

## DSBSC, Coherent Detection, SSB, and VSB

### Lecture Outline

- Product Modulators for DSBSC
- Coherent Detection of DSBSC
- Costas Loop
- Noise in AM
- Single Sideband Modulation (SSB)
- Vestigial Sideband Modulation (VSB)

#### 1. 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.

#### 2. 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.

#### 3. 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.

#### 4. Noise in AM Receivers

- SNR at the receiver output is the integral of the signal PSD divided by the integral of the noise PSD.
- We know the impact on PSD of both noise and the signal due to filtering and multiplying by a cosine.
- For DSBSC with additive white noise,  $\text{SNR} = P_s / (N_0 B)$ , where  $P_s = .5 A_c^2 P_m$  is the power of the transmitted signal  $A_c \cos(2\pi f_c t + \phi) m(t)$  (where  $P_m$  is the power in  $m(t)$ ) and  $N_0 B$  is the noise power within the bandwidth of interest ( $2B$ ).

## 5. Single Sideband Modulation (SSB)

- Only transmits upper or lower sideband of an AM wave.
- Reduces transmit signal bandwidth by a factor of 2.
- The transmitted signal can be written in terms  $m(t)$  and the Hilbert Transform of  $m(t)$  as  $s(t) = A_c[m(t) \cos(2\pi f_c t) \pm m_h(t) \sin(2\pi f_c t)]$
- Use same demodulator as DSBSC.
- SSB has half the SNR of DSBSC for half the transmit power: no SNR gain.
- SSB can introduce significant distortion at DC where the sidebands meet: not good for TV signals.

## 6. Vestigial Sideband Modulation (VSB)

- VSB is similar to SSB but it retains a small portion (a vestige) of the undesired sideband to reduce DC distortion.
- VSB signals are generated using standard AM or DSBSC modulation, then passing modulated signal through a sideband shaping filter.
- Demodulation uses either standard AM or DSBSC demodulation.
- VSB modulation with envelope detection used to modulate image in analog TV signals (sound is modulated with FM).

### Main Points:

- 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.
- The Costas loop provides phase synchronization using a VCO and feedback control (synchronization a big challenge in all demodulators).
- The signal to noise ratio in DSBSC, which dictates signal quality, increases with transmit signal power and decreases with noise spectral density and signal bandwidth.
- Single sideband AM (SSB) is a spectrally-efficient AM modulation technique that uses half the bandwidth of standard AM.
- Vestigial sideband (VSB) uses slightly more bandwidth than SSB with a lower DC distortion.