full wave description for thin wire structures with TLST and perturbation theory
Fabian Ossevorth[1], Ralf Jacobs[1], Hans Georg Krauthäuser[1]
([1]Technische Universität Dresden)

A full wave description of a thin wire structure, that includes mutual interactions and radiation, can be obtained in closed form with the so-called Transmission Line Super Theory (TLST) or a perturbation method. In either method, a set of mixed potential integral equations (MPIE) is solved for the currents that propagate along the wires. The TLST is an iterative procedure, where the wire parameters like the inductance and capacitance per unit length are first determined under the assumption to be dependent upon position only. Frequency dependence is accounted for in the following iteration. With these parameters, a system of ordinary differential equations of first order with variable coefficients can be established and solved for the unknown currents with the aid of a matrizant, but the solution of the resulting system of equations is computationally extensive. In the perturbation method, the currents to be determined are initially approximated with values calculated using the conventional transmission line theory. These currents are sub- sequently employed to compute the parameters of the wire structure using the MPIE. The parameters are then used in a system of ordinary differential equations similar to the TLST to ascertain the currents on the wires. In contrast to the TLST, it is not necessary in the pertur- bation method to determine the wire parameters in a first iteration, which thus requires less computation time. The focus of this investigation is on the perturbation theory and its application to thin wire problems. A detailed description on how geometrical features of a wire structure are modelled and the resulting current distributions are determined will be provided.

12:10 – 12:30 Uhr: KH2017-Mo-E2-04
Ort: Brauerei Keller, Tagungsraum
The response of nonlinearly loaded antennas to repetitive HPEM excitations as obtained from equivalent circuit models
Devanand Palur Palanivelu[1], Frank Gronwald[1], Jiayi Hu[1], Matthias Kreitlow[2]
([1]Universität Siegen, [2] Wehrwissenschaftliches Institut für Schutztechnologien - ABC-Schutz)

Most models of Electromagnetic Compatibility (EMC) are based on linear relationships between Electromagnetic Interference (EMI) sources and victims [1,2]. It is known, however, that nonlinear effects not only modify the spectrum of the EMI source but also can considerably amplify certain parts of that spectrum, due to resonance effects [3]. While these effects have mainly be investigated for steady-state and periodic excitations, transient excitations have recently been considered in this context both from a measurement and modeling perspective [4], [5]. It has been verified that even a single transient HPEM excitation does produce

notable nonlinear effects if applied to a nonlinearly loaded receiving antenna if put in a resonating environment. This contribution extends the results of [5] to explore the possibility to amplify these effects by repetitive HPEM excitations. The analysis is based on the equivalent circuit models derived in [5] which, in turn, can either numerically be studied by SPICE models or analytically be studied on the basis of differential equations. As a general result it can be stated that due to the presence of a nonlinearity the electric energy stored in the system can be built up by repetitive pulses, thus leading to electric fields and voltages that persist in the system while the actual transient excitation already decayed. This circumstance will be illustrated by the analysis of the equivalent circuit models, SPICE models, and numerical electromagnetic field simulation in time domain.

[1] K.S.H. Lee (ed.): "EMP Interaction: Principles, Techniques, and Reference Data", revised printing, (Taylor & Francis, Washington D.C., 1995).
[2] F. M. Tesche, M. V. Ianoz, and T. Karlsson: "EMC Analysis Methods and Computational Methods" (John Wiley & Sons, New York 1997).
[3] H.G. Krauthäuser, S. Tkachenko, and J. Nitsch: "The Action of Non-Linear Effects in a Resonator", in Proc. of the XXVIIth General Assembly of the International Union of Radio Science, URSI GA 2002, Maastricht, The Netherlands, August 2002, 4 pages.
[4] M. Kotzev, M. Kreitlow, and F. Gronwald: "Transient Excitation of Nonlinearly Loaded Resonators and Observation of System Responses in Time Domain", in Proc. of EMC Europe 2016, Wroclaw, Poland, September 2016, pp. 75-78. [5] M. Kotzev, X. Bi, M. Kreitlow, and F. Gronwald: „Equivalent circuit simulation of HPEM-induced transient responses at nonlinear loads", Advances in Radio Science, vol. 15, (2017), in press.

15:00 – 17:00 Uhr: Mo-F1
Ort: Brauerei Keller, Tagungsraum
F: Wave Propagation and Remote Sensing
Sitzungsleiter: Gerd Wanielik und Madhu Chandra

15:00 – 15:20 Uhr: KH2017-Mo-F1-01
Ort: Brauerei Keller, Tagungsraum
Head tracking based driver's glance behaviour estimating for non-driving activity recognition in the context of highly automated driving
Timo Pech[1], Gerd Wanielik[1], Dominik Raeck[1], Stephan Enhuber[1], Bernhard Wandtner[2]
([1]Technische Universität Chemnitz, [2]Opel Automobile GmbH)

With the continuous development and improvement of ADAS up to highly automated driving functions, the driving task is changing. There is no need for the driver to permanently supervising automatic driving functions of SAE J3016 level 3 and 4. However, if the automated vehicle reaches its limitations, a takeover request is sent to the driver. For an optimized individual and comfortable support during the takeover, knowledge of the driver's status and behaviour is inevitable for the technical system. In relation to this, the driver's visual behaviour is an important aspect due to the significant relevance of the visual perception. In order to draw conclusions about the non-driving activity of the driver, his visual orientation to areas, which are significant for special non-driving activities, is used. To determine the viewing direction or the visual field, camera-based head- or eye-tracking systems can be used. However, the main problem of eye tracking systems is that in case of large head rotations such as shoulder glances the eyes are not detectable. Furthermore, glasses or sunglasses may cover the driver's eyes. For in-vehicle applications, mostly expensive sensor configurations are required for eye tracking. Head-mounted eye tracking systems are only suitable for driving simulator studies and not for applications in a real vehicle. Therefore, an approach was chosen that estimates the current glance area of the driver, based on the measured head position and orientation. A Bayes classifier determines the probability that the driver looks at a defined area. The required sample data for training the classifier was collected in a driving simulator study. The head tracking based glance area estimation determines the probability of the region that the driver looks at in real time with a mean accuracy of 75%. It can be shown that the visual orientation is an essential feature for recognize non-driving activities in the context of highly automated driving.

15:20 – 15:40 Uhr: KH2017-Mo-F1-02
Ort: Brauerei Keller, Tagungsraum
Estimating the driver's hand position during highly automated driving using a two dimensional occupancy grid to determine non-driving activities
Stephan Enhuber[1], Isabel Ebert[1], Timo Pech[1], Gerd Wanielik[1], Bernhard Wandtner[2]
([1]Technische Universität Chemnitz, [2]Opel Automobile GmbH)

Highly automated vehicles enable non-driving activities while off the wheel. However, referred to SAE J3016 level 3 and 4 specific situations cannot be safely managed by the automation and require to take over control back to the driver. Possible non-driving activities affect the driver's awareness and verification of a risk-free flying changeover must provide an adaptive design for an adequate Take-Over-Request. On the one hand complex tasks increase the necessary time for the driver to be prepared for manual driving after a Take-Over-Request occurs. On the other hand the warning signal indicating a Take-Over-Request must match the driver's perceptual field. That means the driver's ability for a secure takeover is strongly related to present non-driving activities and detecting them should be worth to take into account. Thus it is in the interest of research to implement a Driver Monitoring System to identify respective non-driving activities. Amongst others including the detection of the driver's hand position as it is an important feature concerning to characteristics of several non-driving activities, e.g. usage of car related devices such as the centre console or the navigation system. Therefore a two-dimensional occupancy grid based approach is presented. Applying on incoming depth data from an infrared camera, yet reliable results in scenes with static environments in the background and possible hand movement in the foreground have been achieved convenient to the vehicle interior. Regions of interest defining where the driver's interactions are taking place have been determined together with according inverse sensor models based on data of a driving simulator study with participants executing different non-driving activities. In this context performances reached a sensitivity index d' > 2 for some regions of interest. Furthermore it has been revealed as a suitable input information for a statistical classifier that is used to calculate the probabilities of specified non-driving activities in real time.

15:40 – 16:00 Uhr: KH2017-Mo-F1-03
Ort: Brauerei Keller, Tagungsraum
Polarimetric SAR Tomography for Monitoring Changes in Agricultural Crops
Hannah Joerg[1, 2], Matteo Pardini[1], Irena Hajnsek[2, 1]
([1]Deutsches Zentrum für Luft- und Raumfahrt – DLR, [2]ETH Zürich)

Synthetic Aperture Radar (SAR) measurements contain information about bio- and geophysical parameters of crops due to the sensitivity of microwaves to dielectric properties of the individual plant components and of the soil. However, for conventional (polarimetric) SAR the scattering contributions of soil and vegetation are mixed within one resolution cell and their dynamics over time cannot be analysed separately. By acquiring multi-baseline (MB) data, the variation of amplitude and phase between the acquisitions can be exploited to estimate the vertical reflectivity using tomographic SAR techniques. Hence, the ability to resolve scattering contributions at different heights enables to separately address dynamics in the soil and the vegetation. The focus of this work is to investigate in which way MB SAR data can be exploited to resolve this ambiguity of soil and plant changes as well as geometric and dielectric dynamics of the plants over time.

16:00 – 16:20 Uhr: KH2017-Mo-F1-04
Ort: Brauerei Keller, Tagungsraum
A Low-Cost Radar Target Simulator
Andreas R. Diewald
(Hochschule Trier)

Radar technology was invented in 1904 and is well-known for more than one century. Nevertheless it has mainly been used for military and air traffic over seventy years. Radar systems often were bulky (hollow waveguide plumbing) and expensive. Starting in the seventies radar has been investigated for nonmilitary application. In the nineties radar was firstly used for automotive applications like adaptive cruise control (e.g. by Toyota (1997), BMW (1998), Mercedes (1999)). Starting from that point radar technology became cheaper and easier to fabricate due to the development in semiconductor technologies and material development (RF substrates, interconnection technology, etc.) for even higher frequencies. Actually radars are also applied for industrial purposes (e.g. automation and measurement applications) and personal safety reasons (e.g. in the car interior). With increasing radar activities in the automotive, industrial and private sector there is a need to test radar sensors in their environment. The testing of a radar system is not easy. Mostly radars under test (RuT) are tested with real targets like radar reflectors, other cars, passengers, etc. These tests are often not

reproducible especially when driving around to test radar systems. A radar target simulator can help to test radar systems repeatably. The term "radar target simulator" has two meanings: 1. a software analysis tool in order to simulate the reflection on a target in a computational environment. For the software based analysis there is no need for a real radar system. The radar system must be modeled in the software. 2. a hardware tool as a device which is able to receive the transmit power of a RuT, modifies it and send it back towards the RuT so that an artificial target is detected in a predefined distance in front of the RuT. In this paper the RaTaSim means the hardware-based device and the author gives a theoretical abstract for two concepts of hardware-based radar target simulation which is missing in some actual publications. An overview of actual state-of-the-art systems is presented and a proposal how to implement such hardware as a low-cost variant is given.

16:20 – 16:40 Uhr: KH2017-Mo-F1-05
Ort: Brauerei Keller, Tagungsraum
Application of Split Ring Resonators in Design of Dual Linear Polarized Patch Antenna Arrays
Sadiq Kadhim Ahmed Aqbi[1], Madhukar Chandra[1]
([1]Technische Universität Chemnitz)

This paper describes the development and performance of several dual-linear polarized antenna element and arrays, which have been characterized extensively over the past decade for various applications, such as polarimetric synthetic aperture radar (PSAR). In order to obtain the dual polarization operation with a low cross-polarization, metamaterial structures have been adopted as a band stop characteristic and placed around each microstrip feed line or between of them. Thus, they absorb some radiation of the microstrip feed lines, therefore, suppress higher order modes and leads to improve the co-cross polarization discrimination (XPD). These designs are realized as 8*1 linear antenna array and 8*2 planar antenna array. This paper is divided into two major parts: The first is related to the design of antenna array that operates at the frequency of 5.5 GHz. In this section, the two orthogonal microstrip feed lines are loaded by split ring resonators (SRRs). The second part is connected to the design of antenna array that operates at the frequency of 10 GHz. The antenna array exhibits in this section approximately has the similar structure of the first part, except the split ring resonators, are set between two orthogonal microstrip feed lines. Additionally, a comparison is achieved between two configurations. The simulation of the dual linear polarization antenna arrays reveals that a significant improvement in their performance. The co-cross polarization discrimination of the antenna array is 31.35 and 37 dB in principle planes (E- and H- planes). The obtained peak gain has the values of 24.6 and 27.83 dB. The isolation between two orthogonal ports is -24.5 and -40 dB at boresight. Furthermore, the side lobe levels are less than -24 dB for two planar arrays, respectively. The design parameters of the antenna array are optimized using High-Frequency Structure Simulation (HFSS) software to get the high co-cross polarization discrimination, the suitable radiation patterns, and S-parameters.

16:40 – 17:00 Uhr: KH2017-Mo-F1-06
Ort: Brauerei Keller, Tagungsraum
Digital Beamforming Radar Frontend with Non-broadside Patch Antenna Arrays
Andreas R. Diewald[1], Simon Müller[1]
([1]Hochschule Trier)

Radar systems are well-known for military applications for several decades. In the automotive market radars are establishing since 20 years. But mostly radars are used in the car exterior (e.g. by companies like BOSCH, CONTINENTAL, DELPHI, TRW, etc.). In the vehicle compartment radars are not supposed to be operating. Nevertheless automotive supplier companies are investigating this technology for detection and surveillance of passengers in the car interior. The company BOSCH was investigating radar for driver's vital sign monitoring in 2005 [1]. Ten years later the company IEE presented a small radar system at 24 GHz in order to detect forgotten children on the rear bench of the vehicle interior [2]. It can be supposed that other automotive suppliers are investigating this technology for the car interior without publishing their research. The goal of this derivation is to detect the occupancy state of a rear bench with a radar system at 24 GHz. There are different mounting positions in the car interior, but one of the best would be behind the headliner of the car roof. The installation directly on the center line directly over the rear bench is not possible because a passenger sitting on the middle seat will shadow the other rear bench seats with his head. Thus the sensor must be installed a certain distance in front of the rear bench, somewhere between driver and co-driver seat. Due to the shift towards the front of the car the radiation lobe of the antenna must be tilted. One possibility is to skew the complete PCB behind the headliner thus a conventional broadside radiating patch antenna could be used. In conventional cars the space between headliner and the car roof is very small and a skewing of a PCB including

housing and radome is not possible. There is a strong need of a patch antenna array with an tilted radiation lobe which is pointing towards the rear bench when mounted completely horizontally behind the headliner in front of the rear bench. For this a novel traveling wave patch antenna at 24 GHz has been presented in [3] which is not radiating into broadside direction. The radiation maximum of the antenna is found at 30° normal to the PCB surface. In this paper the radar front end including the non-broadside patch antenna arrays is presented. In the next chapter the specification for the antenna and the radar front end is given. The following chapters show the development and measurement of the front end. In the end the front end development is concluded.

[1] Michael N. Mahler, "Radarbasierte Sensorkonzepte fuer den KfZ-Innenraum", Cuvillier Verlag Goettingen, 2005
[2] Diewald, A.R. et al., "RF-based child occupation detection in the vehicle interior," 17th International Radar Symposium (IRS), Krakow, 2016.
[3] Diewald, A. R.; Tatarinov, D. "Non-broadside Patch Antenna for Car-Interior Passenger Detection", 18th International Radar Symposium, June, 28-30, Prague, Czech Republic, 2017

09:00 – 13:20 Uhr: Di-YSA1
Ort: Altes Rathaus, Eingangshalle
Aushang der Young Scientist Award Poster
Sitzungsleiter: Ludger Klinkenbusch

KH2017-Di-YSA1-01
Ort: Altes Rathaus, Eingangshalle
Fast spherical near-field antenna measurements by advanced sampling and direct spherical wave expansion
Rasmus Cornelius[1], Dirk Heberling[1]
([1]RWTH Aachen)

Spherical near-field (SNF) antenna measurements are a well-established technique for the characterization of antenna radiation properties such as the radiation pattern. Although near-field measurements provide high accuracy, they have not completely replaced far-field measurements. The required position accuracy (≤ λ/50), the need of the phase information and the measurement duration are the main disadvantages of near-field measurement systems. In general, the measurement time is long because the near field has to be measured in a certain area around the antenna under test (AUT) - even if only a single far-field pattern point has to be determined. The measurement duration limits the throughput of an antenna measurement chamber and, thus, fast measurement techniques are desirable and have attracted many researchers.
Although measurement data on the complete sphere around the AUT is required in SNF antenna measurements, the scan area might be truncated and filled with zeros in order to reduce the measurement time. By this, information is lost which causes inaccuracies in the calculated far-field pattern. The truncation error is difficult to predict because it depends on the AUT as well as on the measurement parameters such as measurement distance and probe antenna.
The aim of this contribution is to discuss methods to reduce the measurement time without truncation. This is achieved by minimizing the acquisition path length and maximizing the scan speed along that path. The latter is usually determined by the used positioning and RF equipment. In contrast, the acquisition path length can be chosen with some degree of freedom and will be the focus of this contribution. The path length depends on the number of samples, the point distribution and the measurement trajectory.
A transformation procedure will be presented which always minimizes the required number of measurements according to the spatial bandwidth of the AUT. Further, it will be discussed that spiral scanning is advantageous in practice because the samples are well distributed and inherently lie on a simple continuous path.
By this, fast spherical near-field measurements without truncation are possible. The transformation is exact, similar to other transformation approaches, in the case of a noiseless measurement and a strictly bandlimited AUT spectrum. It is interesting to note that the proposed method is valid for every closed surface and is not restricted to spheres. The introduced spherical wave expansion is independent of the measurement geometry and, thus, offers flexibility in the design of the measurement range. For example, a hemispherical scanner could be combined with a linear scanner in order to enclose the half sphere volume. It can be expected that these flexibilities will be exploited in the future to improve new as well as existing spherical near-field antenna measurement ranges.

KH2017-Di-YSA1-02
Ort: Altes Rathaus, Eingangshalle

Where to Go from Here? New Cross Layer Techniques for LTE Turbo-Code Decoding at High Code Rates

Stefan Weithoffer[1], Norbert Wehn[1]
([1]Universität Kaiserslautern)

Today, the monthly data traffic per smartphone is expected to increase from 2.7 GB per month in 2016 to 18 GB per month in 2021 due to the widespread use of streaming video services, which creates more than 50 % of the annual mobile traffic increase. To satisfy this hunger for higher data rates, sophisiticated wireless baseband signal processing is necessary. Here, we focus on the channel decoder, which is one of the most computationally intensive parts in baseband processing and thus a major source of latency and power comsumption.
Wireless communication standards like the 3GPP Long Term Evolution (LTE) use rate compatible Turbo-Codes as channel code and adjust the transmit data rate (or code rate) r dynamically to achieve a desired Signal-to-Noise-Ratio (SNR) while keeping the transmit power P constant and maximizing the information throughput. As a result, the channel decoder has to be extremely flexible while achieving a very high throughput and a low decoding latency for large code block sizes. From the perspective of the decoder, flexibility means excellent decoding performance across a wide range of code rates and code block sizes.
Highly parallel architectures as presented in literature, achieve LTE Turbo-Code throughput requirements. However, for the high degree of parallelism which is required to fulfill the throughput demands, the individual code blocks have to be split into (small) sub-blocks, which makes additional calculations to compute estimates for the state metrics at the sub-block borders necessary in order to mitigate a degradation of the decoding performance. This, in turn, limits the maximum degree of decoder parallelism that can be achieved for a given target FER. Moreover, this effect is even more pronounced for high code rates, which are mandatory to increase the information throughput.
In this paper, we follow a cross-layer approach to increase the FER performance for a fully LTE-A Pro compatible Turbo-Code decoder hardware architecture without the need to trade off throughput against FER performance. We employ a combination of new techniques developed in our group and use synergies accross different layers of the decoding to improve the FER performance significantly accross a wide range of code block sizes and code rates.
Starting from a fully LTE-A Pro Turbo-Code decoder architecture optimized for high throughput, we demonstrate the negligible hardware overhead of improved algorithms recently proposed by our group. For that, the improved FC algorithm, which makes significant coding gains possible, is combined with a special CRC calculation scheme and hardware architecture. The resulting flexible architecture achieves state-of-the-art throughput and area efficiency numbers while having a communications performance surpassing state-of-the-art for high code rates.
To the best of our knowledge, a most advanced hardware implementation of a complete Turbo-Code decoder with the new TB and CB level techniques, which enable coding gains up to 1.8 dB compared to state-of the-art with negligible overhead, is demonstrated for the first time. Post place & route results, show the architecture to be competetive in terms of throughput (1.375 Gb/s), area (0.55mm2) and energy efficiency (0.04 nJ/bit/iter).

KH2017-Di-YSA1-03
Ort: Altes Rathaus, Eingangshalle

Simulation and Experimentally Based Analysis of the Dependence of the Quality of Environments for Antenna Calibration on Site Parameters

Ines Barbary
(Helmut-Schmidt-Universität Hamburg)

Assigning the correct value of an ambient electric field strength to the output signal of an antenna usually requires a delicate calibration process. To this end, a calibration site is required that allows for a sufficiently accurate calibration by a comparison to a well calibrated antenna. Such a comparison can only be done with sufficient accuracy if all construction parameters of the considered test site are within a certain range. Criteria for the validation of the suitability of a particular environment are given by the relevant industrial standards. Typical environments for antenna calibration include Open Area Test Sites (OATS), Full and Semi Anechoic Chambers, and Electric Reverberation Chambers (ERC), where the OATS defines the referential case since it provides the highest accuracy.
The purpose of this work is to provide methods that enable to assess to what extend the quality of a test site for antenna calibration depends on its construction parameters or other factors of influence such as necessary equipment. For a given frequency, the measurement setup can always be tuned such that measurement results are close to theoretical values, but the aim of this work is to find a unique measurement configuration permitting

to obtain accurate results for all frequencies within the considered range. To this end, two types of models are developed for the example of an OATS and used to assess the influence of its construction parameters. The two approaches comprise a full numerical simulation, which allows for an accurate evaluation of parameter influences, and a hybrid model, where part of the interaction of different components is modeled by a network approach, while the electromagnetic properties of individual components of the network are determined by simulation. Although a network approach requires additional approximations, it permits an easier assessment of the size of the influence of particular parameters and, thus, facilitates a construction of a new test site or the identification of reasons for inaccuracy.
This work mainly focuses on OATS, since they represent the referential situation. Subsequently, it is discussed, in how far the developed methods can be transferred to other test environments. The results of this work also apply to ElectroMagnetic Compatibility (EMC) tests, which use the same type of environments. Since the present EMC regulations allow for larger deviations from the underlying metrological standard than the regulations for antenna calibration, the harder case of antenna calibration is considered in this work.
To ensure that a real OATS meets the qualities required by the standard CISPR 16-1-5 (2013), the measurement equipment and all site parameters have to be arranged very carefully. Particularly, reflections at the masts and at the borders of the OATS cause severe problems for high and, respectively, small frequencies. The developed numerical simulation method allows for identification of suitable designs for antenna masts, field boundaries and other quantities such that an OATS operates within the required thresholds. With an also developed network-type model, the order of influence of different factors can easily be assessed. The models have been carefully validated by experiments.

KH2017-Di-YSA1-04
Ort: Altes Rathaus, Eingangshalle
Polarimetric SAR Tomography for Monitoring Changes in Agricultural Crops
Hannah Joerg[1, 2], Matteo Pardini[1], Irena Hajnsek[2, 1]
([1]Deutsches Zentrum für Luft- und Raumfahrt – DLR, [2]ETH Zürich)

Synthetic Aperture Radar (SAR) measurements contain information about bio- and geophysical parameters of crops due to the sensitivity of microwaves to dielectric properties of the individual plant components and of the soil. However, for conventional (polarimetric) SAR the scattering contributions of soil and vegetation are mixed within one resolution cell and their dynamics over time cannot be analysed separately. By acquiring multi-baseline (MB) data, the variation of amplitude and phase between the acquisitions can be exploited to estimate the vertical reflectivity using tomographic SAR techniques. Hence, the ability to resolve scattering contributions at different heights enables to separately address dynamics in the soil and the vegetation. The focus of this work is to investigate in which way MB SAR data can be exploited to resolve this ambiguity of soil and plant changes as well as geometric and dielectric dynamics of the plants over time.

09:00 – 10:40 Uhr: Di-S1
Ort: Altes Rathaus, Bürgersaal
Special Session Statistical Methods in EMC
Sitzungsleiter: Lars Ole Fichte

09:00 – 09:20 Uhr: KH2017-Di-S1-01
Ort: Altes Rathaus, Bürgersaal
Advanced EMC assessment of braids shielding: from transfer impedance statistics to sensitivity analysis
Sébastien Lalléchère[1], Sébastien Girard[2], Pierre Bonnet[2], Françoise Paladian[2], Chaouki Kasmi[3], Jose Lopes-Esteves[3], Lars Ole Fichte[4]
([1]Université Clermont Auvergne, [2]Université Blaise Pascal, [3]French Network and Information Security Agency - ANSSI, [4]Helmut-Schmidt-Universität Hamburg)

The state-of-the-art regarding electrical shielding protection of braid cables and bundles of wires is rich for almost eighty years. Even if the theoretical equations dealing with the electromagnetic hardening of braids are well-known, the nature of the electromagnetic threats sets this issue as a crucial and topical subject. Indeed, intentional and non-intentional electromagnetic interferences (IEMI and NIEMI) have been considered as major threats for the last decades and have been addressed by different European programs such as STRUCTURES and HIRF SE. In this context, the intrinsic randomness of the electromagnetic sources involved (magnitude, polarization, patterns) requires severe EMC (electromagnetic compatibility) test procedures to be designed in order to get rid of this random complexity. Additionally to the statistical nature of EMC testing processes, and

focusing on the shielding strength of cables braids, the aim of this proposal is to assess the probabilistic overview of braid characteristics (mostly by considering transfer impedance). Due to the huge diversity of products available (different designs, wires carriers, number of wires per carrier, conducting material), manufacturing processes (mass production), and conditions of use (harsh environmental conditions: thermal, mechanical, chemical changes for instance), braid systems are subject to randomly driven variations. Practically, Monte Carlo-like (MC-like) method is widely spread to propose trustworthy statistics regarding the influence of random input variations. Obviously, the propagation of those uncertainties is demanding in terms of realizations (for instance tens of thousands to hundreds of millions experiments) which is absurd for the most common EMC measurement test procedures. In this framework, two strategies have to be considered and will be treated in this work. On the one hand, referring to approximated theoretical relations and/or numerical simulations may be useful to assess a huge amount of results with reasonable computing time. On the other hand, it is also possible to try to define advanced methods for the prediction of braid characteristics from a stochastic point of view with a restricted number of information (i.e. with a minimum number of experimental and/or numerical experiments). This work will be organized as follows: after a brief description of our problem statement, we will present the foundations of the different methods used for the statistical assessment of braid transfer impedance (e.g. Monte Carlo, stochastic collocation moment generating function, stochastic order reduction, bootstrapping techniques), then numerical results will be presented regarding the constitutive parts of transfer impedance (e.g. diffusive part, braid inductive term), finally we will demonstrate the interest of the proposed methods for sensitivity analysis and model order reduction.

09:20 – 09:40 Uhr: KH2017-Di-S1-02
Ort: Altes Rathaus, Bürgersaal
Spectrum management and compatibility studies with Python
Benjamin Winkel[1], Axel Jessner[1, 2]
([1]Max-Planck-Institut fuer Radioastronomie, [2]CRAF - Committee for Radio Astronomical Frequencies)

We developed the pycraf Python package, which provides functions and procedures for various tasks related to spectrum-management compatibility studies. This includes an implementation of ITU-R Rec. P.452 that allows to calculate the path attenuation arising from the distance and terrain properties between an interferer and the victim service. A typical example would be to calculate the interference levels at a radio telescope produced from a radio broadcasting tower. Furthermore, pycraf provides functionality to calculate atmospheric attenuation as proposed in ITU-R Rec. P.676.
The rich Python eco-system offers hundreds if not thousands of highly sophisticated libraries that bring scientific computing to a new level. This includes Bayesian statistics and machine learning (e.g., based on deep neural networks), but also many tools for the daily life, such as plotting facilities that produce publication-ready figures. Using this scientific stack, offered by Python, and our pycraf package, we performed a number of compatibility studies. In our presentation, we will explain a recent case study, where we analyzed the potential harm that the next-generation cell-phone standard 5G could bring to observations at the Effelsberg radio observatory. For this we developed fast Monte-Carlo sampling techniques to deal with the quasi-statistical spatial distribution of base stations and cell phones in the Cologne-Bonn region in Germany. Since the true spatial distribution is not yet known today it was estimated from the population density, as derived from the last population census (Zensus 2011) in Germany.

09:40 – 10:00 Uhr: KH2017-Di-S1-03
Ort: Altes Rathaus, Bürgersaal
Propagation of Current Waves along a Transmission Line with Randomly Located Non-Uniformities in Rectangular Resonator
Sergey Tkachenko[1], Juergen Nitsch[1], Moustafa Raya[1], Ralf Vick[1], Ronald Rambousky[2]
([1]Otto-von-Guericke University Magdeburg, [2]Wehrwissenschaftliches Institut für Schutztechnologien - ABC-Schutz)

Investigation of electromagnetic coupling to antennas and transmission lines inside resonator - like objects (shielded rooms, computer cases, aircraft fuselages, satellites, etc.) is one of the most challenging task in modern electromagnetic compatibility. The developing of corresponding calculation methods is a quite advanced mathematical problem. In reality the problem is more complicated, because of the exact geometrical and electrical parameters of the transmission line, which define such coupling, are unknown in practical applications. As result one can only talk about the probability of the one or the other parameters. The numerical methods (like MoM, TLM, etc.) which are usually applied for the solution of this group of problems are applicable for specific cases only and they are computationally intensive. In contrast to that, analytical and semi-analytical methods are applicable on general cases, and allow to make a fast analysis of the problem. In this work, we

investigate the propagation of high-frequency current waves along a stochastic transmission line in a rectangular cavity using as a basis the model of transmission line with the symmetry of the resonator. For a rectangular resonator the wire is conducted parallely to four walls of the resonator and connects two other opposite walls. This system allows an exact analytical solution by a spatial Fourier transformation for any kind of excitation, including any finite number of lumped sources and loads, which can be considered as controlled voltage sources. In the case of multiple loads the problem is reduced to the solution of linear system of Nth order (N is a total number of sources and loads). This method is computationally effective, fast (contains only double mode sums) and allows to solve stochastic problems with relative large statistical samples. The stochastization of the line is created by the stochastically arranged chain of lumped impedances, which can have reactive as well losses components. Calculations in the considered method are greatly facilitated by the fact that, for the each Fourier mode, an amplitude of the lumped potential and its position define only the nominator of the corresponding Fourier series coefficient through simple trigonometric functions. The denominator, including one-dimensional summation and depending from transversal geometry of resonator, is the same for each element. The method can be used to obtain statistical moments of current and the square of its absolute value as well as the PDF of these values. The research has shown a significant difference between the propagation of the current wave along the transmission line with stochastically arranged loads (TL with stochastic geometry) in free space and in the resonator. In the first case, the average square of the absolute value of the transmission coefficient exponentially tends to zero with increasing length of the line because of interference phenomena for current waves. In the second case, in the average, the current can penetrate through the stochastical chain of the loads (TL with stochastic geometry) due to the re-reflection of the signal from the walls of resonator.

10:00 – 10:20 Uhr: KH2017-Di-S1-04
Ort: Altes Rathaus, Bürgersaal
Time-Domain Modeling of Noisy EM Field Propagation Using Correlation Information
Johannes Russer
(Technische Universität München)

In this contribution we present the time-domain (TD) modeling of stochastic electromagnetic fields. Stochastic electromagnetic fields with Gaussian amplitude probability distribution can be fully described by auto- and cross correlation functions of the field components in time domain or by auto- and cross correlation functions in frequency domain. The cross correlation functions or spectra, respectively, have to be known for the pairs of field components taken at different spatial points. The radiated EMI of electronic devices and circuit boards can be measured by two-point correlation measurements. Two field probes measure the radiated EMI simultaneously. The measured signals are recorded by a digital sampling oscilloscope and the auto- and cross correlation functions or spectra, respectively are computed from the measured data. Based on this data the spatial distribution of the radiated EMI can be computed. Areas of application are the modeling of the electromagnetic interference radiated by digital circuitry inside the system and also into the environment.

We already have developed a numerical method for modeling of the noisy EM field propagation based on the transformation of the correlation spectra with Green's functions and subsequent transformation into a network problem via Method of Moments (MoM) [1]. This network problem is solved by correlation matrix methods. Furthermore we have presented a TLM-based time-domain method [2]. In this contribution we present a time-domain Green's function based method for direct TD modeling of the propagation of the correlation functions of the stochastic EM. The correlation functions of the electric and magnetic field components are represented by dyads and the TD correlation Green's function is a rank 4 tensor.
The radiated electromagnetic interference (EMI) of electronic circuitry is recorded by two-point measurements of the tangential electric or magnetic field components. The field propagation is modeled with the TD propagation method and compared with measurements.

[1] J. A. Russer and P. Russer, "Modeling of Noisy EM Field Propagation Using Correlation Information," IEEE Transactions on Microwave Theory and Techniques, vol. 63, no. 1, pp. 76-89, Jan. 2015.
[2] J. A. Russer, A. Cangellaris, and P. Russer, "Correlation Transmission Line Matrix (CTLM) Modeling of Stochastic Electromagnetic Fields," in Proceeding of IEEE International Microwave Symposium, IMS, San Francisco, CA, USA, 2016.

10:20 – 10:40 Uhr: KH2017-Di-S1-05
Ort: Altes Rathaus, Bürgersaal
Statistische Betrachtung der Validität von NEMP-Systemtests
Lars Ole Fichte[1], Sven Knoth[1]
([1]Helmut-Schmidt-Universität Hamburg)

Bestimmte elektronische Geräte (im besonderen für militärische Anwendungen, aber auch im Bereich der kritische zivilen Infrastruktur) müssen auch funktionieren, wenn sie extremen elektromagnetischen Signalen wie Nuklearen Elektromagnetischen Pulsen (NEMP) ausgesetzt sind. Infolgedessen sind Feldversuche mit HEMP-Simulatoren zwingend erforderlich.
Ein neuartiger Ansatz zur Beurteilung der Qualität des HEMP-Feldtests auf der Grundlage des Acceptance Sampling wird vorgestellt. Wir diskutieren das Prüfprotokoll nach deutschen und internationalen Normen und schlagen verbesserte Prüfprotokolle vor, die auf modernen statistischen Auswertungen basieren, für die wir Konfidenzintervalle bestimmen. Im Ausblick werden weitere Methoden diskutiert.

11:10 – 12:30 Uhr: Di-B1
Ort: Altes Rathaus, Bürgersaal
B: Fields and Waves
Titel: Computational Methods
Sitzungsleiter: Rolf Schuhmann

11:10 – 11:30 Uhr: KH2017-Di-B1-01
Ort: Altes Rathaus, Bürgersaal
Universal Finite-Element Matrices for Curvilinear Tetrahedra with Continuously Varying Material Properties
László Tóth[1], Romanus Dyczij-Edlinger[1]
([1]Universität des Saarlandes)

When straight-shaped finite-elements (FE) are used for modeling curvilinear structures, the order of convergence is typically limited by the error in geometry approximation rather than by the degree of the FE basis functions. Isogeometric analysis eliminates geometry errors entirely, but mesh generation proves to be difficult for real-world applications, and the cost of computing the element matrices is high. A more traditional solution path is by curvilinear FEs which interpolate the geometry by polynomials, i.e., FE basis functions. In this case, the element matrices may be computed either by numerical quadrature, which is slow, or by polynomial interpolation of the Jacobian, which enables fast integration based on pre-computed universal matrices. The technique proposed in this paper belongs to the latter class of methods. It covers hierarchical H1 and H(curl) conforming basis functions on curvilinear tetrahedra. Its unique feature is the use of a hierarchical and block-orthogonal basis for geometry approximation. The benefits of the suggested approach are as follows: The underlying universal matrices are exact, even in presence of curvilinear geometry and/or continuous variations in material properties. The sole source of error stems from approximating the metric. In the higher-order case, the element matrices exhibit a great amount of sparsity. The numerical cost of element matrix integration is low, thanks to pre-computed universal matrices. Moreover, all geometry-interpolation points are located symmetrically within the FE. The talk will detail the underlying theory of the proposed method and demonstrate its efficiency and improved rates of convergence by numerical examples.

11:30 – 11:50 Uhr: KH2017-Di-B1-02
Ort: Altes Rathaus, Bürgersaal
Model Reduction Based on Maximal Information Gain for Nonlinear Electro-Quasistatic Problems
Fotios Kasolis[1], Markus Clemens[1]
([1]Bergische Universität Wuppertal)

In the past few years, devices with nonlinear electric field stress grading material have become of interest. Here, we consider the electro-quasistatic (EQS) approximation of Maxwell's equations, which is suitable for low-frequency electric field simulations of high-voltage devices. These devices may include zinc oxide (ZnO) electric field grading material, among other materials that have constant or no electric conductivity. Field grading materials may exhibit an almost switch-like behavior, depending on the values of the electric field strength. Hence, the corresponding initial-boundary value problems for the scalar potential formulation can be strongly nonlinear. High-fidelity spatial and temporal discretizations of the strongly nonlinear EQS problem at hand, such as the finite element method combined with implicit time integration, give rise to a sequence of algebraic

systems of equations; thus, high-fidelity approximations of the electric potential can become prohibitive to compute and model reduction methods become important. For the purpose of model reduction, we employ a modified version of the so-called discrete empirical interpolation method (DEIM). The DEIM approximates a nonlinear function by its projection onto a low-dimensional space. More precisely, after obtaining a low-dimensional basis generated using proper orthogonal decomposition (POD), the DEIM, greedily selects interpolation nodes that minimize the interpolation error at each node-selection step. Given high-fidelity approximations of the scalar potential for a particular number of time steps, the so-called snapshot matrix, we obtain the DEIM nodes. Then, we enrich the resulting set of interpolation nodes by nodes that provide maximal information gain with respect to the selected DEIM nodes. To this end, we compute the spectral Kullback-Leibler divergence between the DEIM-selected and DEIM-neglected nodes. The Kullback-Leibler divergence is a relative measure of discrimination between the nodal states. This way, we ensure a minimal addition of interpolation nodes, with each added node contributing to information gain, in a maximal sense. We call this approach maximal information refinement (MIR). Numerical experiments confirm that MIR yields improved approximations, in particular, at nodes located within regions associated with the strong nonlinearity of zinc oxide varistor material.

11:50 – 12:10 Uhr: KH2017-Di-B1-03
Ort: Altes Rathaus, Bürgersaal
RWG Discretized Combined Source Integral Equation with Improved Iterative Solver Convergence
Jonas Kornprobst[1], Thomas F. Eibert[1]
([1]Technische Universität München)

Surface integral equations are a valuable tool in computational electromagnetics due to their low complexity. With lowest-order discretization, i.e. with the divergence-conforming Rao-Wilton-Glisson (RWG) basis and testing functions, the electric field integral equation (EFIE) generally shows very accurate results. For the magnetic field integral equation (MFIE), RWG discretization does not give results with acceptable accuracy. However, the MFIE shows a much better condition number than the EFIE. To avoid the interior resonance problem and improve the condition number of the system matrix, and, thus, the iterative solver convergence, the combined field integral equation (CFIE) as the summation of EFIE and MFIE is usually employed. Consequently, the accuracy of the CFIE is also deteriorated by the MFIE contributions.
In this contribution, the combined source integral equation (CSIE) is considered as an, also interior-resonance free, alternative to the CFIE. Similar to the CFIE, the CSIE shows a better conditioned system matrix than the EFIE. The discretization of the electric and magnetic surfaces current densities within the CSIE for perfect electrically conducting objects is performed with RWG functions on triangular meshes. The testing of the additional combined source side condition as a global relationship between electric and magnetic current unknowns is also performed by RWG functions. I.e., the combined source condition is implemented in a weak form leading to an approximate orthogonality between electric and magnetic surface current densities.
To accelerate the iterative solver convergence and reduce the number of unknowns, the magnetic currents are calculated from the electric currents for each matrix vector product. Hence, the number of unknowns is halved which improves convergence and memory consumption of the employed generalized minimum residual solver. Numerical results demonstrate the excellent accuracy and the convergence stability at interior-resonances of the CSIE formulation. The advantageous convergence behavior of the new CSIE formulation with only electric current unknowns is demonstrated in various examples.

12:10 – 12:30 Uhr: KH2017-Di-B1-04
Ort: Altes Rathaus, Bürgersaal
Solution of Nonlinear Eigenvalue Problems in Electromagnetic Field Computation using Contour Integrals
Carla Schenker[1], Philipp Jorkowski[1], Kersten Schmidt[1], Rolf Schuhmann[1]
([1]Technische Universität Berlin)

Electromagnetic eigenvalue problems arising from Finite Element or Finite Integration simulations may become non-linear (in the algebraic sense) if they include certain loss mechanisms which depend on the searched eigenfrequency. Beyn's algorithm (Beyn, Linear Algebra and its Applications 436:3839-3863, 2012) provides a novel method for solving such nonlinear eigenvalue problems. The algorithm uses contour integration to compute all eigenvalues inside a given closed contour in the complex plane. The main challenge is the large computational cost that arises from solving a number of shifted linear systems of equations at each integration node. We depict the error caused by the numerical integration using an interpretation of the quadrature rule as a filter function. A significant speed up of the algorithm is achieved through a well-considered choice of contours together with quadrature rules. Using conformal mapping techniques the performance near points of non-

holomorphicity can be drastically improved (Barel, Kravanja, Journal of computational and applied mathematics 292(1):526-540, 2016). Convergence results are demonstrated for a model of a waveguide-coupled cavity discretised with the Finite Integration Technique (FIT). The choices of parameters within the algorithm are discussed as well as further improvements.

14:00 – 15:00 Uhr: Di-P2
Ort: Altes Rathaus, Bürgersaal
Sitzungsleiter: Lars Ole Fichte
Plenary Talk: Management of the Variability in Electro-magnetism and in Dosimetry in Particular
Joe Wiart (Telecom ParisTech)

Thanks to the important progress in high performance calculation, numerical simulations have an increasing role in applied electromagnetics such as in numerical dosimetry. Numerical methods such as FEM or FDTD are more and more used to design system, antennas and assess performances and quantities such as gain and human exposure. With the versatile use of the devices and the increasing complexity of the networks the "deterministic " assessment of the human population RF exposure is facing limits with variable configurations and usages. Despite the increasing progress in high performance calculations the computattion time does not often allow to usel Monte Carlo method to handle variability. The design of system is facing similar challenge with the propagation of the uncertainty of the simulation inputs. To overcome such limits and face the challenges new approaches based on statistic have been developped in applied electromagnetism. They aim to built meta-model, having a quick computation time, substituting time consuming calculation methods such as FDTD. Nowadays, in applied electro-magnetics, parsimonious methods such as Planning Experiment, Polynomial Chaos Expansion, Kriging or Low rank tensors approximation are often used to manage variability and performed uncertainty quantification. In this talk we will introduce these methods and we will illustrate them with studies in dosimetry.

15:30 – 16:30 Uhr: Di-S2
Ort: Altes Rathaus, Bürgersaal
Special Session Statistical Methods in EMC
Sitzungsleiter: Lars Ole Fichte

15:30 – 15:50 Uhr: KH2017-Di-S2-01
Ort: Altes Rathaus, Bürgersaal
Propagation of the Cross-Spectral Density of Stochastic Electromagnetic Fields.
Johannes Russer
(Technische Universität München)

In the case of EMI problems we have to deal with stochastic electromagnetic fields. If a stochastic electromagnetic field originates from a sufficiently large number of statistically independent processes, the field amplitudes will exhibit a Gaussian probability distribution due to the central limit theorem. A Gaussian process can be described completely by its mean value and its second order moments. These second order moments are represented by the respective auto- and cross correlation functions. Stochastic electromagnetic fields with Gaussian probability distribution can be described completely by the autocorrelation spectrum of each field variable and the cross correlation spectra of field variables at distinct points of observation [1, 2].
Due to the equivalence principle an equivalent source distribution determined by amplitude and phase scanning of the tangential electric or magnetic field on a surface enclosing the radiating structure is equivalent to the internal sources and allows to model the environmental field. Characterization of a stochastic electromagnetic field requires the sampling of the EM field in pairs of observation points and the determination of the cross correlation functions for all pairs of field samples [2]. For full characterization of a stochastic electromagnetic field in the near-field region two-point sampling allows high resolution far below the wavelength limit. On the other hand, due to the increase of transverse coherence with increasing distance from the source [3], with increasing distance the required density of reference scanning points decreases. It has been shown, that in the far-field the correlation matrices summarizing the sampled E-field correlation spectra exhibit Toeplitz character [4]. Therefore in the far-field a single reference point is required. On the other hand, scanning in the far-field region limits the reconstruction of the spatial source distribution to a resolution in the order of half the wavelength. In this paper we introduce the Helmholtz equation for the correlation dyadics of stochastic electromagnetic fields and investigate the propagation of the cross-spectral density of stochastic electromagnetic fields to show the trade-off between achievable resolution in source reconstruction and the required density of two-point sampling points.

[1] J. A. Russer and P. Russer, "An efficient method for computer aided analysis of noisy electromagnetic fields," in Microwave Symposium Digest (MTT), 2011 IEEE MTT-S International. IEEE, Jun. 2011, pp. 1-4.
[2] J. A. Russer and P. Russer, "Modeling of Noisy EM Field Propagation Using Correlation Information," IEEE Transactions on Microwave Theory and Techniques, vol. 63, no. 1, pp. 76-89, Jan. 2015.
[3] J. W. Goodman, Statistical Optics, wiley classics. ed. John Wiley & Sons, Sep. 2000.
[4] J. A. Russer and P. Russer, "Imaging of sources of radiated electromagnetic interference," Frequenz, vol. 65, pp. 261-265, Sep. 2011.

15:50 – 16:10 Uhr: KH2017-Di-S2-02
Ort: Altes Rathaus, Bürgersaal
Modeling of Propagation of Correlation Information of Stochastic Signals in Multiport Devices by using Wave Digital Network
Biljana Stosic[1], Michael Haider[2], Johannes Russer[2], Nebojsa Doncov[1], Peter H Russer[2]
([1]University of Nis, [2]Technische Universität München)

The development of modern electronic circuits and systems (ECS) is characterized by increasing bandwidth and bit rates, lower signal amplitudes and higher density of the circuitry. On the one hand, it makes use of distributed passive circuit structures and, on the other hand, yields radiated electromagnetic interference (EMI) in a broad frequency range and a high circuitry sensitivity to EMI. Therefore, a full-wave electromagnetic (EM) analysis of such systems becomes computationally more and more costly as their complexity increases. Furthermore, EMI sources are commonly assessed in the frequency domain assuming static emissions which is not valid in a highly complex ECS environment due to the stochastic nature of the noise signals and due to multifunctional devices with many operating modes. Newly developed methods for compact model generation of complex distributed EM structures and tools comprising network and wave digital methods for their modeling, allow for efficient computer-aided design of modern ECS complying with EMC/EMI standards. In addition to that, a recently developed approach for the simulation of radiated EMI propagation based on equivalent source models, obtained by near-field measurements, and supported by a network-oriented correlation matrix methodology is capable to find a solution of stochastic EM field representation and its propagation and therefore prevent and solve failures and interference in modern electronics.
In this paper a combination of a systematic network-oriented design approach and correlation matrix methodology will be used to present an approach for an efficient computation of stochastic EM field propagation in linear passive distributed microwave circuits. In the proposed method, as the first step, the network synthesis techniques for lumped element equivalent circuits, such as canonical Foster representation, will be used for network representation of multiport microwave circuit. The synthesized equivalent circuit will be then transformed into a wave digital network (WDN) model of the multiport under consideration, providing a powerful framework for the treatment of time-discrete network models by establishing the transfer functions of the multiport model. In the last step, this time-discrete transmission line segment circuit (TLSC) algorithm will be incorporated into the correlation matrix calculation to consider the propagation of stochastic signals in multiport device for an arbitrary correlation between the port sources. As a numerical example, a 4-port device will be investigated in this contribution in order to illustrate the capabilities of the presented approach and the impact of variable degrees of source correlation on the device output.

16:10 – 16:30 Uhr: KH2017-Di-S2-03
Ort: Altes Rathaus, Bürgersaal
Localizing Equivalent Dipole Sources for Radiated Stochastic Interference
Michael Haider[1], Johannes Russer[1], Peter H Russer[1]
([1]Technische Universität München)

Interference between different analog and digital circuits within an electronic device has become a key issue regarding wireless communication and signal integrity. Since the actual sources of radiated electromagnetic interference are often very complex and in general unknown, the radiated noise needs to be treated as a stochastic electromagnetic field. As long as Gaussian statistics can be assumed, the stochastic electromagnetic field can be completely described by its second order moments, given by auto- and cross-correlation spectra. Especially in electromagnetic compatibility considerations, the locations of the origins of the noisy radiated interference are of particular interest. If those locations are known, one can identify hot-spots of radiated energy and hence the sources of interference.
In this paper, we present a method for localizing equivalent dipoles directly on the device, when the tangential field components on all pairs of points on an observation plane at a known distance h from the source plane are known. The tangential field components on all pairs of points can be obtained by two-probe scanning in the near-field. From the tangential field components, we calculate the auto- and cross-correlation spectra on the

observation plane. In the next step we place a fine virtual grid on the source plane, i.e. at a distance -h from the observation plane, and calculate the numerical propagator for each grid point to each observation point using a method of moments discretization of the dyadic Green's function in the near field. From this finely discretized numerical propagator, we form the inverse propagator by means of the Moore-Penrose pseudo inverse. This inverse propagator is optimal in a least-squares sense. With the inverse propagator known, we can give an estimate of the spectral energy density in the virtual source plane. The actual locations of the equivalent dipoles can be identified as the maxima of the spectral energy density. The number of equivalent dipoles still remains to be estimated. It turns out that the number of independent sources corresponds to the number of dominant principal components, which are obtained by performing a principal component analysis on the given data set. Altogether, we have formulated an algorithm for identifying the locations of radiating noise sources by using an inverse numerical propagator in the near-field and principal component analysis, in order to perform a model order estimation. Finally the locations of equivalent dipoles are calculated by identifying N maxima of the estimated spectral energy density in the source plane, where N is the number of dominant principal components of the correlation matrix.

16:30 – 17:10 Uhr: Di-K
Ort: Altes Rathaus, Bürgersaal
K: Electromagnetics in Biology and Medicine
Sitzungsleiter: Lars Ole Fichte

16:30 – 16:50 Uhr: KH2017-Di-K-01
Ort: Altes Rathaus, Bürgersaal
Effiziente Bestimmung der räumlichen SAR-Verteilung in Modenverwirbelungskammern am Beispiel biologischer Proben
Robert Hollan[1], Lars Ole Fichte[1], Claas Hendrik Schlie[1], Jens Storjohann[1], Marcus Stiemer[1]
([1]Helmut-Schmidt-Universität Hamburg)

Elektromagnetische Felder (EMF) sind eine alltägliche Begleiterscheinung der Informationsgesellschaft. Neben einer thermischen Wirkung, auf der die Definition der spezifischen Absorptionsrate (SAR) basiert, ist eine spezifische nicht-thermische Wirkung bisher noch nicht wissenschaftlich reproduzierbar. Die Untersuchung der Auswirkungen beider Effekte erfordert als Maßstab geeignete Proben wie auch deren homogene Befeldung. Letztere kann beispielsweise im Freifeld, in Absorberkammern oder auch in Modenverwirbelungskammern (MVKn) erfolgen. Im Gegensatz zu den ersten beiden Möglichkeiten, mit denen definierte EMF erzeugt werden können, lässt sich das Feld einer MVK nur statistisch beschreiben. Bei einer kleinen MVK - beispielsweise in der Größe eines Schrankes anstelle eines Raumes - ist zu prüfen, ob die zu befeldende Probe (das Device Under Test, DUT) elektromagnetisch hinreichend klein im Vergleich zur Kammer ist. Um den Vorteil einer kleinen und günstig zu realisierenden MVK für die Prüfung der elektromagnetischen Verträglichkeit (EMV) oder für die spezifische Beeinflussung einer chemischen Reaktion nutzen zu können, ist eine genaue Kenntnis u. a. der Feldstärkeverteilung erforderlich. Die Untersuchung der Wirkung elektromagnetischer Felder auf biologische Systeme reicht von in Nährlösungen suspendierten Zellkulturen bis zu Tierversuchen. Da die Proben in der Regel ein relativ großes Volumen einnehmen, darf auch hier nicht ohne weiteren Nachweis von einer räumlich homogenen Verteilung der elektromagnetischen Feldwirkung ausgegangen werden. Die Untersuchung der thermischen bzw. der nicht-thermischen Wirkung elektromagnetischer Felder kann durch Messung der Feldgrößen wie auch anhand der Wirkung auf das DUT selbst erfolgen. Die Messung der elektrischen Feldstärke kann durch Feldmesssonden für eine hinreichend große und geeignet verteilte Anzahl an Raumpositionen erreicht werden. Die räumliche Verteilung der SAR lässt sich prinzipiell aus dem Temperaturverlauf des DUT-Materials an besagten Raumpositionen während der Befeldung anhand einer Leistungsbilanz bestimmen, die alle Wärmetransport- und Energiewandelprozesse berücksichtigt. Die Anzahl der für eine effiziente Aufzeichnung der Temperaturverläufe erforderlichen Sonden ist jedoch meist begrenzt und eine Bestimmung der Oberflächentemperaturverläufe des DUTs mittels Thermografie wird von anderen Faktoren, wie dessen Wärmeleitfähigkeit, beeinflusst. Der hier verfolgte Ansatz besteht darin, das DUT-Material an dafür geeigneten Raumpositionen derart aufzustellen, dass dabei die Wärmeleitung und -strahlung weitgehend unterbunden wird. Auf diese Weise werden mittels Thermografie parallel die Temperaturverläufe des Probenmaterials in der Fokusebene aufgezeichnet, so dass daraus die SAR-Verteilung, die sich im DUT einstellen würde, in allen Punkten der Ebene bestimmt werden kann. Zur Positionierung des DUT-Materials wird Polystyrol verwendet, um die Beeinflussung des EMF zu minimieren. Anstelle der Zellkulturen in Nährlösung wird als Demonstrator physiologische Kochsalzlösung verwendet. Zur Aufnahme dieses DUT-Fluides werden definierte Vertiefungen in die Polystyroloberflächen eingebracht und jeweils mit der identischen Menge DUT-Fluid gefüllt. Durch die elektromagnetische Befeldung steigen die Temperaturen der DUT-Fluide entsprechend der Feldverteilung, und auftretende Temperaturgradienten indizieren einen Verbesserungsbedarf im

Messaufbau bzw. in der Messdurchführung. Bei richtigem Arrangement sollte die Richtcharakteristik der Antenne z.B. keine Rolle spielen. Anhand der so gewonnenen Erkenntnisse können Kammer- und DUT-Parameter so aufeinander abgestimmt werden, dass eine räumlich homogene Durchdringung des DUTs sichergestellt ist.

16:50 – 17:10 Uhr: KH2017-Di-K-02
Ort: Altes Rathaus, Bürgersaal
Simulationsgestützte Charakterisierung biologischer Zellen anhand elektrischer Eigenschaften
Nils Kielian[1], Sebastian Böhmelt[1], Michael Dudzinski[1], Marco Rozgic[1], Marcus Stiemer[1]
([1]Helmut-Schmidt-Universität Hamburg)

Bei der elektromagnetischen Exposition einer biologischen Zelle kommt es zu verschiedenen Effekten, die sich maßgeblich in zwei Kategorien einteilen lassen. Zum einen entstehen thermische Effekte, die durch die Umwandlung der aufgenommenen Energie des elektrischen Feldes entstehen. Zum anderen gibt es nicht-thermische Effekte, die meist Zellmechanismen wie die pH-Wert Regulierung oder den Zellstoffwechsel beeinflussen. Diese Effekte können unter anderem in der Medizin ausgenutzt werden, um beispielsweise bestimmte Medikamente in eine kranke Zelle einzubringen oder Tumore direkt durch eine bestimmte Befeldungsdosis abzutöten. Für diese Anwendungen ist ein tiefgreifendes Verständnis rund um das Verhalten einer biologischen Zelle im elektrischen Feld unabdingbar. In dieser Arbeit wird ein effizientes, parallelisierbares, numerisches Verfahren basierend auf einer Finiten Elementen Methode (FEM) zur rechnergestützten Exploration dieses Verhaltens vorgestellt. Dabei wird hier der Frequenzbereich zwischen 10 kHz und 1 Ghz untersucht. Dieser Bereich wird β-Dispersionsbereich genannt. Bei diesen Frequenzen bilden sich kapazitive Felder aus, die durch die elektroquasistatischen Maxwellgleichungen beschrieben werden können. Diese bilden die Grundlagen für die FEM-Simulation. Die Größenverhältnisse der Zelle stellen dabei eine besondere Herausforderung an die Numerik: Während die Zelle einen Radius von mehreren Mikrometern besitzt, ist ihre Zellmembran nur einige Nanometer dick, dies muss eine entsprechende Gebietsdiskretisierung beachten. Zur Lösung dieses Multiskalenproblems wird eine Variante der iterativen schwarzschen Gebietszerlegung verwendet. Dabei werden die partiellen Differentialgleichungen der Elektroquasistatik auf Teilgebiete eingeschränkt über robinsche Randbedingungen, die sich aus den Übergangsbedingungen für das elektrische Feld, die elektrische Flussdichte und die elektrische Stromdichte ergeben, miteinander gekoppelt und iterativ gelöst. Dieses Verfahren allein ist bereits parallelisierbar, jedoch können die jeweiligen Netze nicht unabhängig voneinander erzeugt werden. Um dies zu erreichen, wurde ein Verfahren entwickelt, bei dem lediglich das Netz der Membran leicht modifiziert werden muss: an den Rändern der Membran werden zusätzliche dünne Streifen angefügt, die einen Überlapp mit dem Inneren und Äußeren der Zelle haben. Auf diese Weise lassen sich die jeweiligen Sprungbedingungen realisieren und die Netze des Zellinneren, -äußeren und der Zellmembran können unabhängig voneinander erzeugt werden. Eine Lokalisierungsstrategie, basierend auf AABB (axis aligned bounding box)-Graphen, wurde implementiert, um das zuvor entwickelte schwarzsche Iterationsschema weiterhin nutzen zu können. Dieses Vorgehen der Entkopplung der Netze führt zu einer Reduktion der benötigten Elemente um 75% und folglich zu einer kürzeren Laufzeit. Prinzipiell ist diese flexible Methode auf beliebige Zellgeometrien und durch die Parallelisierbarkeit auf Zellverbände anwendbar. Mithilfe des Algorithmus werden Polarisation, Transmembranpotential und SAR-Werte für verschiedene Zellgeometrien bestimmt. Durch die Effizienz und Flexibilität der entwickelten Methode ist es möglich, biologische Zellen anhand ihrer elektrischen Eigenschaften zu charakterisieren. So wird es möglich, die Simulation zur Konzeptentwicklung in der Biotechnologie, z.B. zur Zellsortierung durch elektrische Felder, zu nutzen. Ferner erlaubt die entwickelte Methode die Bestimmung zellulärer Befeldungsdosen realer Zellen. Somit stellt sie eine Basis für die Identifikation einer Dosis - Wirkungsbeziehung elektrischer Felder auf biologische Zellen dar.

09:00 – 10:40 Uhr: Di-A2
Ort: Brauerei Keller, Gambrinus – Stube
A: Electromagnetic Metrology
Sitzungsleiter: Michael Vogt

09:00 – 09:20 Uhr: KH2017-Di-A2-01
Ort: Brauerei Keller, Gambrinus – Stube
Skalierte Messungen an Rechteckhohlleitern mit einem Seitenverhältnis von 2:1
Karsten Kuhlmann[1], Yuma Ritterbusch[1], Ulrich Stumper[1], Rolf Judaschke[1]
([1]Physikalisch-Technische Bundesanstalt)

Rechteckhohlleiter werden in der Radar- und Nachrichtentechnik unter anderem für die Übertragung von hohen Leistungen im Mikrowellen- und Millimeterwellenbereich verwendet, da sie eine geringere Dämpfung aufweisen als Koaxialleitungen. Sie dienen außerdem häufig als Anschluss für Antennen mit hoher Richtwirkung wie beispielsweise Hornantennen. In diesen und in anderen Fällen werden zum Teil sehr genaue Messungen benötigt, die den Einsatz von genormten Präzisionsflaschen erfordern. Eine genormte Flanschverbindung richtet die Aperturen zweier Hohleiter im Rahmen der in der Norm beschriebenen mechanischen Toleranz aus. Die Auswirkungen dieser mechanischen Toleranz auf die elektrischen Eigenschaften (komplexer Reflexions- und Transmissionsfaktor) sind für Rechteckhohlleiter schon in [1] untersucht und in ein vereinfachtes analytisches Modell überführt worden. Das Modell befasst sich mit Verschiebungen der Rechteckaperturen in der E- und H-Ebene Verschiebungen als auch Verdrehung der Aperturen zueinander werden bereits in [2] untersucht. Die Gültigkeit der Modelle aus [1] und [2] wird unter anderem in [3] für ausgesuchte Fälle mit numerischen Simulationen bestätigt bzw. leicht korrigiert. In der vorliegenden Arbeit wird das Modell aus [1] detailliert für viele Verschiebungen untersucht und unter anderem mit numerischen Simulationen verglichen. Kern der Arbeit ist ein Vergleich mit Messdaten, die mit speziell entworfenen Hohlleiterflanschen gewonnen werden. Diese Flansche ermöglichen sowohl präzise Verschiebungen in der E- und H-Ebene (und Kombinationen davon) als auch Verdrehungen. Als Basis der Untersuchung dient das Ku-Band von 12,4 GHz bis 18 GHz und der genormte Flansch WR-62. Andere gültige Bezeichnungen für WR-62 sind R-140, RG-91 und WG-18. Untersucht werden Verschiebungen bis 1,5 mm in der E- und H-Ebene in fünf Schritten zu 0,3 mm. Dies entspricht knapp 10 % der Hohlleiterbreite a (a=15.7988mm), womit wiederum eine Anpassung von 20 dB oder besser im gesamten Band erreicht wird. Derartig aufwendige Messungen sind nach Wissen der Autoren zuvor noch nicht durchgeführt worden. Die Messergebnisse stimmen für viele Fälle mit den Daten des Modells und der numerischen Simulation überein, es gibt jedoch für einige Fälle Abweichungen, die im Detail während der Tagung präsentiert werden. Gemäß dem Prinzip der skalierten Messung ist es möglich, die Ergebnisse dieser Arbeit auf andere Hohlleiter mit einem Seitenverhältnis von 2:1 zu übertragen. Wenn die Verschiebungen unterhalb von 10 % der Hohlleiterbreite a bleiben, können die Auswirkungen beispielsweise für den Flansch UG-387 bis 170 GHz bestimmt werden, und mit dem relativ neuen Flansch IEEE P1782.2a sogar bis ca. 1 THz. Dies stellt einen Frequenzbereich dar, der mittel- bis langfristig den Bedarf der PTB und deren Kunden an präzisen Hohlleitermessungen abdeckt.

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[2] D. Bannister et al.: On the dimensional tolerances of rectangular waveguide for reflectometry at millimetric wavelengths, NPL Report DES 95, Sep 1989.
[3] Dylan F. Williams: 500 GHz-750 GHz Rectangular-Waveguide Vector-Network-Analyzer Calibrations, IEEE Transactions on Terahertz Science and Technology, 1(2), 364 - 377, Nov 2011.

09:20 – 09:40 Uhr: KH2017-Di-A2-02
Ort: Brauerei Keller, Gambrinus – Stube
Simulation and Experimentally Based Analysis of the Dependence of the Quality of Environments for Antenna Calibration on Site Parameters
Ines Barbary
(Helmut-Schmidt-Universität Hamburg)

Assigning the correct value of an ambient electric field strength to the output signal of an antenna usually requires a delicate calibration process. To this end, a calibration site is required that allows for a sufficiently accurate calibration by a comparison to a well calibrated antenna. Such a comparison can only be done with sufficient accuracy if all construction parameters of the considered test site are within a certain range. Criteria for the validation of the suitability of a particular environment are given by the relevant industrial standards. Typical environments for antenna calibration include Open Area Test Sites (OATS), Full and Semi Anechoic

Chambers, and Electric Reverberation Chambers (ERC), where the OATS defines the referential case since it provides the highest accuracy.
The purpose of this work is to provide methods that enable to assess to what extend the quality of a test site for antenna calibration depends on its construction parameters or other factors of influence such as necessary equipment. For a given frequency, the measurement setup can always be tuned such that measurement results are close to theoretical values, but the aim of this work is to find a unique measurement configuration permitting to obtain accurate results for all frequencies within the considered range. To this end, two types of models are developed for the example of an OATS and used to assess the influence of its construction parameters. The two approaches comprise a full numerical simulation, which allows for an accurate evaluation of parameter influences, and a hybrid model, where part of the interaction of different components is modeled by a network approach, while the electromagnetic properties of individual components of the network are determined by simulation. Although a network approach requires additional approximations, it permits an easier assessment of the size of the influence of particular parameters and, thus, facilitates a construction of a new test site or the identification of reasons for inaccuracy.
This work mainly focuses on OATS, since they represent the referential situation. Subsequently, it is discussed, in how far the developed methods can be transferred to other test environments. The results of this work also apply to ElectroMagnetic Compatibility (EMC) tests, which use the same type of environments. Since the present EMC regulations allow for larger deviations from the underlying metrological standard than the regulations for antenna calibration, the harder case of antenna calibration is considered in this work.
To ensure that a real OATS meets the qualities required by the standard CISPR 16-1-5 (2013), the measurement equipment and all site parameters have to be arranged very carefully. Particularly, reflections at the masts and at the borders of the OATS cause severe problems for high and, respectively, small frequencies. The developed numerical simulation method allows for identification of suitable designs for antenna masts, field boundaries and other quantities such that an OATS operates within the required thresholds. With an also developed network-type model, the order of influence of different factors can easily be assessed. The models have been carefully validated by experiments.

09:40 – 10:00 Uhr: KH2017-Di-A2-03
Ort: Brauerei Keller, Gambrinus – Stube
Ergebnisse des nationalen Ringvergleichs der Messgröße Anstiegszeit von Oszilloskopen und Pulsgeneratoren im Deutschen Kalibrierdienst (DKD)
Kai Baaske[1], Arno Rowedder[2], Achim Schäfer[2], Lutz Müller[3], Bertram Krotz[4], Christian Rott[5], Norbert Maier[2], Karsten Thurow[6], Bernhard Kistinger[7], Gerhard Rösel[7], Ralf Riedel[8], Eugen Sander[9], Harald Würschig[10], Karl-Peter Lallmann[11], Thomas Kleine-Ostmann[1]
([1]Physikalisch-Technische Bundesanstalt, [2]Atlas Copco Tools Central Europe GmbH, [3]DB Systemtechnik GmbH, [4]esz AG Calibration & Metrology, [5]GfM Gesellschaft für Metrologie mbH, [6]Kalibrierzentrum der Bundeswehr, [7]Rohde & Schwarz GmbH, [8]Tektronix GmbH, [9]testo Industrial Services GmbH, [10]Trescal GmbH, [11]1A CAL GmbH)

Für die Charakterisierung von Messgeräten für Kommunikationssysteme, die zum Teil mit Bitraten im zweistelligen GBit/s-Bereich arbeiten, werden Oszilloskope und Pulsgeneratoren verwendet, die für diese Messungen sehr kurze Eingenanstiegszeiten aufweisen müssen. Um ein hohes Vertrauen in die Messwerte und deren Unsicherheit legen zu können, bedarf es einer fundierten metrologischen Rückführung. Zu diesem Zweck wurde unter dem Dach des Deutschen Kalibrierdienstes (DKD) ein Ringvergleich von der Physikalisch-Technischen Bundesanstalt (PTB) organisiert, um den durch die Deutsche Akkreditierungsstelle - DAkkS - akkreditierten Laboratorien eine Vergleichsmöglichkeit zu bieten. Dieser Vergleich dient der Beurteilung der technischen Kompetenz der Labore und bietet insbesondere die Möglichkeit vorhandenes Verbesserungspotential zu identifizieren und die vorhandene Kompetenz zu vertiefen.
Zu diesem Zweck wurden als Artefakte ein Stufenpulsgenerator 4015C von Picosecond Pulse Labs und ein Rohde & Schwarz RTE1052 Oszilloskop ausgewählt. Der Stufenpulsgenerator liefert eine nominelle Anstiegszeit von 15 ps, die optional mit Hilfe eines zusätzlichen Tiefpassfilters auf 350 ps verlängert werden kann. Das digitale Echtzeit-Oszilloskop bietet eine nominelle Bandbreite von mehr als 500 MHz bei einer Anstiegszeit von kleiner als 700 ps. Bei beiden Geräten wurden die Anstiegszeiten und zusätzlich beim Oszilloskop die Bandbreite, sowie die Dämpfung bei 500 MHz gemessen. Durch die Wahl der Geräte konnte eine Vielzahl von Laboratorien mit unterschiedlichem Leistungsspektrum teilnehmen. Die angewendeten Messverfahren für die Messgrößen Anstiegszeit und Bandbreite basieren auf der Richtlinie VDI/VDE/DGQ/DKD 2622 Blatt 4, Kalibrieren von Messmitteln für elektrische Größen - Oszilloskope.

10:00 – 10:20 Uhr: KH2017-Di-A2-04
Ort: Brauerei Keller, Gambrinus – Stube
Realisierung einer temperaturstabilen Multipol-Resonanz-Sonde in LTCC-Technologie für die Plasmadiagnostik
Dennis Pohle[1], Christian Schulz[1], Moritz Oberberg[1], Peter Uhlig[2], Alexandra Serwa[2], Peter Awakowicz[1], Ilona Rolfes[1]
([1]Ruhr-Universität Bochum, [2]IMST GmbH)

Der Einsatz von Plasmen in industriellen Prozessen hat in den letzten Dekaden stark an Bedeutung gewonnen. Die vielfältigen Anwendungsgebiete liegen in der Elektronik, Medizintechnik und Optik und reichen bis zu Applikationen für die Luft- und Raumfahrt sowie die Automotive-Industrie. Besonders hervorzuheben sind dabei Plasmaabscheidungsprozesse (bspw. Plasma Ion Assisted Deposition - PIAD), welche für die Produktion von modernen ultradünnen Multifunktionsschichten eine bedeutende Rolle spielen. Die Qualität sowie die Eigenschaften dieser Oberflächen werden dabei direkt von den Parametern des Plasmas beeinflusst. Zur Sicherstellung eines optimalen Prozessablaufs ist folglich eine Überwachung der vorherrschenden Plasmaparameter zwingend erforderlich. Die hierfür benötigte Sensorik sollte dabei präzise, schnell und zuverlässig arbeiten. Außerdem sollte sie durch den Abscheidungsprozess nahezu nicht beeinflusst werden sowie umgekehrt den Prozess selbst nicht stören.
Eine mögliche Realisierung eines solchen Sensors stellt die sogenannte Multipol-Resonanz-Sonde dar, welche auf dem Prinzip der aktiven Plasma-Resonanz-Spektroskopie (APRS) basiert. Hierbei wird ein hochfrequentes Signal zwischen 100 MHz und 6 GHz in das Plasma eingebracht und die resultierende Frequenzantwort gemessen. Aus dieser wiederum lassen sich die für eine effektive Überwachung des Prozesses erforderliche Elektronendichte, Elektronentemperatur und Stoßfrequenz auf Basis eines analytischen Modells ermitteln. Die Sonde besteht hierbei aus zwei symmetrisch gespeisten metallischen Hemisphären, welche durch ein Substrat voneinander getrennt sind. Die symmetrische Speisung wird über einen Balun realisiert. In zahlreichen Tests wurde die Funktionsweise des Sensorkonzepts bestätigt.
Die in technischen Prozessen verwendeten Niederdruckplasmen können trotz ihres geringen Ionisierungsgrads Neutralgastemperaturen von weit über 500°C aufweisen. Aufgrund der verwendeten Materialien und Substrate eignen sich die bisher verwendeten Sondenmodelle jedoch nur in einem Bereich unter 200°C.
Im Rahmen des BMBF-geförderten Verbundprojekts PLUTO+ werden daher Sensorkonzepte erforscht, die für höhere Temperaturbereiche geeignet sind, um auch Plasmaprozesse bei höheren Gastemperaturen messtechnisch überwachen zu können. Eine hierfür aussichtsreiche Technologie stellt die sogenannte LTCC-Technologie (Low Temperature Cofired Ceramics) dar, die auf gesinterten Keramikträgern basiert und neben der erhöhten Temperaturstabilität ebenfalls gute Hochfrequenzeigenschaften aufweist. Um eine höhere mechanische Stabilität zu erreichen, besteht dabei die Möglichkeit einen mehrlagigen Aufbau zu wählen.
In dem Beitrag wird die Untersuchung eines solchen auf LTCC-basierenden Sondenkonzepts vorgestellt. Hierbei wird sowohl die Entwicklung eines linear getaperten Baluns präsentiert, der in Hinblick auf gute Anpassung und Symmetrierung der Signale entworfen und optimiert wurde, als auch der Entwurf des Sondenkopfs gezeigt. Zudem wird auf die Ankopplung des signaleinspeisenden Koaxialkabels zum Balun eingegangen. In CST Microwave Studio wurde eine Gesamtsimulation durchgeführt, die sowohl die Sonde als auch die weiteren notwendigen Komponenten zusammen mit dem Plasma sowie dem Reaktor nachbildet. In Simulationsreihen wurde das Verhalten evaluiert. Hierbei zeigte sich in Übereinstimmung mit der Theorie eine ausgeprägte Resonanzfrequenz, die sich mit zunehmender Plasmaelektronenfrequenz zu höheren Frequenzen verschiebt. Die Fertigung der Testsonden wurde im Anschluss von der Hybridtechnologie-Abteilung der IMST GmbH durchgeführt. In ersten Messungen in einem DICP-Reaktor (Double Inductively Coupled Plasma) mit verschiedenen Plasmen konnte die Funktionsweise der Sonde bestätigt werden.

10:20 – 10:40 Uhr: KH2017-Di-A2-05
Ort: Brauerei Keller, Gambrinus – Stube
Implementierung eines schnellen numerischen GPR-Simulators zur stochastischen Analyse von improvisierten Sprengsätzen in Kolumbien
Jochen Jebramcik[1], Jan Barowski[1], Christoph Baer[1], Ilona Rolfes[1]
([1]Ruhr-Universität Bochum)

Anti-Personen-Minen und sogenannte unkonventionelle Explosions- und Brandvorrichtungen stellen in Kolumbien wie auch in anderen Ländern der Erde ein großes Problem für die Zivilbevölkerung dar. Radarverfahren (GPR - Ground Penetrating Radar) wurden vielfach erfolgreich zur Identifizierung solcher Sprengsätze eingesetzt und sind daher eine bewährte Alternative zu anderen Methoden, wie beispielsweise Metalldetektoren. Bei den in Kolumbien vorrangig eingesetzten Sprengfallen handelt es sich um improvisierte Sprengsätze (IED - Improvised Explosive Devices), die in verschiedenster Form konstruiert werden können und unterschiedlichste Explosionsstoffe und Auslösemechanismen nutzen. Darüber hinaus weisen sie einen

vergleichsweise geringen Anteil metallischer Komponenten auf, was zum einen die zuverlässige Detektion und zum anderen die Unterscheidung von anderen vergrabenen Objekten erschwert. Um das durch den kleinen Radarrückstreuquerschnitt geringe SNR zu verbessern, werden oftmals Methoden zur Fokussierung der Radarechos auf Basis von SAR-Algorithmen (SAR - Synthetic Aperture Radar) eingesetzt. Darüber hinaus kann das Ausnutzen des Resonanzverhaltens bestimmter Komponenten der Sprengsätze eine Identifikation ermöglichen. Die gemessenen Radardaten sind hierbei sowohl von der Beschaffenheit und Orientierung der Sprengsätze selbst als auch von verschiedenen Bodeneigenschaften, wie beispielsweise Feuchtigkeit und Oberflächenrauigkeit, abhängig. Die Auswirkung dieser großen Parameteranzahl kann durch Messungen alleine nicht untersucht werden, weshalb eine effektive und genaue Simulationsumgebung für eine stochastische Analyse benötigt wird. Eine vollständige 3D-Simulation des Gesamtszenarios, bestehend aus Antenne, Bodenstruktur und IED führt aufgrund der sehr kleinen Details (z.B. der Zünder der Mine) in Kombination mit dem großen Simulationsraum zu sehr langen Rechenzeiten und ist hierfür daher ungeeignet. In diesem Zusammenhang wird eine Simulationsumgebung vorgestellt, die auf der zweidimensionalen Finite-Differenzen-Methode im Frequenzbereich (FDFD) beruht. Bei der FDFD handelt es sich um ein exaktes numerisches Verfahren, welches ähnlich der FDTD die Lösung elektrischer Feldprobleme auf einem diskreten Gitter (Grid) ermöglicht und bereits erfolgreich zur Simulation von photonischen Kristallen und periodischen Gittern eingesetzt wurde. Eine Implementierung im Frequenzbereich bietet im Bezug auf GPR-Messungen den Vorteil, dass die großen Verluste und das stark dispersive Verhalten der Bodenstruktur einfach berücksichtigt werden können und darüber hinaus resonantes Verhalten der Sprengsätze effektiv simuliert wird. Die Eigenschaften der Antenne haben ebenfalls einen großen Einfluss auf die realen Messdaten eines GPR-Systems. Die Simulation der Antenne als vollständiges Modell ist allerdings sehr aufwendig, weshalb mithilfe der Total-Field / Scattered-Field - Methode (TF/SF) eine Möglichkeit implementiert wurde, das Quellfeld direkt in die Simulation einzufügen und auf diese Weise Simulationszeit zu sparen. Ein großes Problem bei der Detektion von oberflächennahen Objekten ist Clutter, bedingt durch die starke Reflexion an der Bodenoberfläche. In diesem Zusammenhang werden Simulationsergebnisse vorgestellt, die den Einfluss von Oberflächenrauigkeit auf die Rohdaten (B-Scan) und fokussierten Daten zeigen. Zur Fokussierung wurde hierbei der Backprojection-Algorithmus verwendet, der eine pulsweise Verarbeitung der Daten ermöglicht und daher für den Einsatz in einem mobilen Gerät mit Echtzeit-Prozessierung geeignet ist. Die Simulation zeigt, dass durch die Fokussierung eine Verbesserung des Radarechos des Sprengsatzes erreicht werden kann und die Bodenreflexion räumlich stärker begrenzt ist, wodurch oberflächennahe Objekte besser erkannt werden können.

11:10 – 12:30 Uhr: Di-D1
Ort: Brauerei Keller, Gambrinus – Stube
D: Electronics and Photonics
Sitzungsleiter: N.N.

11:10 – 11:30 Uhr: KH2017-Di-D1-01
Ort: Brauerei Keller, Gambrinus – Stube
Speicher mit 1 Tbit/s Lesedurchsatz für einen sehr schnellen Arbiträrsignalgenerator in einer 28 nm FDSOI-CMOS-Technologie
Thomas Veigel[1], Simon Brandl[1], Markus Groezing[1], Manfred Berroth[1]
([1]Universität Stuttgart)

Schnelle Speicherschaltungen auf einem Sende- bzw. Empfangschip werden heutzutage eingesetzt, um große Datenmengen zwischenpuffern zu können, z.B. die von Arbiträrsignalgeneratoren (engl. Arbitrary Waveform Generator, AWG) ausgegeben bzw. von Echtzeitoszilloskopen eingelesen werden. Dadurch erübrigt sich der Einsatz aufwändiger, mehrfach paralleler Echtzeitschnittstellen von teuren FPGAs. In diesem Beitrag wird ein Speicher vorgestellt, der speziell für einen AWG mit einer Umsetzungsrate von 128 GSample/s bei 8 bit nomineller Auflösung angepasst ist. Der Speicher hat eine Gesamtkapazität von 256 kSample bzw. 2 Mbit. Dahinter folgt ein Digital-Analog-Umsetzer (DAU) mit zwei Kernen, die zeitverschachtelt über einen analogen Multiplexer zusammengeführt werden. Daher wird der komplette Speicher in zwei Blöcke aufgeteilt, von denen jeder Block einen DAU-Kern bedient. Da der DAU für eine nominelle Auflösung von 8 bit ausgelegt ist, besteht jeder Speicherblock aus acht Bitfeldern. Jedes Bitfeld besteht aus vier Speichermatrizen mit einer Einteilung in 512 Zeilen und 64 Spalten. Das bedeutet, dass eine Speichermatrix eine Kapazität von 32 kbit, ein Bitfeld eine Kapazität von 128 kbit aufweist. Jede Speichermatrix enthält ihre eigenen Peripherieschaltungen, wie Vorladeschaltung, Adressdekodierer, Entscheider und Schieberegister zum Serialisieren des 64-fach parallel ausgelesenen Wortes. Das Schieberegister ist so entworfen, dass es sowohl zum langsamen Beschreiben als auch zum schnellen Auslesen der Speichermatrix verwendet werden kann. Der Speicher verfügt über eine Debug-Schnittstelle, die es ermöglicht, den Speicher langsam über eine serielle Schnittstelle auszulesen. Damit kann unabhängig vom DAU überprüft werden, ob der Speicher korrekt beschrieben wurde, oder es kann

festgestellt werden, ob es defekte Speicherzellen gibt. Die Einzelspeicherzelle besteht aus einer Sechs-Transistorzelle, deren Dimensionierung hinsichtlich Chipflächenbedarf, Geschwindigkeit und Zuverlässigkeit optimiert ist. Die Lesesteuerung erfolgt über einen Zähler mit Adressdekodierer. Die Zeilenfortschaltungsfrequenz beträgt 250 MHz. Jede Speichermatrix liefert 16 Gbit/s, d.h. ein Bitfeld liefert 64 Gbit/s. Auf den Gesamtspeicher bezogen entspricht dies einem Lesedurchsatz von 1 Tbit/s. Die Schaltung, bestehend aus Speicher und DAU, wird in einer fortschrittlichen 28 nm FDSOI-CMOS-Technologie hergestellt. Die Kantenlänge des gesamten Chips beträgt 1,88 mm. Der eigentliche Speicher einschließlich Peripherie belegt eine Fläche von rund 1,6 mm². Die durchschnittliche simulierte Stromaufnahme des Gesamtspeichers beträgt bei einer Taktfrequenz von 4 GHz rund 250 mA bei 1 V Versorgungsspannung.

11:30 – 11:50 Uhr: KH2017-Di-D1-02
Ort: Brauerei Keller, Gambrinus – Stube
A differential 19 channel 64 Gbit/s 16:1 multiplexer including a clock network in a 28 nm CMOS Fully-Depleted Silicon-on-Insulator technology
Daniel Widmann[1], Markus Groezing[1], Manfred Berroth[1]
([1]Universität Stuttgart)

An attractive solution to provide several channels with very high data rates of tens of Gbit/s for cost-efficient arbitrary waveform generators is to use an on-chip memory and a high speed multiplexer (MUX) in front of the digital-to-analog converter (DAC). Here, we present a differential 19 channel 16:1 MUX for output data rates up to 64 Gbit/s per channel including a low skew (~ 6 ps) two-phase frequency divider and clock distribution network that is completely realized in CMOS for low power consumption. The circuit is designed in a 28 nm Fully-Depleted Silicon-on-Insulator technology and will be used in an 8 bit 64 GBaud segmented (4 bits unary weighted, 4 bits binary weighted) DAC between the on-chip memory and the DAC output stage. One MUX channel is realized in four 2:1 stages, each of them consisting of five latches in a two-latch-three-latch structure and two transmission gates. This configuration avoids simultaneous transitions at the transmission gates inputs and limits the number of required clock phases for all clock domains to two. Furthermore, the frequency dividers are realized as flipflop dividers. As input signal, a 32 GHz clock is used. To drive the whole MUX tree, 16 GHz, 8 GHz and 4 GHz clocks are generated. The differential 32 GHz input signal clocks the last MUX stage for the 64 Gbit/s output signal as well as the frequency divider to generate the 16 GHz clock. For proper multiplexing, a precise alignment of phases, i.e. low skew of the different frequency domains, is essential. To compensate for clock-to-output delays of the dividers in the other branches, replica circuits are inserted. Moreover, the driver capability has to be increased by a cascade of inverters with an effective fan-out of approximately 1.4 to 1.5 building up the clock distribution network together with a transmission line. Non-corresponding fan-outs in different branches are compensated by dummy loads. Although the number of latches and MUXs doubles for every stage down to the 4 Gbit/s domain, the load is kept the same by consequent downscaling of MOSFET widths. Therefore, the same driver capability is used for all stages. Finally, simulations on schematic level reveal a data dependent jitter of about 350 fs at the output of one MUX channel with a total average power consumption of approximately 700 mW of the whole clock and MUX network and potentially 1.216 Tbit/s throughput of the system.

11:50 – 12:10 Uhr: KH2017-Di-D1-03
Ort: Brauerei Keller, Gambrinus – Stube
A high linearity SAR ADC employing Sigma-Delta DAC
Ahmad AlMarashli[1], Jens Anders[1], Joachim Becker[1], Maurits Ortmanns[1]
([1]Universität Ulm)

This work introduces an architecture and design for high resolution, high linearity Nyquist rate SAR ADCs requiring only a single simple calibration at startup. The proposed architecture benefits from an intrinsically linear 1.5 bit Sigma Delta DAC to resolve the fine bits of the SAR ADC after a coarse conversion phase with a monotonically switched capacitive DAC. No additional analog block is required for calibration, instead, the Sigma Delta DAC is used for a single shot calibration of the coarse CDAC which therefore does not require good matching and can be sized solely upon noise requirements. The SAR ADC employs two parallel dynamic comparators for improved power efficiency. The employed redundancy relaxes settling and matching requirements on coarse DAC as well as the comaprators offset mismatch and fine DAC settling. A prototype was fabricated in 40nm CMOS, with power supplies of 1.1V and 2.5V. It occupies an active area of only 0.074 mm2. The prototype achieves a measured peak SFDR of 107 dB and a noise limited SNDR of 84.8 dB at 80 kS/s Nyquist rate operation. The core power consumption is 101 uW at 80 kS/s. In oversampling mode, the ADC achieves an SNDR above 90 dB over a 5 kHz bandwidth.

12:10 – 12:30 Uhr: KH2017-Di-D1-04
Ort: Brauerei Keller, Gambrinus – Stube
Interferer Induced Jitter Reduction in BP CT Sigma Delta Modulators for Receiver Applications
Jiazuo Chi[1], Maurits Ortmanns[1]
([1]Universität Ulm)

The jitter sensitivity of continuous-time ΣΔ modulators becomes a severe performance bottleneck when interferers are present together with colored phase noise, which is common in receiver applications. In this paper, an analog and a digital interferer suppression techniques are applied to bandpass ΣΔ modulators. By eliminating the most dominant interferers before any sampling or mixing, the resulting architecture is more tolerant to interferer induced jitter error, making it advantageous compared to all common receivers concerning phase noise requirements.

15:30 – 16:50 Uhr: Di-D2
Ort: Brauerei Keller, Gambrinus – Stube
D: Electronics and Photonics
Sitzungsleiter: N.N.

15:30 – 15:50 Uhr: KH2017-Di-D2-01
Ort: Brauerei Keller, Gambrinus – Stube
Ein linearisierter, temperatur- und prozessunabhängiger Transimpedanzverstärker für hochempfindliche Strommessungen
Denis Djekic[1], Klaus Lips[2], Jan Behrends[3], Georg Fantner[4], Maurits Ortmanns[1], Jens Anders[1]
([1]Universität Ulm, [2]Helmholtzzentrum Berlin, [3]Freie Universität Berlin, [4]EPFL Schweiz)

Hochempfindliche Transimpedanzverstärker werden in Anwendungen wie der elektrisch detektierten Magnetresonanz (EDMR) oder der Rasterionenleitfähigkeitsmikroskopie (SICM) verwendet, um Stromsignale im Bereich von wenigen Nano- bis einigen Mikroampere möglichst rauscharm auszulesen. Den Stand der Technik stellen dabei Transimpedanzverstärker mit kapazitiven Rückkopplungselementen dar, die jedoch eine zusätzliche Gleichstromkompensation benötigen, um eine Sättigung des Verstärkerausgangs zu vermeiden. Transimpedanzverstärker mit sehr hochohmigen (> 10 MOhm), linearen, resistiven Rückkopplungselementen sind hingegen aufgrund ihres hohen Flächenbedarfs und ihrer hohen Parasiten nur schwer realisierbar. Eine Alternative zur Realisierung hochohmiger resistiver Transimpedanzverstärker besteht in der Verwendung von PMOS-Transistoren in schwacher Inversion im Rückkoppelpfad. Da diese allerdings intrinsisch eine exponentielle Kennlinie aufweisen, die zu starken nichtlinearen Verzerrungen führt, wird in dem vorgestellten Transimpedanzverstärker ein stark modifizierter Pseudowiderstand verwendet.
Der vorgestellte Pseudowiderstand besteht dabei aus 16 in Serie geschalteten, symmetrischen und floatenden Pseudowiderstandselementen in schwacher Inversion. Die Werte der einzelnen PMOS-Widerstandselemente sind mittels einer von einem NMOS-Transistor erzeugten Biasspannung einstellbar. Zur Vermeidung von Prozessschwankungen aufgrund des Biasings eines PMOS- durch einen NMOS-Transistor, wird der Ruhestrom des NMOS-Transistors durch eine zusätzliche Schaltung mit reziproken Prozessschwankungen generiert. Durch diese zusätzliche Schaltung ist der Widerstandswert nur noch vom Matching gleicher Transistoren (PMOS-PMOS und NMOS-NMOS) abhängig. Außerdem wird durch diese Maßnahme die bei in schwacher Inversion betriebenen Transistoren exponentielle Temperaturabhängigkeit zu einer proportionalen verringert. Zur weiteren Kompensation des Temperaturverhaltens wird der Referenzstrom der Schaltung durch einen in schwacher Inversion betriebenen Beta-Multiplizierer erzeugt, der ein PTAT-Verhalten aufweist und somit die lineare Temperaturabhängigkeit der Pseudowiderstände in erster Näherung beseitigt. Schließlich verbessert die Serienschaltung mehrerer Elemente die Linearität, minimiert den Einfluss von Parametermismatch und reduziert den Einfluss von Schrotrauschen.
Der vorgestellte Transimpedanzverstärker wurde in einer 180-nm-CMOS-SOI-Technologie gefertigt. Die Verwendung eines SOI-Prozesses vergrößert dabei durch die stark reduzierte Wannenkapazität der PMOS-Widerstandselemente die erzielbare Bandbreite der Schaltung. Die Transimpedanz des vorgestellten Designs ist über einen weiten Bereich von 1 MOhm bis 1 GOhm einstellbar und die erzielbare Bandbreite liegt je nach eingestellter Transimpedanz zwischen 7 kHz und 2 MHz. Die Variation der Transimpedanz über einen Temperaturbereich von -40 °C bis 125 °C beträgt für alle Transimpedanzen weniger als 15 %. Damit eignet sich der Transimpedanzverstärker hervorragend als universell einsetzbare Ausleseschaltung für sehr kleine Stromsignale in Anwendungen wie EDMR oder SICM.

15:50 – 16:10 Uhr: KH2017-Di-D2-02
Ort: Brauerei Keller, Gambrinus – Stube
Humidity and temperature sensor system demonstrator with NFC tag for hybrid system-in-foil application
Amro Eldebiky[1], Mourad Elsobky[1], Harald Richter[1], Joachim Burghartz[1]
([1]Institut für Mikroelektronik Stuttgart)

Hybrid System-in-foil (HySiF) is a branch of flexible electronics in which ultra-thin silicon chips are integrated with other flexible electronic components in polymeric foils [1,2]. Intensive attention is given to the implementation of flexible environmental sensing platforms for logistics and food packaging [3,4,5]. The aim of this work is the implementation of sensor system demonstrator using HySiF components, namely ultra-thin microcontroller chip in addition to on-chip temperature and on-foil humidity sensors.
The measurement concept for the relative humidity sensor is measuring the differential capacitance between a humidity dependent sensor capacitor, and another humidity independent reference capacitor. Both capacitors are fabricated on a 50-µm thick polymer substrate normally used for ultra-thin chip embedding [2]. A controlled climate chamber (Votsch VCL 0010) was used for sensor characterization. The measured relative sensitivity is 75% with response time of about 6 seconds.
The electrical readout is based on the charge amplifier switched capacitor circuit. It is implemented using commercially available microcontroller (EM microelectronics EM6819) operating at supply of 3V (Vsup=3V). The circuit structure is mapped on the microcontroller resources (operational amplifier (op-amp), 10-bit Analog-to-Digital converter (ADC) and GPIOs). On-foil capacitors like sensor, reference, and feedback capacitors are homogeneously integrated on-foil because it is always required to minimize the number of external components used in flexible electronics. Both 400-µm, and 30-µm MCU dies are used in this application. The internal bandgap reference voltage is used as the common mode voltage for the op-amp due to the absence of integrated Vsup/2 voltage. As a result, the effective number of bits is reduced to 9.78 with digital code ranging from 0-884 and dynamic range from 0V to 2.472V. Good linearity is observed in the operation region before saturation (coefficient of determination =0.9933). A relative humidity level range from 0% to 100% is achieved. The internal bandgap temperature sensor is used. The typical range of the operation of the MCU is from -40°C to 85°C. The MCU's ADC is time multiplexed between the charge amplifier structure and the internal temperature sensor. The relative humidity and the temperature sensor readings are written to a Near-Field-Communication tag based on EM NF4 chip using a serial interface, and can be accessed using an android application on a smartphone.
We gratefully acknowledge the German Federal Ministry of Education (BMBF) for financial support with the project Parsifal 4.0 (Project ID.16ES0435).

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16:10 – 16:30 Uhr: KH2017-Di-D2-03
Ort: Brauerei Keller, Gambrinus – Stube
Evaluation of frontend readout circuits for high performance automotive MEMS accelerometer
Alice Lanniel[1], Thomas Alpert[1], Tobias Boeser[1]
([1]Robert Bosch GmbH)

This work relates to the evaluation of different capacitive sensor readout frontends circuits for high performance MEMS applications. A fully differential, pseudo differential, open loop and single ended architectures are analyzed. The primary design parameters and the tradeoffs are presented. The focus is placed on size, linearity, EMV robustness, noise considerations and sensitivity. The aim of this work is to analyze existent readout architectures and derive the best for automotive specifications. MEMS accelerometer are used in cars for ESC or airbag applications and in general for navigation, space gravity instruments and increasing consumer applications as for example headsets for virtual reality or mobile phones. In the last years, the interest for high performance devices has increased significantly due to potential features of small size, low cost and low power dissipation. Depending on the application, the design and development methods are different due to distinct requirements. Whereas in consumer electronics the emphasis is put on size, cost and power consumption, for

the automotive requirements safety, robustness, long term supply, reliability, quality and harsh environment functioning are critical. Capacitive sensors consist of a moving proof mass suspended on springs over a set of fixed electrodes, which form a differential pair of capacitances. This sensing method detects the deflection of the proof mass resulting from an acceleration. The created capacitive change has to be sensed by a readout circuit. One of the key challenge in the design of capacitive sensor interface circuits is the high impedance readout node, which is susceptible to parasitic and electromagnetic interferences. Also the signal detection should not alter the sensor. Several readout interfaces can be found in literature, each of them optimized for different applications. The capacitive sensor readout interface can be categorized into two main groups, which are open loop and force feedback. In open loop circuits the proof mass displaces from its nominal position, while in force feedback interfaces the proof mass is enclosed in a negative feedback loop and an electrostatic force is employed to oppose displacement of the proof mass from its nominal position. Force feedback improves several characteristics of a sensor. It allows for higher linearity, higher dynamic range and wider signal bandwidth. Open loop architectures are generally lower cost and are largely used in consumer applications. Open loop and force feedback systems can be designed as fully differential, pseudo differential and single ended configuration. Fully differential structures have the advantage of better EMC and power supply rejection as well as first order cancellation of substrate coupling and therefore are often preferred to their single ended counterpart. The presented frontends are implemented in switched capacitor technology and use a capacitance to voltage converters to convert the variation of capacitance into a voltage, which is then digitized by an ADC. The sigma delta modulation is interesting because it provides a digital output, has a wide bandwidth and can be implemented in high density CMOS technologies. Each architecture will be compared at system level and theoretical noise analysis will be done.

16:30 – 16:50 Uhr: KH2017-Di-D2-04
Ort: Brauerei Keller, Gambrinus – Stube
Schottky-Fotodioden basierend auf laserkristallisierten Germanium-Schichten
Frederik Dreyer[1], Niklas Hoppe[1], Jürgen Köhler[1], Wolfgang Vogel[1], Morris Dahlinger[1], María Félix Rosa[1], Lotte Rathgeber[1], Jurgen Werner[1], Manfred Berroth[1]
([1]Universität Stuttgart)

In der Nachrichtentechnik herrscht eine stetige Nachfrage nach höheren Datenraten, wodurch die Forschung im Bereich der integrierten Silizium-Photonik vorangetrieben wird. Man verspricht sich kostengünstige Produktlösungen in der Siliziumtechnologie mit hohen elektrooptischen Bandbreiten. Auf der Empfängerseite werden in der Siliziumtechnologie typischerweise p-i-n-Wellenleiter-Fotodioden aus Germanium eingesetzt, da Germanium im Gegensatz zu Silizium bei den Telekom-Wellenlängenfenstern in der Nähe von 1310 nm bzw. 1550 nm ausreichend absorbiert und die Bauelemente monolithisch integrierbar sind. Dabei werden Bandbreiten von über 70 GHz bei gleichzeitig hoher Empfindlichkeit von etwa 1 A/W erreicht [1]. Darüber hinaus sind aus der Literatur Schottky-Fotodioden bekannt, die als Metall-Halbleiter-Metall (MSM) Strukturen ausgeführt werden [2]. Diese Strukturen unterstützen durch kurze Drift- und Rekombinationszeiten der Ladungsträger noch höhere Bandbreiten [3]. Zur Herstellung der Germaniumdioden werden auf die wellenleitenden Siliziumschichten dünne, kristalline Germaniumschichten aufgebracht, dotiert und strukturiert. Üblicherweise werden die Schichten dabei über zeitintensive und teure epitaktische Verfahren abgeschieden. Diese Arbeit verwendet für die Herstellung von Germanium-Schottky-Fotodioden einen neuartigen Prozessschritt: Die lokale Laserkristallisation dünner Germaniumschichten auf Silizium-Auf-Isolator (SOI) Substraten. Bei diesem schnellen und kostengünstigen Prozess schmilzt ein linien-fokussierter, gepulster, frequenzverdoppelter Nd:YAG-Laser eine ungefähr 120 nm dicke, zuvor auf monokristallines Silizium aufgedampfte, amorphe Germaniumschicht auf. Der Laser emittiert ca. 50 ns kurze Laserpulse einer Wellenlänge von 532 nm. Beim Erstarren des flüssigen Germaniums rekristallisiert dieses in polykristalliner Form. In dieser Arbeit beschäftigen wir uns mit der Optimierung von Prozessparametern wie Laserleistung und Pulsdauer, um die Germaniumschicht sowie einen Teil des darunter liegenden Siliziums aufzuschmelzen. Diese einkristalline Siliziumschicht unterstützt das epitaktische Wachstum größerer Germaniumkristalle. An der Grenzfläche entsteht eine dünne Siliziumgermanium-Mischkristallschicht. Diese verringert graduell die Gitterfehlanpassung zwischen Silizium und Germanium und verbessert somit die Kristallqualität. Die Charakterisierung der hergestellten Schichten erfolgt mit Hilfe der Raman-Spektroskopie. Die Spektren zeigen die für kristallines Germanium typischen Germanium-Germanium-Bindungscharakteristiken und ermöglichen anhand der relativen Größe der Ramanintensität der Silizium-Germanium-Bindung in Bezug zur Ramanintensität der Germanium-Germanium-Bindung die Bestimmung der Schmelztiefe der Doppelschicht. Die besten Ergebnisse liefern die mit einer Laserpulsenergiedichte von 0,83 J/cm² bestrahlten Proben. Mit den auf SOI-Substraten rekristallisierten Germaniumschichten werden Schottky-Fotodioden sowohl mit aufgedampften Aluminiumkontakten als auch mit aufgesetzten Gold-Messspitzen demonstriert. Aus dem bei einer Wellenlänge von 1298 nm und vertikaler Bestrahlung gemessenen Fotostrom resultiert eine Empfindlichkeit von ca. 1 mA/W. Die niedrige Empfindlichkeit führen wir vor allem auf den geringen Absorptionsgrad (etwa 7%) in der nur 120 nm

dicken Germaniumschicht und auf das noch nicht optimierte Design der Fotodioden zurück. Nach weiterer Optimierung der Germaniumschicht-Herstellung und einem verbesserten Fotodioden-Design haben diese Dioden ein großes Potenzial für die Anwendung als breitbandige, auf SOI-Substraten integrierbare Wellenleiter-Fotodioden mit hoher Empfindlichkeit.

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09:00 – 10:40 Uhr: Di-C4
Ort: Brauerei Keller, Tagungsraum
C: Radio Communication Systems and Signal Processing
Titel: Wireless communications and sensing
Sitzungsleiter: Jens Anders

09:00 – 09:20 Uhr: KH2017-Di-C4-01
Ort: Brauerei Keller, Tagungsraum
A Digital Receiver Signal Strength Detector for Multi-Standard Low-IF Receivers
Tobias Saalfeld[1], Tobias Piwczyk[1], Ralf Wunderlich[1], Stefan Heinen[1]
([1]RWTH Aachen)

In multi-mode, multi-standard receivers (RX) the Low-IF architecture with delta-sigma analog to digital converter (DS ADC) is a well-fitted solution due to its high reconfigurability. Furthermore, DS ADC can tolerate a high dynamic range, which relaxes the requirements of the analog frontend by reducing the need for high gain as well as a fine or even a continuous tuning of analog gain provided by variable gain amplifiers. Hence, coarse gain steps of LNA or the ones provided by the baseband (BB) bandpass filters fulfill the sensitivity specifications for a standard like Bluetooth or Zigbee and are suitable to ensure sufficient signal levels at the ADC input. Accordingly, the automated gain control (AGC) loop of the RX frontend alone does not need a high resolution. Therefore, a coarse analog power detector is sufficient for the AGC loop but does not provide enough information to calculate the receiver signal strength indication (RSSI). In order to determine the RSSI value with a high resolution the digital AGC loop of the digital BB filters has to be taken into account. However, these filters have a comparatively high current consumption. Consequently, power consuming circuit parts can be replaced or powered down if an energy and area efficient solution both for RSSI calculation and for the frontends AGC loop is available.
This work presents a digital implementation for RSSI calculation based on a discrete Fourier Transformation algorithm without area consuming digital multipliers. Furthermore, the input power dependent RSSI quality is monitored during calculation to minimize the computation time. The algorithm directly processes the oversampled DS ADCs single bit output data without previous digital filtering or down conversion to DC. Since the Fourier Transformation is a highly selective filter itself, down conversion, filtering, demodulation and down sampling of the digital BB processing can be deactivated if the received data is dispensable. This is the case in whitespace operation where it has to be ensured that the desired band is not occupied. Likewise, listen before talk functionality can be implemented in an energy efficient way by deactivating digital system components with high power consumption.
The presented RSSI calculation has been designed and tested using synthesized VHDL executed on an FPGA and connected to a custom triple-band multi-standard transceiver ASIC. An overview of the system requirements and the used RX system will be given. Subsequently, the RSSI calculation algorithm will be discussed in detail and solutions for an area efficient implementation are given. Furthermore, the measurement setup is presented and the results are shown.

09:20 – 09:40 Uhr: KH2017-Di-C4-02
Ort: Brauerei Keller, Tagungsraum
Development of a 6loWPAN sensor Node
Josua Arndt[1], Tim Lauber[1], Ralf Wunderlich[1], Stefan Heinen[1]
([1]RWTH Aachen)

The Internet of Things (IoT) and Industry 4.0 is developing and has a high demand for reliable electronics. This work contributes to the need of user-friendly and robust applications for the IoT. The topic of this work is the development of a Radio Communication System regarding the requirements for the end user and high flexibility for the application. The decision was made to design a core board with support of USB programming capability to flash the user application, USB power delivery for batterie charging, a fuel gauge as well as a MCU and RF transceiver. This core board can be combined with different sensor or actor shields to increase the flexibility and reusability. First, the system requirements are shown and explained in detail. Then, the implementation to satisfy these requirements are presented. A sensor node is often batterie powered and thus needs a batterie management. To address this a power management IC is used and for fast charging of the battery, USB Power Delivery is used. This brings up challenges for implementing USB C for up to three Ampere currents on a two-sided PCB. The USB C connector implementation is presented, including power path simulations. Also, the implementation and simulations for the Hi-Speed USB transmission lines are shown. The power consumption in different power modes is discussed. For a sensor node which is mostly in idle or standby the DC-DC converter must be efficient down to mA to reduce power dissipation. A DC-DC solution is selected which offers high flexibility in voltage domain from 1.8 to 3.3 Volt, for core board and shield voltage. The transceiver RF path and the matching network are considered and explained in detail with simulations, followed by the measured antenna matching. As a basic shield, a plant sensor with soil moisture, humidity and temperature sensors is presented. This work presents the considerations and simulations needed for the development of Radio Communication Systems with state of the art features.

09:40 – 10:00 Uhr: KH2017-Di-C4-03
Ort: Brauerei Keller, Tagungsraum
Optimierung von Empfänger, Datenerfassung und Signalverarbeitung für schnelle RFID Winkelschätz-Anwendungen
Philipp Eschlwech[1], Alois Ascher[1], Erwin Biebl[1]
([1]Technische Universität München)

Die Industrie in Deutschland befindet sich im Wandel. Die Vernetzung und Digitalisierung die bereits in vielen Teilen des öffentlichen Lebens allgegenwärtig ist wird langsam auch auf Produktions- und Logistikprozesse übertragen. Hierdurch entstehen flexiblere Strukturen die zum einen eine effizientere Produktion aber auch den heute vom Kunden geforderten Variantenreichtum ermöglichen.
Ein Kernbestandteil der Technologien die hierfür benötigt werden ist die Lokalisierung die es ermöglicht Bauteile, Ladungsträger, Werkzeuge und Werker zu verorten und so effizient und klar definiert einzusetzen. FÜr die Lokalisierung kommen je nach Einsatzszenario, Stückzahl und Kostendruck unterschiedliche Systeme in Frage, für Situationen in denen hohe Stückzahlen bei niedrigen Kosten gefordert werden bietet sich gerade RFID als Schlüsseltechnologie an.
Eine genaue Lokalisierung durch RFID kann durch Einsatz von Radarmethoden, genauer gesagt der Winkelschätzung erfolgen. Hierbei werden jedoch durch die Umgebungsbedingungen am Einsatzort und durch Eigenheiten der RFID-Kommunikation spezielle Anforderungen an die zur Lokalisierung verwendete Hard- und Software gestellt. Prinzipbedingt ist in den Aufgezeichneten Signalen die zur Winkelschätzung herangezogen werden immer ein sehr starker Anteil des Trägersignals vertreten welches vom RFID-Reader ausgesendet wird. Hierdurch kann es einfach zur Übderdeckung des vom RFID-Tag ausgehenden Nutzsignals kommen. Da Nutz- und Trägersignal spektral sehr nahe beieinander liegen ist eine Filterung mit sehr steilen Filterflanken notwendig. Dies kann über mehrere Ansätze verfolgt werden, wobei zwischen Hardwareaufwand und Softwareaufwand abgewogen werden muss um ein schnelles, aber noch Kosten-kompetitives System zu erhalten.
In dem Vortrag wird anhand von zwei Prototypen eines RFID-Winkelschätz-Systems aufgezeigt wie mit angepasster Empfängerhardware und optimierter Signalverarbeitungs-Software ein schnelles kosteneffizientes RFID-Winkelschätz-System realisiert werden kann. Hierbei ist der erste Prototyp als multifunktionaler Empfänger ausgelegt der auch für Winkelschätzung anderer Signale im 868MHz ISM Band herangezogen werden kann. Dies ist jedoch mit erhöhtem Rechenaufwand und verringerter Dynamik und damit geringerer Reichweite verbunden. Der zweite Empfänger ist genau auf den Einsatz in der RFID-Winkelschätzung zugeschnitten und erlaubt es den digitalen Signalverarbeitungsaufwand drastisch zu reduzieren und die erzielbare Dynamik zu erhöhen. Abschließend werden Messdaten der beiden Prototypen verglichen und die erreichbare Genauigkeit, auch in realen Einsatzumgebungen in Industriehallen, aufgezeigt.

10:00 – 10:20 Uhr: KH2017-Di-C4-04
Ort: Brauerei Keller, Tagungsraum
Simultane Übertragung von Leistung und Daten über induktiv gekoppelte Spulen mittels OFDM
Benedikt Sanftl[1], Martin Trautmann[1], Aron Reitz[1], Robert Weigel[1, 2], Alexander Koelpin[3]
([1]Universität Erlangen-Nürnberg, [2]Eesy-id, [3]Brandenburgische Technische Universität)

Der Einsatz von induktiver Leistungsübertragung erhält vor allem durch die voranschreitende Ausbreitung von Elektromobilität eine immer größer werdende Bedeutung. Diese Technik kommt zusätzlich auch vermehrt in der Produktionstechnik zur Anwendung. Hierbei werden bewegliche Teile nicht mehr durch Schleppketten mit Strom versorgt. Durch induktive Schleifen und Spulen zur Auskopplung wird die Leistung kontaktlos an den Verbraucher übertragen. Ebenso kann bei Industrierobotern auf die Verwendung von wartungsintensiven Schleifringen bei Kugellagern verzichtet werden. Dazu wird eine Spule am Kugellager und eine Spule auf der Rotorachse zur Leistungsübertragung angebracht.
Im Zuge von Industrie 4.0 und voranschreitender Digitalisierung wird diese Leistungsübertragungstechnik meist mit einer drahtlosen Kommunikationstechnik kombiniert. Hierbei gibt es verschiedene Verfahren um dies zu realisieren wie zum Beispiel IEEE 802.11/15. Dies bedarf jedoch zusätzlicher Komponenten und durch die Koexistenz mit vielen anderen Systemen im gleichen Band ist eine störungsfreie Übertragung für Regelungszwecke nicht immer garantiert. Das vorgestellte System verwendet daher einen anderen Ansatz. Die bereits induktiv gekoppelten Spulen der Leistungsübertragung werden durch Frequenzmultiplexing simultan für die Datenübertragung verwendet. Es entsteht ein geschlossener, störungsfreier Kanal.
Bei der Untersuchung des Kanals wurde festgestellt, dass dieser statisch sowie frequenzselektiv ist. Daher eignet sich OFDM zur Übertragung von Daten besonders gut. In diesem Beitrag wird die Analyse dieses Kanals, sowie die Gründe für den Einsatz von OFDM präsentiert. Des Weitern wird die Hardware des Systems vorgestellt, die für die Realisierung des Datenlinks benötigt wird. Zusätzlich wird neben der Hardware auch die nötige Signalverarbeitungskette präsentiert. Sowohl Vor- als auch Nachteile des Systems werden in dem Beitrag diskutiert und mit dem Stand der Technik verglichen.
Mit den extrahierten Messdaten aus dem System kann nun die Performanz der Datenübertragung bestimmt werden. Zudem werden die Messdaten mit simulativen Untersuchungen verglichen. Die Hauptkriterien sind dabei Datenrate und Fehleranfälligkeit. Wie in der drahtlosen Nachrichtentechnik üblich, muss hierbei zwischen diesen beiden Hauptkriterien abgewogen werden. Das System ist jedoch so konzipiert, dass sowohl eine sehr robuste Übertragungsart mit geringer Datenrate als auch eine schnelle, aber fehleranfälligere Variante angewandt werden kann.

10:20 – 10:40 Uhr: KH2017-Di-C4-05
Ort: Brauerei Keller, Tagungsraum
Low-Power wake up receiver based on Surface Acoustic Wave Correlator
Sa'ed Abughannam[1], Christoph Scheytt[1]
([1]Universität Paderborn)

Wireless Sensor Networks (WSN) consist of large number of distributed sensors nodes which are able to sense, read and transmit physical measurements such as temperature, humidity and pressure over wireless communication links. WSN nodes are often powered by batteries or can use energy harvesting methods from environmental energy sources. One of the major challenges in the design of WSN nodes is the high level of power dissipation for sensing, processing and communication. Operating at low-power levels reduces maintenance effort for periodic battery replacement or can even provide unlimited operation by means of energy harvesting. Since the communication process is the most power hungry process, ultra-low-power wireless communication is an enabler for network applications such as cyber-physical systems, Internet-of-Things and Industry 4.0 etc.
Our research is based on Wake-up Receivers (WuR) architectures. Each of the WSN nodes contains a WuR which is always-on, listening for a wake-up signal from other nodes or the base station, and activating the node only when a wake-up signal is detected. By this scheme the communication with the base station becomes asynchronous, real-time and on-demand. Due to the centrally-coordinated, collision-free communication such WSNs can be scaled to very large node numbers. Designing always-on WuR at ultra-low-power dissipation levels makes the WSN nodes very energy efficient because they are only activated when a wake-up-signal is received. Additionally, the WuR must be robust to noise and co-channel interference in order to operate safely in parallel to other wireless systems.
We investigate a novel radio architecture for the WuR using Linear Frequency Modulation (LFM) and passive analog signal processing by means of a Surface Acoustic Wave (SAW) correlator. The base station sends the required WSN node ID using LFM signal at 2.4 GHz. The node ID is encoded as chirp up or chirp down signal with chirping bandwidth of 80MHz. On the receiver side, the SAW chirp correlator demodulates the received LFM signal while suppressing other wireless signals. In order to achieve proper demodulation and high Signal-

to-Noise Ratio (SNR), the SAW correlator is designed to behave like a Matched Filter (MF) which boosts up the SNR. After that the signal is amplified/detected by baseband amplifier stage, it is compared with the unique ID of the node, and the node's Wake up signal is asserted accordingly. Since the SAW correlator operates completely passive, the WuR can be implemented in a very energy-efficient way, without the need to use power hungry device such as Low Noise Amplifiers (LNA) or down conversion Local Oscillators (LO).

08:00 – 09:00 Uhr: Mi-P3
Ort: Altes Rathaus, Bürgersaal
Sitzungsleiterin: Larissa Vietzorreck
Karl Rawer Plenary Talk: IRI the International Standard for the Ionosphere
Dieter Bilitza (George Mason University & NASA Goddard Space Flight Center)

This presentation will give an overview of the International Reference Ionosphere (IRI) project and model. IRI is recognized as the official standard for the ionosphere by the International Standardization Organization (ISO), the International Union of Radio Science (URSI), the Committee on Space Research (COSPAR), and the European Cooperation for Space Standardization (ECCS). I will briefly review the history of the IRI project, its current status and report on some of the future plans for this project that is jointly sponsored by URSI and COSPAR. The presentation will introduce the latest version of the model (IRI-2016, Bilitza et al., 2017) and discuss some of its successes and areas were future improvement are needed. Of special importance is a better description of IRI densities and temperatures at very low solar activities in view of the discrepancies found during the last unusually low and extended solar minimum (2007-2009) and because the current solar cycle may reach again very low solar activities. The topside electron density, in particular, has been shown to be overestimated by IRI in comparisons with C/NOFS, CHAMP, and GRACE satellite measurements. High priority is also given to the better use of solar ionosphere-effective indices or potentially the development of new ones. This is of particular urgency because of the recent revision of the sunspot number index that was the index of choice for many of the older sub-models used in IRI. We will discuss potential solutions to this problem and short-term fixes currently applied in IRI. The extension into the plasmasphere is another area where more work and data are needed to come up with a standard model (Gulyaeva and Bilitza, 2011). An exciting new direction is the development of the Real-Time IRI based on an assimilation of real-time data into the IRI background model. For example, the effort of Galkin et al. (2012) using worldwide digisonde data from the Global Ionospheric Radio Observatory (GIRO) network. Other data sources of interest for assimilation into the Real-Time IRI are data from the Global Navigation Satellite Systems (GNSS). I will end with a discussion of validation and usage of the IRI model.

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Keywords: IRI-2016, Topside, Plasmasphere, Indices, Real-Time IRI.

09:10 – 10:30 Uhr: Mi-GHJ1
Ort: Altes Rathaus, Bürgersaal
G: Ionospheric Radio and Propagation,
H: Waves in Plasmas,
J: Radio Astronomy
Sitzungsleiter: M. Foerster

09:10 – 09:30 Uhr: KH2017-Mi-GHJ1-01
Ort: Altes Rathaus, Bürgersaal
The 6-hour tide in the mesosphere/lower thermosphere over Collm (51.3°N, 13.0°E) observed by meteor radar
Christoph Jacobi[1], Amelie Krug[2]; Christoph Geißler[1]
([1]Universität Leipzig, [2]Goethe-Universität Frankfurt)

12 years of meteor radar data at Collm (51.3°N, 13°E) have been analyzed with respect to the seasonal and interannual variability of the quarterdiurnal tide (6 hr oscillation) at 82-97 km altitude. Tidal amplitudes increase with height, with maximum values of more than 7 m/s in winter at 97 km. Meridional phases lead zonal ones by slightly less than 90°. The vertical wavelengths are very long in winter, but shorter and on the order of 20 km in summer. Bispectrum analysis of Collm tides indicate that nonlinear self-interaction of the semidiurnal tide plays an important role in winter, while direct solar forcing remains the major source of the tide in general. Numerical modeling of 6 hr amplitudes reproduce the seasonal structure of the observed 6 hr wave at Collm.

09:30 – 09:50 Uhr: KH2017-Mi-GHJ1-02
Ort: Altes Rathaus, Bürgersaal
Delayed response of the ionosphere to solar EUV variabilities
Erik Schmölter[1], Jens Berdermann[1], Norbert Jakowski[1], Christoph Jacobi[2]
([1]Deutsches Zentrum für Luft- und Raumfahrt - DLR, [2]Universität Leipzig)

The ionospheric plasma reacts on solar EUV and UV variations with a time delay of 1-2 days. This delay is assumed to be owing to thermospheric transport processes from the lower ionosphere to the F region, but only limited modeling has been performed so far to prove this hypothesis. Here we will present first results of the ionospheric delay based on a comprehensive and reliable data base on assimilated TEC model and EUV spectral flux data. We specify the various dependencies from geographic/geomagnetic location, altitude, season, local time, geophysical and solar radiation conditions such as the solar activity level. These first results can provide more insight into ionospheric processes and are of interest for ionospheric applications in forecasting ionospheric weather, e.g. for the use in GNSS error analyses and predictions.

09:50 – 10:10 Uhr: KH2017-Mi-GHJ1-03
Ort: Altes Rathaus, Bürgersaal
Ionospheric response to solar EUV variations: Preliminary results
Rajesh Vaishnav[1], Christoph Jacobi[1], Jens Berdermann[2], Erik Schmölter[2]
([1]Universität Leipzig, [2]Deutsches Zentrum für Luft- und Raumfahrt - DLR)

The current study investigates the ionospheric response to solar Extreme Ultraviolet (EUV) variations using different proxies, based on solar EUV spectra observed from the Extreme Ultraviolet Variability Experiment (EVE) onboard Solar Dynamics Observatory (SDO), and the Solar Extreme Ultraviolet Experiment (SEE) onboard the Thermosphere Ionosphere Mesosphere Energetic and Dynamics (TIMED) satellite, the F10.7 index (solar radio flux at 10.7cm) and the Bremen composite Mg-II index during 2011-2014. The daily mean proxies are compared with global mean total electron content (TEC) calculated from global IGS TEC maps. The preliminary analysis shows a significant correlation between global mean TEC and integrated flux from SDO-EVE, SEE and Mg II index, while F10.7 correlates less with TEC. The correlation of EUV proxies and global TEC at different time periods are presented. An ionospheric delay is observed at the solar rotation cycle with time scale of about 1-2 days.

10:10 – 10:30 Uhr: KH2017-Mi-GHJ1-04
Ort: Altes Rathaus, Bürgersaal
PMSE spectral parameter estimation from aperture synthesis radar imaging experiments with MAARSY
Ralph Latteck[1], Jorge Chau[1], Juan Urco[1], Toralf Renkwitz[1]
([1]Leibniz-Instituts für Atmosphärenphysik – IAP)

The Middle Atmosphere Alomar Radar System (MAARSY) provides a high flexibility of beam forming and beam steering in combination with multi receiver capability allowing beam swinging operation as well as the use of interferometric applications for improved studies of mesospheric echoes with high spatiotemporal resolution. The implementation of imaging algorithms such as Capon or Maximum Entropy on the multi-channel receiving system of MAARSY is suitable to discriminate space and time scattering ambiguities. We present PMSE spectral parameter estimations from MAARSY experiments using a wide radar beam in combination with a multi-receiver setup allocated to 15 subgroups of the MAARSY antenna array. The temporal variations of PMSE characteristics are discussed on the basis of spatial resolved structures of the derived parameters as e.g. signal strength, spectral width and radial velocity within the radar beam. Our preliminary results show that PMSE scattering is not homogeneous by improved estimations of turbulence and horizontal wind fields.

11:00 – 12:00 Uhr: Mi-GHJ2
Ort: Altes Rathaus, Bürgersaal
G: Ionospheric Radio and Propagation,
H: Waves in Plasmas,
J: Radio Astronomy
Sitzungsleiter: A. Kraus

11:00 – 11:20 Uhr: KH2017-Mi-GHJ2-01
Ort: Altes Rathaus, Bürgersaal
The MPIfR S-Band Frontend System for the MeerKAT observatory
Gundolf Wieching[1], Christoph Kasemann[1], Michael Kramer[1, 2]
([1]Max-Planck-Institut für Radioastronomie, [2]University of Mancheser)

The Max-Planck Institute für Radioastronomie (MPIfR) is designing and constructing a 1.75- 3.44 GHz S-Band receiver system for the MeerKAT observatory in South Africa.
MeerKAT is a fully funded radio observatory under construction in the Northern Cape of South Africa. When complete, MeerKAT's 64 13.5-m dishes will form the - by far - most sensitive telescope in the Southern hemisphere, being equivalent to a 110 m dish. Due to the dish design with an offset Gregorian feed it will be 60% more sensitive than large center feed single dishes of comparable size. The science potential of MeerKAT is therefore enormous and will be unbeaten until its integration into SKA Phase 1.
The aim of the MPIfR Receiver System for MeerKAT is to enhance and utilize the capabilities of the MeerKAT telescope. The MPIfR S-Band receiver will complement the original planed MeerKAT receiver suite covering the UHF range (0.58 - 1.015 GHz) as well as the L-Band (0.9 - 1.67GHz) and will allow observations at a frequency range at, currently unavailable, sensitivity and spatial resolution in the Southern hemisphere.
In July 2017 the MPIfR will install and commission two preproduction receivers at the MeerKAT observatory before going into full production of the 64 receiver systems. Here we will give an overview on the commission results and the novel receiver design. We will also present possible usage of this new design for existing telescopes, such as the Effelsberg 100m observatory.

11:20 – 11:40 Uhr: KH2017-Mi-GHJ2-02
Ort: Altes Rathaus, Bürgersaal
Observations of the Sun with the radio telescope LOFAR
Gottfried Mann[1], Christian Vocks[1]
([1]Leibniz-Institut für Astrophysik Potsdam)

LOFAR (LOw Frequency ARray) is a novel radio interferometer originally designed for the frequency range 10-240 MHz at ASTRON in the Netherlands. It presently consists of 50 stations distributed over central Europe. It is operated as the International LOFAR Telescope (ILT) by several European countries. The radio signals of each individual station are transferred via a high data rate link to ASTRON, where they are correlated to a radio map of sky.
Since the radio emission of active processes of the Sun takes place in LOFAR's frequency range and because of LOFAR's imaging and spectroscopic capabilities, LOFAR is highly interesting for the solar physics community

for observing flares, coronal mass ejections and related phenomena in the corona. Hence, the science with LOFAR is coordinated in terms of the key science project (KSP) "Solar Physics and Space Weather with LOFAR". 32 scientists from 10 European countries participate in this KSP. We report on first observations of the Sun with LOFAR and demonstrate that LOFAR is really able to work as a dynamic spectroscopic radio imager of the Sun. This allows for the first time to track fast moving electron beams in the corona. That provides a better understanding of the nature of type III radio bursts as discussed.

11:40 – 12:00 Uhr: KH2017-Mi-GHJ2-03
Ort: Altes Rathaus, Bürgersaal
Very-Long-Baseline Interferometry with LOFAR: Imaging echoes of a pulsar
Olaf Wucknitz
(Max-Planck-Institut für Radioastronomie)

The Low-Frequency-Array (LOFAR) consists of dozens of stations that observe in the frequency range 10-250 MHz. Most of these are located in the Netherlands with limited baseline length. In addition, the array has currently 12 international stations in Germany, Sweden, France, the UK and Poland, and more will come online soon. These stations provide baselines beyond 1000 km and allow resolutions in the sub-arcsec range. In the standard observing mode all stations are correlated online at the central computing facility. In this contribution I want to present another observing mode that has been pioneered by the German subarray, organised by the German Long Wavelength Consortium (GLOW). In this mode we record the raw data locally and correlated them later, which gives us maximum flexibility. In an ongoing project we study echoes in the signal from a pulsar. These echoes are believed to be caused by scattering in the interstellar medium. With combined imaging and pulsar analysis we can investigate the properties of the medium causing the scattering and potentially use the different lines of sight as a giant natural interferometer.

13:30 – 15:10 Uhr: Mi-GHJ3
Ort: Altes Rathaus, Bürgersaal
G: Ionospheric Radio and Propagation,
H: Waves in Plasmas,
J: Radio Astronomy
Sitzungsleiter: Ch. Jacobi

13:30 – 13:50 Uhr: KH2017-Mi-GHJ3-01
Ort: Altes Rathaus, Bürgersaal
Global sporadic E layer observations from GPS radio occultation measurements
Christina Arras[1], Jens Wickert[1]
([1]Deutsches GeoForschungsZentrum – GFZ)

The GPS radio occultation (RO) technique is employed to study ionospheric sporadic E (Es) layers on a global scale. Our data set is based on FORMOSAT-3/COSMIC radio occultations of the years 2006 and 2016 and comprises about 2,200 globally distributed RO measurements per day. GPS RO signals are sensitive to strong vertical electron density gradients that are found in the presence of Es layers. These gradients cause strong fluctuations in the signal to noise ratio (SNR) of the 50 Hz GPS L1 occultation signal. More than 5 million of these SNR profiles are analysed in order to obtain a global picture of sporadic E occurrence and its intensity. The intensity property is related to the fbEs parameter provided by ground-based ionosonde soundings. We will present a global overview on sporadic E occurrence as well as its properties and we will demonstrate that Es formation results from complex coupling processes in the thermosphere-ionosphere-magnetosphere system. We will discuss several geophysical parameters such as tidal winds in the upper atmosphere, the presence of metallic ions and the Earth's magnetic field influencing the Es formation.

13:50 – 14:10 Uhr: KH2017-Mi-GHJ3-02
Ort: Altes Rathaus, Bürgersaal
Observation of plasma bubbles in the equatorial region using GPS radio occultation data
Ankur Kepkar[1, 2], Christina Arras[1], Jens Wickert[2]
([1]Technische Universität Berlin, [2]Deutsches GeoForschungsZentrum – GFZ)

Since the presence of electrons in the upper atmosphere affects radio waves, GNSS signals which operate at radio frequencies result in weak signal strength at reception. Such affected signals can be associated with the Signal-to-Noise (SNR) ratio to study disturbances which are caused by irregularities in the Earth's ionosphere. For this study we use data obtained by the GPS radio occultation method, a satellite-satellite remote sensing technique. The general idea of this method is to track the GPS radio signal, as it passes through the Earth's atmosphere crossing Earth's limb. This weather independent method provides global coverage, high accuracy and a high vertical resolution. Due to the refraction of the GPS electromagnetic waves induced by electron density gradients in ionospheric altitudes, the GPS signals contain information on current ionospheric conditions.
The study mainly focuses on providing insights into bubble formation in the ionosphere taking into account the measurements obtained from FORMOSAT-3/COSMIC (2007-2016). We use GPS L1 profiles tracked in 1Hz mode which scans the Earth's atmosphere with a altitude resolution of 2km. Strong SNR fluctuations are referred to vertical changes in the electron density. The six FORMOSAT-3/COSMIC satellites provide in total about 2,000 radio occultation profiles per day on an average. About 5 millions of profiles were processed for this study, of which 0.15% contain strong disturbances in the ionospheric F-region. We observed that this F-region irregularity phenomenon occurs mainly at night time close to the Earth's magnetic equator during years with high solar activity. Distinctive seasonal variations can be seen from such investigations when analyzed for different years of data. This phenomenon is traditionally explained as a consequence of plasma instability.

14:10 – 14:30 Uhr: KH2017-Mi-GHJ3-03
Ort: Altes Rathaus, Bürgersaal
Small scale irregularities and their impact on GNSS receiver in equatorial latitudesi
Jens Berdermann[1], Martin Kriegel[1], Felix Antreich[2], Volker Wilken[1], Friederike Fohlmeister[1], Norbert Jakowski[1], Mogese Mersha[1]
([1]Deutsches Zentrum für Luft- und Raumfahrt - DLR, [2]Federal University of Ceara - UFC)

Small scale ionospheric disturbances are a threat to global navigation satellite systems (GNSS) as they can lead to fluctuations of the received satellite signal, so called signal scintillations. All GNSS signals are affected by this phenomenon, but the influence on the different GNSS signals is expected to be different, since the signals are transmitted by different carrier frequencies and are constructed in different ways. Recently, we built a new measurement setup in the equatorial region (Fortaleza,Brazil), which is able to record and replay GNSS raw data. This setup allows investigating the receiver sensitivity during ionospheric scintillation events. Such information is essential to identify the receiver based contribution to scintillation occurrence. We will present the recently installed bitgrabber setup and show first results of its capabilities. Furthermore a first analysis of TEC depletions (due to Equatorial Plasma Bubbles) will be presented based on measurements in the equatorial region (Bahir Dar, Ethiopia).

14:30 – 14:50 Uhr: KH2017-Mi-GHJ3-04
Ort: Altes Rathaus, Bürgersaal
Dynamics of the magnetosphere-ionosphere-thermosphere system during 20th November 2003 storm, reproduced with CTIPe
Claudia Borries
(Deutsches Zentrum für Luft- und Raumfahrt – DLR)

The extreme space weather storm of the 20th November 2003 generated numerous perturbations in the magnetosphere-ionosphere-thermosphere (MIT) system. Observations show that in mid-latitudes, the ionosphere was characterised by a strong positive storm, accompanied by the presence of large scale ionospheric disturbances (LSTIDs), which are the signatures of atmospheric gravity waves. The source region of the LSTIDs was the ionospheric trough region, which moved equatorward during the course of the storm due to compression of the plasmasphere. The Coupled Thermosphere Ionosphere Plasmasphere electrodynamics (CTIPe) is a state of the art numerical model. It reproduces the upper atmosphere and ionosphere using solar wind and F10.7 parameter as upper boundary and the whole atmosphere model as lower boundary conditions. In a case study for the European region, the capability of CTIPe to reproduce the observed perturbations will be presented. Additionally, CTIPe delivers insight into the storm driving mechanisms. Clearly strong Joule heating

is present in the ionospheric trough region, following well the equatorward shift due to the extension of the Auroral oval. CTIPe confirms the generation of a storm wind cell and large scale gravity waves, which cause significant changes in the composition and electron density in mid-latitudes.

14:50 – 15:10 Uhr: KH2017-Mi-GHJ3-05
Ort: Altes Rathaus, Bürgersaal
Global numerical modelling of the hemispherical asymmetric ionospheric response during the St. Patrick's Day storm event 2015
Matthias Förster[1], Boris Prokhorov[1], Elvira Astafyeva[2], Irina Zakharenkova[2], Eelco Doornbos[3]
([1]Deutsches GeoForschungsZentrum – GFZ, [2]Institut de Physique du Globe de Paris, [3]Delft University of Technology)

With a sudden storm commencement (SSC) at 04:45 UT on St. Patrick's day this year (March 17, 2015) started the most severe geomagnetic storm in solar cycle 24 up to now. It occurred without any significant precursor X- or M-type solar flares and appeared as a two-stage geomagnetic storm with a minimum SYM-H value of -233 nT. In the response to the storm commencement in the first activation, a short-term positive effect in the ionospheric vertical electron content (VTEC) occurred at low- and mid-latitudes on the day-side. The second phase commencing around 12:30 UT lasted longer and caused significant and complex storm-time changes around the globe with hemispherical different ionospheric storm reactions in different longitudinal ranges. At mid-latitudes, positive storm signatures were observed in the Northern Hemisphere (NH) of the European sector, whereas a large positive storm occurred in the Southern Hemisphere (SH) of the American sector. The negative storm phase was found to be strongest in the Asian sector, in particular in the NH, but developed globally on March 18 at the beginning of the recovery phase. These observations pose a challenge for the global numerical modelling of thermosphere-ionosphere storm processes as the storm, which occurred around spring equinox, obviously signify the existence of other impact factors than seasonal dependence for hemispheric asymmetries to occur. First numerical simulation trials using the Potsdam version of the Upper Atmosphere Model (UAM-P) are presented to interpret these storm processes.

09:10 – 10:30 Uhr: Mi-B2
Ort: Brauerei Keller, Gambrinus – Stube
B: Fields and Waves
Titel: Electromagnetic Theory
Sitzungsleiter: Herbert De Gersem

09:10 – 09:30 Uhr: KH2017-Mi-B2-01
Ort: Brauerei Keller, Gambrinus – Stube
Modellierung und Simulation von stochastisch deformierten Hohlleitern nach der Schelkunoff-Methode
Hoang Duc Pham[1], Sören Plönnigs[1], Wolfgang Mathis[1]
([1]Leibniz Universität Hannover)

Die Maxwell-Gleichungen lassen sich nur für spezielle geometrische Anordnungen analytisch lösen. Schelkunoff hat eine Methode zur Bestimmung von elektromagnetischen Wellen in Hohlleitern vorgestellt, bei der die Maxwell-Gleichungen und deren Randbedingungen in ein unendlich großes Gleichungssystem aus gewöhnlichen Differentialgleichungen vom Leitungstyp überführt werden. Diese Gleichungen werden auch als verallgemeinerte Leitungsgleichungen bezeichnet. Die Lösungen des Gleichungssystems entsprechen den Basiskoeffizienten der allgemeinen Lösung für die elektromagnetischen Felder im Hohlleiter. Mit der Methode nach Schelkunoff lassen sich auch inhomogene Hohlleiter beschreiben (Randbedingungen oder Dielektrikum). In den Arbeiten von Unger und Reiter konnte für eine Reihe von praktischen Hohlleiterstrukturen gezeigt werden, dass das elektromagnetische Feld in einem nicht idealen Hohlleiter durch unendlich viele Normalmoden des idealen Hohlleiters dargestellt werden können. Allerdings wurden bisher keine numerischen Berechnungen dazu durchgeführt.
In diesem Beitrag wird, ausgehend von den Arbeiten von Schelkunoff, Unger und Reiter, die verallgemeinerten Leitungsgleichungen für einen stochastisch deformierten zylindrischen Rundhohlleiter hergeleitet und die elektromagnetischen Felder simuliert. Der Schwerpunkt liegt dabei in der Ableitung der gestörten Randbedingung des Hohlleiters und der Modellierung des stochastischen Prozesses. Über das Störungsverfahren und der Impedanz Darstellung von Shchukin und Leontovich wird die Randbedingung des stochastisch deformierten Rundhohlleiters modelliert. Zur Beschreibung des stochastischen Prozesses wird ein geeigneter Wahrscheinlichkeitsraum benötigt. Der stochastische Prozess selbst wird über eine Polynomfunktion mit stochastischen Koeffizienten (Zufallsvariable) dargestellt. Die Störung wird zunächst nur in Winkelrichtung

angenommen. Die sich daraus ergebende Zustandsgleichung wird in einen deterministischen und stochastischen Anteil separiert. Für den Fall von stochastischen Störungen in Winkelrichtung ergibt sich für eine Realisierung des stochastischen Prozesses (Pfad) konstante Kopplungsmatrizen, sodass das Gleichungssystem mit üblichen Integrationsverfahren gelöst werden kann. Ebenfalls wird die Plausibilität der Spannungs- und Stromkoeffizienten überprüft. Es werden für verschiedene Störgrößen die Koeffizienten berechnet. Die Störgröße selbst wird prozentual zum nominellen Radius angegeben. Es lässt sich zeigen, dass bei sehr geringen Störungen (< 0,01%) praktisch keine Kopplungen zwischen den Moden auftreten. Dies spiegelt sich ebenfalls in den transversalen Feldverteilungen des stochastisch deformierten Rundhohlleiters wieder.

09:30 – 09:50 Uhr: KH2017- Mi-B2-02
Ort: Brauerei Keller, Gambrinus – Stube
Leja-based adaptive sparse grids for uncertainty quantification in high-frequency electromagnetics
Dimitrios Loukrezis[1], Ulrich Römer[1], Herbert De Gersem[1]
([1]Technische Universität Darmstadt)

Since its introduction, the stochastic collocation method has been one of the most efficient and versatile tools available for uncertainty quantification purposes. Its major advantages are the black-box treatment of stochastic-parametric problems, i.e. deterministic models or solvers remain intact, as well as its fast convergence, given appropriate, i.e. smooth enough, quantities of interest.
In the multivariate case, the tensor-product stochastic collocation suffers from the curse of dimensionality, thus becoming intractable even for a small number of uncertain parameters, typically more than 4-5. The use of sparse grids can alleviate this effect, however the problem remains and renders traditional sparse-grid approaches unusable, when a large number of parameters, typically more than 10-15, is considered.
In this work, we will present a dimension-adaptive method for the construction of sparse grids, taking into consideration the sensitivity of the quantity of interest with respect to each uncertain parameter. Lagrange interpolation on Leja nodes is used for the construction of the surrogate model. Due to the strong monotonicity and granularity of Leja grids, the greedy construction of the surrogate model leads to a reduced number of solver calls, while still achieving the desired accuracy levels.
The performance of the proposed method will be demonstrated in examples from the field of computational electromagnetics. Specifically, the method will be applied to analytical and fnite-element-based waveguide models featuring geometrical and material uncertainties.

09:50 – 10:10 Uhr: KH2017- Mi-B2-03
Ort: Brauerei Keller, Gambrinus – Stube
An approximation for reflection and transmission coefficients of periodic arrays of metal rings and circular slots
Ezgi Özis[1], Andrey Osipov[1], Thomas F. Eibert[2]
([1]Deutsches Zentrum für Luft- und Raumfahrt – DLR, [2] Technische Universität München)

Radomes are covers for protecting antennas against hostile environment, e.g. air humidity or aerodynamic drag. Ideal radomes should be perfectly transparent. A promising approach to increase the transmission and reduce the reflection is the use of metamaterials. Metamaterials can also bring new features, such as an improved transmission over a broader range of antenna scan angles, reconfigurable bandpass behavior, polarization selectivity and switching ability. Metamaterials are periodic structures of typically metal particles embedded in a dielectric substrate with a unit cell smaller than the operational wavelength. Ultra-thin metamaterials consisting of a single layer of particles are called meta-sheets [1,2]. As long as the wavelength of the incident electromagnetic wave is larger than the unit cell, electromagnetic properties of metamaterials and meta-sheets can be approximated by equivalent circuit models. These models consist of reactances and capacitances with values that can be estimated analytically only for several specific particle shapes [3,4]. For metal circular rings, which are the focus of our study, the equivalent circuit model has not been developed yet. In this study the complex reactance and capacitance are described by Taylor series in terms of the radius of the ring. The corresponding analytical transmission function is fitted to HFSS simulations to determine the coefficients of the expansion. By using the Babinet principle [5], the reflection coefficient of the complementary structure (periodic array of circular slots in a metal screen) is obtained from the transmission coefficient of the ring array without recalculation. It is assumed that the influence of the thin dielectric substrate and of the thickness of the planar particle on reflection/transmission can be neglected. The developed approximation is used to describe the bandpass and bandstop behavior of meta-sheets in the frequency range from 3 to 30 GHz.

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10:10 – 10:30 Uhr: KH2017- Mi-B2-04
Ort: Brauerei Keller, Gambrinus – Stube
Using Kramers-Kronig relations to retrieve the conductivity from the effective complex permittivity
Mostafa Mohamed Bakry[1], Ludger Klinkenbusch[1]
([1]Christian-Albrechts-Universität Kiel)

While measuring the effective complex permittivity of dispersive material it might be interesting to distinguish the electric conductivity (e.g. due to free electrons) from the dielectric losses (e.g. due to bounded electrons) which both are contained in the imaginary part. This usually turns out to be a non-trivial task unless assuming for instance a suitable dispersion model for both, the dielectric and the conductivity properties of the material. In this paper we present a more general method to separate the conductivity from the effective complex permittivity of a dispersive material based on the Kramers-Kronig transforms. These integral relations describe unique relationships between the real and the imaginary parts of any causal system, for instance the complex dielectric permittivity. If we add a conductivity to the imaginary part, the corresponding real part generally will change and thus will not represent the correct Kramers-Kronig correspondent. This basic feature is the basis for the principle of the method described in the talk. A combination of a numerically performed Kramers-Kronig transform and an optimization algorithm is applied to find an estimate of the electric conductivity within a given effective complex permittivity. The features of the numerical Kramers-Kronig transform will be discussed in detail as the corresponding integrations are originally extended from zero to infinity and thus must be finite for a computational treatment. The proposed method and the corresponding algorithm are verified by some synthetic (assumed) values of the real part of the permittivity and the corresponding imaginary part obtained by the Kramers-Kronig transform. Then some conductivity is added to the imaginary part which together with the unchanged real part forms the effective complex permittivity. Afterwards the algorithm is started to retrieve the conductivity from that effective complex permittivity. Finally the method is applied to some measured data sets found in the literature describing the effective complex permittivity of composite material.
Keywords; conductivity, permittivity, Kramers-Kronig relations, dispersive materials.

11:00 – 12:00 Uhr: Mi-B3
Ort: Brauerei Keller, Gambrinus – Stube
B: Fields and Waves
Titel: Antennas and Radiation
Sitzungsleiter: Ludger Klinkenbusch

11:00 – 11:20 Uhr: KH2017- Mi-B3-01
Ort: Brauerei Keller, Gambrinus – Stube
Comparison of traveling wave and resonant series-feed patch antenna arrays at 24GHz
Andreas R. Diewald[1], Simon Müller[1]
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In this paper, the authors compare two types of microstrip patch antenna arrays. Since both antennas are intended to be used in a digital beamforming radar at 24GHz, a compact series-feed configuration with six patches was chosen. One array is designed as resonant and the second as traveling wave type. The resonant approach allows for simpler design since the microstrip patches are not impedance matched at all, but have less bandwidth what may cause problems by production tolerances. The traveling wave class requires a more extensive development process due to impedance matching which causes a wider bandwidth [1]. The simulated results (CST microwave studio) of both structures are presented with farfield plots and input reflection. For the measurements, both arrays were produced on a 0.254mm Rogers RO4350B substrate with ENIG surface finish.

To establish electrical contact, SMA connectors (Rosenberger 32K243) which are proven to be well-suited for K-band frequencies earlier [2], were used at the input. Measurements were performed with a vector network analyzer (Rohde & Schwarz ZNB40); an additional horn antenna allowed surveying their relative field patterns in longitudinal and transverse geometrical direction. For the correct determination of the input reflection at a reference plane equal to that one used in the simulation, the connector was deembedded by the procedure that was utilized in [3]. In a direct comparison of traveling wave and resonant antenna patterns in the span from 24000MHz to 24250MHz, both come up with comparable antenna gain in the main direction, with smaller side lobes but a slightly tilted main lobe for the resonant array.

[1] C. A. Balanis, Modern Antenna Handbook, John Wiley & Sons, 2011
[2] Mueller, S.; Diewald, A.R.; "Methods of Connector S-Parameter Extraction Depending on Broadband Measurements of Symmetrical Structures", The Loughborough Antennas and Propagation Conference (LAPC) 2015, 11th, Nov. 2015
[3] Mueller, S., Thull, R., Huber, M., Diewald, A.R., "Microstrip Lines and Patch Antennas on EUROCIRCUITS Process", The Loughborough Antennas and Propagation Conference (LAPC) 2016, 12th, Nov. 2016

11:20 – 11:40 Uhr: KH2017- Mi-B3-02
Ort: Brauerei Keller, Gambrinus – Stube
A Low-Reflectivity Vacuum Window
Christian Koenen[1], Uwe Siart[1], Thomas F. Eibert[1]
([1]Technische Universität München)

Measuring plasma parameters in a nuclear fusion experiment often requires microwave diagnostic systems with their antennas installed inside the vacuum vessel. Microwaves are guided either in fundamental rectangular or oversized cylindrical hollow waveguides to connect the antennas inside the vessel with the transmitter and receiver outside the vessel. Fusion plasma discharges require ultra-high vacuum inside the vessel, which is why the waveguide openings have to be sealed against the atmospheric pressure. The simplest approach covers the waveguide cross section with a dielectric sheet. Due to the discontinuity of the dielectric constants between the waveguide filling (air or vacuum) and the dielectric window, reflections occur. If the same waveguide channel is used for transmission and reception of the diagnostic signal, the reflection from the window limits the dynamic range and may saturate the receiver or even destroy it.
This contribution focuses on a millimeter-wave vacuum window in WR10 rectangular hollow waveguide technology which is supposed to reduce window reflections over almost the whole W-band (75 GHz - 105 GHz, 33% relative bandwidth) and support two individual channels in a CF-35 vacuum flange (ConFlat with 35 mm tube inner diameter). State-of-the-Art vacuum window designs in rectangular hollow waveguides reduce reflections over approximately 15% relative bandwidth (such as multiple quarter-wave space windows, pill-box windows) or over the full band when realized in oversized cylindrical waveguide technology (Brewster windows). However, the latter windows require a large installation space and do not fit into a CF-35 flange. There is no vacuum window concept that meets both, electrical and spatial constraints.
Therefore, a vacuum window concept is proposed, which is based on a hybrid-lattice network and a pair of two identical vacuum windows. On the air side and on the vacuum side, hybrid-junctions split and combine the signal. The reflections from the two individual windows interfere destructively with each other at the input port of the first hybrid-junction (either air of vacuum side). Reflections are directed to absorbers and are, thus, eliminated from the signal path. The transmitted signals through both vacuum windows combine constructively at the output port (i.e., or input port) of the second hybrid-junction. The whole design is small enough to support two individual channels in a CF-35 vacuum flange. Simulation and measurements of a prototype window show that reflections are below -15 dB in the frequency range from 75 GHz to 105 GHz.

11:40 – 12:00 Uhr: KH2017- Mi-B3-03
Ort: Brauerei Keller, Gambrinus – Stube
Fast spherical near-field antenna measurements by advanced sampling and direct spherical wave expansion
Rasmus Cornelius[1], Dirk Heberling[1]
([1]RWTH Aachen)

Spherical near-field (SNF) antenna measurements are a well-established technique for the characterization of antenna radiation properties such as the radiation pattern. Although near-field measurements provide high accuracy, they have not completely replaced far-field measurements. The required position accuracy (≤ λ/50), the need of the phase information and the measurement duration are the main disadvantages of near-field measurement systems. In general, the measurement time is long because the near field has to be measured in

a certain area around the antenna under test (AUT) - even if only a single far-field pattern point has to be determined. The measurement duration limits the throughput of an antenna measurement chamber and, thus, fast measurement techniques are desirable and have attracted many researchers.
Although measurement data on the complete sphere around the AUT is required in SNF antenna measurements, the scan area might be truncated and filled with zeros in order to reduce the measurement time. By this, information is lost which causes inaccuracies in the calculated far-field pattern. The truncation error is difficult to predict because it depends on the AUT as well as on the measurement parameters such as measurement distance and probe antenna.
The aim of this contribution is to discuss methods to reduce the measurement time without truncation. This is achieved by minimizing the acquisition path length and maximizing the scan speed along that path. The latter is usually determined by the used positioning and RF equipment. In contrast, the acquisition path length can be chosen with some degree of freedom and will be the focus of this contribution. The path length depends on the number of samples, the point distribution and the measurement trajectory.
A transformation procedure will be presented which always minimizes the required number of measurements according to the spatial bandwidth of the AUT. Further, it will be discussed that spiral scanning is advantageous in practice because the samples are well distributed and inherently lie on a simple continuous path.
By this, fast spherical near-field measurements without truncation are possible. The transformation is exact, similar to other transformation approaches, in the case of a noiseless measurement and a strictly bandlimited AUT spectrum. It is interesting to note that the proposed method is valid for every closed surface and is not restricted to spheres. The introduced spherical wave expansion is independent of the measurement geometry and, thus, offers flexibility in the design of the measurement range. For example, a hemispherical scanner could be combined with a linear scanner in order to enclose the half sphere volume. It can be expected that these flexibilities will be exploited in the future to improve new as well as existing spherical near-field antenna measurement ranges.

13:30 – 15:10 Uhr: Mi-B4
Ort: Brauerei Keller, Gambrinus – Stube
B: Fields and Waves
Titel: Applications
Sitzungsleiter: Sebastian Schöps

13:30 – 13:50 Uhr: KH2017-Mi-B4-01
Ort: Brauerei Keller, Gambrinus – Stube
Optimization of Electric Field Grading Systems for Surge Arresters
Yvonne Späck-Leigsnering[1], Erion Gjonaj[1], Herbert De Gersem[1]
([1]Technische Universität Darmstadt)

Surge arresters protect power system equipment from transient overvoltages, e.g. lightning surges. Typically, station class arresters consist of several segments which are interconnected by metallic flanges. In each segment, the inner metal-oxide (MO) resistor column is embedded in a porcelain housing. An overvoltage event injects a thermal energy impulse into the arrester's MO resistors which feature a strongly nonlinear U-I-characteristic. Due to their temperature dependence, a thermal runway may occur, causing arrester failure. A dedicated coupled electro-quasistatic-thermal (EQST) 2D-Finite-Element-Method was developed to analyze the transient arrester behavior after impulse injections. For the application in energy transmission substations, surge arresters are traditionally equipped with metallic toroids, so-called field grading rings to equalize the potential distribution. The grading ring is attached to the high voltage electrode by a number of metallic suspensions rendering it a 3D-problem. In order to apply the 2D EQST simulation procedure, a 2D-rotationally symmetric surrogate model is required. A simple 2D-configuration that neglects the suspensions does not reproduce the correct electric field stresses in the MO resistors. Hence, a replacement ring geometry including an additional field grading ring instead of the suspensions is introduced. Hereby, the geometric parameters of both toroids are obtained by optimization. The reference 3D- and the surrogate 2D-configuration are simulated for the electrostatic and electro-quasistatic (EQS) case without thermal effects. The bounded optimization problem is set up by minimizing the quadratic differences of the capacitance matrix coefficients and the electric field stresses in the MO resistors which are both suitable optimization goals, respectively. An equalized potential distribution is assumed beneficial for the surge arrester performance over its lifetime. Thus, in a next step, the EQS surrogate model can be optimized such that the electric field stresses are well-balanced across all MO resistors. Finally, EQST simulations prove if a well-balanced electrical field distribution improves the thermal stability behavior of the station class surge arrester.

13:50 – 14:10 Uhr: KH2017-Mi-B4-02
Ort: Brauerei Keller, Gambrinus – Stube
Modelling of Partial Discharge Inception at the Contact Line of Water Droplets Oscillating under AC Voltage
Yun Ouedraogo[1], Erion Gjonaj[1], Herbert De Gersem[1], Thomas Weiland[1]
([1]Technische Universität Darmstadt)

Fluid motion induced by strong electric fields affects many engineering applications. On the surface of insulators used in surge arrestors, the strength of the AC electric field is locally increased in the vicinity of rain droplets. This effect can be sufficient to trigger partial discharges on the surface of the insulator, leading to surface damage. Asymmetric motion of droplets, possibly originating from the presence of free charge in the liquid or at the surface of the insulator, affects the electric field distribution, further increasing the peak electric fields. The effect is compounded with mechanical resonances, which, for millimetric droplets, occur in the same frequency range as commercial power frequencies.
At the contact line separating the fluid phases and the dielectric surface, the electric field distribution is singular. The singularity index of the electric field depends on the electric properties of the materials as well as the contact angle of the water-air interface with the solid surface. This singularity cannot be easily resolved by the means of numerical simulations. We therefore propose to evaluate the effect of the singularity of the fields at the contact line on the risks of partial discharge using a semi-analytical model. In a first step, we perform the coupled electrohydrodynamic simulation of single 20 microliters droplets oscillating under 27Hz AC voltage, close to the mechanical resonance frequency. The electrohydrodynamic model is based on the Finite Volume implementation provided by the OpenFOAM library, and takes into account the effect of surface wettability through dynamics contact angle model which includes pinning effects at the contact line. In a second step, a simple model of the contact line, based on multiple point dielectric transitions at the contact line is used to calculate the electric field singularity index and the field distribution. The field strength and the contact angle between the water-air interface and the solid surface are obtained at the region of highest electric fields from the full 3D simulations of droplet oscillations. Using the obtained singularity index and field strength, the streamer inception criterion can be evaluated along the surface of the insulator, providing with insight on the risks of partial discharges originating from the singular fields at the contact line.

14:10 – 14:30 Uhr: KH2017-Mi-B4-03
Ort: Brauerei Keller, Gambrinus – Stube
Crosstalk Cancellation in Inductively Coupled Full-Duplex Data Transfer Systems by a single Multipole Dualport Coil Structure
Christian Schmidt[1], Martin Buchholz[1], Madhukar Chandra[2]
([1]Hochschule für Technik und Wirtschaft des Saarlandes, [2]Technische Universität Chemnitz)

Short range inductive data transfer has become very popular in the last years with the increased interest in technologies like RFID and NFC. Additionally, wireless power transfer has been a field of intensive research and 5 product development. In industrial applications, a combination of both is often needed to replace mechanical contacts, mainly for safety and reliability reasons, especially regarding spark prevention and maintenance reduction. In this paper, we present a compact inductive structure that 10 can be implemented in an existing wireless energy transfer system. The structure is developed by field considerations, leading to a single structure comprising two signal ports that are decoupled from each other, but can be used to transfer a signal to a second structure of that kind with very small 15 interference. An optimisation to achieve comparable channel characteristics is conducted by using 3D field simulations. Subsequent measurements are conducted to verify the achieved performance.

14:30 – 14:50 Uhr: KH2017-Mi-B4-04
Ort: Brauerei Keller, Gambrinus – Stube
Planare Multipol-Resonanz-Sonde: Industrietaugliche Plasmadiagnostik
Michael Friedrichs[1], Jens Oberrath[1]
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Die moderne Nutzung technischer Plasmen in industriellen Anwendungen, erfordert eine immer genauere Überwachung und Beeinflussung der wichtigsten Plasmaparameter wie der Elektronendichte und der mittleren Elektronenenergie. Nur wenige Diagnostikmethoden halten den strengen Anforderungen der Industrie stand. Nutzt man die natürliche Eigenschaft aller Niederdruckplasmen, in der Nähe der Plasmafrequenz in Resonanz zu geraten, so kann man mit Hilfe eines Sensors, welcher mit einer hochfrequenten Spannung das Plasma in der Nähe der Sonde zu Schwingungen anregt, wichtige Zustandsgrößen über eine spektrale Analyse der

Systemantwort ermitteln. Dieses Konzept wird Aktive Plasmaresonanzspektroskopie (APRS) genannt. Mit einem mathematischen Model der APRS muss eine möglichst einfache Relation zwischen Resonanzfrequenz und Elektronendichte als auch zwischen Halbwertsbreite und mittlerer Elektronenenergie bestimmt werden, um die gewünschten Plasmaparameter zu ermitteln.
Trotz des vielversprechenden Konzepts der aktiven Plasmaresonanzspektroskopie sind die meisten Umsetzungen dieses Verfahrens invasiv. Die Sonden stören des Plasmas alleine durch ihre physikalische Präsenz und sind damit für industrielle Prozesse ungeeignet. Ein Ausweg stellt ein planares Design einer Sonde dar, das eine Integration in die Reaktorwand ermöglicht und als planare Multipol-Resonanz-Sonde (pMRP) vorgestellt wurde. Sie besteht aus zwei halbkreisförmigen Elektroden die mit 180° phasenverschobenen Spannungen gespeist werden und somit den zusätzlichen Vorteil einer ausschließlichen Kopplung zwischen den Elektroden gewährleistet.
In diesem Beitrag wird ein fluiddynamisches Model der pMRP und dessen Lösung mit funktionalanalytischen Methoden vorgestellt. Es wird gezeigt, dass die spektrale Systemantwort, die Admittanz der Sonde-Plasma-Wechselwirkung, als Matrixelemente der Resolventen des dynamischen Operators darstellt werden können. Mit Hilfe einer orthonormalen Basis kann die Admittanz entwickelt und approximiert werden. Die approximative Berechnung der Admittanz erlaubt dann die Bestimmung der Resonanzfrequenz, die zur Berechnung der Elektronendichte herangezogen werden kann.
(Die Autor bedanken sich bei der DFG für die finanzielle Unterstützung im Projekt OB 469/1-1.)

14:50 – 15:10 Uhr: KH2017-Mi-B4-05
Ort: Brauerei Keller, Gambrinus – Stube
Determining Bond Wire Temperatures in Electronic Devices by a 1D-3D Coupling Approach
Thorben Casper[1], Ulrich Römer[1], Sebastian Schöps[1]
([1]Technische Universität Darmstadt)

Due to the continuous downscaling of feature sizes in micro- and nanoelectronics, power densities increase and result in thermal issues that need to be predicted and eventually avoided. Commonly, these issues are identified as hot spots in the design phase and subsequently circumvented by iterative re-designs. For the identification of hot spots in a specific design, simulation tools capable of electrothermal analysis are required. Due to the mostly rectangular geometries in electronic designs, structured meshes are often used.
In integrated circuit packaging, the connections from the chip to the package are commonly established by bond wires. When such a package is considered for simulation, these thin wires require a locally very fine mesh that leads to high computational effort especially for structured meshes. Therefore, we circumvent this problem by introducing a 1D wire model that communicates to the 3D domain at a defined number of 1D-3D coupling points.
This coupling approach gives rise to singular contributions to the 3D domain. These singular points again require a fine mesh to recover the expected convergence rates for non-singular domains. After all, the refinement of the coupling points typically result in less degrees of freedom than the refinement of the entire wire geometry. Furthermore, the number of coupling points gives an additional user defined parameter to control the trade-off between accuracy and computational effort. Another advantage is that there is no need to resolve the commonly curved geometry of the wires, which again is especially important for structured meshes.
To analyze the convergence behavior of the proposed method, it was applied to numerical test examples. Additionally, the wire temperatures in an industry-relevant chip package were determined using electrothermal simulations.
While we mostly focus on bond wires here, this approach is indeed not only restricted to bond wires nor the packaging in electronics. Instead, the proposed method applies to any field in which thin wire-like geometries are involved. Examples also include other disciplines as, e.g., the simulation of blood flow through tissues in medical applications.