COURSE NUMBER: CE3110

COURSE TITLE: Wireless Communications Systems

COURSE DESCRIPTION:

This is an advanced electronic communications course focusing on modern wireless communication systems. It provides a background in radio wave propagation. A systems-level approach to the architecture, design, and operation of VHF and UHF mobile radio systems, cellular telephone systems, microwave and satellite-based communication systems is presented.

PREREQUISITES: CE2280 – Modulation & Encoding
CE2730 – RF Transmission & Antennas

CO-REQUISITES: None

CREDIT VALUE: Five (5)

COURSE HOURS PER WEEK: Four (4)

LAB HOURS PER WEEK: Three (3)

SUGGESTED TEXT:

Jajszczyk, A. (Ed). (2012). *A guide to the wireless engineering body of knowledge (WEBOK)* (2nd ed.). San Francisco, CA: Wiley-IEEE Press. ISBN-13: 978-1-1183-4357-9

LEARNING RESOURCES: To be determined by Instructor

MAJOR TOPICS:

1.0 Radio Wave Propagation
2.0 VHF Mobile Radio Communications Systems
3.0 UHF Mobile Radio Communications Systems
4.0 Cellular Telephone Systems
5.0 Microwave Communications Systems
6.0 Satellite Communications Systems

LEARNING OBJECTIVES:

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

1.0 Radio Wave Propagation

1.1 CCIR Frequency band designations
- 1.1.1 Identify the different frequency ranges associated with the band designations

1.2 Optical properties of radio waves
- 1.2.1 Apply the concept of refraction of light to the bending of a radio wave propagated through the atmosphere
- 1.2.2 Apply the concept of diffraction of light to the scattering of a radio wave around an obstruction
- 1.2.3 Apply the concept of reflection of light to a radio wave reflected from the surface of a body of water

1.3 Ionosphere Layering
- 1.3.1 Describe the D, E & F layers of the Ionosphere
- 1.3.2 Describe the effects of ionization density on radio waves

1.4 Propagation of Waves
- 1.4.1 Explain how a Ground Wave travels along the Earth's surface factoring in the importance of its polarization with respect to the ground
- 1.4.2 Describe how a Space Wave travels through the Earth's atmosphere
- 1.4.3 Explain how Space Wave is essential for line-of-sight microwave communications
- 1.4.4 Explain the problems with Sky Wave propagation
- 1.4.5 Explain how Sky Wave propagation is affected by Ionospheric conditions
- 1.4.6 Calculate the Critical frequency (f_c) limit for sky-wave propagation critical angle
- 1.4.7 Calculate the Critical angle (θ_c) for sky-wave refraction
- 1.4.8 Calculate the Virtual height above the Earth's surface where sky-wave refraction occurs

2.0 VHF Mobile Radio Communications Systems

2.1 VHF Frequency Band Allocation
- 2.1.1 Ascertain the frequencies allocated for use for mobile communications in the VHF band
- 2.1.2 Indicate the alphabetic designations of the frequencies ascertained in 2.1.1
- 2.1.3 Determine the limitations when designing a Mobile Communications System using a restricted number channels

2.2 Radio Propagation for Vehicular Communications
- 2.2.1 Evaluate appropriate site for mobile repeater operation based on learned criteria
- 2.2.2 Calculate receive signal levels for a mobile radio receiver over a path
- 2.2.3 Draw coverage pattern for a mobile repeater operation using topographic maps for Circuit Merit 3 quality
- 2.2.4 Calculate shadow loss on a mobile path using the appropriate graphical

analysis

2.3 Radio Frequency Interference
- 2.3.1 Evaluate the criteria for selection of frequency assignments in the VHF band:
  - 2.3.1.1 Co-channel
  - 2.3.1.2 Adjacent channel
  - 2.3.1.3 Category and nature of service
  - 2.3.1.4 Potential interference
- 2.3.2 Calculate the Intermodulation Products resulting from the mixing of several VHF frequencies
- 2.3.3 Identify which products will cause interference and approximate signal levels
- 2.3.4 Select the applicable Governmental Regulatory practices and license forms for submission of a proposed VHF Mobile Communications System

2.4 Receiver Specifications
- 2.4.1 Identify the sources of noise in a VHF Mobile Communications System
- 2.4.2 Determine the selectivity of a receiver
- 2.4.3 Determine how the selectivity controls the problem of intermodulation and adjacent channel interference
- 2.4.4 Determine the sensitivity of a receiver
- 2.4.5 Determine how a receiver becomes desensitized
- 2.4.6 Describe the effect of sensitivity on a VHF Mobile Communications System
- 2.4.7 Describe the significance of a Signal to Noise Ratio (S/N or SNR) in a receiver specification

2.5 Application of Cavity Filters and Duplexers
- 2.5.1 Explain the theory of operation of cavity filters and duplexers
- 2.5.2 Design a Mobile Communications System design to control or eliminate interference problems by incorporating cavity filters and duplexers
- 2.5.3 Interpret specifications from attenuation graphs through references to applicable product catalogues

2.6 Selections of Antenna Configurations
- 2.6.1 Determine antenna type to be used in the design of a VHF Mobile Communications System using the applicable product information catalogues. Specifications should include the following criteria:
  - 2.6.1.1 Gain
  - 2.6.1.2 Front/back ratio
  - 2.6.1.3 Number of dipoles
  - 2.6.1.4 Directivity
- 2.6.2 Plan an antenna arrangement based on system requirements and design

criteria

2.6.2.1 Develop an antenna arrangement using separate transmit & receive antennas

2.6.2.2 Develop an antenna arrangement using combined transmit & receive antennas

2.6.3 Draw an antenna and tower schematic showing Plan Views, Elevation Views and Block diagrams of various antenna configurations. These should include the following details:

2.6.3.1 Gain
2.6.3.2 Azimuths
2.6.3.3 Elevations
2.6.3.4 Antenna type
2.6.3.5 Separate transmit and receive configuration
2.6.3.6 Waveguide losses
2.6.3.7 Connector losses
2.6.3.8 Frequency assignments
2.6.3.9 Cavity filters and notch filters
2.6.3.10 Duplexers and Multicouplers

2.7 Basic Mobile System Operation

2.7.1 Explain the various methods of calling patterns

2.7.2 Explain how these types of calls can be designed to fit into a coherent communications system. These patterns should include such call types as:

2.7.2.1 Mobile to mobile calls
2.7.2.2 Repeater talk around
2.7.2.3 Trunked repeater talk around
2.7.2.4 Mobile to network calls
2.7.2.5 Network to mobile calls

2.7.3 Determine based upon availability of channel assignments the different calling modes to implement the different calling patterns. These modes should include such types as:

2.7.3.1 Simplex mode
2.7.3.2 Half-duplex mode
2.7.3.3 Full duplex mode

3.0 UHF Mobile Radio Communications Systems

3.1 UHF Frequency Band Allocations

3.1.1 Determine the frequencies allocated for use for mobile communications in the UHF band (450 MHz)

3.1.2 Determine the alphabetic designations of the frequencies determined in 3.1.1

3.1.3 Contrast the design of a Mobile Communications System using the UHF Band versus the VHF Band

3.2 Radio Propagation in the UHF Band
- 3.2.1 Draw the coverage pattern for a mobile repeater operation in the UHF band using topographic maps for Circuit Merit 3 quality
- 3.2.2 Calculate shadow loss on a mobile path using the appropriate graphical analysis

3.3 Comparison of Mobile Radio Transmission in the 150 MHz and 450 MHz Bands
- 3.3.1 Discuss the advantages and disadvantages of Mobile Radio System designs in the VHF and UHF Bands

4.0 Cellular Telephone Systems

4.1 Concept of Cell Patterns and Propagation
- 4.1.1 Explain the concept of cell based coverage structures
- 4.1.2 Allocate frequency assignments to a cell according to governmental regulatory practices
- 4.1.3 Design a cell system layout using frequency assignment and frequency re-use
- 4.1.4 Split an existing cellular layout and subdivide the associated frequency allocation
- 4.1.5 Compare the basic cell plans and their antenna configurations
- 4.1.6 Explain the concept of reducing a cell's coverage area to increase system capacity using:
  - 4.1.6.1 Transmit power
  - 4.1.6.2 Low Noise Amplifier (LNA) gain
  - 4.1.6.3 Antenna gain
  - 4.1.6.4 Beamwidth
  - 4.1.6.5 Downtilt
- 4.1.7 Compare propagation and coverage of cellular systems to previous types of mobile systems

4.2 Evolution of Modern Cellular Systems
- 4.2.1 Describe the evolution cellular service from an analog-based 1G system to an all-IP Enhanced Packet Core (EPC) in 4G networks
- 4.2.2 Describe the use of multiple access technologies in the evolution of cellular systems including:
  - 4.2.2.1 Time Division Multiple Access (TDMA)
  - 4.2.2.2 Frequency-Division Multiple Access (FDMA)
  - 4.2.2.3 Code Division Multiple Access (CDMA)
  - 4.2.2.4 Wideband Code Division Multiple Access (W-CDMA)
  - 4.2.2.5 Orthogonal Frequency Division Multiple Access (OFDMA)
- 4.2.3 Explain the methods used to increase achievable data rates in successive generations of cellular systems

4.2.4 Compare the spectrum allocation in successive generations of cellular systems

4.3 Basic cellular operation & call progression
- 4.3.1 Describe location management in cellular networks
- 4.3.2 Describe authentication and encryption mechanisms in cellular networks
- 4.3.3 Describe how incoming and outgoing calls are processed
- 4.3.4 Describe cell hand-off strategies
- 4.3.5 Describe roaming in cellular networks

4.4 System Architecture and Interfaces
- 4.4.1 Describe the main functional components of modern cellular networks
- 4.4.2 Describe the interfaces between functional components

5.0 Microwave Communications Systems

5.1 Fresnel Zones
- 5.1.1 Derive the concept of Fresnel Zones
- 5.1.2 Explain how the Freznel Zones concept is used to analyze a Line of Sight Microwave Path
- 5.1.3 Explain the effect of terrain on a Microwave Radio Beam using the Fresnel Zones and its associated attenuation curves
- 5.1.4 Explain the difference between knife edge diffraction and smooth sphere diffraction
- 5.1.5 Explain the attenuation caused the following diffractions:
  - 5.1.5.1 Knife edge
  - 5.1.5.2 Smooth sphere

5.2 Atmospheric Refraction
- 5.2.1 Determine the environment factors which affect a Microwave Radio Beam.
- 5.2.2 Interpret the applicable Communications Research Centre documents to obtain the factors affecting a microwave radio beam
  - 5.2.2.1 Tropospheric Refractivity Atlas for Canada (K values)
  - 5.2.2.2 Rain Attenuation Statistics for Terrestrial Microwave Links in Canada
- 5.2.3 Describe the effect of the earth's atmosphere on a microwave radio beam
- 5.2.4 Discuss the effect of seasonal changes influencing a line of sight path design

5.3 Free Space Propagation
- 5.3.1 Derive the formula to calculate the loss of a microwave beam as it travels through free space

5.4 Establishing Performance Objectives

5.4.1 Calculate the propagation reliability of a Microwave Path based on Fade Margin, Climate and Terrain factors
5.4.2 Evaluate the different established clearance criteria and determine which is suitable for Light Route and heavy Route microwave communications systems

5.5 Hypothetical Reference Circuit
5.5.1 Explain the component equipment making up the Hypothetical Design Circuit
5.5.2 Sketch the block diagram associated with the Hypothetical Design Circuit
5.5.3 Define the outage factors affecting unavailability in the Hypothetical Design Circuit
5.5.4 Calculate the outage in percent for a Hypothetical Design Circuit

5.6 Plotting Path Profiles from Topographic Maps
5.6.1 Locate sites appropriate for a single hop microwave system using a topographic map
5.6.2 Select a suitable path between two sites
5.6.3 Plot a ground profile between the two sites
5.6.4 Calculate the tower and antenna heights using Line of Sight clearance criteria for a Single hop microwave system

5.7 Design of Point-to Point Microwave Radio Systems
5.7.1 Construct a Path Data Sheet for a given system design by organizing all the system specifications in a tabular form, analyzing all relevant parameters and calculating fade margin and system reliability; using an iterative approach.
5.7.2 Analyze, with the aid of a schematic, all the elements required for a point-to-point microwave radio system design including:
5.7.2.1 Filters
5.7.2.2 Multiplexers
5.7.2.3 Isolators
5.7.2.4 Duplexers
5.7.2.5 Circulators

5.8 Frequency and Space Diversity Systems
5.8.1 Explain the rationale for the different diversity systems
5.8.2 Solve problems of surface reflection and reliability through the incorporation of a diversity protection system in a Microwave Radio path
5.8.3 Explain the Monitored Hot Standby diversity system

5.9 Surface Reflections and Passive Repeaters
5.9.1 Identify possible cases of surface reflection
5.9.2 Modify a system design to prevent reflected signal
5.9.3 Describe the operation of passive repeaters including:
5.9.3.1 Billboard type passive repeaters

5.9.3.2 Parabolic back-to-back antenna configuration

5.10 Power Requirements & Redundancy
- 5.10.1 Investigate power system requirements for radio Sites. This investigation should include the following:
  - 5.10.1.1 Battery bank configuration
  - 5.10.1.2 Generator systems
  - 5.10.1.3 UPS systems

5.11 Microwave Services
- 5.11.1 Compare analog, digital, and IP-based microwave systems
- 5.11.2 Compare WiMAX (IEEE 802.16) to equivalent IP cellular data services

6.0 Satellite Communications Systems

6.1 Orbital Satellites
- 6.1.1 Explain the difference between active and passive satellite
- 6.1.2 Contrast non-synchronous and synchronous satellites
- 6.1.3 Explain, through the use of illustrations, the following:
  - 6.1.3.1 Prograde
  - 6.1.3.2 Retrograde
  - 6.1.3.3 Apogee
  - 6.1.3.4 Perigee
- 6.1.4 Explain the characteristics of the following satellite orbits:
  - 6.1.4.1 Low altitude
  - 6.1.4.2 Medium altitude
  - 6.1.4.3 High altitude

6.2 Geostationary Satellites
- 6.2.1 Contrast the advantages and disadvantages of geosynchronous satellites

6.3 Orbital Patterns
- 6.3.1 Explain, through the use of illustrations, the following:
  - 6.3.1.1 Equatorial Orbit
  - 6.3.1.2 Polar Orbit
  - 6.3.1.3 Inclined Orbit

6.4 Look Angles
- 6.4.1 Explain, through the use of illustrations, the following:
  - 6.4.1.1 Look Angles
  - 6.4.1.2 Angle of Elevation
  - 6.4.1.3 Azimuth
- 6.4.2 Determine the azimuth and elevation angle given the longitude and latitude of an earth station, and longitude of the satellite

6.5 Orbital Spacing and Frequency Allocation
- 6.5.1 Explain the satellite spatial separation
- 6.5.2 Discuss restrictions associated with satellite spatial separation

6.6 Radiation Patterns
- 6.6.1 Explain and illustrate the following terms:
  - 6.6.1.1 Footprint
  - 6.6.1.2 Spot
  - 6.6.1.3 Earth coverage radiation pattern
- 6.6.2 Explain the purpose of reuse of frequency spectrum

6.7 Satellite System Link Models
- 6.7.1 Draw a block diagram for the following models:
  - 6.7.1.1 Satellite uplink
  - 6.7.1.2 Satellite transponder
  - 6.7.1.3 Satellite downlink
- 6.7.2 Explain the function of each block diagram in 6.7.1

6.8 Satellite System Parameters
- 6.8.1 Explain and illustrate the following:
  - 6.8.1.1 Bit energy
  - 6.8.1.2 Effective isotropic radiated power
  - 6.8.1.3 Equivalent noise temperature
  - 6.8.1.4 Noise density
  - 6.8.1.5 Carrier-to-noise density ratio
  - 6.8.1.6 Energy of bit to noise ratio
  - 6.8.1.7 Gain to equivalent noise temperature ratio

6.9 Satellite System Link Equation
- 6.9.1 Analyze the uplink and downlink sections of a single radio frequency carrier satellite system

6.10 Link Budget
- 6.10.1 Given the satellite system parameter, estimate the link budget

6.11 Frequency-Division Multiplexing/Frequency Modulation (FDM/FM) Satellite Systems
- 6.11.1 Discuss the drawbacks of using FDM/FM modulation for satellite multiple accessing systems
- 6.11.2 Contrast pre-assignment and demand assignment

6.12 Multiple Accessing
- 6.12.1 Explain through the use of illustrations the following:

6.12.1.1 FDMA
6.12.1.2 Single channel per carrier PCM multiple Access Demand assignment Equipment (SPADE) System

6.12.2 Draw a FDMA earth station transmitter
6.12.3 Compare the advantage of FDMA and TDMA

EVALUATION:

Laboratories:	15%
Assignments:	10%
Tests and/or Quizzes:	25%
Final Exam:	50%

DATE DEVELOPED: March 2012 **DATE REVIEWED:**

REVISION NUMBER: **DATE REVISED:**

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