BESSER ASSOCIATES®

The Worldwide Leader in RF and Wireless Training

2015 COURSE OUTLINES & INSTRUCTOR BIOS

May 2015

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Contents

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Advanced Radio System Architectures

Course 214

•Oct 12-Oct 14, 2015 - San Jose, CA / Richard Ranson

Summary

The ideas associated with sampling and digital signals that revolutionised modulation systems and are now revolutionising radio system design. This course continues the theme of block diagram rather than circuit diagram design, presenting an up to date view on concepts for advanced radio systems that incorporate digital signal processing at RF frequencies and the concepts of software defined radio. It is a practical approach for technical professionals to understand the latest designs and architectures for radio systems that include DSP.

Learning Objectives

Upon completing the course the student will be able to:

•Understand important features of ADC/DAC with respect to sampling theory, filtering, Eb/No
•perform cascade system analysis incorporating ADC functions
•select oscillators, mixers, and frequency synthesizers for specific applications
•understand PLL measurements of gain, phase margin, phase noise
•create accurate IQ modulators and demodulators
•weigh strengths and weaknesses of various system architectures including SuperHet and ZIF designs
•plan and distribute frequency control and gain blocks including automatic control loops
•balance analog/digital and hardware/software distribution for a given system

Target Audience

This is an intermediate to advanced level course for system architects, design engineers and managers looking for up to date information on recent advances in the field of radio system design. The objective is to expand the range of radio design into the DSP era. Learning objectives include identifying the critical RF parameters in wireless transceiver technology, understanding the various trade offs in different architectures and understanding the balance of analogue to digital processing for cost effective design solutions. These concepts have a broad range of application from low cost terminal devices for mobile communications, multifunction radio systems, remote sensing, advanced concept radios for radar/surveillance and enabling wireless connectivity in a variety of product and services.
The course is suitable for those working in radio as well as in the mobile phone industry, handset or base station, satellite communications, radar and EW / ECM.

Outline

Day One

Sampling, DSP and Software Defined Radio

- Important features of ADC/DAC
- Sampling theory
- Baseband filtering
- Eb/No
- Digital processing
- Digital down conversion
  – *Software defined radio*

System Level Parameters

- Signal and noise levels
- Intermodulation
- Dynamic range
- Standard cascade analysis extended to include ADC

Day Two

Local Oscillators

- Stability
- Tuning range
- Linearity

Mixers

- Image band
- Choice of IF
- Spurious signal responses
- Examples

Frequency synthesizers

- Direct
- Indirect
- Digital
- Examples showing options and designs

System Level Performance

- Mixers, multipliers, PLL contributions to spurious and noise
- Measurement techniques
- PLL gain, phase margin, phase noise
- IQ modulator/demodulators for accurate signals

Day Three

Transceiver Architecture Incorporating DSP

- Examples of real system architectures
- strengths and weaknesses
- Superhet radio
- Single/multiple IF designs
- Direct conversion/zero IF (ZIF)
- Near-zero IF
- Frequency and Gain planning
- Automatic gain control loops
- Automatic frequency control loops

DSP Considerations

- Relevance to radio system architecture
- Balance of analog to digital functional blocks
- Balance of hardware to software

Bonus Materials on Included CDROM

- Custom applications
- Spreadsheets
- Simulation files
- Selected application notes
- Web links

Antennas & Propagation for Wireless Communications

Course 037

•Oct 12-Oct 15, 2015 - San Jose, CA / Steven Best

Summary

This four-day course provides participants with comprehensive coverage of a wide variety of antenna and propagation topics. The course provides an understanding of basic antenna property definitions, antenna design fundamentals and considerations, numerous antenna types and RF propagation fundamentals. The course also provides an overview of how antenna properties and propagation characteristics affect communication system performance. Topics covered include fundamental antenna performance properties, antenna specifications and data sheets, basic antenna types, elementary antennas, electrically small antennas, wireless device antennas, medical device antennas, low profile antennas, aperture and reflector antennas, circular polarized antennas, antenna arrays, propagation channel characteristics, antenna diversity and MIMO, and an overview of different antennas used in today's wireless communication systems and markets.

Learning Objectives

Upon completing the course the student will be able to:

- Understand the concepts associated with antenna performance, operation and classification.
- Understand, evaluate and define antenna performance specifications.
- Describe and understand a broad spectrum of antenna types.
- Illustrate antenna operating principles with a factual knowledge of antenna theory.
- Understand the basic performance trade-offs associated with antenna design.
- Understand how to design basic antenna elements.
- Understand basic principles associated with the implementation of antenna arrays.
- Understand and describe how antenna performance and the RF propagation environment impact wireless communication system performance.
- Understand the basic types of antennas that are used in today's wireless communications markets.

Target Audience

Anyone working within the field of general RF systems, wireless, cellular and microwave systems will benefit from this comprehensive coverage of antenna properties and design. The course is well suited for design engineers and program mangers who require an understanding of antenna principles and design concepts. Basic mathematical and computing skills are a prerequisite for this course. An electrical engineering background or equivalent practical experience is recommended but not required.

Outline

Day One

Basic RF Concepts

- Review of fundamental RF Concepts
- Basic design and performance requirements of a wireless communication system

Basic Antenna Concepts

- Definitions of basic antenna properties
  - *impedance, VSWR, bandwidth, directivity, gain, radiation patterns, polarization, etc.*

Types of Antennas

- Resonant antennas
- Traveling wave antennas
- Frequency Independent antennas
- Aperture antennas
- Phased arrays
- Electrically small antennas
- Circularly polarized antennas

Classification of Antenna Types

- By frequency
- By size
- By directivity

Fundamental Antenna Elements

- The monopole
- The dipole
- The loop
- The folded dipole
- The slot

Microstrip Antennas

- Element types
- Microstrip element design
- Design trade-offs
- Designing and 802.11 microstrip patch

Baluns

Ground Plane Considerations

- Vertically polarized antennas
- horizontally polarized antennas
- The impact of the surrounding environment on antenna performance

Day Two

Circularly Polarized Antennas

- Achieving circular polarization
- The helix antenna
- The crossed dipole antenna
- The microstrip patch
- The quadrifilar helix

Aperture Antennas

- Aperture design concepts
- The horn antenna
- The reflector antenna
- The corner reflector

Impedance Matching

- Impedance matching networks

Broadband Antennas

- Monopole configurations
- Feed considerations
- Dipole configurations
- Bandwidth improvement techniques

Frequency Independent Antennas

- The log-periodic antenna
- The spiral antenna

Electrically Small Antennas

- Impedance, bandwidth and quality factor of antennas
- Defining electrically small
- Fundamental performance limitations
- The small dipole
- The small loop
- Design and Optimization of small antennas

Day Three

Antenna Arrays

- Fundamental array theory
- Types of antenna arrays
- Feed network design considerations
- Beam steering and shaping concepts
- Performance trade-offs
- Microstrip patch arrays
- Dipole element arrays

Friis and Link Budget

- The communication link
- Understanding and calculating path loss
- Receiver Sensitivity and antenna noise figure
- Link budget calculations

Receive Properties of Antenna

- How does an antenna capture power
- Aperture area and efficiency
- Coupling between antennas

Fractal Antennas

- Fractal antenna types
- Performance properties of fractal antennas

RFID Antennas

- RFID system basics
- Performance properties of RFID antennas

Ultra Wideband (UWB) Antennas

- Time domain considerations in antenna design
- Antenna performance requirements in UWB systems

Low Profile Antennas

- The inverted L and inverted F antennas
- The planar inverted F antenna (PIFA)

Device Integrated Antennas

- Antennas commonly used in wireless device applications

Day Four

Propagation Channel Considerations

- RF path loss
- Reflection, multipath and fading
- Noise and interference
- Polarization distortion
- Diversity implementation
- MIMO

Types of Antennas used in Communications Systems

- Wireless base station antennas
- Wireless handset and portable device antennas
- GPS antennas
- HF, UHF and VHF communication antennas
- Earth station and satellite communication antennas

Numerical Modeling of Antennas

- Software packages
- Comparison with measurements

Antenna Design and Simulation Examples Using Commercial Antenna Design Software

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Applied Design of RF/Wireless Products and Systems

Course 161

Summary

This 3-day intermediate-level course focuses on the practical design and development of modern RF and wireless communications circuits and systems using common digital modulation standards. In today's highly competitive global wireless industry, the design-to-production cycle is of crucial importance. However, developing modern wireless products, such as Wi-Fi, GPS, Bluetooth, Zigbee, and 3G/4G devices, presents many challenges. Advanced skills and knowledge are required, not only to architect these systems and devise suitable circuit topologies, but also to solve the challenging integration and manufacturability issues associated with high-volume products. This course teaches the practical aspects of developing robust RF and wireless designs suitable for high-volume production.

Learning Objectives

Upon completing the course the student will be able to:

•Describe common digital modulation standards and modulation formats
•Explain the key component-level specifications of each transceiver circuit block
•Explain the component and system-level measurements required to characterise digital modulation systems
•List the key features, strengths and weaknesses of common transceiver architectures
•Specify the key measurements for digital receivers and transmitters
•Identify the effects of PCB layout on system performance, and use best practices to minimise layout-related problems
•Mitigate against yield, tolerancing, self-EMC, conducted and radiated integration problems.
•Identify verification methods to validate a digital modulation system

Target Audience

The course is aimed at engineers, technicians and engineering managers working in the wireless communications industry. The audience typically includes RF engineers and technicians working in research and development, manufacturing test and production environments and systems engineers responsible for the architecture of RF communications systems. The course will also be of interest to managers who oversee these groups..

Outline

Day One

Digital Modulation Fundamentals

- System link block diagram
  - *modulation, transmission, channel, reception, demodulation*
- Why Digital?
  - *Resistance to fading, voice vs. packet data, capacity*
- IQ modulation representation
  - *constellation, eye diagram display formats*
- BPSK, QPSK, MSK, properties of gaussian and RRC filtering, concept of ISI
- Channel characteristics, diversity, fading types, mitigation techniques, Spread spectrum, OFDM, equalisation and training
- TDMA, FDMA, CDMA definitions
- TDD, FDD

Common Modulation Standards and Implications for RF Implementation

- Constant envelope modulation examples
  - *Bluetooth, GSM*
- Non-constant Envelope Modulation examples
  - *EDGE, W-CDMA, LTE, CDMA2000, 802.11a/b/g/n/ac, GPS, Bluetooth EDR*

Transceiver System Considerations

- Common RF System Components
  - *Amplifiers, mixers, filters, etc.*
- Imperfections: Distortion and noise, spurious responses
- Transceiver architectures and trade-offs
  - *Frequency planning, analysis of cascaded blocks, TDD and FDD considerations*
- Transceiver architectural examples
- GSM example, Bluetooth example, 3GPP example. Superhet, Zero IF, low IF, Analogue quadrature modulator, Digital IF, Up-mixing. Upconversion loop

Day Two

RF Component-level Measurements

- Linear measurements
  - *Power, S-Parameters (including Balanced devices), Group delay, Noise figure, Phase noise*
- Nonlinear measurements
  - *Intermodulation, Load-pull, EVM, ACP, AM-AM and AM-PM calculated from IQ measurements*
- Two-tone Intermodulation
- ACP
  - *GSM and W-CDMA measurement examples*
- Modulation Accuracy - EVM
  - *Rms, peak, 95th percentile*
- Measurement uncertainty properties of small EVMs
- Load-pull
- Source and Load plane contours of gain, efficiency, ACP, EVM

Receiver Measurements

- Analysis of Cascaded Blocks
- BER
  - *Bit errors, block errors, frame erasure, sync errors, Typical measurement system, including loopback mode*
- Sensitivity Definitions, e.g. 1E-3 BER point
- Receiver Blocking Mechanisms
- Selectivity Measurements
- Spurious Response Measurements
- Measurement techniques
  - *- analogue IF / IQ / RSSI level sweep with interferer*

Transmitter Measurements

- Spurious Emissions
  - *Tx noise in rx band, Har-*

monics and mixing products

- Transient Behaviour
  - *Power - time response, Frequency spectrum due to power burst, Frequency kick due to power ramping*
  - *Due to modulation, due to power switching transients*
- Modulation Accuracy - EVM
- Code Domain Power and PCDE
- ACP

Day Three

Fabrication Technologies

- PCB types
- Etching tolerances, board layer construction, vias/drill sizes, thermal reliefs, implications on RF performance
- TDR characterisation

RF System Integration

- choosing PCB layer structure
- grounding strategies
- coupling between components
- floorplanning
  - *which side of the board to place components to maximise isolation*
- shielding / screening, gaskets, effectiveness
- mismatches when cascading filters and amplifiers, pulling and buffering
- Tolerancing / Yield
- Thermal and electrical derating for reliability

Integration of RF and Baseband

- processor clocks getting into receivers
- system planning to avoid harmonics at specific frequencies
- reference spurs on VCOs
- "hot" supply lines and control lines, and their effect on the system

The Design Verification Process

- What to test and what to look for at each prototype iteration
- Integration Do's and Don'ts
- Minimising the number of Prototype Iterations required
- Automated Design Verification Testing

Case Studies - Products and circuit examples including:

- GSM
- W-CDMA
- DECT
- FSK
- PWT
- 802.11 series WiFi
- Zigbee
- GPS

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Applied Embedded Control Systems

Course 259

•Sep 14-Sep 18, 2015 - San Jose, CA / Tim Wescott

Summary

This five-day course is a complete course in basic automatic control theory and application, yet requires no prior control system design training. With this advanced knowledge the student will be equipped to address getting the highest performance out of a wide variety of automatic control systems - even systems that have such difficult nonlinearities as friction and backlash.

This course includes hands-on sessions with real hardware to demonstrate the practical application of the theory being taught, as it is taught.

Learning Objectives

Upon completing the course the student will be able to:

- Understand the z transform use it in control systems design
- Understand performance measures for control systems
- Specify pertinent, useful, and realistic performance measures for control systems
- Read, understand, and compose control system block diagrams
- Analyze control system behavior by manipulating block diagrams
- Analyze control systems for stability, robustness and performance
- Use various control system design techniques, including structured design of PID controllers
- Use sampling theory to design discrete time control systems for real-world problems
- Measure system characteristics through frequency response and interpret the results
- Implement control systems in embedded systems in software
- Deal with the most common real-world issues involved with controlling nonlinear systems

Target Audience

Engineers and managers who are actively designing systems, circuits or software employing embedded processors or FPGAs which must effectively control dynamic systems. In particular, embedded software engineers, embedded circuit designers, systems architects and managers who work with such systems.

Outline

Day 1

Basics

- Definition of a control system, definition of the parts of a control system, formal definitions of signals and systems.
- Definition of the z transform, modeling systems using transfer functions, system stability.

Performance

- Establishing performance measures in the time and frequency domains

Hands-on Design

- Design of controllers using pole placement

Day 2

Block Diagramming

- The control system block diagramming language, block diagram analysis

Analysis

- Effects of feedback on performance, estimating performance and stability in the face of plant variations.

Design

- Definition of a controller, evolution of the PID controller, advanced controllers.

Day 3

Hands-on Design

- Design of controllers using frequency domain design techniques on plant models (hands-on)

Sampling in the Real World

- Sampling theory, aliasing, orthogonal signals, noise, effects of nonideal sampling

Dealing with Continuous Time

- The Laplace transform, modeling continuous-time systems, converting models from continuous to discrete time.

Day 4

Nonlinear Systems

- Characteristics of nonlinear systems, design by linear approximation, designing with nonlinear compensation

Measuring System Characteristics

- Measuring frequency response

Hands-on Design

- Using measured frequency response to tune controllers

Software Theory

- Data types and their effects, quantization effects, overflow and underflow, resource issues.

Day 5

Software Practice

- Implementation examples common controllers using fractional, floating point, and integer math.

Instructor Q&A

- A generous portion of time is set aside on the final day for instructor questions and answers, for hand-on time with the demonstration hardware, and for students to pose questions about their own control systems for instructor comments and suggestions.

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Applied RF II: Advanced Wireless and Microwave Techniques

Course 086

Summary

This five-day course provides participants with an in-depth examination of advanced RF and microwave design techniques. Antennas and filters are covered briefly, followed by a detailed discussion of figures of merit. Mixers and oscillator designs are also evaluated. Considerable attention is devoted to defining, classifying, and improving the efficiency and linearity of power amplifiers. Numerous design examples are provided for participant exploration.

Students are encouraged to bring their laptop computers to class. CAD software will be used to simulate design examples.

Learning Objectives

Upon completing the course the student will be able to:

- Select optimum receiver architectures.
- Describe the practical limitations of small antennas and filters.
- Detect hot spots in proposed designs.
- Use figures of merit to optimize new designs and available integrated circuits.
- Evaluate spurious responses.
- Evaluate tradeoffs between noise figure, IIP3, match, isolation and DC power.
- Design low noise and highly linear amplifiers.
- Design passive and active mixers.
- Explain and design VCOs and stable oscillators.
- Design low distortion and efficient power amplifiers.
- Utilize modern circuit simulators and a simple system simulator.

Target Audience

Component and system level designers, as well as engineering managers will benefit from this course. Basic knowledge of microwave measurements and transmission line (Smith Chart) theory is assumed.

Outline

Day One - Receivers and Their Components

Small Antennas

- Simple
- Diversity
- Small size
- Efficiency
- Tuning

Filters: a 1 hour overview

- Performance
- Limitations
- RF Filter loss
- Selectivity
- Size
- Cost
- Active vs. passive

Receiver Types

- Architectures
- Performance
- Limitations
- Modulation - how that impacts architecture
- Hot spots, the problem areas

Figures of merit: preparing to evaluate circuit techniques, IC's

- Noise figure
- IIP3
- Match
- Isolation
- DC power tradeoffs
- Spurious response effects
- Comparing technologies

Day Two - Linear Receiver Circuits

LNA Design - A 2 Hour Review

- Specification hierarchy
- Design
  - *noise figure*
  - *gain*
  - *match*
- How to choose a device
- Review design of a 2.5 GHz low noise amplifier
- LNA and IF amplifier - reducing non-linearity
- Intermodulation, cross modulation, and blocking
- Evaluating IC performance
- Design
  - *Noise figure*
  - *gain*
  - *IIP3*
- Detailed design of a 1.9 GHz high IIP3 LNA
- Appying the techniques to a high performance IF amplifier

Mixers

- Specifications
- Evaluating available Ics
- Mixer types

Baluns

- Balance
- Size
- Loss
- Cost
- Some solutions

Day Three - Non-Linear Design

Mixers: Diode or FET, Active or Passive?

- Harmonic mixers
- Spurious responses
- Design of an active, a passive, and a doubling mixer

LO - Local Oscillator

- Specifications
  - *noise*
  - *spurs*
  - *stability*
- How to choose a device
  - *gain*
  - *size*
  - *current*
  - *technology tradeoffs*
- Feedback vs. negative resistance oscillators
- Circuit design overview
  - *loop gain*
  - *crossing angle*
  - *topology*
  - *types*
- Detailed designs
  - *1GHz VCO*
  - *2GHz LO*
  - *5 GHz DRO*
- Stabilization
  - *supply*
  - *load*
  - *temperature effects*
  - *squegging*

Day Four - Oscillators and Power Amplifier Design

Crystal Oscillators

- An overview
- Crystal characteristics and equivalent circuit
- Overtone oscillator
  - *what affects noise*
  - *spurious output*

Power Amplifiers

- Introduction
- Amplifiers classes A through Z
- Straightforward (Cripps) approach
- Real device characteristics and their impact
- Modelling with harmonic balance and SPICE
- Design of a class AB amplifier

Day Five - Power Amplifier Design

Improving Efficiency

- Class B and C amplifiers
  - *gain*
  - *load line*
  - *efficiency enhancement*
- Class E, F and harmonic termination amplifiers: realistic expectations
- Push- pull amplifiers, bipolar and FET

Multistage design theory

- Driver amplifiers and interstage matching, some solutions
- Balanced amplifiers, a solution to some matching problems
- Design of a 2 stage amplifier

Linearization Techniques

- Predistortion
- Feed-forward
- Lossless feedback

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Applied RF Techniques I

Course 001

Summary

Switching from traditional circuit definitions based on voltages and currents, to power-flow concepts and scattering parameters, this course offers a smooth transition into the wireless domain. We review S-parameter measurements and applications for both single-ended (unbalanced) and balanced circuits and have a brief introduction to RF systems and their components. Impedance matching is vitally important in RF systems and we use both graphical (Smith Chart) and analytical techniques throughout the course. We also examine discrete and monolithic component models in their physical forms, discussing parasitic effects and losses, revealing reasons why circuit elements behave in surprising manners at RF.
Filters, resonant circuits and their applications are reviewed through filter tables and modern synthesis techniques, leading into matching networks and matching filter structures.
Since wires and printed circuit conductors may behave as transmission line elements, we also cover microstrip and stripline realizations. 2D and 2,5D electromagnetic field simulators are used in the course to illustrate transmission line behavior and component coupling effects.
In the area of active circuits, we first examine fundamental limitations posed by noise and distortion. The next topic is small-signal linear amplifier design, based on scattering parameter techniques, considering input/output match and gain flatness RF stability is examined both with S-parameters and also with the Nyquist test using nonlinear device models. Since DC biasing affects RF performance, we review active and passive bias circuits and see how they can be combined with impedance matching circuits. Another important consideration is circuit layout, therefore we look at problems caused by coupling, grounding and parasitic resistance. Narrow- and broadband designs are compared, using lossless and lossy impedance matching as well as feedback circuits. Low-noise amplifier design is illustrated, discussing trade-offs among gain flatness, noise, RF stability, and impedance match. Harmonic and inter-modulation performance is also examined. Performance trade-offs of balanced amplifiers are viewed. The course concludes by examining large-signal and ultra wideband feedback amplifiers.

Students are encouraged to bring their laptop computers to class. CAD software is used in this course.

Learning Objectives

Upon completing the course the student will be able to:

- Describe RF circuit parameters and terminology.
- State the effects of parasitics on circuit performance at RF.
- Use graphical design techniques and the Smith Chart.
- Match impedances and perform transformations.
- Design filters with lumped and distributed components.
- Perform statistical analysis: design centering, yield optimization.
- Predict RF circuit stability and stabilize circuits.
- Design various RF amplifiers: small-signal, low-noise, and feedback.

Target Audience

The course is designed for practicing engineers who are involved with the production, test, and development of RF/Wireless components, circuits, sub-systems, and systems, in the 100-4000 MHz frequency range. It is equally useful to new engineers and to those who may have practical experience but have not had opportunity of getting a thorough foundation of modern, computer-oriented RF circuit techniques.
Engineering degree or at least three years applicable practical experience is recommended.

Outline

Day One

Introduction to RF Circuits

- Linear circuit analysis in RF systems
- Frequency range of coverage: 100-3000 MHz
- Log conversion, dB and dBm scales
- Complex numbers in rectangular and polar form
- Component Qs
- Importance of Impedance Matching
- Normalization
- RF component related issues

CAE/CAD Applications

- Computer Aided Design Methods
- Major Optimization Methods in Microwave CAD
- Network Synthesis Procedure
- Physical Limitation on Broadband Impedance Matching
- Electromagnetic (EM) Simulation
- Reliability and Yield Considerations
- Monte Carlo Simulation

RF/MW Fundamentals

- Complex impedance and admittance systems
- Resonance effects
- One-port impedance and admittance
- Series and parallel circuit conversions
- Lumped vs. distributed element representation
- Characteristic impedance and electrical length
- Signal transmission/reflection and directional couplers
- Key parameters
  - *Gamma*
  - *mismatch loss*
  - *return loss*
  - *SWR*
- Impedance transformation and matching
- Illustrative exercise

The Smith Chart and Its Applications

- Polar Gamma vs. Rectangular Z plots
- Impedance and Admittance Smith Charts

- Normalized Smith Charts
- Lumped series/parallel element manipulations
- Constant Q circles
- Expanded and compressed Smith Charts
- Impedance and admittance transformations
- Transmission line manipulations
- Illustrative examples

Scattering Parameters

- Review of one-port parameters
- Two-port Z-, Y-, and T-parameters
- Cascade connections and de-embedding
- S-parameters of commonly used two-ports
- Generalized S-parameters
- Illustrative examples
- Mixed-mode S-parameters

Day Two

Impedance Matching Techniques

- Power-flow in two-port networks
- Transmission zeros, LC network order
- Maximum power transfer from Z1 to Z2
- Single LC-section impedance matching
- Bandwidth and parasitic considerations
- Wideband match -- low circuit-Q
- Narrowband match -- high circuit-Q
- Illustrative examples

Lumped RF Component Models

- Resistors
- Inductors
- Effective Inductance and Q Variations
- Capacitors
- Effective Capacitance and Q variations
- Definitions of Magnetic Properties
- Magnetic Core Applications
- Ferrite Bead Impedance
- Exercise: Complex Impedance Matching
- Primary self-resonance

Day Three

Transmission Lines and Ground Parasitics

- Via-Hole and Wrap-Around Ground Inductance
- Parasitic Inductance and Capacitance Effects at RF
- Multilayer PC-Board Parasitics
- PCB/Interconnects
- Open Stub Effects in Differential Vias
- PC Board Materials
- Transmission Line Realizations
- Transmission Line Discontinuities
- Converting an Electrical Circuit to Physical Form

Filters and Resonant Circuits

- Introduction
- Recipes for lumped-element filters
- Parasitic loss and Q factor
- Impedance inverters
- Band pass filters with resonant structures
- Piezoelectric filters

Day Four

Active Circuit Fundamentals

- Linear circuit definition
- Amplifier Performance Limitations
- Thermal Noise Definition
- Harmonic Distortion Definitions
- Gain Compression
- Intermodulation Distortion
- Spurious-Free Dynamic Range
- Error Vector Magnitude
- Various Power Gain Definitions
- Testing for RF Stability
- Causes of RF Oscillation
- Typical Stability Circles for an RF Transistor
- RF Stabilization Techniques
- Nyquist Stability Analysis

Small Signal Amplifier Design

- Transducer Gain Expression
- Simultaneous Conjugate Match for Maximum Gain
- Class Exercise
- Two-stage Amplifier Design for Gmax
- Gain Definition - Block Diagram
- Operating Gain Definitions
- Operating Gain Circle Application
- Maximizing Output Power
- Available Gain Definitions
- Available Gain Circles

Day Five

Low Noise Amplifier Design

- Sources of RF noise
- Noise Factor and Noise Figure definitions
- Noise of cascaded stages
- Two-port noise parameters
- Low-noise design procedure
- Illustrative example

Broadband Amplifiers

- Broadband Concepts
- Wideband Amplifier Design Overview
- Voltage Gain Phase Shift
- Gain Control and Impedance Matching in Feedback Amplifiers
- Series and Parallel Feedback Applications
- 10-4000 MHz Feedback Amplifier Design
- Equivalent Circuit for Microwave FET
- Lumped Transmission Line and Distributed Amplifier
- Mitigating Cdg: the Cascode

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Applied RF Techniques II

Course 003

Summary

This five-day course is a follow up course to Applied RF Techniques I and provides participants with the critical tools to design, analyze, test, and integrate nonlinear transmitter and receiver circuits and subsystems. Circuit level engineers will master the latest nonlinear design techniques to both analyze and design transceiver circuits. System engineers will examine commercially available integrated circuit functions; learn the performance limits and how to establish specifications. Test engineers will learn how to test and evaluate circuits. Transceiver circuits to be covered include power amplifiers and the critical receiver elements: oscillators and mixers. Receiver architecture and synthesizer design to meet critical requirements will be presented. Techniques to successfully integrate circuit functions for the transceiver will be presented.

Students are encouraged to bring their laptop computers to class. CAD software will be used to simulate design examples.

Learning Objectives

Upon completing the course the student will be able to:

- Understand and quantify nonlinear effects of transmit and receive systems
- Use CAD nonlinear models to analyze/design circuits and transceivers
- Design efficient linear power amplifiers, using load pull data, as well as full nonlinear techniques for digital and analog input signals
- Compare and select various transmitter distortion reduction techniques
- Design high dynamic range sensitive receivers with multiple input signals
- Design signal sources using advanced phased lock loop techniques
- Design/specify/test low noise oscillators (DROs, Crystal, VCOs, VCXOs) and predict/minimize phase noise
- Design/specify/test passive and active mixers with various configurations and compare performance
- Integrate circuit functions considering PCB selection, grounding, interconnection techniques, isolation, and component interaction

Target Audience

Component and system designers, engineering managers, test and engineering technicians will benefit from this course. Applied RF Techniques I or equivalent practical experience is recommended for this course.

Outline

Day One

Nonlinear Circuits & Concepts

High Efficiency Power Amplifier Design

- Transmitter elements and modulation
- PA transistors
- Matching for maximum gain or output power
- Load-pull measurement techniques
- Predicting output power contours, design examples
- High efficiency techniques
- Class A, B, C, D, E, F, harmonic termination consideration
- Power combining

Nonlinearities in RF Amplifiers

Day Two

Power Amplifier Distortion Reduction Techniques

- power back-off
- Cartesian feedback
- fixed predistortion
- RF predistortion
- digital predistortion
- feed-forward
- LINC

Alternate transmitters

- Kahn, Polar, Doherty, Chierix-Outphasing

CAD of Nonlinear Circuits

- Nonlinear circuit analysis and transistor nonlinear models
- Complete BJT and FET CAD circuit design example

Day Three

Receivers and Their Architecture

- RF receiver types, performance characteristics, comparison
- A/D considerations
- Receiver nonlinearities

Modulation Techniques

- AM, FM, digital
- Receiver architectures and design
  - *amplification, filtering, LO selection, mixing, demodulation*
- Testing

Frequency synthesis, PLL design

Day Four

Feedback and negative resistance oscillator design

- RF stability, pushing, pulling considerations

AM FM Noise Considerations

- Low phase-noise design
- Post tuning drift

Dielectric Resonators

- Dielectric resonator stability techniques

VCOs and crystal oscillators

- Electronic tuning strategies
- Oscillator specification, testing
- Commercially available VCO's

Day Five

Diode and Transistor Mixers

- resistive and active, design examples
- Mixer types
  - *single, balanced, doubly balanced, image reject, image enhanced, harmonic*
- Conversion loss/gain

Harmonic suppression, linearity, and dynamic range

Integrated assemblies

- PCB materials, grounding, layout and interconnection techniques, isolation, component interaction

Transceiver Integration

- Commercially available transceiver IC chips

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Behavioural Modeling & Digital Pre-Distortion of RF Power Amplifiers

Course 212

Summary

The goals of RF power amplifier design are high efficiency and linearity. With modern cellular communications modulation formats such as LTE and WCDMA these goals are difficult to achieve simultaneously with traditional RF PAs, and high-efficiency architectures such as Doherty, Envelope Tracking, and so forth are becoming more commonplace. These PAs require an additional linearization system to achieve the mandated linearity specifications. The emergence of high-speed digital signal processing techniques has enabled the linearization to be accomplished in the digital signal domain, and digital pre-distortion (DPD) is now the preferred linearization technique. This course explains the nonlinear behaviour of RF power amplifiers, developing general modeling techniques to describe the nonlinearities and memory effects. A system-level approach to the modeling and linearization of the PA is adopted, and techniques for implementation of DPD in practical situations are described.

Learning Objectives

Upon completing the course the student will be able to:

- Understand and describe the nonlinear behaviour and memory effects found in RF power amplifiers
- Use and understand the mathematical algorithms for behavioural modeling and digital pre-distortion
- Use and implement digital pre-distortion methods for linearization of RF Pas
- Evaluate and compare modeling and DPD techniques

Target Audience

This course is suitable for RF PA designers, DSP designers, and System-Level engineers who are involved in the specification, design, and implementation of linearized RF PAs and transmitter systems, or who are developing pre-distortion methods, software and algorithms for linearization of RF PAs. Electrical Engineering degree or equivalent and at least two years applicable practical experience is recommended.

Outline

Day One

RF Power Amplifiers in Modern Wireless Communications Systems:

- Modern Wireless Communications modulations formats: LTE, WCDMA
- Signal Metrics: Peak-to-Average Power Ratio
- High-efficiency PA architectures: Doherty, Envelope Tracking
- PA metrics: AM-AM, AM-PM, ACLR, EVM

Introduction to Models and Modeling

- Compact models, Behavioural models
- Introduction to System Identification methods

Day Two

Behavioural Modeling Methods

- Nonlinear modeling
- Memory effects
- Nonlinear dynamical models: Volterra Series formulations and practical implementations
- Frequency-domain models and methods: X-parameters

Day Three

Digital Pre-Distortion Methods

- Typical approaches using digital control techniques; ‘indirect learning’; LUT and algorithmic approaches
- Adaption techniques: convergence, optimization
- DPD implementations: architectures and hardware, system components
- Practical and commercial DPD systems overview

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BER, EVM, & Digital Modulation Testing for Test & Product Engineers

Course 221

Summary

This class focuses on learning and applying BER and EVM measurement techniques to RF SOC/SIP products and is ideal for test and product engineers working with production ATE (Automatic Test Equipment). Each pair of students will be given hardware and software to use during the class. Throughout the class students will develop BER and EVM test solutions and analyze and compare results. Students will get to develop both parametric and system level test solutions that are used throughout industry for a variety of RF and Mixed Signal devices including: ZigBee, Bluetooth, DECT, WiFi, FM, GPS, 3G 4G mobile/cellular phones. Students will develop EVM & BER test solutions for OOK, BPSK, QPSK, QAM, AM/FM, and OFDM modulation for production ATE.

Student solutions will include: BER Sensitivity, BER with interferences (Co-Channel, Adjacent Channel), Frequency Hopping BER, and EVM.

Parametric measurements that students will develop include: INL/DNL, SNR, audio SINAD, audio THD, Harmonics, SFDR, IQ Amplitude/Phase imbalances,PLL/Synthesizer settling time, and Carrier Drift.

Students will spend a majority of the class time using real hardware and software to generate, capture and analyze various modulated signals. Students will get to compare and optimize testing solutions to achieve the best results.

Hardware and Software Provided:

Each pair of students will be provided with an FM transmitter that will be used during the class to transmit and receive signals to and from other students. Signals will be created, analyzed and measured using a USB Data Acquisition (DAQ) device

Learning Objectives

Upon completing the course the student will be able to:

•Implement modern system level tests including physical layer BER and packet based BER & EVM on RF SOC and SIP devices.
•Implement static (INL/DNL) and dynamic (SNR, SFDR, THD, etc.) measurements on DACs (Digital-to-Analog Converters) and ADCs. (Analog-to-Digital Converters) utilizing best known techniques Undersampling, Oversampling, Decimation, Digital Filtering, and Averaging) to achieve lowest COT and best production test results.
•Implement traditional parametric measurements like Gain, Intermodulation Distortion, Harmonics, Jitter, Noise, Phase noise, Spectral Mask in a production testing environment.

Target Audience

The course is designed for new and practicing test/application/product engineers who are tasked with developing production and manufacturing test solutions using ATE (Automatic Test Equipment) and other instrumentation for wireless SOC/SIP chipsets including: 2G/3G/4G, WiFi, ZigBee, GPS, Bluetooth, etc.

Student Requirements:

Students will control and operate hardware using student supplied laptop. Laptop should have Windows XP, or Windows 7. Software and drivers to control the hardware will be supplied and installed at the beginning of class.

Outline

Day One

Analog Measurements

- DACs (Digital-to-Analog Converters)
- ADCs (Analog-to-Digital Converters)
- Static DNL/INL testing (Differential Non-Linearity and Integral Non-Linearity)
- Generating Ramps
- Missing Codes
- FFT Overview
- Dynamic Range
- ENOB (Effective Number of Bits)
- Quantization Noise
- DC Offsets
- Histogram testing

Day Two

Applied Mixed Signal Testing

- Time Domain / Frequency Domain Analysis
- Random Processes and Gaussian Distributions
- Digitizer Sampling
- Coherency
- Aliasing
- SNR
- Undersampling
- Oversampling
- Decimation
- Filter Testing
- Noise

Day Three

Applied Mixed Signal and RF Testing

- Dynamic Testing using Sinusoids
- IMD
- SINAD
- THD
- Cross Talk
- SFDR
- ACPR
- Spectral Mask
- CMRR
- Jitter
- Multi-tone testing
- Intermodulation Distortion
- NPR
- Baseband Signaling
- IQ Modulator
- IQ Amplitude/Phase Imbalance
- Carrier/LO/Side Band Suppression

Generating Modulated Signals

- Generating, Transmitting, Capturing and Analyzing AM/FM/OOK/BPSK Modulated Signals
- Pulse Shaping
- IQ Constellation
- IQ Trajectory
- Synthesizer Lock Time
- Calculating/Correcting Frequency Drift
- Calculating/Correcting Phase and Frequency Errors

Day Four

BER and EVM Testing

- QAM
- Generating, Transmitting, Capturing and Analyzing QPSK/QAM Modulated Signals
- Generating,
- Capturing, and Analyzing OFDM Signals
- Implementing System Level BER & EVM Measurements
- Packet Based BER & EVM Testing

Day Five

Advanced BER and EVM Testing

- BER Sensitivity Testing, EVM (per Symbol)
- BER & EVM Interference Testing (Co-channel, Adjacent
- Channel)

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Cavity Filters and Multiplexers for Wireless Applications

Course 005

Summary

Low loss and highly selective filters and multiplexers are key components in the wireless networks that surround us. A low loss diplexer allows the transmitter and receiver of a basestation to simultaneously share the same antenna. The same filter must also guarantee that co-located basestations using competing transmission standards do not interfere with each other. Many of these filters and multiplexers are based on cavity combline technology, which is relatively simple to manufacture. Others are based on dielectric resonator (DR) technology that can realize a high quality factor (Q) filter in a smaller volume.

Introducing non-adjacent couplings (cross-couplings) into a microwave filter can generate transmission zeros in the lower and or upper stopbands. It is the filter order and the clever placement of these transmission zeros that generates the selectivity needed for wireless applications. The theory of cross-coupled filters was first introduced in the 1960's. It was then adopted for satellite multiplexer applications in the 1970's and for wireless applications in the following decades.

EM simulation is also an essential component of modern cavity filter design. We now have the ability to model and optimize complete filter structures in the EM domain. These virtual prototypes have greatly reduced the number of hardware prototypes that must be built and tuned. Occasionally, we find unexpected spurious couplings in our virtual EM prototypes that prevent us from tuning the filter to the desired response. These spurious couplings would be very difficult and expensive to diagnose after the hardware is built.

This course is focused on practical filter design methods for cavity combline filters for wireless systems. The core material is a universal procedure for narrow band filter design that can be applied to virtually any filter technology or topology. The procedure is rooted in Dishal's method with powerful extensions that include the port tuning concept, equal ripple optimization techniques, and efficient EM simulation. All the techniques presented can be implemented using commercially available CAD tools.

Practical procedures for extracting unloaded Q, external Q, and coupling coefficients are quite important in the design process and in evaluating prototypes. These techniques will include extracting data from hardware and from EM simulations. Some tutorial material on field-solvers will also be presented. The EM simulation examples relate specifically to cavity filter design and include tips and techniques for more accurate and efficient simulation.

Example filter designs will be presented with measured data and error analysis. The instructor will choose examples to develop based on the interests of the class.

DAY ONE

We will present the briefest possible introduction to basic filter design concepts. Starting with lowpass prototypes, we will touch on Chebyshev and elliptic prototypes and finding prototype element values. Next we will turn to a brief overview of the most common filter design techniques. Topics will include synthesis from an insertion or return loss function, the coupling matrix approach, and synthesis by optimization. The use of general purpose linear simulators for equal-ripple optimization will also be discussed. Finally, we will introduce the port tuning concept.

DAY TWO

Our approach to narrow band filter design starts with Dishal's method and moves a step beyond with port tuning of a full EM model. The port tuned model is a virtual prototype that can be diagnosed and optimized before any hardware is built. Modern TEM filters often employ cascade triplets and quads to realize transmission zeros in the stopband or flatten group delay in the passband. These filters can also be designed using our approach. At some point, practical procedures are needed to measure unloaded Q, external Q, and coupling coefficients. Systematic methods for tuning filters are also needed. All of these methods and procedures can be applied to actual hardware or to an EM simulation of the hardware.

DAY THREE

When high unloaded Q is required, designers often turn to cavity combline or dielectric resonator filters. Combline and DR filters are now used in high volumes in wireless base stations. Meeting customer requirements often requires additional transmission zeros in the stopbands, which are realized using various types of cross-couplings. Some applications also call for these high performance filters to be diplexed or multiplexed. Again, strategies for efficient design and EM simulation will be discussed for all the topologies presented.

Learning Objectives

Upon completing the course the student will be able to:

- use a universal procedure for narrow band filter design that can be applied to virtually any filter technology or topology
- understand fundamentals of practical filter design for RF and microwave systems
- apply Dishal's method - with powerful extensions that include the port tuning concept, equal ripple optimization techniques, and efficient EM simulation
- extract data from hardware and from EM simulations
- extract unloaded Q, external Q, and coupling coefficients during the design process and in evaluating prototypes

Target Audience

The course material is suitable for filter designers, designers of other components, systems engineers, and technical managers.

Outline

Day One

Introduction to Filter Design, Optimization, and Port Tuning

Basic Filter Concepts

- Chebyshev and Elliptic Prototypes
- Synthesis From Insertion Loss Functions
- Coupling Matrix Approach
- Synthesis by Optimization
- Equal-ripple Optimization
- The Port Tuning Concept

Day Two

Narrow Band Filter Design and EM Simulation

- Narrow Band Filter Design
- Cascade Triplets and Quads
- EM Filter Prototypes
- Unloaded Q
- External Q
- Coupling Coefficients
- Filter Tuning

Day Three

Designing Combline Filters, DR Filters, and Multiplexers

- Cavity Combline Filters
- Dielectric Resonator Filters
- Diplexers and Multiplexers
- Strategies for Design and EM Simulation

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CMOS RF Circuit Design

Course 206

Summary

The surge in demand for high performance and low cost wireless circuits has accelerated the shift to CMOS RFIC technology. As future wireless radios continue to push the available bandwidth and shift to mm-wave range, RF CMOS is expected to remain the predominant technology. This 3-day course will cover in depth the practical aspects of CMOS RF design at both the circuit and device level. The course will begin by an overview of the CMOS transistor and passives from RF perspective, analyzing key concepts in modeling and noise behavior. An overview of various RF circuit blocks highlighting design architectures and circuit implementation tradeoffs will be provided. This will include selected topics in designing low noise amplifiers (LNAs), mixers, voltage controlled oscillators (VCOs) and power amplifiers (PAs). The course will provide insightful guidance in the circuit design process including transistor sizing, layout effects, parasitic reduction techniques and tradeoffs between various circuit topologies. The focus throughout this course will be on providing practical circuit design and implementation techniques utilizing numerous design examples.

Learning Objectives

Upon completing the course the student will be able to:

•Learn and utilize accurate RF CMOS transistor and passive models
•Understand various parasitic effects due to layout and substrate
•Arrive at an in-depth understanding of CMOS noise sources and account for them in various circuits
•Design, at the basic level, CMOS RF LNAs, mixers, VCOs and Pas
•Understand the tradeoffs in circuit architectures and how they translate to RF systems parameters
(e.g. noise figure, IIP3, phase noise, etc.)
•Design matching elements and utilize them in various circuit blocks
•Use simple back-of-the-envelope calculations to predict RF circuits' performance
•Analyze the impact of CMOS technology scaling on various circuit blocks

Target Audience

RFIC and analog baseband design engineers, researchers and graduate students who are interested in designing CMOS RF circuits. In addition, RFIC engineers who specialize in GaAs and other III-V technologies will also find this course useful in learning how to transition to CMOS technology. Technical managers will also learn current technology limitations and future technology trends.

Outline

Day 1

• CMOS technology overview (applications and technology trends)
• Analog device models including long and short channel effects
• RF CMOS model for high frequency operations (gate and channel resistance and non-quasi static effects)
• Modeling RF passives (inductors, capacitors and resistors)
• Impedance Transformation & Matching Networks
• CMOS Noise Models and minimum noise figure

Day 2

• Low noise amplifier design (input matching, gain and linearity analysis, noise figure, stability analysis, narrowband vs. wideband design, LNA topologies, design examples)
• Mixer design (principle of operation, passive vs. active mixers, Gilbert cell mixers, linearity and noise analysis , port isolation, image reject mixers)

Day 3

• Voltage controlled oscillators (Figures of merit, oscillation conditions, phase noise, types of oscillator topologies; ring oscillator, Colpitt oscillator, -gm oscillator, design examples)
• Power amplifiers (Figures of merit; efficiency and linearity, impedance matching, linear vs. non linear classes of operation, design examples)

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Cognitive Radios, Networks, and Systems for Digital Communications
Course 251

Summary

This seminar provides a tutorial on multiple cognitive functions and capabilities at multiple levels including an overall cognitive system approach to reduce the effects of the environment. It covers a wide range of cognitive techniques, including cognitive radios, dynamic spectrum access DSA, adaptive power control using control theory for stability, adaptive modulation, adaptive spreading and error correction, dynamic antenna techniques using AESAs, cognitive antennas and MIMO, adaptive filters, orthogonalizing techniques, cognitive re-configuration of networks including mesh and Adhoc networks, optimizing networks, learning and reasoning techniques for cognitive decisions, goal conflicts, and cognitive system approach utilizing all available adaptive and controllable capabilities in the system. In addition, several examples and step processes are discussed to determine the optimal solutions and tradeoffs between the many cognitive capabilities.

Learning Objectives

Upon completing the course the student will be able to:

- Understand the concepts and definition of cognitive and adaptive processes.
- Realize the need to provide cognitive process for the future digital communication links and networks
- Evaluate the reasons for poor QoS for a digital communication system and learn of the many different cognitive techniques to mitigate their effects.
- Learn how to use Dynamic Spectrum Access DSA in a cognitive system and the process and flow of each of the nodes in a network.
- Understand adaptive power control in a cognitive system and learn what is needed for an open loop solution and a stable closed loop power control system between two users
- Analyze the methods to incorporate cognitive modulations and the advantages and disadvantages of higher order modulation techniques..
- Understand additional cognitive capabilities including adaptive filters, adaptive burst clamps, adaptive error correction and interleaving, spread spectrum, adaptive signal detection, and orthogonality methods.
- Evaluate the techniques used to incorporate cognitive processes including software defined radios, software defined networks, and low-cost available system for use in test and evaluation of the cognitive processes.
- Perform trade-offs between multiple capabilities to provide the optimal cognitive solution for the minimal cost of effect on the system.
- Understand controllable AESA antennas for null-steering, beam forming, directivity, multipath communications, and MIMO systems.
- Evaluate cognitive techniques using learning, reasoning, monitor and control, and goals for the cognitive system.
- Understand how Mobile Adhoc NETworks MANET can using cognitive processes to improve their performance.
- Realize the need for a complete cognitive solution using all available capabilities over single cognitive components.

Target Audience

This course will be of interest to RF, analog, digital, systems and software engineers and managers who are interested in learning more about cognitive capabilities and learning how to evaluate and improve the total system through cognitive system processes.
This applies to both those that want to gain an understanding of basic cognitive capabilities and those that are experienced engineers that want a better understanding of cognitive processes.

Outline

Day 1

- Cognitive Technique for a changing environment
- Definition of Cognition
- Cognitive radios using software defined radios
- Cognitive goals
- Cognitive capabilities
- Evaluation of the environment
- Adaptive techniques including DSA, power control for a stable closed-loop solution, modulation, spread spectrum, and error correction, interleaving, detection, cosite filters, multi-hop adhoc meshed networks.

Day 2

- Adaptive Burst clamp
- Demodulation Techniques
- Adaptive Filters for narrowband band suppression in a wideband signal
- Adaptive Orthogonal functions to reduce jammer effects
- Adaptive and Cognitive Networking and capabilities to perform Tradeoffs
- Dynamic antenna techniques and capabilities including MIMO for system cognition
- Cognitive MANET networks
- Combined cognitive system solution by evaluation of all system capabilities
- Learning and reasoning techniques for improved cognitive capability
- Monitor and control functions, and goal conflicts
- Cognitive system control processes and examples for optimizing the system solution
- Parallel evolution preferred over serial 'stovepipe' solutions to cognition

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Design of CMOS Power Amplifiers

Course 254

•Oct 5-Oct 9, 2015 - Web Classroom, WebEx / Malcolm Smith

Summary

Until recently, power amplifiers have been considered the exclusive province of GaAs, GaN, Si LDMOS and other processes. Recently, there has been renewed interest in the use of CMOS for power amplifiers targeted at the mobile market. Aside from the potential to integrate the PA with the transceiver chip or front-end switch, the main driving factors have been cost and access to a standard foundry process. Although CMOS processes offer significant cost benefits, MOS transistors do have performance limitations when compared to other processes being used for PA design. These limitations require design changes to enable CMOS to be used from PA design. As a result, although there are many similarities to PA design in other processes there are additional aspects that are unfamiliar to PA designers. Therefore CMOS PA design requires a combination of the skills of a PA designer with those of an RFIC design engineer.

This seminar contains material typically covered in one full day of instruction but is divided into five 90 minute web-classroom presentations.(9:00am to 10:30am Pacific time) Each daily session is a live event but the recording can be made available for up to 7 days to support students requiring a more convenient viewing time. Please contact the office for details at info@besserassociates.com.

This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.

Students will receive a signed Certificate of Completion.

Learning Objectives

Upon completing the course the student will be able to:

•Understand PA basics and the differences in design for power and design for gain
•Understand tradeoffs in class of operation
•Understand the differences and trade-offs in saturated and linear amplifier design
•Describe the limitations of the MOS transistor when used in power applications
•Understand techniques used to overcome MOS limitations

Target Audience

RFIC and analog baseband design engineers, researchers and graduate students who are interested in designing CMOS PA circuits. In addition, RFIC engineers who specialize in GaAs and other III-V technologies will also find this course useful in learning how to transition to CMOS technology. Technical managers will also learn current technology limitations and future technology trends.

Outline

Web Classroom

PA Basics

- Introduction
- Load-line theory
- Load Pull
- Class of operation
  - *A, AB, B, C*
- Stability

CMOS Reliability

- Mechanisms of MOS performance failure
- Maximum stress limits expected
- MOS transistor tolerance limits
- Output network reliability concerns
- ESD
- Approaches to CMOS PA implementation
- Cascode output structure and operation

Switching Mode CMOS Power Amplifiers

- Switching mode amplifier types
- Class D and Class E
- Stability concerns

Linear CMOS Power Amplifiers

- Definition of a linear amplifier
- Explanation of linearity specifications
- Gain enhancement and gain compression
- Phase non-linearities in CMOS
- Linearizing a PA
- Advantages and disadvantages of linearization schemes
- Class F introduction

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Digital Mobile and Wireless Communications- The Radio Interface for 4G, IMT-Advanced, 5G, Broadband Wireless Access

Course 016

Summary

The goal of this course is to introduce the participant to those digital modulation methods, coding techniques, space, time and frequency diversity techniques and multiple access techniques presently in use or being considered for use in mobile wireless and/or broadband wireless communication systems (many of these techniques are also used in satellite, wireline, and power-line communications).

The future is already here! Amazingly, 4G-LTE- Fourth Generation (and Mobile Wi-Max) systems based on OFDMA have entered commercial use in the past three years. The actual IMT-Advanced Fourth Generation Standards were published two years ago, and now industry is discussing the standard for 5G-LTE, Fifth Generation Systems. We will discuss some new concepts being considered for 5G including HetNets.

Orthogonal Frequency Division Multiplexing (OFDM) techniques are used in almost all of the new broadband wireless and mobile wireless access systems, e.g., 3G-LTE, 4G-LTE, 5G-LTE, IEEE802.11a,g and n (Wi-Fi), Wi-Gig (60 GHz), IEEE 802.16e (Wi-Max and "Mobile" Wi-Max), the WiMedia Alliance, IEEE 802.15 and IEEE 802.22 Standard.

The OFDM techniques consist of OFDM, OFDMA, and SC-FDMA. These systems use MIMO and advanced coding concepts, as well carrier aggregation techniques to improve performance. We will cover all of these topics during the course. We will also describe relatively new concepts such as massive MIMO. We will discuss the very important DMT implementation of the OFDM modulations.

We will also study the modulations and multiple access techniques (including CDMA and WCDMA) in use in present Second and Third-Generation systems including the (UMTS) IMT-2000 Third Generation Mobile Systems.

In addition to the OFDM-based modulations mentioned above, we will discuss QAM, QPSK, MPSK, PAM and continuous phase modulations (CPM), e.g., GMSK. All of these modulations are being used in wireless, satellite and wireline communication systems.

We will devote much time to the subject of BLAST and MIMO (Multiple-Input Multiple-Output) antenna systems. These techniques have been introduced in modern broadband wireless communications. We will also describe some recent ideas such as massive MIMO.

As previously mentioned, we will discuss the coding techniques used in the mobile/wireless broadband systems, including convolutional coding, turbo-coding and iterative decoding techniques. The idea of combining MIMO antenna arrays with OFDM, and coding, is an attractive idea for present and future broadband and mobile wireless systems.

In addition to all of the above, we will also devote time to a discussion of the bounds, or limits, on communications based on Shannon's Information Theory. It is Shannon's work, which has led to breakthroughs in coding, OFDM (multitone) communications, MIMO and much more.

At the end of the course, we will also describe the now classic multiple access techniques, e.g., CDMA, WCDMA, FDMA, and TDMA, used in the physical or radio interfaces of mobile wireless and broadband wireless systems. We will include a discussion of the radio interfaces of IS-95 and WCDMA, including topics such as Walsh codes and OVSF codes, the RAKE receiver, pseudo-random sequences, intra-cell and intercell interference, Gold codes and synchronization techniques.

We will also discuss some of the new ideas being considered for 5G-LTE systems including HetNets, and backhaul problem.

Learning Objectives

Upon completing the course the student will be able to:

- Understand multiple access techniques such as OFDMA, the multiple access technique used in broadband wireless access and 4G/LTE mobile systems.
- Understand BLAST and MIMO concepts and how they are used to greatly improve bandwidth efficiency for wireless communications.
- Analyze new techniques to improve communications efficiency, such as adaptive modulation and coding techniques, OFDM, space-time coding and iterative techniques.
- Evaluate the performance of modulations on channels with Rayleigh fading, and the diversity techniques used to overcome degradation caused by fading.
- Analyze different modulations and multiple access techniques, on the basis of detectability, bandwidth and complexity of implementation
- Understand constant envelope CPM modulations such as GMSK, used in the GSM, GPRS, Bluetooth, and EDGE systems.
- describe the latest and future commercial wireless systems and understand the underlying technologies that have been selected to implement them.

Target Audience

This course will be of interest to hardware, software and systems engineers who are entering the field of communication systems, or experienced engineers who are not familiar with modern modulations and concepts. The course participant should have some familiarity with the Fourier Transform and the topic of probability. An electrical engineering background (BSEE or equivalent practical experience) is recommended.

Outline

Day One

Introduction - A "Bit" of History

- Brief Review of Wireless Communications Concepts
- Cellular Concept-Femtocells
- Frequency Reuse

The Fading Channel

- Multipath Rayleigh Fading
- Delay Spread
- Frequency Selective Fading
- Introduction to Diversity Techniques

Brief Review of Important Concepts

- Fourier transform
- Probability
- Power spectral density
- White Gaussian noise

Introduction to Analog and Digital Modulations

Day Two

Nyquist Baseband Signaling

- Raised-Cosine Filters
- Optimum Filtering-Square-Root Nyquist Filters
- Linear Equalization
- Decision Feedback Equalization-Introduction
- Duobinary Signaling
- Partial Response Signals

Modulations and Performance

- Modulation Definitions
  - *BPSK*
  - *QPSK*
  - *MPSK*
  - *QAM*
  - *BFSK*
  - *MFSK*
- Optimum Detection of Binary Signals
- The Optimum Detector
- Matched Filter

BPSK and BFSK Modulations

- Spectra, Detectability, Synchronization
- Optimum FSK

Performance of Modulations on Rayleigh Fading Channels

- BER Performance-No diversity-SISO
- Classic Antenna Diversity-SIMO
- Detectability Performance for SIMO

Multiple-Input Multiple Output (MIMO) Antenna Diversity

- MIMO Concept
- BLAST Concept
- Massive MIMO
- Beam-Forming Techniques

MSK-type Signals

- QPSK, SQPSK, pi/4-QPSK
- MSK, SFSK
- Adjacent Channel Crosstalk
- ACI Cancellation Techniques

M-ary Signals

- Optimum Detection
- MPSK, QAM, MFSK
- Nyquist Modulating Signals

Information Theory

- A brief review of important results
- Shannon Capacity
- Why code?
- Multitone Concept
- Discrete Multitone (DMT) Implementation

Day Three

OFDM

- Orthogonal Frequency Division Multiplexing-OFDM-What is it?
- Why do we use OFDM?
- DMT Implementation of OFDM
- Adaptive Modulation and Coding Techniques
- OFDMA (and Scalable OFDMA) as a multiple access technique
- OFDM-BLAST (OFDM-MIMO)
- OFDM-UWB-WiMedia Standard-Radio Interface

Radio Interfaces of a Number of Systems

- Radio Interface-IEEE802.11a,n (Wi-Fi)
- Radio Interface-3G-LTE and 4G-LTE (IMT-Advanced)
- Radio Interface- Wi-Gig (60 GHz)
- Radio Interface of IEEE 802.16e- (Wi-Max and Mobile Wi-Max) (Optional topic)
- SC-FDMA (Single Carrier FDMA)-3G-LTE and 4G-LTE
- Carrier Aggregation for 4G-LTE
- MIMO in 4G-LTE
- New Ideas for 5G-LTE-Het-Nets, MU-MIMO

Coding Techniques

Block Coding

- Interleaving for the Fading Channel
- Performance with coding and interleaving

Viterbi Algorithm and Trellis Coding

- Viterbi Algorithm- What is it?
- Trellis (Ungerboeck) Coding
- Performance Gains
- Interleaving for Fading Channels
- Performance on a Rayleigh Fading Channel
  - *Viterbi Equalizer (GSM)*

Convolutional Coding

- Performance on the Fading Channel

Day Four

Turbo-coding- Iterative Decoding Concepts

- Turbo-Coding –What is it?
- Interative Decoding
- Iterative Decoding Combined with…
  - *Equalization*
  - *OFDM*
  - *Space and Antenna Diversity*
  - *CPM*
- OFDM, MIMO and Coding
- Introduction to LDPC Codes

Information Theory Bounds on Fading Channels

- Capacity for MIMO, MISO, SIMO and SISO Systems

Space-Time Coding

- Alamouti Coding
- MIMO-OFDM-Coding

Multi-user Diversity

Continuous Phase Modulations (CPM)

- TFM, GTFM, GMSK (GSM, DCS, DECT, Bluetooth)
- CPM, Coding and Iterative Decoding

Adjacent Channel Interference

Non-coherent Detection

- DPSK

The FM Receiver (DECT, Bluetooth)

- FSK
- CPM signals

Day Five

CDMA, WCDMA

- The Concepts
  - *RAKE Receiver*
  - *Pseudo-Random Sequences*
  - *Power Control*
  - *Intra and Intercell Interference*
  - *Capacity*

IS-95 Radio Interface (1 x EV or IS- 856)

- Walsh Functions
- Pseudo-Random Sequences
- RAKE Receiver

IMT-2000 WCDMA System Radio Interface (FDD, TDD) Standards

- OVSF Functions, Gold Codes
- EDGE

Cellular Communications-Radio Interface of Classic 2G Systems

- Introduction
- Multiple Access Techniques
  - *FDMA*
  - *TDMA*
  - *CDMA*
- TDMA
  - *GSM (GPRS)*
  - *IS-136*

UWB-Ultra-Wideband Radio-Impulse Radio (Optional topic)

Summary and the Future

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Digital Predistortion Techniques For RF Power Amplifier Systems

Course 170

Summary

Cellular, TV Broadcast, Satellite and Terrestrial point-to-point links all require linear performance from their RF Transmitters. Modern modulations formats such as OFDM and CDMA now demand linearity from their transmitters that are increasingly impossible to achieve without some form of linearisation. Digital Predistortion has increasingly become the preferred linearisation method in the past few years. This course explains the techniques involved and how to implement them.

Learning Objectives

Upon completing the course the student will be able to:

- Describe, measure and analyze non-linear effects in Power Amplifiers
- Evaluate digital predistortion methods
- Utilize and implement digital predistortion techniques
- Design and develop linearized power amplifiers

Target Audience

This course is suitable for a wide range of RF PA designers, DSP Engineers, and system level designers, who are either involved directly with PA design or a system which uses one. Digital hardware and software designers who are involved with RF systems will also find that the course will give them most of the necessary background to design control and DSP functions for the PA stages in a linearised transmitter system.

Outline

Day One

Distortion and Non-Linear Mechanisms in PA's

Review of Modulation Formats and Performance Requirements

- QPSK/QAM families
  - *OFDM, CDMA*
- EVM
- ACLR
- PCDE metrics

Modulation Amplitude Probability Distributions

- Peak to Average Ratio

Introduction to Predistortion

Theory and Limitations of Predistortion

Digital Predistortion Architectures; including Multi-carrier

Bandwidth, Clock Rate and Precision Issues

LUT and Algorithmic Approach

Memory Effect Modeling

- Wiener, Hammerstein, Volterra Series models

Adaption Issues

Power Control

Day Two

Introduction to DSP and DPD Hardware

ADC and DAC Technology

DSP, FPGA, ASIC Technology

Practical DPD Architectures

- RF Architectures

Linearised Software Development

- Multi-carrier
- Adaption
- Power Control
- Crest Factor Reduction

Linearisation System Components

- Envelope and Phase Detectors
- Gain and Phase Modulators; Vector Modulators

Digital Signal Processing and Wireless Communications

Course 029

Summary

This four-day course provides participants with an in-depth examination of wireless digital communication design strategies. Topics covered include digital modulation, radiowave propagation characteristics, signal detection methods, BER performance improvement and simulation techniques, DSP techniques, and RF/hardware architectures.

Learning Objectives

Upon completing the course the student will be able to:

•Describe the migration path for modulation and demodulation techniques.
•List and describe signal processing building blocks for wireless systems.
•Explain methods for mitigating wireless channel impairments.
•Perform system simulations ((de)modulation, BER and channel models).
•Predict system performance and evaluate tradeoffs.
•Describe TDMA, CDMA, 4G LTE and 5G evolution techniques.
•Describe design issues for wireless systems, particularly those issues in which transmit and receive implementation affect system performance.

Target Audience

System designers entering or currently working in the field of wireless digital communication will benefit from this comprehensive overview of practical design techniques. An electrical engineering background (or equivalent practical experience) is required. Attending the course, DSP- Understanding Digital Signal Processing (Course 27), is suggested.

Outline

Day One

Digital Modulation

- Introduction to some wireless standards
- Multiple Access Principles (TDMA, CDMA, FDMA, SDMA, OFDMA)
- Complex envelope representation of signals and systems
- Stochastic theory review
- Digital modulation theory
  - *BPSK, DPSK, QPSK, OQPSK, MSK, GMSK, FSK, DQPSK, p/4- DQPSK, FQPSK, p/4-FQPSK, 16PSK, 16QAM, 64QAM, etc.*
  - *Pulse shaping filter selection*
  - *Nonlinear amplification affects (spectral regrowth)*
  - *Advanced modulation techniques*
- Spread spectrum
  - *Frequency Hoping*
  - *Direct Sequence CDMA*
  - *RAKE Receiver*
  - *uplink and downlink example*
  - *PN code coarse and fine time tracking*
  - *Receiver block diagram*
  - *WCDMA Introduction*
- Orthogonal Frequency Division Multiplexing (OFDM)
  - *Single Carrier and Multiple Carrier Examples*
  - *Multipath Mitigation Technique*
  - *Frequency Domain Equalization*

Day Two

Radio Propagation Characterization

- AWGN channel
- Rayleigh multipath fading
- Rician multpath fading
- Delay spread concept (flat vs. frequency selective fading)
  - *Indoor propagation measurements*
  - *Outdoor propagation measurements*
- Log Normal Shadowing
  - *Governing Principles*
  - *Carrier Frequency Dependency*
- Path Loss
  - *Free Space, Hata, Walfish-Bertoni, etc.*
  - *Micro cell measurements*
  - *Macro cell measurements*
- Man made interference
  - *Adjacent channel interference*
  - *Co-channel interference*
- Simulating multipath fading channels
  - *Jakes, LPF-ing, etc.*

Signal Detection Methods

- BER performance discussion between theory and practice
- Coherent detection architectures
  - *Open Loop, Closed Loop, etc.*
- Non-coherent detection of p/4-DQPSK, DQPSK & GMSK
  - *Differential Detection, Maximum Likelihood, etc.*
- Implementation issues and design for manufacturability
- BER Performance Comparison
  - *Various Channel Conditions*

Day Three

Performance Improvement Techniques

- Forward Error Correction
  - *Block, Convolutional, Turbo, Reed-Solomon, Concatenated*
- Punctured coding discussion
  - *BER performance discussion*
- Interleaver/de-interleaver
- Antenna receiver diversity techniques
  - *Switching, Equal Gain, Maximal Ratio, Optimal Combining*
- Symbol timing recovery methods
- Equalization techniques
  - *Linear, decision feedback, MLSE*
- Equalization coefficient adaptation schemes
  - *LMS, RLS, SMI, etc.*
- Space Time Equalization
  - *ML perspective*
  - *Generalized RAKE (G-RAKE)*
- Adaptive Antenna Arrays
  - *MMSE and MSINR based cost functions*
  - *Eigen-spectra investigation*
- Antenna transmitter diversity techniques
  - *Space-time block codes, closed loop*
  - *MIMO*

Day Four

Digital Signal Processing

- Automatic frequency control
- Automatic gain control

- Channel quality estimation techniques
- Concept of dual detection receivers
- Power control loops
  - *Uplink and Downlink*
  - *Multipath mitigation*
- Transceiver block diagrams
  - *Transmitter issues*
  - *Receiver structures*
- Transmit power amplifier linearization Overview

Computer Simulation Techniques

- Goals of computer simulations
- Simulation tools
  - *Complex Envelope domain*
- Estimation Methods
  - *Monte Carlo, Importance Sampling, Tail Extrapolation, Semi-Analytic*
- A Comparison of the simulation methods discussed
  - *Usage guidelines*

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DSP - Understanding Digital Signal Processing

Course 027

•Oct 19-Oct 21, 2015 - San Jose, CA / Richard Lyons

Summary

This three-day course is the beginner's best opportunity to efficiently learn DSP. Intuitive, nonmathematical explanations and well-chosen examples develop the student's fundamental understanding of DSP theory. The practical aspects of signal processing techniques are stressed over discrete system theory. Participants will leave with a collection of tricks-of-the-trade used by DSP professionals to make their processing algorithms more efficient. Public course attendees will receive a copy of the book - Understanding Digital Signal Processing by Rick Lyons

Learning Objectives

Upon completing the course the student will be able to:

•Apply DSP techniques to real-world signal acquisition, spectral analysis, signal filtering, and quadrature processing problems.

•Fluently speak the language of DSP.

•Understand written descriptions (articles, application notes, textbooks) of common, practical DSP techniques.

•Obtain further DSP information using a comprehensive list of references.

Target Audience

Practicing RF hardware engineers and technicians, and computer programmers seeking an understanding of DSP technical theory and algorithms will benefit from this course. The course does not cover the internal architecture of commercial DSP integrated circuits.

Outline

Day One

Discrete Sequences and Systems

- Sequences and their notation
- Processing operational symbols

Periodic Sampling

- Aliasing
- Sampling low-pass signals
- Sampling bandpass signals
- Spectral inversion in bandpass sampling

Discrete Fourier Transform (DFT)

- Understanding the DFT equation
- DFT properties
- Inverse DFT
- DFT leakage

Day Two

Discrete Fourier Transform (cont'd)

- Use of window functions
- DFT results interpretation
- DFT processing gain

Fast Fourier Transform (FFT)

- FFT's relationship to DFT
- Guidelines on using FFTs in practice
- FFT software availability

Quadrature Signals

- Math Notation of Quadrature Signals
- Generating Quadrature Signals
- Quadrature Processing Applications

Finite Impulse Response (FIR) Filters

- Introduction
- Convolution
- Half-band/Matched/Comb Filters
- FIR Filter Design and Analysis Examples
- Phase response

Day Three

Infinite Impulse Response (IIR) Filters

- Introduction
- Laplace transforms
- z-transforms
- Design methods
- Pitfalls in building IIR digital filters
- Cascade and parallel combinations of digital filters
- Comparison of IIR and FIR filters

Advanced Sampling Techniques

- Quadrature sampling
- Quadrature sampling with digital mixing
- Sample Rate Conversion (decimation & interpolation)

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EMC/Shielding/Grounding Techniques for Chip & PCB Layout

Course 140

•*Jun 22-Jun 26, 2015 - Web Classroom, WebEx / Allen Podell*

Summary

This seminar discusses techniques for identifying the sources of unwanted coupling and radiation, and systematic approaches for their minimization. The class offers approximately one day's worth of material, but is typically offered in five 90-minute sessions (9:00am to 10:30am Pacific time) via web-classroom. Each daily session is a live event but the recording can be made available for up to 7 days to support students requiring a more convenient viewing time. Please contact the office for details at info@besserassociates.com.

This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.Students will receive a signed Certificate of Completion.

Learning Objectives

Upon completing the course the student will be able to:

•Define electromagnetic compatibility.
•Identify sources of coupling and radiation.
•Discuss and simulate the effectiveness of various shielding strategies.

Target Audience

Product and package design engineers of all expertise levels will benefit from this course. A basic engineering background (BSEE or equivalent) is required.

Outline

Day One

Electomagnetic Compatibility

- Definition of EMC
- Ground definitions
- Measuring Radiation
  – *large scale (test box) and localized (probes)*

Coupling and Radiation

- Differential and common mode connections
- Coupling control techniques
- Crosstalk between microstrip vs other lines
- Radiation vs. loop area
- Isolation techniques

Shielding

- Shielding effectiveness and wave impedance; shield materials
- Effects of slots and holes in shield
- Multiple small or fewer large holes?
- Transfer impedance as the effectiveness parameter

Grounding

- Current distribution between shield and ground plane
- Coupling through common ground inductance
- Shared vias
- Ground plane discontinuities and inductance effects
- Choking off ground currents, filtering the power lines

Experimental/Numerical Techniques of Problem Solving

Case Studies

Besser Associates
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EMI/EMC and Signal Integrity Boot Camp

Course 249

•*Nov 2-Nov 6, 2015 - San Jose, CA / Arturo Mediano*

Summary

This special five day workshop covers the methodology of designing and/or troubleshooting an electronic product to minimize the possibility of electromagnetic interference (EMI), signal integrity (SI) and/or Electromagnetic Compatibility (EMC) problems. The basics of designing electronic products with EMI, SI and EMC in mind are introduced in a very understandable and entertaining style.
The course is intended to cover the material from courses #243 (Signal Integrity and EMI Fundamentals) and #230 (EMI/EMC Design and Troubleshooting) as a comprehensive program including examples and simple experiments. The course presents the ways in which an electronic system can generate and/or receive EMI, thereby causing failure to meet EMC regulations. A practical approach with many real world examples, techniques, simulation and hardware tools for EMI/SI design will be explained to minimize costs, production and marketing delays by considering key factors and techniques in the design phase.
No prior EMI/SI knowledge is needed but an electrical engineering background (BSEE or equivalent experience) is recommended.
The five day course has a very practical approach through many real world examples, techniques, simulation and hardware demos:
•Fundamentals
•Basics Of Emi/Emc
•High Speed/Frequency Effects In Electronic Circuits
•Components In Rf/Emi/Emc/Si
•Transmission Lines: Controlling Propagation
•Matching
•Signal Integrity Parameters
•Grounding
•Filtering
•Printed Circuit Boards (PCBs)
•Shielding
•Cables
•Transients
•Diagnostic And Troubleshooting Techniques

DAY 1 is dedicated to the BASICS OF EMI/EMC/SI including coupling mechanisms, why to consider EMC, typical sources and victims, time domain vs. frequency domain, near vs. far field, non ideal components, controlling signal return currents, differential vs. common mode currents, radiation and pickup from loop and dipoles, the "hidden schematic" idea, etc. Scattering parameters (s-parameters) are presented as a very useful set of parameters for experimental characterization and design.
DAY 2 is dedicated to a review of COMPONENTS IN THE HIGH FREQUENCY/speed domain. TRANSMISSION LINES are explained in a very practical approach as a way to control signal propagation and impedance. Finally, MATCHING techniques are explained with many examples to obtain optimum power transfer and to avoid reflections.
DAY 3 is dedicated to the basics of SIGNAL INTEGRITY in electronic circuits including undesired effects, propagation time and delay, reflections and ringing, crosstalk (near and far) and jitter. Delays. Jitter. After SI basics, a key topic is presented: GROUNDING. Signal ground versus safety ground, grounding strategies, ground loops, techniques to minimize ground impedance are discussed. Finally principles of FILTERING are explained: reflection vs. dissipation, source and load influence, damping resonances and ringing, insertion losses, components and layout in filters, ferrites, decoupling and bypass, mains filters, filter mounting and layout.
DAY 4 covers the DESIGN OF PCBS, component selection and placement, special components for EMI (e.g. spread spectrum clocks), typical problems, layers (how many and distribution), layout, traces, transmission line effects, ground planes, splits in planes, decoupling (how, where, distributed, resonances, etc), crosstalk and examples. We will cover the topic of SHIELDING: influence of material, shielding effectiveness, low frequency magnetic fields, how to destroy a shield, holes and slots, gaskets, evaluation of shields, shield penetrations (how to do).
DAY 5 is dedicated to CABLES from EMI/SI point of view including how they can radiate or pick-up (they are antennas), shielded cables, cable grounding, connectors, types of cables (wires, twisted pairs, coax, shielded cables, ribbon cables, etc) and their influence in the EMC profile of the product. A review of TRANSIENTS and protection (including ESD basics) is presented. Finally simple instrumentation and DIAGNOSTIC AND TROUBLESHOOTING TECHNIQUES for EMI/EMC/SI problems are discussed.

Learning Objectives

Upon completing the course the student will be able to:

•understand the basics and fundamentals of EMI, EMC and SIGNAL INTEGRITY (SI) issues.
•look at high frequency fundamentals of EMI/SI, modeling problems to propose solutions.
•design an electronic equipment to avoid common EMI/EMC/SI failures.
•use EMI diagnostic and troubleshooting techniques to locate and fix EMI/EMC problems in equipments already finished.
•locate and fix EMI/SI/EMC problems in a product or installation.
•know the way of doing simple prequalification EMC tests.
•reduce time and cost of EMI/SI diagnostic and fixes.

Target Audience

This course will be of interest to:
• design engineers/technicians from the electronics

industry involved in EMI and SIGNAL INTEGRITY (SI) problems.
•those interested in a working knowledge of EMI/SI engineering principles and concerned with EMI/SI problems as high speed digital designers, RF designers and PCB layout engineers.
•managers responsible for design, production, test and marketing of electronic products.
•marketing engineers who need a general and practical knowledge of the EMI/SI basics.
•design and test engineers/technicians from the electronics industry involved in EMI/EMC/SI problems. Analog, digital, RF, mechanical and system engineers and technicians interested in design process to avoid EMC problems.
•those interested in a working knowledge of EMI/EMC engineering principles and concerned with EMC regulations.
•laboratory personnel involved in measurement and troubleshooting of EMC failures.
•managers responsible for design, production, test and marketing of electronic products.
•marketing engineers who need a general and practical knowledge of the EMI/EMC basics.

Outline

Fundamentals

Back to Basics

- Electrical signals
- Maxwell vs. Kirchhoff: limits of circuit theory
- Spectrum of a signal: time domain vs. frequency domain
- Decibel and logarithmic scales
- Resonance
- Quality factor (Q) both loaded and unloaded
- Bandwidth
- Impedance matching definition
- Frequency vs. dimensions (size)
- Time vs. distance
- Scattering parameters (s-parameters)
- Typical formats and how to measure them

Basics of EMI/EMC

An introduction to the Electromagnetic Compatibility Problem

- Why EMI affects electronic systems, examples
- EMC: legal requirements
- EMI/EMC classification (1)
  - *radiated vs. conducted*
- EMI/EMC classification (2)
  - *emissions vs. immunity*
- Source and victim and coupling mechanisms
- EMI/EMC tests basics
  - *emissions and immunity/susceptibility*

High Speed/Frequency Effects in Electronic Circuits

How to think in high frequency

- High speed and RF effects
  - *attenuation, gain, loss and distortion*
- Skin effect, return current and parasitic effects
- The importance of rise time and fall times (dv/dt and di/dt)
- Key factors for EMI
- Controlling signal return currents
- Differential vs. common mode currents
- EMI coupling mechanisms
- Non ideal components
- The “hidden schematic” concept
- Antenna basics
  - *dipoles and loops*
- Antenna resonance
- Antenna gain
- Antenna matching
- Antenna radiation pattern
- Near vs. far field
- Low and high impedance signals and circuits
- “Hidden antennas”: radiation and pickup

Components in RF/EMI/EMC/SI

When a capacitor is an inductor

- Resistors, capacitors and inductors
- Ferrites
- Transformers
- Diodes
- Transistors
- ICs
- Digital and high speed circuits
- Key parameters: power, speed and package
- es, cables and connections basics
- Transmission lines basics
- Lumped vs. distributed systems
- PCB structures
- Vias (effects and modeling in high frequency)
- Switches
- Heat sinks
- Shielding components

Transmission Lines

Controlling Propagation. Controlling Impedance

- Wiring and connecting components
  - *limitations for high frequency and high speed systems*
- What is a transmission line?
- Motivation: signal propagation
- Modeling a transmission line
- Characteristic impedance and velocity of propagation
- General description of typical transmission lines
  - *coax, pairs, microstrip and stripline*
- Reflection coefficient
- Standing Wave Ratio (SWR, VSWR and ISWR) and Return loss
- Intuitive explanation
- Examples from real world

Matching

Avoiding Reflections. Achieving Maximum Power Transfer

- Maximum transfer of power and avoiding reflections
- Matching with LC components
- Matching networks
- L, PI and T networks
- Matching in narrow and broadband applications
- Matching with transformers
- Matching with transmission lines
- rminations to avoid SI/EMI problems: solutions and techniques
- Using software to design a matching network
- Examples from real world

Signal Integrity Parameters

How Your Signal is Destroyed

- What is Signal Integrity (SI) in electronic circuits?
- Undesired effects
- Propagation time and delay
- Reflections and ringing
- Inductive vs. capacitive coupling: crosstalk (near and far).
- Delays
- Jitter
- Ground bounce
- Power supply noise
- Common mode impedance
- High frequency, dv/dt and di/dt

Grounding

99% of Our Problems Come from the Ground System Design

- Signal ground vs. safety ground
- Ground in high frequency/speed applications: low impedance path
- Minimizing ground impedance
- Common impedance
- Ground strategies (single point, multipoint, and hybrid)
- Ground loops

Filtering

How to Process Your Signal from an Analog Point of View

- Basic ideas
- Filters for known impedances (no EMI applications)
- Basic design techniques

with examples
- Filters for EMI/EMC
- How filters work: reflection vs. dissipation
- Insertion losses
- Source and load influence
- Parasitic and location effects
- Filtering with ferrites
- Saturation and undesired coupling effects
- Decoupling and bypass fundamentals
- Damping resonances and ringing
- Three terminal and feed through components
- Mains filters (differential mode and common mode)
- filter mounting and layout

Printed Circuit Boards (PCBs)

Problems Start in Your PCB Design

- Basic ideas
- Typical problems in PCBs
- Design strategy
- Partitioning and critical zones
- PCB structures (dielectric materials, structures, dissipation factor)
- Choosing the PCB structure: how many layers and distribution
- Power planes design and distribution
- Layout and routing (1, 2 and multilayer) techniques
  - *traces*
  - *microstrip and stripline*
  - *corners*
  - *vias*
  - *controlling impedance for SI*
  - *transmission line effects and solutions*
- Ground planes
- Splits or ground discontinuities in planes (slots)
- Decoupling and bypass (how, where, resonances, etc)
  - *discrete capacitors vs. embedded techniques in high speed/RF designs*
- Crosstalk and guards
- How ground plane layout affects crosstalk
- Mixed signal PCBs (A/D designs)
- Controlling clock waveform
- Clock distribution
- Clock shielding
- Examples from real world

Shielding

It's Easy to Destroy Your Shielding System

- Basic ideas
- how shields work: reflection vs. absorption
- Influence of material, shielding effectiveness
- Low vs. high frequency fields, electric vs. magnetic fields
- How to destroy a shield
  - *holes and slots*
  - *shield penetrations*
  - *holes for fans and displays*
- Gaskets
- Evaluation of shields
- Shields and paint (for good and bad results)
- transformer stray fields and real world examples

Cables

Paths for Your Signals. Hidden Antennas

- Cable fundamentals
- Types of cables
  - *wires, twisted pairs, coax, shielded cables, ribbon cables, etc*
- Cable impedance
- Shielded cables and cable grounding
- Connectors
- Cables as antennas for emissions and pickups
- Avoiding crosstalk and reflections in cables (layout and terminations)
- Avoiding common impedance in cables
- Reducing emissions and pick-up in cables
- Examples from real world

Transients

The World is not Ideal. Are You Ready to Protect Your Circuits?

- Transients from natural and human sources
- Typical transient problems
  - *energy from inductance, ESD basics and high switching activity*
- Methods for transient protection
  - *filtering, clamping and crowbar*
- Firmware and transients

Diagnostic and Troubleshooting Techniques

Being Sherlock Holmes to Find the Culprit

- Useful tools and instruments
  - *voltage probes, current probes, near field probes*
- Measuring voltage
  - *Scope and probe limitations*
- Measuring current
  - *probe response and transfer impedance*
- Diagnostic and troubleshooting techniques and hints
- Locating EMI sources with near field probes
- Examples from real world

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EMI/EMC Design and Troubleshooting

Course 230

Summary

This course covers the methodology of designing an electronic product to minimize the possibilities of having problems of electromagnetic interferences (EMI) or Electromagnetic Compatibility (EMC). Useful techniques for troubleshooting an EMI/EMC problem are presented to help in products where problems exist. The basics of designing electronic products with EMI and EMC in mind are introduced in a very understandable and entertained style. The course presents the ways in which an electronic system can generate and/or receive EMI causing failure to meet EMC regulations. A practical approach with many real world examples, techniques, simulation and hardware tools for EMI design will be explained to minimize costs, production and marketing delays considering EMI in the design phase.

First, we cover the BASICS OF EMI/EMC including coupling mechanisms, why to consider EMC, typical sources and victims, time domain vs. frequency domain, near vs. far field, non ideal components, controlling signal return currents, differential vs. common mode currents, radiation and pickup from loop and dipoles, the "hidden schematic" idea, etc.

Second part is dedicated to a key topic: GROUNDING. Signal ground versus safety ground, ground loops, grounding strategies, minimizing ground impedance, etc.

Third, the principles of FILTERING are explained: reflection vs. dissipation, source and load influence, damping resonances and ringing, insertion losses, components and layout in filters, ferrites, decoupling and bypass, mains filters, filter mounting and layout.

Fourth, the main design blocks of a system are explained: printed circuit boards (PCBs), shielding and cabling. We will discuss the DESIGN OF PCBS, component selection and placement, special components for EMI (e.g. spread spectrum clocks), typical problems, layers (how many and distribution), layout, traces, transmission line effects, ground planes, splits in planes, decoupling (how, where, distributed, resonances, etc), crosstalk and examples.

We will cover the topic of SHIELDING: influence of material, shielding effectiveness, low frequency magnetic fields, how to destroy a shield, holes and slots, gaskets, evaluation of shields, shield penetrations (how to do).

We explain how CABLES can radiate or pick-up (they are antennas), shielded cables, cable grounding, connectors, types of cables (wires, twisted pairs, coax, shielded cables, ribbon cables, etc) and their influence in the EMC profile of the product.

Finally, a review of TRANSIENTS and protection (including ESD basics) is included, firmware and EMI subjects are discussed and DIAGNOSTIC TECHNIQUES AND HINTS (including near field probes) and measurement and tests for EMC are explained.

Learning Objectives

Upon completing the course the student will be able to:

- understand the basics and fundamentals of EMI/EMC issues,
- look at the high frequency fundamentals of EMI, modelling the problems to be able to propose solutions,
- locate and fix EMI/EMC problems in a product or installation,
- design electronic equipment to avoid common EMI/EMC failures,
- use lab measurements and tools to find or fix typical EMI/EMC problems,
- perform simple prequalification EMC tests,
- use EMI diagnostic and troubleshooting techniques to locate and fix EMI/EMC problems in existing equipment
- reduce time and cost of EMI/EMC diagnosis and repair.

Target Audience

No prior EMI/EMC knowledge is needed but an electrical engineering background (BSEE or equivalent experience) is recommended.

This course will be of interest to:

- design and test engineers/technicians from the electronics industry involved in EMI/EMC problems. Analog, digital, RF, mechanical and system engineers and technicians interested in design process to avoid EMC problems,
- those interested in a working knowledge of EMI/EMC engineering principles and concerned with EMC regulations,
- laboratory personnel involved in measurement and troubleshooting of EMC failures,
- managers responsible for design, production, test and marketing of electronic products,
- marketing engineers who need a general and practical knowledge of the EMI/EMC basics.

Outline

Day One

Basics of EMI/EMC

- Why EMI affects electronic systems
- why consider EMC
- EMI/EMC classifications
- typical sources and victims
- coupling mechanisms
- spectrum of a signal
- time domain vs frequency domain
- near vs far field
- decibels
- di/dt and dv/dt
- non ideal components
- frequency vs dimensions in EMI
- controlling signal return currents
- diferential vs common mode currents
- "hidden antennas" radiation and pickup from loop and dipoles
- the "hidden schematic" idea
- how EMI/EMC tests are done, etc.

Grounding

- Signal ground versus safety ground
- Ground in high frequency/ speed applications: low impedance path
- Minimizing ground impedance
- Common impedance
- Ground strategies (single point, multipoint, hybrid) and minimizing ground impedance, etc.
- Ground loops

Filtering

- Filters for EMI/EMC
- how filters work: reflection vs dissipation
- insertion losses
- source and load influence
- parasitic and location effects
- filtering with ferrites
- saturation and undesired coupling effects
- decoupling and bypass fundamentals
- damping resonances and ringing
- three terminal and feed through components
- mains filters (differential mode and common mode)
- filter mounting and layout

Day Two

Printed Circuit Boards (PCBs)

- basic ideas
- typical problems in PCBs
- design strategy
- partitioning and critical zones
- choosing the PCB structure: how many layers and distribution
- power planes design and distribution
- layout and routing (1, 2 and multilayer) techniques
- traces, microstrip and stripline, corners, vias, controlling impedance, transmission line effects and solutions
- ground planes
- splits or ground discontinuities in planes (slots)
- decoupling and bypass (how, where, resonances, etc)
- crosstalk and guards
- mixed signal PCBs (A/D designs)
- clocks and critical signals
- Examples from real world

Shielding

- Basic ideas
- how shields work: reflection vs absorption
- Influence of material
- shielding effectiveness
- low vs high frequency fields
- electric vs magnetic fields
- how to destroy a shield
- holes and slots
- gaskets
- evaluation of shields
- shield penetrations (how to do)
- holes for fans and displays
- Shields and paint (for good and bad results)
- Transformer stray fields and real world examples

Day Three

Cables

- Basic ideas for cable fundamentals
- cables in EMI
- transmission lines in EMI
- cable termination
- crosstalk
- how cables can radiate or pick-up
- The control of return current
- Cable impedance
- Shielded cables
- cable grounding
- Types of cables
  - *wires, twisted pairs, coax, shielded cables, ribbon cables, etc*
- Connectors
- Reducing emissions from cables
- Examples from real world

Transients

- Transients from natural and human sources
- Typical transient problems
  - *energy from inductance, ESD basics and high switching activity*
- Methods for transient protection
  - *filtering, clamping and crowbar*
- Firmware and transients

Diagnostic and Troubleshooting

- Diagnostic and troubleshooting techniques and hints
- Locating EMI sources with near field probes
- Typical fast and low cost solutions
- Measurement and tests for EMC
- Examples from real world

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Filters and Multiplexers for Military Systems

Course 246

Summary

Filters are one of the fundamental building blocks used in integrated microwave assemblies, along with amplifiers, oscillators, mixers and switches. Depending on the frequency range and bandwidth we might use printed distributed filters, printed pseudo lumped filters, chip and wire lumped element filters and in some cases, cavity combline filters. Switched filter banks are common and sophisticated multiplexers are used in some systems.

Many broadband microwave down converters and up converters are built using thin-film technology on ceramic substrates. The substrates are placed in a channelized housing which isolates the various signal paths from each other. The front end, band select filters may be as broad as octave bandwidth, while the IF filters are typically much narrower. Filters used to clean up harmonics in the LO chain may be narrower still. It the past decade there has been a trend to use more printed circuit board technology when possible and even use commercial off the shelf (COTS) parts in military systems.

EM simulation is also an essential component of filter design for military systems. Distributed filters in a cut-off waveguide channel excite, and couple to, evanescent modes in the channel. The net result is the measured bandwidth of the filter is radically different with the cover on and the cover off. If the channel dimensions change, the filter must be redesigned. A design procedure that incorporates EM simulation is needed to include all the filter layout details and the coupling of the filter layout to the waveguide channel.

This course is devoted to the fundamentals of practical filter design for RF and microwave systems. The core material is a universal procedure for narrow band filter design that can be applied to virtually any filter technology or topology. The procedure is rooted in Dishal's method with powerful extensions that include the port tuning concept, equal ripple optimization techniques, and efficient EM simulation. All the techniques presented can be implemented using commercially available CAD tools.

Broader band filters generally require a synthesized starting point for our design. But once we have a reasonable starting point we apply the same port tuning techniques to rapidly fine tune the design. The key in both the narrow band and the broadband cases is to minimize the number of full EM solutions that we run. The port tunings we apply in our circuit simulator always indicate the direction and relative magnitude of the corrections that need to be made to the filter geometry. Example filter designs that cover a broad range of military applications will be presented with measured data and error analysis. The instructor will choose examples to develop based on the interests of the class.

DAY ONE

We will present the briefest possible introduction to basic filter design concepts. Starting with lowpass prototypes, we will touch on Chebyshev and elliptic prototypes and finding prototype element values. Next we will turn to a brief overview of the most common filter design techniques. Topics will include synthesis from an insertion or return loss function, the coupling matrix approach, and synthesis by optimization. The use of general purpose linear simulators for equal-ripple optimization will also be discussed. Finally, we will introduce the port tuning concept.

DAY TWO

Our approach to narrow band filter design starts with Dishal's method and moves a step beyond with port tuning of a full EM model. The port tuned model is a virtual prototype that can be diagnosed and optimized before any hardware is built. Modern TEM filters often employ cascade triplets and quads to realize transmission zeros in the stopband or flatten group delay in the passband. These filters can also be designed using our approach. At some point, practical procedures are needed to measure unloaded Q, external Q, and coupling coefficients. Systematic methods for tuning filters are also needed. All of these methods and procedures can be applied to actual hardware or to an EM simulation of the hardware.

DAY THREE

Filters in planar form can be built using several different topologies and technologies. Various single and multilayer ceramic and soft substrate (PCB) technologies are available to the filter designer. We will cover the more common distributed topologies including edge-coupled, hairpin, and interdigital. More recent coupled and cross-coupled loop topologies will also be presented. At lower microwave frequencies a pseudo-lumped approach using printed inductors and capacitors is more space efficient. Lowpass, elliptic lowpass, and bandpass filters using this approach will be presented. Strategies for efficient design and EM simulation will be discussed for all the topologies presented.

Learning Objectives

Upon completing the course the student will be able to:

- understand fundamentals of practical filter design for RF and microwave systems
- apply Dishal's method - with powerful extensions that include the port tuning concept, equal ripple optimization techniques, and efficient EM simulation
- extract data from hardware and from EM simulations
- design Planar Filters

Target Audience

The course material is suitable for filter designers, designers of other components, systems engineers, and technical managers.

Outline

Day One

Introduction to Filter Design, Optimization, and Port Tuning

- Basic Filter Concepts
- Chebyshev and Elliptic Prototypes
- Synthesis From Insertion Loss Functions
- Coupling Matrix Approach
- Synthesis by Optimization
- Equal-ripple Optimization
- The Port Tuning Concept

Day Two

Narrow Band Filter Design and EM Simulation

- Narrow Band Filter Design
- Cross-Coupled Filters
- EM Filter Prototypes
- Unloaded Q
- External Q
- Coupling Coefficients
- Filter Tuning

Day Three

Designing Planar Filters

- Planar Filters
- Edge-coupled, Hairpin, and Interdigital
- Coupled and Cross-coupled Loops
- Pseudo-lumped Lowpass and Bandpass
- Strategies for Design and EM Simulation

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Frequency Synthesis and Phase-Locked Loop Design

Course 052

Summary

This three-day course provides both the theoretical and practical knowledge necessary to design frequency synthesis circuits and systems using phase-locked loops and related technologies.

Learning Objectives

Upon completing the course the student will be able to:

- Describe the theory of operation for PLLs and related components.
- Analyze how PLL performance impacts system performance.
- Develop and explain designs of PLL components including mixers, phase detectors, oscillators, and dividers.
- Examine limitations of real world components, design tradeoffs and their effect on PLL performance.
- Develop and explain more advanced frequency synthesis systems designs.
- Test PLL circuits and systems to verify design integrity.

Target Audience

Engineers designing or specifying PLL frequency synthesis circuits and systems will benefit from this course. Prerequisites include basic digital circuit design, solid analog design skills including transfer functions, basic control and communication theories, and practical experience using PSPICE and/or MATHCAD, and modern RF/analog test equipment and construction methods.

Outline

Day One

Frequency Synthesis

- History from test and measurement perspective
- Direct and indirect frequency synthesizers
- Performance requirements

PLLs: Basic Model and Analysis

- Laplace transfer function and linear model
- Loop types and properties
- Loop filters
- Open and closed loop gain
  - *Bode plots*
  - *phase and gain margin*
  - *stability*
- Calculation of transfer functions and time domain response
- Frequency modulation (FM)
- Acquisition, lock and hold in range, small signal switching speed
- Sampling and Z transforms
- Nonlinear modeling/simulation
- Analyses and simulations of all PLL concepts using Mathcad and PSPICE

Day Two

Phase Noise and Spurs

- Phase noise types and graphs
- Effects on system performance
- Modeling PLL noise performance using Mathcad and PSPICE
- Spur types, reduction methods

Phase Detectors

- Mixer
- Sample and hold, microwave samplers
- Digital and interface to analog circuitry
- Commercial product examples

Dividers

- Pre-scalers: silicon, GaAs, and dual and multiple modulus
- Pulse swallowing counters in conjunction with dual modulus pre-scalers
- Noise, limitations, other issues

Oscillators

- Feedback and negative resistance models
- Resonator types
- Modeling and predicting phase noise from crystal oscillations
- Crystals and crystal oscillators
- Oscillator design using PSPICE and Compact

Day Three

Fractional N Loops

- Implementation techniques
- Fractional N beyond loop bandwidth
- Analog and digital methods for fixing fractional N spurs

Direct Digital Synthesis (DDS)

- Theory, errors and limitations
- Commercial products
- Incorporating DDS in PLLs

More Complex Loops

- Single sideband mixer/fractional N loop
- Multiple (sum and step) loops
- Heterodyning and mixing
- Reducing oscillator phase noise using delay line methods
- Increasing frequency range

Testing

- Phase noise
- Switching speed
- Loop dynamics
- Real world test data

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Fundamentals of LTE - OFDM, WCDMA

Course 223

Summary

Understanding the evolution of wireless data transmission from 3G to 4G technologies is critical to today's commercial component and system vendors. This comprehensive three day program covers the key technologies in a clear and concise manner.

The course begins by covering fundamental digital signal concepts. We look at the relationship between complex digital signals and the hardware (specifically complex envelope, quadrature modulators and demodulators). This will also be used to provide insight into the modulation schemes chosen by these standards. Various reasons why certain decisions have been made by the 3GPP standards body will be provided. A practical pulse shaping filter discussion will be presented. Channel impairments such as noise (AWGN) and multipath fading are introduced. Forward error-control coding (convolutional, Turbo, etc) and the Viterbi decoder will be discussed in detail, as well as functionality partitioning between hardware and software.

Moving on, we will present the components of a WCDMA system. We will start with the protocol overview and the where certain functions are located (and why) in the network. We discuss the purpose of the physical channels and the issues to be aware of when designing a RAKE receiver to demodulate them. We then point out the issues related to WCDMA to support packet data and introduce HSDPA & HSUPA. A RAKE receiver will be discussed and specific implementation details such as ADC location, dedicated HW and SW control will be provided. PN code sequences will be discussed as well as the method used to shift the sequence. A block diagram of the NodeB transceiver will be provided to show location of ADC, transport channel multiplexing, closed loop operations, etc. A discussion on why certain choices were made in the implementation partitioning.

Finally, we discuss the components of the LTE system. We will start with the protocol overview and the where certain functions are located (and why) in the network. We discuss the purpose of the physical channels and the issues to be aware of when designing a receiver. The OFDM transceiver will be discussed as well as options needed to be implemented to support the various BWs defined. We will discuss the implementation partitioning to support link adaptation. Antenna diversity details around the LTE standard will be provided to introduce the various modes of operation that need to be supported.

Learning Objectives

Upon completing the course the student will be able to:

- understand multipath fading issues when deploying WCDMA and LTE.
- describe receive antenna diversity techniques and issues surrounding their implementation.
- compare the implementation complexity of TDMA, CDMA and OFDMA as the supported data rates increase.
- Know the issues and obstacles related to multiple access schemes and how to overcome them.
- address issues pertaining to timing tracking and channel estimation.
- describe the expected UE behavior with regards to cell search.
- address the timing requirements for closed loop power control.
- describe various LTE system scenarios such as random access and link adaptation.

Target Audience

Engineers and technical managers who need a technical understanding of third and fourth generation cellular data transmission techniques will benefit from this course. Knowledge of fundamental signal processing concepts (Fourier transform, etc.) is assumed.

Outline

Day One

Digital Modulation Overview

- Complex envelope representation of signals and systems
  - *Relationship to HW components*
  - *Impact of PA non-linearity (spectral reqrowth) Impact of PA non-linearity (spectral reqrowth)*
  - *Gain & Phase imbalance*
- Digital modulation overview
  - *BPSK, QPSK, 16QAM & 64QAM*
  - *Block diagrams*
  - *Pulse shaping filter selection (Nyquist and Raised Cosine filtering)*
- System Metrics: BER, SNR, Eb/No definitions

Radio Propagation Characterization

- AWGN channel
- Rayleigh/Rician multipath fading
  - *Background & Practical explanations*
- Delay spread concept (flat vs. frequency selective fading)
  - *Indoor & Outdoor propagation measurements*
- Delay spread & coherence bandwidth (outdoor & indoor)
- Updated 3GPP Reference Channel Models

Performance Improvement Techniques

- Forward Error Correction
  - *Convolutional (Viterbi Algorithm, Punctured Coding)*
  - *Turbo (Encoder and Decoder)*
  - *Interleaver/de-interleaver - advantages & disadvantages*
- Performance comparisons
- Antenna receiver diversity techniques
  - *Switching, Equal Gain, Maximal Ratio, Optimal Combining*
  - *Theoretical SNR improvement & BER Performance*
  - *Issues to be aware of when implementing spatial*

diversity

Multipath Mitigation Techniques

- Explain how different standards resolve multipaths
  - *TDMA vs. CDMA vs. OFDMA solutions*

Day Two

3GPP WCDMA System Components (Building Blocks)

- System Goals (latency, throughput, etc.)
- 3GPP Release Overview (Release 99 to Release 9 features)
- WCDMA Signaling Channels (UL and DL)
  - *Logical Channels*
  - *Physical Channels*
- WCDMA Protocol Overview
  - *Layer1-PHY, Layer2-MAC, Layer3-RLC functions*
- High Speed Downlink Packet Access (HSDPA)
  - *HSDPA Physical Channels*
- High Speed Uplink Packet Access (HSUPA)
  - *HSUPA Physical Channels*
- PN sequences discussion: m sequences, gold codes, OVSF
- NodeB Transceiver block diagram
  - *Spreader & despreader, etc.*
- RAKE receiver Overall Block Diagram Discussion
  - *RAKE Receiver Signal Processing*

3GPP WCDMA System Scenarios

- Echo profile manager (searcher)
  - *Discussion on sample rate changes*
- PN time tracking & acquisition
- SIR power control
  - *Inner, Outer and Closed Loop*
  - *UL and DL Closed Loop Comparison*
- Pilot symbol aided coherent detection for Channel estimation
  - *What is the timing impact ?*
- Modulation (HPSK)
- Cell search & Handoffs
  - *Expected UE behavior*
- Paging Discussion
  - *Comparison of EIA/TIA-95, CDMA2000 and WCDMA Paging Protocols*
  - *Power Consumption conclusion*
- Call Flow Diagrams
  - *Mobile Originated (MO) Call*
  - *Mobile Terminated (MT) Call*
- Network Architecture (NodeB, Radio Network Controller, Core Network)
  - *Partitioning of Protocol Stack Across Network*
- Security Architecture
  - *Ciphering Examples*
  - *Integrity Protection*
  - *Confidentiality*
  - *WCDMA & HSDPA examples*

Day Three

LTE System Components (Building Blocks)

- System Goals (latency, throughput, etc.)
  - *Discussion on trend toward IP services*
- LTE Signaling Channels (UL and DL)
  - *Logical Channels*
  - *Physical Channels*
- Network Architecture (E-UTRAN, EPC)
  - *Element Interfaces*
- Protocol Architecture (RRC, RLC, MAC)
  - *Partitioning of Protocol Stack across Network*
- OFDM Principles and details for LTE
  - *Transmission & modulation (subcarrier, IFFT, S/P, etc.)*
  - *Sub-carrier discussion*
  - *Reception and Demodulation (FFT, P/S, etc.)*
  - *Purpose and values of Cyclic Prefix (CP)*
  - *OFDM Receiver block diagrams*
- FDD & TDD Modes

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GaN Power Amplifiers

Course 228

•*Jun 2-Jun 4, 2015 - Web Classroom, WebEx / Ali Darwish*

Summary

There are a number of semiconductor technologies being used for power amplifier design. This course introduces students to the GaN transistor, its properties, various structures, discrete and MMIC devices. The properties of GaN will be presented showing the advantage of these devices over other materials for power amplifier applications. Material will be presented on GaN HEMT transistors, geometries, semiconductor processes and structures with associated breakdown voltages, power capability, gain, efficiency, and frequency performance. Guidelines for reliable operation will be presented considering device junction temperature including thermal management techniques. MMIC matching and biasing elements will be shown. The nonlinear models of GaN HEMT devices necessary for the Computer Aided Design (CAD) of power amplifiers will be presented. Design considerations for both constant amplitude envelope signals as well as the non-constant amplitude envelope signals will be presented. Design procedures will be shown for various GaN PA examples including different classes of operation as well as the popular Doherty PA. The class offers approximately one day's worth of material, but is typically offered in three 2-hour sessions (9:00am to 11:00am Pacific time) via web-classroom. Each daily session is a live event but the recording can be made available for up to 7 days to support students requiring a more convenient viewing time. Please contact the office for details at info@besserassociates.com..

This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.Students will receive a signed Certificate of Completion.

Learning Objectives

Upon completing the course the student will be able to:

•Understand GaN semiconductor technology, its properties, and its advantage over other materials
•Learn how the GaN FET geometry and semiconductor processing affect the PA breakdown voltages, gain, power capability, efficiency, and frequency performance.
•Choose the correct nonlinear model to design the PA
•Understand design considerations for constant amplitude envelope signals as well as non-constant envelop amplitude signals
•Learn design procedures for GaN PA various classes of operation and the Doherty PA using modern simulators.

Target Audience

Semiconductor, component, and system designers including engineering managers will benefit from this course. RF/wireless engineers who want to understand the performance enhancements of GaN PAs. Application and product engineers supporting customers in areas relating to GaN PAs. PA circuit designers who wish to learn design techniques for nonlinear GaN PAs. Basic knowledge of microwave measurements and transmission line (Smith Chart) theory is assumed.

Outline

The following topics are spread over three 2-hour sessions

GaN Semiconductor and GaN HEMT PA Capabilities

- GaN semiconductor properties
- GaN HEMT transistors
- geometries
- semiconductor processes
- breakdown voltages
- thermal resistance
- power capability
- reliability
- thermal management techniques
- gain
- efficiency
- frequency performance

GaN FET PA Devices and Models

- GaN HEMT vendors and devices
- comparison of MMIC devices and performance
- MMIC matching and biasing elements
- nonlinear GaN HEMT models

GaN FET PA Design Considerations

- Constant amplitude envelope design considerations
- non-constant amplitude envelop (CDMA, WCDMS, LTE) design considerations and solutions

GaN FET PA Design Examples

- PA design for various classes of operation as well as the popular Doherty amplifier using the latest nonlinear CAD circuit programs

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Hardware DSP: A guide to building DSP Circuits in FPGAs

Course 244

Summary

This three day course covers implementation techniques for building DSP circuits in field programmable gate arrays (FPGAs). As the conversion rates increase for both analog to digital converters (ADCs) and digital to analog converters (DACs) the point of digitization of the analog signal gets closer to the antenna. However the resultant high data rates are often too much for a typical DSP processor and so the DSP algorithms needed to process the high data rate must be built directly in hardware. FPGAs are a cost effective choice for this task. Where ever possible, pictures, diagrams, and videos are used to illustrate the operations of DSP algorithms such as the Discrete Fourier Transform, convolution, polyphase decomposition, etc., thus providing more deeper insight to those who learn best through pictures.

Learning Objectives

Upon completing the course the student will be able to:

•Understand the architectural trade-offs between size and throughput for DSP algorithms built directly in hardware
•Apply the concepts and techniques learned in the course to real world applications in disciplines such as digital communications and sensor processing
•Know how to use and configure the DSP IP cores provided by FPGA vendors
•Judge which FPGA devices are best suited for their application

Target Audience

Hardware/FPGA engineers who need to build DSP circuits, software DSP engineers who need to understand hardware DSP concepts, DSP system engineers who need to understand implementation choices. The course assumes attendees have been exposed to DSP theory and concepts but now need to reduce that theory to practice. Prerequisite: Course 027: DSP - Understanding Digital Signal Processing or equivalent.

Outline

Day 1

DSP Theory Review seen Through a Hardware DSP Prism

- Discrete Time Signals
  - *Why sinusoids ?*
  - *Trigonometry – the mathematics of sinusoids*
- Discrete Time Systems – operations on signals
  - *Convolution, Correlation*
- Alternate Views of Signals and Systems
  - *Z transform, frequency domain, time domain*
- Number Representation
  - *Fixed point, floating point*
  - *Quantization effects*
- Architecting Algorithms for parallel processing
  - *Introduction To Systolic Array Processing*
  - *Process replication, process partitioning*

Day 2

Functions needed for building DSP Systems

- Phase calculation via the CORDIC algorithm
- Digital oscillators built via Direct Digital Synthesis (DDS)
- Filter structures
  - *Single Rate - distributed arithmetic ,systolic, transposed FIR*
  - *Multi-rate - Polyphase decomposition, CIC, Farrow interpolation*
  - *Parallel filters for high data rates*
- Fast Fourier Transforms (FFTs) Algorithms
  - *Cooley_Tukey -a powers of 2 transform*
  - *Winograd -a non-powers of 2 transform*

Day 3

Building Systems with our Hardware DSP function

- Channelizers
- Basics of beamforming
- Basic Digital Communications Processing
  - *Up/down conversion*
  - *Waveform Modulation*
  - *Carrier Synchronization*
- Basic Radar Processing
  - *Pulse Compression*
  - *Doppler*
  - *Fast Convolution*

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How to Speak RF (and Wireless)

Course 187

Summary

This 2 day course will explain the basic principles of RF and wireless telecommunications equipment so that professionals in non-technical jobs can understand what their technical colleagues are talking about. The course begins with a discussion of how voice, video and data communication systems work. Then the eight important vocabulary terms of RF are carefully explained. The key components that make up any RF communication system are then described, and illustrated with hardware examples. The function of base stations and access points are then explained. Multiple access techniques, which allow the maximum number of customers to use a particular system are defined. The cell phone industry, from its start, to its present capability, and on into the future is described. Finally high speed data systems, like 802.11 are explained.

Attend this course, and the language of RF and Wireless will no longer be a mystery.

Learning Objectives

Upon completing the course the student will be able to:

- Speak the vocabulary of RF and Wireless equipment.
- Understand what their technical colleagues are talking about.
- Communicate effectively about RF and wireless equipment

Target Audience

Professionals in management, finance, public relations, marketing, personnel, and other non-technical specialties who need to understand their company's technical goals, project status, and what their technical counterparts are doing.
Prerequisites:
Absolutely none, except the desire to learn what RF and wireless is all about.

Outline

Day One

How Telecommunication Systems Work

- Telecom signals in time and frequency
- Voice signals
- Video signals
- Digitizing voice and video signals
- Data signals
- Compression
- Error correction

The RF concepts you need

- Frequency
- Wavelength
- The electromagnetic spectrum
- RF power
- dB and dBm made simple
- Phase
- Impedance
- propagation and multipath fading

RF communication systems

- Block diagram
- Functions of each RF part

Transmission lines

- Waveguide and coax
- Microstrip
- Mismatches

How each part in the block diagram works

- Phase locked oscillator
- Modulator
- Upconverter
- Power amplifier
- Antennas
- Filter
- Low Noise Amplifier
- Mixer
- RF integrated circuits

Day Two

Base stations and access points

Multiple access – How the maximum number of users can be served

- FDMA, TDMA
- CDMA
- OFDM, OFDMA
- Packet data

Cell phone evolution

- Then: 1G analog and 2G digital
- 3G with voice, video and data capability
- LTE

Short range, high data rate systems

- 802.11

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Introduction to Data Converters: ADC & DAC

Course 239

Summary

Data converters are one of the most fundamental building blocks in mixed-signal systems. This course will introduce the fundamental principles of Analog to Digital Converters (ADC) and Digital to Analog Converters (DAC) including the most common Nyquist-rate and oversampling architectures. The course will cover basic system and circuit architectures, performance metrics, data converter characterization, performance limitations, practical implementations, and design procedures.

Learning Objectives

Upon completing the course the student will be able to:

•Understand data converters system specifications, performance parameters and data sheets, data converters characterization, and spectral analysis.
•Understand performance tradeoffs (power, area, sampling rate, resolution, etc
•Understand basic circuit topologies and circuit design procedures of the most common Nyquist-rate and oversampling data converters

Target Audience

Analog design engineers, researchers and graduate students who are interested in data converter design, and mixed-signal SoC designers. In addition, product, test, and application engineers will learn about testing and characterization of data converters and their limitation. Course 027: DSP - Understanding Digital Signal Processing or equivalent is recommended.

Outline

Day One

System Level Concepts

- Basic definitions
- Data converters tasks

Performance Metrics of Data Converters

- Resolution
- SNR
- SNDR
- THD
- Dynamic Range
- ENOB
- SFDR

Performance Limitations

- Tripping Points
- Offset Errors
- Gain Errors
- INL Errors
- DNL Errors
- Absolute and Relative Accuracy
- Monotonicity Errors
- Timing Errors

Introduction to FFT

- spectral characterization of data converters

Flash ADC topology

- basic concepts
- design procedure
- circuit implementation
- practical performance limitations and non-idealities

Day Two

Continuation of flash ADC topology

• design procedure and circuit implementation • practical performance limitations and non?idealities

Nyquist?rate ADC Architectures

• Sub?Ranging ADC
• Pipelined ADC• SAR ADC• Integrating ADC

Day Three

Oversampling ADC Architectures (Sigma?Delta)

- One?bit Converters
- Noise Shaping
- higher order noise-shaping
- basic circuit implementation

Nyquist?rate DAC Architectures

- Resistor String DAC
- Binary?Scaled Resistors DAC
- Current?Mode Binary?Scaled DACs
- Thermometer?Code DACs

Introduction to FFT and spectral characterization of data converters

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Introduction to Impedance Matching

Course 229

Summary

The need for impedance matching is rooted in basic AC circuit analysis principles. In basic terms, maximum power transfer occurs when the current and voltage are in phase. This workshop examines the ins and outs of delivering the most power possible to an RF load. Q factor and its effect on matching network bandwidth are also described.
The course runs from 9:00 AM to 11:00 AM Pacific time. A recording of the course will be available for one week for those who are unable to attend the live event, and questions will be answered both during the session and via email after the session has ended. This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.

Learning Objectives

Upon completing the course the student will be able to:

- •Understand the basis of impedance matching and its importance in energy transfer.
- •Understand complex impedances
- • Match unequal terminations
- •Optimize matching networks for wider bandwidth

Target Audience

Engineers and technicians who are new to RF and need to work with matching networks.

Outline

Session One

Impedance Matching Fundamentals

- Electrical energy transfer.
- AC voltage and current in resistors, inductors and capacitors.
- Complex numbers and complex arithmetic.
- Impedance and admittance.
- Conjugate match.
- Q Factor.
- Impedance matching with simple parasitics.
- Impdedance matching between unequal terminations.
- Improving bandwidth.

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Introduction to Radar

Course 253

Summary

This seminar provides an introduction tutorial on basic Radar design, techniques and operational capabilities. It covers a definition of radar, basic radar fundamentals, types of radars, derivation of the radar equation in multiple forms, radar range equation and range ambiguity, minimal detectable range, signal and noise analysis, MDS, clutter, detection process, probability of detection and false alarm, range accuracy and resolution, range and bearing determinations, radar cross section, displays PPI, Moving Target Indicator MTI, blind speeds, multiple pulse MTI radar, Doppler, multipath, basic radar operation, radar directional antennas including AESAs, transmitters, receivers, frequency and bandwidth advantages and applications, group delay, dynamic range, AGC/STC, frequency diversity, radar path budget, PRI/PRF, , two-way channel losses including free-space loss and examples, and radar pulse shaping. Also included are techniques to use radar systems for communications using PPM and other modulation. In addition, direction finding DF using radar is discussed along with SATCOM radars and frequencies. In addition, several examples and step processes are discussed to determine the optimal solutions and tradeoffs between the many cognitive capabilities.

Learning Objectives

Upon completing the course the student will be able to:

•Understand the concepts and definition of basic radar design.
•Become familiar with techniques to improve radar performance in the presence of clutter
•Learn how to develop the radar equation, and all of its derivatives.
•Evaluate the Probability of Detect compared to the Probability of False Alarm and how to determine the threshold level including tradeoffs.
•Learn how to use radar to provide long distance communications for broadcast messages LOS connections.
•Discover how to use multiple radars in a combined system to mitigate blind speeds and other anomalies.
•Learn how Moving Target Indicator MTI radar eliminates large stationary targets and detect small moving targets. Also learn what system problems that are inherent in radars and learn how to mitigate or reduce the problems.
•Understand the hardware that makes up a radar system and learn to determine the optimal solutions.
•Learn how radar can be used for a 3-dimensional direction finding system with two separate radar receive antennas.

Target Audience

This course will be of interest to RF, analog, digital, systems and software engineers and managers who are interested in learning more about the basic functionality of radar and learning how to evaluate and improve the detection process. This applies to both those that want to gain an understanding of basic radar and those that are experienced engineers that want a better understanding of radar.

Outline

Day 1

Definition and history of radar
Pulse radar including modulation
Basic two-way channel analysis
Develop the Radar equation and its derivatives and show how it is used
Range determination, calculation, ambiguities, resolution, and minimum detectable range
Bearing determination including accuracy and resolution
Displays and how they indicate the targets both PPI and A-scope
Basic radar operation

Day 2

Directional antenna gain, types including AESAs, reflector configurations, and examples
Antenna capabilities including electronic steerable arrays.
Frequency diversity radars and antennas
Radar transmitter and hardware designs and configurations
Radar Pulse shaping, advantages and disadvantages, types of shaping used
Radar receiver and hardware designs and configurations
Probability of Detection and False Alarms
Determining the frequency of operation, advantage and disadvantages and their applications

Day 3

Group Delay definitions and mitigations, Aliasing definitions and mitigations
Dynamic Range and AGC with control theory to guarantee stability and how to measure it
Moving Target Indicator MTI design and improvements and Multiple pulse radars to mitigate blind speeds
Doppler effects, Doppler and Tracking radars, Pulse Theory
How to use Radars for communications using pulse position modulations and others
Types of Multipath, techniques to reduce multipath for radar applications
Satellite Radar, frequencies, and types of satellites, antennas and feeds
Three-dimensional radar interferometer for direction finding

Introduction to Wireless Communication Systems

Course 235

Summary

This seminar provides an overall view of wireless communications including commercial and military applications for Program Managers, Engineering Managers, and others that do not have a technical engineering background. This is a very informative class at a high level so managers that are involved or going to be involved with Wireless Communications can understand at a high level what the engineers and programs are developing. It includes high level descriptions, enough detail to understand the concepts with little math or analysis involved. This is focus towards spread spectrum systems, which is nearly all of communications today. It covers a wide range of data link communication techniques, including tradeoffs of the system including cost reduction and size reduction methods using a budget to determine what is needed for the wireless system. It discusses the advantages of digital systems that are used extensively today, receivers and transmitters, digital modulation and demodulation techniques of phase-shift keyed and frequency hopped spread spectrum systems using easy-to-understand phase diagrams. It also addresses gain control, high level probability, jamming reduction method using various adaptive processes, error detection and correction, global positioning systems (GPS) data link, and satellite communications. The course discusses broadband communications including Link 16, JTRS, military radios, and networking. It also includes commercial applications such as 3G, 4G, WiFi, WiMax, LTE and home networking. Various techniques and designs are evaluated for modulating and sending/receiving digital data. Thus the student gains a firm understanding of the processes needed to effectively understand wireless data link communication systems which is vital to their jobs.

Learning Objectives

Upon completing the course the student will be able to:

•Understand the tradeoffs in a Wireless Communications system using a simple tool called a Link Budget. This includes signal and noise evaluations.
•Understand the advantages between digital communications and analog communications. This includes different ways to modulate the carrier frequency such as Phase Shift Keying (BPSK, QPSK, etc), and also spread spectrum and its advantage to prevent inference from others.
•Learn the principles to separate users from each other by using time, frequency, code, and others.
•Learn how cell phones and other wireless communications handle near/far problems, adjacent channel interference, automatic gain control and dynamic range.
•Understand basic concepts such as Image Frequency, Group Delay (important with Digital Communications), Aliasing, Feedback which is necessary to understand digital communications.
•Learn about pulse position modulation and how to use it in burst communications. Examine the advantages and disadvantages of Absolute vs Differential.
•Understand the advantages and disadvantages of Coherent vs Differential that can be applied to all types of digital modulation.
•Learn about how to retrieve the data by eliminating the carrier and the spread spectrum code to achieve the desired data.
•Examine simple concepts to show the probability of errors in the system, and to detect and correct the errors for more reliable communications.
•Learn to minimize inter-system interference that causes unreliable detection of the data.
•Learn about the tradeoffs between high data rate modulations and lower more robust modulations.
•Examine difference types of Multi-path and how it affects digital communications and radar signals. Also show how antenna diversity can improve the signal against multipath.
•Learn techniques on how to remove unwanted signals from interfering with your signal.
•Understand the basic concepts for GPS and how it has become a commodity in the civilian community.
•Learn how satellites are used in providing digital communications. Also how older satellites are being used for unique applications. In addition, learn what satellites are available and what type of communications they provide.
•Examine communication techniques including 3G, 4G, Bluetooth, WiFi, WiMax, and LTE.
•Discover how multiple antennas are being used to increase the data rates and improve the signal quality using MIMO and others.
•Learn about different types of Networks that tie the communications together.
•Discuss Military radios including, Legacy Radios, JTRS, and Link 16.

Target Audience

This course will be of interest to Program Managers, Engineering Managers, Business and Finance Managers and others who are looking to understand both military and commercial Wireless Communications systems at a high level. This includes anyone wishing to be more effecting in dealing with customers, staff, and those working on these programs. It is also an excellent refresher course for those engineers that want to be more involved with Digital Communications in their careers.

Outline

Day One

Wireless Tradeoffs in Digital Communications Using a Link Budget

• Understand the tradeoffs in a Wireless Communications system using a simple tool called a Link Budget. This includes signal and noise evaluations.

Digital Communication Advantages

- Understand the advantages between digital communications and analog communications.
- Different ways to modulate the carrier frequency such as Phase Shift Keying (BPSK, QPSK, etc), and also spread spectrum and its advantage to prevent inference from others

Basic Principles of Digital Communications

- Learn the principles to separate users from each other by using time, frequency, codes, and others.
- Learn how cell phones and other wireless communications handle near/far problems, adjacent channel interference, automatic gain control and dynamic range.
- Understand basic concepts such as Image Frequency, Group Delay (important with Digital Communications), Aliasing, Feedback which is necessary to understand digital communications.

Modulation Techniques used to Improve Communications

- Learn about pulse position modulation and how to use it in burst communications.
- Examine the advantages and disadvantages of Absolute vs Differential.
- Understand the advantages and disadvantages of Coherent vs Differential that can be applied to all types of digital modulation.

Day Two

Receiving the Signal and Detecting and Correction Errors

- Learn about how to retrieve the data by eliminating the carrier and the spread spectrum code to achieve the desired data
- Examine simple concepts to show the probability of errors in the system, and to detect and correct the errors for more reliable communications.
- Learn to minimize inter-system interference that causes unreliable detection of the data.

Higher Data Rates vs More Robust Signal

- Learn about the tradeoffs between high data rate modulations and lower more robust modulations.

Multipath, Antenna Diversity, and Removing Undesired Signals

- Examine difference types of Multi-path and how it affects digital communications and radar signals.
- Show how antenna diversity can improve the signal against multipath
- Learn techniques on how to remove unwanted signals from interfering with your signal.

Satellite Communications and GPS

- Understand the basic concepts for GPS and how it has become a commodity in the civilian community.
- Learn how satellites are used in providing digital communications. Also how older satellites are being used for unique applications. In addition, learn what satellites are available and what type of communications they provide.

Commercial and Military Communications

- Examine communication techniques including 3G, 4G, Bluetooth, WiFi, WiMax, and LTE.
- Discover how multiple antennas are being used to increase the data rates and improve the signal quality using MIMO and others.
- Learn about different types of Networks that tie the communications together.
- Discuss Military radios including, Legacy Radios, JTRS, and Link 16.

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LTE & LTE-Advanced: A Comprehensive Overview

Course 225

Summary

This three-day course provides a comprehensive overview of the system architectures, principles involved, techniques applied, and performance achieved in UMTS's Long Term Evolution (LTE) and LTE-Advanced mobile broadband access (MBWA) systems. The typical types of packet switched data conveyed by this system is studied. Key enabling technologies are presented including: relevant digital modulation techniques, error detection/correction methods, and multiple access and NLOS techniques employed in Point-to Multipoint (PMP) systems. The non-line-of-sight (NLOS) mobile wireless fading path is reviewed. The LTE network architecture and supporting protocols are introduced in some detail. Key physical layer and MAC features are presented comprehensively. A downlink coverage analysis is given. The key parameters of LTE's UMTS predecessor, HSPA, as well as those of Mobile WiMAX, are compared to those of LTE. Finally, the next evolution of LTE, i.e., LTE-Advanced, is introduced, including key features of Rel.10 and Rel. 11.

Learning Objectives

Upon completing the course the student will be able to:

•Understand the relationships between the ITU's IMT-2000, ETSI, UMTS 3GPP group, and HSPA/LTE.
•Describe the structure of various forms of packet switched data signals conveyed by MBWA systems such as IP, VoIP, and Mobile IP.
•Be familiar with the operation, spectral density, and bit error rate (BER) performance of digital modems employing BPSK, QPSK, 16QAM and 64QAM.
•Understand the various path loss and fading phenomena possible over a mobile NLOS wireless channel and how this impacts transmission performance.
•Understand the basics of Block, Convolution, and Turbo codes and how these codes are applied to improve the BER performance of LTE systems.
•Be familiar with the various techniques required for LTE PMP communications, such as signal duplexing methods, and non-line-of-sight (NLOS) methods including Orthogonal Frequency Division Multiplexing (OFDM), Orthogonal Frequency Division Multiple Access (OFDMA), Single Carrier-Frequency Division Multiple Access (SC-FDMA), Adaptive Antenna Systems (AAS), Antenna Diversity Systems including Delay Diversity (DD), Cyclic Delay Diversity (CDD), Space Time Block Coding (STBC) and Space Frequency Block Coding (SFBC), and Multiple Input/Multiple Output (MIMO) systems.
•Develop a firm and detailed understanding of the system architecture, supporting protocols, key features, specifications and performance parameters of LTE and LTE-Advanced.

Target Audience

Hardware, software and system engineers, engineering managers, and product marketing managers involved in the planning, development, marketing and implementation of LTE mobile broadband wireless access systems. Some familiarity on the part of participants with basic trigonometry, and general electronics will be helpful.

Outline

Day One

Introduction

- UMTS Evolution: From WCDMA to LTE
- Cellular Coverage: Cellular Structure, Spectral efficiency definitions

Wireless Payload: Packet Switched Data

- TCP/IP, VoIP, and Mobile IP

Helpful Mathematical Tools

- Spectral Analysis
- Statistical methods
- Thermal Noise

Enabling Technologies I

- Digital Modulation: The Basic Principles
- BPSK, QPSK, 16QAM and 64QAM modulation systems
- QAM systems Peak-to-Average Power Ratio (PAPR)
- Linear Modem Realization Techniques: Scrambling/Descrambling, Carrier recovery, Timing recovery
- The Receiver Front End

The Mobile NLOS Wireless Path

- Antennas
- Free Space Propagation
- Received Input Power and Fade Margin
- Terrain fading effects
- Mean Path Loss
- Shadowing
- Fading due to: Time delay spread (multipath fading), Doppler spread
- Multipat and Doppler Shift fading analysis
- LTE DL Coverage Analysis example

Enabling Technologies II

- Cyclic Redundancy Check (CRC)
- Automatic Request for Repeat (ARQ)
- Repetition codes
- Convolution codes
- Code Interleaving
- Turbo codes
- Hybrid-ARQ (H-ARQ)
- Transmission Signal Duplexing: FDD, H-FDD, TDD
- Medium Access Control (MAC)
- Scheduling
- Adaptive Modulation and Coding (AMC)
- Transmitter Power Control (TPC)

Day Two

Enabling Technologies II (cont'd)

- Non Line-of-Sight (NLOS) Techniques:
  - *Orthogonal Frequency Division Multiplexing (OFDM)*
  - *Orthogonal Frequency Division Multiple Access (OFDMA)*
  - *Single Carrier-Frequency Division Multiple Access (SC-FDMA)*

- *Receive Diversity*
- *Transmit Delay Diversity (DD)*
- *Transmit Cyclic Delay Diversity (CDD)*
- *Transmit Space Block Time Coding (STBC) Diversity*
- *Transmit Space Frequency Block Coding (SFBC)*
- *Multiple Input/Multiple Output (MIMO) scheme*
- *Adaptive Antenna Systems (AAS)*
- *Single-User MIMO and Multi-User MIMO*

Key features and parameters of UMTS LTE Standard

- LTE Radio Access Overview
- System Architecture
- E-UTRAN Protocol Architecture
- Frame Structure
- Downlink Structure and features:
  - *DL channel mapping*
  - *DL Logical, Transport and Physical Channels*
  - *DL Control Data and Physical Signals*
  - *DL Physical Resource and mapping to that resource*

Day Three

Key features and parameters of UMTS LTE Standard (cont'd)

- Downlink Structure and features (cont'd)
  - *DL Maximum Data Rate*
  - *DL Multiple Antenna Transmission Schemes*
  - *DL Multimedia Broadcast Multicast services (MBMS)*
- Uplink Structure and Features
  - *UL channel mapping*
  - *UL Logical, Transport and Physical Channels*
  - *UL Control Data and Physical Signals*
  - *UL Physical Resource and Mapping to that Resource*
  - *UL Maximum Data Rate*
  - *UL Multiple Antenna Transmission Scheme*
- H-ARQ Operation
- Radio Link Control (RLC) Protocol Operation
- Scheduling
- UL Power Control
- UL Timing Alignment
- Discontinuous reception (DRX)
- Access Procedures
- Mobility
- Inter-cell Interference Coordination
- Self Optimizing Networks
- Voice over LTE
- QoS of EPS Bearers
- UE Categories and Peak Data Rates
- Designated Frequency Bands
- Key Base Station/Mobile Station Specifications
- LTE overview chart
- UE and eNodeB Conformance Testing
- UE Certification Process
- Comparison of LTE and HSPA+
- Comparison of LTE and Mobile WiMAX
- Beyond LTE: LTE-Advanced
  - *Introduction*
  - *Rel. 10 Carrier Aggregation*
  - *Rel. 10 Enhanced Downlink multi-antenna transmission*
  - *Rel. 10 Enhanced Uplink multi-antenna transmission*
  - *Rel. 10 Relaying*
  - *Rel. 10 Support for heterogeneous networks*
  - *Rel. 10 MBMS enhancements*
  - *Rel. 10 UE Categories*
  - *Rel. 11 Coordinated Multipoint Transmission/Reception (CoMP)*
  - *Rel. 11 Carrier Aggregation enhancements*
  - *Rel. 11 New DL control channel*
  - *Rel. 11 MBMS enhancements*
  - *Rel. 11 High Power UE*
  - *Cell spectral efficiency for LTE and LTE-Advanced*

Conclusion

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LTE & LTE-Advanced: An Overview

Course 213

Summary

This two-day course provides an overview of the system architectures, principles involved, techniques applied, and performance achieved in UMTS's Long Term Evolution (LTE) and LTE-Advanced mobile broadband access (MBWA) systems. The typical types of packet switched data conveyed by these systems is studied. Key enabling technologies are presented including: relevant digital modulation techniques, error detection/correction methods, and multiple access and NLOS techniques employed in Point-to Multipoint (PMP) systems. The non-line-of-sight (NLOS) mobile wireless fading path is reviewed. The LTE network architecture and supporting protocols are introduced.Key physical layer and MAC features are presented. The key parameters of LTE's UMTS predecessor, HSPA, as well as those of Mobile WiMAX are compared to those of LTE. Finally, the next evolution of LTE, i.e. LTE-advanced, is introduced.

Learning Objectives

Upon completing the course the student will be able to:

•Understand the relationships between the ITU's IMT-2000, ETSI, UMTS 3GPP group, and HSPA/LTE.
•Describe the structure of various forms of packet switched data signals conveyed by MBWA systems such as IP, VoIP and Mobile IP.
•Be familiar with the operation, spectral density, and bit error rate (BER) performance of digital modems employing BPSK, QPSK, 16QAM and 64QAM.
•Understand the various path loss and fading phenomena possible over a mobile NLOS wireless channel.
•Understand the basics of Block, Convolution, and Turbo codes and how these codes are applied to improve the BER performance of LTE systems.
•Be familiar with the various techniques required for LTE PMP communications, such as signal duplexing methods, and non-line-of-sight (NLOS) methods including Orthogonal Frequency Division Multiplexing (OFDM), Orthogonal Frequency Division Multiple Access (OFDMA), Single Carrier-Frequency Division Multiple Access (SC-FDMA), Adaptive Antenna Systems (AAS), Antenna Diversity Systems including Delay Diversity (DD), Cyclic Delay Diversity (CDD), Space Time Block Coding (STBC) and Space Frequency Block Coding (SFBC), and Multiple Input/Multiple Output (MIMO) systems.
•Develop an understanding of the system architecture, supporting protocols, key features, specifications and performance parameters of LTE and LTE-Advanced.

Target Audience

Hardware, software and system engineers, engineering managers, and product marketing managers involved in the planning, development, marketing and implementation of LTE mobile broadband wireless access systems. Some familiarity on the part of participants with basic trigonometry and general electronics will be helpful.

Outline

Section One

Introduction

- UMTS Evolution: From WCDMA to LTE
- Cellular Coverage: Cellular Structure, Spectral efficiency definitions

Wireless Payload: Packet Switched Data

- TCP/IP, VoIP, and Mobile IP

Helpful Mathematical Tools

- Spectral Analysis
- Thermal Noise

Enabling Technologies I

- Digital Modulation: The Basic Principles
- BPSK, QPSK, 16QAM and 64QAM modulation systems
- Linear Modem Realization Techniques
  - *Scrambling/Descrambling, Carrier recovery, Timing recovery.*

The Mobile NLOS Wireless Path

- Antennas
- Free Space Propagation
- Received Input Power and Fade Margin
- Mean Path Loss
- Fading due to: Time delay spread, Doppler spread

Enabling Technologies II

- Cyclic Redundancy Check (CRC)
- Automatic Request for Repeat (ARQ)
- Repitition codes
- Convolution Codes
- Code Interleaving
  - *Turbo Codes*
  - *Hybrid-ARQ (H-ARQ)*
- Transmission Signal Duplexing: FDD, H-FDD, TDD
- Medium Access Control (MAC)
- Scheduling
- Dynamic Bandwidth Allocation (DBA)
- Adaptive Modulation and Coding (AMC)
- Non Line-of-Sight (NLOS) Techniques:
  - *Orthogonal Frequency Division Multiplexing (OFDM)*
  - *Orthogonal Frequency Division Multiple Access (OFDMA)*
  - *Single Carrier-Frequency Division Multiple Access (SC-FDMA)*

Section Two

NLOS Techniques (cont'd)

- *Receive Diversity*
- *Transmit Delay Diversity (DD)*
- *Transmit Cyclic Delay Diversity (CDD)*
- *Transmit Space Block Time Coding (STBC) Diversity*
- *Transmit Space Frequency Block Coding (SFBC)*
- *Multiple Input/Multiple Output (MIMO) scheme*
- *Adaptive Antenna Systems (AAS)*

Key features and parameters of UMTS LTE Standard:

- LTE Radio Access Overview
- System Architecture
- E-UTRAN Protocol Architecture
- Frame Structure
- Downlink Structure and features:
  - *DL Channel Mapping*
  - *DL Logical, Transport and Physical Channels*
  - *DL Control Data and Physical Signals*
  - *DL Physical Resource and mapping to that resource*
  - *DL Maximum Data Rate*
  - *DL Multiple Antenna Transmission Schemes*
  - *DL Multimedia Broadcast Multicast Services (MBMS)*
- Uplink Structure and Features:
  - *UL Channel Mapping*
  - *UL Logical, Transport and Physical Channels*
  - *UL Control Data and Physical Signals*
  - *UL Physical Resource and Mapping to that Resource*
  - *UL Maximum Data Rate*
  - *UL Multiple Antenna Transmission Scheme*
- H-ARQ Operation
- Radio Link Control (RLC) Protocol Operation
- Scheduling
- Inter-cell Interference Coordination
- Access Procedures
- Mobility
- QoS of EPS Bearers
- UE Categories and Peak Data Rates
- Designated Frequency Bands
- Key Base Station/Mobile Station Specifications
- LTE overview chart
- Comparison of LTE and HSPA+
- Comparison of LTE and Mobile WiMAX
- Beyond LTE: LTE-Advanced
  - *Carrier Aggregation*
  - *Enhanced multi-antenna support*
  - *Relaying*
  - *Support for heterogeneous networks*
  - *Coordinated Multipoint transmission/reception (CoMP)*
  - *New DL control channel*

Conclusion

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Modern Radar Systems

Course 258

•Nov 16-Nov 20, 2015 - San Jose, CA / Christopher J. Baker

Summary

Radar sensing has long been an indispensable tool for military surveillance and civil remote sensing. The ability to function day and night, in all weathers and to cover wide areas rapidly means that radar has found wide application from short ranges of a few hundred meters to space based operations. In recent years, radar systems have gone through something of a revolution with the advent of high speed, wide dynamic rage A to D converters and corresponding digital processors. This has led to array based antennas, ultra high range resolution and imaging, advanced adaptive processing for enhanced detection, tracking and target classification. Indeed, radar sensing is continually being extended and new areas such as cognitive sensing and sensing for autonomous applications are set to bring about a further revolution. This course begins by introducing the basic, underpinning concepts that are the foundation of all radar systems. It then builds on this to introduce contemporary methods for moving target detection, array antennas for radar, tracking, high-resolution techniques, imaging and target classification. Throughout the course, real life examples are used to illustrate the key points and ensure that concepts are presented in a realistic and meaningful way.

Learning Objectives

Upon completing the course the student will be able to:

- Define the key concepts underpinning modern radar design
- Demonstrate the radar equation and its application
- Derive mathematics in relation to radar engineering design
- Examine the operation and trade-offs of modern radar design
- Identify and explain engineering problems in relation to radar design
- Understand the operation of phased array antenna, array technology and techniques for controlling E scan resources
- Understand and compute radar system performance for MTI and tracking radar
- Be familiar with the differences between monostatic and bistatic radar, the concepts and design of passive bistatic radar air target detection
- Examine how high resolution is generated in radar, radar imaging (SAR and ISAR)
- Understand the processes used in target classification
- Have an appreciation of future trends in radar, radar signal processing and new areas of application

Target Audience

Radar engineers, radar system architects, test engineers, product engineers and technicians. Technical managers who are working in radar related fields ad require exposure to RF system technology.

Outline

Day One

Radar Basics

- a little history
- radar parameters
- ranging
- range resolution
- radar equation

Radar Performance Prediction

- noise
- clutter and clutter modeling
- targets and target modeling
- radar performance prediction

Day Two

Radar sub-systems

- transmitters
- antennas
- receivers
- displays

Waveforms

- waveform types
- matched filtering
- pulse compression
- ambiguity function analysis
- linear frequency modulation
- phase modulation
- ultra low side lobe design

Day Three

Radar Modes

- FM radar
- air traffic management radar
- Doppler
- MTI
- DPCA
- STAP
- parameter estimation
- monopulse
- alpha-beta filtering
- Kalman filtering
- array antennas
- array technology
- array radar resource management

Day Four

Bi static and multistatic radar

- bistatic radar concept
- design parameters
- target modeling
- clutter modeling
- bistatic ambiguity function
- multistatic radar
- passive bistatic radar
- direct signal interference removal
- spectrum efficiency

Day Five

High Resolution Radar and Imaging

- high resolution techniques
- waveform agility
- stretch processing
- synthetic aperture radar (SAR)
- inverse synthetic aperture radar (ISAR)
- 3-D interferrometric SAR (InSAR)
- imaging radar systems
- impact of far-out phase noise on receivers and transmitters

Target Classification

- classification definitions
- performance metrics

- classification process
- target signatures
- classification methods
- classification performance

- quadrature mixing and DC offset
- transmitter architectures : spectrum mask, ACI, EVM

Stealth/Counterstealth and Future Trends

- passive stealth techniques
- active stealth techniques
- low frequency radar
- MIMO radar
- ultra wide band radar
- cognition and radar sensing

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Monolithic Microwave Integrated Circuit (MMIC) Design

Course 181

Summary

The successful design of monolithic microwave integrated circuits (MMICs) is the fruit of a disciplined design approach. This three-day course covers, in detail, the theory, and practical strategies required to achieve first-pass design success. Specifically, the course covers the monolithic implementation of microwave circuits on GaAs and GaN substrates including instruction on processing, masks, simulation, layout, design rule checking, packaging, and testing. Numerous design examples are provided with emphasis on increasing yield, and reliability.

Students are encouraged to bring their laptop computers to class. CAD software is used in this course.

Learning Objectives

Upon completing the course the student will be able to:

•Learn the advantages and limitations of MMIC Designs
•Take advantage of the inherent benefits of MMICs over hybrid circuits.
•Account for the parasitics of the active device.
•Design biasing networks for active circuits.
•Design gain amplifiers MMICs using lumped and distributed matching.
•Design power amplifiers MMICs.
•Improve the yield of MMIC chips.
•Calculate the lifetime of MMIC chips in packaged and unpackaged assemblies.

Target Audience

Microwave engineers who want to design, fabricate, and test robust RF/Wireless MMICs, in the 1-50 GHz frequency range, will benefit from this comprehensive design course. Basic knowledge of microwave measurements and transmission line (Smith Chart) theory is assumed.

Outline

Day One

Introduction to MMIC Design

- Advantages and tradeoffs: cost, performance, reliability, size.
- Applications: Satellite communications, wireless LANs, microwave links, cellular networks.
- Choosing among device technologies: GaAs FET/ pHEMT, GaAs HBT, GaN HEMT
- MMIC Design cycle
  - *process selection, device characterization, circuit topology decision, design, taping-out, testing.*

Passive MMIC Elements

- Lumped element modeling
  - *resistors, capacitors, inductors, via holes.*
- Transmission line modeling
  - *microstrip, coplanar.*
- Combiners and dividers
  - *Wilkinson, Lange.*
- Baluns, coupled lines, transformers, couplers.
- Design example: 50-to-5 ohm matching network.

Two-port network basics

- S-, Y-, Z-, and H-parameters.
- Gain definitions
  - *Gmax, MSG, Unilateral gain.*
- Conjugate matching.
- Stability analysis
  - *odd mode, even mode analysis.*

Day Two

Active Devices

- De-embedding, Characterization, modeling.
- GaAs MESFET, HEMT, HBT, and GaN HEMT
- Emerging technologies
  - *Si CMOS, SiGe BiCMOS*
- Device parameters
  - *ft, fmax, gm, RON, COFF, parasitics.*
- Equivalent circuit—physical basis.
- Intrinsic equivalent circuit.
- Illustrative example: equivalent circuit extraction.
- Thermal resistance and lifetime estimation.
- Design example: choosing FET gate-pitch and bias for 10+ years lifetime.

Buffer Amplifiers

- Biasing network selection.
- Single stage design: lumped vs. distributed matching.
- Design example: 30 GHz power amplifier.
- Multi-stage design.
- Feedback amplifiers.
- Design example: 5 GHz, 1/2 – Watt power amplifier.

Day Three

Layout steps

- Microstrip layout rules.
- Coplanar layout rules.
- Process control and monitoring.
- Design rules and component values limitations.
- Reverse engineering.
- Yield and sensitivity analysis.

ItemTesting and Packaging

- Rapid testing: on-wafer, dc-screening.
- Package design.
- Package parasitics: cavity effects, stabilization.
- Thermal management: epoxy, eutectic.

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Network Security: Penetration Attack Testing

Course 238

Summary

This two-day course is meant to bring security professionals up to speed with tools, tactics, and skills of today's hackers. It also serves as an introduction to the methodology of penetration testing and how to conduct and manage such test. The skills learnt throughout this course are the first steps towards being an effective penetration tester. We will learn about the characteristics of social engineering attacks, how they exploit human emotions, how a successful attack is conducted, and proper defense mechanisms against them. We will also discuss physical and logical penetration, the tactics hackers follow to place themselves physically or logically inside an organization, and proper defense mechanisms. Insider attacks are one of the most dangerous as they involve entities that already have some level of access. We will discuss examples of insider attacks and how to defend against them. Finally, we will learn about vulnerability analysis (scanning and fuzzing), exploitation (software buffer/heap overflow), and Wi-Fi penetration. This is an experiment-oriented course where we will be conducting experiments in a lab environment for every topic discussed. Students will participate in experiments, which the instructor will prepare, to show how a given attack is conducted and how to defend against it.

Learning Objectives

Upon completing the course the student will be able to:

- Understand the ethics of penetration testing
- The legal system and how it might affect a penetration test
- Social engineering attacks, how one is conducted, and proper defense mechanism (Lab: using the Social Engineering Toolkit)
- Insider attacks, the potential damage, how such attack is carried, and proper defense mechanisms (Lab: password cracking)
- Vulnerability analysis (using Nessus and OpenVAS) and fuzzing
- Vulnerability exploitation (using Metasploit/W3AF/custom exploits)
- Wi-Fi penetration testing (scanners, password crackers, DoS)
- Managing a successful penetration test

Target Audience

Professionals such as engineers, product developers, managers, security officers, city/state government or law enforcement professional, and network administrators who have a special interest in quickly getting up to speed with the penetration testing methodology, skills, and techniques

Outline

Day One

Introduction to Penetration Testing

- Overview of penetration testing
- Ethics of penetration testing
- Pennetration testing and the Legal System

Penetration Testing Techniques I

- Social engineering attacks
- Physical penetration testing
- Insider attacks

Day Two

Penetration Testing Techniques II

- Vulnerability analysis
- Vulnerability exploitation
- Wi-Fi penetration testing
- Managing a penetration test

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PCB Filters and Multiplexers Using Standard SMT Components

Course 245

Summary

Filters are one of the fundamental building blocks of RF and microwave systems, along with amplifiers, oscillators, mixers, and switches. When we design a printed circuit board (PCB) based system, we rely on surface mount technology (SMT) components to realize a very compact, low cost system. Although there are now some standard filter designs available in SMT format, we often need to design a custom filter or multiplexer. These custom filter designs can be realized using standard SMT inductors and capacitors and perhaps a few printed distributed structures as well. Successful designs have been demonstrated across a frequency range of tens of MHz up to 6GHz. This frequency range covers most of the current wireless standards and many of the military communications bands as well.

This course is devoted to the fundamentals of practical filter design for RF and microwave systems in a low cost, PCB environment. The central challenge is to identify the most useful filter topologies for this construction method and frequency range. The search for a useful topology must include knowledge of each component's spurious response. Various SMT component libraries will be examined with this in mind. Another serious challenge to the designer is the rather limited catalogue of standard component values that are readily available. Simple techniques to overcome this limitation will be demonstrated. Although the majority of designs are fixed in frequency and bandwidth, some tunable bandpass and notch filter topologies will be presented.

We will apply EM simulation to our designs when the layout becomes highly compacted, or when non-standard connections to library components are required. EM simulation will also be used to optimize the performance of edge launched PCB connectors. Example filter designs that cover a broad range of applications will be presented with measured data and error analysis. The instructor will choose examples to develop based on the interests of the class.

DAY ONE

We will start with a brief discussion of PCB construction techniques and how they affect our filter designs. Then we will turn to basic filter design concepts. Starting with lowpass prototypes, we will touch on Chebyshev and elliptic prototypes and finding prototype element values. Next we will turn to the concept of cross-couplings and how they introduce finite transmission zeros. Finally, we will discuss some of the more useful filter topologies we have found for PCB based bandpass and notch filters.

DAY TWO

The bulk of this session will be devoted to examples of Chebyshev and elliptic function filters that have been built using standard SMT components. In most cases we will show the evolution of the design from ideal lumped prototype to final layout with comments on the design decisions that were made. Before we can measure our filters we need a reliable transition from the PCB to our connector of choice. SMA edge launch connectors are quite popular and are available in several styles. We will spend a few moments discussing how to optimize these connectors for higher frequency performance.

Learning Objectives

Upon completing the course the student will be able to:

- understand and design filters using PCB layout and SMT components
- understand fundamentals of practical filter design for RF and microwave systems
- extract data from hardware and from EM simulations

Target Audience

The course material is suitable for filter designers, designers of other components, systems engineers, and technical managers.

Outline

Day One

Introduction to PCB Filter Design

- Basic PCB Construction
- Basic Filter Concepts
- Chebyshev and Elliptic Prototypes
- Cross-Coupled Filters
- Useful Bandpass Topologies
- Useful Bandstop Topologies

Day Two

PCB Filters and Connectors

- Lowpass Filter Examples
- Bandpass Filter Examples
- Notch Filter Examples
- Diplexer Examples
- Multiplexers
- Edge Launch Connectors

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Phase Noise and Jitter

Course 220

Summary

Timing-related problems associated with signal sources are one of the major bottlenecks in designing today's highly complex systems. Over many decades, jitter has been extensively studied and utilized to characterize timing inaccuracies in both digital and analog systems. Conversely, phase noise has been exclusively used in RF systems to represent frequency or phase inaccuracy. For both timing and frequency sensitive systems, phase noise measurement is emerging to be the most accurate method of characterizing all types of signal sources (RF, analog or digital). This short course covers the fundamentals of phase noise and jitter, which ultimately set the limit to PLL performance in applications such as frequency synthesis, serial data communication and clock/data recovery. Simple techniques to model phase noise at the circuit component-level and relate it to the overall phase noise and jitter performance of PLLs are presented. The course will also provide a detailed analysis of the different phase noise measurement techniques along with in-depth noise floor analysis. The focus throughout this course will be on providing practical measures utilizing numerous real life examples. This class is typically offered in three 2-hour sessions (9:00am to 11:00am Pacific time) via web-classroom. Each daily session is a live event but the recording can be made available for up to 7 days to support students requiring a more convenient viewing time. Please contact the office for details at info@besserassociates.com.
This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.Students will receive a signed Certificate of Completion.

Learning Objectives

Upon completing the course the student will be able to:

- •Get in-depth understanding of phase noise representation and become familiar with the different terminologies used to characterize phase noise and spurs
- •Understand the relation between phase noise spectrum, power spectral density and frequency spectrum density
- •Learn the difference between AM and PM noise
- •Learn about the different types of phase noise (i.e. additive vs. multiplicative noise) and how each is derived for a given system
- •Analyze the impact of phase noise on communication systems and the relation between RMS phase error and error vector magnitude (EVM)
- •Derive the relation between RMS phase error and bit error rate (BER) for different modulation schemes (e.g. BPSK, QPSK, 16-QAM, 64-QAM)
- •Understand the impact of phase noise on OFDM systems
- •Learn about various phase noise measurement techniques and equipment
- •Analyze random vs. deterministic jitter and different jitter measurement types (i.e. phase jitter, period jitter and cycle-to-cycle jitter).
- •Learn about jitter measurement techniques and equipment
- •Gain knowledge at extracting jitter information from phase noise measurement.

Target Audience

- •Engineers seeking to understand fundamental PLL designs issues relating to frequency stability and timing jitter.
- •Engineers involved in board, circuit and system-level design of wireless or wireline systems.
- •Test engineers and technicians involved in phase noise and jitter measurement.
- •Engineers designing PLLs systems or subsystems such as voltage-controlled oscillators (VCOs) or reference oscillators (e.g. crystal oscillators)
- •Application and product engineers supporting customers in areas relating to frequency generation.

Outline

Session 1 (2 hours)

- Phase noise representation and different terminologies used to characterize phase noise and spurs
- AM vs. PM noise
- Relation between phase noise spectrum, power spectral density and frequency spectrum density
- Types of phase noise (i.e. additive vs. multiplicative noise)
- Phase noise upconversion process (AM to PM)
- Relation between RMS phase error and error vector magnitude (EVM)

Session 2 (2 hours)

- Impact of close-in phase noise on communication systems
- Relation between RMS phase error and bit error rate (BER) for different modulation schemes (e.g. BPSK, QPSK, 16-QAM, 64-QAM
- Impact of phase noise on OFDM systems
- Impact of far-out phase noise on receivers and transmitters

Session 3 (2 hours)

- Phase noise measurement techniques and equipment
- Random vs. deterministic jitter
- Jitter measurement types (i.e. phase jitter, period jitter and cycle-to-cycle jitter)
- Modeling Jitter
- Jitter measurement techniques and equipment
- Extracting jitter from phase noise measurement

Besser Associates
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Phase-Locked Loop and Frequency Synthesis Design

Course 236

Summary

This two-day course provides the practical knowledge necessary to design frequency synthesis circuits and systems using phase-locked loops and related technologies. Coverage includes each of the basic building blocks that are used in phase locked oscillators and frequency synthesizers. Understanding how each block operates will give you an appreciation for its impact on the overall performance of the oscillator with respect to phase noise and tuning range/lock time, among other factors.

Learning Objectives

Upon completing the course the student will be able to:

- Describe the theory of operation for PLL, DAS, and DDS frequency synthesis techniques.
- Develop and explain principles and uses of PLL components including mixers, phase detectors, oscillators, and dividers.
- Examine limitations of real world components, design tradeoffs and their effect on PLL performance.
- Develop and analyze more advanced frequency synthesis systems designs.
- Test PLL circuits and systems to verify design integrity.

Target Audience

Engineers designing, specifying, or new to PLL frequency synthesis circuits and systems will benefit from this course. Prerequisites include basic digital circuit design, analog design skills including transfer functions, and basic control loops.

Outline

Day One

Frequency Synthesis

- History from test and measurement perspective
- Direct and indirect frequency synthesis
- Performance requirements

Direct Analog Synthesis (DAS)

- Oscillator combinations
- Harmonics, multiplication and division
- Divide-and-mix
- Spurious signals
- Noise
- Specifying the reference
- Example
- the Synthesizer Equation

Indirect Frequency Synthesis

- Stability transfer
- Frequency lock
- Phase lock

PLLs: Basic Model and Analysis

- Block diagrams
- Laplace transfer function and linearized model; loop types and orders
- Loop filters
- Open and closed loop gain; Bode plots; phase and gain margin
- stability and transient times
- Acquisition, lock and hold in range
- Frequency modulation (FM) problems and solutions
- Sampling effects
- Calculation of transfer functions and time domain response
- Nonlinear modeling/simulation

Phase Detectors

- General principles
- Mixer
- Sample and hold, microwave samplers
- Digital options
- the phase-frequency detector
- Charge pumps

Dividers

- Pre-scalers: single, dual, and multiple modulus
- Noise floor
- input impedance variation
- power supply phase modulation (PSPM)

Oscillators

- Feedback and negative resistance structures
- Delay oscillators
- Reference types
- Inductor issues
- pulling and pushing effects
- injection locking and field feedback
- General noise characteristics
- VCO characterization

Day Two

PLL Synthesizer Design Techniques

- Important parameters and hierarchy
- loop filter types, active and passive
- Loop filter design functions
- MS Excel worksheet
- stability while managing wide component variations
- component value tolerance
- Acquisition of lock
- divider value minimization

Phase Noise and Spurs

- Phase noise components
- reference noise
- divider noise
- PD noise and FOM
- VCO noise
- Loop filter noise
- Modeling PLL noise using MS Excel
- measuring PLL noise floor
- noise variations with loop bandwidth
- reference sidebands: causes and solution options
- reduction of loop filter noise

Fractional-N PLL

- Basic principles
- inherent spurious mechanism
- fractional-N implementation techniques
- sigma-delta benefits and consequences
- addressing fractional N spurs

Direct Digital Synthesis (DDS)

- Numeric oscillator
- square vs. sine waveforms
- spurious signal causes and their minimization
- spur diagnosis methods

Synthesis Technique Combinations

- Synthesizer equations
- DAS + PLL
- DAS + DDS
- DDS + PLL
- DAS + DDS + PLL
- Multiple loops
- Increasing frequency range

- Phase noise measurement details
- Switching speed
- Loop dynamics validation

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Power Amplifier ABC's

Course 216

Summary

This course aims to bring participants up to speed on the basics of RF power amplifier design and operation in the shortest possible amount of time. Considerable attention is devoted to defining, classifying, and improving the efficiency and linearity of power amplifiers. Numerous design examples are provided for participant exploration. The class offers approximately one day's worth of material, but is typically offered in five 90-minute sessions (9:00am to 10:30am Pacific time) via web-classroom. Each daily session is a live event but the recording can be made available for up to 7 days to support students requiring a more convenient viewing time. Please contact the office for details at info@besserassociates.com. This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.Students will receive a signed Certificate of Completion.

Learning Objectives

Upon completing the course the student will be able to:

•Design low distortion and efficient power amplifiers.
•Bias power amplifiers for class A, A/B, B, and C operation
•Understand the tradeoffs among the classes of operation.
•Design amplifiers for gain or power or a compromize of the two.
•Describe several techniques used to linearize power amplifier output.
•Utilize modern circuit simulators and a simple system simulator.
•Understand the effect of harmonics on PA performance.

Target Audience

Component and system level designers, as well as engineering managers will benefit from this course. RF/wireless engineers who wish to expand their circuit design skills from basic linear design techniques to nonlinear methods, or just wish to understand power amplifier performance at the design level. Basic knowledge of microwave measurements and transmission line (Smith Chart) theory is assumed.

Outline

PA Design - Five 90 Minute Web Classroom Sessions

Getting Started with Power Amplifiers

- Introduction
- Amplifiers classes A through Z
- Straightforward (Cripps) approach
- Real device characteristics and their impact
- Modelling with harmonic balance and SPICE
- Design of a class AB amplifier

Improving Efficiency

- Class B and C amplifiers
  - *gain, load line, efficiency enhancement*
- Class E, F and harmonic termination amplifiers: realistic expectations
- Push- pull amplifiers, bipolar and FET

Multistage design theory

- Driver amplifiers and interstage matching, some solutions
- Balanced amplifiers, a solution to some matching problems
- Design of a 2 stage amplifier

Linearization Techniques

- Predistortion
- Feed-forward
- Lossless feedback

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Power Regulation & Conversion Design for VLSI and SoC Systems

Course 224

Summary

Developing power conversion/regulation solutions for VLSI systems and mixed-signal analog/RF System-on-Chip (SoC) types of loads require engineers with solid background in both traditional power converters design as well as analog/RF mixed-signal VLSI design. Power conversion/regulation circuits with such a VLSI and SoC focus are rarely covered in graduate or undergraduate power electronics courses. With the growing demand in semiconductor industries for expertise in this area, there is a serious shortage in engineers who have the necessary background combination to design efficient and cost-effective solutions for such loads. This course will introduce the fundamental principles of power conversion/regulation circuits such as Linear/switching regulators, DC - DC converters, and battery chargers used in VLSI systems. This includes: Architectures, Performance metrics, characterization, stability and noise analysis, practical implementations, on-chip integration issues, and design considerations for portable, wireless, and RF SoCs.

Learning Objectives

Upon completing the course the student will be able to:

•Understand power conversion/regulation system specifications, performance parameters, and data sheets.
•Understand performance tradeoffs and the special requirements for large mixed-signal SoC loads.
•Understand limitations and requirements of on-chip integration of power converter circuits.
•Understand basic circuit topologies and circuit design procedures of linear regulators and switching DC - DC converters (buck, boost, and buck-boost).• Understand basic circuit topologies of linear and switching Li-Ion battery chargers.

Target Audience

Analog and power management design engineers, researchers and graduate students who are interested in power management design, design engineers who are interested in power management integration in nanometer CMOS technologies, and mixed-signal SoC designers. In addition, RFIC design engineers will find this course very helpful in understanding issues related to powering RF circuits. Technical managers will also learn current technology limitations and future technology trends.

Outline

Day One

System level concepts, performance metrics, linear regulators

- Basic definitions
- Power management tasks
- Schemes and challenges in mixed-signal SoCs
- Types of loads
- Performance metrics of voltage regulators (power management language)
  - *DC, small-signal AC, and large-signal transient metrics*
- Regulation Concepts
- Basic linear regulator design
- stability analysis and compensation

Day Two

Linear Regulators and Switching Regulators

- Continuation of basic linear regulator design
- PMOS versus NMOS power FETs
- on-chip versus off-chip output capacitor
- Basic switching power concepts
- Step-down switching regulator (Buck)
- basic design equations
- continuous and discontinuous conduction modes
- Control Techniques (pulse width and pulse frequency modulation)
- AC analysis
- stability and compensation techniques

Day Three

Switching Regulators

- Current-mode control
- hysteretic and gated-oscillator control
- loss mechanisms in switching regulators
- ripple analysis and mitigation techniques
- Step-up switching regulator (Boost)
- basic design equations
- continuous and discontinuous conduction modes
- AC analysis
- stability and compensation techniques

Day Four

Switching Regulators and battery chargers

- Other switching converter topologies
  - *Buck-Boost, Forward, and Fly-back*
- Battery Chargers
- types of batteries
- charging profiles
- constant-current constant-voltage charging
- pulse charging
- charger topologies (linear and switching)

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Practical Digital Wireless Signals

Course 232

Summary

This three day course is designed to provide all participants with a physically intuitive understanding of wireless communication signals and why they work the way they do. With the growing impact of wireless communications on the basic operation of society, the need for a more general understanding of the basis for this technology is more important than ever.
This course approaches wireless communications signals through the window of physics and physical principles. While a solid understanding of the mathematical theory of wireless communications signals is essential for detailed system design and analysis, the fundamental choices in system application and approach are often best approached physically. We do not shun math in this presentation, but instead of using math as the presentation base we instead use it as a follow up illustrator of the principles discussed.
The sessions cover all of the major modulations used in digital wireless communication, including ASK, FSK, PSK, QAM, and OFDM. Spread spectrum operation is included, comparing the relative performances of Direct Sequence (DS) and Frequency Hopping (FH) techniques. System principles are also presented such as an extensive discussion of the Shannon Capacity Limit, the physical basis of Nyquist filtering, plus an introduction to antennas and wireless signal propagation. Important system parameters and analysis tools which are common to any modulation type are presented and demonstrated. Public course attendees will receive a copy of the book - Practical Digital Wireless Signals by Dr. Earl McCune.
Physically intuitive understanding is the purpose for this course on Wireless signal and system fundamentals. Understanding why these signals and techniques work, not just how, is the key objective of this course.

Learning Objectives

Upon completing the course the student will be able to:

•Explain the fundamental differences among ASK, FSK, and PSK wireless signals
•Understand the demodulation effort (cost) differences among digital wireless signals
•Understand the basic performance metrics of any digital wireless system
•Explain the principles of modern QAM and OFDM signals
•Understand what is a spread spectrum modulation (and what is not), and the differences between direct sequence and frequency hopping techniques
•Show how the Shannon Limit predicts the many difficulties in building high data rate, long range, finite bandwidth wireless systems
•Understand the relationship between antenna gain and directivity
•Understand the need for coding, the fundamental types of coding, and their top level costs and benefits

Target Audience

This course will be of interest to people new to wireless communications design, and to communication specialists who are very familiar with the mathematics of wireless signals but may desire broadening this understanding with a physical perspective. It will also be interesting to technical marketing engineers who desire a physical intuition into the tradeoffs that the corresponding design engineering teams are wrestling with.

Outline

Dav One - Common Signal Parameters, Modulation Types

Common Background Issues and Tools

- What is keying?
- Signaling definitions
- polar and rectangular equivalence
- time-spectrum correspondences
- symbol construction
- filtering characteristics
- the special properties of Nyquist filters
- simples vs. duplex
- constellation and vector diagrams
- eye diagrams
- SNR vs. Eb/No

Modulation Types

ASK (Amplitude-shift keying)

- Definitions
- constellations
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- PAPR
- envelope statistics
- energy efficiency
- demodulation principles
- introduction to noise performance

FSK (Frequency-shift keying)

- Definitions
- phase tree
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- Doppler shift
- energy efficiency
- signal limiting
- demodulation principles
- introduction to noise performance
- FM threshold effect

Day Two - PSK and QAM Modulations

PSK (Phase-shift keying)

- Definitions
- constellations
- Why nearly all PSK signals are really QAM
- CPM is not a PSK
- offset PSK
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- PAPR
- envelope statistics
- energy efficiency
- Doppler tolerance
- demodulation principles
- introduction to noise performance

QAM (Quadrature Amplitude Modulation)

- Definitions
- constellations and signal structure
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- PAPR
- envelope statistics
- offset QAM
- Doppler tolerance
- energy efficiency
- demodulation principles
- introduction to noise performance

Day Three - Systems and Applications

OFDM (Orthogonal Frequency Division Multiplex)

- Definitions
- constellations
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- PAPR
- envelope statistics
- energy efficiency
- Doppler intolerance
- demodulation principles
- introduction to noise performance

Antennas and Wireless Propagation

- Path Loss
- Transmit Power
- Antenna Gain
- Antenna Directivity
- Near and Far Fields
- Polarization
- Receive Sensitivity
- Range Expectations
- Level Diagrams
- Delay Spread
- Diversity
- Correlation

Shannon's Capacity Limit

- Shannon's Fundamental Theorem on Information Theory
- Shannon-Hartley equation
- capacity density
- SNR vs. Eb/No forms
- finite available power
- power vs. bandwidth
- signal design region

Principles of Coding

- Motivations
- definitions
- coding for bandwidth efficiency
- coding for spectrum control and link operation
- coding for error control
  - *block codes, convolutional codes, turbo codes*
- coding to manage error bursts
- coding for channel throughput (MIMO)
- equalization

Spread Spectrum

- Direct Sequence and Frequency Hopping
- cyclic cancellation
- synchronization
- interference suppression
- process gain
- jamming margin
- chips and spreading codes
- frequency hopping details
- direct sequence details
- DS vs. FH comparison

Cost Comparisons among Signal Implementations

- The Keep-It-Simple (KIS) Procedure

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Practical Digital Wireless Signals - Measurements and Characteristics

Course 210

Summary

This five day lecture and measurement based course is designed to provide all participants with a physically intuitive understanding of wireless communication signals and why they work the way they do. With the growing impact of wireless communications on the basic operation of society, the need for a more general understanding of the basis for this technology is more important than ever.

This course approaches wireless communications signals through the window of physics and physical principles. While a solid understanding of the mathematical theory of wireless communications signals is essential for detailed system design and analysis, the fundamental choices in system application and approach are often best approached physically. We do not shun math in this presentation, but instead of using math as the presentation base we instead use it as a follow up illustrator of the principles discussed.

The five days cover all of the major modulations used in digital wireless communication, including ASK, FSK, PSK, QAM, and OFDM. Spread spectrum operation is included, comparing the relative performances of Direct Sequence (DS) and Frequency Hopping (FH) techniques. System principles are also presented such as an extensive discussion of the Shannon Capacity Limit, the physical basis of Nyquist filtering, plus an introduction to antennas and wireless signal propagation. Important system parameters and analysis tools which are common to any modulation type are presented and demonstrated.   Public course attendees will receive a copy of the book - Practical Digital Wireless Signals by Dr. Earl McCune.
Physically intuitive understanding is the purpose for this course on Wireless signal and system fundamentals. Understanding why these signals and techniques work, not just how, is the objective of these five days.

Learning Objectives

Upon completing the course the student will be able to:

- Explain the fundamental differences among ASK, FSK, and PSK wireless signals
- Understand the demodulation effort (cost) differences among digital wireless signals
- Understand the basic performance metrics of any digital wireless system
- Explain the principles of modern QAM and OFDM signals
- Understand what is a spread spectrum modulation (and what is not), and the differences between direct sequence and frequency hopping techniques
- Show how the Shannon Limit predicts the many difficulties in building high data rate, long range, finite bandwidth wireless systems
- Understand the relationship between antenna gain and directivity
- Understand the need for coding, the fundamental types of coding, and their top level costs and benefits

Target Audience

This course will be of interest to people new to wireless communications design, and to communication specialists who are very familiar with the mathematics of wireless signals but may desire broadening this understanding with a physical perspective.   It will also be interesting to technical marketing engineers who desire a physical intuition into the tradeoffs that the corresponding design engineering teams are wrestling with. This course will also be helpful to those who need to identify signals based on their measured characteristics.

Outline

Dav One - Common Signal Parameters, Measurements, and Tools

Common Background Issues and Tools

- What is keying?
- Signaling definitions
- polar and rectangular equivalence
- time-spectrum correspondences
- symbol construction
- filtering characteristics
- the special properties of Nyquist filters
- simples vs. duplex
- constellation and vector diagrams
- eye diagrams
- SNR vs. Eb/No

Day Two - Modulation Types and Type-Specific Measurements

ASK (Amplitude-shift keying)

- Definitions
- constellations
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- PAPR
- envelope statistics
- energy efficiency
- demodulation principles
- introduction to noise performance

FSK (Frequency-shift keying)

- Definitions
- phase tree
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- Doppler shift
- energy efficiency
- signal limiting
- demodulation principles
- introduction to noise performance
- FM threshold effect

Day Three - Modulation Types and Type-Specific Measurements

PSK (Phase-shift keying)

- Definitions
- constellations
- Why nearly all PSK signals are really QAM
- CPM is not a PSK
- offset PSK
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- PAPR

- envelope statistics
- energy efficiency
- Doppler tolerance
- demodulation principles
- introduction to noise performance

QAM (Quadrature Amplitude Modulation)

- Definitions
- constellations and signal structure
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- PAPR
- envelope statistics
- offset QAM
- Doppler tolerance
- energy efficiency
- demodulation principles
- introduction to noise performance

Day Four - Modulation Types and Type-Specific Measurements

OFDM (Orthogonal Frequency Division Multiplex)

- Definitions
- constellations
- occupied bandwidth
- bandwidth efficiency
- power efficiency
- PAPR
- envelope statistics
- energy efficiency
- Doppler intolerance
- demodulation principles
- introduction to noise performance

Antennas and Wireless Propagation

- Path Loss
- Transmit Power
- Antenna Gain
- Antenna Directivity
- Near and Far Fields
- Polarization
- Receive Sensitivity
- Range Expectations
- Level Diagrams
- Delay Spread
- Diversity
- Correlation

Day Five - Systems and Applications

Shannon's Capacity Limit

- Shannon's Fundamental Theorem on Information Theory
- Shannon-Hartley equation
- capacity density
- SNR vs. Eb/No forms
- finite available power
- power vs. bandwidth
- signal design region

Principles of Coding

- Motivations
- definitions
- coding for bandwidth efficiency
- coding for spectrum control and link operation
- coding for error control
    - *block codes, convolutional codes, turbo codes*
- coding to manage error bursts
- coding for channel throughput (MIMO)
- equalization

Spread Spectrum

- Direct Sequence and Frequency Hopping
- cyclic cancellation
- synchronization
- interference suppression
- process gain
- jamming margin
- chips and spreading codes
- frequency hopping details
- direct sequence details
- DS vs. FH comparison

Cost Comparisons among Signal Implementations

- The Keep-It-Simple (KIS) Procedure

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Production Testing of RF and SOC Devices for Wireless Communications

Course 166

Summary

This class focuses on back-end production and manufacture testing of RF and wireless products. Implementing the lowest Cost Of Test (COT) solutions on production ATE (Automatic Test Equipment) is a requirement to be a successful test/product/application engineer. This guiding principal is used throughout the class as we learn how to implement both parametric and system level testing solutions using a variety of ATE systems including: Advantest T2000, Verigy's 93K, 84K, Credence ASL3K, Teradyne Catalyst, and Flex systems).
Increasingly System-On-a-Chip (SOC) and SIP (System In a Package) technology is merging RF with baseband and high speed digital devices. These combination chipsets require highly skilled test/application engineers with knowledge of RF, mixed-signal, high speed digital, and baseband modulation/demodulation to implement low cost, fast time to market solutions on ATE.
This course is newly updated to provide test engineers with the necessary SOC/SIP and ATE skills required for the next generation devices. Students will receive a copy of the book - Production Testing of RF and System-on-a-Chip Devices for Wireless Communications by Keith Schaub.

Learning Objectives

Upon completing the course the student will be able to:

- Describe RF, mixed signal and basic digital circuit parameters and terminology.
- Perform COT (cost of test) analysis and make recommendations based upon economic criteria
- Break down the classical radio (super-heterodyne) and newest radio (ZIF (Zero IF)) block diagrams into their constituent parts (amplifiers, modulators, mixers, phase locked loops (PLLs), filters, DACs (Digital-to-Analog Converters) and ADCs. (Analog-to-Digital Converters)
- Understand traditional measurements like gain, power compression, TOI (third-order intercept), harmonics, noise figure, phase noise, ACPR (Adjacent Channel Power Ratio) and their continued importance in testing the building blocks of today's SOCs.
- Examine modern system level tests like BER and EVM (Error Vector Magnitude) and develop and understanding of how they are used in conjunction with traditional tests to architect a wireless device's test list
- Perform an in-depth analysis of Bluetooth testing requirements and how to implement the multiple BER (bit error rate) techniques currently used in industry today
- Understand the basics of noise figure and phase noise in relation to SOC devices in a production environment.

Target Audience

The course is designed for new and practicing test/product engineers who are involved with the production, test, and development of RF/Wireless SOC solutions in the DC to 8 GHz frequency range. It is equally useful to engineers wishing to expand their existing skill set to cover the broad technology range requirements as well as the in-depth discipline range requirements of wireless SOC devices.
Engineering degree or at least three years applicable practical experience is recommended.

Outline

Day One

Introduction to Production Device (DUT) Testing

- Test systems vs. rack & stack
- Moving from bench to production testing
- COT associated with testing discrete devices
- Test houses, test cells
- Peripherals
  - *handlers*
  - *probers*
  - *contactors*
  - *load boards*
- devices
  - *LNA*
  - *PA*
  - *oscillator*
  - *mixer*
  - *IQ modulator*
  - *filter*
  - *VGA*
  - *ADC/DACs*

Day Two

Measurement Overviews for All Discrete Devices

- S-parameters
- power
- modulated power
- gain
- power compression
- TOI (Third Order Intercept)
- harmonics
- LO leakage
- image suppression
- carrier suppression
- noise figure
- phase noise
- adjacent channel power
- SNR (signal to noise ratio)
- SFDR (spurious free dynamic range)
- MDS (minimum detectable signal)
- noise floor
- accuracy

Day Three

Introduction to Mixed Signal Testing

- Time domain vs. frequency domain
- FFTs
- Digitizers and AWGs (test system hardware)

Today's SOC Radios: Hardware & Measurement Requirements

- Traditional super-heterodyne
  - *Source and receive measurements*
- Newer homodyne transceivers (ZIF - Zero IF)
  - *IP2 vs. IP3*
- Translating RF/mixed signal measurement theory
  - *RF-to-analog base band architectures*
  - *Translating RF to mixed signal*
  - *RF-to-digital bits architectures*
  - *RF-to-digital IQ - Base band implications; IQ, differential, DC offsets, power servo*

Day Four

Bluetooth Radio

- Origins of Bluetooth
- Frequency hopping
- Bluetooth Modulation
- Bluetooth data rates and data packets
- Adaptive power control
- The parts of a Bluetooth radio

Bluetooth Radio Transmitter Tests

- Synthesizer settling time - power vs. time & frequency vs. time
- transmit output spectrum
- modulation characteristics
- ICFT (Initial Carrier Frequency Tolerance)
- carrier frequency drift
- VCO drift
- frequency pulling & pushing

Bluetooth Receiver Tests

- Bit Error Rate
  - *XOR method*
  - *FPGA*
  - *digital pin*
  - *digitizer*
- BER receiver measurements
  - *sensitivity*
  - *Carrier to Interference*
  - *Adjacent Channel Interference*
  - *In-band & out-of-band blocking*
  - *intermodulation interference*
  - *maximum input power level*

Production test times and their relative COT implications

Analyze the WLAN radio and its production testing requirements

- 802.11b
- 802.11a
- 802.11g
- Turbo modes impact on base band hardware
- Digital I&Q architectures on DSP offerings

Analyze the CDMA radio and its production testing requirements

- Review of CDMA technology
- Wide bandwidth considerations
  - *ACPR, ACLR*
  - *Dynamic range*

Day Five

Moving Beyond Production Testing

- Today's COT model
  - *Fixed cost, recurring cost, lifetime, utilization, yield, accuracy, multi-site testing, parallel testing, test engineering skill*
- RF BIST (Built-In-Self-Test)
- RF DFT (Design for Testability)
  - *RSSI (Received Signal Strength Indicator)*
  - *Internal BER testing*
- Parallel testing
  - *True parallel testing*
  - *Pseudo parallel testing*
  - *Alternative parallel testing techniques*
- Emerging production testing methods
  - *Interleaving*
  - *DSP threading*
  - *Concurrent testing*

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Radio System Design - Theory and Practice

Course 180

Summary

This course identifies the key system design parameters, showing how they compound in a given configuration and hence how they relate to the top-level specifications. The course builds from basic models and descriptions of system behaviour. Describing common receiver and transmitter architectures, understanding the key impairments to reliable communications and looking at system solutions to modulation, multiple access and air interface standards. Various tools are used to provide accurate initial estimates of component performance while others show the relative contribution of each circuit block to the total. These tools help isolate critical parameters allowing designers to focus on the key aspects. In this way, designers can focus on the key elements that have to be solved to meet a design requirement in a cost effective manner while making sure that all the parts, when put together, will work as expected.

Recognizing that system design is not completely analytic, the course illustrates the art of design with practical analysis tools. The lectures contain useful formulations of key analysis techniques as well as Excel templates and practical tips applied to commercial CAD tools. The more advanced design concepts are illustrated with examples using commercial software.

Learning Objectives

Upon completing the course the student will be able to:

- understand the basics of system performance from constituent component block characteristics
- anticipate how component blocks interact
- relate component level parameters to top-level system specifications
- compare common receiver and transmitter architectures
- illustrate both good and bad architecture solutions
- demonstrate the relative strengths and weaknesses of simple spreadsheets, commercial software and CAD packages

Target Audience

The key objective of this course is to understand the basics of system performance from constituent component block characteristics, how they interact and how they can be related, to top-level system specifications. It uses examples and some historical perspective to help understand how and why modern radio systems work.

This is an intermediate level course for engineers or project managers. It is suitable for system designers wishing to better understand component level implications or practicing component design engineers interested in managing more complex sub-assemblies and systems. The course is suitable for those working in radio as well as in the mobile phone industry, handset or base station, satellite communications, radar and EW / ECM.

Outline

Day One - Signal Integrity

Noise

- Origins and Definitions
  - *Noise figure, noise factor, noise temperature, Bandwidth assumption, Thermal floor -174 dBm/Hz*
- Cascade Calculations
  - *Standard formulae, Single step simplification, Calculating per stage increase and percentage contribution*
- Examples

Intermodulation

- Textbook Definitions
  - *Input or output reference, 2nd, 3rd and Nth order IM*
- Cascade Calculations
  - *Single step cascade - phase addition, Calculating per stage increase and percentage contribution*
- Sensitivity, selectivity and spur free dynamic range

Compression

- Textbook Description: Useful approximations
  - *Cascade Calculations*
- Example illustrating the Linear / Non-Linear Continuum

Day Two - Signal Translation

- General Discussion

Mixers

- Signal Conversion
- Image Band - Signal and Noise
  - *Noise figure of mixers*
- Calculating Spurs
  - *Frequency and level*
  - *Identifying worst ones*
- Phase noise and LO effects
- I / Q conversion

Filters

- Selectivity
  - *Estimating complexity*
  - *Effects of diplexing*
- Passband Loss
  - *Qu considerations*
  - *Bandwidth considerations*
- Filter Functions without the Circuit Theory
  - *Standard methods*
  - *transfer functions*

Day Three - System Architecture

Architecture

- Choosing the Correct IF
  - *High and low side mixing*
  - *Up/down or multiple conversion*
  - *Direct conversion*
- Gain Distribution
- Special Considerations for Transmitters
- The Role of DSP

Design Tools

- Spreadsheets - Plusses and Minuses
- Examples and Uses of Low Cost Programs
- Commercial System Simulators and examples

Day Four - Signal Transport

Link Budget

- Introduction to antennas
- Free space propagation path analysis
- Effects of fading, delay spread and Doppler
- Balancing the link budget

Modulation

- Analog modulation AM and FM
- Digital modulation schemes, BER
- Advanced schemes OFDM
  – *bandwidth utilisation and channel capacity*

Day Five - Radio Layer Standards

Multiple Access Methods

- The distinction between modulation and access methods
- The dimensions of frequency, time and symbols
- Examples of FDMA, TDMA, CDMA and OFDMA
- Multiple access planning, frequency re-use capacity and efficiency

Advanced Concepts

- 3G Long Term Evolution, HSDPA and beyond
- 4G networks, MIMO, Ad hoc networks and Cognitive radio

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RF & Wireless Made Simple Online Course

Course 061

Summary

Learn how to speak engineer...or at least understand them!
...and learn at your own pace....

RF & Wireless Made Simple online course can teach a basic understanding of RF and wireless technology in as little as 8 hours, or up to six months whenever you need a "refresher".

Frequently used terms will be explained, as well as how to calculate dB. The names and functions of RF system components are discussed and a description of how they interact to generate and process signals is provided. The course explains the basic principles of signal processing and multiple access techniques in wireless telecommunications. A variety of relevant topics will be covered including a comparison of the specifications of commercial wireless systems. The course concludes with a discussion on the future of wireless technology and its applications.

Learning Objectives

Upon completing the course the student will be able to:

Describe the integral relationship of the EM spectrum, basic wave theory, and power calculations with RF and wireless technology.

Define and elaborate on impedance, resistance, reactance, and mismatch.

List the names and functions of RF system components and describe how they interact to generate and process signals.

Explain the basic principles of signal processing.

Identify and describe the basic principles of multiple access techniques in wireless telecommunications.

Explain the process underlying propagation of electromagnetic waves.

List and compare the specifications of commercial wireless systems.

Discuss the future of wireless technology and its applications. More information…

Target Audience

Marketing, sales, instructors, and all other nontechnical personnel working with the RF and wireless industry will benefit from this course. No prior technical knowledge is required to learn from this online course. More information...

Outline

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RF and High Speed PCB and EMI Design Fundamentals

Course 042

Summary

This two-day course enables practicing engineers and CAD technicians to develop design rules for RF and high-speed designs, choose an optimal design tool, and organize the design process to most efficiently execute the design that will insure circuit performance, and minimize costs and production time.

Learning Objectives

Upon completing the course the student will be able to:

- Discuss fundamental RF and digital PCB design issues.
- Compare and contrast transmission lines types, characteristics, and situations in which they can be used.
- Describe, evaluate, and compare termination types, PCB materials and fabrication processes, and packaging types.
- Identify and compensate for sources of interference - EMI and EMC.
- Measure and fine-tune circuit performance.
- Identify and select tools for developing transmission line design rules.

Target Audience

Anyone working with RF circuits or high-speed digital logic, including RF engineers, digital logic engineers, technicians, and PCB layout professionals will benefit from this course. A practical engineering background and basic mathematics are required to follow the course.

Outline

Day One

Fundamentals of Digital and RF Circuits

- RF vs. high speed digital
- Signal integrity
- Properties of high speed logic gates
- Pulse rise/fall times
- Propagation time
- Spectra of digital signals

Simple but very important physics

- Electric fields, dielectrics, and capacitance
- Magnetic fields, mu-materials, and inductance
- Electromagnetics and boundaries
- Frequency, wavelength, and phase
- Resistance and Ohm's Law

Transmission Line Fundamentals

- PCB traces
- Velocity of propagation
- Electrical length
- Skin effect
- Microstrip lines
- Striplines
- Coaxial
- Coplaner
- Line impedance
- Transmission energy
- Reflected waves
- Terminations

Use of Transmission Lines

- Transmission line or wire ?
- Line impedance control
- Transmission line systems
- Line parasitics

Day Two

PCB Layout Strategies

- Grounding via placement
- DC Power distribution
- "Ground" return
- Ground bounce
- Plane layers

PCB Materials and Fabrication

- Dielectric materials
- The basic fab process
- Layer Stack-ups
- Multi-layer parasitics
- Dispersion

Sources of Interference

- Cross talk
- PCB inductors
- Mutual inductance
- Shield traces
- Ribbon cables

EMI Issues

- Current loop size
- Bypass capacitors
- CMOS special considerations
- Ground discontinuity
- Slew rate control

EMC Issues

- Managing fields
- Differential signals

Delay Matching

- Harder than it looks
- Serpentine line coupling

Design Rules

- For low noise
- For Signal Integrity
- For low EMI
- Notching ground planes
- Danger of autorouting

Besser Associates
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RF and Microwave Transistors/Semiconductor Materials

Course 233

Summary

This introductory tutorial develops a picture of how electrons behave in semiconductor materials and applies it to functional descriptions of the basic semiconductor devices: the P-N junction, heterojunction, the bipolar transistor and the FET. The effects of material properties will also be discussed.The course runs from 9:00 AM to 11:00 AM Pacific time. A recording of the course will be available for one week for those who are unable to attend the live event, and questions will be answered both during the session and via email after the session has ended. This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.

Learning Objectives

Upon completing the course the student will be able to:

•Explain the basics of semiconductor materials and structures

Target Audience

Engineers and Managers who can benefit from an introduction to the semiconductor devices they use in design and/or manufacture of RF/microwave products.

Outline

Tutorial Topics

- FET and BJT structures
- Electrons and holes in semiconductors
- Junctions
- Transistor operation
- Using heterojunctions for higher performance
- Effects of material properties

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RF and Wireless Made Simple

Course 234

Summary

This two-day day course provides nontechnical professionals with a firm understanding of basic RF principles and technical concepts. RF technology, wave propagation and transmission techniques will be characterized for various performance requirements. This course will also convey a conceptual understanding of RF wireless systems and how they work for the multiple wireless standards. All explanations use simple physical descriptions without complex mathematics.

Learning Objectives

Upon completing the course the student will be able to:

•Understand the RF language
•Describe RF energy and transmission techniques
•Convert numbers to dB without a calculator
•Describe RF performance and electrical signal principles
•Illustrate the block diagram of a complete wireless system
•Describe how voice and video signals are digitized, compressed, and corrected
•Explain multiple access technology
•Describe high data rate, short range wireless systems

Target Audience

Nontechnical personnel working with the RF and wireless industry will benefit from this course. Engineers and technicians with limited RF experience will also benefit. There are no prerequisites for this course.

Outline

Day One

RF Principles and Terminology

- RF energy- what is it ?
- The characteristics of RF waves
- Understanding basic RF terms: Frequency, wavelength, power, occupied bandwidth
- The magic of RF propagation
- Connecting all the building blocks through transmission lines
- Defining RF performance: Return Loss, VSWR, Reflection Coefficient, S-parameters
- Electrical Signal Principles: Time and frequency, voice and video, digitizing of analog signals, data, bit error rate (BER)

Day Two

Basic RF System Architectures

- The basic building blocks of transmitters and receivers:
  - *oscillators*
  - *mixers*
  - *attenuators*
  - *amplifiers and filters*
- Defining system performance terms: Dynamic range, noise figure, minimum detectable signal, intermodulation distortion• 3rd order Intercept point (IP3)
- Modulation and multiple access techniques (OFDM, OFDMA, BPSK, QPSK, QAM).
- Antenna principles
- Using link budgets to model performance
- The fundamentals of operating systems: WCDMA, LTE, Wi-Fi(802.11), Bluetooth, WiMAX

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RF and Wireless Made Simple II

Course 058

Summary

This two-day seminar provides anyone working in the RF industry with the opportunity to efficiently increase their understanding of RF terminology, components, and systems.

Learning Objectives

Upon completing the course the student will be able to:

Convert dB and dBm values competently.
Convert mismatch specifications to return loss, SWR, or reflection coefficient.
Design microstrip transmission lines.
Match with the Smith Chart.
Explain an RF system block diagram.
Describe the function and operation of each component of an RF system.
Design a receiver to meet noise figure and intermod requirements.
Select appropriate RF components for each system block from datasheets.
Use simple RF software.

Target Audience

Practicing RF and wireless design and manufacturing engineers, general managers, technicians, salespersons and marketers will all benefit from this course. Prerequisites include attendance at RF and Wireless Made Simple I (or equivalent experience), and the ability to use a handheld scientific calculator.

Outline

Day One

Review of dB and dBm Conversions

Specifying Mismatches

- Return loss
- SWR
- reflection coefficient
- S Parameters
- Conversion from one definition to another

Microstrip Transmission Lines

- Choosing board material
- Designing a 50-ohm line
- Calculating microstrip line wavelength

Matching with the Smith Chart

- Software
- Matching of a transistor mounted on a microstrip board

RF System Block Diagram

Transmitter Components

Day Two

Receiver Components

- Filters
- Low noise amplifiers
- Mixers

Receiver Performance

- Noise figure
- Intermodulation products
- Dynamic range
- Software

Antennas and Duplexers

RF System Design Exercise

- Selecting appropriate components from a review of manufacturers' datasheets

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RF and Wireless Transceiver Design & Evaluation Techniques

Course 199

Summary

This 5-day course provides technical professionals with the design concepts and development tools required to architect RF transceivers for most wireless applications. The course is intended for working engineers that are in the design, test or support phase of new transceiver technology.. Also, Critical system specifications will be discussed based on worldwide standards and an in-depth review of transceiver configurations will be evaluated. The use of RF simulation tools will be used to show design concepts and the trade-offs between modulation techniques and RF performance. RF air interface requirements and specifications will be presented for various wireless standards including LTE and systems like GPS, Bluetooth, 802.11, wideband CDMA, EDGE and others. Radio architectures based on digital modulation techniques like OFDM, OFDMA, SC-FDMA, QAM, BPSK, QPSK, GSM, 8PSK, GFSK will be analyzed using simulation tools and design examples.
Transmitter architectures and designs will be shown and include discussions on power control, modulation schemes, and linearization techniques. Various receiver architectures including zero IF, low IF and superhetrodyne, multifunction and software defined radio are described with design examples. Receiver nonlinearities and dynamic noise performance will be modeled to show system limitations.
Designs of the latest architectures including 4G LTE transceivers will be presented with class participation using the lasted CAD design tools. Finally, transceiver test and troubleshooting procedures from RF to baseband will be described. Students are encouraged to bring their laptop computers to class.

Learning Objectives

Upon completing the course the student will be able to:

•Describe common wireless standards and their impact on RF transceiver architectures
•Analyze physical layer radio specifications for WCDMA, LTE, Bluetooth and 802.11
•Describe major digital modulation schemes and their relationship to RF transceiver designs
•Analyze transmitter Architectures and linearization techniques
•Describe common types of receivers and their components
•Understand the overall end-to-end network archicetures for 3GPP technologies.
•Analyze typical performance parameters, and accompanying limitations
•Learn how to architect a receiver to meet requirements
•Evaluate modern system architectures including multifunction/multi-standard types including the software defined radio
•Test, and troubleshoot complex radio system from RF to baseband

Target Audience

Component designers, test engineers, system designers, managers and technicians with an RF background will benefit from this course. Students should bring a notebook computer to class.

Outline

Day One

Wireless Specifications

- Specifications: LTE, WiMAX, and others
- UMTS Evolution from WCDMA to LTE
- 3GPP Physical layer standards
- Defining Quality of Service(QoS) Classes
- Categories of data transmission
- Performance Goals
- Air Interface Concepts
- The Open Systems Interconnection(OSI) reference model
- Spectrum Options and Migration Plans
- Spectrum deployed for TDD mode and FDD mode
- The future of Mobile Broadband-Beyond LTE

RF System Requirements and Architectures

- Digital modulation schemes
  - *BPSK, QPSK ,GFSK, GSM, OFDM, QAM*
- Multiple access techniques
  - *OFDMA, SC-FDMA*
- Phase lock Loop analysis
  - *Phase noise, loop bandwidth for optimum noise performance, PLL designs*
- Up-down converters
  - *conversion gain/loss, noise figure, port-port isolation, nonlinearity effects*
- Amplifiers
  - *Classes of operation, small signal parameters, large signal parameters, dynamic range*
- Filters
  - *types , Amplitude/ Phase distortion, band pass response*
- Digital signal-to-noise ratios (Eb/No) for different modulation schemes
- Signal-to inference ratios (SIR)

Day Two

Receiver Architecture and System Design

- Receiver block diagrams
- Important receiver parameters
  - *Sensitivity*
  - *Minimum Detectable Signal (MDS)*
  - *Dynamic range (IP2 & IP3)*
  - *Spurious free dynamic range*
  - *System noise figure*
  - *Wideband receiver performance in terms of BLER and BER*
- Receiver types
  - *zero IF*
  - *low IF*
  - *Superheterodyne*
- A/D considerations
- Receiver elements description with typical performance
- Receiver demodulation techniques for various systems
- IF frequency selection for

spurious free operation
- Filtering and shielding
- CAD and evaluation of complete receiver types
- Evaluating trade-offs
  - *Desensitization Vs QoS*
  - *Intermodulation distortion Vs power control*
  - *Multipath fading Vs BLER*

Day Three

Transmitter Architecture and System Design

- Transmitter nonlinearities and distortion
  - *harmonic/intermodulation distortion*
  - *AM/AM – AM/PM*
  - *ACLP*
  - *EVM*
- Transmitter noise and filtering
- Transmitter power devices
- Efficiency enhancing techniques
  - *voltage, current, load line modulation*
- Transmitter distortion reduction
- Transmitter architecture design examples for 4G LTE

Physical layer Power Control Architectures

- WCDMA
- HSPA, Enhanced Link and LTE Power requirements
- Uplink power control
- RACH
- Algorithms for processing TPC commands
- Reed-Miller encoded PCC bits
- Open Loop power control
- Closed loop power control
- Inner loop power control
- Outer loop power control
- Digital /Analog gain partitioning
- Subcarrier power mapping

Day Four

Multifunction Transceiver Architecture and Design

- Link budget design
- Commercially available transceiver elements and their specifications
- Complete system design and architecture
  - *LTE, WiMAX, and others*
- Multifunction transceiver design and examples
- Software defined radio

Day Five

System Test and Evaluation

- Transmitter in-channel measurements
  - *channel bandwidth*
  - *carrier frequency*
  - *channel power*
  - *sub-channel power*
  - *occupied bandwidth*
  - *peak-to-average power ratio*
  - *peak power*
  - *EVM*
  - *phase/frequency error*
- Transmitter out-of-band measurements
  - *spurious*
  - *harmonics*
- Factors affecting transmitter impairments
  - *compression*
  - *incorrect filter coefficient*
  - *LO phase noise*
  - *I/Q amplitude/phase imbalance*
- Receiver in-channel measurements
  - *Signal to Interference ratio*
  - *Sensitivity at specified BLER*
  - *co-channel rejection*
  - *intermodulation distortion*
  - *dynamic range*

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RF Design: Applied Techniques

Course 248

•Sep 14-Sep 18, 2015 - San Jose, CA / Bob Froelich

Summary

This new course incorporates the most popular topics from Applied RF Techniques 1 and 2 in a 5-day format. The material presented provides participants with the critical tools to design, analyze, test, and integrate linear and nonlinear transmitter and receiver circuits and subsystems.

Impedance matching is vitally important in RF systems and we use both graphical (Smith Chart) and analytical techniques throughout the course. We also examine discrete and monolithic component models in their physical forms, discussing parasitic effects and losses, revealing reasons why circuit elements behave in surprising manners at RF. Filters, resonant circuits and their applications are reviewed through filter tables and modern synthesis techniques, leading into matching networks and matching filter structures. Since wires and printed circuit conductors may behave as transmission line elements, we also cover microstrip and stripline realizations. 2D and 2.5D electromagnetic field simulators are used in the course to illustrate transmission line behavior and component coupling effects.

In the area of active circuits, we first examine fundamental limitations posed by noise and distortion. The next topic is small-signal linear amplifier design, based on scattering parameter techniques, considering input/output match and gain flatness RF stability is examined both with S-parameters and also with the Nyquist test using nonlinear device models. Since DC biasing affects RF performance, we review active and passive bias circuits and see how they can be combined with impedance matching circuits. Another important consideration is circuit layout, therefore we look at problems caused by coupling, grounding and parasitic resistance. Narrow and broadband designs are compared, using lossless and lossy impedance matching as well as feedback circuits. Low-noise amplifier design is illustrated, discussing trade-offs among gain flatness, noise, RF stability, and impedance match. Harmonic and intermodulation performance is also examined. Performance tradeoffs of balanced amplifiers are viewed. The course concludes by examining large-signal and ultra wideband feedback amplifiers.

Circuit level engineers will master the latest linear and nonlinear design techniques to both analyze and design transceiver circuits. System engineers will examine block level circuit functions; learn the performance limits and how to establish specifications. Test engineers will learn how to test and evaluate circuits. Transceiver circuits to be covered include power amplifiers, oscillators (PLL, VCO, etc.) and the critical receiver elements. Receiver architecture and synthesizer design to meet critical requirements will be presented. Techniques to successfully integrate circuit functions at the system level will be discussed.
Students are encouraged to bring their laptop computers to class. The design software available for use in this public course is from NI (formerly AWR).

Learning Objectives

Upon completing the course the student will be able to:

•Describe RF circuit parameters and terminology
•Match impedances and perform transformations
•Understand Impedance matching, component models, and PCB layout issues
•Design filters with lumped and distributed components
•Predict RF circuit stability and stabilize circuits
•Design various RF amplifiers: small-signal, low-noise, and feedback
•Understand and quantify nonlinear effects of transmit and receive systems
•Use CAD models to analyze/design circuits
•Design low noise and highly linear amplifiers
•Understand receiver performance parameters and modulation techniques
•Design signal sources using PLL (phased lock loop) techniques
•Explain and design VCOs and stable oscillators

Target Audience

The course is designed for engineers who are involved with the production, test, and development of RF components, circuits, sub-systems, and systems.
Engineering degree and the course, RF Design - Core Concepts (#247), or equivalent background, including Smith chart and concepts such as wavelength, electrical length, and dB notation, are recommended.

Outline

Day One

Impedance Matching Techniques

• Transmission zeros, LC network order
• Maximum power transfer from Z1 to Z2
• Single LC-section impedance matching
• Bandwidth and parasitic considerations
• Wideband match -- low circuit-Q
• Narrowband match -- high circuit-Q • Illustrative examples

Lumped RF Component Models

• Resistors • Inductors
• Inductance and Q Variations
• Capacitors • Effective Capacitance and Q Variations
• Primary self-resonance variations
• Definitions of Magnetic Properties

- Magnetic Core Applications
- Ferrite Bead Impedance

Transmission Lines and Ground Parasitics

- Via-Hole and Wrap-Around Ground Inductance
- Parasitic Inductance and Capacitance Effects at RF
- Multilayer PC-Board Parasitics • PCB/Interconnects
- Open Stub Effects in Differential Vias
- PC Board Materials
- Transmission Line Realizations • Transmission Line Discontinuities
- Converting an Electrical Circuit to Physical Form

Filters and Resonant Circuits

- Introduction • Recipes for lumped-element filters
- Parasitic loss and Q factor
- Impedance inverters
- Band pass filters with resonant structures
- Piezoelectric filters
- Filter element transformations

Day Two

Active Circuit Fundamentals

- Linear circuit definition • Amplifier Performance Limitations
- Thermal Noise Definition • Harmonic Distortion Definitions
- Gain Compression • Intermodulation Distortion
- Spurious-Free Dynamic Range • Error Vector Magnitude
- Various Power Gain Definitions
- Testing for RF Stability • Causes of RF Oscillation
- Typical Stability Circles for an RF Transistor
- RF Stabilization Techniques
- Nyquist Stability Analysis

Small Signal Amplifier Design

- Transducer Gain Expression
- Simultaneous Conjugate Match for Maximum Gain
- Two-stage Amplifier Design for Gmax • Gain Definition - Block Diagram
- Operating Gain Definitions • Operating Gain Circle Application
- Maximizing Output Power
- Available Gain Definitions • Available Gain Circles

Low Noise Amplifier Design

- Sources of RF noise • Noise Factor and Noise Figure definitions
- Noise of cascaded stages • Two-port noise parameters
- Low-noise design procedure

Broadband Amplifiers

- Broadband Concepts • Wideband Amplifier Design Overview
- Gain Control and Impedance Matching in Feedback Amplifiers
- Series and Parallel Feedback Applications
- 10-4000 MHz Feedback Amplifier Design
- Equivalent Circuit for Microwave FET
- Distributed Amplifier and Cascode Connection

Day Three

Nonlinear Circuits & Concepts

- Where nonlinearity is important
- Methods for nonlinear analysis
- X Parameters

High Efficiency Power Amplifier Design

- PA transistors • Matching for maximum gain or output power
- Load-pull measurement techniques
- Predicting output power contours
- High efficiency techniques
- Class A, B, C, D, F, harmonic termination consideration

Day Four

Receivers and Their Architecture

- Noise floor, maximum input, and dynamic range
- Receiver spurs • Block diagram
- Channel selection • Filtering
- Downconverters / Mixers
- Effects of phase noise
- Quadrature demodulation

Modulation Techniques

- AM, FM, digital
- Multiple access
- Bit error rate and SNR
- CDMA • MIMO
- Baseband filtering • Effects of distortion

Frequency synthesis, PLL design

- Basic PLL and closed-loop response
- Loop filters • Frequency dividers
- Output spectrum • Contributors to phase noise

Day Five

Feedback and negative resistance oscillator design

- RF stability and loop gain
- Feedback oscillators and open-loop design
- Reflection oscillators

AM FM Noise Considerations

- AM and FM decomposition of noise
- Physical origins of noise
- Noise conversion in amplifiers and oscillators

VCOs, DROs and crystal oscillators

- Electronic tuning strategies
- Oscillator specification, testing
- Commercially available VCO’s

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RF Design: Core Concepts

Course 247

•*Aug 24-Aug 28, 2015 - Web Classroom, WebEx / Bob Froelich*

Summary

This course is the first in a series for RF Design engineers and other professionals in that field. It presents core concepts essential in understanding RF technology and presents circuit-level designers with the foundation needed to work effectively with high frequency electronics. Participants gain analytical, graphical (Smith Chart), and computer-aided techniques to analyze and optimize RF circuits in practical situations. This course reviews traditional circuit definitions based on voltages and current and transitions to power-flow concepts and scattering parameters (S-parameters) used in the wireless domain. The material covered forms the foundation for follow-on courses dealing with specific RF and Microwave circuit and component design.
This seminar contains material typically covered in one full day of instruction but is divided into five 90 minute web-classroom presentations.(9:00am to 10:30am Pacific time) Each daily session is a live event but the recording can be made available for up to 7 days to support students requiring a more convenient viewing time. Please contact the office for details at info@besserassociates.com. This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.Students will receive a signed Certificate of Completion.

Learning Objectives

Upon completing the course the student will be able to:

•Describe RF circuit parameters and terminology
•Work comfortably with dB notation
•Understand Modern CAE/CAD Techniques
•Work with transmission lines
•Use graphical design techniques and the Smith Chart

Target Audience

The course is designed for professionals working in the RF domain for the first time as well as seasoned veterans requiring a good review of the core concepts. An electrical engineering background (or equivalent practical experience) is recommended, as well as a familiarity with complex numbers. This program prepares students to take the follow-on RF Design: Applied Techniques course.

Outline

Introduction to RF Circuits

• Linear circuit analysis in RF systems
• Frequency range of coverage: 100-3000 MHz • Log conversion, dB and dBm scales
• Complex numbers in rectangular and polar form
• Component Qs
• Importance of Impedance Matching
• Normalization
• RF component related issues

RF/MW Fundamentals

• Complex impedance and admittance systems
• Resonance effects
• One-port impedance and admittance
• Series and parallel circuit conversions
• Lumped vs. distributed element representation
• Signal transmission/reflection and directional couplers
• Key parameters : Gamma, mismatch loss, return loss, SWR
• Impedance transformation and matching • Illustrative exercise

Transmission Lines

• Transmission line types: coaxial, microstrip, stripline, waveguide
• Characteristic impedance and electrical length
• Input impedance of loaded transmission line

The Smith Chart and Its Applications

• Polar Gamma vs. Rectangular Z plots
• Impedance and Admittance Smith Charts
• Normalized Smith Charts
• Lumped series/parallel element manipulations
• Constant Q circles
• Expanded and compressed Smith Charts
• Impedance and admittance transformations
• Transmission line manipulations
• Illustrative examples

Scattering Parameters

• Review of one-port parameters
• Two-port Z-, Y-, and T-parameters
• Cascade connections and de-embedding
• S-parameters of commonly used two-ports
• Generalized S-parameters
• Mixed-mode S-parameters
• Illustrative examples

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RF Fundamentals, Modeling and De-Embedding Techniques

Course 186

Summary

This 3-day course provides technical professionals with the fundamental concepts and engineering tools needed to understand RF fundamentals and test fixture de-embedding techniques. The latest software simulation tools are used to demonstrate these concepts and techniques.

Learning Objectives

Upon completing the course the student will be able to:

•Describe RF waves and their characteristics
•Understand how to model RF Passive devices and Test fixtures at RF Frequencies
•Understand Basic De-embedding Techniques
•Explain RF measurement & Calibration Techniques
•Understand Measurement Limitations and Error Functions

Target Audience

Test and measurement technicians and engineers who need to understand proper techniques for modeling fixtures and passive devices.

Outline

Day One

RF Fundamentals

- Characteristics of Electromagnetic Energy
- Conductors vs. Transmission Lines
- Voltage/Current Relationships
- Complex Impedance and Admittance Systems
- RF Transmission Lines
- Impedance Transformations and Matching

The Smith Chart/Scattering Parameters

- Understanding the Fundamentals of the Smith Chart
- Two-Port Definitions (S-parameters)
- The 2*2 Scattering Matrix
- Cascaded Two- Port Connections

Day Two

Passive Component Modeling

- Resistors at RF Frequencies
- Straight Wire Inductance
- Capacitors and Equivalent Models
- Simulation Models Vs Measured Results
- Package Parasitic Models

Transmission Lines and Ground Parasitics

- Via-Hole and Wrap Around Ground Inductance
- Transmission Lines Analysis
- Microstrip Line Modeling Vs Frequency
- PCB Multilayer Designs and Tradeoffs, Ground Effects

Day Three

Measurements

- De-Embedding
- De-Embedding Techniques (LRL,TRL, etc.)
- Developing De-Embedding Test Fixture Models
- Calibration and Measurement Error Corrections
- Calculating Total Uncertainties
- De-Embedding Using T-Parameters

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RF Measurements:Principles & Demonstration

Course 135

Summary

This 5-day lecture-based course explains essential RF measurements that must be made on modern wireless communications equipment - mobile/smart phones, wireless LANs, GPS navigation systems, and others. Current models of the essential test instruments will be explained and demonstrated, including vector network analyzers, power meters, spectrum analyzers, digitally modulated signal generators and vector signal analyzers.

All of the measurements will be demonstrated on actual RF wireless components including power amps, LNAs, mixers, upconverters, and filters. These measurements will include traditional tests of power, gain, group delay, S parameters, AM to PM, intermodulation products, harmonics and noise figure. The unique measurements of wireless communications will then be made with PSK and FSK digitally modulated signals including spectral regrowth, constellation diagram distortion, error vector magnitude (EVM), and bit error rate.

Learning Objectives

Upon completing the course the student will be able to:

•describe the RF measurements that must be made on modern wireless communication equipment.

•take proper care of RF cables and connectors in the lab

•explain why the various measurements must be made.

•operate the RF test equipment that is used to make these measurements

•setup and calibrate a Vector Network Analyzer measurement

•make measurements on power amps, LNA's, mixers, upconverters and filters

• make traditional tests of power, gain, group delay, S parameters, AM to PM, intermodulation products, harmonics, and noise figure with CW signals.

•ensure that distortion products from the instrumentation are not corrupting the measurement results

•make measurements with PSK and FSK digitally modulated signals of spectral regrowth, constellation diagram distortion and ISI, error vector magnitude, and bit error rate.

•develop reasonable expectations for measurement uncertainties.

Target Audience

Design and production engineers and technicians interested in improving measurement skills through a practical approach will benefit from this course. The lecture includes a review of wireless communication systems, RF components and the tests that must be made, making this an ideal course for professionals wishing to have a thorough grounding in the knowledge of how wireless systems operate.

Outline

Day One

Course Objectives and Course Outline

- Review of RF principles
- Wave parameters
  - *frequency, amplitude, phase*
- basics of propagation
- dB and dBm
- Mismatches
- Conversion between mismatch expressions
  - *Reflection coefficient, return loss, mismatch loss, SWR*
- The Smith Chart - an overview
- S-parameters

RF Test Equipment - Principles of Operation

- Cable and connector types/ proper care
- Signal generators
- Power meters and power sensors
- Frequency counter
- Vector network analyzer
- Demonstration: how to setup and calibrate a basic VNA measurement
- Vector network analyzer measurements on non-packaged devices

Day Two

- Spectrum analyzer
- Demonstration: how to operate a spectrum analyzer
  - *Resolution Bandwidth, Video Bandwidth, Attenuation, Scaling*
- Noise figure meter
- Vector signal analyzer

Measurement Uncertainties

- Mismatch uncertainty
- VNA - motivation for measurement calibration

RF Communication system block diagram

- Specifications of components to be tested

Transmitter components

Phase locked oscillator

- principles of operation
- measurement of phase noise
  - *log/video vs. rms averaging on Spectrum Analyzer*
  - *Marker noise function*

Upconverter

- Modulation basics
- principles of operation
- demonstration: measurement of conversion gain using a spectrum analyzer
  - *output spectrum of upconverter*

Day Three

Power Amplifier

- principles of operation
- demonstration measurement
  - *swept gain*
  - *power sweep/1 dB compression point*
  - *AM to PM distortion*
  - *phase on the Vector Network Analyzer*
- Harmonic power using Spectrum Analyzer
- checking for distortion products in the test equipment

Receiver Components

Noise and Noise Figure

- Noise figure measurement
- demonstration measurement

using Y-factor technique

Filters

- Principles of operation
- Demonstration measurement
  - *passband*
  - *inband loss*
  - *match*
  - *group delay on the Vector Network Analyzer*

Day Four

Low Noise Amplifiers

- principles of operation
- Noise figure
- intermodulation products
- demonstration measurement
  - *gain/1dB compression point*
  - *output power*
  - *phase using power sweep on Vector Network Analyzer*
- demonstration measurement
  - *S-parameters vs. frequency on the Vector Network Analyzer*

Mixer

- principles of operation
  - *conversion gain*
  - *output power*

Intermodulation Products

- description of intermodulation products
- Demonstration: IP3/TOI using a spectrum analyzer
- definition of IP2

Overall Receiver Performance

- Typical overall receiver performance
- Calculating system performance

Day Five

Multiple Access Techniques

- FDMA
- TDMA
- CDMA
- OFDMA

Performance of RF components with digital signals

- Block diagram
- Digital modulation fundamentals
- demonstration measurement
  - *Adjacent Channel Power (ACP) performance vs. power amplifier nonlinearity with different modulation techniques*
- zero span function on Spectrum Analyzer

Vector Signal Analyzer Modulation Quality Measurements

- Principles of operation
- EVM/Distortion of digital signal due to power amplifier nonlinearity
- EVM/Distortion of digital signal due to IF filter group delay
- EVM/Distortion due to LO phase noise with mixer
- Troubleshooting digital modulation with a Vector Signal Analyzer

Description of Bit Error Rate (BER)

Review

- RF Communication System Operation

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RF Power Amplifier Techniques - including GaN plus Si & GaAs semiconductors

Course 222

•Sep 28-Oct 2, 2015 - San Jose, CA / Ali Darwish

Summary

Power amplifiers are crucially important in determining a communications system cost, efficiency, size, and weight. Designing high power / high efficiency amplifiers that satisfy the system requirements (bandwidth, linearity, spectral mask, etc.) is challenging. It involves difficult trade-offs, proper understanding of the theory, and careful attention to details. Additionally, designing, building, and testing power amplifiers usually pushes test equipment and lab components to their limits and frequently results in damage to the circuit or lab equipment. This course will examine the different aspects of this challenge with emphasis on hand-on exercises and practical tips to build power amplifiers successfully.

This course will give special attention to GaN power amplifiers, the latest arrival on the power amplifier scene. Differences between GaN pHEMT, Si LDMOS, and GaAs MESFETs will be discussed.

Students are encouraged to bring their laptop computers to class. CAD software will be used to simulate design examples. The design software available for use in this public course is from NI (formerly AWR).

Learning Objectives

Upon completing the course the student will be able to:

•Learn the advantages and limitations of various technologies.
•Gain an understanding of the pros and cons of various classes operations.
•Learn how to characterize device for power amplifier design.
•Acquire design know-how of high efficiency amplifiers.
•Attain practical knowledge on the design of linear amplifiers.
•Calculate the lifetime of power amplifiers in packaged and unpackaged assemblies.

Target Audience

Microwave engineers who want to design, fabricate, and test power amplifiers, in the 1-50 GHz frequency range, will benefit from this comprehensive design course. Basic knowledge of microwave measurements and transmission line (Smith Chart) theory is assumed.

Outline

Day One

Power amplifier Fundamentals

• Device technologies: GaAs, LDMOS, GaN, Si, SiGe.
• Small signal model generation, transistor speed (ft, and fmax) calculation.
• Power Amplifier Stability: even mode, odd mode.
• Optimum power load estimation, calculation, and simulation.
• Load-pull characterization of devices.
• Device characteristics and non-idealities.
• Dependence of transistor parameters on drive level.
• Large signal models.
• Power Amplifier biasing.
• Exercise: GaN pHEMT small signal model generation.

Day Two

Conventional and High Efficiency Amplifier Design

• Power amplifier classes A, B, AB, C, and D; concepts, designs, and examples.
• Waveform engineering for maximum efficiency.
• Envelope Tracking
• Class E Switching mode power amplifiers: Concept, Design, Limitations, Maximum Frequency, Exercises, and Examples.
• Class F (and F-1) power amplifiers: Concept, Design, Limitations, and Examples.
• Comparison of various classes: efficiency, output power, and frequency limitations.
• Doherty power amplifiers: Concept, Design, Limitations, and Examples.
• Effects of knee voltage, harmonic terminations, and nonlinearities.
• GaN pHEMT power amplifiers
• Exercise: High efficiency power amplifier design.

Day Three

Linearization Techniques and Signal Modulations

• Classical Modulation schemes: AM, FM, PM.
• Modern Modulation: FSK, PSK, MSK, BPSK, QPSK, ?/4-DQPSK, OQPSK, QAM, etc.
• Distortions in power amplifiers.
• Harmonic balance and time domain simulations.
• Linear/Non-linear Memory effects; electrical and thermal memory effects.
• Measures of Distortion: Third order intermodulation, ACPR, NPR, M-IMR.
• X-parameters.
• Linearization techniques: Feed Forward, Predistortion, LINC, Cartesian Feedback, Reflect Forward, Envelope Elimination and Restoration, Cross Cancellation.
• Comparison of Linearization Techniques.
• Real world design examples, challenges, and solutions.

Day Four

Power Combing, Packaging, and Reliability

• Multistage amplifiers, interstage matching.
• Push-pull, Balanced amplifiers, and Traveling Wave Combiners.
• Power combining techniques.
• Exercise: Design of a power combiner.
• Package design.
• Thermal management and reliability calculations.
• Biasing and transient considerations.
• Exercise: calculating required biasing for 20+ year lifetime.

Day Five

Hands-on Implementation

• Detailed hands-on design using NI Microwave Office ® tools.
• Translating the concepts learned into actual designs including device selection

based on specifications, circuit topology, simulation, and layout	• Exercise: Design of class AB amplifier, from start to finish. • Exercise: class-F amplifier	design • Simulations of power added efficiency (PAE), linearity	(AM-AM and AM-PM), etc.

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RF Productivity: Core Analytical Tools

Course 250

Summary

This course is the first in a series for RF production engineers, technicians and other professionals in the wireless field. It presents the key analytical tools necessary for working with RF technology, such as the dB scale, impedance matching with the Smith Chart, and S-parameters.
The material covered forms the foundation for follow-on courses dealing with specific RF and Microwave productivity skills and test/measurement.
This seminar contains material typically covered in one full day of instruction but is divided into five 90 minute web-classroom presentations.(9:00am to 10:30am Pacific time)
This course is intended for registered individual students only. Please contact us for group rates at info@besserassociates.com or 650-949-3300. Recording, copying, or re-transmission of classroom material is prohibited.

Learning Objectives

Upon completing the course the student will be able to:

- work natively with dB values (without using a calculator)
- understand basic wave parameters and propagation
- appreciate the effects of parasitics on component behavior
- understand the effects of mismatches at RF
- create basic matching networks using the Smith Chart
- describe basic transmission line structures and input impedance
- interpret S-parameters from measurements and datasheets

Target Audience

This course is ideally suited for production engineers and technicians who are new to the RF/wireless field. It is also suitable for those who have been working in the field but who have not had a formal introduction to the key concepts that form the basis of understanding and troubleshooting wireless systems. The course is intended to improve your technical proficiency without delving into design-level details and methods.

Outline

Analytical Tools

Wave Parameters

- Amplitude definitions
- frequency
- wavelength
- phase

Propagation and Fading

- energy spread
- mean path loss
- multipath

dB Notation

- the decibel system
- arithmetic in dB
- approximating dB values intuitively
- dBm, dBW scales

Complex Numbers and Impedances

- AC circuit theory
- rectangular and polar coordinates
- complex number arithmetic
- complex impedance system
- complex admittance system

Resonance and Parasitics

- resonance
- inductive and capacitive reactances
- complex series impedance
- complex parallel admittance
- example: effect of inductive self-reactance
- Q-factor
- resonance

Transmission Lines

- RF wave impedance
- transmission line definition
- characteristic impedance
- transmission line types
- effective dielectric constant
- waveguide
- electrical length
- input impedance
- special cases
  - *half-wavelength*
  - *quarter wavelength*
- 5% rule
- lumped elements vs. transmission lines

Mismatch and Reflection

- underlying cause of reflections
- reflection coefficient
- SWR
- return loss
- mismatch loss

The Smith Chart

- impedance and reflection coefficient
- development of the Smith Chart
- impedance and admittance Smith Charts
- impedance matching with the Smith Chart
- Q on the Smith Chart
- broadband match
- transmission lines
- matching with transmission line stubs

S-Parameters

- matrix representations
- S-parameter definition
- N-port S-parameters
- differential/mixed mode S-parameters

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RF Productivity: Signals and Propagation

Course 255

Summary

This course has been designed for applications, production, manufacturing engineers and technicians as well as other professionals who need to have a solid background in the fundamentals of working with RF and wireless products. This course is part two of a four part program that provides a thorough understanding of RF analytical tools, communications signals, RF devices and test instruments. Signals and modulation formats are described in this session along with propagation fundamentals.

The course consists of pre-recorded lectures followed by online exercise workbooks. Q&A forums are also available. Students have six weeks to complete the material.

Learning Objectives

Upon completing the course the student will be able to:

- describe the modulation formats used to impress information onto the RF carrier
- understand the basic principles of multiple access techniques such as TDMA, CDMA, OFDMA

Target Audience

Prerequisite: RF Productivity: Analytical Tools course or equivalent experience is assumed prior to taking this course. This program is ideally suited for applications, manufacturing and production engineers or technicians who are new to the RF/wireless field. It is also suitable for those who have been working in the field but who have not had a formal introduction to the key concepts that form the basis of understanding and troubleshooting wireless systems.

Outline

Part 2 - Signals and Modulation

Modulation

- Analog
  - *AM, FM*
  - *PSK*
  - *QAM*
- IQ Modulation

Multiple Access Techniques

- FDMA
- TDMA
- CDMA
- OFDMA

Performance of RF Components with Digital Signals

- digital modulation fundamentals
- adjacent channel power ACP
- error vector magnitude EVM
- EVM due to power amplifier compression and AM to PM
- EVM due to group delay
- EVM due to phase noise
- IQ modulator troubleshooting with the VSA

Description of Bit Error Rate

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RF Productivity: Test Equipment

Course 256

Summary

This course has been designed for applications, production, manufacturing engineers and technicians as well as other professionals who need to have a solid background in the fundamentals of working with RF and wireless products. This course is part three of a four part program that provides a thorough understanding of RF analytical tools, communications signals, RF devices and test instruments. Specialized test and measurement equipment for RF and wireless such as spectrum and network analyzers are described.

The course consists of pre-recorded lectures followed by online exercise workbooks. Q&A forums are also available. Students have six weeks to complete the material.

Learning Objectives

Upon completing the course the student will be able to:

- describe the basic function of spectrum analyzers, vector network analyzers, and power meters
- know the limitations on accuracy/uncertainty that affect all RF and high frequency measurements

Target Audience

Prerequisite: RF Productivity: Analytical Tools, Signals and Propagation courses or equivalent experience is assumed prior to taking this course.

This program is ideally suited for applications, manufacturing and production engineers or technicians who are new to the RF/wireless field. It is also suitable for those who have been working in the field but who have not had a formal introduction to the key concepts that form the basis of understanding and troubleshooting wireless systems.

Outline

Part 3 - Test Equipment

Cables and Connectors

- cable and connector care
- connector types

Vector Network Analyzer

- directional couplers
- basic block diagram
- calibration
- basic measurement setup

Spectrum Analyzer

- time domain vs. frequency domain
- basic block diagram
- typical measurements

Signal Generator

- basic block diagram

Power Meters

- power detection

Noise Figure Meter

Vector Signal Analyzer

- basic introduction

Measurement Uncertainties

- mismatch uncertainty
- systematic errors in VNA measurements
- VNA calibration
- instrument-generated distortion products

Measurements of Non-connectorized devices

- de-embedding
- alternate calibration types:
TRL
- fixturing

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RF Productivity: Wireless/Radio System Components

Course 257

Summary

This course has been designed for applications, production, manufacturing engineers and technicians as well as other professionals who need to have a solid background in the fundamentals of working with RF and wireless products. This course is part four of a four part program that provides a thorough understanding of RF analytical tools, communications signals, RF devices and test instruments. A basic block diagram of a transmitter/receiver chain forms the backbone of the course outline. Each component is described, and the relative performance parameters defined. Key impairments are introduced as they become relevant to the operation of the system. Basic system calculations are covered.
The course consists of pre-recorded lectures followed by online exercise workbooks. Q&A forums are also available. Students have six weeks to complete the material.

Learning Objectives

Upon completing the course the student will be able to:

•describe the operation of the main components of an RF transceiver system
•interpret key performance parameters such as P1dB, IP3, noise figure, etc.

Target Audience

Prerequisite: RF Productivity: Analytical Tools, Signals and Propagation, Test Equipment courses or equivalent experience is assumed prior to taking this course.
This program is ideally suited for applications, manufacturing and production engineers or technicians who are new to the RF/wireless field. It is also suitable for those who have been working in the field but who have not had a formal introduction to the key concepts that form the basis of understanding and troubleshooting wireless systems.

Outline

Part 4 - System Components

Phase Locked Oscillator

- principles of operation
- phase noise
  - *measurement techniques*
  - *impacts of phase noise on sytem performance*

Upconverter

- modulation basics
- principles of operation
- 1 dB compression point for active devices
- output spectrum of upconverter

Power Amplifier

- principles of operation
- 1 dB compression point, saturation
- AM to PM distortion
- harmonics

Antennas

- description of antenna types
- dBi, dBd gain parameters

Filters

- common filter types
  - *Butterworth, Chebychev, Gaussian*
- transfer function
- inband loss
- match
- bandwidth
- group delay

Noise and Noise Figure

- definition of thermal noise
- definition of noise figure
- techniques for measuring noise figure
  - *Y-factor technique*
  - *cold-source*

Low Noise Amplifiers

- principles of operation
- noise figure
- intermodulation products
- S-parameters
  - *input vs. output match*
- 1 dB compression point

Mixer

- principles of operation
- image noise from LNA

Intermodulation products

- how intermodulation products are produced
- definition of IP3
- definition of IP2

Overall Receiver Performance

- typical overall receiver performance
- cascaded noise figure, IP3
- SFDR Spur Free Dynamic Range

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RF Technology Certification

Course 009

•*Jun 22-Nov 23, 2015 - Web Classroom, WebEx / Rex Frobenius*

Summary

This online program has been designed for applications, production, manufacturing engineers and technicians as well as other professionals who need to have a solid background in the fundamentals of working with RF and wireless products. This four part program provides a thorough understanding of RF analytical tools, communications signals, RF devices and test instruments. Starting with basic analytical tools such as the decibel scale, S-parameters and the Smith Chart, this program covers test instrumentation, RF components, and modulation. A basic block diagram of a transmitter/receiver chain forms the backbone of the course outline. Each component is described, and the relative performance parameters defined. Key impairments are introduced as they become relevant to the operation of the system. Basic system calculations are covered, as well as modulation formats and multiple access techniques. The program consists of four online sessions spread out over a six month period. Each five to six week session consists of pre-recorded self-paced lectures combined with a live one to two hour Q&A/tutorial webcast with the instructor as well as forums. Each session has a brief test as well. The program is equivalent to approximately 40 hours of training. After finishing the program students will receive a signed certificate of completion.

Learning Objectives

Upon completing the course the student will be able to:

•work natively with dB values (without using a calculator)
•understand basic wave parameters and propagation
•appreciate the effects of parasitics on component behavior
•understand the effects of mismatches at RF
•create basic matching networks using the Smith Chart
•describe basic transmission line structures and input impedance
•interpret S-parameters from measurements and datasheets
•describe the basic function of spectrum analyzers, vector network analyzers, and power meters
•know the limitations on accuracy/uncertainty that affect all RF and high frequency measurements
•describe the operation of the main components of an RF transceiver system
•interpret key performance parameters such as P1dB, IP3, noise figure, etc.
•describe the modulation formats used to impress information onto the RF carrier
•understand the basic principles of multiple access techniques such as TDMA, CDMA, OFDMA

Target Audience

This program is ideally suited for applications, manufacturing and production engineers or technicians who are new to the RF/wireless field. It is also suitable for those who have been working in the field but who have not had a formal introduction to the key concepts that form the basis of understanding and troubleshooting wireless systems.

Outline

Part 1

Analytical tools

- wave parameters
- dB & dBm
- mismatches and reflection
- impedance matching and the Smith Chart
- transmission lines
- device parasitics and their effects
- S-parameters

Part 2 - Signals and Modulation

Modulation

- Analog
  - *AM, FM*
- IQ Modulation
  - *PSK*
  - *QAM*

Multiple Access Techniques

- FDMA
- TDMA
- CDMA
- OFDMA

Performance of RF Components with Digital Signals

- digital modulation fundamentals
- adjacent channel power ACP
- error vector magnitude EVM
- EVM due to power amplifier compression and AM to PM
- EVM due to group delay
- EVM due to phase noise
- IQ modulator troubleshooting with the VSA

Description of Bit Error Rate

Part 3 - Test Equipment

Cables and Connectors

- cable and connector care
- connector types

Vector Network Analyzer

- directional couplers
- basic block diagram
- calibration
- basic measurement setup

Spectrum Analyzer

- time domain vs. frequency domain
- basic block diagram
- typical measurements

Signal Generator

- basic block diagram

Power Meters

- power detection

Noise Figure Meter

Vector Signal Analyzer

- basic introduction

Measurement Uncertainties

- mismatch uncertainty
- systematic errors in VNA

measurements
- VNA calibration
- instrument-generated distortion products

Measurements of Non-connectorized devices

- de-embedding
- alternate calibration types: TRL
- fixturing

Part 4 - System Components

Phase Locked Oscillator

- principles of operation
- phase noise
  - *measurement techniques*
  - *impacts of phase noise on sytem performance*

Upconverter

- modulation basics
- principles of operation
- 1 dB compression point for active devices
- output spectrum of upconverter

Power Amplifier

- principles of operation
- 1 dB compression point, saturation
- AM to PM distortion
- harmonics

Antennas

- description of antenna types
- dBi, dBd gain parameters

Filters

- common filter types
  - *Butterworth, Chebychev, Gaussian*
- transfer function
- inband loss
- match
- bandwidth
- group delay

Noise and Noise Figure

- definition of thermal noise
- definition of noise figure
- techniques for measuring noise figure
  - *Y-factor technique*
  - *cold-source*

Low Noise Amplifiers

- principles of operation
- noise figure
- intermodulation products
- S-parameters
  - *input vs. output match*
- 1 dB compression point

Mixer

- principles of operation
- image noise from LNA

Intermodulation products

- how intermodulation products are produced
- definition of IP3
- definition of IP2

Overall Receiver Performance

- typical overall receiver performance
- cascaded noise figure, IP3
- SFDR Spur Free Dynamic Range

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RF Wireless System Design Fundamentals

Course 063

Summary

This three-day course combines theory with real-life examples to provide participants with a complete foundation in digital communication techniques and their effects on RF circuit parameters, to help them
close the gap between traditional RF engineering design and the needs of modern communication systems.

Learning Objectives

Upon completing the course the student will be able to:

- State digital wireless communication system concepts and performance limitations.
- Analyze system degradation due to RF components.
- Develop wireless communication system budget profiles.
- Calculate propagation lossess and link budgets.
- Assess cost vs. performance issues.
- Evaluate the performance of differing RF wireless system architectures.

Target Audience

Professionals required to work in high frequency domains for the first time, as well as seasoned veterans, will benefit from this comprehensive overview of practical design techniques. An electrical engineering background (BSEE or equivalent practical experience) is recommended, as well as a familiarity with complex numbers.

Outline

Day One

RF Wireless Services

- Cellular telephone systems
- Personal communications
- Market overview

System Design Fundamentals

- Historical development of radio receiver architectures
- Digital wireless communication requirements
  - *methodologies*
  - *Eb/No vs. SNR*
  - *BER vs. noise*
  - *bandwidth limitations*

RF System Design Considerations

- Noise figure
- Receiver sensitivity, desensitization and blocking
- Dynamic range
- Intermodulation distortion (third order intercept point IP3)
- Power output and spectral efficiency
- System limitations

Day Two

RF Components Requirements for Wireless Systems

- PLL noise (dBc/Hz, RMS)
- Fractional dividers (phase noise improvement)
- Loop bandwidth for optimum noise performance
- Effect of phase noise in RF communications

Modulators

- Digital modulation techniques
  - *BPSK*
  - *QPSk*
  - *OQPSK*
  - *power efficiency vs. spectral efficiency*
  - *linear amplification requirements*

Mixers

- Properties and characteristics
  - *conversion gain/loss*
  - *noise figure*
  - *RF/IF isolation*
  - *LO/IF isolation*
  - *distortion*
  - *power consumption*
- Mixer comparison table

Amplifiers

- Large signal
  - *power output vs. efficiency*
  - *gain and phase requirements*
  - *nonlinearity issues (EVM)*
  - *intermodulation distortion (IMD)*
  - *spectral regrowth*
- True dynamic range

Day Three

Filters

- Terminology
- Types
- Responses
- Amplitude/Phase distortion (group delay)
- Design fundamentals
- Effect of distortion and drift in RF communication systems

Antenna Types

Systematic Analysis of Transceiver Design

- Specifications
- Block diagrams
- Small signal analysis (budget profile)

Propagation Losses

- Free space path loss
- Reflection and scattering loss
- Multipath
- Rayleigh fading models

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Semiconductor Device Physics for RF Design

Course 183

Summary

This course provides microwave circuit designers with an in-depth look at their "toolkit" of semiconductor devices. Starting with a brief look at quantum mechanics, the course develops a picture of how electrons behave in semiconductor materials. This is applied to functional descriptions of the basic semiconductor devices: the P-N junction, the bipolar transistor and the FET. Further material describes how properties of different semiconductor materials and the ability to create certain material structures leads to the large variety of modern devices, each with its own characteristics, advantages and disadvantages. A final section describes principals of semiconductor fabrication and how limitations in materials and fabrication lead to limitations in performance and repeatability of microwave devices.

Learning Objectives

Upon completing the course the student will be able to:

- Describe the significance of energy bands for the conductivity of semiconductors
- Visualize the operation of diode rectifiers, bipolar transistors and FETs in terms of drift and diffusion of charge carriers.
- Identify the structures and microwave applications of GaAs FETs, HEMTs, and HBTs.
- Understand the MMIC fabrication process in overview.
- List major factors and failure mechanisms that limit device performance.

Target Audience

Circuit engineers and engineering managers who can benefit from a deeper understanding of the devices they use in design and/or manufacture of microwave products. Familiarity with undergraduate Physics, Electromagnetics and Calculus is strongly recommended.

Outline

Day 1: Electrons and Holes in Semiconductors

- Quantum Mechanics
  - *Schroedinger's Wave Equation and energy levels*
- Band Theory of Solids
  - *Valence and conduction energy bands, Fermi-Dirac distribution, generation and recombination, intrinsic carriers, direct and indirect materials*
- Doping in Semiconductors
  - *Donor and acceptor levels, Fermi Level, Law of Mass Action*
- Advanced Concepts (as class interest dictates)
  - *k-space, density of states, effective mass, Brilloun zones*
- Carrier Transport
  - *Drift and mobility, excess carriers and diffusion, Carrier Continuity Equation, concept of a plasma*

Day Two: PN Junctions

- PN junction at equilibrium
  - *depletion region, built-in potential, band curvature*
- PN junction at reverse bias
  - *thermal saturation current, avalanche breakdown (as class interest dictates)*
- PN junction at forward bias
  - *minority injection, diffusion current, Law of the Junction, Carrier Continuity and diode I-V relation*
- Circuit properties
  - *junction capacitance and conductance*
- Schottky diodes
  - *M-S junction, switching speed, reverse leakage*

Day 3: Bipolar Transistors and FETs

Transistor Structure

- BJT in Saturation
  - *bias state, Carrier Continuity in base, injection efficiency, Beta*
- Other effects in BJTs
  - *base width modulation and the Early Effect, doping gradients*
- Circuit properties of BJTs
  - *small signal model with major and secondary effects, intrinsic and extrinsic elements*
- FET basics
  - *Gradual Channel Approximation and Threshold Voltage*
- Microwave FET Structures
  - *Short channel effects and Schottky gate*

Device Materials

- Characteristics of Microwave Materials
- Silicon, GaAs, InP
- Hybrid Materials and Special Transistor Structures
  - *SiGe, HEMT, HBT*
- Device Fabrication
  - *Diffusion, Ion Implantation, Epitaxial Growth*
- Fabrication Issues
  - *Parasitic Transistors and latchup, traps, surface states, hydrogen poisoning*

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Signal Integrity and EMI Fundamentals

Course 243

Summary

This course covers the methodology of designing an electronic product to minimize the possibilities for electromagnetic interferences (EMI) and signal integrity (SI) problems. The techniques are useful specially for designers of high speed digital and analog circuits, and radiofrequency designers. The basics of designing electronic products with SI and EMI in mind are introduced in a very understandable and entertained style. This is a three day course with a very practical approach through many real world examples, techniques, simulation and hardware demos.

First, the basics of EMI and SIGNAL INTEGRITY in electronic circuits including a review of components in the high frequency/speed domain are presented. The typical EMI/SI problems (crosstalk, reflections, coupling mechanisms, radiation, pickup, etc.) are discussed in a general perspective. Transmission lines and impedance matching are covered because of the importance in the design of a robust system as explained in the rest of the course.

Second, GROUNDING, FILTERING and the design techniques for PRINTED CIRCUIT BOARDS (PCBS) in high frequency/speed systems are covered.

Finally, CABLES, the longest elements in our designs are discussed. They are key elements in the signal propagation and antenna effects of any electronic design. A general and intuitive explanation of antenna fundamentals is included for non RF specialists explaining in a very intuitive way the radiation and pick-up behaviour of cables as "hidden antennas." Finally instrumentation and measuring and troubleshooting techniques for EMI/SI problems are included.

No prior EMI/SI knowledge is needed but an electrical engineering background (BSEE or equivalent experience) is recommended.

Learning Objectives

Upon completing the course the student will be able to:

- understand the basics and fundamentals of EMI and SIGNAL INTEGRITY (SI) issues.
- look at the high frequency fundamentals of EMI/SI, modelling the problems to be able to propose solutions.
- locate and fix EMI/SI problems in a product or installation.
- design electronic equipment to avoid common EMI/SI failures.
- use lab measurements and tools to find or fix typical EMI/SI problems.
- reduce time and cost of EMI/SI diagnostic and fixes.

Target Audience

- Design engineers/technicians from the electronics industry involved in EMI and SIGNAL INTEGRITY (SI) problems.
- those interested in a working knowledge of EMI/SI engineering principles and concerned with EMI/SI problems as high speed digital designers, RF designers and PCB layout engineers.
- managers responsible for design, production, test and marketing of electronic products.
- marketing engineers who need a general and practical knowledge of the EMI/SI basics.

Outline

Day One

Fundamentals

- Electrical signals
- Maxwell vs. Kirchhoff: limits of circuit theory
- Decibel and logarithmic scales
- Spectrum of a signal: time domain vs. frequency domain
- Resonance
- Quality factor (Q) both loaded and unloaded
- Bandwidth
- Impedance matching definition
- Frequency vs. dimensions (size)
- Time vs. distance
- Scattering parameters (s-parameters)
- Typical formats and how to measure them

High speed/frequency effects in electronic circuits: when a capacitor is an inductor

- High speed and RF effects: attenuation, gain, loss and distortion
- Skin effect, return current and parasitic effects
- The importance of rise time and fall times (dv/dt and di/dt)
- Controlling signal return currents, differential vs. common mode currents
- Non ideal components
- Introduction
- The "hidden schematic" concept
  - *Resistors, capacitors and inductors*
  - *Ferrites*
  - *Transformers*
  - *Diodes*
  - *Transistors*
  - *ICs*
- Digital and high speed circuit key parameters
  - *power, speed and package*
- Wires
- Cables and connections
- PCB structures (dielectric materials, structures, dissipation factor, the multi-layer structure idea)
- Transmission lines basics
- Lumped vs. distributed systems
- Vias (effects and modelling in high frequency)
- Shielding basics
- Clocks

Transmission lines: controlling propagation

- Wiring and connecting components
  - *limitations for high frequency and high speed systems*
- What is a transmission line?
- Motivation: signal propagation
- Modelling a transmission line
  - *Characteristic impedance*
  - *Velocity of propagation*
- description of typical transmission lines

- *coax, pairs, microstrip and stripline*
- Reflection coefficient
- Standing wave ratio (SWR, VSWR and ISWR) and Return loss
- Intuitive explanation
- Examples from real world

Matching: Avoiding reflections. Obtaining maximum power transfer

- Maximum transfer of power and avoiding reflections
- Matching with LC components
- Matching networks: L, PI and T networks
- Matching in narrow and broadband networks
- Matching with transformers
- Matching with transmission lines
- Terminations to avoid SI/EMI problems: solutions and techniques
- Using software to design a matching network
- Examples from real world

Day Two

Signal Integrity Parameters

- What is Signal Integrity (SI) in electronic circuits?
- undesired effects
- Propagation time and delay
- Reflections and ringing
- Inductive vs. capacitive coupling
  - *crosstalk (near and far)*
- Delays
- Jitter
- Ground bounce
- Power supply noise
- High frequency, dv/dt and di/dt

Grounding: the most important subject

- Signal ground vs. safety ground
- Ground in high frequency/speed applications
  - *low impedance path*
- Minimizing ground impedance
- Common impedance
- Ground strategies (single point, multipoint, and hybrid)
- Ground loops

Filtering

- Basic ideas
- Filters for known impedances (no EMI applications)
- Basic design techniques with examples
- Filters for EMI/EMC
- How filters work: reflection vs. dissipation
- Insertion losses
- Source and load influence
- Parasitic and location effects
- Filtering with ferrites
- Saturation and undesired coupling effects
- Decoupling and bypass fundamentals
- Damping resonances and ringing
- Three terminal and feed through components

Printed Circuit Boards (PCBs)

- Basic ideas
- Design strategy
- Partitioning and critical zones
- PCB structures
  - *dielectric materials, structures, dissipation factor*
- Choosing the PCB structure: how many layers and distribution
- Power planes design and distribution
- Layout and routing (1, 2 and multilayer) techniques
  - *traces*
  - *microstrip and stripline*
  - *corners*
  - *vias*
  - *controlling impedance for SI*
  - *transmission line effects and solutions*
- Ground planes
- Splits or ground discontinuities in planes (slots)
- Decoupling and bypass (how, where, resonances, etc): discrete capacitors vs. embedded techniques in high speed/RF designs
- Crosstalk and guards
- How ground plane layout affects crosstalk
- Mixed signal PCBs (A/D designs)
- Controlling clock waveform
- Clock distribution
- Clock shielding
- Examples from real world

Day Three

Cables

- Basic ideas for cable fundamentals
- The control of return current
- Types of cables (wires, twisted pairs, coax, shielded cables, ribbon cables, etc.)
- Cable impedance
- Shielded cables and cable grounding
- Connectors
- Parasitics in connectors for high speed signals
- Avoiding crosstalk and reflections in cables (layout and terminations)
- Avoiding common impedance in cables
- Reducing emissions and pick-up in cables
- Examples from real world

Measuring and Troubleshooting Techniques

- Antenna basics
- How to measure EMI and SI effects
  - *tools, instruments and techniques*
- Scope and probe limitations
- Review of some typical errors in measurement techniques
- Measuring high frequency current in electronic circuits
- Diagnostic and troubleshooting techniques and hints
- Locating EMI sources with near field probes

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The Radio Modem: RF Transceiver From Antenna to Bits and Back

Course 241

•Sep 28-Oct 2, 2015 - San Jose, CA / Waleed Khalil

Summary

Over the past two decades, there has been a significant increase in the complexity of RF technology to meet the growing demand for fixed and mobile communication systems. Moving forward, we expect this trend to continue with emerging cellular and wireless standards employing complex modulation schemes and occupying higher bandwidth while emphasizing stringent spectrum efficiency requirements. These advances call for employing sophisticated design principles at both the circuit and system levels and hence the need for a comprehensive understanding of the radio modem.

This course is intended for design, application and test engineers as well as technicians interested to learn about the system aspect of the radio design space covering the entire signal chain from antenna to bits and back. The aim is apply intuitive system design methods to dissect the radio modem at RF, analog and digital domains with emphasis on: a) physical understanding of the interaction between components and different radio architectures and b) quantitative performance evaluation using simple hand calculations and simulation. Throughout the course, students will be exposed not only to theoretical analysis but also to concrete examples of radio architectures from existing commercial systems (GSM, WCDMA, 4G LTE, WLAN, Bluetooth and WiMAX). Towards the end of this course, students will build -using commercial system design software- a simple but powerful full radio transceiver system (including both digital transmitter and receiver blocks) and simulate end-to-end metrics such as bit error rate (BER), error vector magnitude (EVM) and spectrum emission.

Students are encouraged to bring their laptop computers to class. The design software available for use in this public course is from NI (formerly AWR).

Learning Objectives

Upon completing the course the student will be able to:

•Gain in-depth understanding of the different block-level specifications and impairments (e.g. noise, P1dB, IIP3, IIP2, gain, bandwidth, phase noise and spurs) and how to relate them to system level performance metrics (e.g. BER, EVM, modulation type, blocker performance, sensitivity and selectivity)

•Analyze and abstract (at block level) the most critical blocks in today's RF modem (e.g. low noise amplifier, mixer, voltage-controlled oscillator, power amplifier and analog and digital baseband circuits such A/Ds, D/As and filters).

•Evaluate the impact of different impairments in radio front-ends on performance, including interference, different noise sources, circuit nonlinearity and phase noise.

•Understand the trade-offs between block-level performance, choice of radio architecture and overall system performance (e.g. power, area and cost) in relation to a given communication standard

•Learn the major aspects of the digital signal processing chain at both the modulation and demodulation ends

•Use simple back-of-the-envelope calculations and understanding of path loss and fading to predict RF system's performance in terms of link budget and link margin.

•Traverse between block level specifications and overall system performance and backwards

•Design and simulate (at block level) a full modem including RF, analog and digital components.

•Tie between system level performance parameters and test equipment specifications

•More...

Target Audience

RF and baseband IC engineers, system architects, test engineers, product engineers and technicians. Technical managers who would like to get exposure to RF system technology.

Outline

Day One

RF Basics

- dB units
  - *dB, dBm, dBW, dBV, dBHz, dBK and dBc*
- voltage and power gain
- transmission line properties (RL and VSWR)
- S-parameters
- Matching and power transfer
- amplifiers and attenuators
- cascaded gain

Radio Propagation

- free space line of sight (LOS) propagation
- atmospheric losses
- NLOS propagation
- multipath and fading
- path loss calculation

Antennas

- antenna types
- circuit model
- antenna parameters
  - *impedance*
  - *efficiency*
  - *bandwidth*
  - *pattern*
  - *beam-width*
  - *directivity and gain*

Day Two

Noise

- noise sources
- noise in passive networks
- noise representation in time and frequency domains
- noise figure
- cascaded noise figure analysis
- sensitivity
- link budget
- combining noise sources
- spectrum analyzer
- noise temperature
- attenuator NF

Distortion

- harmonic generation vs. Intermodulation

- 2nd order distortion
  - *single tone and two tone analyses and filtering*
- 3rd order distortion
  - *single tone and two tone analyses and filtering*
- gain compression
- receiver desensitization and blocking
- Calculations
  - *P1dB*
  - *IM2*
  - *IP2*
  - *IM3*
  - *IP3*
  - *Cascaded IIP3*
  - *spurious free dynamic range (SFDR)*

Day Three

Mixers

- selectivity vs. sensitivity
- mixer types
- block vs. channelized conversion
- the image problem
- Modulation
- complex vs. real signals
- properties of complex signals
- frequency
- phase and time representation of complex signals
- noise types
- frequency and time domain representation of AWGN

Day Four

Digital Modulation

- channel parameters and capacity limits
- constellation diagrams (IQ and polar representation)
- quadrature modulation
- analog modulation types
  - *AM, FM and PM*
- digital modulation schemes
  - *ASK, OOK,BPSK, QPSK, QAM, BFSK*
- noise performance
- spectrum limitation
- digital pulse shaping
- ISI
- spectrum efficiency
- raised and root-raised cosine filtering
- Gaussian filter
- digital modulation: step-by-step
- Aerial Access: multiple access vs. duplexing
- time and frequency duplexing
- multiple access techniques
  - *FDMA, TDMA, CDMA*

Day Five

Phase Noise

- phase noise vs. jitter
- phase noise definition
- PSD of voltage and phase signals
- phase noise measurement techniques
- RMS phase error and EVM
- Impact of RMS phase error on BER
- impact of far-out phase noise on receivers and transmitters

Transceiver Architectures

- Heterodyne receiver
- image reject filter
- image reject receiver
- image rejection ratio
- Homodyne receiver
- quadrature mixing and DC offset
- transmitter architectures
  - *spectrum mask, ACI, EVM*

Transceivers Case Studies

- cellular radio evolution and frequency bands
- transmit and receive impairment case studies

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Transceiver and Systems Design for Digital Communications

Course 208

Summary

This seminar provides an intuitive approach to transceiver design for both commercial and military sectors, allowing a broad spectrum of readers to understand the topics clearly. It covers a wide range of data link communication design techniques, including link budgets, dynamic range and system analysis of receivers and transmitters used in data link communications, digital modulation and demodulation techniques of phase-shift keyed and frequency hopped spread spectrum systems using phase diagrams, multipath, gain control, an intuitive approach to probability, jamming reduction method using various adaptive processes, error detection and correction, global positioning systems (GPS) data link, satellite communications, direction-finding and interferometers, plus a section on broadband communications and home networking including Link 16, JTRS, military radios, and networking. Also included is a section on Cognitive Systems. Various techniques and designs are evaluated for modulating and sending digital data. Thus the student gains a firm understanding of the processes needed to effectively design wireless data link communication systems. Students will receive a copy of the instructor's textbook, Transceiver and Systems Design for Digital Communications, 3rd Edition.

Learning Objectives

Upon completing the course the student will be able to:

•Perform link budgets for communication links including spread spectrum, system design tradeoffs, BER, Eb/No, EIRP, free-space loss, process gain, coding gain and link margin.•
Evaluate the performance of different types of wireless communication transceivers including PSK, FSK, MSK, QAM, CP-PSK, PRS code generator, multiple access techniques, TDMA, CDMA, FDMA, PAs, VSWR, LOs, and sideband elimination
•Analyze and understand different communication methods including spread spectrum modems using maximum power transfer principle, digital versus analog, SDRs and cognitive radios, multiple access systems, OFDM, and error detection/correction, Gold codes, maximal length sequence codes, code taps, jamming margin, power control, time hopping, chirped-FM, spectral regrowth, and shaping filters
•Understand superheterodyne, dynamic range, 2-tone DR, SFDR, IMDs, phase noise, group delay and compensation, sampling theorem and aliasing, and DSPs
•Analyze and model AGC systems using control theory, loop filters, integrator for zero steady state error, and PLL/AGC commonalities
•Understand demodulation techniques, matched filter, correlators, PPM, coherent vs differential, carrier recovery loops, Costas and squaring loops. symbol synchronizer, eye pattern, ISI, scrambler/descrambler, and Shannon's limit
•Understand basic probability and pulse theory, gaussian process, quantization and sampling errors, probability of error, probability of detection and false alarms, error detection and correction, CRCs, FECs, interleaving, linear block codes, hamming, convolutional, turbo, and other codes, viterbi decoder, and Multi-h
•Understand multipath and techniques on how to reduce multipath and jammers, specular and diffuse, mitigation techniques, and antenna diversity
•Analyze techniques to reduce jammers using burst clamps, adaptive filters, GSOs, and evaluate intercept receivers
•Understand GPS and the data link used for sending information, how to mitigate errors using different techniques, narrow correlator, SA, differential, relative, KCPT, and other satellite positioning systems
•Understand satellite communications and the uses, and evaluate data links for G/T, ADPCM, geosynchronous, geostationary, antennas, FSS, propagation delays, cost and regulations, and types of satellites
•Understand the techniques used for broadband communications in both commercial and military radios including mobile users, distribution, IEEE 802.xx, Bluetooth, WiMAX, networking, SDRs, JTRS, Link 16, clusters, gateways, stacked nets, and time slot reallocation
•Analyze a 3 dimension Direction Finding system using basic two antenna interferometer using direction cosines and coordinate conversions

Target Audience

This course will be of interest to RF, analog, digital, systems and software engineers and managers who are interested in the field of communications of all types of wireless systems for both commercial and military use. This applies to both those that want to gain an understanding of basic wireless communications and those that are experienced engineers that want to capture an intuitive approach to wireless data link design. An electrical engineering background (BSEE or equivalent practical experience) is recommended but not required. From this course you will learn how to evaluate and develop the system design for digital communication transceivers including spread spectrum systems and more.

Outline

Day One

Transceiver Design and Link Budget

- Signal Frequency of Operation
- Link Budget
- Power in dBm
- Transmitter gain and losses
- EIRP
- the Channel
- Free-Space Attenuation
- Propagation Losses
- Multipath Losses
- Receiver gain and losses
- LNA

- noise figure
- Eb/No
- coding gain
- process gain
- link budget example
- spreading losses

The Transmitter

- Transmitter Basic Functions
- Antenna
- T/R
- PA
- upconversion
- VSWR
- maximum power transfer principle
- digital Communications
- Digital versus Analog Communications
- Software Defined Radios and Cognitive Radios
- Digital Modulation
  - *PSK, BPSK, DPSK, QPSK, OOPSK, 8-PSK, 16-QAM*
- phasor constellations and noise immunity
- CP-PSK
- spectral regrowth
- MSK, FSK sidelobe reduction and shaping filters
- DSSS
- FHSS
- anti-jam
- process gain
- maximal length sequence codes and taps
- Gold codes
- spectral lines
- time hopping chirped-FM
- multiple access techniques
- OFDM
- power control

The Receiver

- Superheterodyne Receiver
- antennas
- T/R switch
- limiters
- Image Reject Filter/Band Reject Filter
- Dynamic Range/Minimum Detectable Signal
- Types of DR
- Two-Tone
- SFDR
- IMDs
- Tangential Sensitivity
- LNAs
- multiple bands
- phase noise
- mixers
- filters
- group delay

AGC Design and PLL Comparison

- AGC modeling
- AGC Amplifier Curve
- Linearizers
- Detector
- Loop Filter
- Threshold Level
- Integrator
- Control Theory Analysis
- AGC Design Example
- Modulation Frequency Distortion
- Comparison of the PLL and AGC Using Feedback Analysis Techniques
- Basic PLL
- Comparisons of the PLL and AGC
- Feedback Systems and Oscillations

Day Two

Demodulation Techniques

- Types of Demodulation
- Pulsed Matched Filter
- Digital Matched Filter Correlator
- PPM
- Code Division Encoding and Decoding, Coherent versus Differential Digital Modulation and Demodulation
- Carrier Recovery
- Squaring Loop
- Costas Loop
- Modified Costas Loop and AFC Addition
- Despreading Correlator
- Symbol Synchronizer
- The Eye Pattern
- Digital Processor
- ISI
- Scrambler/Descrambler
- Phase-Shift Detection
- Shannon's Limit

Basic Probability and Pulse Theory

- The Gaussian Process
- Quantization and Sampling Errors
- Probability of Error
- Probability of Detection and False Alarms
- Error Detection and Correction
- Parity
- Checksum
- CRC
- Redundancy
- FEC
- Interleaving
- Linear Block Codes
- Hamming Code
- Convolutional Codes
- Viterbi Decoder
- Multi-h
- Turbo codes
- LDPC

Multipath

- Basic Types of Multipath
- Specular Reflection on a Smooth Surface
- Specular Reflection on a Rough Surface
- Diffuse Reflection
- Curvature of the Earth
- Pulse Systems (Radar)
- Vector Analysis Approach
- Power Summation Approach
- Multipath Mitigation Techniques
- Antenna Diversity

Improving the System Against Jammers

- Burst Jammer
- Adaptive Filter
- Digital Filter Intuitive Analysis
- Basic Adaptive Filter
- LMS Algorithm
- Digital/Analog ALE
- Wideband ALE Jammer Suppressor Filter
- Digital Circuitry
- Simulation Results
- Amplitude and Phase Suppression
- Gram-Schmidt Orthogonalizer
- Basic GSO
- Adaptive GSO Implementation
- Intercept Receiver Comparison

Day Three

Global Navigation Satellite Systems

- Satellite Transmissions
- Data Signal Structure
- GPS Receiver
- Atmospheric Errors
- Multipath Errors
- Narrow Correlator
- SA
- Carrier Smoothed Code
- Differential GPS
- DGPS Time Synchronization
- Relative GPS
- Doppler
- KCPT
- Double Difference
- Wide Lane/Narrow Lane

Satellite Communications

- General Satellite Operation
- Frequencies
- Modulation
- ADPCM
- Fixed Satellite Service
- Geosynchronous and Geostationary Orbits
- Ground Station Antennas
- Noise and the Low-Noise Amplifier
- Equivalent Temperature Analysis
- G/T
- satellite link budget
- Carrier Power/Equivalent Temperature
- Multiple Channels in the Same Frequency Band
- Multiple Access Schemes
- Propagation Delay
- Cost for Use of the Satellites
- Regulations
- Types of Satellites Used for Communications
- System Design for Satellite Communications

Broadband Communications and Networking

- Mobile Users
- Types of Distribution Methods for the Home
- Power Line Communications
- OFDM
- Home Phoneline Networking Alliance
- Radio Frequency Communications
- IEEE 802.11
- Bluetooth
- WiMAX
- Military Radios and Data Links
- JTRS
- SDRs

- SCA compliance
- Waveforms
- Network Challenge
- Gateway and Network Configurations
- Link 16
- Link 16 Modulation
- TDMA
- “Stacked” Nets
- Time Slot Reallocation
- Bit/Message Structure

Cognitive Systems

- Cognitive Radio
- Cognitive hardware and software
- Cognitive antennas
- MIMO Techniques
- Adaptive Power Control
- Dynamic Spectrum Allocation
- Adaptive Frequency Control
- Network Re-Configuration
- Multi-Hop Techniques
- Cognitive System Approach

Direction finding and Interferometer Analysis

- Interferometer Analysis
- Direction Cosines
- Basic Interferometer Equation
- Three-Dimensional Approach
- Antenna Position Matrix
- Coordinate Conversion Due to Pitch and Roll
- Using Direction Cosines
- Alternate Method

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Wireless Circuits, Systems and Test Fundamentals

Course 112

Summary

This five day course provides engineers with the fundamental concepts needed to work effectively with high frequency wireless circuits and systems. Participants gain analytical, graphical, and computer-aided techniques to analyze, test and optimize RF circuits and systems in practical situations. The course also addresses RF measurement techniques as they apply to today's wireless products.

Learning Objectives

Upon completing the course the student will be able to:

- Describe RF circuit parameters and terminology.
- Understand the effects of parasitics on RF circuit performance.
- Understand wireless architectures and system specifications.
- Analyze system degradation due to RF component variances.
- Understand the tradeoffs between power efficient and spectral efficient modulation techniques.
- Understand RF system test standards and measurement techniques.
- Describe test requirements needed for new wireless networks (Bluetooth, Home RF, 802.11, etc.).

Target Audience

Engineers, programmers, chip designers, and engineering managers involved in the design, planning, implementation, or testing of communication systems would benefit from this intermediate-level course. Participants should have a BSEE or equivalient.

Outline

Day One

RF Terminology

- dB, dBm, and RF port loss
- Power-flow and traveling waves
- Reflection coefficient, VSWR
- Return loss and mismatch
- The Smith Chart
- Two terminal z- and y- parameters
- Scattering (S) parameters

Day Two

Optimizing RF Circuit Performance

- Conjugate impedance matching
- Real and complex terminations
- Bandwidth considerations
- Component equivalent circuits
- Component losses and parasitics
- Test fixtures and de-embedding

Grounding Techniques

- Printed circuit board layout issues
- Transmission line structures
- Transmission line matching

Day Three

System Design Fundamentals

- Historical development of radio receiver techniques
- Digital wireless terminology
  - *Eb/No*
  - *BER*
  - *etc.*
- Noise Figure
- Receiver sensitivity
- Desensitization and blocking
- Dynamic range
- Intermodulation distortion
- Overview of transceiver architectures

Day Four

RF Component Specifications and Performance Limitations

- Phase locked loop oscillators
- Modulators/demodulators
- Mixers
- Amplifiers
- Filters
- Attenuators

Day Five

RF Test Setups and Measurement Techniques

- Wireless standards, test specifications
- Test equipment overview
- Measurement techniques and error correction

Test Measurements

- Noise Figure
- Spurious free dynamic range
- Sensitivity
- Selectivity
- Power
- Adjacent Channel Power (ACP)
- Error Vector Magnitude (EVM)
- BER
- SINAD

Besser Associates
The Worldwide Leader in RF & Wireless Training

Wireless LANs

Course 227

Summary

This three-day course is an experiment-oriented course that integrates topics at the MAC layer (and above) of Wireless LANs (WLANs) and Wireless Personal Area Networks (WPANs). The course emphasizes hands-on learning through experiments and case studies. It will offer attendees the ability to conduct laboratory experiments and design projects that cover a broad spectrum of issues in WLANs and WPANs. The characteristics and operations of IEEE 802.11a/b/g/n WLANs will be described as well as that of Bluetooth WPANs. Laboratory experiments will be conducted to show the tradeoffs of the virtual carrier sensing mechanism, observe interference issues with other devices operating on the ISM band, describe Mobile Ad-hoc NETwork (MANET) operations and routing protocols, configure secure infrastructure and MANET WLANs, deploy hotspots, and use modeling, simulation, and emulation tools to evaluate WLANs (including system in the loop capabilities). Real infrastructure and MANET WLANs will be deployed and configured in class under different network scenarios. Different tools and techniques will be introduced to monitor, measure, and characterize their performance (and realize the tradeoffs). Known techniques to attack WLANs will be shown and proper security practices to avoid well-known threats will be discussed. All concepts will be summed up in an experiment that aims at deploying a secure hotspot.

Students are encouraged to bring their laptop computers to class in order to participate in the exercises.

Learning Objectives

Upon completing the course the student will be able to:

- Describe the characteristics and operation of IEEE 802.11 WLANs and Bluetooth WPANs.
- Understand the different knobs and dials that affect performance of IEEE 802.11 WLANs and the tradeoffs of each.
- Construct and manage 802.11 WLANs (infrastructure and ad-hoc) and Bluetooth WPANs in Windows and Linux environments.
- Use diagnosis tools and techniques to monitor, measure, and characterize the performance of WLANs and WPANs.
- Use of network simulation tools to model and evaluate the performance of MANETs.
- What it takes to deploy a hotspot (user access control, NAT-ing, logging).

Target Audience

Professionals such as engineers, product developers, managers, security officers, city/state government or law enforcement professional, and network administrators who have a special interest in quickly getting up to speed with practical aspects of WLAN (infrastructure, ad-hoc) and WPAN (piconet, scatternet) management and operation.

Outline

Day One

Introduction

- Introduction to WLANs
- Getting to know your toolkit

WLAN Overview

- Wireless environment and an overview of the IEEE 802.11 family of standards
- MAC overview
- Adaptive rate control
- Link layer positive acknowledgements
- Frame Check Sequence
- Error recovery
- Hidden node problem
- CSMA/CA
- Virtual carrier sensing
- Interframe spacing
- MAC backoff
- Fragmentation
- Management operations
- Framing
- Power save mode

Day Two

WPAN Overview

- Characteristics
- Modes of operation
- Packet format
- Air interface
- Security
- Coexistence issues with 802.11

MANETs

- Concept of operation
- Routing basics
- AODV
- OLSR
- ETX metric

Day Three

WLAN Modeling, Simulation, and Emulation

- Modeling, simulation, and emulation tools
- OPNET IT Guru
- NS-2
- CORE
- System in the loop

WLAN Security

- WEP basics
- Security vulnerabilities
- Breaking WEP
- DoS against a WLAN
- Using 802.11i (WPA2)

Hotspot

- Building blocks
- DHCP
- NAT
- User access control

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Wireless/Computer/Telecom Network Security

Course 226

Summary

This three-day course is an experiment-oriented course that focuses on security aspects in computer and telecommunication systems. The course will cover aspects related to security policies and mechanisms, access control mechanisms (role-based, DAC, MAC, and ORCON), data encryption standards (DES, AES, Blowfish, RC4, and PKI), key management and authentication mechanisms, digital signatures (x509), message authentication codes, malicious logic (viruses, trojan horses), IPSEC, firewalls, VPN, as well as the 5 phases of a computer security attack (attack reconnaissance, scanning, gaining access, maintaining access, and covering tracks). Experiments will be conducted to show cryptanalysis techniques, x509 certificate generation, how to configure and manipulate firewalls, and all phases of a cyber attack that end in taking control of victim machine. Experiments will also be prepared to show how to break IEEE 802.11 WEP keys, launch denial of service (DoS) attacks on IEEE 802.11 networks, and how to properly secure wireless LANs using the IEEE 802.11i standard.
Students are encouraged to bring their laptop computers to class in order to participate in the exercises.

Learning Objectives

Upon completing the course the student will be able to:

•Understand security policies and mechanisms and their different types.
•Understand the basic concept of operation of cryptosystems (i.e. SPNs, confusion and diffusion).
•Understand the key generation functionalities and attacks against key exchange protocols.
•Describe the basic operation of IPSEC, firewalls, and VPNs.
•Understand the different types of malicious logic and their basic concept of operation.
•Describe the different types of threats, the phases of a cyber attack, and defense techniques against each phase.
•Describe the security failures within the IEEE 802.11 protocol and how to properly secure WLANs using the IEEE 802.11i standard.

Target Audience

Professionals such as engineers, product developers, managers, security officers, city/state government or law enforcement professional, and network administrators who have a special interest in quickly getting up to speed with computer and telecommunication security concepts.

Outline

Day One

Introduction

- Basic components of computer security
- Threats
- Risk analysis
- Design principles of security policies

Access Control

- Access control mechanisms, lists, and capabilities
- Mandatory access control
- Discretionary access control
- Role-based access control
- Attribute-base access control

Security Policies

- Confidentiality policies
- Integrity policies
- Hybrid policies

Day Two

Cryptosystems

- Basic cryptography and ciphers techniques
- DES
- AES
- Blowfish
- RC4
- Cryptanalysis
- PKI
- Hashing
- Cryptographic checksums
- Key management

Authentication Mechanisms

- Password-based
- Token-based
- One-time passwords

Malicious Logic

- Viruses, trojan horses, bacteria, logic bombs

Day Three

Telecom Security

- Firewalls, VPN, IPSEC

Phases of a Cyber Attack

- Attack preparation
- Target scanning
- Buffer overflow
- Integer overflow
- SQL injection
- Cross-site scripting
- Man-in-the-middle attacks
- Denial of service attacks
- Backdoors
- Botnets
- Covering tracks and flux networks

Defense Techniques

- Vulnerability scanning and network mapping
- Firewall settings
- Patching
- IDS

Christopher J. Baker

Dr. Chris Baker is the Ohio State Research Scholar in Integrated Sensor Systems at The Ohio State University. Until June 2011 he was the Dean and Director of the College of Engineering and Computer Science at the Australian National University (ANU). Prior to this he held the Thales-Royal Academy of Engineering Chair of intelligent radar systems based at University College London. He has been actively engaged in radar systems research since 1984 and is the author of over two hundred and fifty publications. His research interests include, Coherent radar techniques, radar signal processing, radar signal interpretation, Electronically scanned radar systems, Radar imaging, natural and cognitive echo locating systems. He is the recipient of the IEE Mountbatten premium (twice), the IEE Institute premium and is a Fellow of the IET. He is a visiting Professor at the University of Cape Town, Cranfield University, University College London, Wright State University, Nanyang Technical University and Strathclyde University.

Public Course:

- *Modern Radar Systems: Nov 16-Nov 20, 2015 San Jose, CA*

Les Besser

In 1985 Les Besser formed Besser Associates, an organization dedicated to continuing education. He retired and sold Besser Associates in 2004.A native of Hungary, Les Besser began his engineering career in 1966 in Hewlett Packard's Microwave Division, developing broadband microwave components, receiving a patent for the first thin-film amplifier circuitry used in the CATV industry. Next, he concentrated on MICs, GaAs FET Amplifiers, and CATV systems at the Microwave and Optolectronics Group of Fairchild. During this time he became interested in CAD and wrote the SPEEDY program that offered a transistor database with high-frequency device parameters. He later joined Farinon Electric Company to direct their microcircuit design and development effort. During that period he authored COMPACT, the first commercially successful microwave circuit optimization routine, soon to become the industry standard. He then founded Compact Software, a pioneer CAD software company (now part of Ansoft), and was active in serving the engineering design needs of the RF/Microwave industry during the next ten years. In 1980, his company merged with Communication Satellite Corporation (COMSAT) where Dr. Besser functioned as a Senior Vice President. He was instrumental in the formation of the RF EXPO Short Course program between 1986 and 1991. From 1988 to 1990 he also served as Editorial Director of Microwave Systems News (MSN) magazine.

Dr. Besser has published over 70 technical articles, developed three one-week short courses, contributed to and co-authored several textbooks, including the two-volume, Practical RF Circuit Design for Modern Wireless Systems, which is also available in Chinese language. He has been involved in numerous IEEE activities. A Life Fellow of the IEEE, in 1983 he received the IEEE MTT "Microwave Applications Award," the IEEE RFTG "Career Award" in 1987, the IEEE “Third Centennial Medal" in 2000, the IEEE Educational Activities Board’s “Meritorious Achievement Award in Continuing Education” in 2006 and the IEEE MTT “Distinguished Educator” award in 2007. He is also listed in Marquis' "Who Is Who In The World," and in Microwave Hall of Fame.

Steven Best

Steven R. Best is a Senior Principal Sensor Systems Engineer with the MITRE Corporation in Bedford, MA. He received the B.Sc.Eng and the Ph.D. degrees in Electrical Engineering in 1983 and 1988, respectively, from the University of New Brunswick in Canada. Dr. Best has over 28 years of experience in business management and antenna design engineering in both military and commercial markets. Prior to joining MITRE, Dr. Best was with the Air Force Research Laboratory (AFRL) at Hanscom AFB, where his research interests included electrically small antennas, wideband radiating elements, conformal antennas, antenna arrays and communications antennas. Prior to joining AFRL, he was President of Cushcraft Corporation in Manchester, NH from 1997 to 2002. He was Director of Engineering at Cushcraft from 1996 to 1997. Prior to joining Cushcraft, he was co-founder and Vice President and General Manager of Parisi Antenna Systems from 1993 through 1996. He was Vice President and General Manager of D&M/Chu Technology, Inc. (formerly Chu Associates) from 1990 - 1993. He joined Chu Associates as a Senior Electrical Engineer in 1987.

Dr. Best is the author or co-author of 3 book chapters and over 100 papers in various journal, conference and industry publications. He frequently presents a three-day short course for the wireless industry titled *Antennas and Propagation for Wireless Communication*, he is the author of a CD-ROM series on antenna theory and design, and he has presented several Webinars on antenna topics. He has also authored an IEEE Expert Now module on electrically small antennas. Dr. Best is a former Distinguished Lecturer for IEEE Antennas and Propagation Society (AP-S), a former member of the AP-S AdCom, a former Associate Editor for the IEEE Transactions on Antennas and Propagation, and Senior Past Chair of the IEEE Boston Section. He is also a former Editor-in-Chief for AP-S Electronic Communications. Dr Best is a Fellow of the IEEE and a Past-President of the IEEE Antennas and Propagation Society.

Public Course:

- *Antennas & Propagation for Wireless Communications: Oct 12-Oct 15, 2015 San Jose, CA*

Joe Boccuzzi

Joseph Boccuzzi, Ph.D.

Dr. Boccuzzi is currently Director of System Architectures at Mindspeed Technologies involved with 4G systems. Previously he was a Principal Scientist for Broadcom Corporation designing wireless communication systems. His responsibilities cover the mobile station (MS, UE) and base station (BTS, NodeB) with emphasis on EDGE, WCDMA, HSDPA/HSUPA & their evolution, as well as LTE (i.e. Turbo 3G) radio access technologies. He worked on the WCDMA evolution path such as supporting VoIP, MBMS, MIMO, Femto Cells, etc.

He developed multimode reconfigurable receiver architectures supporting spread spectrum (WCDMA, IS-95, CDMA2000, WLAN and GPS); worked on Adaptive Antenna Array (Smart Antenna) algorithms for WCDMA, TDMA and OFDMA systems. He also investigated SISO, SIMO, MISO and MIMO antenna configurations.

He has designed complete uplink and downlink digital communication system simulations for both Wireless and Wireline technologies including: Modems, Codecs, RF Impairments, Channel models, etc. These simulations supported both the link and network levels and involved mathematical analysis. The algorithms included: high speed cable modems, power line communications, satellite systems, Flex paging systems, CT-2, DECT, JDC, IS-136, GSM, DVB-H, WiMax, WLL, Bluetooth, etc.

An author of technical papers, prepared technology presentations worldwide and holds over 20 patents, domestic and international. He is the author of Signal Processing for Wireless Communications, published by McGraw Hill.

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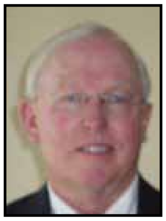
Scott Bullock



Scott R. Bullock received his BSEE degree from Brigham Young University in 1979 and his MSEE degree from the University of Utah in 1988. Mr. Bullock worked in research and development for most of his career developing a radar simulator, a spread spectrum microscan receiver, a new spread spectrum receiver where he applied for a patent and was awarded company funds as a new idea project to develop the concept..

Mr. Bullock also developed a spread spectrum environment simulator for a spread spectrum wideband countermeasures receiver using BPSK, QPSK, SQPSK, MSK, frequency hopper, hybrids, AM, FM, voice generator, jammers, and noise. He also designed a high-frequency adaptive filter used to reduce narrowband jammers in a wideband signal; a broadband, highly accurate frequency hop detector; an instantaneous Fourier transform (IFT) receiver; a chopper modulated receiver; a KU-band radio design for burst spread spectrum communications through a troposcatter channel; a Gram-Schmidt orthogonalizer to reduce jammers; an advanced tactical data link; RF analysis of an optical receiver study; a portable wideband communications detector; and an acoustic-optic spectrum analyzer photodiode array controller.

Mr. Bullock developed the first handheld PCS spread spectrum telephone with Omnipoint in the 902-928 MHz ISM band. He also received a patent for his work on reducing spectral lines to meet the FCC power spectral density requirements.

Mr. Bullock was responsible for various types of spread spectrum data links for the SCAT-1 program related to aircraft GPS landing systems. He was an active participant in the RTCA meetings held in Washington, DC, for the evaluation and selection of the D8PSK data link to be used as the standard in all SCAT-1 systems. He also worked on the concepts of the Wide Area Augmentation System (WAAS), low probability of intercept (LPI) data link, DS/FH air traffic control asynchronous system, JTRS, and Link-16.

Mr. Bullock developed several commercial products such as wireless jacks for telephones, PBXs, modems, wireless speakers, and other various wireless data link products. He has performed data link communications work and taught seminars for Texas Instruments, L-3 Com, BAE, Omnipoint, E-Systems, Phonex, L-3 SND, Raytheon, CIA, SAIC, MKS/ENI, Northrop Grumman, and Thales.

Mr. Bullock has held many high-level positions, such as Vice President of Engineering for Phonex Broadband, Vice President of Engineering for L-3 Satellite Network Division, , Senior Director of Engineering for MKS/ENI, Engineering Fellow at Raytheon, and Consulting Engineer for Northrop Grumman. He specializes in wireless data link design and system analysis and directs the design and development of wireless products for both commercial and military customers.

Mr. Bullock holds 18 patents and 22 trade secrets in the areas of spread spectrum wireless data links, adaptive filters, frequency hop detectors, cognitive radios and systems, and wireless telephone and data products. He has published numerous articles dealing with spread spectrum modulation types, multipath, AGCs, PLLs, and adaptive filters. He is the author of two books; Transceiver and System Design for Digital Communications, and Broadband Communications and Home Networking. He is a licensed professional engineer and a member of IEEE and Eta Kappa Nu. He has taught seminars at many different companies for over 10 years. He has taught an advanced communication course at ITT, an engineering course at PIMA Community College, and was a guest lecturer on multiple access systems at PolyTechnic University, Long Island, New York.

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Steve Cripps

Dr Steve C. Cripps obtained his Ph.D. degree from Cambridge University, England. He worked for Plessey Research (now GECMM) on GaAsFET hybrid circuit development. Later he joined Watkins-Johnson's solid state division , Palo Alto, CA, and has held Engineering and Management positions at WJ, Loral, and Celeritek. During this period, he designed the industry's first 2-8 Ghz and 6-18 Ghz 1 watt solid state amplifiers, and in 1983 published a technique for microwave power amplifier design, which has become widely adopted in the industry. In 1990 he became an independent consultant and was active in a variety of commercial RF product developments, including the design of several cellular telephone power amplifier MMIC products. In 1996 he returned to England, where his consulting activities continue to be focused in the RF power amplifier area. He has just published a second edition of his best-selling book, "RF Power Amplifier Design for Wireless Communications" (Artech House). He is currently vice-chair of the High Power Amplifier subcommittee of the Technical Co-ordination and Technical Program Committees of the IEEE Microwave Theory and Techniques Society, and writes the regular "Microwave Bytes" column in the IEEE Microwave Magazine. Dr Cripps is an IEEE fellow and a Professorial research fellow at Cardiff University, UK.

Ali Darwish

Ali Darwish, Ph. D., received his Ph.D. degree from Massachusetts Institute of Technology (MIT), Cambridge, MA, in 1996. In 1990, he joined COMSAT Laboratories where he conducted the experimental work on his M. S. thesis. In 1992, he joined the Optics and Quantum Electronics Group, MIT as a research assistant. In 1997, he co-founded Amcom Communications Inc., a leading supplier of high power microwave integrated circuits. At Amcom Communications he served as the vice president of product development where he designed and commercialized several product lines. In May 2003 he joined a US government research lab where he conducted research on wide bandgap materials (GaN), thermal analysis of active devices, and novel MMIC concepts.

Dr. Darwish designed several state-of-the-art monolithic microwave integrated circuits (MMICs) including an X-band low phase noise oscillator, GaN mm-wave power amplifiers, SiGe mm-wave amplifiers, broadband high power amplifiers (in the L-, S-, X-, Ku-, and Ka-band), mixers, a DC-40 GHz digital attenuator, phase shifters, and charge pumps. He also built and tested a 1000-Watt linearized amplifier for WCDMA base stations, a high efficiency 200-Watt S-band amplifier, and a Ku-band packaged power amplifier MMIC for very small aperture terminal (VSAT) applications.

He has published over 70 technical articles, and has developed a number of short courses on microwave circuit design through Besser Associates Inc.. He is currently conducting research on thermal effects in MMICs, and innovative power amplifier topologies.

Public Course:
- *GaN Power Amplifiers: Jun 2-Jun 4, 2015 Web Classroom, WebEx*

Public Course:
- *RF Power Amplifier Techniques - featuring GaN plus Si & GaAs semiconductors: Sep 28-Oct 2, 2015 San Jose, CA*

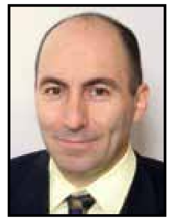
Eric Drucker

Eric Drucker has almost 33 years of RF/analog circuit design experience, mainly in the area of high performance synthesizer/PLL design. He received his BS from the University of Michigan in 1972 and his MSEE from Stanford University in 1974. He spent 18 plus years at the Fluke Corporation, the majority of the time in the signal generator group and a few years designing high-speed cable testers for LAN applications. After the signal generator group was dissolved at Fluke in 1991 and sold to Giga-tronics he joined them for a short time and continued to consult for them throughout the 1990's. While still in Seattle, he joined a start-up, Metawave Communications where he designed circuitry for smart antenna systems. He also worked for Datacom Technologies and Motorola for short periods during the 90's.

In 2000 he accepted a position with Agilent Technologies in Santa Rosa, CA in the frequency synthesis advanced development group. He is responsible for forward-looking system and circuit design of high-performance state of the art frequency synthesizers that are used throughout Agilent's product line.

He is also part of an Agilent sponsored collaboration with Sonoma State University to start an electrical engineering program. Here he is currently teaching Electronics I, the first class on active devices and circuits. He also teaches short courses for Besser Associates, Inc. He has 10 patents.

Oren Eliezer



Dr. Oren Eliezer has over 25 years of experience in the design and productization of communication systems and chips for telecom and wireless applications.

He received his BSEE and MSEE degrees from the Tel-Aviv University in 1988 and in 1997, focusing on communication systems and signal processing, and his PhD in microelectronics from the University of Texas at Dallas in 2008.

After serving for 6 years as an engineer in the IDF, he cofounded Butterfly Communications, which was acquired by Texas Instruments (TI) in 1999.

He was relocated by TI to Dallas in 2002, where he was elected senior member of the technical staff, and took part in the development of TI's digital-radio-processor (DRP) technology and in digital-signal processing techniques for built-in compensation and testing in wireless SoCs.

He joined Xtendwave in Dallas in 2009, where he received several government research grants and was responsible for redesigning the US government's atomic-clock broadcast (WWVB).

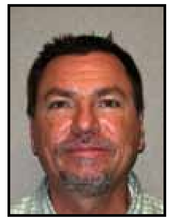
He has authored and coauthored over 50 journal and conference papers and over 45 patents, and has given over 40 invited tutorials related to communication system design and productization.

He is currently the chief technology officer at Xtendwave and participates in the research at the Texas Analog Center of Excellence (TxACE) at UTD. He is a technical program committee member for the IEEE RFIC conference and has chaired several local IEEE conferences.

Ayman Fayed

Ayman Fayed received his B.Sc. in Electronics & Communications Engineering from Cairo University in 1998, and his M.Sc. and Ph.D. in Electrical & Computer Engineering from The Ohio State University in 2000 and 2004 respectively. From 2000 to 2009, he held several technical positions in the area of analog and mixed-signal design at Texas Instruments Inc., where he was a key contributor to many product lines for wire-line, wireless, and multi-media devices. From 2000 to 2005, he was with the Connectivity Solutions Dept. at TI, where he worked on the analog frontend design of high-speed wire-line transceivers such as USB 2.0, IEEE1394b, and HDMI. He also worked on the design of fully integrated switching/linear regulators and battery chargers for portable media players. From 2005 to 2009, he was a member of the technical staff with the wireless analog technology center at TI, where he worked on the design of several delta-sigma data converters for various wireless standards and the development of fully integrated power management solutions for mixed-signal SoCs with mutli-RF cores in nanometer CMOS. Dr. Fayed joined the Dept. of Electrical & Computer Engineering at Iowa State University in 2009, where he held the Northrop Grumman Assistant Professorship and is currently an associate professor. He is the founder and director of the Power Management Research Lab (PMRL) and his current research interests include on-chip smart power grids for dynamic energy distribution in highly-integrated systems, low-noise wide-band power supply modulators for RF, high-frequency switching regulators with on-chip and on-package passives, energy harvesting for power-restricted and remotely-deployed systems, and power converter design in emerging technologies such as GaN. Dr. Fayed has many publications and patents in the field and has authored a book in the area of adaptive systems entitled *Adaptive Techniques for Mixed Signal System On Chip* (Springer 2006). He is a senior member of IEEE, an associate editor for IEEE TCAS-II, and serves in the technical program committee of RFIC, ISCAS, and the steering committee of MWSCAS. Dr. Fayed is a recipient of 2013 NSF CAREER Award.

Rick Fornes



Rick Fornes

Rick Fornes has twenty years of hands-on experience as an RF/Microwave Engineer, Program Manager, Engineering Director and Consultant, with companies such as Nokia, Lucent, Trimble Navigation and Plantronics. Initially his interest was focused on designing low-noise, broadband, and power amplifiers for military communication systems. Later his interest expanded to complete RF systems for commercial radio products and was involved in the design and development of low-cost

RF circuits and sub-systems for wireless products. He also consults as a Technical Trainer for a number of telecommunication companies. During the past five years he has taught nearly 200 courses worldwide on RF circuit and system design, as well as RF test and measurements for Besser Associates, Inc . He has put together numerous conference papers on RF-related topics, dealing with the design of power amplifiers and low-cost wireless systems. Mr. Fornes is a licensed amateur radio operator.

•20 years of innovative RF circuit design, system design and engineering management

•Licensed amateur radio operator since 1971

•Member of IEEE, Eta Kappa Nu, The EE Honor Society and ARRL

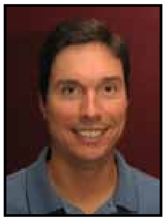
•Patents pending (advanced RF system architectures)

•Member of Who's Who National Register's (2002-2003)

•Member of Technical Advisory Board for Besser Associates

•BSEE, advanced studies in microwave circuits, system engineering and business management

Rex Frobenius

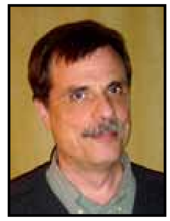


Rex Frobenius has been working at Besser Associates for over 19 years, where he is VP of Engineering and co-owner. To date he has presented nearly one hundred courses to over one thousand students in the United States, Europe, and Asia. His main focus has been course development for linear RF circuit design and test and measurement courses, with his latest project having been the online RF Technology Certification program. He has been the co-author of several articles and has co-authored the recently published text "*RF Measurements for Cellular Phones and Wireless Data Systems*" with Al Scott. Working for Besser Associates has given Rex the unique opportunity to be mentored by many of the industry's leading engineers including company founder Les Besser. He received his BSEE from UC Davis and also has a BA in Rhetoric from UC Berkeley, which makes him uniquely qualified to develop and present materials for training in the RF industry. Rex has developed several Java-based RF-related utility applets which are featured in Besser training courses and available for free on the Bessernet.com website.

Public Course:
- *RF Technology Certification: Feb 20-Aug 28, 2015 Web Classroom, WebEx*

Public Course:
- *RF Technology Certification: Jun 22-Nov 23, 2015 Web Classroom, WebEx*

Bob Froelich



Dr. Bob Froelich is an RF and Microwave Engineer with 30 years of experience in design of circuits and systems for radar, radio astronomy and wireless communications, the latter including GPS, Bluetooth and proprietary systems. He has worked with Watkins-Johnson, Trimble Navigation, CellNet Data Systems, M/A-COM, and Cobham Defense Systems.

Bob received his BS in Electrical Engineering, Summa Cum Laude, from the University of Michigan. He remained there to complete a Ph.D. in Electrical Engineering in 1982, studying aspects of semiconductor physics as applied to IMPATT diodes. He has written a number of technical articles on device modeling and microwave measurement techniques. He currently teaches web-based classes and short courses for Besser Associates, Inc.

Public Course:
- *RF Design: Core Concepts: Aug 24-Aug 28, 2015 Web Classroom, WebEx*

Public Course:
- *RF Design: Applied Techniques: Sep 14-Sep 18, 2015 San Jose, CA*

Sean Gallagher

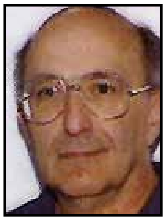
Sean received his Masters in Computer Engineering from Villanova University and has a total of 19 years experience building algorithms in FPGAs. This experience includes 10 years as a senior staff DSP Specialist for Xilinx Inc., and currently as an independent consultant doing business as Hardware DSP Solutions Inc. Sean taught an introduction to DSP class as adjunct professor at Temple University for 3 years and has been an adjunct professor for 7 years at Villanova University where he currently teaches a graduate course in Hardware DSP. He teaches the course *Hardware DSP - A guide to building DSP Circuits in FPGAs* for Besser Associates, Inc.

Rowan Gilmore

Rowan Gilmore received his undergraduate education at the University of Queensland, Brisbane, Australia, where he was awarded the University Medal and the B.E. degree in Electrical Engineering (Hons) in 1976, and his graduate education at Washington University in St. Louis where he was awarded the D. Sc. Degree in 1984. His research area was in the modeling of nonlinear behaviour in microwave MESFET circuits, as a result of which he was a pioneer in applying harmonic balance analysis to RF and microwave circuit design. Subsequently, while Vice President of Engineering with Compact Software, Dr. Gilmore led the introduction of Microwave Harmonica, the world's first commercial simulator applicable to the nonlinear design of microwave and RF circuits.

Dr. Gilmore gained his design experience over a number of years at Schlumberger, where he developed an RF tool for measurement of oil wells, and at Central Microwave, where he designed and developed numerous linear microwave power amplifiers, as well as oscillators and switching components. Subsequently, while at Compact Software, he was responsible for the development of their entire software suite of computer aided design tools. He was later Vice President at SITA-Equant, operator of the world's most extensive data network, where he worked with a number of airlines and multinationals on their data telecommunications and IT needs. He spent eight years as the Chief Executive Officer of the Australian Institute for Commercialisation, located in Brisbane, Australia, working on establishing liaisons and facilitating technology transfer between universities and industry. He holds an appointment as Adjunct Professor of Electrical Engineering at the University of Queensland. He is currently a Director of EMSolutions, a specialist designer and producer of Ka-band microwave components and satellite systems, and Chairman of EMClarity, a producer of terrestrial point-to-point microwave communication systems.Dr. Gilmore is a Chartered Engineer and Senior Member of the IEEE. He has published more than thirty articles in the field of microwave systems and circuit design, and has served on the editorial boards of the IEEE Transactions on Microwave Theory and Techniques, and of Wiley's International Journal of RF and Microwave Computer-Aided Engineering. He has been active in the education of graduate engineers in industry, having taught courses around the world to nearly fifteen hundred practicing RF and microwave engineers for the over a decade. With Dr. Besser, he is co-author of the widely read two-volume textbook 'Practical RF Circuit Design for Modern Wireless Systems'.

Irving Kalet

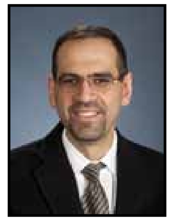


Irving Kalet
PhD, Tel Hai College, Haifa, Israel, and Columbia University, New York, USA.

Dr Kalet has been teaching and working in the area of digital communications in both Israel and the United States for more than 30 years. While in Israel, he teaches at the Technion in Haifa. He is also currently an Adjunct Professor in the Department of Electrical Engineering in Columbiua University in New York. He has worked in the area of mobile wireless communications and digital transmission over the twisted-pair cable (HDSL, ADSL, and the 56 Kbps modem) at Bell Laboratories and in the area of satellite communications at MIT Lincoln Laboratories.

Dr Kalet has published many papers in the area of digital communications and is the author of the chapter on Multitone Modulation in Sublet and Wavelet Transforms - Design and Applications, Kluwer Academic Publishers-1995. He is presently working in the areas of digital modulation techniques and multiple access techniques for wireline and wireless communication systems.

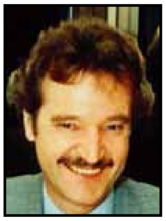
Waleed Khalil



Waleed Khalil, PhDWaleed Khalil is currently serving as an Associate Professor at the ECE department and the ElectroScience Lab, The Ohio State University. He received his B.S.E.E. and M.S.E.E degrees from the University of Minnesota in 1992 and 1993, respectively, and his PhD degree from Arizona State University in 2008. He is a founder of CLASS (Circuit Laboratory for Advanced Sensors and Systems) at OSU where he conducts research in digital intensive RF and mm-wave circuits and systems, high performance clocking circuits, GHz A/D and D/A circuits. Prior to joining OSU, Dr. Khalil spent 16 years at Intel Corporation where he held various technical and leadership positions in wireless and wireline communication groups. While at Intel, he was appointed the lead engineer at the advanced wireless communications group, where he played an instrumental role in the development of the industry's first Analog Front-end IC for third generation radios (3G). He established Intel's first analog device modeling methodology for mixed signal circuit design and also contributed to the development of Intel's first RF process technology. He later co-founded a startup group to develop Intel's first RF front-end IC, as a principle leader of the radio transmitter chain. In 2010, he was awarded TSMC's outstanding research award in the area of circuit design technologies. He authored and co-authored 11 issued and several other pending patents, over 60 journal and conference papers and three book/book chapters. He is a senior member in IEEE and serves in the steering committee for the RFIC Symposium and technical program committee for the Compound Semiconductor IC Symposium. He also teaches web-based classes and short courses for Besser Associates, Inc.

Public Course:
- *The Radio Modem: RF Transceiver From Antenna to Bits and Back: Sep 28-Oct 2, 2015 San Jose, CA*

Lutz Konstroffer



Dr Konstroffer is a technical consultant with focus on short-range wireless applications. He started his career in the field of fiber optics, where he did theoretical and experimental investigations in wavelength division multiplexing and optical heterodyning. As a head of a working group in the research and development department of the Kathrein-Werke Rosenheim, his area of responsibility included the design of an optical heterodyne transmission system, the development of hardware and software for optical and electrical
measurements, the design and engineering of laser diode modules as well as the design of optical transmitters and receivers up to 2 GHz. In 1996, he joined Texas Instruments were he set up the company's European RF application lab. He was responsible for customer support of RF products in Europe, designed evaluation boards for cordless and ISM applications and held in-house seminars. Dr. Konstroffer is an author of several technical publications. Since
2000, he works as an independent consultant and managing director of RF Consult GmbH.

Jeff Lange

Jeff Lange, President of Besser Associates, has over 20 years of experience in RF/Wireless design, manufacturing, and management. He has been responsible for the design and development of numerous RF, Microwave, and Navigation components and systems for companies such as Trimble Navigation, Sony, and Watkins-Johnson. He has spent a considerable portion of his career involved with GPS based navigation systems for military and commercial applications, including in-vehicle telematics. In addition, he served in a variety of leadership positions spanning portable wireless systems development, IC engineering, program management, and operations management. Mr. Lange received a BSEE from Cal Poly, San Luis Obispo, and an MBA from Santa Clara University. He is a member of Tau Beta Pi, Eta Kappa Nu, and Phi Kappa Phi honor societies..

Richard Lyons

Richard G. Lyons
Richard Lyons has been the Lead Hardware Engineer for numerous multi-million dollar signal processing systems for both the National Security Agency (NSA) and TRW (now Northrop Grumman). An experienced lecturer and instructor at the University of California Santa Cruz Extension, he has delivered signal processing seminars and training courses for Besser Associates throughout the US and Europe to companies such as Motorola, Lockheed-Martin, Texas Instruments, Nokia, Honeywell, Qualcomm, National Semiconductor, Northrop Grumman, Sandia National Laboratories, Wright-Patterson Air Force Base, etc. He has written numerous articles on DSP topics, and authored the top selling DSP book *Understanding Digital Signal Processing,* now in its third edition. Lyons is the primary contributor to, and Editor of, the book *Streamlining Digital Signal Processing: A Tricks of the Trade Guidebook*. He is an Associate Editor of the IEEE Signal Processing magazine, where he created and edits the "DSP Tips & Tricks" column; and a member of Eta Kappa Nu, the electrical engineering honor society. He received the 2007 IEEE Signal Processing Magazine Best Column Award and the IEEE Signal Processing Society's 2012 Education Award

Public Course:
- *DSP - Understanding Digital Signal Processing: Oct 19-Oct 21, 2015 San Jose, CA*

Earl McCune Jr.

Dr. McCune has over 35 years of experience in wireless communication technology, systems, and circuit design. He has learned across this career that a thorough understanding of physical fundamentals is essential to avoid making huge mistakes, providing an extremely useful check on mathematical derivations and computer simulations (not to mention young engineers!).

Earl holds over 40 US patents, and is frequently an invited speaker at conferences worldwide. He is a graduate of UC Berkeley, Stanford, and UC Davis. He has been a Silicon Valley entrepreneur since 1986, starting up two groundbreaking technology companies that both provided successful exits to the investors. His work experience includes NASA, Hewlett-Packard, Watkins-Johnson, Cushman Electronics, Digital RF Solutions (start-up #1), Proxim, Tropian (start-up #2), and Panasonic. He is now a semi-retired consultant, instructor for Besser Associates, and visiting professor at multiple universities.

Arturo Mediano

Arturo Mediano received both his M.Sc. (1990) and his Ph. D. (1997) in Electrical Engineering from the University of Zaragoza, Spain. He has been involved in design and management responsibilities for R&D projects with companies in the radiofrequency (RF) and EMI/EMC fields for communications, industry and scientific/medical applications since 1990.

Since 1992 he has held a teaching professorship with special interest in Electromagnetic Interference and Electromagnetic Compatibility (EMI/EMC) and RF (HF/VHF/UHF) design for Telecom and Electrical Engineers.

His research interest is high efficiency switching mode RF power amplifiers with experience in applications like mobile communication radios, broadcasting, through-earth communication systems (TTE), induction heating, medical equipment, plasmas for industrial applications and RFID.

He has substantial experience in collaboration with industries with a focus on training and consulting in RF design and EMI/EMC design and troubleshooting.

He has taught more than 40 courses and seminars for industries and institutions in the fields of RF/EMI/EMC in Spain, USA, Switzerland, France, UK, Italy and The Netherlands.

He has been involved in approximately 50 R&D projects for companies and/or institutions in the fields of EMI/EMC/RF (in more than 40 projects as Main Researcher). Usually the result was directly used in a marketed product.

Dr. Mediano is author/co-author for around 50 publications and 8 patents as result of activity in research activities listed before.

He has been a speaker in paper sessions and tutorials of some of the most important symposiums and conferences related to RF and EMC (RF EXPO, IEEE IMS, and IEEE Intl. Symp. EMC, URSI, EPE, ARFTG, EUROEM, IEEE RWS, EuMW, etc).

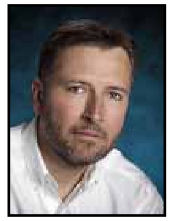
He is a Senior Member of the IEEE, where he has been an active member since 1999 (Chair since Jan 2013) of the MTT-17 (HF/VHF/UHF technology) Technical Committee of the Microwave Theory and Techniques Society and member of the Electromagnetic Compatibility Society (member of the directive of the EMC Spanish Chapter).

Arturo shares free time between his family, fly fishing, and drawing cartoons.

Public Course:

- *EMI/EMC and Signal Integrity Boot Camp: Nov 2-Nov 6, 2015 San Jose, CA*

Steve Moore



Steve Moore has over twenty-five years experience working for many of the industries top RF/Wireless companies. He has a BSEE degree from UC Berkeley, an MSEE degree from Santa Clara University and has worked his entire career in the Silicon Valley area for both large companies and small startups. After many years as a design engineer working on microwave circuits (and subsystems) for Watkins-Johnson Company he transitioned to the commercial wireless industry and was an engineering manager for Wireless Access developing 2-way pagers and then an applications manger for SiRF Technology supporting customers working on GPS products. After that he worked for a Bluetooth startup company and then took over the Product Line Management role for WiFi products at Symbol Technologies. Most recently he was the VP of Sales and Applications for Micro Linear Corporation selling/supporting consumer wireless ICs for radio applications such as audio, video, and control. Steve has spent nearly his whole career managing, teaching, training, and supporting RF/wireless design engineers and now spends his time teaching and consulting.

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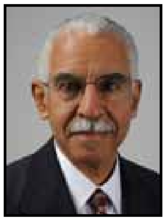
Douglas H. Morais



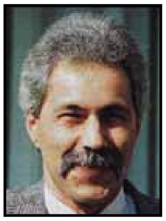
Douglas H. Morais
Doug Morais has over 40 years of experience in wireless design and management. Before starting Adroit Wireless Strategies, a wireless consulting and training company, he held executive management positions at Harris Corporation, Digital Microwave Corporation, California Microwave Inc., and Ortel Corporation. At Harris, he held microwave radio design and engineering management positions for 11 years. He has authored several papers on digital microwave communications and the book Fixed Broadband Wireless Communications. He holds a U.S. patent that addresses point-to-multipoint microwave radio communications. He has a Ph.D in Electrical Engineering, is a senior and life member of the IEEE, and a member of the IEEE Communications Society.

Ed Niehenke

EDWARD C. NIEHENKE, Ph.D., PE, Lecturer & President of Niehenke Consulting

Dr. Niehenke has pioneered the development of state-of-the-art RF, microwave, and millimeter wave components at Westinghouse/Northrop Grumman. Circuits include low noise amplifiers, low noise oscillators, mixers, frequency multipliers, power amplifiers, phase shifters, limiters, low-noise fiber optical links, and miniature integrated assemblies and subsystems. He previously worked in cryogenic electronics research at Martin-Marietta. Since 1983 he has been actively teaching linear, nonlinear, power amplifier, and transceiver circuit design for wireless communications to over 3000 professionals throughout the world for Besser Associates and the Continuing Education of Europe. He has given over 120 presentations at symposia, workshops, IEEE chapter/section meetings, and keynote addresses at conferences. He holds nine patents, one George Westinghouse Innovation Award, and has authored over 30 papers on RF, microwave, and millimeter wave circuits. Dr. Niehenke is a member of Microwave and Millimeter Wave Integrated Circuits, Microwave Systems, and Wireless Communications MTT-S Technical Committees and is a fellow of the IEEE.

Istvan Novak



Dr. Istvan Novak, Distinguished Engineer, Signal and Power Integrity, SUN Microsystems, Inc., Boston, MA

In the past eleven years Dr. Novak was responsible for the power distribution and high-speed signal integrity designs of SUN's successful V880, V480, V890, V490, V440, T1000, T2000, T5120 and T5220 midrange server families. He introduced the industry's first 1-mil laminates into volume-produced server PCBs, and drove the multi-company development of controlled-ESR and low-inductance bypass capacitors. He was SUN's representative on the InfiniBand Cable and Connector Workgroup. He is engaged in the methodologies, designs and characterization of power-distribution networks.

Dr.Novak has thirty years of experience with high-speed digital, RF, and analog circuit and system design and has twenty five patents. He is Fellow of IEEE for his contributions to the signal-integrity and RF measurements as well as simulation methodologies, lead-author of the book "Frequency-Domain Characterization of Power Distribution Networks" (Artech House, 2007) and Executive Editor of the book "Power Distribution Design Methodologies" (IEC, 2008).

Previously Dr. Novák advised the European Laboratory for Particle Physics (CERN) on signal-integrity and EMC issues for Fibre Channel data-collection systems of the Large Hadron Collider. He worked and consulted for several companies in the computer and telecommunications industry, to do clock- and power-distribution networks, switching-mode power converters as well as high-speed backplanes, and copper and optical interconnects in the GB/s range.

Dr. Novak had his technical education from the Technical University of Budapest, and his Ph.D. degree from the Hungarian Academy of Sciences. He organized and led the High Speed Technology Team at the Technical University of Budapest, where his teaching activity covered transmission lines and wave propagation, communications systems, EMC and signal-integrity issues of high-speed designs.

Allen Podell

Allen Podell
Allen Podell, an IEEE Life Fellow, has designed monolithic and discrete circuits on gallium arsenide, silicon, sapphire, and plastic. With a solid foundation in device-circuit interaction, he specializes in the practical realization of modern circuit techniques. An author of over 70 technical papers, he founded three companies (Anzac Electronics, Podell Associates, and Pacific Monolithics) and he holds 60 US patents ranging from IMPATT diodes, silicon power transistors, and 3-decade bandwidth microwave components, stereo demodulators, antennas, gallium arsenide integrated circuits - and more recently, high power, wideband components. Previously, as VP of Technology at Besser Associates and later at Podell Consulting, he has taught advanced wireless design courses and provided consulting services worldwide.

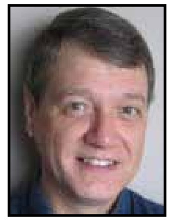
Public Course:
- *EMC/Shielding/Grounding Techniques for Chip & PCB Layout: Jun 22-Jun 26, 2015 Web Classroom, WebEx*

Chris Potter

Dr. C. M. Potter

Chris Potter is presently a consultant with Cambridge RF Ltd. in Cambridge UK, working on diverse projects for clients in the fields of GPS receivers, Bluetooth testers, Envelope Tracking PAs, Security tag readers, Microwave radios, and DVB over fibre. Previously, he has designed a variety of microwave and RF test equipment at Marconi Instruments, worked at Tality UK on RF architectures and product designs for GSM, EDGE, Bluetooth, 802.11a/b and W-CDMA. His main research interests are in the field of adaptive linearization of PAs. He is also active in RF system designs, and tools for automation of the RF design process. Chris Potter received his Ph.D. degree in 1987 from the University of London, England.

Richard Ranson



Dr. Ranson is the founder and Engineering Director of Radio System Design a bespoke design and consultancy service specialising in microwave communications technology. He received his Ph.D. degree from the University of Leeds and has been in industry, actively involved in research and development of microwave components and systems for over 25 years. He has been interested in radio from an early age. He obtained a Class A amateur radio license at the age of 14 and has been building and studying radios ever since. At university he specialised in microwave engineering obtaining a PhD on the now not so common topic of Transferred Electron Devices Amplifiers.

His early work was on military systems, designing IFM and band translators for ECM equipment at MEL, then a part of Philips Electronics. He moved to the USA where he worked for AIL and Watkins Johnson Co. As well as various converter and customer specific products Dr. Ranson became a project leader on three major microwave receiver developments. One was the first upconverting, broadband microwave ELINT receiver employing an approximately 22 GHz first IF. The second was an innovative microwave impulse receiver where he was responsible for the key filter designs and the last was a very high dynamic range, triple conversion microwave to baseband processor.

In 1996 Dr. Ranson returned to the UK as Subsystems Engineering Director for Filtronic Comtek. There he grew the development team and expanded the company business and capabilities in integrated front end products. Prior to the most recent position Dr. Ranson was Director of Wireless Research working with a team focused on high efficiency power amplifiers for W-CDMA base stations. This has produced innovative designs for single and multi-carrier linear power amplifiers, employing large Filtronic GaAs pHEMTs and achieving state-of-the-art power added efficiencies. Until recently he was the Engineering Director of the Integrated Products Group of Filtronic plc responsible for engineering across the four business units in the group. This broad technology base ranged from semiconductor device and MMIC development, through integrated assemblies for point to point radios to advanced radar and ECM sub-systems.

Dr. Ranson is a Fellow of both the IEE now IET and the IEEE. He is a visiting Professor at Leeds University and has published technical articles, organized and presented in MTT workshops and presented numerous internal presentations and international seminars. He was the Digest Editor for the 1996 MTT Symposium in San Francisco, where he helped pioneer the publication on CD-ROM. He is a member of the MTT-S 2007 Technical Program Committee, the past Chairman of the MTT Technical Coordination Committee 20 on Wireless Communications. In 2006 he was the Technical Program Committee Chairman for European Microwave Week and the General Chair of the ECWT. He is also a member of the Board of Directors for the European Microwave Association and a member of the Steering Committee for the European Conference on Wireless Technology. (EuWit) and an Invited Editor for the Special Issue of the MTT Microwaves Letters focussed on European wireless communications technology.

Public Course:

- *Advanced Radio System Architectures: Oct 12-Oct 14, 2015 San Jose, CA*

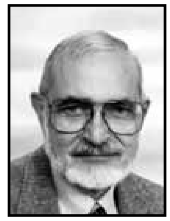
Tamer Refaei

Tamer Refaei received his PhD in Computer Engineering from Virginia Tech in 2007, and B.Sc. in Computer Science from the University of Maryland in 2000. He has been with MITRE Corporation since 2008 as a Senior Engineer/Scientist. His prior experience includes serving as a research consultant to NIST (National Institute of Standards and Technologies), and as an Intern at Fujitsu Labs of America. He has been teaching computer security and wireless networking related courses for the past 6 years at Johns Hopkins University, George Washington University, and Virginia Tech. He has a number of publications related to wireless networks and security in MANETs. He has received a number of technical awards from MITRE and a fellowship from NSF.

Keith Schaub

Keith Schaub Founder of Wireless SOC Test Inc, author of the book, Production testing of RF and SOC devices for Wireless Communications, has over 14 years of experience in RF/microwave system design and test engineering. Additionally, he has authored/co-authored several papers and editorials on the state of RF/wireless SOC/SIP testing and the trends of the market including: "MIMO challenges existing ATE", Test & Measurement World, "Reducing EVM Test Time and Indentifying Failure Mechanisms", Evaluation Engineering, "Evolutionary Changes For RF Device Testing", Evaluation Engineering; "Needed: New Thinking For Wireless/RF Testing", Test and Measurement World, and "Concurrent-Parallel Testing of Bluetooth/802.11x Chip Sets."

Bernard Sklar



Bernard Sklar
With over 40 years experience at companies such as Hughes Aircraft, Litton Industries, and The Aerospace Corporation, Bernard Sklar's credits include the MILSTAR satellite system and EHF Satellite Data Link Standards. He has taught worldwide, and at major universities such as UCLA and USC. He has authored many technical papers and the book Digital Communications (Prentice-Hall, 1988). He received the IEEE Prize Paper Award in 1984 for his tutorials on digital communications.

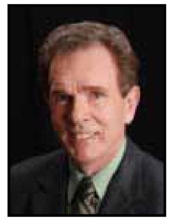
Malcolm Smith

Malcolm H. Smith is an independent consultant in the field of RF systems, RFIC , analog, and mixed-signal circuit and system design. He has over 25 years of experience in the semiconductor field and over 18 years of those have been in designing chips for cellular handset applications. He was previously a Senior Manager at RFMD, which he joined with the acquisition of Amalfi Semiconductor. At Amalfi and RFMD he lead a team designing the World's highest performing Band I 3G PA. While at Amalfi he invented the method used in the latest generation of GSM/GPRS Tx Modules where the switching function is moved onto the CMOS die. He also invented the output stage architecture used on all Amalfi PAs. Before joining Amalfi Semiconductor he was at Intel where he designed the architecture used in an EDGE transceiver chip which made the first phone call on a public telephone network using an Intel RF chip. Before Intel he was at Bell Labs where he was a circuit designer working on chips used in cellphones and pagers. Dr. Smith started his industrial experience in the UK at STC semiconductors and also worked at Matsushita Electric Works (Panasonic) in Osaka, Japan where he designed analog sensor chips. Dr Smith has a B.Sc. (Hons) Degree from the University of Edinburgh, an M.Sc. Degree from the University of Westminster, and the Ph.D. Degree from the University of Kent. He has over 40 patents granted with several pending. Dr. Smith is a Senior Member of the IEEE and a Member of the IET.

Public Course:

- *Design of CMOS Power Amplifiers: Oct 5-Oct 9, 2015 Web Classroom, WebEx*

Dan Swanson



Daniel G. Swanson, Jr.Distinguished Fellow of Technology
Tyco Electronics (M/A-COM), Lowell, MA, USA.

Dan received his BSEE degree from the University of Illinois and his MSEE degree from the University of Michigan. He started his career at Narda Microwave West, where he developed broadband amplifiers and a de-embedding system for S-parameter device characterization. At the Wiltron Company he designed YIG tuned oscillators for use in microwave sweepers. He also developed a broad-band load-pull system for optimization of output power. At Avantek Inc. he developed thin-film microwave filters, software for filter design, and a low-frequency, broad-band GaAs MMIC amplifier. In 1989, he joined Watkins-Johnson Company as a Staff Scientist. His work there included thin-film filter design for broadband surveillance receivers, high performance filters for wireless base stations, and the application of electromagnetic field solvers to microwave component design. Mr. Swanson joined AMP M/ACOM in 1997 where he was a Senior Principal Engineer. As a member of the Central R&D group, he applied electromagnetic field-solvers to the design of multilayer PC boards, RF and digital connectors, couplers and other microwave components. Mr. Swanson joined Bartley R.F. Systems in 1999. He designed high Q filters for wireless base stations and developed novel design methods based on EM simulation. Mr. Swanson returned to Tyco Electronics (M/A-COM) in 2003 as a Distinguished Fellow of Technology. As a member of the Strategic R&D group he supports filter and antenna design efforts and consults on EM simulation issues in general.

Mr. Swanson is a Fellow of the IEEE. He is past chairman of the MTT-8 Filters and Passive Components Technical Committee. He is on the editorial board for the IEEE MTT-S Transactions, IEEE MTT-S Microwave and Wireless Components Letters, and the Int. Journal of Microwave and Millimeter-Wave Computer-Aided Engineering and Microwave Journal. Mr. Swanson is the primary author of Microwave Circuit Modeling Using Electromagnetic Field Simulation, published by Artech House. He has published numerous technical papers, given many workshop and short course presentations, and holds two patents.

Tim Wescott

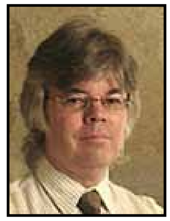
Tim Wescott has over 20 years proven expertise in control systems analysis and design, general embedded system software and hardware design, and teaching on topics related to implementing control systems and sampled-time data systems.

Mr. Wescott founded and runs Wescott Design Services, where he has worked on projects such as motion control systems for therapeutic exercise equipment, down-hole oil well communications, accurate control of diesel engine speeds in generator sets, detection algorithms to localize cell phones in enhanced 911 networks, and Kalman filters for sensor fusion in high performance vehicle navigation systems.Mr. Wescott wrote the book, *Applied Control Theory for Embedded Systems* (Elsevier/Newnes, 2006), which is based on years of experience with making real control systems work in the real world. In this book he combines the necessary theoretical knowledge of control system design with the real-world issues that are often left out of textbooks, to give the reader a balanced and immediately useful combination of theory and practice.Mr. Wescott also contributed a chapter on system design to the book *Developing and Managing Embedded Systems and Products: Methods, Techniques, Tools, Processes and Teamwork* by Kim Fowler and Craig Silver (Elsevier/Newnes, 2015). Mr. Wescott holds a Master's of Science degree from Worcester Polytechnic Institute, and is a senior member of the IEEE and a member of Eta Kappa Nu.

Public Course:

- *Applied Embedded Control Systems: Sep 14-Sep 18, 2015 San Jose, CA*

John Wood



John Wood, PhD

John Wood received B.Sc. and Ph.D. degrees in Electrical and Electronic Engineering from the University of Leeds, UK, in 1976 and 1980, respectively. He is currently Senior Principal Member of Technical Staff in Maxim Labs at Maxim Integrated Products, Inc, Sunnyvale, CA, where he is working on Envelope Tracking and Digital Pre-Distortion systems for wireless communications applications. He was formerly a Distinguished Member of the Technical Staff responsible for RF System & Device Modeling in the RF Division of Freescale Semiconductor, Inc, Tempe, AZ, USA. His areas of expertise include the development of compact device models and behavioural models for RF power transistors and Ics, and linearization and pre-distortion of high-power amplifiers. To enable and support these modeling requirements, he has been involved in the specification of high power pulsed I-V-RF test systems, for connectorized and on-wafer applications, and in the development of large-signal network analyzer (LSNA), loadpull, and envelope measurement techniques. From 1997-2005 he worked in the Microwave Technology Center of Agilent Technologies (then Hewlett Packard) in Santa Rosa, CA, USA, where his research work has included the investigation, characterization, and development of large-signal and bias-dependent linear FET models for millimetre-wave applications, and nonlinear behavioural modeling using LSNA measurements and nonlinear system identification techniques.

He has organized, co-organized, and presented at many workshops at IMS and RWS in recent years; he was on the Steering Committee for IMS 2006, and has been a member of the IMS Technical Program Committee for the past four years, currently Chair of SC-20 'High-Power Amplifiers.' He has been a member of the ARFTG Executive Committee from 2007-14, was the Technical Program Chair for the 70th & 75th ARFTG Conferences (2007, 2010), and the General Chair for the 78th ARFTG Conference in Fall 2011. He was Technical Program Chair for the IEEE Power Amplifier Symposium 2008, 2010, and was General Chair in 2009 and 2011. He is a regular reviewer for IEEE Transactions on Microwave Theory & Techniques, on Electron Devices, and on Circuits & Systems. He is author or co-author of over 130 papers and articles in the fields of microwave device and system modeling and characterization, and microwave device technology. He is the co-author of Modeling and Characterization of RF and Microwave Power FETs (Cambridge, 2007), and co-editor of Fundamentals of Nonlinear Behavioral Modeling for RF and Microwave Design (Artech House, 2005). He is Editor-in-Chief of the IEEE Microwave magazine for 2012-14: this is the magazine of the IEEE Microwave Theory & Techniques Society (MTT-S); he is also an MTT-S Distinguished Microwave Lecturer for 2012-14. He received the ARFTG Technology Award in 2007. He is a Fellow of the IEEE.

Amir Zaghloul

Amir I. Zaghloul is with the US Army Research Laboratory on an IPA agreement with Virginia Polytechnic Institute and State University (Virginia Tech), where he has been with the Bradley Department of Electrical and Computer Engineering since 2001. Prior to Virginia Tech, he was at COMSAT Laboratories for 25 years performing and directing R&D efforts on satellite communications and antennas, where he received several research and patent awards, including the Exceptional Patent Award. He held positions at the University of Waterloo, Canada (1968-1978), University of Toronto, Canada (1973-74), Aalborg University, Denmark (1976) and Johns Hopkins University, Maryland (1984-2001). He is a Life Fellow of the IEEE and the recipient of the 1986 Wheeler Prize Award for Best Application Paper in the IEEE Transactions on Antennas and Propagation and the best track paper at the 2004 IEEE Digital Avionics Systems Conference. He is also a Fellow of the Applied Computational Electromagnetics Society (ACES), Associate Fellow of The American Institute of Aeronautics and Astronautics (AIAA), and a Member of Commissions A, B & C of the International Union of Radio Science (URSI). He was the general chair of the 2005 "IEEE International Symposium on Antennas and Propagation and USNC/URSI Meeting," held in Washington, D.C.

He is the author or co-author of more than 220 publications and over 40 patents and invention disclosures in the areas of antennas, RF and microwave systems, sensors, metamaterials, nano-technology, terahertz imaging, and satellite and wireless communication systems. He led successful product developments and patent licensing of consumer electronic equipment based on his patents.

Dr. Zaghloul received the Ph.D. and M.A.Sc. degrees from the University of Waterloo, Canada in 1973 and 1970, respectively, and the B.Sc. degree (Honors) from Cairo University, Egypt in 1965, all in electrical engineering. He also received a MBA degree in Management of Science, Technology and Innovation from the George Washington University, Washington, DC in 1989

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