

**Advanced RF  
Measurements  
Course Code: EE-940**

**Course Description**

This course focuses on RF and microwave measurements. In particular, a strong emphasis is placed on device characterization and validation. Another purpose of this course is to enable the student to understand the measurement techniques and calibration, standard models and errors analysis. The spectrum analyzers and vector network analyzers will be discussed, and their working mechanism will be highlighted. At the conclusion of the course, the student should be able to successfully perform the electrical measurements of active and passive networks and have hands-on experience of working in measurement laboratories.

**Text Book:**

1. Fundamentals of Vector Network Analysis by Michael Hiebel, Edition 1, Rohde & Schwarz GmbH & Co., ISBN- 978-3939837060
2. Vector Network Analyzer (VNA) Measurements and Uncertainty Assessment by Noshewan Shoaib, Edition 1, Springer International Publishing, ISBN- 978-3-319-44772-8
3. Modern RF and Microwave Measurement Techniques by Valeria Teppati, Andrea Ferrero and Mohamed Sayed, Edition 1, Cambridge University Press, ISBN- 978-1107036413

**Reference Book:**

1. Microwave Engineering by David M. Pozar, Edition 1, Wiley, ISBN: 978-1-118-29813-8
2. "Spectrum Analyzer Basics", Application Note 150, Agilent Technologies

**Prerequisites**

NA

**ASSESSMENT SYSTEM**

Quizzes	10%
Assignments	10%
Mid Terms	30%
Project	10%
ESE	40%

**Teaching Plan**

Week No	Topics	Learning Outcomes
1	Introduction	Course Outline, objectives, teaching plan, assessment method, concepts review

2-6	Spectrum Analyzers	<p>Spectrum Analyzers</p> <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Architecture of a Spectrum Analyzer</li> <li><input type="checkbox"/> RF Attenuator</li> <li><input type="checkbox"/> Low Pass Filter or Pre-selector</li> <li><input type="checkbox"/> IF Gain</li> <li><input type="checkbox"/> Signal Resolution</li> <li><input type="checkbox"/> Detector Types</li> <li><input type="checkbox"/> Averaging Processes</li> <li><input type="checkbox"/> Digital Filters</li> <li><input type="checkbox"/> Resolution Bandwidth/IF Bandwidth</li> <li>• Sensitivity and Noise</li> <li>• Dynamic Range</li> <li>• Modern Signal Analyzers</li> <li>• Measurement Laboratory</li> </ul>
7-8	Network Analyzers	<p>Network Analyzers</p> <ul style="list-style-type: none"> <li>• Scalar network analyzer</li> <li>• Vector network analyzer</li> <li>• Architecture of a Vector network analyzer</li> <li>• Test Set and Generator</li> </ul>
9	<b>MID TERM EXAM</b>	
10-12	Network Analyzers, Measurement Accuracy and Calibration	<p>Network Analyzers</p> <ul style="list-style-type: none"> <li>• Architecture of a Vector network analyzer</li> <li>• Reference and Measurement Receiver</li> <li>• Measurement Procedure</li> </ul> <p>Measurement Accuracy and Calibration</p> <ul style="list-style-type: none"> <li>• Systematic Measurement Errors</li> <li>• Random Measurement Errors</li> <li>• Thermal Drift</li> <li>• Noise</li> <li>• Repeatability</li> <li>• Calibration Standards</li> <li>• Coaxial Calibration Standards</li> <li>• Waveguide Calibration Standards</li> <li>• Microstrip Calibration Standards</li> <li>• Cable and connector repeatability</li> <li>• Linear Error Models and Calibration Techniques</li> <li>• 3-term VNA Error Model</li> <li>• 7-term VNA Error Model</li> <li>• Different Calibration Techniques</li> <li>• TRL, LRM, LRRM, SOLT</li> <li>• Practical Hints for Calibration</li> </ul>

13-17	<p>Measurement Accuracy and Calibration, Usage of Anechoic Chamber for Antenna Measurements, On-wafer Chip Measurements</p>	<p>Measurement Accuracy and Calibration</p> <ul style="list-style-type: none"> <li>• De-embedding techniques</li> <li><input type="checkbox"/> Two port de-embedding</li> <li><input type="checkbox"/> TRL based de-embedding</li> <li>• Non-linear Vector Network Analyzer</li> <li><input type="checkbox"/> X-Parameters</li> <li>• Measurement Uncertainty</li> </ul> <p>Usage of Anechoic Chamber for Antenna Measurements</p> <ul style="list-style-type: none"> <li>• Anechoic Chamber Design Characteristics</li> <li>• Absorbing Material Shapes and Characteristics</li> <li>• Quiet zone of an anechoic chamber</li> <li>• Compact Range</li> <li>• Antenna Measurements</li> </ul> <p>On-wafer Chip Measurements</p> <ul style="list-style-type: none"> <li>• Microwave Probes</li> <li>• Probe Station Essentials</li> <li>• Probe Tip Calibration</li> <li>• Impedance Standard Substrates (ISS)</li> </ul>
18	<p><b>End Semester Exams</b></p>	

