WMG (IMS) Monday 08:00 – 17:00 BCEC Room 156C
New Component Technologies for Vehicular and Industrial Radar Applications
Full-day workshop reviewed by MTT-2, MTT-11, MTT-16

Organizer(s):
Linus Maurer, DICE, Linz, Austria.
Andreas Stelzer, University of Linz, Austria.
Thomas Ußmüller, University of Erlangen-Nuremberg, Germany
Robert Weigel, University of Erlangen-Nuremberg, Germany; AdCom, MTT-2, IMS TPC.

For a long time radar systems were only used for military systems and for civil aviation. One major reason for the limited application scenarios were the high costs involved with these systems. Nowadays the application scenarios are much broader. They range from location-aware smart-sensor systems for industrial applications to automotive systems for enhanced car safety. The recent advances in semiconductor technology have opened new mass-market potentials for radar systems. This workshop will give insights to several aspects of industrial and automotive radar systems. The topics covered during this workshop span from sub-component design to application scenarios. Fully integrated radar frontends in silicon technologies will be shown. Furthermore, challenges and solutions for the integration of these transceiver ICs into complete systems will be addressed. Another important aspect for the complete system is the antenna design, which will be covered by a separate talk. In addition, examples for modern industrial and automotive radar systems will be shown.

Speakers:
1. Dietmar Kissinger, University of Erlangen-Nuremberg, Germany
"High-Linearity 77-GHz SiGe Automotive Radar Front-Ends"

The harsh automotive environment poses a series of challenging performance demands to integrated 77-GHz radar frontends. Besides a large temperature range of operation, sufficiently large output power of the transmitter and corresponding receiver sensitivity have to be guaranteed. The large dynamic range of the received signal additionally demands a highly linear behaviour of such receiver circuits. This presentation deals with the design of high-linearity integrated receiver frontends and its subcomponents for 77-GHz automotive radar applications based on high-performance SiGe technologies. These include low-noise amplifiers and down-conversion mixer circuits as well as fully integrated receiver frontends. The authors give insight to the design and measurement techniques of state-of-the-art highly linear 77-GHz radar building blocks. Different circuit architectures are investigated and the corresponding designs and performance parameters are presented.

2. Joy Laskar, GEDC at Georgia Tech, Atlanta, USA
"Digital CMOS Phase Shifter Technology for Precision Radar Applications"

Integrated digital CMOS phase shifters are critical for on-chip digital beam former integration, in particular for the implementation of CMOS precision radar beyond 40GHz. Several types of millimeter wave reflection type and vector modulator phase shifters have been implemented in standard digital CMOS. Conventional and innovative topologies, using passive and active approaches will be presented. In addition, a fully integrated digitally controlled 60GHz single chip CMOS beam-former with integrated signal processor will be highlighted, addressing integration issues such as combining and synchronization. The circuits topology advantages and trade-offs will be compared and supported by analysis and measured results.

3. S.P. Voinigescu, University of Toronto, Canada
"W- and D-Band CMOS and SiGe BiCMOS Radars for Remote Sensing and Industrial Applications"

This presentation will discuss architectures and transceiver implementations for intelligent mm-wave sensors for a variety of active imaging applications. We will compare CMOS and SiGe BiCMOS technology performance at the transceiver level. Particular emphasis will be placed on digitally controlled oscillators, switches, attenuators and IQ phase shifters as critical components to achieve on-chip self-test and electronically steerable arrays. We will conclude with examples of a 94GHz Doppler transceiver in 65nm CMOS and of a SiGe BiCMOS transceiver with on-die antennas operating at 170GHz.

4.Thomas Ussmueller, University of Erlangen-Nuremberg, Germany
"Concepts and Design Methods of Antennas for Automotive Long Range Radar"

The antenna has significant impacts on the direction-of-arrival (DOA) estimation performance of automotive radar sensors. Increasing demands on safety functions require the capability for angular resolution of targets even in the same distance-velocity cell. A comparative study of various antenna concepts is given. The antenna characteristic has to feature low side lobe levels for clutter echo attenuation and a distinct half power beam width. A novel digital-beam-forming lens antenna concept for long range radar is presented, enabling a more flexible antenna design in azimuth and elevation, respectively, and superior elevation beam shaping compared to a planar design. Three dimensional lens optimization involves the computation of very large electrical structures. Thus, alternative simulation techniques with geometric optics (GO) ray launching and two dimensional techniques are presented, enabling a fast optimization of the lens parameters in conjunction with feed antenna positions.

5. Johann-Peter Sommer, Fraunhofer Research Institution, Germany
"FE Simulations and Micro-Range Deformations Measurements – Efficient Tools for Design Support"

High functionality and reliability of new advanced electronic products requires for analysing thermal as well as thermo-mechanical properties. Numerical studies by means of FEA are very efficient to check the desired properties. Complementary, the deformation of suitably designed test structures with respect to appropriate thermal and/or mechanical loading conditions can be measured with the microDAC methodology, developed by CWM and Fraunhofer IZM/ENAS. The electronic components of an adaptive distance control (ADC) unit, based on a 77 GHz radar sensor, special divider network structures which feed RF antennas in space applications, or packages with both analogue and digital circuits at a common die are outlined. Targets like high reliability and low cost design must not be in contradiction. One way to meet it is to follow the so-called "chip in duromer" approach. The Si-components are moulded directly into so-called submodules which are embedded finally into the final systems.

6. Johnna Powell, Massachusetts Institute of Technology, Cambridge, USA
"77 and 94-GHz SiGe Receiver Front Ends and Integrated Antennas for Millimeter-Wave Applications"

SiGe wideband front end receivers with integrated antennas for passive imaging have been designed and characterized at 77 GHz and 94 GHz. These front end systems exhibit wideband performance exhibiting high gain and low noise figures. These systems each comprise a fully differential integrated antenna, LNA, and a double-balanced mixer. The 94-GHz receiver achieves 47 dB max conversion gain, 7-12.5 dB NF, and PDC of 120 mW. The antenna performance yields gains of 10-13 dB over 70-100 GHz, with greater than 90% efficiency. The integrated antenna exhibits a typical loss of 0.5-1 dB, or 80-90% efficiency, and a worst-case radiation loss of □-2 dB (efficiency = 63%). These reported results exceed published on-chip antenna performance, which typically achieve 10% efficiency. The antenna and receiver chip co-design and integration optimizes antenna loss and enhances overall performance.

7. P. Feil, Institute of Microwave Techniques, University of Ulm, Germany
"Broadband Automotive Sensors in Industrial and Security Applications"

An increased implementation of automotive radars forced the development and availability of integrated components (MMICs) and sensors in the millimeter-wave range. Besides the automotive application, also industrial and security applications can take benefit from these components. In this workshop contribution, two sensors designs - an imaging sensor at 24 GHz and a broadband sensor at 78 GHz - and novel applications of these will be presented. The 24 GHz sensor was successfully tested in brown coal surface mining areas, both to protect the surrounding of bucket excavators but also to monitor the cross-section of a wagon during the loading process. Using the broadband 78 GHz sensor, a feasibility study for airport runway surveillance was conducted. It could be shown that sensitivity and resolution are sufficient to detect even very small objects on

the runway surface. It is intended to develop a distributed system consisting of a number of comparatively low-cost and low-profile sensors

8. A. Teplyuk, University of Kiel, Germany
"94-GHz Industrial Radar Sensor for the Quantitative Monitoring of Dust Particles and Aerosoles"

The contribution will report on a Doppler radar with extremely high sensitivity and its signal processing, which is intended for the use e.g. in industrial process control. A radar will be described, which is configured for the quantitative measurement of streams of small particles and aerosoles in the near range. The precise calibration of the instrument will also be described.

9. A. Stelzer, Johannes Kepler University, Linz, Austria
"FMCW MIMO Radar Concepts based on SiGe Transceivers"

Recent achievements in the integration of mm-wave radar-systems have led to many new applications and features. An outstanding development is the integration of multi-channel systems, which allows the utilization of beamforming and/or phased array techniques for mass market applications. Nevertheless, standard sensor concepts offer only limited performance in such systems, due to the restrictions imposed by the need for low-cost solutions. This contribution will give an introduction to standard beamforming concepts applied to FMCW radar sensor concepts. Furthermore the limiting factors of conventional approaches will be shown. Methods to overcome these limitations will be discussed. By means of a prototype system operating at a frequency of 77 GHz, the emerging MIMO-radar technique will be illustrated. The presentation will cover multiple aspects of radar sensor design and signal processing algorithms.