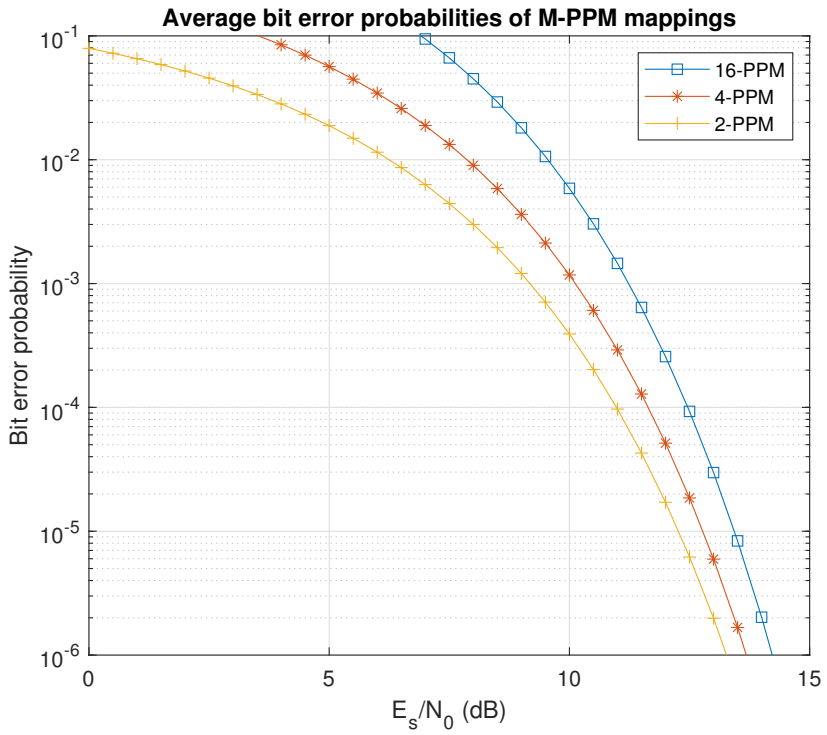
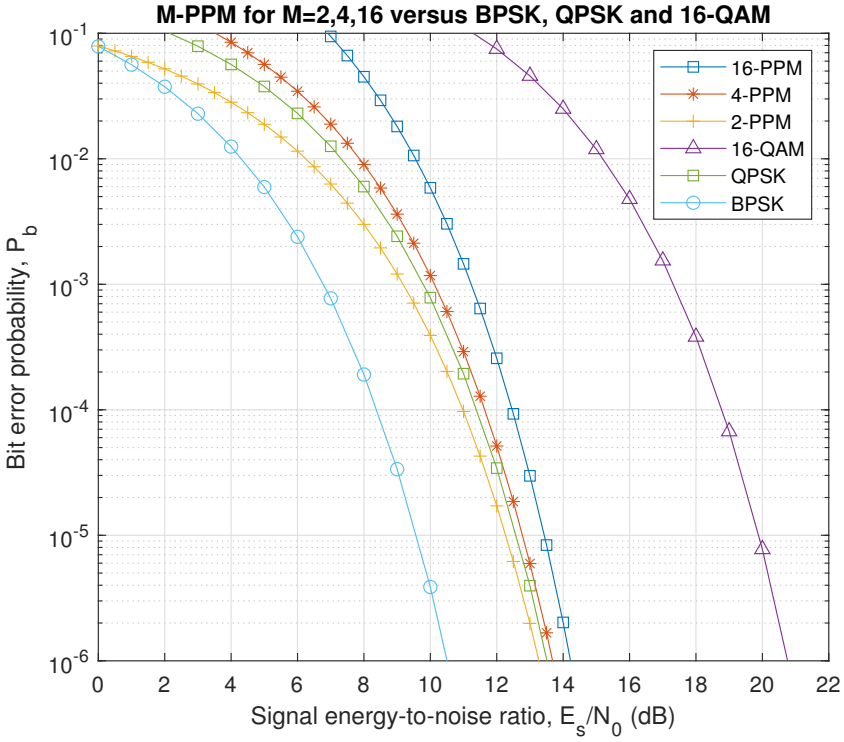
Solution of Homework # 4

1. Plot:



(a) Plot to compare (For $M = 2$-QAM we use BPSK):



For $M = 4$, PPM and QAM have practically the same performance. On the other hand, 16-PPM is better than 16-QAM in the sense that it requires less signal power - by at least 6 dB - to achieve the same bit error rate.

(b) A key disadvantage of PPM compared to QAM is that it requires higher bandwidth in order to transmit at the same rate. In fact, M-PPM requires M times the bandwidth of M-QAM. (Think of partitioning a time segment of length T into M pieces.)

2. (a) Average bit error probability (ABEP) for 16-QAM,

$$P_{b.16-\mathrm{QAM}} = \frac{3}{4} Q\left(\sqrt{\frac{E_s}{5N_0}}\right).$$

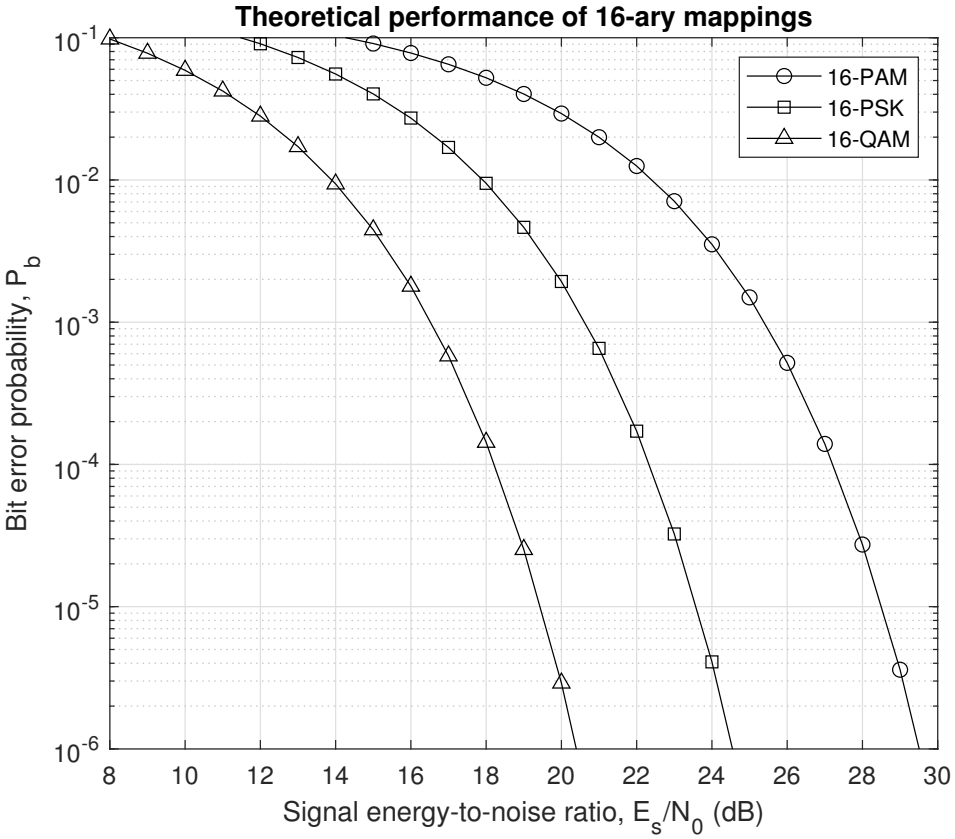
ABEP for 16-PAM,

$$P_{b.16-\mathrm{PAM}} = \frac{30}{64} Q\left(\sqrt{\frac{2E_s}{85N_0}}\right).$$

ABEP for 16-QPSK,

$$P_{b.16-\mathrm{PSK}} = \frac{2}{3} Q\left(\sqrt{\frac{2E_s}{N_0}\,\sin^2\left(\frac{\pi}{8}\right)}\right).$$

Plot:



(b) 16-QAM has best performance compared to 16-PSK and 16-PAM as expected.

(c) Required E_s/N_0 (dB) to achieve $P_b = 10^{-2}$:

Scheme	E_s/N_0 (dB)
16-QAM	14
16-PSK	18
16-PAM	22.4