Digital Communications

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What is communications

- Information exchange
- There has to be a medium
  - Fiber
  - Cable
  - Light
  - Acoustic wave

Why Acoustic

- God said, `Let there be light,' and there was light
  —— Bible, Old Testament, 01 The Creation of the World
- Electromagnetic wave attenuates rapidly
- We will focus on acoustics in this course

Digital communications

- Finite alphabet
- Merits
- In this course, only digital methods

Modulations

- Carrier

$$s_i(t) = Acos(2\pi f_o t + \theta)$$

- May exist carrierless communications
- Still requires spectrum control

What modulation can you think of?

- Mapping from alphabet to waveforms

$$s_i(t) = Acos(2\pi f_o t + \theta)$$

- Amplitude, frequency, and phase

Inner product

- Vector

$$\langle (x_1, x_2, \ldots, x_n), (y_1, y_2, \ldots, y_n) \rangle = x_1\, y_1 + x_2\, y_2 + \cdots x_n\, y_n$$

- Waveform

$$\langle f, g \rangle = \int_a^b f\, g\, dx.$$

Orthonormal basis

- Properties

$$x = \sum_{b \in B} \frac{\langle x, b \rangle}{\|b\|^2} b.$$

$$x = \sum_{b \in B} \langle x, b \rangle b$$

$$\|x\|^2 = \sum_{b \in B} |\langle x, b \rangle|^2.$$

- Mapping from waveform to basis

Optimum decoding

- Maximum a posteriori (MAP) detection

$$\hat{\theta}_{\mathrm{MAP}}(x) = \arg\max_{\theta} \frac{f(x|\theta)\, g(\theta)}{\int_{\vartheta} f(x|\vartheta)\, g(\vartheta)\, d\vartheta} = \arg\max_{\theta} f(x|\theta)\, g(\theta).$$

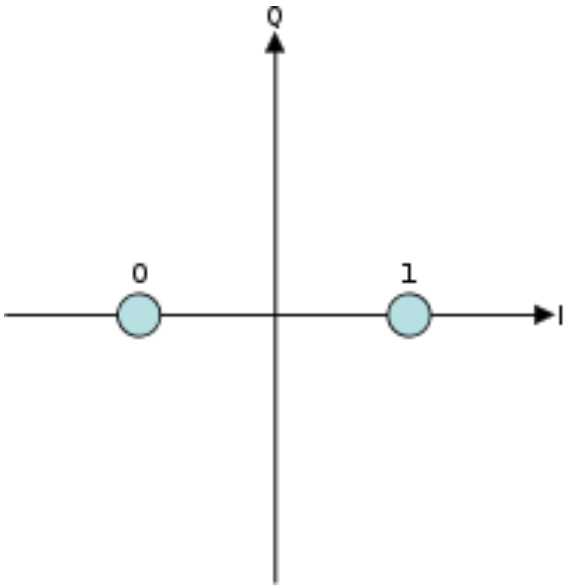
- Maximum likelihood (ML), when

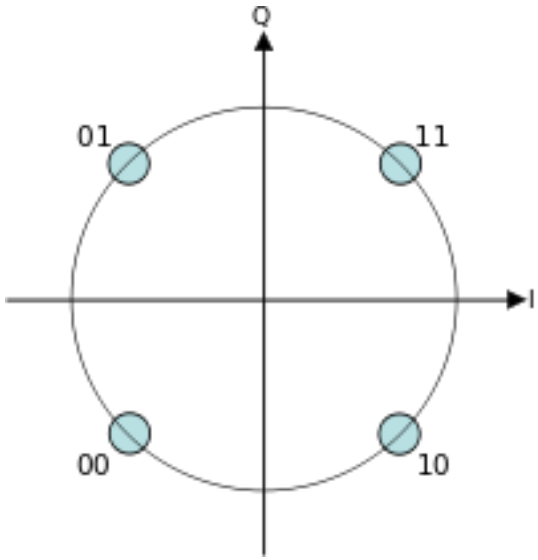
$$\hat{\theta}_{\mathrm{ML}}(x) = \arg\max_{\theta} f(x|\theta)$$

- Minimum Euclidian Distance, when

Error performance

- y=x+z
- AWGN





$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

Error performance of FSK

- 2FSK?
- MFSK?