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RF and Microwave Circuit Design: Theory and Applications

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Barcelona (Spain)



RF and Microwave Circuit Design: Theory and Applications

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Course Introduction

Radio frequency and microwave circuit design is a specialized field that supports modern communication, radar, aerospace, defense, satellite, sensing, navigation, wireless, and electronic systems. As operating frequencies increase, conventional low-frequency circuit assumptions become less reliable. Interconnections begin to behave as transmission lines, component parasitics become significant, impedance matching becomes essential, and electromagnetic interaction can strongly affect circuit performance.

Designing circuits in the radio frequency and microwave range requires a clear understanding of both theory and practical implementation. Engineers must be able to analyze signal behavior, manage reflections, control losses, select suitable components, and evaluate the effect of layout, materials, packaging, and manufacturing tolerances. A design that performs correctly in simulation may still fail during testing when these physical factors are not properly considered.

Organizations often encounter challenges such as poor impedance matching, excessive insertion loss, unstable amplifiers, weak noise performance, unwanted coupling, limited bandwidth, and inconsistent results between prototypes. These problems can delay development, increase redesign costs, and reduce the reliability of communication and sensing systems. They may also affect regulatory compliance, electromagnetic compatibility, power efficiency, and overall system performance.

The RF and Microwave Circuit Design: Theory and Applications course provides a structured understanding of the principles, methods, and practical considerations required to design high-frequency circuits. It begins with wave behavior and transmission-line theory before progressing to impedance matching, network parameters, passive circuits, active devices, amplifiers, oscillators, mixers, filters, and measurement techniques.

Participants will learn how to work with complex impedance, reflection coefficients, standing waves, scattering parameters, and graphical design tools. They will explore how these concepts are used to evaluate circuit behavior and develop matching networks for different bandwidth and performance requirements. The course also examines the role of microstrip, stripline, coaxial structures, waveguides, and substrate properties in high-frequency circuit implementation.

A major focus is placed on connecting theory with engineering practice. Participants will analyze circuit performance, interpret simulation and measurement results, identify common sources of error, and apply systematic troubleshooting methods. Attention is also given to stability, gain, noise figure, linearity, power handling, thermal effects, grounding, shielding, and electromagnetic coupling.



The course is relevant to RF engineers, microwave engineers, electronics designers, communication specialists, radar and antenna teams, test engineers, researchers, technical managers, and professionals working in telecommunications, aerospace, defense, satellite systems, industrial electronics, automotive technology, and advanced manufacturing. It helps participants make stronger design decisions, improve circuit performance, reduce development risk, and build a more reliable connection between theoretical analysis and practical implementation.

Course Objectives

By the end of this course, participants will be able to:

- Explain the fundamental behavior of signals at radio and microwave frequencies.
- Distinguish between low-frequency and distributed circuit behavior.
- Analyze transmission lines using characteristic impedance and propagation concepts.
- Calculate reflection coefficient, return loss, standing-wave ratio, and delivered power.
- Interpret impedance and admittance using graphical and analytical methods.
- Apply scattering parameters to two-port and multiport networks.
- Design impedance-matching networks for different circuit conditions.
- Evaluate microstrip, stripline, coaxial, and waveguide transmission structures.
- Analyze passive RF and microwave components.
- Assess amplifier gain, stability, noise, and linearity.
- Understand the operating principles of oscillators, mixers, and frequency converters.
- Design and evaluate RF and microwave filter structures.
- Identify layout, grounding, shielding, and packaging effects.
- Select suitable measurement instruments and calibration methods.
- Diagnose common circuit design and implementation problems.
- Develop a practical RF or microwave circuit design and validation plan.

Course Modules

Day 1: RF and Microwave Fundamentals

- Radio frequency and microwave spectrum.
- Wavelength, frequency, phase, and propagation velocity.
- Lumped and distributed circuit models.
- Complex impedance and admittance.
- Electromagnetic wave behavior.
- Power flow in high-frequency circuits.
- Component parasitic effects.
- Resonance and quality factor.
- Loss mechanisms at high frequencies.
- Skin effect and conductor losses.
- Dielectric properties and losses.
- High-frequency design workflow.



Day 2: Transmission Lines and Impedance Matching

- Transmission-line equations.
- Characteristic impedance.
- Propagation constant.
- Incident and reflected waves.
- Reflection coefficient.
- Return loss and mismatch loss.
- Voltage standing-wave ratio.
- Input impedance of transmission lines.
- Quarter-wave transformers.
- Single- and double-stub matching.
- Graphical impedance-matching techniques.
- Broadband matching considerations.

Day 3: Network Analysis and Passive Circuit Design

- Two-port network concepts.
- Scattering parameter definitions.
- S-parameter measurement and interpretation.
- Gain and loss calculations.
- Reciprocity and symmetry.
- Cascaded network analysis.
- Microstrip and stripline structures.
- Couplers and power dividers.
- Attenuators and phase shifters.
- Resonators and cavities.
- RF and microwave filter principles.
- Passive component selection.

Day 4: Active RF and Microwave Circuits

- High-frequency transistor models.
- Biasing of active devices.
- Small-signal amplifier design.
- Power gain definitions.
- Stability factors and stability circles.
- Input and output matching.
- Noise figure and noise parameters.
- Low-noise amplifier principles.
- Power amplifier operation.
- Linearity and intermodulation.
- Oscillator design principles.
- Mixer and frequency-conversion fundamentals.



Day 5: Implementation, Measurement, and Practical Design

- Printed circuit board material selection.
- RF layout and routing practices.
- Grounding and return-current paths.
- Shielding and isolation techniques.
- Connector and transition design.
- Packaging and enclosure effects.
- Thermal management.
- Vector network analyzer operation.
- Spectrum and signal analysis.
- Calibration and de-embedding.
- Practical circuit design and simulation exercise.
- Design verification and improvement plan.

Why Should You Attend This Course?

- Build a strong foundation in RF and microwave circuit theory.
- Understand why high-frequency circuits behave differently from low-frequency designs.
- Improve impedance-matching and power-transfer performance.
- Interpret S-parameters with greater confidence.
- Design passive and active high-frequency circuits more effectively.
- Reduce losses, instability, noise, and unwanted reflections.
- Improve amplifier, filter, oscillator, and mixer performance.
- Recognize layout and packaging issues before prototype testing.
- Apply measurement and calibration techniques correctly.
- Troubleshoot differences between simulation and practical results.
- Reduce redesign time and development cost.
- Strengthen technical decision-making in communication and microwave projects.

Course Conclusion

RF and microwave circuit design requires a combination of electromagnetic theory, circuit analysis, practical implementation, and accurate measurement. At high frequencies, physical dimensions, material properties, transmission effects, and component parasitics can influence performance as strongly as the circuit schematic itself.

This course gives participants a structured understanding of transmission lines, impedance matching, network parameters, passive components, active circuits, and measurement methods. It also develops their ability to interpret circuit behavior, assess design trade-offs, and identify the causes of poor performance.

The course outcomes can be applied in the development of communication equipment, radar systems, satellite electronics, wireless devices, sensing platforms, and industrial high-frequency applications. Participants will be able to improve matching networks, evaluate component choices, refine layouts, and verify designs using appropriate laboratory techniques.



Over the long term, these capabilities help organizations improve product reliability, shorten development cycles, and reduce technical risk. They also strengthen the link between theoretical design, simulation, prototyping, testing, and final system performance.

