T/R Module Design and Calibration

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(Session Organizers)

Transmit/Receive (T/R) modules are the heart of any phased array radar system. There is currently a great deal of work going on in this area right now, with a focus on lowering the cost of phased arrays and increasing the functionality and capability. With advances in digital beamforming, the digital technology moves closer to the array every year, and the barriers between the digital receiver/exciter, T/R module, and the antenna radiating elements become blurred. This tutorial will present an overview of the current state of T/R modules including advances in solid state devices and packaging, as well as advances in digital beamforming hardware components and receiver/exciters. The tutorial is composed of three separate segments, with multiple contributors for each part. The coordinators of each segment are listed above.

1. Introduction to T/R Modules, Design and Packaging Approaches, and Microwave Characterization and Calibration

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This introduction will discuss T/R modules and their role as a system element in radar designs. We will discuss design and integration approaches incorporating off-the-shelf components including board design, interconnects, packaging, module housings, and thermal mitigation strategies. Microwave characterization and measurements both on the benchtop and in the antenna range will be discussed, as well as calibration of the module. Finally, the role of emerging component and packaging technology and their potential impact on future phased arrays will be discussed.

2. Emerging Component and Packaging Technology for Radar T/R Modules and Integrated Receiver/Exciters

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This segment will discuss emerging component technology which is relevant for next-generation radar T/R modules and integrated digital receiver/exciters (DREXs). The tutorial will survey different IC technologies of interest to both T/R modules and DREXs,

including both SiGe devices and GaN-based HPA MMICs. The discussion will also include the development of integrated SiGe receiver/exciters including a novel Tx/Rx chipset developed at AFRL and packaged and tested at MIT/LL and an integrated synthesizer chipset developed at MIT/LL.

3. Low Cost Panel Based Phased Array Technology: Multifunction Phased Array Radar (MPAR) for Air Traffic Control and Weather Surveillance

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MPAR (Multifunction Phased Array Radar) has been proposed as the Next Generation Weather Surveillance and Air Traffic Control Radar System for the U.S. MPAR is an S-Band phased array system supporting dual linear and circular polarizations. Each installation will consist of four faces to provide 360 degree coverage. There are two basic system sizes: 1) terminal MPAR with approximately 5000 elements per face and 2) en-route MPAR with approximately 20,000 elements per face. To provide full coverage of the U.S. airspace 356 systems are required. The scale of MPAR is significantly larger than any phased array program to date, driving a demand for many million T/R modules. MPAR presents significant cost and performance challenges which must be overcome for the program to be viable.

To meet the cost and performance goals of MPAR, commercial manufacturing practices are being exploited at the IC, packaging, module and aperture board level. The proposed RF building block of the MPAR system is an 8x8 array panel, manufactured in laminate technology, containing radiating elements, beam forming networks and dual channel T/R modules. The RFICs, the heart of the T/R module, are packaged in industry standard PQFN packages. The T/R module supports horizontal, vertical and circular polarization modes. On transmit, each polarization channel is capable of 8 watts at a 10% duty cycle.

The semiconductor technology, packaging, printed circuit board and thermal design consideration will be presented. Various trade-offs considered in the realization of the MPAR aperture will be explored.

Biographies

Dr. William H. Weedon

Dr. William H. Weedon founded Applied Radar, Inc in 1996 and has been employed full-time as the President/CEO since then. The company was originally started as a consulting company, but has grown significantly with the help of dozens of DoD SBIR contracts and other DoD and commercial work to over $6.0M annual revenues and 30 employees. Applied Radar specializes in the development of advanced radar systems,

primarily for DoD customers such as the US Air Force, the US Army, US Navy, DARPA, SOCOM and MDA.

As President and CEO of Applied Radar, Inc., Dr. Weedon has served as Principal Investigator on numerous DoD research and development contracts in areas covering antenna design and modeling, RF transceiver development at X-band, Ku-band and W-band, high-speed real-time digital processing hardware, and radar and electronic system development. This has resulted in numerous publications, technical reports and several US patent applications.

Dr. Weedon received a BSEE degree in Electrical Engineering (Summa Cum Laude) in 1989 and MSEE in 1990 from Northeastern University and a Ph.D. in Electrical Engineering from the University of Illinois at Urbana-Champaign in 1994 under the direction of Prof. Weng Cho Chew. He is a member of the Tau Beta Pi, Phi Kappa Phi, Eta Kappa Nu honor societies, is formerly Co-Chairman (1999-2003) of the Boston section of the IEEE Antennas and Propagation Society, and is a member of the IEEE Microwave Theory and Techniques society. He was exhibit chairman for the 2003 IEEE Phased Array Systems and Technology Symposium (Waltham, MA) and was also exhibit chairman for the 2007 Radar Conference in Boston, MA. He is currently Publicity Chairman for the 2010 IEEE Phased Array Systems and Technology Symposium (Waltham, MA).

Dr. Leonard M. Johnson

Dr. Leonard M. Johnson is Assistant Leader of the Analog Device Technology Group at MIT Lincoln Laboratory. He has extensive experience in technology development for wideband RF mixed-signal systems. Over the past four years, Dr. Johnson has led the development of new technologies for highly-compact wideband transmit/receive modules for phased-array radar applications. This effort encompasses the design of state-of-the-art silicon germanium integrated circuits, advanced multi-chip-module (MCM) packaging, and wideband digital firmware. He is also currently leading an effort on high-performance charge-domain samplers for wideband digital receivers. In earlier efforts, Dr. Johnson pioneered key photonic technologies for wide-dynamic-range fiber-optic antenna remoting and optical beamforming systems. In addition, he has been engaged in numerous study efforts focused on advanced electronic technologies for DoD systems. Dr. Johnson received the BS, MS and PhD degrees from the Massachusetts Institute of Technology, all in Electrical Engineering.

Selected Publications:

1. R. G. Drangmeister, L. M. Johnson et al, “Multi-Chip-Module Based X-Band Receiver Utilizing Silicon Germanium MMICs,” *Proceedings of the 33rd Annual GOMAC Tech Conference,* Las Vegas, NV, March, 2008.
2. T. K. Quach, C. A. Bryant, G. L. Creech, K. S. Groves, T. L. James, A. G. Mattamana, P. L. Orlando, V. J. Patel, R. G. Drangmeister, L. M. Johnson, B. K. Kormanyos, and R. K. Bonebright, “X-Band Receiver Front-End Chip in Silicon

germanium technology," *Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems*, Orlando, FL, January, 2008.

Dr. Douglas J. Carlson

Douglas J. Carlson received his ScB in Electronic Material from Brown University in 1983 and his ScD in Electronic Materials from the Massachusetts Institute of Technology in 1989. Dr. Carlson subsequently served on the research staffs of MIT and Bell Laboratory, Murray Hill, NJ. His research focus was on fabrication and characterization of semiconductors and superconductors for microwave applications. In 1990, Dr. Carlson joined M/A-COM, Inc. in its Advanced Semiconductor Division. In his career at M/A-COM he has held Engineering, Operations and Product Management positions. Dr. Carlson is now the Director for Business Development for M/A-COM Technology Solutions RF Semiconductor Division where he is focused on Advanced Technology Development. In this role, Dr. Carlson is pioneering the application of commercial manufacturing practices to demanding Government applications. Dr. Carlson has published over 40 articles in peer reviewed Journals. He has authored numerous invited papers and invited presentations on the topics of Advanced Semiconductors, Packaging, Low Cost Manufacturing and Phased Array Radar.