Low-power radio design for the IoT
Exercise 2 (03.03.2022)

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Problem 1 Phase Mismatch in 16QAM Generator

Due to imperfections, a 16QAM generator produces:

$$x(t) = \alpha_1 A_{\mathrm{c}} \cos(\omega_{\mathrm{c}} t + \Delta\theta) - \alpha_2 A_{\mathrm{c}} (1 + \epsilon) \sin(\omega_{\mathrm{c}} t). \quad (1)$$

where $\alpha_1 = \pm 1, \pm 2$ and $\alpha_2 = \pm 1, \pm 2$.

- Construct the signal constellation for $\Delta\theta \neq 0$ but $\epsilon = 0$.
- Construct the signal constellation for $\Delta\theta = 0$ but $\epsilon \neq 0$.

Problem 2 Spectral Regrowth and Transmission Mask Requirements

A two-tone signal $x(t) = A_1 \cos \omega_1 t + A_2 \cos \omega_2 t$ is the input of a nonlinear power amplifier (PA) with compressing characteristic $y(t)$:

$$y(t) = \alpha_1 x(t) - |\alpha_3| x^3(t) \quad (2)$$

The spectrum of the signal at the output of the PA must respect the transmission mask shown in Fig. 1, where $\Delta f = 0$ corresponds to the center of the band of the input signal.

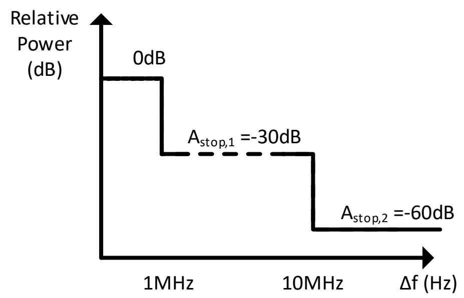

Figure 1: Transmission Mask

Find the value for $|\alpha_3|$ that allows to respect such mask for $\omega_1 = 2\pi * 2.409\,\mathrm{GHz}$, $\omega_2 = 2\pi * 2.41\,\mathrm{GHz}$ and $A_1 = A_2 = 0\,\mathrm{dBm}$.

Problem 3 BER for M-ASK signaling

In the lecture it was shown that the probability of error for the BPSK signal is given by:

$$P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right),\ E_b = \frac{A^2 T_b}{2} \tag{3}$$

for a constellation given in Fig. 2(a). Figure 2(b) shows the constellation points of the 4-ASK modulation.

- Determine the average energy per symbol for the 4-ASK modulation.
- Derive the probability of error for the 4-ASK modulation starting from the expression for the BPSK.
- Derive the probability of error for the general case of M-ASK modulation. Assume the constellation points are given by

$$x_{m1,2} = \pm\frac{2m-1}{2}A,\ m \in [1, M/2]\,. \tag{4}$$

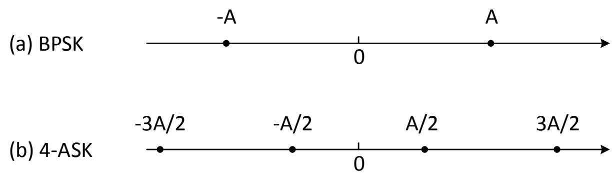

Figure 2: Constellation points of (a) BPSK modulation and (b) 4-ASK modulation.