Course Description

Course name	**#015 - RF Design and Simulation of Wireless Systems**
Duration	**5 days**
Format	**Public Classroom or Inhouse Event. Not suitable Online**

Overview

Dr. Rowan Gilmore, D.Sc., Adjunct Professor, University of Queensland, and former CEO and Managing Director at EM Solutions Pty Ltd, Australia, is teaching this 5-day course in Design and Simulation of Wireless Systems.

Starting from the basics of Communications Theory, this course drills down into the depths of how to construct RF or Microwave Wireless Systems from elemental building blocks.

Then, by simulating those circuits and systems from the bottom up, you will gain an understanding of how and why such complex systems can be designed to achieve their optimal communications performance!

This course will be useful for engineers working in communications, radar, defense, or new space industries to see the "big picture" in system engineering and to help them perfect their wireless systems.

Technical Focus

Whether used for radar or communications, microwave and millimeter wave radio systems and the signals within them are becoming increasingly complex, with the boundary between digital and analog processing moving ever closer to the antenna.

This course will help you to design and piece together the elemental building blocks of wireless **RF systems for optimal performance**. Using powerful system simulation tools, you will gain insight into signals in microwave communications systems, how they behave and can become corrupted, and how this impacts overall performance.

In doing this, we will explore both circuits and systems. **RF circuits** are typically designed to meet power, efficiency, gain, linearity and noise specifications; whereas the **Radio System** itself is driven by complex modulated signals and must be designed to meet specifications like bit error rate, dynamic range, and minimum detectable signal in the presence of interferers. Between two such radios, the communications link itself must achieve a given bit rate, consume minimal bandwidth, not interfere with other systems, and cover a certain distance.

Through understanding the interactions between circuits, and through detailed simulation of both circuits and systems, and modelling the link, we will understand how to design circuits and systems to meet all levels of performance specification.

Course Content
This 5-day course starts with a review of basic communications theory, and from the top down gradually builds the picture of how a radio (or radar) receiver and transmitter system can be designed to achieve wireless communications.

At the communications link level, we will see how link distance, antenna gain, and signal thresholds can be traded off against each other; and how channel bandwidth improves the link capacity in spite of elevating the receiver noise floor.

We will focus on examining trade-offs in the design of wireless systems themselves, and show how to seamlessly move between both the circuit and system level in radio transceivers and other **RF systems**. We do this by looking at typical radio architectures, exploring the design compromises, and simulating at both the circuit and system level. The course treats digitally coded signals in RF and IF components and explores the compromises that are inherent in the design of a radio transceiver. For example, a receiver needs to minimize interference from nearby unwanted stronger signals and allow detection of a desired signal in noise. For the transmitter, avoiding corruption of other signals sharing adjacent spectrum is critical. Filtering might seem to provide the best solution, but we look in more detail at what other complications this creates.

In wireless LAN for instance, we will see how tradeoffs in signal modulation and multiplexing (i.e. OFDM) made to improve performance in some parts of the system, such as multipath reception, have placed tight constraints on other parts of the system, such as the linearity and efficiency of the transmitter. We will interactively simulate a double super-heterodyne, dual-band radio receiver, a direct conversion receiver, and an I-Q modulator and transmitter, as well as various components that make up these systems. This provides the opportunity to explore 'what if?' scenarios. We will also get "inside" the circuits themselves for a greater understanding of how each component works and contributes to overall system performance.

To benefit most, bring your own laptop computer and, prior to attending, obtain a free trial license of the Visual Systems Simulator (VSS) from Cadence.

On completion of the course, you will be:

- Able to choose a system architecture and specify the best types of circuits to meet given system requirements
- Fully conversant with how RF system architectures work, how they are implemented, and the challenges to watch for
- Able to simulate various types of RF and IF systems and circuits, and model component interactions
- Familiar with microwave and RF subsystems such as amplifiers, mixers, and oscillators
- Familiar with the physical layer specifications of an RF wireless system, and understanding how the key system parameters relate to RF hardware and the communications link itself
- Able to understand and write critical RF specifications for wireless communications systems

- Comfortable with reading integrated circuit data sheets for wireless systems, their architecture, and specifications

Who should attend?
This course begins with a revision of communications and is suitable even for those new to system design. It will be most helpful for engineers with some background in electronic circuits already, but who may be wishing to move into microwave system design, or for those who wish to become systems engineers.

The course is suitable for **engineering managers, design engineers**, and experienced **test and production** engineers. Course participants will most likely work for systems integrators, prime contractors, telcos, defense organizations, or in emerging 'new space' industries.

Past participants who have benefited most are those who arrive with an area of detailed expertise and leave with a much broader appreciation of microwave systems.

Course Daily Schedule

Day 1

Radio Systems and Digital Communications

We start at the top by reviewing digital wireless communications and a variety of modulation formats, and the tradeoffs between capacity, bandwidth, signal power, and noise.

- Revision of Communication and Information Theory Principles
- Coding and Modulation Formats
- Baseband Filtering and Impact on Signal Constellation

We then look at the elemental building blocks that make up a system – amplification; frequency generation; frequency translation; and filtering and see how these can be assembled in typical receiver and transmitter architectures to achieve communications functionality.

- Typical Receiver System Architectures - Direct Conversion, Superheterodyne, Dual Conversion Superheterodyne

Day 2

Today we consider a simplified form of the air-interface specification for a common RF system. This describes the overall radio system requirements and enables multiple system operators to co-exist and interoperate. We will define and examine the key system parameters that have to be measured - parameters such as noise, distortion, sensitivity, selectivity, and interference. We also examine how the IF frequency is chosen.

Characterization of Receivers

- Noise in Receivers
- Selectivity, Sensitivity and Minimum Detectable Signal
- Nonlinearities and Third-Order Intermodulation Distortion
- Reception in the Presence of Interferers
- Dynamic Range and How to Improve It with AGC

Characterization of Transmitters

- Power and Harmonic Distortion
- Spurious Products
- ACPR, Spectral Regrowth and Linearity with Different Modulation Formats
- Efficiency

Frequency Selection

- The Image Frequency
- Choosing the Correct Intermediate Frequency

Day 3

Today we will see how system performance parameters can be met by assembling a number of components. We will turn to their data sheets to discover how each is characterized, and examine the tradeoffs involved in selecting them. We will extract key defining features that describe the behaviour of each circuit and then simulate both the component and the system in the systems simulator.

Systems Simulation - Behavioral Modeling
Simulation of a Dual-band CDMA Superhet Radio Receiver

- Spreadsheet-based Linear Systems Analysis
- Calculation of Sensitivity and Dynamic Range
- Systems Simulation to Compare with Linear Analysis
- Using AGC to Increase the Dynamic Range
- Effect of Changing the Gain, Intercept Point, and Filtering

We now start to explore how the key RF functions of amplification, frequency synthesis (oscillation), and frequency translation (mixing) are achieved at the circuit level. We begin with various ways to change frequencies.

Revision of some RF Basics
Mixers

- Spurious Analysis
- Image Reject and Single Sideband Mixers
- I-Q Modulators and the Importance of Quadrature
- Basics of Mixer Design and typical mixer problems

Day 4

Today we continue the detailed design process and explore some of the key tradeoffs in design, for example, between the power, efficiency, and linearity in a transmitter, and how to model these tradeoffs. We will focus on discrete design and review some IC designs of frequency generators (oscillators) and signal amplifers.

Oscillators

- Basic Concepts of Oscillator Design
- Deriving the VCO Tuning Curve and Explaining Mode Hopping
- Phase Noise in Oscillators and its Impact on Communications Systems
- Calculating Allowable Phase Noise from System Specifications

Power Amplifiers

- Design Tradeoffs between Linearity, Power, and Efficiency
- Classes of Amplifier Operation
- Simulation of Spectral Regrowth with Different Modulation Formats

Day 5

Finally, we look at putting everything together, including the modelling of a complete communications link. We will consider a variety of challenges facing the systems designer; we examine some 'real' air interface specifications, and we work an example of the complete design process, from air interface specification through to circuit design.

The Link Budget

- Modelling a communications link and understanding the tradeoffs
- Characterising a receiver by G/T and a transmitter by its EIRP – and understanding why these measures are useful

Noise in more detail

- Reconciling the treatment of noise – terrestrial communications and space communications

Simulation of a Direct Conversion Receiver

- Trade-off between Modulation Scheme, Data Rate, RF Bandwidth, Channel Filter, Power, Noise, Phase Noise, and Bit-Error Rate

Review of some technical papers

- Design Considerations of Typical Wireless GaAs and CMOS Chip Sets

Instructor Biography

Dr. Rowan Gilmore, D.Sc., Adjunct Professor, University of Queensland, and former CEO and Managing Director at EM Solutions Pty Ltd, Australia

Dr. Gilmore was a pioneer in developing and applying harmonic balance analysis to RF and microwave circuit design, enabling for the first time the accurate modeling of non-linear behaviour in microwave circuits. While Vice President of Engineering with Compact Software, he led the introduction of Microwave Harmonica, the world's first commercial simulator applicable to the nonlinear design of microwave and RF circuits, and that is now commonplace in designers' toolkits.

Dr. Gilmore gained his RF circuit and systems experience over a number of years at Schlumberger 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 (now part of France Telecom's Orange Network), where he worked with a number of airlines and multinationals on their data telecommunications and IT needs. He has been CEO of EM Solutions since 2011, where he leads an award-winning team of engineers who are involved in the design of multi-band, high power receivers, transmitters, and mobile terminals used in satellite communications systems sold around the world.

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. With Dr. Les Besser, he is co-author of the widely read two-volume textbook Practical RF Circuit Design for Modern Wireless Systems. He is a Fellow of the Australian Academy of Technological Scientists and Engineers.

Dr. Gilmore has been a member of the Continuing Education Institute-Europe faculty since 1995.

Publications:

Dr. Rowan Gilmore and his colleague Dr. Les Besser have written two books that they recommend, however, the books are not compulsory for the course:

Publisher: Artech House

Title: **Practical RF Circuit Design for Modern Wireless Systems**

Volume I: Passive Circuits and Systems. ISBN 1-58053-521-6 (2003)

Title: **Practical RF Circuit Design for Modern Wireless Systems**

Volume II: Active Circuits and Systems. ISBN 1-58053-522-4 (2003)

Students may order the books over the Artech House website, https://us.artechhouse.com/ and receive a 15% discount by entering the promotion code "CEI" in the online order form.