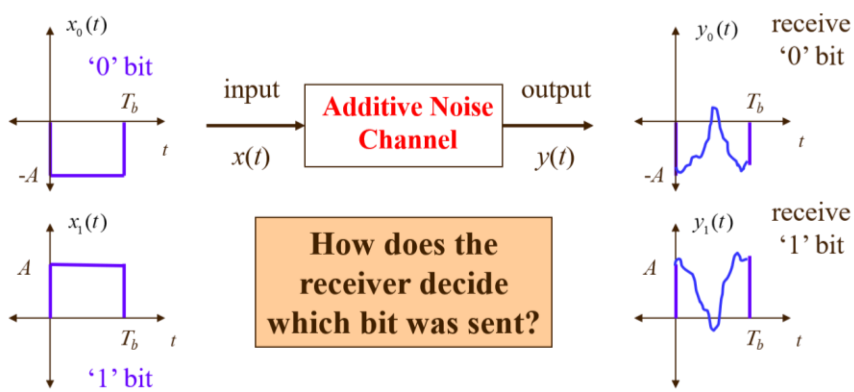
[10:30am] Takeaways from Lecture 12 on Channel Impairments

- Model #1: thermal noise modeled as an additive random time-domain signal
  - Noise from random motion of particles (electrons) due to temperature
  - Apply Central Limit Theorem to particles that contribute at each point in time
    - At each point in time, signal amplitude follows a Gaussian distribution
    - Mean μ is typically zero
    - Variance σ^2 is power due to thermal noise in the channel and receiver
  - In simulation: $\text{SNR} = \frac{\text{Signal power}}{\text{Noise power}}$ and set σ^2 to achieve a certain SNR value
- Model #2: LTI system model for wired or wireless channel
  - Captures spreading in time and distortion in frequency due to signal propagation
    - Wired: voltage signal faces impedance, inductance, capacitance (RLC circuit)
    - Wireless: propagating wave experiences reflection, scattering, etc.
  - Channel impulse response stays roughly the same over its coherence time:
    - Wireless – train/high-speed car (10μs – 100μs)
    - Wireless – medium-speed car. *Example*: 2.5ms for 1GHz @ 64 km/h [Ref]
    - Wireless – pedestrian speeds. *Example*: IEEE 802.11a 5GHz Wi-Fi: 25.39ms @ walking 1m/s, 12.69ms @ 2m/s; 8.46ms @ 3m/s [Ref]
    - Wired – no mobility (1-10s)
  - Channel coherence time decreases with increasing carrier frequency [Ref]
  - Update the LTI model within each coherence time
- Model #3: LTI system followed by additive thermal noise
- Model #4: Add fading as a slowly time-varying random gain before model #3

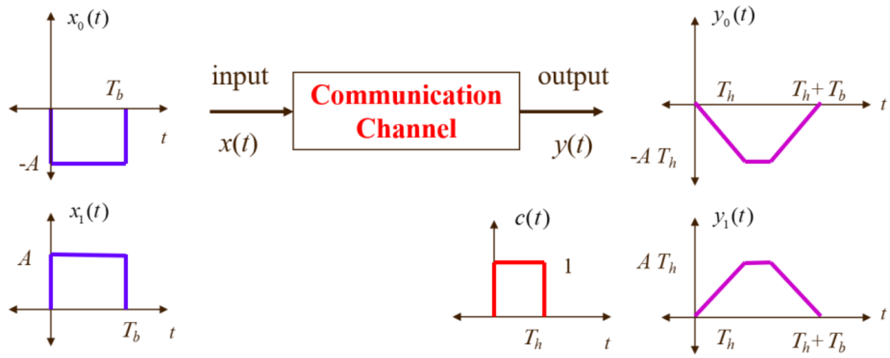
[10:50am] Lecture 14 slides on Matched Filtering

- Transmitting one bit with noise

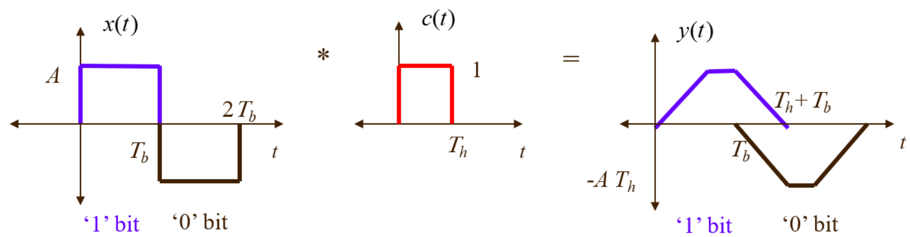


  - Matched filter: correlate received signal with transmitter pulse shape
    - Matched filter is lowpass and reduces out-of-band noise
    - Maximizes probability of correct detection
  - After matched filter, sample at symbol time and compare to zero to detect bit

- Transmitting one bit with simplified LTI model, no noise

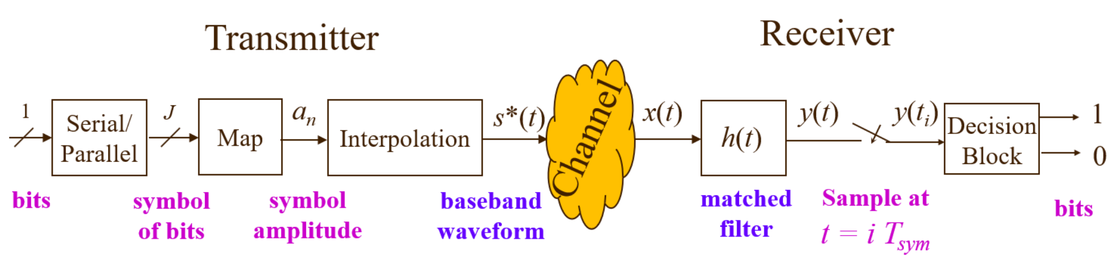


  - Estimate channel delay using a training sequence (chirp, PN sequence)
  - Apply matched filter to received signal after applying offset
- Transmitting two bits with simplified LTI model, no noise



  - Overlap results in intersymbol interference
  - Two options to prevent ISI:
    - Option #1: Increase the symbol period (reduces data rate)
    - Option #2: use channel equalizer determined via training sequence

- Full model for 2-PAM system:



  - Design matched filter to maximize SNR at output
  - Output of matched filter:

$$y(t) = g(t) * h(t) + w(t) * h(t) = g_0(t) + n(t)$$

  - Want to maximize power of $g_0(t)$, minimize power of $n(t)$

[11:35] In-lecture assignment #5 (steepest ascent/descent)

- Objective function: $J(x) = 8 - x^2 + 6\cos(6x)$
- Objective is sum of concave down parabola and cosine

- Has many local maxima, minima.
- Has a global maximum at $x = 0$.
- Update requires gradient:

$$\frac{dJ(x)}{dx} = -2x - 36\sin(6x)$$

- Algorithm will converge to the local maxima nearest the initial guess
  - Initial guess of 0.7 converges to a local maximum which is not the global max.
  - Initial guess must be between $-\pi/6$ and $\pi/6$ to converge to global maxima