Analog Communication

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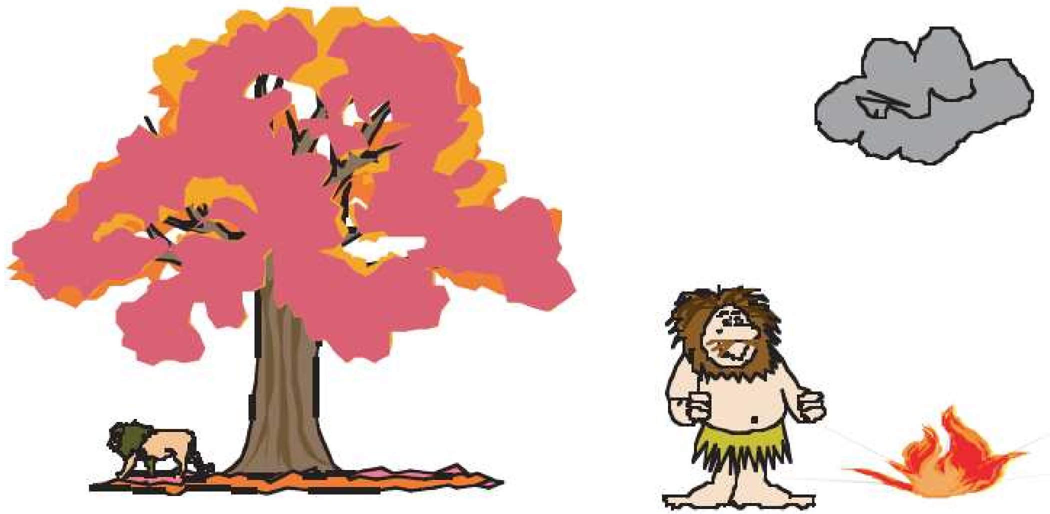


- Tele is Greek for “at a distance” , and Communicare is latin for “to make common”.
- Telecommunication is the process of long distance communications.
- Early telecommunications involved smoke, flags, drums, and other such methods

Basic Communications System Elements

- Transmitter
  - Transducer
  - Modulator
  - Power amplifier
- Receiver
  - Filtering
  - Demodulation
- Medium: terrestrial (e.g. cable, coax, wire, etc.), and x-terrestrial (radiotransmission)

Modulation

Modulation

- Encoding information into a carrier signal that can be transmitted over the channel
  - Information signals must be modulated from baseband (centered around DC) onto a passband (e.g., 2.5 GHz) signal
    - Wireless channels reject baseband signals → need to match signal to channel
  - Information signal alters the amplitude, frequency or phase of the modulated signal
  - Demodulation used to get information signal from modulated signal
  - Analog and digital modulation: baseband signal can be either analog or digital

Analog Modulation Techniques

- Continuous Wave
  - Linear CW
    - Amplitude (AM)
  - Exponential CW
    - Frequency (FM)
    - Phase (PM)
- Pulse Modulation
  - Analog Pulse
    - PAM
    - PWM
    - PPM
  - Digital pulse Modulation
    - PCM
    - Delta Modulation

Amplitude Modulation

- Modulated signal

$$s_{AM}(t) = A_c[1 + m(t)]\cos(2\pi f_c t)$$

  - Information signal = $m(t) = n_a x(t)$
  - Carrier signal = $A_c \cos(2\pi f_c t)$
  - n_a = modulation index, ratio of amp. of input signal to carrier
- Frequency content

$$S_{AM}(f) = \frac{1}{2} A_c[\delta(f-f_c) + M(f-f_c) + \delta(f+f_c) + M(f+f_c)]$$

Amplitude Modulation

- modulation index = $\dfrac{\text{peak modulating voltage}}{\text{peak carrier voltage}} = \dfrac{E_m}{E_c}$

Amplitude Modulation

- Bandwidth
  - $B_{AM} = 2f_m$
- Transmitted power
  - $P_{AM} = ½ A_c^2[1 + 2\langle m(t)\rangle + \langle m^2(t)\rangle]$ where $\langle \bullet \rangle$ is the average value
  - If $m(t) = k \cos(2\pi f_m t)$ then
    - $P_{AM} = ½ A_c^2[1 + P_m] = P_c[1+k^2 /2]$
    - $P_c = ½ A_c^2$ = power in carrier signal
    - $P_m = \langle m^2(t)\rangle$ = power in modulating signal

AM with Suppressed Carrier

$$s_{AM-SC}(t) = A_c m(t)\cos(2\pi f_c t)$$

- No carrier transmitted with signal
- Advantage of SC
  - All transmit power in message component
  - Efficient use of transmit power

$$P_{AM-SC} = \frac{1}{2} A_c^2 P_m$$

- Disadvantage of SC
  - Harder to demodulate

Single Sideband (SSB)

- Sidebands contain identical information
- Only need to transmit upper or lower sideband to reconstruct the signal—single sideband AM
  - Sends only one sideband
  - Eliminates other sideband and carrier
- Advantages
  - Only half the bandwidth is required
  - Less power is required
- Disadvantages
  - Suppressed carrier can't be used for synchronization purposes
  - Filters with Sharp cut off can't be realized practically

SSB AM

- Bandwidth
  - $B_{SSB} = f_m$
  - More bandwidth efficient than AM
- To get SSB:
  - BPF to remove one sideband of $s_{AM}(t)$
  - Create m'(t) and modulate in-phase and quadrature components separately

SSB AM

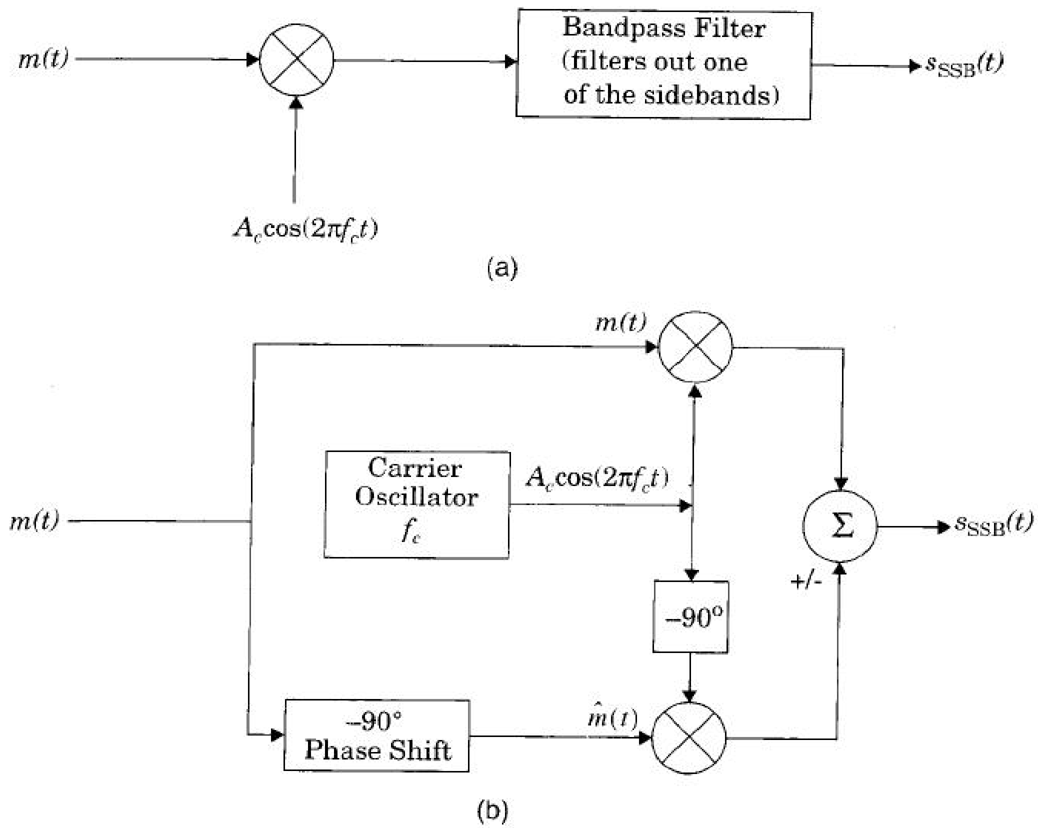


Figure 6.3 Generation of SSB using (a) a sideband filter and (b) a balanced modulator.

Demodulation of AM Signals

- Coherent: receiver knows the carrier frequency and phase
  - Works for SNR below 0 dB
- Noncoherent: receiver does not know the phase
  - Envelop detector outputs signal proportional to real envelope of received signal (need SNR > 10 dB)

Review Questions?

1. If the voltage of a modulating signal is doubled, what happens to the modulation index?
2. If the voltage of the carrier signal is doubled, what happens to the modulation index?
3. If the frequency of a modulating signal is doubled, what happens to the modulation index?
4. If the frequency of the carrier signal is doubled, what happens to the modulation index?
5. If the voltage of the carrier signal is doubled, what happens to the average power?
6. If the frequency of the modulating signal is doubled, what happens to the bandwidth?
7. If the frequency of the carrier signal is doubled, what happens to the bandwidth?
8. If the modulation index is doubled, what happens to bandwidth?

Answers

1. It doubles.
2. It halves.
3. No change.
4. No change.
5. quadruples.
6. It doubles.
7. No change
8. No change

EXPONENTIAL MODULATION

- FM and PM can provide much better protection to the message against the channel noise as compared to the linear modulation schemes.
- Because of their constant amplitude nature, they can withstand nonlinear distortion and amplitude fading.
- The price paid to achieve these benefits is the increased bandwidth requirement

Frequency Modulation (FM)

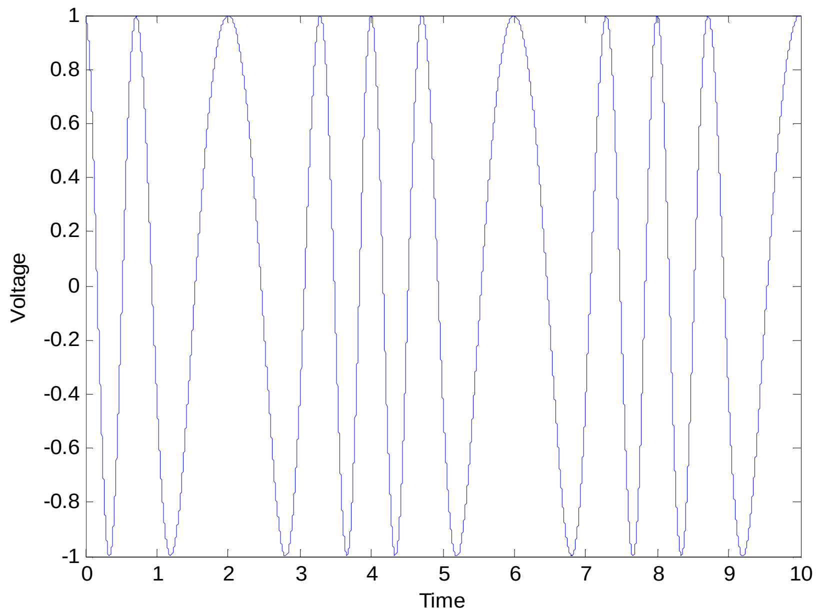
- Modulated signal

  $s_{FM}(t) = A_c \cos(2\pi f_c t + q(t))$

  $= A_c \cos(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(t)\, dt)$

  - Information signal = m(t)
  - k_f is the frequency deviation constant (Hz/volt)

Frequency Modulation (FM)



As both PM and FM have constant amplitude *Ac* , the average power of a PM or FM signal is,

$$P_{av} = \frac{A_c^2}{2},$$

regardless of the value of *kp* or *kf* .

FM Bandwidth

- Deviation Ratio $D = \Delta f / W$
  - Δf = peak frequency deviation
  - W = message BW = f_m
- Carson's rule: $B = 2(\Delta f + W)$
- $B = 2W(D + k)$

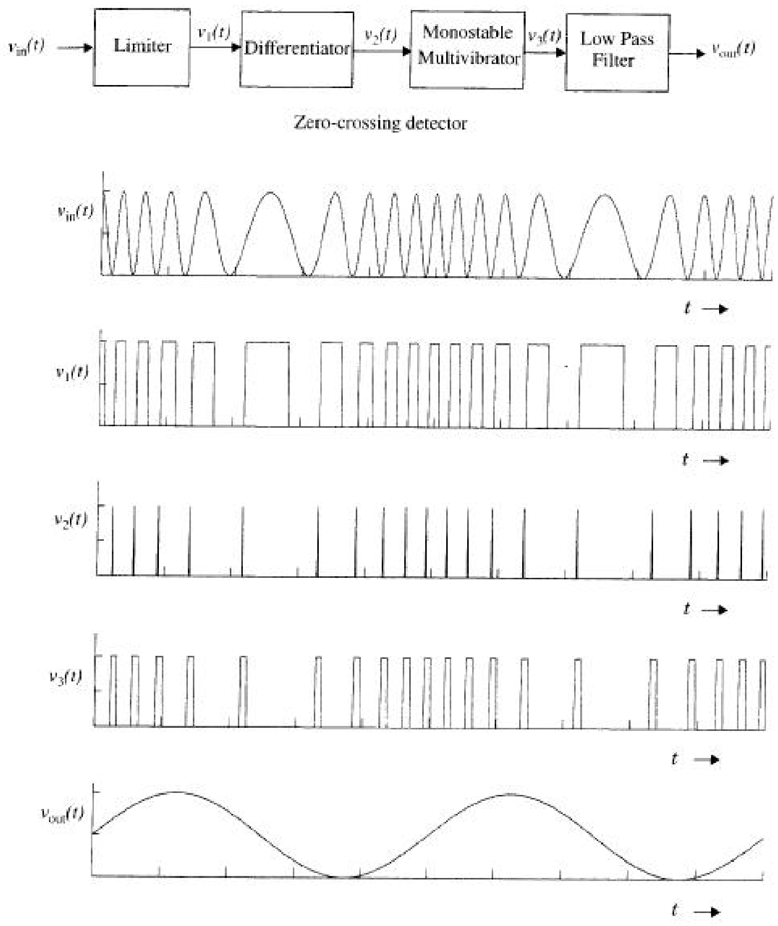
Generation of FM

- There are two distinct methods of generating WBFM signals:
- Direct FM
  - *Voltage Controlled Oscillator* (VCO)
- Indirect FM.
  - Attributed to Armstrong - first a narrowband FM signal is generated. This is then converted to WBFM by using frequency multiplication.

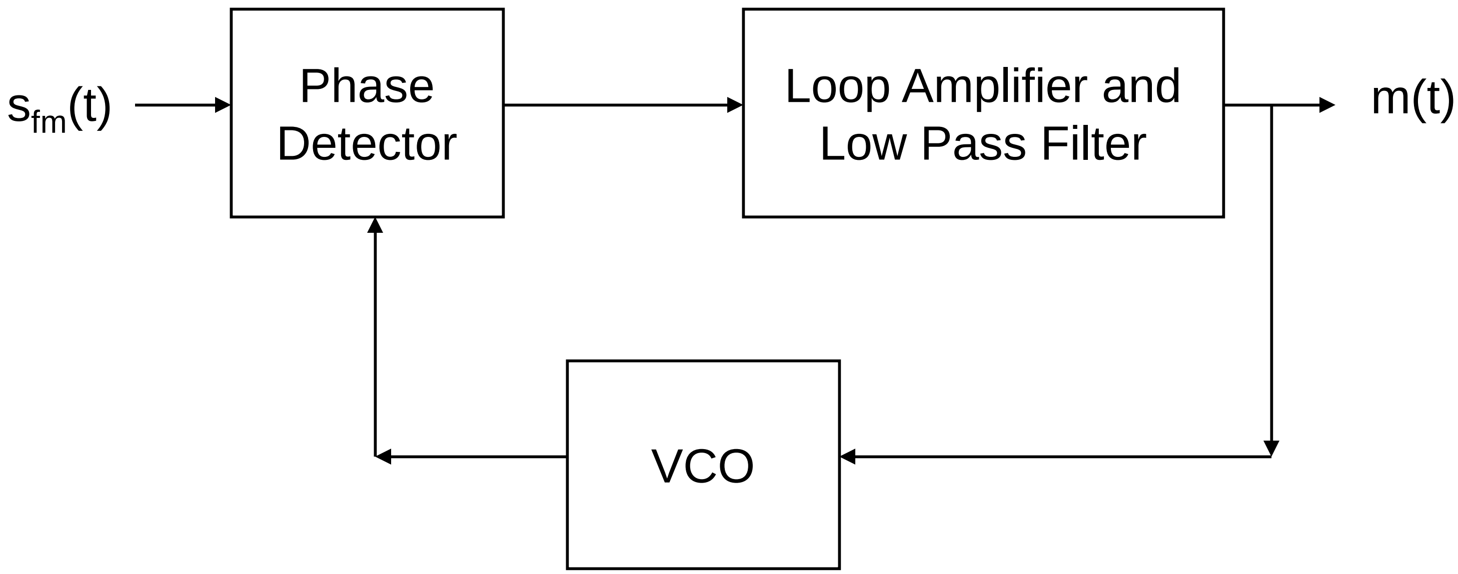
FM Demodulation

- FM Demodulation
  - Many ways to extract frequency information from r(t)
    - Detect slope of r(t) using differentiator and envelop detector
    - Count zero-crossings
    - Use phase-locked loops (PLLs)
    - Quadrature detection

FM Demodulation using zero crossing Detection



FM Demodulation PLL



FM SNR

- SNR for FM signal
  - $SNR_{in} = (A_c^2/2) / (2N_o(\beta_f+1)W)$ (before demod)
  - $SNR_{out} = 6(\beta_f+1)\beta_f^2(m(t)/V_p)^2\ SNR_{in}$ (after demod)
  - SNR_{out} increases with increased β_f → can increase SNR by increasing transmit signal bandwidth rather than increasing transmit power
  - If $m(t) = A_m\cos(2\pi f_m t)$ →
    - $SNR_{out} = 3(\beta_f+1)\ \beta_f^2\ SNR_{in} = (A_c^2/2)\ 3\ \beta_f^2 / (2N_oW)$

Summary

- Advantages
  - Trade bandwidth for SNR
  - Constant transmitted power (does not depend on m(t))
  - Do not need to maintain strict amplitude linearity→ can use power efficient amplifiers
  - Automatic rejection of interferers (if desired signal is received at a higher signal level)
- FM disadvantages
  - Requires more bandwidth than AM
  - More complex modulators and demodulators

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