COURSE NUMBER: CE2280

COURSE TITLE: Modulation and Encoding

COURSE DESCRIPTION:

This course is designed to provide learners with a foundation in the fundamental methods of modulating or encoding analog and digital signals for transmission over a modern communication system. The methods for the transmission of analog and digital signals across an analog medium are covered as well as the methods for transmitting analog and digital signals across a baseband digital medium. The impact of noise on these methods is also discussed.

PREREQUISITES: MA1101 – Mathematics
CI1110 – Signals & Measurement

CO-REQUISITES: AE2330 – Analog Electronics I or
AE2300 – Analog Electronics I

CREDIT VALUE: Five (5)

COURSE HOURS PER WEEK: Four (4)

LAB HOURS PER WEEK: Two (2)

SUGGESTED TEXT:

Beasley, J., & Miller, G. (2007). *Modern electronic communication* (9th ed.). Upper Saddle River, NJ: Pearson/Prentice Hall. ISBN-10: 0132251132; ISBN-13: 978-0-13-225113-6

LEARNING RESOURCES: To be determined by instructor

MAJOR TOPICS:

1.0 Introduction to Analog Communications
2.0 Amplitude Modulation (AM) and AM Systems
3.0 Single-Sideband Techniques
4.0 Frequency and Phase Modulation (FM and PM) Systems
5.0 Complex Modulation Systems and Modems
6.0 Noise Effects on Modulated Systems
7.0 Information, Error Detection and Coding
8.0 Digitization of Analog Signals

LEARNING OBJECTIVES:

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

1.0 Introduction to Analog Communications

1.1 The Elements of a Communication System
- 1.1.1 Define the practical need for electronic communications systems
- 1.1.2 Draw a block diagram of a communications system
- 1.1.3 Explain the main elements of a communication system
- 1.1.4 Explain the effects of noise on information flow in communications systems

1.2 Information – Continuous and Discrete
- 1.2.1 Define information
- 1.2.2 Distinguish between continuous and discrete information
- 1.2.3 Identify information sources and sinks

1.3 Radio Frequency Spectrum
- 1.3.1 Identify the bands within the radio frequency spectrum
- 1.3.2 Calculate the wavelength of a given frequency

1.4 Communication Channel Terminology
- 1.4.1 Define carrier
- 1.4.2 Compare baseband and broadband
- 1.4.3 Illustrate the difference between baseband and carrier operations and frequencies
- 1.4.4 Determine the bandwidth of a communications channel
- 1.4.5 Illustrate Adjacent Channel Interference (ACI)
- 1.4.6 Describe the use of filters to avoid ACI

1.5 Modulation and Multiplexing, Demodulation, and Demultiplexing
- 1.5.1 Compare modulation and multiplexing
- 1.5.2 Compare time division multiplexing (TDM) and frequency division multiplexing (FDM)
- 1.5.3 Compare demodulation and demultiplexing

1.6 Noise and Effects
- 1.6.1 Sources of Noise
  - 1.6.1.1 Identify five sources of noise in a radio receiver
  - 1.6.1.2 Calculate the thermal noise voltage in a receiver given bandwidth, impedance, and temperature values
  - 1.6.1.3 Define shot and thermal noise
  - 1.6.1.4 Define
    - 1.6.1.4.1 Noise factor
    - 1.6.1.4.2 Noise figure

1.6.1.4.3 Noise temperature

1.6.1.5 Calculate each of the elements noted in 1.6.1.4

1.6.2 Modeling the Effects of Noise
1.6.2.1 Draw the following associated with a cascaded system
1.6.2.1.1 An equivalent noise figure
1.6.2.1.2 A noise temperature model

1.6.2.2 Calculate the signal-to-noise ratio at different points in a radio receiver

2.0 Amplitude Modulation (AM) and AM Systems

2.1 Continuous AM Principles
2.1.1 Define amplitude modulation (AM)
2.1.2 Illustrate the trigonometric basis of AM
2.1.3 Calculate the modulation index of an AM signal
2.1.4 Define sidebands
2.1.5 Calculate the frequency and amplitude of sidebands
2.1.6 Illustrate the difference between frequency domain and time domain representations of an AM signal
2.1.7 Calculate the power distribution in an AM signal

2.2 Amplitude Shift Keying (ASK) Principles
2.2.1 Define amplitude shift keying (ASK)
2.2.2 Illustrate the algebraic basis for ASK
2.2.3 Calculate the modulation index of an ASK signal
2.2.4 Illustrate the difference in the frequency domain and time domain representations of an ASK signal vs. an AM signal

2.3 AM Radio Transmitters Circuits
2.3.1 High-level AM transmitter
2.3.1.1 Define high-level modulation
2.3.1.2 Draw a block diagram of a high level AM transmitter
2.3.1.3 Explain the function of each block

2.3.2 Low-level AM transmitter
2.3.2.1 Define low-level modulation
2.3.2.2 Draw a block diagram of a low-level AM transmitter
2.3.2.3 Explain the function of each block

2.3.3 Explain the importance of antenna impedance matching

2.4 AM Radio Receiver Circuits
2.4.1 Define sensitivity

2.4.2 Define selectivity
2.4.3 Explain the concept of a superheterodyne receiver
2.4.4 Single-conversion superheterodyne receiver
2.4.4.1 Draw a block diagram
2.4.4.2 Explain the function of each block
2.4.4.3 Define Intermediate Frequency
2.4.4.4 Calculate the Image Frequency

2.4.5 Dual conversion superheterodyne receiver
2.4.5.1 Draw a block diagram
2.4.5.2 List its advantages over a single-conversion receiver

2.4.6 Define automatic gain control stating why it is needed
2.4.7 Explain the operation of a diode detector in AM demodulation

2.5 ASK Modulators and Demodulators
2.5.1 Explain, through demonstration, the concepts of ASK modulators
2.5.2 Explain, through demonstration, the concepts of demodulators

3.0 Single-Sideband Techniques

3.1 Single Sideband (SSB) Signals
3.1.1 Explain the concept of an SSB signal
3.1.2 Compare SSB and Double Sideband (DSB) signals

3.2 Carrier Suppression
3.2.1 Draw a circuit diagram of a balanced modulator
3.2.2 Explain how a balanced modulator functions to produce a Double Sideband – Suppressed Carrier (DSB-SC) signal

3.3 SSB Generation Methods and Circuits
3.3.1 Filter method of SSB generation
3.3.1.1 Draw a block diagram
3.3.1.2 Explain its operation

3.3.2 Phase Method of SSB Generation
3.3.2.1 Draw a block diagram
3.3.2.2 Explain its operation

3.4 Vestigial Sideband Transmission
3.4.1 Explain the vestigial sideband technique
3.4.2 Illustrate applications of vestigial sideband transmission

3.5 SSB and VSB Demodulation and Circuits
3.5.1 Draw a block diagram of SSB demodulator
3.5.2 Explain the SSB demodulation process

3.5.3 Compare coherent and non-coherent SSB receivers
3.5.4 Explain the need for a clarifier in non-coherent SSB receivers

4.0 Frequency and Phase Modulation (FM and PM) Systems

4.1 Continuous Frequency Modulation (FM) Principles
- 4.1.1 Define *angle modulation*
- 4.1.2 Explain the concepts of frequency modulation using mathematics
- 4.1.3 Calculate the modulation index of FM signals
- 4.1.4 Analyse an FM signal using Bessel functions for the following attributes:
  - 4.1.4.1 Bandwidth
  - 4.1.4.2 Modulation index
  - 4.1.4.3 Sideband
  - 4.1.4.4 Carrier amplitudes
- 4.1.5 Analyse an FM signal using spectrum analyzers for the attributes noted in 4.1.4
- 4.1.6 Illustrate the frequency spectrum of a carrier and sideband amplitudes of an FM signal
- 4.1.7 Illustrate the time domain of an FM signal
- 4.1.8 Calculate the total power in an FM signal

4.2 FSK Principles
- 4.2.1 Define frequency shift keying
- 4.2.2 Illustrate the algebraic basis for FSK
- 4.2.3 Calculate the modulation index of an FSK signal
- 4.2.4 Illustrate the difference in the frequency domain and time domain representations of an FSK signal vs. an FM signal

4.3 FM Transmitter Circuits
- 4.3.1 Draw a block diagram of an FM transmitter
- 4.3.2 Explain Class C tuned amplifiers and multipliers in FM transmitters
- 4.3.3 Explain voltage controlled oscillators in FM transmitters
- 4.3.4 Explain crystal controlled oscillators in FM transmitters
- 4.3.5 Explain the use of mixers in FM transmitters
- 4.3.6 Explain the function of Automatic Frequency Control (AFC) in FM transmitters

4.4 FM Receivers Circuits
- 4.4.1 Draw a block diagram of an FM receiver
- 4.4.2 Differentiate the circuits used in FM receivers from those used in AM
- 4.4.3 Explain the need for limiting amplifiers in FM
- 4.4.4 Explain the operation of limiting amplifiers in FM
- 4.4.5 Explain how the operation of a Phase-Locked Loop (PLL) circuit demodulates an FM signal

4.4.6 Explain the role of the pre-emphasis and de-emphasis process in the suppression of high frequency noise

4.5 Continuous Phase Modulation (PM Principles)
- 4.5.1 Differentiate phase modulation from frequency modulation
- 4.5.2 Algebraically explain the concepts of phase modulation

4.6 Principles of Phase Shift Keying (PSK)
- 4.6.1 Define phase shift keying
- 4.6.2 Illustrate the difference between frequency domain and time domain representations of a PSK signal
- 4.6.3 Analyze the operation of PSK modulators and demodulators
- 4.6.4 Illustrate the principles of Quadrature PSK (QPSK)
- 4.6.5 Analyze the operation of QPSK modulators
- 4.6.6 Analyze the operation of QPSK demodulators

5.0 Complex Modulation Systems and Modems

5.1 FM Stereo Broadcast Systems
- 5.1.1 Explain the principles of frequency division multiplexing as it applies to FM stereo
- 5.1.2 Analyze the operation of an FM stereo transmitter
- 5.1.3 Analyze the operation of an FM stereo receiver

5.2 Quadrature Amplitude Modulation (QAM) Modems
- 5.2.1 Explain the principles of QAM modulation
- 5.2.2 Analyze the operation of a QAM modulator
- 5.2.3 Analyze the operation of a QAM demodulator
- 5.2.4 Identify the benefits of QAM over lower-ordered modulation schemes

5.3 Trellis Coded Modulation (TCM) Modems
- 5.3.1 Explain TCM modulation principles
- 5.3.2 Identify the benefits of TCM over lower-ordered modulation schemes

5.4 Modem Modulation Constellations
- 5.4.1 Describe modem modulation constellations
- 5.4.2 Illustrate modem modulation constellations for standard discrete modulation methods

5.5 Carrier Recovery
- 5.5.1 Describe carrier recovery methods

6.0 Noise Effects on Modulated Systems

6.1 Noise in Continuous Time Modulation Systems

6.1.1 Compare the impact of signal to noise (S/N) ratios on the following signals:
6.1.1.1 AM
6.1.1.2 FM
6.1.1.3 PM

6.2 Noise in Discrete Time Modulation Systems
6.2.1 Explain Error Probability
6.2.2 Describe the formation of bit errors in the demodulation of the following signals:
6.2.2.1 ASK
6.2.2.2 FSK
6.2.2.3 PSK
6.2.2.4 QPSK
6.2.2.5 QAM

6.2.3 Calculate Bit Error Rate (BER)
6.2.4 Analyse the relative BER of ASK, FSK, PSK, QPSK, QAM, and TCM

7.0 Information, Error Detection and Coding

7.1 Nyquist Minimum Bandwidth
7.1.1 Explain the Nyquist Minimum Bandwidth concept
7.1.2 Calculate the Nyquist Minimum Bandwidth for a given signal in a non-noisy channel

7.2 Shannon-Hartley Capacity Theorem
7.2.1 Describe Shannon-Hartley Capacity Theorem in noisy channel
7.2.2 Calculate channel capacity, required bandwidth, or maximum S/N using the Shannon-Hartley Capacity Theorem

7.3 Shannon Limit
7.3.1 Discuss the Shannon Limit
7.3.2 Illustrate, through the use of diagrams, the fixing numbers for levels of modulation (Manchester, QPSK)
7.3.3 Discuss how the Number of Levels are limited by the S/N

7.4 Coding Principles
7.4.1 Explain
7.4.1.1 Coding of Message
7.4.1.2 Source Coding

7.4.2 Compare Variable versus Fixed Length Code
7.4.3 Explain Uniquely Decodable Codes
7.4.4 Explain Instantaneous Codes
7.4.5 Outline Average Code Length

7.4.6 Explain Distinct Codes
7.4.7 Outline Code Efficiency
7.4.8 Explain relationship between Entropy and Average Length

7.5 Common Digital Signal Encoding Formats
7.5.1 Compare NRZ-L, NRZI, Bipolar-AMI, HDB3, B8ZS, Manchester, and Differential Manchester encoding

7.6 Parity, LRC, CRC, and Block Codes
7.6.1 Determine the parity (odd or even) of a string of binary digits based on the number of ones or zeros
7.6.2 Explain Vertical Redundancy Check (parity check) redundant bit
7.6.3 Describe Longitudinal Redundancy Check performance
7.6.4 Explain the following:
7.6.4.1 Cyclic Redundancy Check Generator
7.6.4.2 Checker, and Polynomial
7.6.5 Discuss error detection and/or correction code block coding techniques
7.6.6 Describe Generator Matrix and Generic linear block
7.6.7 Illustrate the Hamming block code

7.7 FEC Blocks
7.7.1 Discuss the commonality of long string errors on a communication medium
7.7.2 Describe the process of Interleaving

7.8 Error Correction Methods Common to Complex Modulated Systems
7.8.1 Define Reed-Solomon Cyclic Block Code
7.8.2 Discuss Trellis-coded Convolution Modulation

8.0 Digitization of Analog Signals

8.1 Sampling Theory
8.1.1 Explain Nyquist Sampling Theorem
8.1.2 Calculate the minimum sampling rate given the frequency range of a signal

8.2 Codec Techniques
8.2.1 Describe Delta Modulation
8.2.2 Describe the Pulse Code Modulation (PCM)
8.2.3 Describe the process and purpose for companding

EVALUATION:

Laboratories:	10%
Assignments:	10%
Tests and/or Quizzes:	30%
Final Exam:	50%

DATE DEVELOPED:	March 2012	**DATE REVIEWED:**	
REVISION NUMBER:	1	**DATE REVISED:**	November 2012

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