Analog Up and Downconversion

- The message symbols to reconstructed symbols portion of the PAM digital communication system
Amplitude Modulation with Large Carrier

- **analog message signal**: $w(t)$
- **transmitted/modulated signal**: $v(t)$

$$v(t) = A_c w(t) \cos(2\pi f_c t) + A_c \cos(2\pi f_c t)$$

Diagram showing the transmission process and frequency spectra.
Demodulation

- **demodulation with envelope detector**: If \( w(t) \geq -1 \), envelope of \( v(t) \) matches \( w(t) \). Using a nonlinearity and LPF as envelope detector produces

  ![Graphs showing message signal, carrier, modulated signal, and output of envelope detector](image)

  - **main advantage**: carrier phase and frequency synchronization not needed at receiver
  - **main disadvantage**: power needed for large carrier does not reinforce message signal
Amplitude Modulation with Suppressed Carrier

- analog message signal: $w(t)$
- transmitted/modulated signal: 
  \[ v(t) = A_c w(t) \cos(2\pi f_c t) \]
- transmitted signal spectrum:
  \[ V(f) = \frac{1}{2} A_c W(f + f_c) + \frac{1}{2} A_c W(f - f_c) \]
- ideal demodulation with synchronized mixing and LPF:
  \[ m(t) = \text{LPF}\{v(t) \cos(2\pi f_c t)\} = \frac{1}{2} A_c W(f) \]

- main advantage: extra power not needed for added carrier
- main disadvantage: carrier phase and frequency synchronization needed at receiver
Example

(a) message signal

(b) message after modulation

(c) demodulated signal

(d) recovered message is a LPF applied to (c)
Naive/Ideal Demodulation

• With a perfect (i.e. gain with delay) channel and satisfactory carrier, baud timing, and frame synchronization, the ideal PAM system
Naive/Ideal Demodulation

- Ideal PAM receiver
Sampling at the Receiver

- Free running sampler output

\[ r(t)|_{t=kT_s} = \sum_{i=0}^{N-1} m[i]p(kT_s - iT)\cos(2\pi f_c kT_s) \]

- Recall eye diagram
- Sampling clocks of A/D and D/A at TX and RX
- We need to track optimum sampling times
Sampling at the receiver

- Soft decision samples for 4-level PAM
- Because the soft decisions are so close to the alphabet levels, there are no decision errors and no symbol errors.
Impairment

- *Impairment*: At time representing 20% of duration of simulation window, the channel gain changes abruptly from 1 to 0.5.
Noise

- Noisy signal
Sampling of Noisy signal

- Sampling of noisy signal, decision boundaries are still visible
Carrier Offset

- The carrier frequency offset appears as a low frequency amplitude modulation of the desired outputs.
Switch to PAM Demodulation

- Downconversion by setting your receiver pointer to the beginning of your input buffer.
- First the receiver is on and transmitter is off
- Transmitter starts with marker and PN sequence
- When transmitter starts, carrier detect will switch to PAM downconversion