This course is an introduction to analog and digital communications. We begin the course with a discussion of analog communications, including well-know modulations such as, AM, DSB, SSB VSB and FM. Then we introduce the concept of the Nyquist Sampling Theorem. The Nyquist Theorem allows us to convert analog signals into digital signals, and provides a bridge between analog and digital communications. We then describe the digital modulation and coding techniques, which are gradually replacing analog communications, throughout the world. We will conclude the course with a discussion of Shannon’s Information Theory, which is the basis for almost all of the advancements in communications in the second half of the twentieth century and the beginning of the twenty-first century.

Course Website:
http://www.ee.columbia.edu/~kyee/ELENE3701/

Class: Tu and Th- 4:10-5:25 PM
Room:1127 Mudd

Instructor: Professor I. Kalet

Assistant: Kai Yang
## Course Outline

- **Introduction - A “Bit” of History**
- **Review of Fourier Transform**
  - Impulse Response
  - Filters
  - Causality
  - Distortion - Linear
  - Harmonics
- **Definitions of Analog and Digital Communications**
- **Multiple Access Techniques**
  - FDMA and TDMA
  - Introduction to CDMA

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Analog Communications

- Linear Modulation and Demodulation
  - Double Sideband
  - Quadrature Modulation
  - Amplitude Modulation
    - Envelope Detection
  - Hilbert Transform
  - Analytic Signal
  - Single-Sideband (SSB)
  - Vestigial Sideband
  - Superheterodyne Receiver
    
    \[ \text{H93-98} \quad \text{H90-93} \quad \text{Problem Set #2} \]
    \[ \text{H723-725} \quad \text{H725-734} \quad \text{Problem Set #3} \]
    \[ \text{H98-100} \quad \text{H100-103} \quad \text{Problem Set #4} \]

- Angle Modulation- PM and FM
  - Frequency Modulation
    - Narrowband Signals
    - Bessel Functions
    - Carson’s Rule- Bandwidth
    - Demodulation
      - Phase Lock Loop-PLL –(not covered)
      - Capture Effect-(not covered)
      - Single Sideband FM
    
    \[ \text{H107-109} \quad \text{H109-111} \quad \text{Problem Set #5} \]
    \[ \text{H111-113} \quad \text{H113-120} \quad \text{H117-120} \quad \text{H121-124} \quad \text{H142-143} \quad \text{H157-162} \quad \text{H148-149} \]

- Interference (Single-Tone)
  - Linear Modulation-DSB, SSB, AM
  - Angle Modulation-FM
# Digital Communications

- **Nyquist Sampling Theorem**
  - H183-188

- **Pulse Amplitude Modulation**
  - H188-194

- **Pulse Code Modulation**
  - H201-218
  - Quantization Noise
    - H193-210
  - Delta Modulation
    - H217-227
  - Delta-Sigma Modulation (not covered)
    - H227-229
  - Differential PCM (DCPM) (not covered)
    - H229-234
  - Adaptive DPCM (not covered)

- **Definition of Digital Communications**
  - Bits and Symbols

- **Pulse Shaping**
  - Nyquist Signals
    - H259-264
  - Eye Pattern
    - H259-264
  - Nyquist I Theorem
    - H264-267
  - Nyquist Signals with Raised Cosine Filtering
    - H267-275
  - Duobinary Signaling

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| Detection of Nyquist Signals in           |   |
| White Gaussian Noise Channels             | H261-264 |
| -Nyquist Signals                          | Problem Set #8 |
| -Probability of Error                     |   |
| -The Q-Function                           |   |
| -Optimum Filtering                        |   |
| -Intersymbol Interference                 |   |
| -Linear Equalization                      |   |

| Optimum Detection of Binary Signals       | H253-259 |
| -Time-Limited Signals                     |   |
| -Optimum Detection of Binary Signals      |   |
| -Definition of Distance between signals   |   |
| -Probability of Error                     |   |
| -Antipodal and Orthogonal Signals         |   |
• **Introduction to Digital Modulation and Signal Space**

  - Signal Space—What is it?
  - Orthonormal Basis
  - Definition of Classic Modulations
    - BPSK
    - QPSK
    - MPSK
    - QAM
    - BFSK and MFSK

• **Optimum Detection of Binary Signals**
  - Optimum Detection in Signal Space
  - Minimum Probability of Error
  - Correlation Detection

• **Introduction to Coding**
  - What is a Code?
  - Block Code—Introduction
    - Hamming (7,4) Code
    - Coding Gain

• **Matched Filtering**

• **Introduction to Information Theory**
  - Review of Some of Shannon’s Results
  - Why code?
  - Bandwidth Efficiency vs Power Efficiency

• **Summary**
The Course Textbook


Recommended Books and References:

Final Mark will be based on
1-Midterm- 30%
   (Will only count, if it helps your final grade)
2-Homeworks (Required) 10%
3-Final Exam 60%

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