Radar Systems Prototyping

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Abstract:
Whether you are a student seeking real data to prove your Ph.D. thesis, or a researcher planning for experimentation in your grant proposal, or a system engineer in need of a radar prototype to demonstrate your innovative idea to a customer, you will be faced with prototyping a radar system with limited time and budget. There exist many books and tutorials on basic and advanced signal processing, but little is found on how to build your radar prototype that can support and run these algorithms. This tutorial will provide you with practical skills and techniques needed to build your advanced radar prototype. The focus is not on how devices/algorithms work, but on how to relate the choice of microwave devices and signal processing algorithms to the desired radar specifications.

You will learn how to interpret datasheets and how to interface with vendors. The course will end with a step-by-step MIMO radar design example, starting from the requirements and ending with a schematic and bill of material. All participants will also receive a free consultation to their current radar system design until their project is completed.

Intended Audience:
• Students seeking to develop basic radar systems for academic and research purposes
• Engineers and scientists working in RF engineering seeking practical skills to develop prototype hardware
• Young engineers facing their first radar systems design
• Specialists, theoreticians and academicians who are interested in seeing the “big picture” in radar
• Project and program managers of radar systems who wish to learn how to interpret and evaluate technical content and documents
• Designers new to the radar field or those needing a refresher on the basics of radar system design and an overview of state-of-the-art radar sub-systems technology.

The participant is expected to have a basic exposure to:
• EM, RF and Microwave theory at undergraduate level
• Introductory radar concepts
• Basic linear systems and frequency analysis

Learning Outcome:
Learn how to derive schematics, bill of materials, and algorithm flowcharts from desired radar systems requirements. Learn how the selection of components and algorithms affect the radar performance.
**Detailed Description:**

This introductory level short course provides the student with an ability to perform basic system engineering design and prototyping for common radar applications.

This course will present a procedure to translate mission requirements into detailed radar designs, including subsystems and component selection (with emphasis on COTS). The participant will learn how to develop requirements for each subsystem, the top-level hardware design and DSP architecture as well as developing verification and validation plans.

This tutorial will not address specialized signal processing algorithms or the principles of operation of components, which are properly addressed in other tutorials or university classes. The objective is to learn how to identify the proper component or DSP algorithm that meet the specifications resulted from systems analysis and design. The participant will learn how to evaluate datasheets and how to interface with vendors. Most importantly, the participant will learn how the selection of a particular component or algorithm will affect other components and the radar performance in general. The participant will learn critical system thinking in making the right decisions under realistic constraints.

The proposed syllabus includes, but is not limited to:

1. Principles of system analysis, requirement engineering, SWAP analysis, and trade studies
2. Apply these system approaches for various radar applications (Ground, Air, Imaging, Tracking, Surveillance, Distributed, Passive, GPR, EW, Vehicular)
3. Explore RF chain design techniques applicable from 1 MHz to 300 GHz. Learn what technologies are appropriate for any given frequency band. This includes:
   a. Translate radar performance requirements to RF requirements
   b. Design the RF chain to meet linear dynamic range requirements
   c. Design the RF chain to meet noise requirements
   d. Translate SAR/ISAR/GMTI/FMCW/Passive Radar requirements to phase noise constraints
   e. Impedance matching to meet gain and gain flatness requirements
   f. Derive power, thermal and environmental requirements
4. Front-end components and subsystems. This includes:
   a. The right antenna for the right mission
   b. Cabling methodologies for transmitting and receiving signals, including photonics
   c. Deciphering datasheets
   d. Understanding how the selection of one component may affect the selection of others
   e. Amplifier selection and proper location in the RF chain
   f. How to select oscillators and frequency references that meet the Doppler constraints
5. Back-end Design
   a. Understand ADC and DAC system parameters. Particular focus is given to modern high-order Nyquist sampling
   b. Implementing signal processing in ASIC, FPGA, GPU or CPU
   c. Design the direct digital up/down conversion algorithms that preserve the signal quality obtained by the RF chain. Understand how RF chains directly affect the DSP design, and vice-versa
   d. Understanding the timing distribution issues, in particular for co-located and distributed multistatic/MIMO radar systems
6. Verification and validation
   a. Overview of test equipment: oscilloscopes, logic analyzers and dynamic signal analyzers, spectrum analyzers and power meters, network analyzers
b. Preparing and executing V&V and T&E plans

7. Radar system designs examples
   a. Step-by-step design of an X-band pulse-Doppler radar
   b. Step-by-step design of a passive radar system (optional)
   c. Step-by-step design of a millimeter-wave radar (optional)

Relevance:

Most of the tutorials in the IEEE Radar Conference are specific in nature and tend to present the latest advances in a specialized field or area of interest. These tutorials are aimed at researchers seeking specialization and understanding of the latest radar concepts and developments.

An introductory radar tutorial is normally offered in the IEEE Radar Conference, which usually targets students or young engineering seeking the “big picture” in radar. However, the emphasis is given to the signal processing aspects of Radar systems, which undoubtedly plays a pivotal role.

However, due to the large syllabus to be covered, the introductory radar tutorial usually overlooks the hardware and DSP system design aspect, which is crucial for radar systems engineering joining the commercial or consulting sectors, or researchers seeking to develop their systems.

There is a need for an additional “introductory” radar tutorial complementing the already established ones that emphasize the practical system engineering aspect of radar.

Prior Presentations:
The course has been successfully presented in the following events:

- University of Dayton short course “Introduction to Radar” (full day), presented three times to about 40 participants
- University of Algiers (full day) to about 40 participants
- National Air Space Intelligence Center (full day) to about 20 participants. Feedback from all participants has been unanimously positive
- Air Force Research Laboratory (full day) to about 20 participants. Feedback from all participants has been unanimously positive
- IEEE NAECON Conference, Dayton OH (half day) to about 30 participants
- IEEE Signal Processing Symposium, Debe, Poland (half day) to about 20 participants

Bio-sketch:

Dr. Lo Monte has more than ten years of applied RF, EW, and radar system design experience, from small companies (PCTEL), consulting (Patina) and non-profit institutions (UDRI) to large defense contractors worldwide (Rheinmetall A.G., General Dynamics) and government research agencies (U.S. Air Force Research Laboratory, NATO). He is also an associate professor at the University of Dayton, where he teaches the courses “Introduction to Radar,” “Modern Radar Signal Processing,” “Radar/RF Systems Design,” “Introduction to Electronic Warfare,” and the Keysight-sponsored “RFM µW Measurement Laboratory”. Throughout his career, he gained experience in HF- to-W Band radar systems prototyping, including
monopulse radar, radar transmitters, surveillance radars, multistatic ISAR and tomography, MIMO radar, GPR, passive HF/VHF/UHF systems, radars for IED/EFP detection, ballistic missile defense radar, resonance exploitation, RF/IR integration, DRFM, electronic attack, waveform design, antenna/microwave component design, antenna chamber measurements, instrumentation control, computational electromagnetics, inverse scattering, digital signal processing, electrical/mechanical CAD design. He has been a visiting scholar to Rensselaer Polytechnic Institute and is currently in the adjunct faculty at the University College London.

Academically, Dr. Lo Monte has published over 50 peer reviewed journal and conference papers and two book chapters. He is also the director of the Mumma Radar Laboratory, which hosts the first *tomographic and distributed sensing chamber* worldwide. Dr. Lo Monte has been very active in the IEEE community, serving as vice chair of the IEEE Dayton Section, as an associate editor of the IEEE Sensors Journal and technical reviewer for 11 different IEEE societies. He volunteered as co-chair, technical panel member, steering committee member, judge, special session organizer, and session chair in many transnational conferences.