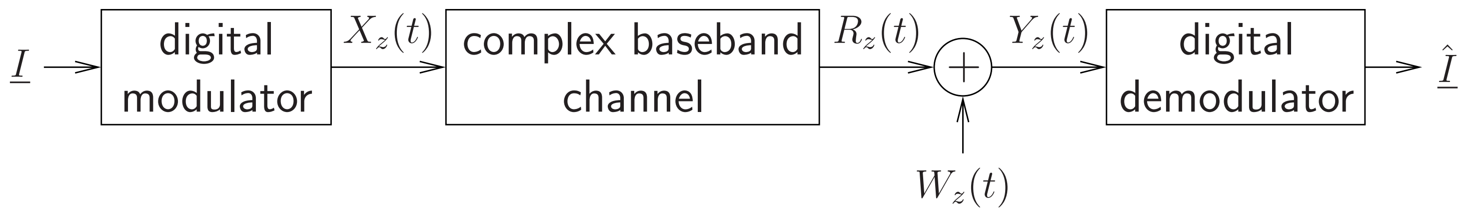
Digital Communication Basics [Ch. 12]:



The main idea:

- Say $\underline{I}$ represents K_b binary bits. We can assign each $\underline{I}$ to an integer $i \in \{0, 1, 2, \ldots, 2^{K_b} - 1\}$.
- To communicate $\underline{I} = i$, we transmit (complex baseband) waveform $x_i(t)$.
- The receiver infers $\hat{\underline{I}}$ from the output of the noisy channel.

We consider these constraints:

- Bandwidth (especially if spectrum is shared)
- Power (to prevent interference and save battery life)
- Data rate (to support application)
- Error rate (to support application)
- Complexity (since usually translates to $$)

We don't consider these:

- Delay (important in, e.g., speech communication)
- Peak-to-average power ratio (n.b., amplifier linearity)
- Size (e.g., antenna length)
- Probability of intercept (e.g., for military apps)

We use these metrics to characterize system performance:

1. Reliability
   - Proportion of bits or words received in error at a particular level of E_b/N_o (i.e., bit energy per noise spectral density).
2. Spectral efficiency η_B
   - Information rate (in bits/sec) transmitted per Hz of bandwidth.
   - For total information rate W_b (bits/sec) and bandwidth B_T (Hz), we have $\eta_B = \frac{W_b}{B_T}$.
3. Complexity

Limits on data communication:

- Shannon (1948) showed that error free communication over the AWGN channel is possible as long as

$$\eta_B \;<\; \log_2(1 + \mathsf{SNR}) \quad \frac{\text{bits}}{\text{sec Hz}}$$

- Notice that we can write SNR as

$$\mathsf{SNR} = \frac{P_S}{P_N} = \frac{E_b W_b}{N_o B_T} = \frac{E_b}{N_o}\eta_B$$

- Thus we can determine the upper limit to achievable spectral efficiency (as a function of $\frac{E_b}{N_o}$) via

$$\eta_B \;=\; \log_2\Bigl(1 + \tfrac{E_b}{N_o}\eta_B\Bigr)$$

Achievable spectral efficiency is below line: