Main Course Ideas so far
Introduction to Modulation, AM Modulation

Lecture Outline

- **Main Course Ideas so far**
- **Introduction to Modulation**
- **Amplitude Modulation**
- **Generation of AM Waves**
- **Detection of AM Waves**

1. **Main Course Ideas so Far:**
   - Analog and digital signals convey information electronically. Key system parameters are data rate and/or performance.
   - Fourier analysis is needed to study modulation, filtering, and channel effects in communication systems.
   - PSD and autocorrelation needed to analyze pwoer signals in communication systems.
   - Probability theory characterizes random events.
   - Random variables map from a probability space to the real line. Characterized by CDF, pdf, or characteristic function.
   - Random processes map from a probability space to a set of functions (realizations). WSS processes are characterized by their PSD and autocorrelation. These are used to study filtering and modulation of random processes.
   - Gaussian white noise is a common model for noise in communication systems. Determines SNR and probability of bit error.

2. **Introduction to Modulation**
   - Basic concept is to vary a carrier signal $c(t) = A_c \cos(2\pi f_c t$ relative to an analog (information) waveform $m(t)$ or bits $\{b_i\}$.
   - Analog modulation varies the amplitude (AM), frequency (FM), or phase (PM) of the carrier $c(t)$.
   - Digital modulation varies the amplitude (M-AM), phase (PSK), pulse characteristics (PAM), or amplitude and phase (MQAM) of the carrier.

3. **Amplitude Modulation**
   - Amplitude modulation varies the carrier amplitude according to an analog information signal $m(t)$
   - In standard AM modulation, a constant term is added to the information signal to yield the transmitted signal $s(t) = A_c[1 + k_a m(t)] \cos(2\pi f_c t)$.
   - The constant term greatly simplifies demodulation but is wasteful of power.
   - The envelope of the transmitted signal is $a(t) = A_c|1 + k_a m(t)|$.

- If $|k_a m(t)| \leq 1 \forall t$ then $a(t)$ is always nonnegative, which simplifies demodulation (can demodulate envelope only), but hurts SNR.
- The spectrum of modulated signal is $S(f) = .5k_a A_c[M(f-f_c) + M(f+f_c)] + .5A_c[\delta(f-f_c) + \delta(f+f_c)]$
- The percentage modulation of the signal is defined as $\max_t[100|k_a m(t)|]$.
- The bandwidth of the modulated signal is twice that of the information signal.

4. **Generation of AM Waves**

   - Multipliers difficult to build in hardware (at least circa 1920)
   - AM waves typically generated using a nonlinear device to obtain the desired multiplication
   - Square law modulator sums carrier $c(t)$ and information $m(t)$ signals, then squares them using a nonlinear device. Unwanted terms are filtered out with a bandpass filter.
   - Switched modulation sums $c(t)$ and $m(t)$ then passes sum through a switch, which approximately multiplies it by a periodic square wave. This generates the desired signal plus extra terms that are filtered out.

5. **Detection of AM Waves**

   - AM detection typically entails tradeoffs between performance and complexity (cost).
   - Square law detector squares the received signal followed by a low pass filter. This detection is simple but introduces an unwanted distortion term proportional to $m^2(t)$.

Main Points:

- Modulation is the process of encoding a message signal or bits into a carrier signal.
- AM modulation modulates the amplitude of the carrier waveform with a message signal.
- A constant term is added to the message signal to simplify demodulation: this is wasteful of power and hurts SNR.
- AM waves are typically generated using nonlinear devices.
- AM waves can be demodulated using nonlinear devices with some distortion.