[10:30am] PAM review

Goal is to transmit information through some medium in space

- Air: Electromagnetic/Acoustic
- Wire: Electromagnetic
- Water: Acoustic
- Deep space: Electromagnetic

Transmitter contains several steps

- Convert bit stream into pulse stream
- Pulse shaping interpolation
- Digital modulation/upconversion
- Discrete-to-continuous conversion
- Analog/RF modulation/upconversion
- Send to antenna/transducer

2-PAM transmission

- Each bit gets mapped to a single pulse
    - Bit of zero → -1
    - Bit of one → +1
- Pulse shaping procedure can increase the range
    - Take into account when scaling and before sending to D/A converter
- Pulse shaping filter plays two roles
    - Time domain: Interpolation
        - Should be even symmetric about midpoint
        - Must be finite length and delayed to realize
        - Should have zero crossings at integer multiples of T_s (except at zero)
    - Frequency domain: Low-pass filter
- Common pulse shapes
    - Sinc
    - Raised cosine
    - Triangular pulse
    - Rectangular pulse

[11:15] Upsampling factor L

- If $L = 1$, we have one sample per symbol
- As L increases, power consumption increases (assuming that fs increases with it)

- More observations create a more reliable receiver
- Less bandwidth used (relative to the sampling rate)
- $f_s = L f_{sym}$

[11:25] Digital interpolation example

- Upsample by 4 ($L = 4$)
- FIR interpolation filter
    - $\omega_{\text{max}} = \frac{\pi}{L}$ at input to filter
    - $\omega_{\text{stop}} < \frac{\pi}{4}$
    - $\omega_{\text{pass}} = 0.9\omega_{\text{stop}}$
- Example: Fall 2021 Midterm problem 2.1

[11:30] In-lecture assignment

- Steepest descent for adaptive element
- Choose an objective function $J(x)$
    - Example: $J(x) = (x - 7)^2$ (mean squared error)
    - Non-negative objective. When objective is equal to zero it is minimized
- To minimize the objective, take a sequence of steps in the opposite direction of the gradient (gradient descent)

$$x[k+1] = x[k] - \underbrace{\mu}_{\substack{\text{step size} \\ 0<\mu<1}} \left. \frac{dJ(x)}{dx} \right|_{x=x[k]}$$