Lecture 13 Digital Pulse Amplitude Transmission Part 3

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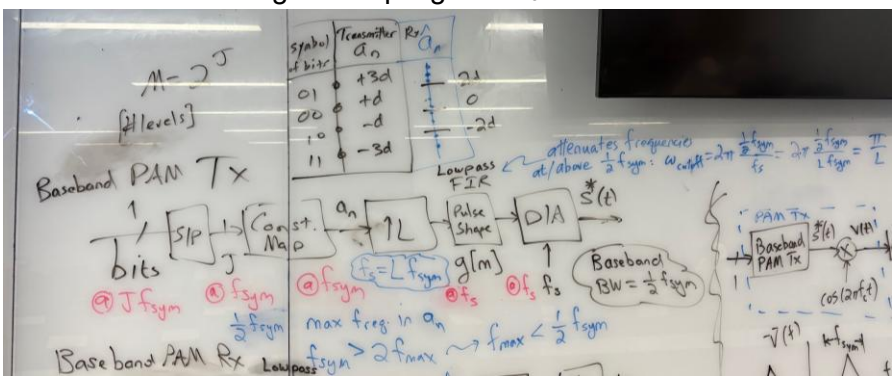
Baseband M-PAM Tx

Convert from stream of bits to stream of pulses

For J bits per symbol, number of symbol levels: $M = 2^J$

Baseband PAM Transmission Steps

- Serial-to-parallel converter: Map stream of bits to stream of J-bit symbols
- Constellation map: Map stream of J-bit symbols to symbol amplitudes a_n
- Upsample a_n by L to convert from the symbol rate f_{sym} to the sampling rate f_s
- Pulse shaping
    - interpolate zero values inserted by upsampler without changing a_n values
    - lowpass filter to enforce the baseband bandwidth of ½ f_{sym} *or pi/L rad/sample*
    - impulse response is rectangular, triangular, sinc, or raised cosine pulse
- D/A converter running at sampling rate f_s



Baseband M-PAM Rx

Convert from stream of pulses to stream of bits

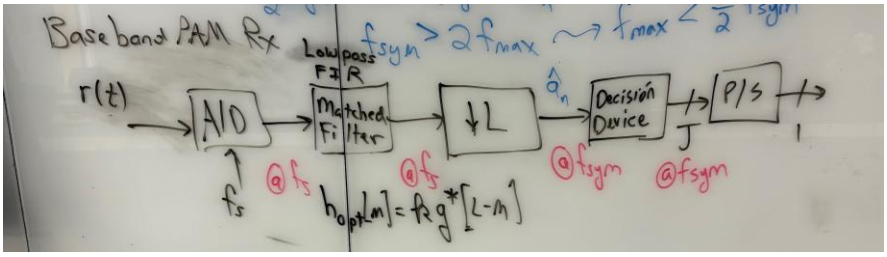
Performs the dual of the operations of the baseband PAM transmitter

- Reverse the directions of the arrows in the baseband PAM transmitter
- Replace each block with its dual (e.g. D/A converter becomes an A/D converter)

Baseband PAM Receiver Steps

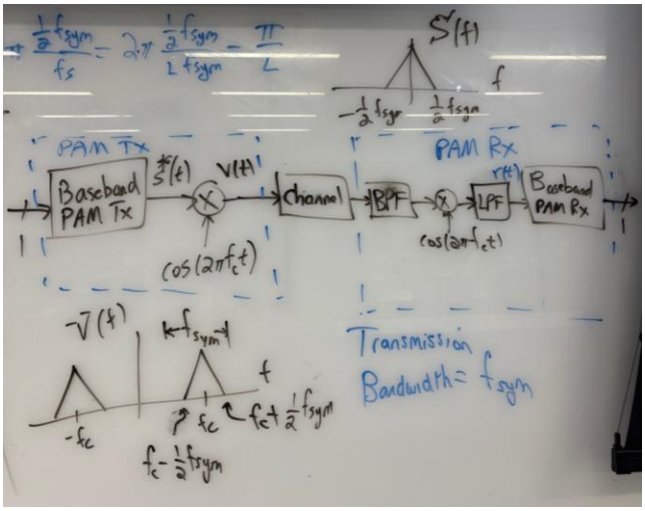
- A/D converter running at sampling rate f_s
- FIR lowpass filter
    - Attenuates noise/interference outside the baseband bandwidth to improve SNR (but filter does not remove in-band noise and other impairments)
    - Anti-aliasing lowpass filter prior to downsampling by L
    - *Best choice*: matched filter
        - Impulse response matched to pulse shape (scaled, time-reversed, complex conjugate, and delayed version of the pulse shape)
        - Intuition: correlates received signal with the pulse shape (derived later)
- Downsample by L to convert from the sampling rate f_s to the symbol rate f_{sym}
- Decision Device to decide which symbol of bits was most likely sent
    - Closest symbol amplitude to received symbol amplitude is our most likely symbol
    - Assuming each symbol amplitude is equally likely (reasonable assumption)

- Decision thresholds between adjacent constellation points are the midpoint of the adjacent pair of symbol amplitude values (-2d, 0, 2d for 4-PAM)
- Linear search: compare against each threshold. $M = 2^J$ compares
- Binary search: each comparison eliminates half constellation points. J compares



Full PAM Transmitter and Receiving Including Upconversion and Downconversion

- Tx analog/RF front end
  - Upconvert baseband PAM Tx signal by sinusoidal modulation
  - Not shown is LPF before modulation and BPF after modulation
- Rx analog/RF front end
  - Bandpass filter to remove noise/interference outside Tx band
  - Demodulate: multiply by cosine then LPF to get baseband signal
- To increase bit rate, increase SNR or increase Tx bandwidth or both



In-Lecture Assignment

- Steepest descent: x[k+1] = x[k] - mu dJ(x)/dx where x is replaced by x[k]
  - Error function: J(x). Also called error surface, objective function, cost function
  - If error^2 goes to 0, error goes to 0
  - Move in opposite direction of the sign of the first derivative of our error function
  - Start with initial guess and update guess until a maximum number of iterations is reached or gradient of the error function is close to zero
  - To keep the process stable, step size μ should be a small positive value.