Exam presentation

Assignment 2.1 and 3

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Overview

- Assignment 2
  - Eye diagrams
  - Q function
  - Matched filter
- Assignment 3
  - Link budget model
  - SNR and P_E
  - Alternative modulations

Eye diagram

- Plot composed by overlaying segments of different bit sequences
- Can be generated with an oscilloscope
- Shows effects of *inter-symbol interference*
- Provides a qualitative measure of the system performance

Eye diagram characteristics

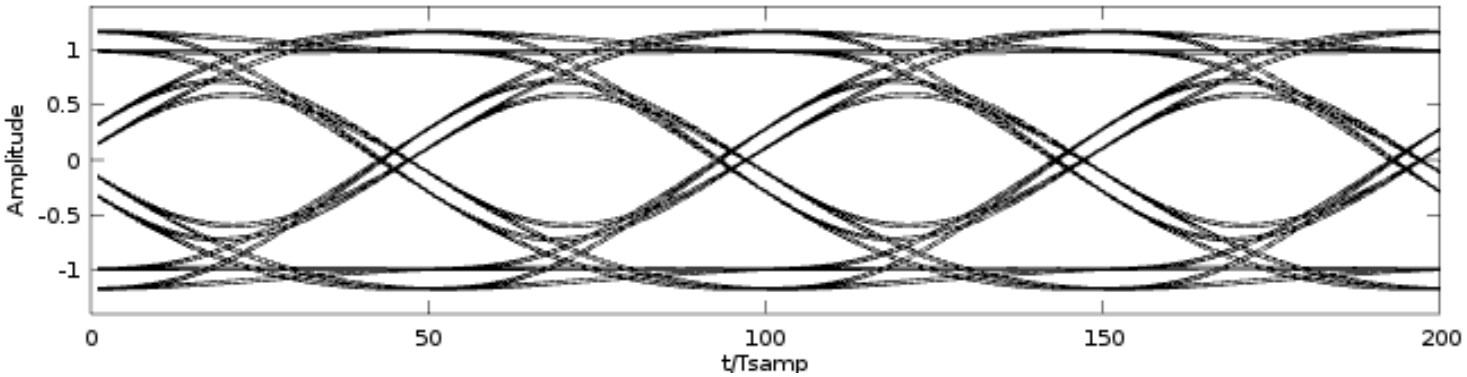


Figure: *Eye diagram of baseband antipodal signal*

A Difference between high and low levels

A_j Difference between A and the eye opening

T_j Deviations from ideal timing

T_b Bit time period

Eye diagram at different bandwidths

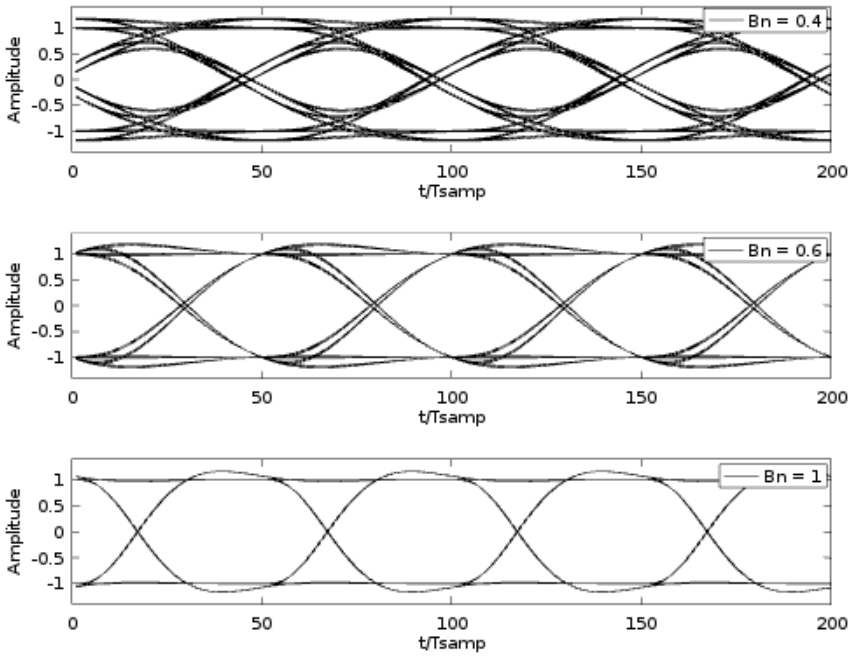


Figure: *Eye diagram for normalized bandwidths 0.3, 0.7, 1.2*

- Low BW: high amplitude and timing jitter
- High BW: no ISI, chances of higher noise

Q function

Matched filters

Link budget model

- A way of estimating the power of a received signal
- Takes into account all the gains and losses of transmitter, channel, and receiver

$$P_R = \left(\frac{\lambda}{4\pi d}\right)^2 \frac{P_T G_T G_R}{L_0}; \tag{1}$$

- In decibels:

$$P_{R,dB} = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) + ERP_{dB} + G_{R,dB} - L_{0,dB}; \tag{2}$$

Link budget model variables

$(\frac{4\pi d}{\lambda})^2$ Free-space loss

$ERP = P_T G_T$ Effective radiated power

G_R Gain of receiver antenna

L_0 Other losses, link budget margin

SNR calculation

- Signal-to-noise ratio in decibels:

$$SNR_{dB} = P_{R,dB} - P_{int,dB} \tag{3}$$

P_R Calculated using link budget model

P_{int} Noise power, proportional to the receiver noise temperature and the transmission bandwidth

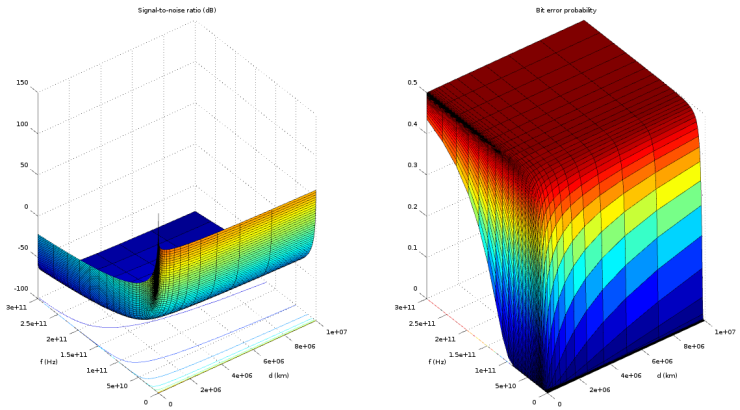
P_E calculation

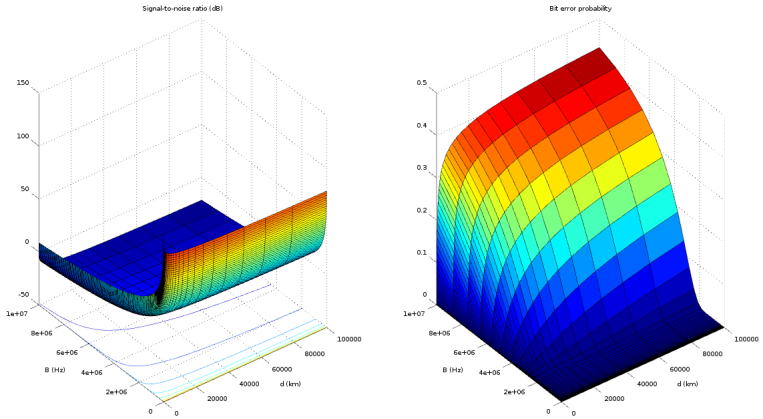
- Bit error probability for BSFK transmissions:

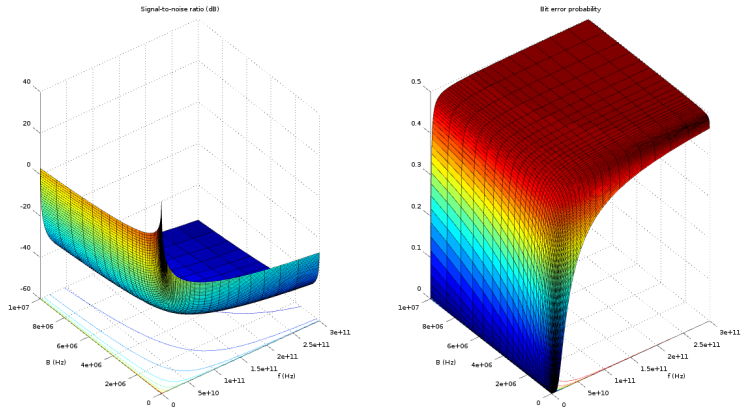
$$P_E = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \tag{4}$$

1. ratio E_b/N_0 derived from $SNR =\rightarrow \frac{E_b}{N_0 B T_b}$
2. For binary BPSK, $B = 2/T_b$
3. Factor BT_b is 2, or 3 dB

Impact of d, λ, B







- SNR and P_E are negatively affected by:
  - Higher distance d
  - Lower wavelength λ
  - Wider bandwidth B (lower influence)

Impact of P_T

- P_E for P_T at 50 W, 5 W, and 500 mW:

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1.4062e-05 9.2684e-02 3.3768e-01
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(5)

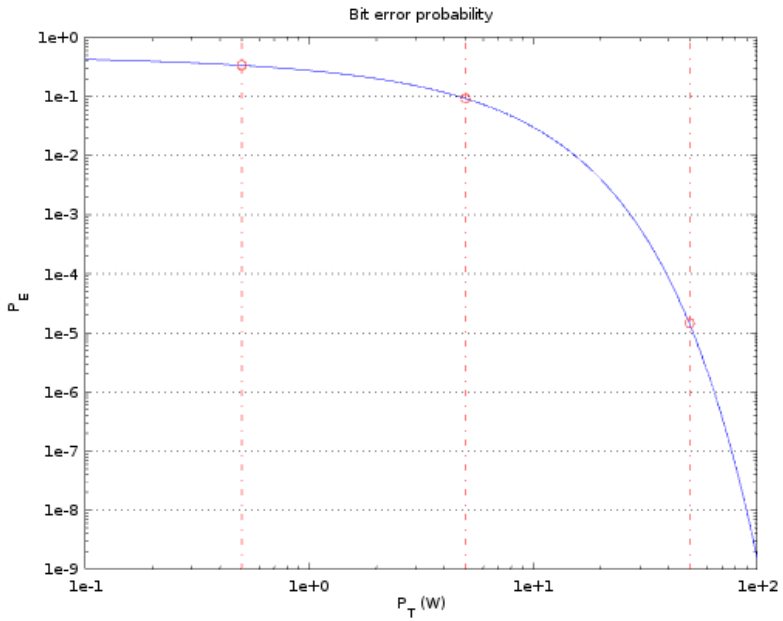

Figure: P_E *over values of* P_T

Alternative modulation: ASK

- Amplitude-shift keying

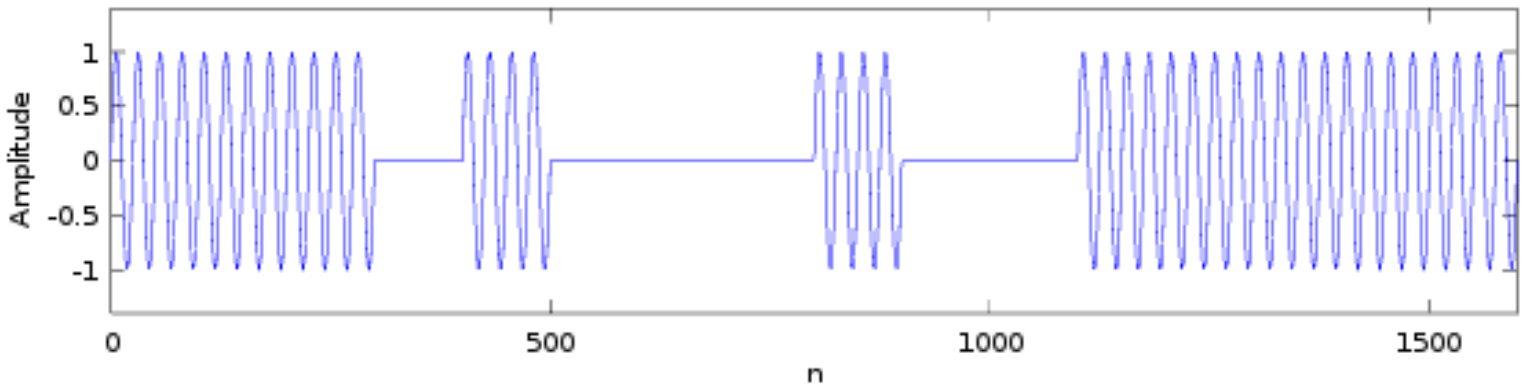

Figure: *Bit stream modulated using ASK*

- 0-bit represented as 0
- 1-bit represented as $A\cos(2\pi f_c t)$

Alternative modulation: ASK (P_E calculation)

- Correlation coefficients:
  - $\rho_{12} = \frac{1}{\sqrt{E_1 E_2}} \int_{-\infty}^{\infty} s_1(t) s_2(t) dt = 0$
  - $R_{12} = \frac{\sqrt{E_1 E_2}}{E_b} \rho_{12} = 0$
- SNR to E_b/N_0: conversion factor $BT_b = 2$
- Bit error probability:

$$P_E = Q\left(\sqrt{(1 - R_{12})\frac{E_b}{N_0}}\right) = Q\left(\sqrt{\frac{E_b}{N_0}}\right) \tag{6}$$

Alternative modulation: FSK

- Frequency-shift keying

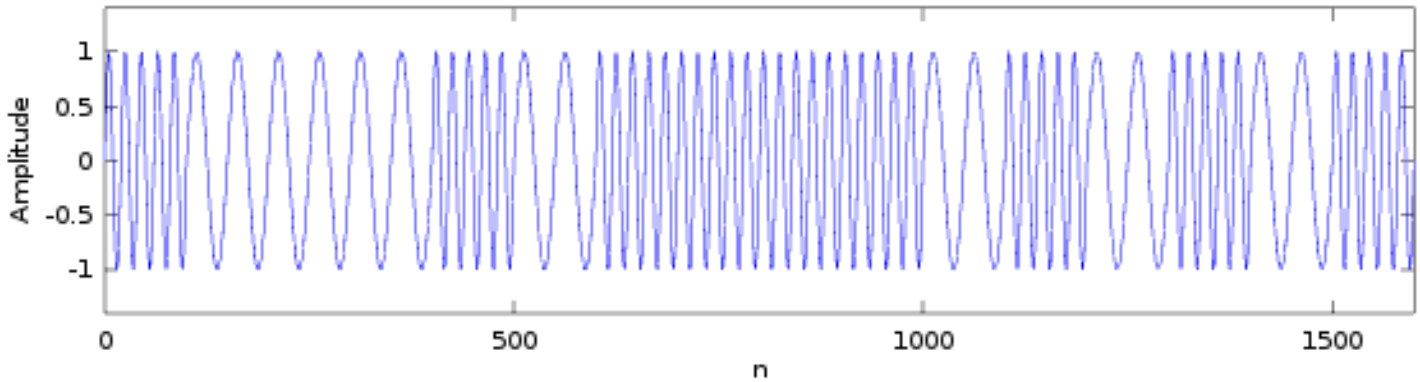

Figure: *Bit stream modulated using FSK*

- 0-bit represented as $A\cos(\omega_c t)$
- 1-bit represented as $A\cos((\omega_c + \Delta\omega)t)$
- Assumptions: $\omega_c = \frac{2\pi n}{T}$ and $\Delta\omega = \frac{2\pi m}{T}$

Alternative modulation: FSK (P_E calculation)

- Correlation coefficient $R_{12} = \frac{\sqrt{E_1 E_2}}{E_b} \rho_{12} = 0$
- SNR to E_b/N_0: conversion factor $BT_b = 2.5$
- Bit error probability:

$$P_E = Q\left(\sqrt{(1 - R_{12})\frac{E_b}{N_0}}\right) = Q\left(\sqrt{\frac{E_b}{N_0}}\right) \tag{7}$$