

SSB, BB Representations, VSB, Superheterodyne RXs, Introduction to FM

Lecture Outline

- Single Sideband Modulation (SSB)
- Baseband Representation of Modulated Signals
- Vestigial Sideband Modulation (VSB)
- Implementation Issues and Superheterodyne Receivers
- Introduction to FM

1. 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.

2. Baseband Representation of Modulated Signals

- Baseband signal representation is a compact way to represent passband signals.
- All passband signals at carrier frequency f_c can be written as $s(t) = s_I(t) \cos(2\pi f_c t) + s_Q(t) \sin(2\pi f_c t)$.
- $s_I(t)$ is called the in-phase signal component; $s_Q(t)$ is called the quadrature signal component.
- The sin and cosine are orthogonal signals, can be used to separate out the in-phase and quadrature components from $s(t)$.
- We define $\tilde{s}(t) = s_I(t) + js_Q(t)$ as the *baseband signal representation*. Then $s(t) = \Re[\tilde{s}(t)e^{j2\pi f_c t}]$, which is a compact way to represent and analyze passband signals.

3. 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).

4. Implementation Issues and Superheterodyne Receivers

- In standard AM demodulation the envelope detectors must be tailored to the carrier frequency.
- In DSBSC or SSB demodulation the local oscillator can radiate out of receiver front end, causing self-interference at the receiver front end.
- Both of these problems go away with by downconverting the signal to an intermediate frequency (IF) and demodulating at this IF.
- The envelope detector and/or filters can be tailored to the IF frequency.
- Current systems are trying to go directly to digital to reduce components, price, and power consumption.

5. Introduction to Angle Modulation and FM

- In frequency modulation the carrier frequency or phase is varied relative to the information signal: $s(t) = A_c \cos[\theta(t)]$, where $\theta(t)$ is a function of $m(t)$.
- FM signals are much less sensitive to amplitude variations in the channel. They are also less sensitive to signal reflections and refractions introduced by the channel.
- In standard FM, $\theta(t) = 2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau$.
- The instantaneous frequency of an FM wave is $f_i(t) = f_c + k_f m(t)$.
- FM signals are categorized as narrowband FM or wideband FM, depending on the maximum magnitude of the information signal $m(t)$.

Main Points:

- Single sideband AM (SSB) is a spectrally-efficient AM modulation technique that uses half the bandwidth of standard AM.
- Baseband signal representations are a compact way to manipulate bandpass signals.
- 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. Technology trying to move away from this structure.
- FM modulation encodes the information signal in carrier frequency instead of amplitude. It is much less sensitive to channel impairments (amplitude variations or signal reflections and refractions).