Lecture 12 - EE 179: Introduction to Communications - Spring 2009

AM Modulation

Lecture Outline

- **Amplitude Modulation**
- **Generation of AM Waves**
- **Detection of AM Waves**
- **Double Sideband Suppressed Carrier (DSBSC)**
- **Product Modulators for DSBSC**
- **Coherent Detection of DSBSC**
- **Costas Loop**

1. **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.

2. **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.

3. **Detection of AM Waves**
   - AM detection typically entails tradeoffs between performance and complexity (cost). Common techniques are square law and envelope detectors.
   - 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 $m^2(t)$.
   - Envelope detector is a simple circuit for AM detection consisting of resistors, a capacitor, and a diode.
   - Envelope detection only works when $|k_a m(t)| \leq 1 \forall t$ (Can't detect sign change).

- R_LC circuit must track envelope but not the carrier ($f_c^{-1} << R_LC << B^{-1}$).

4. **Double Side Band Suppressed Carrier (DSBSC)**
   - AM wasteful of power: constant term with power $A_c^2/2$ is not carrying information.
   - DSBSC suppresses constant term: modulated signal is $s(t) = A_c \cos(2\pi f_c t)m(t)$.
   - Spectrum of DSBSC: $S(f) = .5A_c[M(f - f_c) + M(f + f_c)]$.
   - DSBSC has the same bandwidth as standard AM but requires much less power.

5. **Product Modulators for DSBSC Waves**
   - Direct product difficult in hardware.
   - Product modulator uses two AM modulators and a summer.
   - A ring modulator uses diodes to approximate product of signal with a periodic square wave. This generates desired signal plus extra terms that are filtered out.

6. **Coherent Detection of DSBSC**
   - DSBSC signal demodulated by passing it through a product modulator followed by a LPF
   - The phase offset between carriers in the modulator and demodulator can completely cancel received signal.
   - The carrier signal in the demodulator must be adjusted to have the same phase as the one in the modulator: this is called *coherent detection*.
   - Special circuitry in the receiver is required for this phase synchronization.

7. **Costas Loop**
   - Common circuit for phase synchronization
   - Uses a phase discriminator to determine the phase offset of the receiver oscillator
   - The discriminator output drives a voltage controlled oscillator (VCO), which adjusts the phase of its output carrier based on the input signal.
   - When the phase is synchronized, the VCO input is zero.
   - A Costas loop is an example of a feedback control system.

Main Points:

- AM waves are typically generated using nonlinear devices.
- AM waves can be demodulated using nonlinear devices with some distortion.
- Envelope detectors are simple cheap devices to detect AM waves with no distortion, but they have poor SNR.
- DSBSC eliminates the power inefficiency of standard AM at the expense of significantly higher receiver complexity.
- The DSBSC receiver requires coherent detection (coherent phase between transmitter and receiver).
- The Costas loop provides phase synchronization using a VCO and feedback control.
- Obtaining the carrier phase is one of the biggest challenges for *all* demodulators.