# EE 481/481L: *Microwave Engineering*

**CATALOG DATA:**

**EE 481/481L Antennas for Wireless Communications** (3-1) 4 credits. Prerequisite: EE 382. Presentation of basic principles, characteristics, and applications of microwave devices and systems. Development of techniques for analysis and design of microwave circuits. Students enrolled in EE 581/581L will be held to a higher standard than those enrolled in EE 481/481L.

**TEXTBOOK:**

*Microwave Engineering* (Fourth Edition), Pozar, Wiley, 2012, ISBN 978-0-470-63155-3.

**COORDINATOR:**

Dr. Thomas P. Montoya, Associate Professor

**GOALS:**

The objective of this course is to introduce students to the basic concepts of microwave engineering as well as some design, measurement, and theory.

**CLASS SCHEDULE:**

Lecture: 3 hours per week.
Laboratory: scheduled weekly lab.

**TOPICS:**

1. Electromagnetic Theory
    a. Maxwell's equations
    b. Fields in media and complex permittivity & loss tangent
    c. Electric and magnetic boundary conditions
    d. Wave propagation in lossless and lossy media
2. Transmission Line Theory
    a. Lumped-element circuit model & Telegrapher equations
    b. Lossy & lossless transmission lines (frequency-domain)
    c. Lossless transmission line circuits (frequency-domain)
    d. Smith Charts
3. Impedance Matching and Tuning
    a. Lumped-element matching
    b. L-networks
    c. Single-stub tuning
    d. Quarter-wave transformers
4. Transmission Lines and Waveguides
    a. Rectangular Waveguides
    b. Stripline
    c. Microstrip
5. Microwave Network Analysis
    a. Impedance ($Z$) and admittance ($Y$) matrices

   b. Scattering (*S*-) parameters and matrices
   c. *S*-parameter properties
   d. Shifting reference planes
   e. Generalized *S*-parameters
   f. Transmission (*ABCD*) matrices
   g. Vector network analyzers (VNA)
6. Power Dividers and Directional Couplers
   a. Basic properties of dividers and couplers
   b. T-junction and resistive power dividers
   c. Wilkinson power divider
   d. Quadrature (90°) Hybrid
   e. 180° Hybrid
   f. coupled line directional couplers
   g. Lange directional couplers
7. Microwave Filters
   a. Insertion loss method
   b. Impedance & frequency scaling
   c. Filter transformations
   d. Stepped-impedance low-pass filters
   e. Kuroda's Identities and filter implementation using stubs

**COMPUTER USAGE:**

As part of the coursework, we will use several programs including MATLAB, MathCad, MS Excel, ... to design, analyze, and present data and/or measurements.

**Course Learning Outcomes (CLOs) for Lecture**

Upon completion of this course, students should demonstrate the ability to:

A. Analyze basic transmission line circuits, e.g., compute quantities as reflection coefficients, standing wave ratio, impedance, power, etcetera.
B. Use the Smith chart for basic transmission line calculations.
C. Design and analyze transmission line matching devices including lumped elements, *L*-networks, stub tuners, and quarter-wave transformers.
D. Understand, analyze, and/or design simple transmission lines and rectangular waveguides.
E. Understand and use two-port parameter models (e.g., *Z*, *Y*, *ABCD* and *S*) of simple circuit elements to analyze microwave circuits.
F. Use signal flow graphs to represent simple microwave circuits and solve for quantities of interest, such as reflection coefficients.
G. Design and analyze microwave power dividers (T-junction and Wilkinson) and hybrids (90° and 180°) ~~constructed from printed microstrip~~.
H. Design and analyze coupled line and Lange microwave couplers ~~constructed from printed microstrip~~.
I. Design and analyze microwave filters ~~constructed from printed microstrip~~.

**Course Learning Outcomes (CLOs) for Laboratory**

Upon completion of this course, students should demonstrate the ability to:

A. Be able to calibrate and operate a vector network analyzer including making proper microwave-cable connections using torque wrenches.

B. Find and/or estimate key parameters for lossy transmission lines using datasheets as well as measurements. ~~Make proper microwave-cable connections using torque wrenches~~.

C. Design, analyze, and/or fabricate simple microstrip circuits.

D. Measure the response of simple passive microwave circuits/devices using a vector network analyzer.

E. Properly document and report results of experimental/laboratory work.

**Relation of CLOs to Student Outcomes (SOs)**

Student Outcomes are defined in ABET's accreditation standards for engineering programs:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

The following tables indicates the relative strengths of each course objective in addressing the program's student outcomes listed above (on a scale of 0 to 4 where 4 indicates a strong emphasis)

Lecture

| SO / CLO | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| A | 4 | | | | | | |
| B | 4 | | | | | | |
| C | 4 | 2 | | | | | |
| D | 4 | 2 | | | | | |
| E | 4 | | | | | | |
| F | 4 | | | | | | |
| G | 4 | 2 | | | | | |
| H | 4 | 2 | | | | | |
| I | 4 | 2 | | | | | |

Laboratory

| SO / CLO | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| A | | | | | | 4 | |
| B | 3 | | | | 2 | 4 | 2 |
| C | 4 | | | | 2 | 4 | |
| D | | | | | 2 | 4 | |
| E | | | 3 | | 2 | 3 | |

**PREPARED BY:**

Thomas P. Montoya, Date: January 6, 2019
Revised Thomas P. Montoya, Date: September 6, 2024; August 19, 2025.