ELEC 470 Communication and Information Systems Fall 2014

Review Topics for Exam #1

Please review the "Exam Policies" section of the Exams page at the course web site. Please especially note the following:

1. You will be allowed to use a non-wireless enabled calculator, such as a TI-99.
2. You will be allowed to use one 8.5 × 11-inch two-sided **handwritten** help sheet. No photocopied material or copied and pasted text or images are allowed. If there is a table or image from the textbook or some other source that you feel would be helpful during the exam, please notify me.
3. All help sheets will be collected at the end of the exam but will be returned to you later.

The following is a list of topics that could appear in one form or another on the exam. Not all of these topics will be covered, and it is possible that an exam problem could cover a detail not specifically listed here. However, this list has been made as comprehensive as possible.

Although every effort has been made to ensure that there are no errors in this review sheet, some might nevertheless appear. The textbook is the final authority in all factual matters, unless errors have been specifically identified there. You are ultimately responsible for obtaining accurate information when preparing for your exam.

Electromagnetic spectrum (rough idea of frequency ranges and wavelengths)
- MF, HF, VHF, UHF
- AM, FM, and TV/CATV broadcast services
- usefulness of various parts of spectrum for specific services/purposes

Basic wireless system
- baseband signal
- transmitters and receivers
- the use of radio is a kind of frequency division multiplexing
- transmission lines
- antenna(s)

Amplitude modulation
- double sideband, suppressed carrier (DSB-SC, sometimes called DSB)
- single sideband, suppressed carrier (usually called SSB)
    - upper sideband (USB)
    - lower sideband (LSB)
- double sideband, large carrier (DSB-LC, usually called AM)

Frequency mixer
- ideally equivalent to a signal multiplier (i.e., if $x(t)$ and $y(t)$ are inputs, then $x(t)y(t)$ is the output)
- real mixers often built using diode rings and transformers; equivalent to multiplying the message signal $m(t)$ by a "switching" waveform
- one type of switching waveform:

$$w(t) = \begin{cases} 1, & \text{pos. half cycle of driving voltage} \\ 0, & \text{neg. half cycle of driving voltage} \end{cases}$$

- Fourier series of switching waveform consists of harmonics of fundamental frequency with varying weights
- modulation property of Fourier transform (frequency-shifting property)

DSB

- modulation and demodulation methods
- requirement for phase and frequency synchronization between carrier and local oscillator

AM (specifically, DSB-LC)

- strong carrier added to DSB-SC signal
- significant transmitter power is devoted to carrier part of signal
- signal representation

  $$\phi_{AM}(t) = [A + m(t)]\cos\omega_c t$$

  where $m(t)$ = message signal and A = amplitude of carrier signal
- spectral representation
- modulation index

  $$\mu = \frac{m_p}{A}, \quad \text{where } m_p = \text{peak value of } |m(t)|$$
- overmodulation ($\mu > 1$) leads to distortion of message signal
- generation methods
  - add carrier to DSB signal via oscillator and summing junction
  - vary power supply current and/or voltage in step with $m(t)$ (old approach)
- demodulation methods
  - synchronous demodulation
  - envelope detection
- advantages and disadvantages vs. DSB and/or SSB
  - bandwidth requirements and how they are related to noise
  - ease of demodulation
  - criticalness of receiver tuning
  - power efficiency (power committed to carrier)

SSB

- USB vs. LSB
- Hilbert transform equivalent to shifting phase of all frequency components of a signal by −90°
- signal representations

  $$\phi_{USB}(t) = m(t)\cos\omega_c t - m_h(t)\sin\omega_c t$$

  $$\phi_{LSB}(t) = m(t)\cos\omega_c t + m_h(t)\sin\omega_c t$$

  where $m_h(t)$ = time-domain form of Hilbert transform of $m(t)$
- spectral representation
- methods of SSB signal generation (modulation)
  - filter method
  - phasing method
  - Weaver method
- demodulation methods similar to modulation methods
- synchronous demodulation not always necessary (e.g., for voice transmission)
- effects of asynchronous demodulation

Quadrature amplitude modulation (QAM)

- simultaneously modulation of a carrier with two message signals $m_1(t)$ and $m_2(t)$
- used in old analog TV standard for sending color information
- one form used in now-defunct method for AM stereo transmission

Local carrier synchronization methods
- transmit pilot tone
- pass signal through nonlinear device (such as a squaring stage)
- phase-locked loop
- Costas loop

Phase-locked loop (PLL)
- feedback-based system
- consists of modulator (mixer), loop filter, and voltage-controlled oscillator (VCO)

Angle modulation
- general mathematical representation

  $\phi(t) = A\cos\theta(t)$

  where $\theta(t)$ = time-dependent phase of ϕ_{FM} or ϕ_{PM} signal
- concept of instantaneous frequency

  $\omega_i(t) = \frac{d\theta(t)}{dt}$,
- frequency modulation (FM)
  - signal representation

    $\phi_{FM}(t) = A\cos[\omega_c t + k_f a(t)]$,

    where $a(t) = \int_{-\infty}^{t} m(\tau)d\tau$, $m(t) = \frac{da(t)}{dt}$, and $m(t)$ = message signal
  - Fourier transform of $a(t)$ has the same bandwidth as that of $m(t)$
  - $\theta(t) = \omega_c t + k_f a(t)$ and $\omega_i(t) = \omega_c + k_f m(t)$
  - peak frequency deviation

    $\Delta f_{FM} = \frac{k_f m_p}{2\pi}$, where m_p = peak value of $|m(t)|$
- phase modulation (PM)
  - signal representation

    $\phi_{PM}(t) = A\cos[\omega_c t + k_p m(t)]$,

    where $m(t)$ = message signal
  - $\theta(t) = \omega_c t + k_p m(t)$ and $\omega_i(t) = \omega_c + k_p \frac{dm(t)}{dt}$
  - Fourier transform of $dm(t)/dt$ has the same bandwidth as that of $m(t)$
  - peak frequency deviation

    $\Delta f_{PM} = \frac{k_p \dot{m}_p}{2\pi}$, where $\dot{m}_p$ = peak value of $|dm(t)/dt|$
- comparisons of FM vs. PM
- narrowband FM (NBFM) vs. wideband FM (WBFM)
- narrowband PM (NBPM) vs. wideband PM (WBPM)
- comparison of NBFM or NBPM to AM (DSB-LC)
- bandwidth analysis using power series expansion in $k_f a(t)$ for FM or $k_p m(t)$ for PM
  - $\phi_{FM}(t) = \mathrm{Re}\{\hat{\phi}_{FM}(t)\} = \mathrm{Re}\{Ae^{j\omega t}e^{jk_f a(t)}\}$
  - bandwidth of $a(t)$, $a^2(t)$, $a^3(t)$, etc. [or $m(t)$, $m^2(t)$, $m^3(t)$, etc.]
- deviation ratio

  $\beta = \frac{\Delta f}{B}$, where B = bandwidth of message signal $m(t)$ in Hz

- Carson's rule (applicable to FM and PM)
  $B_{FM} = 2(\Delta f_{FM} + B)$ and $B_{PM} = 2(\Delta f_{PM} + B)$,

<u>Relevant course material:</u>

Homework: #1, #2
Mini-Projects: (none)
Textbook: Chap. 1, Sections 3.3.5; 4.1-4.8; 5.1-5.2
Supplements: (none)
Web Links: (none)
Matlab: (none)