ECE 447 Fall 2025

Lesson 24
Pulse Shaping & Intersymbol Interference (ISI)

Schedule and Admin

- Schedule updated.
- Admin
  - **HW3**. Graded.
  - **HW4**. Due last night.
  - **Lab 4**. Due M25 (17 Oct).
  - **HW5**. Posted on website. Due M27 (23 Oct).

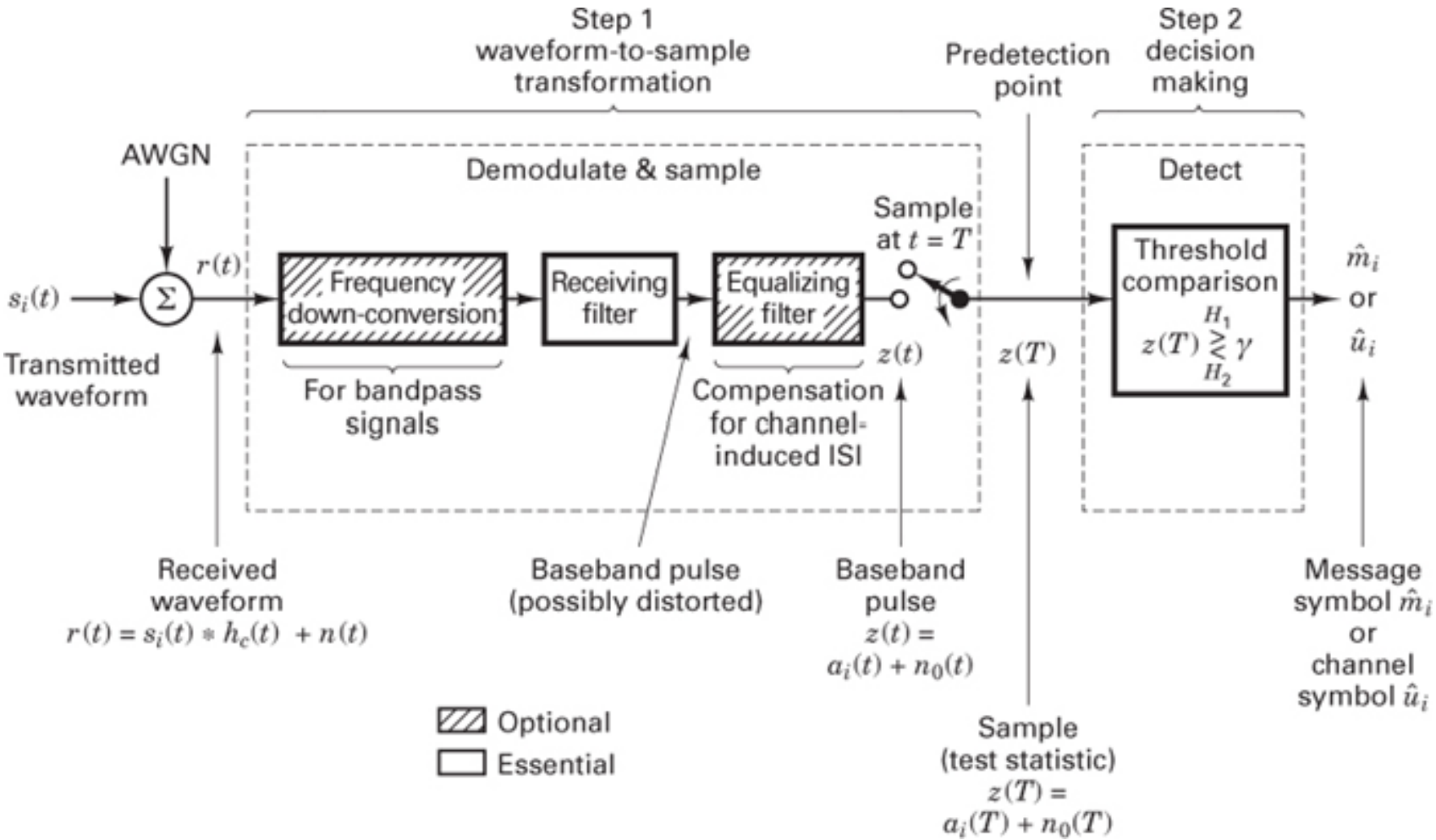
REVIEW

- Line codes - set of symbols a_k that determine the amplitude of the baseband pulses, $p(t)$
- Sum of scaled pulses transmitted at $R_b = 1/T_b$ pulses per second: $y(t) = \sum_k a_k p(t - kT_b)$
- Desired properties:
  - Low bandwidth
  - Power efficiency
  - Error detection/correction capability
  - No DC content
  - Timing info (self-clocking)
  - Transparency
- PSD of $y(t)$ controlled both by line code and pulse shape
- Time-limited signal (e.g., $p(t) = \Pi\left(\frac{t}{T_b}\right)$) has ∞ bandwidth
- Band-limited signal (e.g., $P(f) = \Pi\left(\frac{f}{R_b}\right)$) needs ∞ time

Intersymbol Interference (ISI)

- Time-limited pulse transmitted over low-pass channel → Spectral distortion occurs → Pulse spreads beyond its alloted T_b interval
- Band-limited pulse transmitted over band-limited channel → Not time-limited pulse → Pulse spreads beyond its alloted T_b interval
- Either way ISI occurs!
- ISI is not noise - caused by channels that aren't distortionless over the signal bandwidth
- Pulse spreading fine **as long as no effect at *decision-making instant***

Symbol Detection

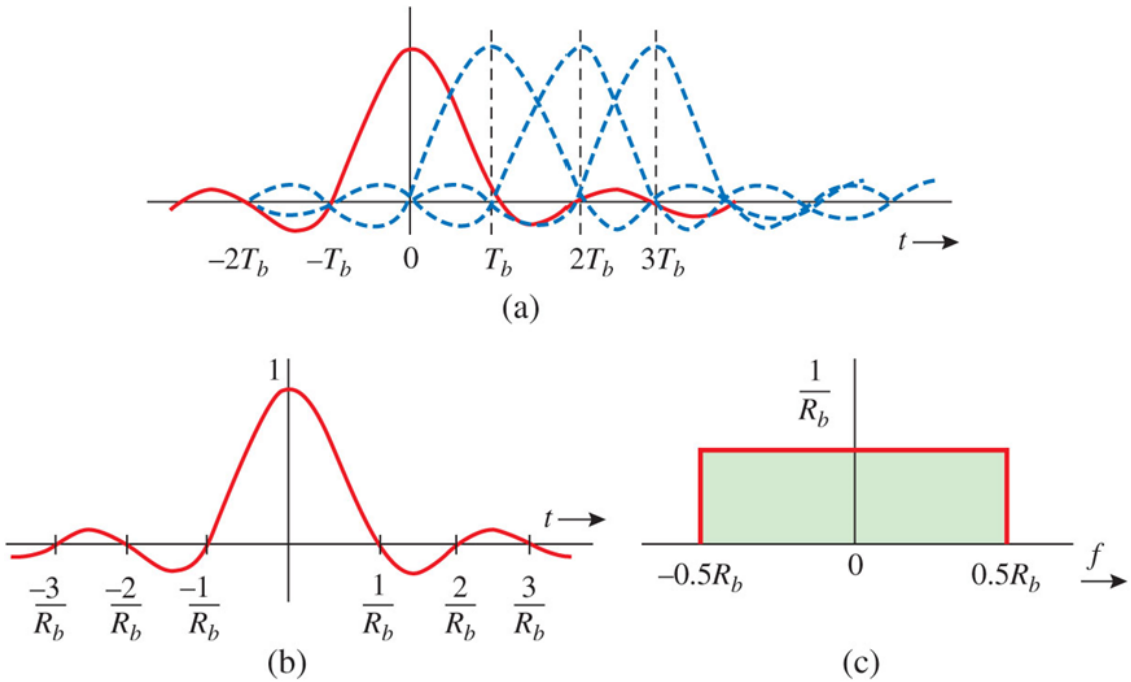


From Sklar textbook

Nyquist's First Criterion for Zero ISI

$$p(t) =$$

- Pulses allowed to overlap, but shaped to have zero ISI at decision points
- $p(t) = \text{sinc}\,(\pi R_b t)$ only one to meet Nyquist's First Criterion with min BW $R_b/2$ Hz, but...



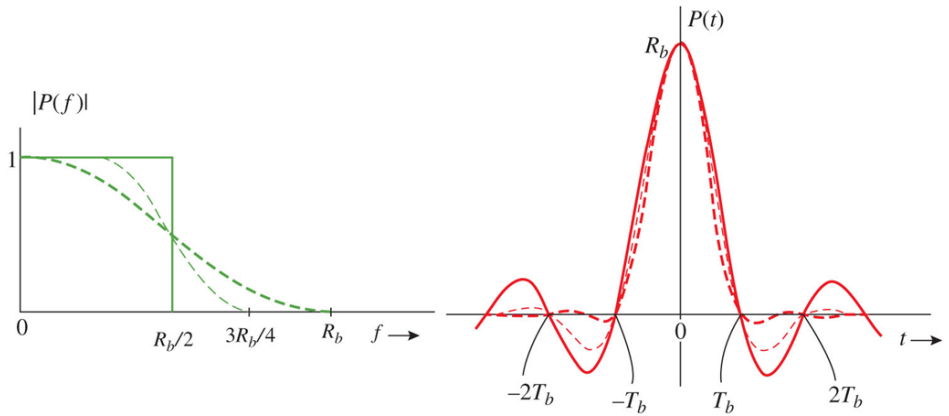
Nyquist's First Criterion for Zero ISI

- Want pulse with sharper roll-off to mitigate time jitter errors
- Nyquist showed this desired pulse will have bandwidth

$$B_T = \frac{(1+r)R_b}{2}$$

where r is the **roll-off factor** between $0 \leqslant r \leqslant 1$

- $r = \frac{\text{excess bandwidth}}{\text{theoretical minimum bandwidth}} = \frac{f_x}{R_b/2}$, where f_x is the bandwidth in excess of min bandwidth $R_b/2$
- Family of raised cosine pulses meets Nyquist's first criterion



(a) (b)

Raised Cosine

- Where have you seen this before?
- We will come back to it in a future lesson on Matched Filters
- Lab 5 flowgraph uses Root-Raised-Cosine (RRC) filtered samples at the transmitter to control the bandwidth - it even has a parameter called ”Excess Bandwidth”!
- Using the square root of the raised cosine creates ISI... but by using another RRC filter on the receiver, we end up with a regular raised cosine filter - which meets Nyquist’s First Criterion and minimizes ISI!