

Costas Loop, Noise in AM, SSB/VSB. AM Radio and Superheterodyne Receivers.

Lecture Outline

- Costas Loop
- Noise in AM
- Single Sideband Modulation (SSB)
- Vestigial Sideband Modulation (VSB)
- AM Radio
- Superheterodyne Receivers

1. 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.

2. 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 ($2B$).

3. 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 of $m(t)$ and the Hilbert Transform of $m(t)$ as $s(t) = \frac{A_c}{2} [m(t) \cos(2\pi f_c t) \pm m_h(t) \sin(2\pi f_c t)]$
- 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.

4. 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).

5. AM Radio

- AM radio frequency multiplexes AM modulated signal with 10 KHz bandwidth with carrier frequency $f_c \in [530, 1610]$ KHz.
- The receiver needs tight filtering to remove adjacent AM signals, and this filter needs to be tuneable, which is hard to build.
- The local oscillator can radiate out of receiver front end, causing interference at the receiver front end.

6. Superheterodyne Receivers

- The need for tuneable BPFs and the LO reradiation problem go away with by downconverting the signal to an intermediate frequency (IF) and demodulating at this IF.
- This receiver structure, called a superheterodyne receiver, simplifies receiver design but results in additional power consumption and excess circuitry.
- Much research and development effort on returning to direct conversion approach.

Main Points:

- 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.
- AM radios and many other systems downconvert to an IF frequency before demodulation to avoid the need for tuneable filters and LO reradiation.