Exercises. Lesson 6
Bandpass digital transmission

Problem 6.1

Calculate the expected value of the number of error bits during a day for the coherent BPSK receiver described below, under continuous operation. The data rate is $5000 bits/s$. The input digital signals are $s_1(t) = A{\cdot}cos(\omega_p t)$ and $s_2(t) = -A{\cdot}cos(\omega_p t)$, where $A = 1mV$, and the unilateral noise power spectral density is $N_0 = 10^{-11} W/Hz$.

Result:

2338 bits

Problem 6.2

A coherent BPSK system operating continuously produces errors at an average rate of 100 errors per day. The data rate is $1000 bits/s$. The unilateral noise power spectral density is $N_0 = 10^{-10} W/Hz$.
a) b)
Un sistema BPSK coherente que opera continuamente comete errores a razón de 100 errores al día como promedio. La velocidad de los datos es de $1000 bits/s$. La densidad espectral unilateral de potencia de ruido es $N_0 = 10^{-10} W/Hz$.

a. If the system is ergodic, which is the average error probability?

b. If the average received power is adjusted to 10^{-6} W, would this value be enough to keep the error probability calculated in a)?

Result:

1. $1.16 \cdot 10^{-6}$
2. No

Problem 6.3

The signal component of a coherent PSK system is defined by the expression

$$s(t) = A_c k sen(\omega_p t) \pm A_c \sqrt{1-k^2} cos(\omega_p t)$$

where $0 \le t < T_b$, and the plus sign corresponds to the 1 symbol, and the minus sign corresponds to the 0 one. The first term on the right hand side of the equation represents a carrier component, included to improve the synchronization between transmitter and receiver. Solve this:

a. Plot the constellation of the signals described; what can be said about this diagram?

b. Show that, in presence of zero-mean additive white Gaussian noise with power spectral density $N_0/2$, the average error probability is

$$P_e = Q\left(\sqrt{\frac{2E_b}{N_0}(1-k^2)}\right)$$

with $E_b = \frac{1}{2}A_c^2 T_b$

c. Assume that 10% of the transmitted power is located in the carrier component. Determine the value of E_b/N_0 required to obtain an error probability of 10^{-4}.

d. Compare this E_b/N_0 value with the one required in a conventional PSK system with the same error probability.

Result:

1. PSK constellation
2. Demonstration
3. $\frac{E_b}{N_0} = 8.02$
4. $\frac{E_b}{N_0} = 7.22$

Problem 6.4

We want to compare two data transmission bandpass systems. One of them employs 16-PSK, the other, 16-QAM. Both systems have to provide an average symbol error probability of 10^{-3}. Compare the signal-to-noise requirements of said systems.

Result:

$\Delta\left(\frac{E_s}{N_0}\right) = 3.68dB$

Problem 6.5

If the performance criterion of a system is the bit error probability, which one of the following modulation schemes would be chosen to operate in an AWGN channel? Show the calculations.

a. Coherent binary orthogonal FSK with $E_b/N_0 = 13dB$.

b. Coherent binary PSK with $E_b/N_0 = 8dB$.

RESULT:

Coherent binary orthogonal FSK