ECE 451 - COMMUNICATION SYSTEMS (2)
FALL 2020

Implementation of a Digital Modulation Project

Submitted to:

Dr. Bassant Abdelhamid

Submitted by:

Group(19)

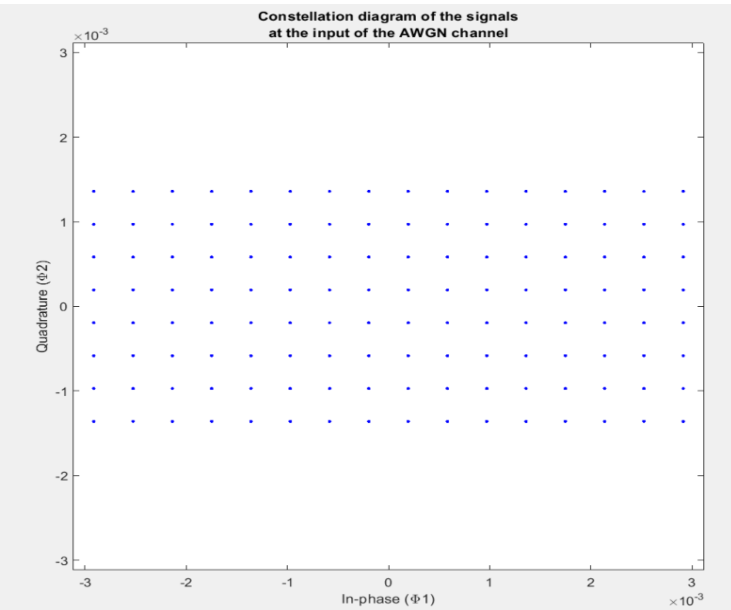
Ahmed Sobhy Mohamed (Code: 1600100)
Ahmed Wael Ibrahim (Code: 1600212)
Islam Adel Gaber Gaber (Code: 1600257)
Eladham Galal Zakaria (Code: 1600285)
Ismail Galal Mohamed (Code: 1600270)
Maria Ahmos Asaad (Code: 16E0138)

Modulation Scheme: 128 – QAM

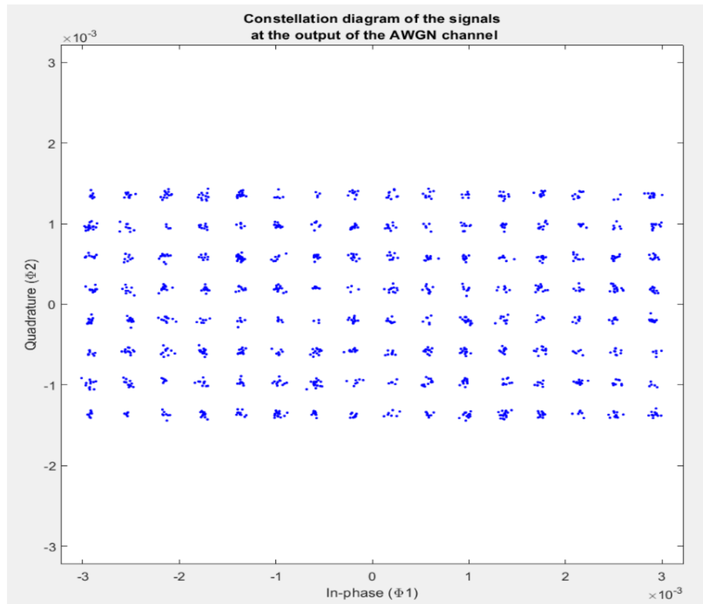
Constellation Diagrams at different SNR Values: Assuming $N_o = 2x10^{-9}$

a) SNR = 30 dB

Input of the AWGN Channel

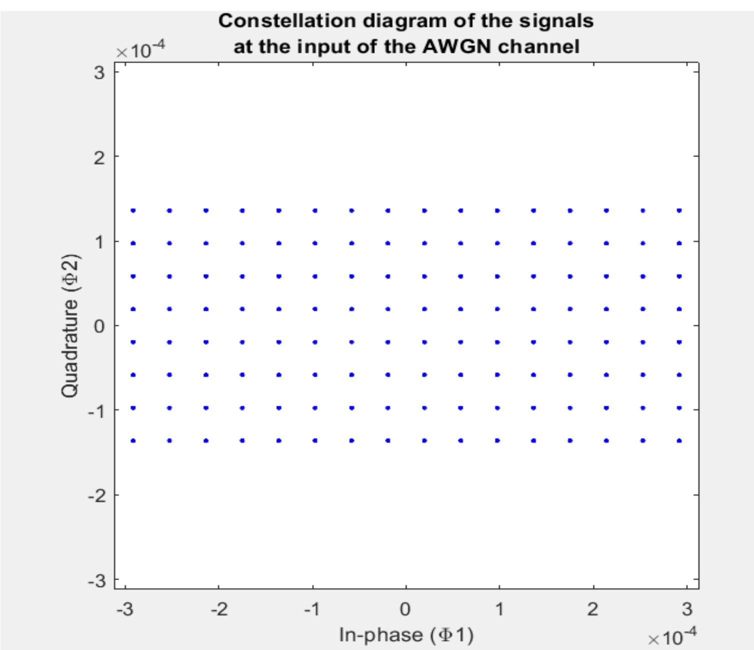


Output of the AWGN Channel

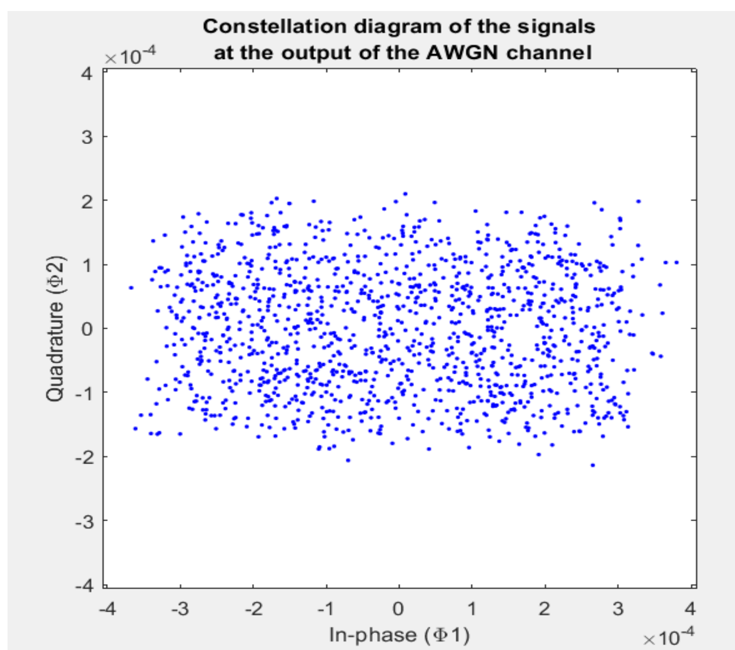


b) SNR = 10 dB

Input of the AWGN Channel

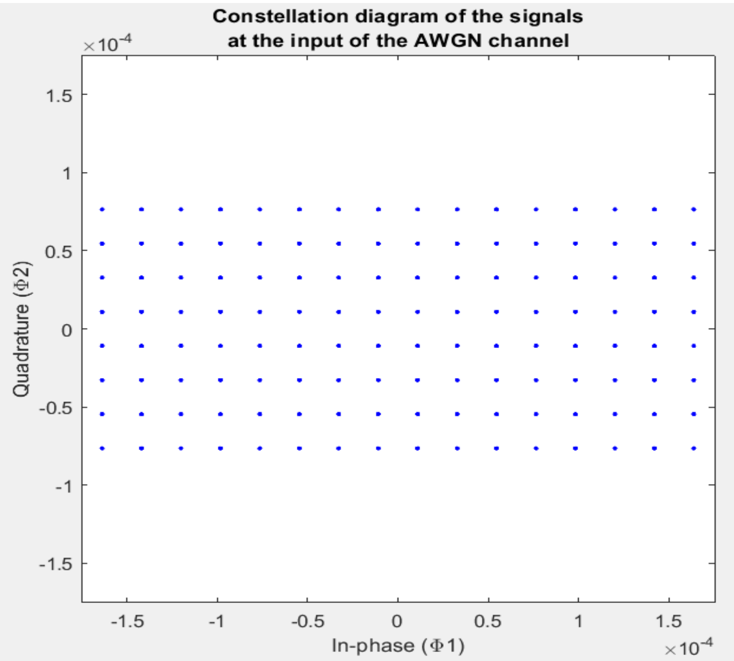


Output of the AWGN Channel

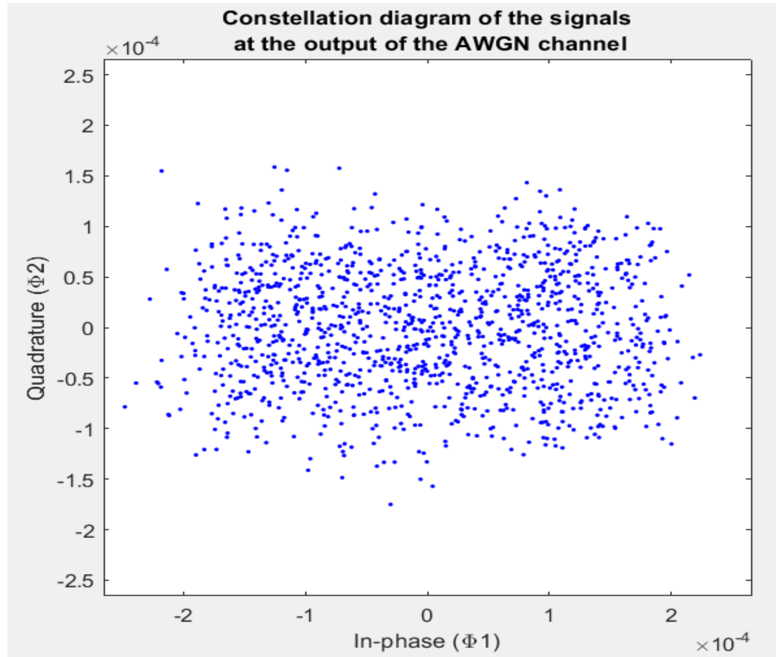


c) SNR = 5 dB

Input of the AWGN Channel

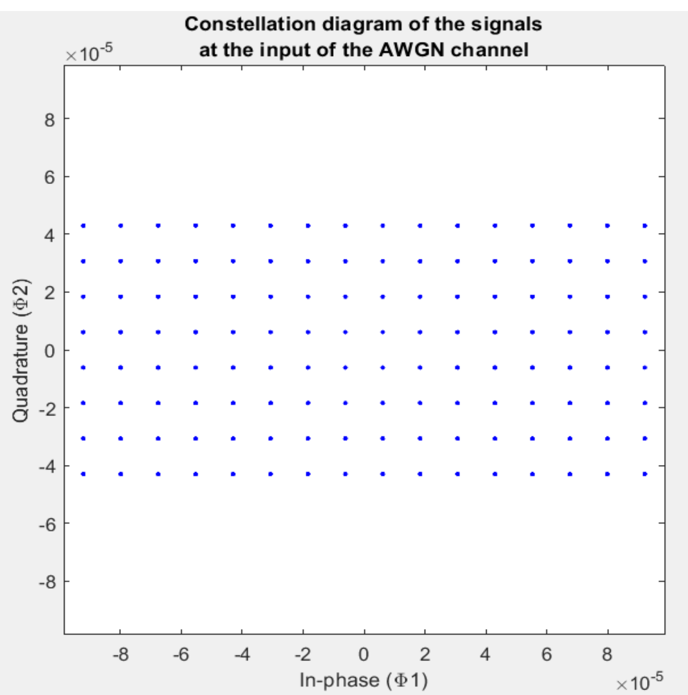


Output of the AWGN Channel

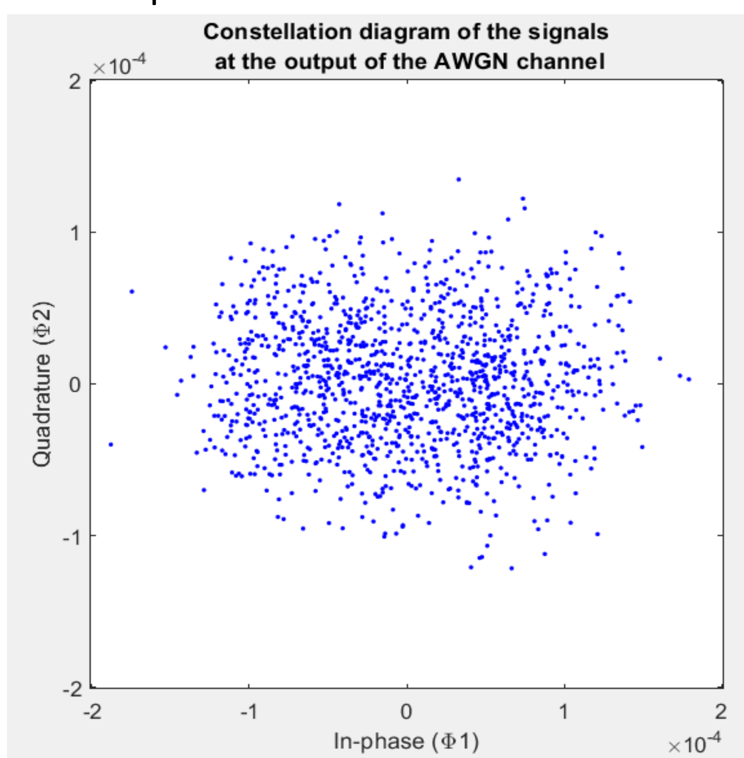


d) SNR = 0 dB

Input of the AWGN Channel

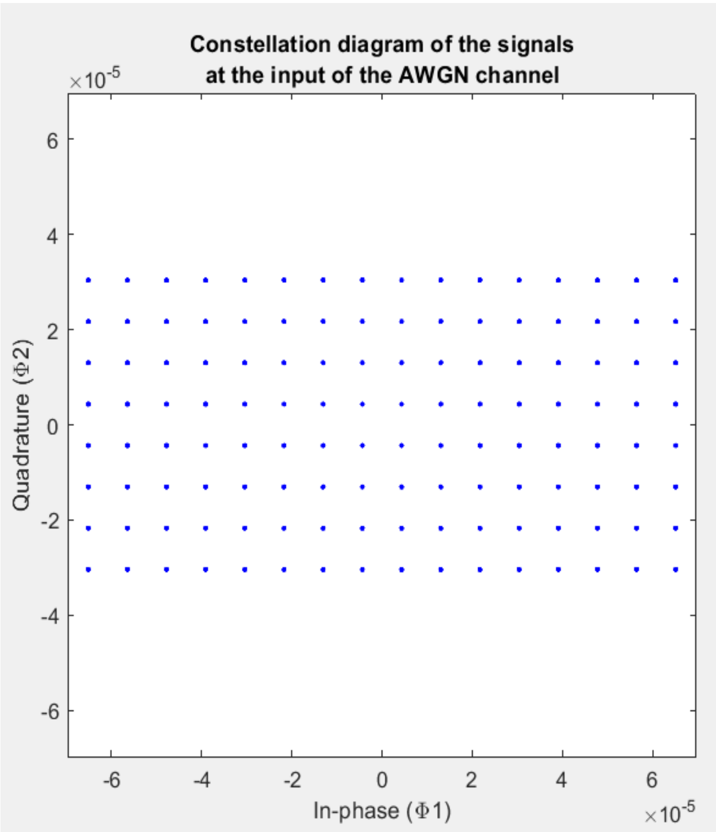


Output of the AWGN Channel

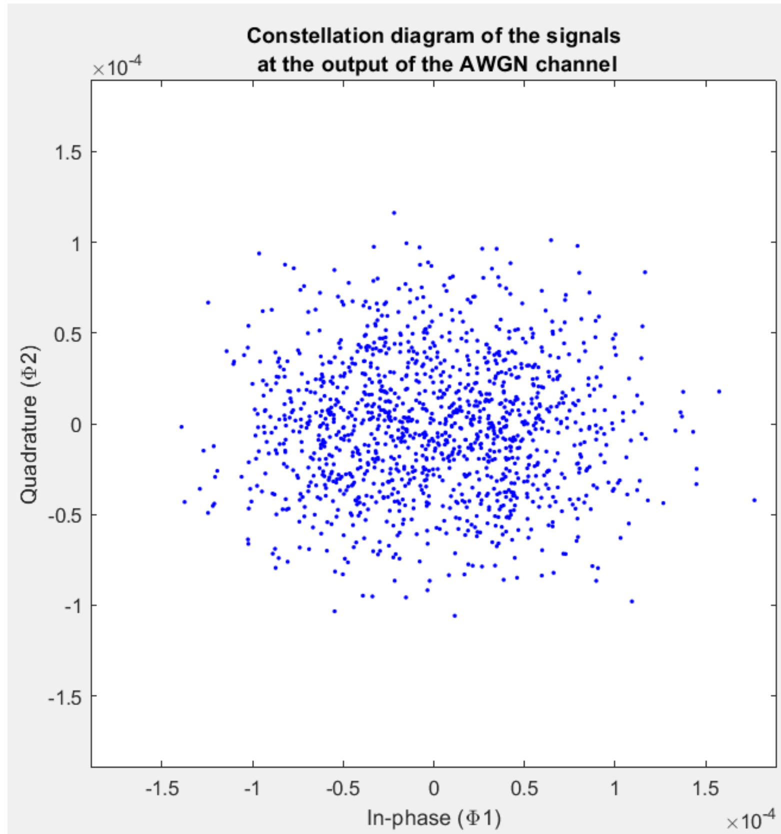


e) SNR = -3 dB

Input of the AWGN Channel



Output of the AWGN Channel



<u>Comment:</u>

As SNR decreases while keeping N_o constant, the signal power decreases with respect to noise power. Thus, the probability of error increases. The result is a 'ball' or 'cloud' of points surrounding each symbol position.

Used Formulas

$$E_{tot} = 4\left(4\sum_{n=1}^{8}(2n-1)^2a^2 + 8\sum_{n=1}^{4}(2n-1)^2a^2\right)$$

$$E_{avg} = \frac{E_{tot}}{M} = SNR \text{ x } N_o \text{ x } 2$$

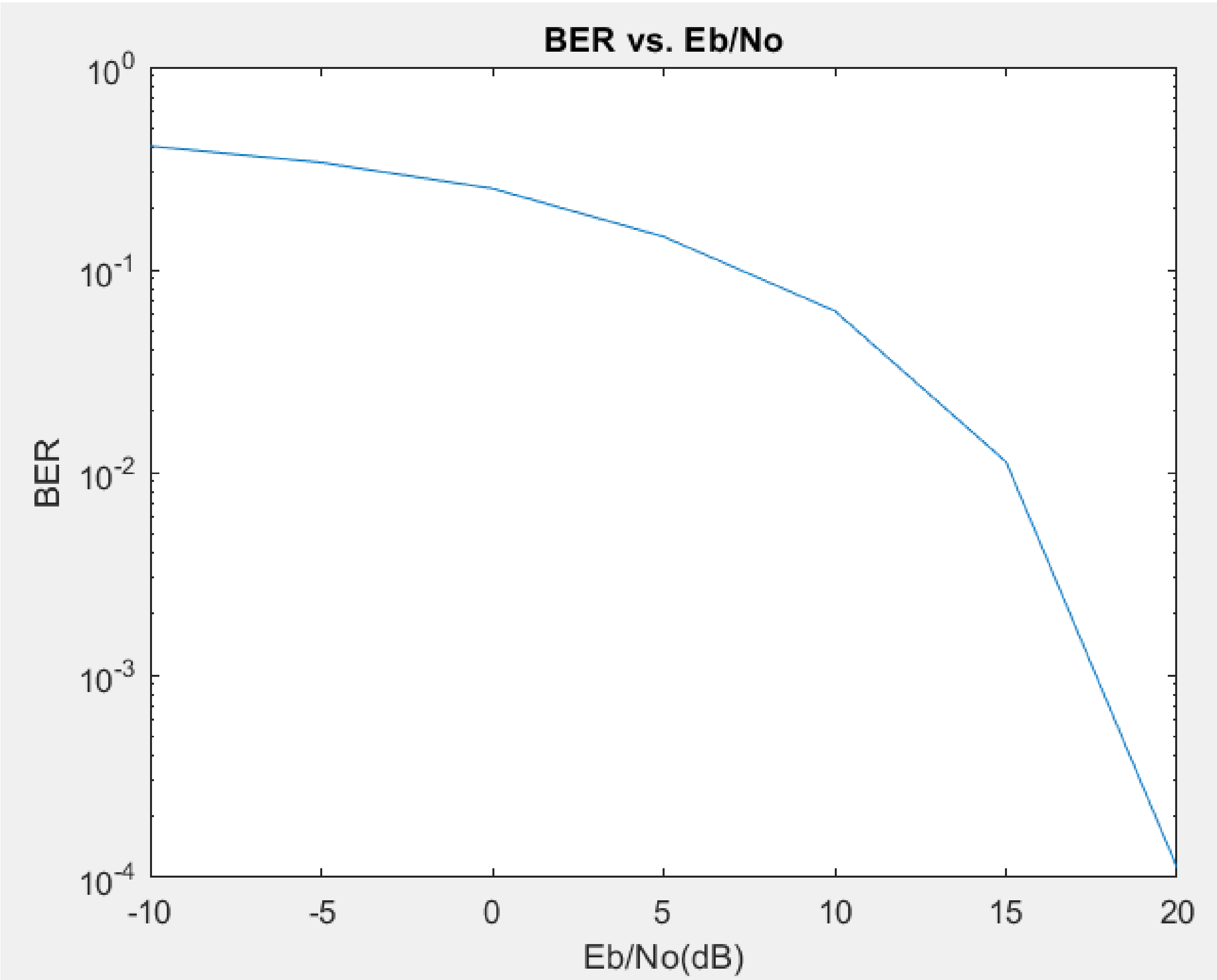
$$E_b = \frac{E_{avg}}{log_2(M)}$$

$$SNR = \frac{E_b}{N_o} \text{ x } \rho$$

$$a = \sqrt{\frac{E_{avg}}{106}}$$

BER vs. Eb/No (in dB) Plots

a) Simulated plot



<u>Comment:</u>

The BER is measured by comparing the bits detected at the output of the demapper with the transmitted bits.

b) Theoretical plot

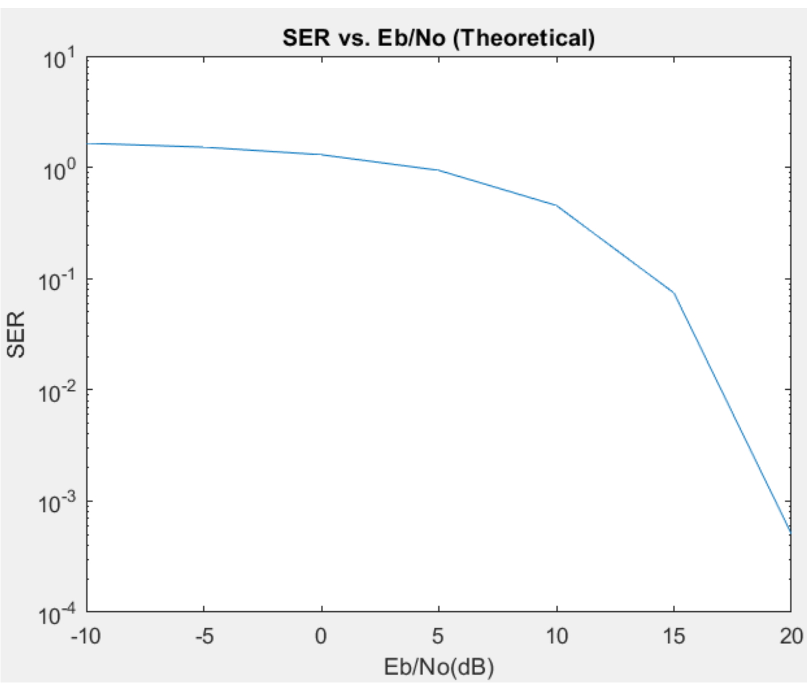
We calculated BER using the approximated formula (in the slides):

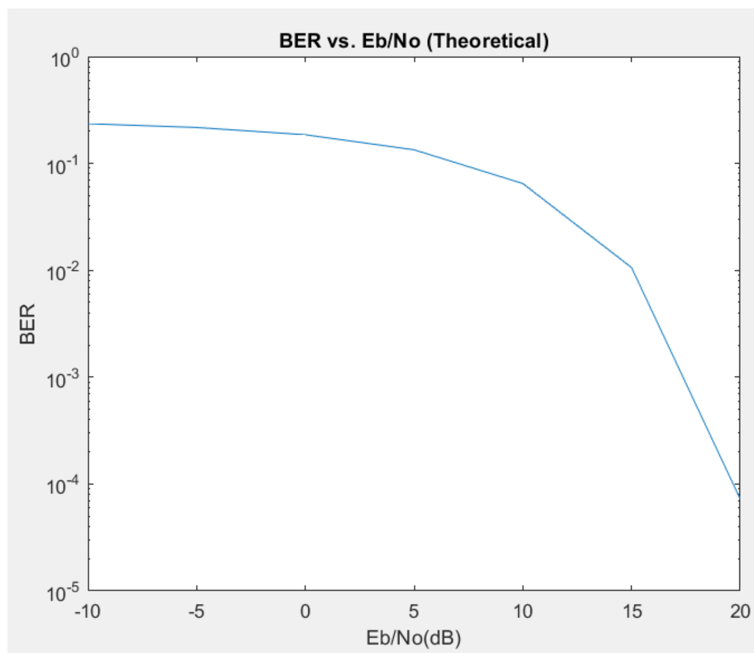
$$P_e = P_{e_{\varphi 1}} + P_{e_{\varphi 2}}$$

$$P_{e_{L\_ASK}} = 2\left(1 - \frac{1}{L_1}\right) Q\left(\frac{2a}{\sqrt{2N_0}}\right) + 2\left(1 - \frac{1}{L_2}\right) Q\left(\frac{2a}{\sqrt{2N_0}}\right)$$

$$P_{e_b} = \frac{P_e}{log_2(M)}$$

Where L1=16 & L2=8. It resulted in the figures below:





Comment:

This calculation resulted in incorrect results as some SER values were larger than 1.

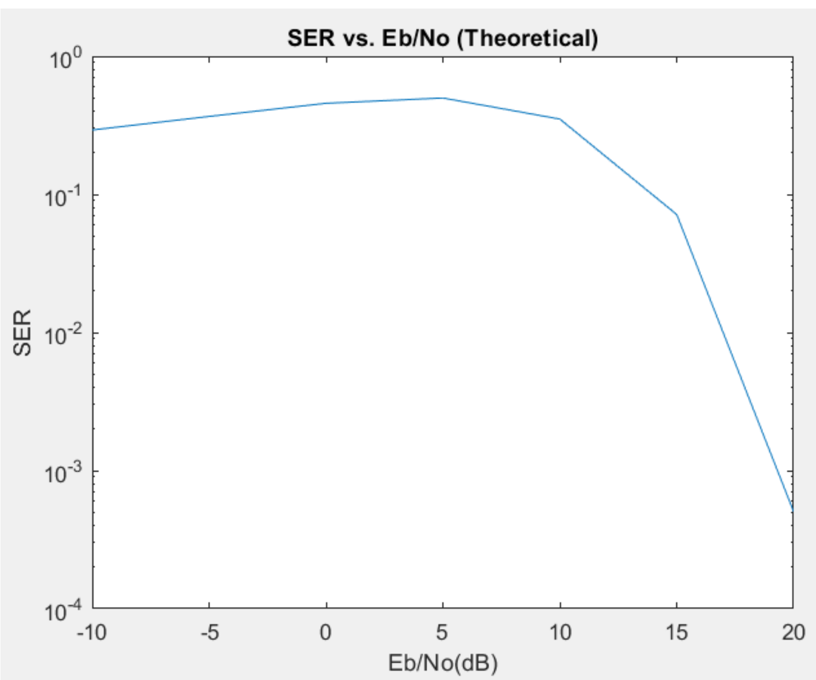
So, we calculated SER using the formula but, neglecting the approximation used in the lecture:

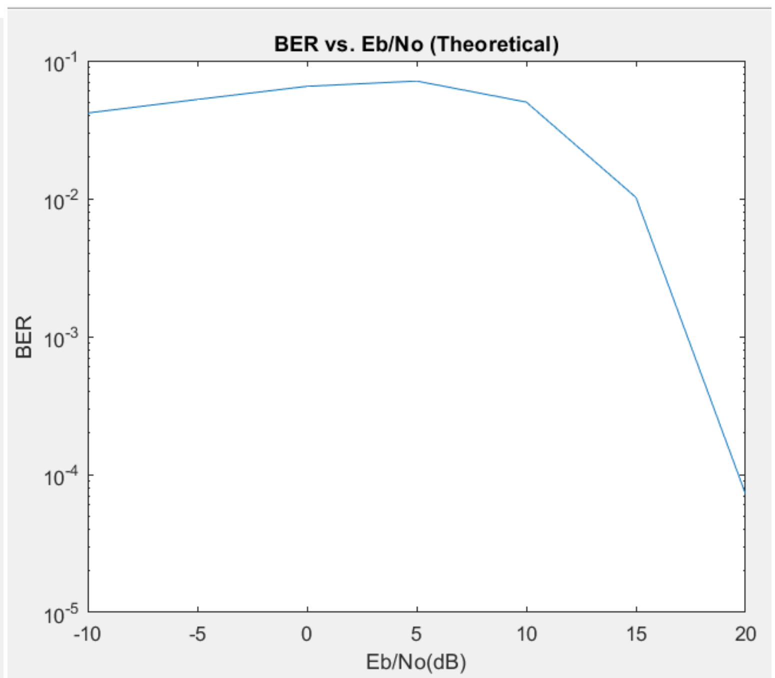
$$P_e = P_{e_{\varphi 1}} + P_{e_{\varphi 2}} - 2\,P_{e_{\varphi 1}} P_{e_{\varphi 2}}$$

$$P_{e_{L\_ASK}} = 2\left(1-\frac{1}{L_1}\right)Q\left(\frac{2a}{\sqrt{2N_0}}\right) + 2\left(1-\frac{1}{L_2}\right)Q\left(\frac{2a}{\sqrt{2N_0}}\right) - 2\left(2\left(1-\frac{1}{L_1}\right)Q\left(\frac{2a}{\sqrt{2N_0}}\right)\right)\left(2\left(1-\frac{1}{L_2}\right)Q\left(\frac{2a}{\sqrt{2N_0}}\right)\right)$$

$$P_{e_b} = \frac{P_e}{log_2(M)}$$

Using this formula (without neglecting the last term), SER values were smaller than 1, resulting in the figures below:





<u>Comment:</u>

These readings were achieved without the approximation, but they're also incorrect as it's noticed in the figure that it increases and then decreases whereas it should decrease.