COURSE NUMBER: CE2730

COURSE TITLE: RF Transmission & Antennas

COURSE DESCRIPTION:

This course provides a comprehensive study of the basic principles of electromagnetic wave propagation as they are applied to transmission lines, waveguides, and antennas with applications in wired and wireless communications systems.

PREREQUISITES:
MA1101 – Mathematics
MP2140 **–** Circuit Analysis I **OR**
ET2100 – Electrotechnology **OR**
ET1151 – Circuit Analysis II **Qatar only**

CO-REQUISITES: None

CREDIT VALUE: Four (4)

COURSE HOURS PER WEEK: Three (3)

LAB HOURS PER WEEK: Two (2)

SUGGESTED TEXT:

Beasley, J., & Miller, G.M. (2007). *Modern electronic communication* (9^{th} ed.). Prentice Hall.
ISBN 13: 978-0132251136

LEARNING RESOURCES: To be determined by instructor

MAJOR TOPICS:

1.0 Fundamentals of Electromagnetic Wave Propagation
2.0 Transmission Line Analysis
3.0 Smith Chart Applications
4.0 Waveguide
5.0 Antenna Analysis and Design
6.0 Radio Wave Propagation

LEARNING OBJECTIVES:

The expected learning outcomes are that the learner will be able to:

1.0 Fundamentals of Electromagnetic Wave Propagation

1.1 Static Fields

- 1.1.1 Draw the electric field between charges
- 1.1.2 Define electric field strength
- 1.1.3 Calculate electric field strength
- 1.1.4 Illustrate the magnetic field surrounding a current-carrying conductor
- 1.1.5 Define magnetic field strength
- 1.1.6 Calculate magnetic field strength

1.2 Medium Properties

- 1.2.1 Discuss electric flux density and material permittivity
- 1.2.2 Discuss magnetic flux density and material permeability
- 1.2.3 Explain how the velocity of propagation changes due to dielectric properties of the medium
- 1.2.4 Calculate the approximate velocity of propagation given a specific dielectric constant
- 1.2.5 Calculate the wavelength of an electromagnetic wave propagating in various media

1.3 Plane Wave Propagation

- 1.3.1 Define a free space and calculate intrinsic impedance
- 1.3.2 Illustrate plane wave propagation in free space
- 1.3.3 Explain the concept of an "isotropic" radiator
- 1.3.4 Calculate the power density at a given distance from an isotropic radiator
- 1.3.5 Illustrate TEM wave propagation

2.0 Transmission Line Analysis

2.1 Transmission Line Descriptions

- 2.1.1 Identify the following types of transmission lines: open wire, twin lead, coaxial, unshielded twisted pair (UTP), shielded twisted pair (STP), ribbon cable, microstrip, and stripline
- 2.1.2 Describe balanced cable lines
- 2.1.3 Describe unbalanced cable lines
- 2.1.4 Describe microstrip lines
- 2.1.5 Describe striplines
- 2.1.6 Sketch a distributed model of a transmission line
- 2.1.7 Describe the loss mechanisms within a transmission line

2.2 Transmission Line Operation

- 2.2.1 Describe the transient operation of energy on a transmission line
- 2.2.2 Evaluate the transmission line equations from the distributed model
- 2.2.3 Illustrate sinusoidal traveling waves
- 2.2.4 Illustrate the reflection characteristics of open lines, shorted lines, and loaded lines

2.2.5 Calculate transmission line parameters for characteristic impedance, propagation coefficient, propagation velocity, and wavelength on the line
2.2.6 Calculate microstrip characteristic impedance and effective dielectric constant
2.2.7 Calculate stripline characteristic impedance and effective dielectric constant
2.2.8 Calculate reflection coefficients of a transmission line
2.2.9 Calculate the voltage standing wave ratio (VSWR) for a given load
2.2.10 Illustrate voltage and current relationships at any point along a transmission line

2.3 Reactive Properties of Transmission Line Sections
2.3.1 Calculate the impedance characteristics of an open line
2.3.2 Calculate the impedance characteristics of a shorted line
2.3.3 Calculate the impedance of a loaded line of arbitrary length
2.3.4 Calculate the impedance of a loaded line at any distance from the load toward the source using transmission line equations
2.3.5 Discuss the impedance transformation characteristics of quarter-wavelength and half-wavelength sections
2.3.6 Design quarter wavelength impedance matching transformers
2.3.7 Observe the effects of impedance matching on VSWR and reflection coefficient
2.3.8 Measure VSWR and reflection coefficient
2.3.9 Calculate RF impedance and admittance from measured parameters

3.0 Smith Chart Applications

3.1 Smith Chart Characteristics
3.1.1 Describe how the resistance circles and the reactance arcs of an impedance (Z) Smith chart represent the impedance at any point from a loaded line
3.1.2 Describe normalized impedances on a Smith chart
3.1.3 Observe the differences among the Z chart, the Y chart and the ZY chart
3.1.4 Calculate and plot normalized impedances and admittances
3.1.5 Observe corresponding values of VSWR, complex reflection coefficient, and impedance at any point from a load towards a generator

3.2 Impedance Transformation using the Smith Chart
3.2.1 Convert networks from series to parallel form
3.2.2 Determine line length required to convert between impedances or admittances
3.2.3 Determine the impedance or admittance at the end of a known length of loaded transmission line

3.3 Impedance Matching using the Smith Chart

3.3.1 Determine the series line length and series quarter-wavelength transformer impedance to match arbitrary impedances or admittances at a given frequency

3.3.2 Determine series line and shunt stub lengths to match arbitrary impedances or admittances at a given frequency

4.0 Waveguide

4.1 Introduction to Rectangular Waveguides

- 4.1.1 Explain why waveguides are used at high frequencies
- 4.1.2 Show the development of the waveguide principle from a parallel line principle
- 4.1.3 Describe loss mechanisms within a waveguide

4.2 Wave Propagation in Rectangular Waveguides

- 4.2.1 Show the geometric interpretation of waveguide propagation
- 4.2.2 Explain why a waveguide has a “cutoff wavelength”
- 4.2.3 Differentiate between “group velocity” and “phase velocity”

4.3 Rectangular Waveguide Modes

- 4.3.1 Illustrate the lower order TE and TM waveguide modes
- 4.3.2 Calculate, for a given mode, cutoff wavelength, guide wavelength, group and phase velocity, and wave impedance

4.4 Coupling Transmission Lines to Waveguides

- 4.4.1 Illustrate the methods used to couple lower order TE modes between coaxial lines and waveguides
- 4.4.2 Illustrate the methods used to couple lower order TM modes between coaxial lines and waveguides
- 4.4.3 Describe the use of waveguide shorts

4.5 Waveguide Components

- 4.5.1 Describe waveguide attenuators and phase shifters
- 4.5.2 Describe waveguide bends, twists, and junctions
- 4.5.3 Describe resonant waveguide structures
- 4.5.4 Describe the modes and fields in a circular waveguide
- 4.5.5 Illustrate and explain the operation of a waveguide rotary joint
- 4.5.6 Describe waveguide ferrite devices
- 4.5.7 Describe waveguide and coaxial cavities

4.6 Waveguide Measurements

- 4.6.1 Use slotted line to observe standing waves in waveguides
- 4.6.2 Measure load reflection coefficient
- 4.6.3 Observe the effects of impedance matching
- 4.6.4 Measure coupled RF power

5.0 Antenna Analysis and Design

5.1 The Antenna as a Transducer
- 5.1.1 Explain the antenna as a transducer for electric current
- 5.1.2 Explain the concept of an “isotropic” radiator
- 5.1.3 Explain “antenna reciprocity”
- 5.1.4 Explain “near and far fields”

5.2 Antenna Parameters
- 5.2.1 Explain antenna gain, beamwidth, bandwidth, impedance, efficiency, and aperture
- 5.2.2 Plot antenna parameters as a function of frequency and geometry
- 5.2.3 Determine antenna gain and beam width from various antenna plots
- 5.2.4 Measure antenna gain and beam width

5.3 Elementary Antennas
- 5.3.1 Describe the properties of a short dipole, a half-wave dipole (Hertz), and a quarter wavelength vertical antenna (Marconi)
- 5.3.2 Design elementary dipole and monopole antennas
- 5.3.3 Use computer software in simple antenna analysis

5.4 Arrays of Antenna Elements
- 5.4.1 Illustrate antenna array principles
- 5.4.2 Illustrate methods of interconnecting simple antennas to form an array
- 5.4.3 Illustrate the array response in comparison to that of the array element
- 5.4.4 Perform preliminary analysis of arrays with passive and active elements (Yagi, log-periodic, dipole arrays)
- 5.4.5 Design arrays with passive and active elements (Yagi, log-periodic, dipole arrays)
- 5.4.6 Calculate gains and beam widths of selected antenna arrays
- 5.4.7 Use computer software in simple array analysis and design

5.5 Planar Antennas
- 5.5.1 Illustrate radiation from a planar patch antenna
- 5.5.2 Use array analysis to obtain planar array response
- 5.5.3 Use computer software in planar antenna analysis

5.6 Horn and Parabolic Reflector Antennas
- 5.6.1 Illustrate radiation from the end of a waveguide
- 5.6.2 Show the effects of flaring a waveguide to form a radiating “horn” antenna
- 5.6.3 Calculate the gain and beam width of a horn antenna
- 5.6.4 Discuss a parabolic surface as a reflector of electromagnetic waves
- 5.6.5 Show a variety of feed mechanisms for reflector antennas
- 5.6.6 Calculate the gain and beam width of a reflector antenna

6.0 Radio Wave Propagation

6.1 Radiation from Conductor Surfaces
- 6.1.1 Explain electromagnetic radiation from a conductor surface
- 6.1.2 Explain the effect of the medium surrounding a conductor on radiation
- 6.1.3 Calculate propagation velocities of radio signals in different media

6.2 Reflection, Refraction, Diffraction of Electromagnetic Waves
- 6.2.1 Illustrate reflection of electromagnetic waves by smooth surfaces
- 6.2.2 Illustrate scattering of electromagnetic waves by rough surfaces
- 6.2.3 Illustrate diffraction of electromagnetic waves by obstacles in the propagation path
- 6.2.4 Illustrate refraction of electromagnetic waves by different propagation media
- 6.2.5 Measure reflection and diffraction effects over defined propagation paths

6.3 Space Wave Propagation
- 6.3.1 Differentiate between near field and far field effects
- 6.3.2 Illustrate free space propagation and calculate free space propagation loss
- 6.3.3 Illustrate ground wave propagation
- 6.3.4 Illustrate ionospheric propagation
- 6.3.5 Illustrate tropospheric effects
- 6.3.6 Measure free space loss between antennas
- 6.3.7 Calculate system losses and gains using appropriate equations
- 6.3.8 Calculate system received power with or without the fade margin considerations

EVALUATION:

Laboratories:	15%
Assignments:	10%
Tests and / or Quizzes:	30%
Final Exam:	45%

DATE DEVELOPED: November 1, 2002 **DATE REVIEWED:**

REVISION NUMBER: 4 **DATE REVISED:** January 2013

Note to instructor: Check PIRS to ensure this outline is the most current version