Communications Lab

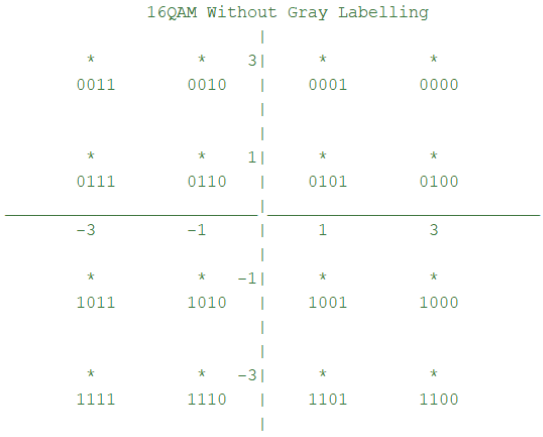
Experiment 5

180030036

Rishabh Tripathi

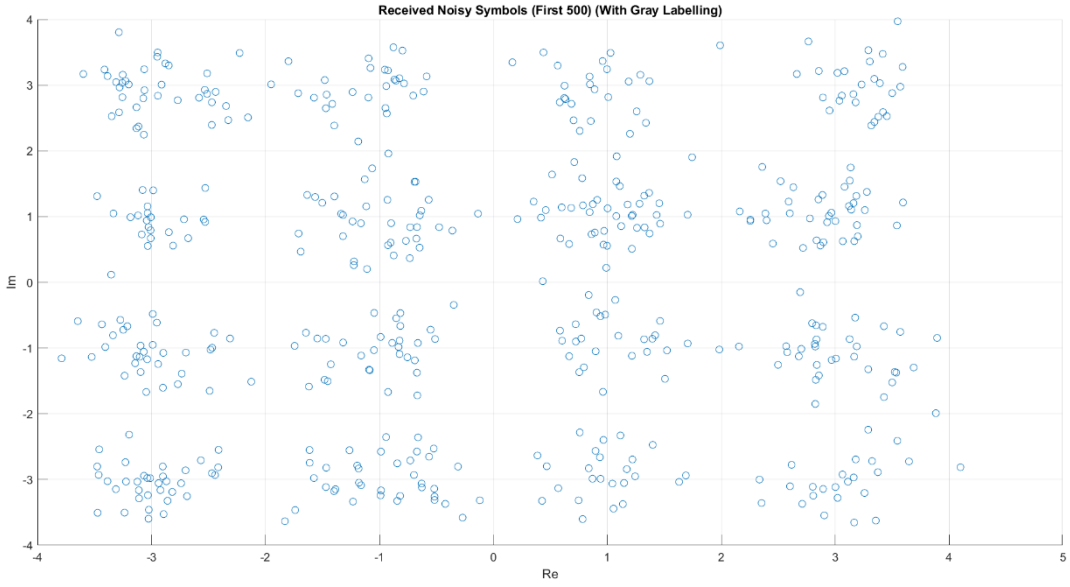
16QAM Communication: Running an example

We generate a signal of randomly generated bits and perform 16QAM modulation. The modulation is done with Gray labelling and without Gray labelling:

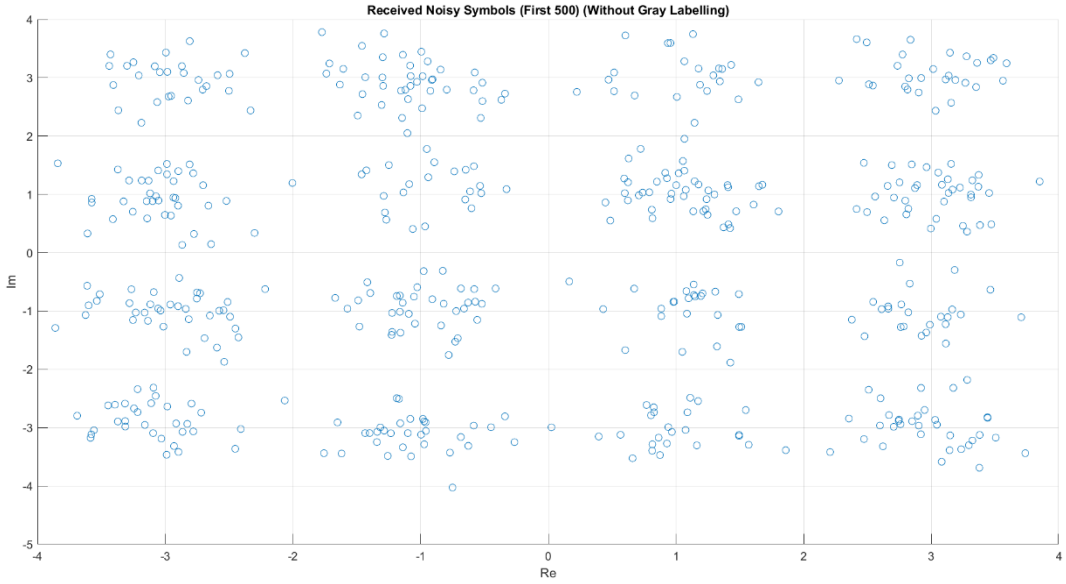


We then add white Gaussian noise (using an SNR = 10 dBW) to our signal and the resulting noisy signal (on z-plane) is as follows (first 500 symbols):

1. With Gray Labelling:



2. Without Gray Labelling:



Then we perform demodulation based on distance boundaries (ML rule) between the symbols. We get the following bit error rates in the two cases:

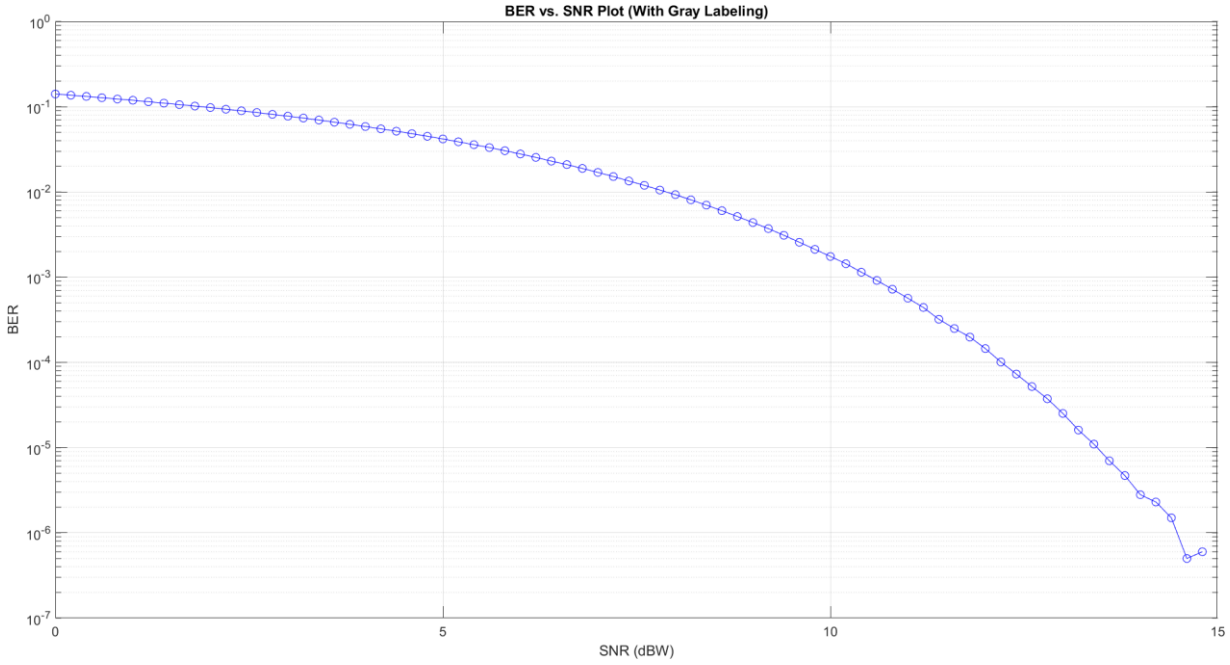
BER with Gray Labelling = 0.0017

BER without Gray Labelling = 0.0022

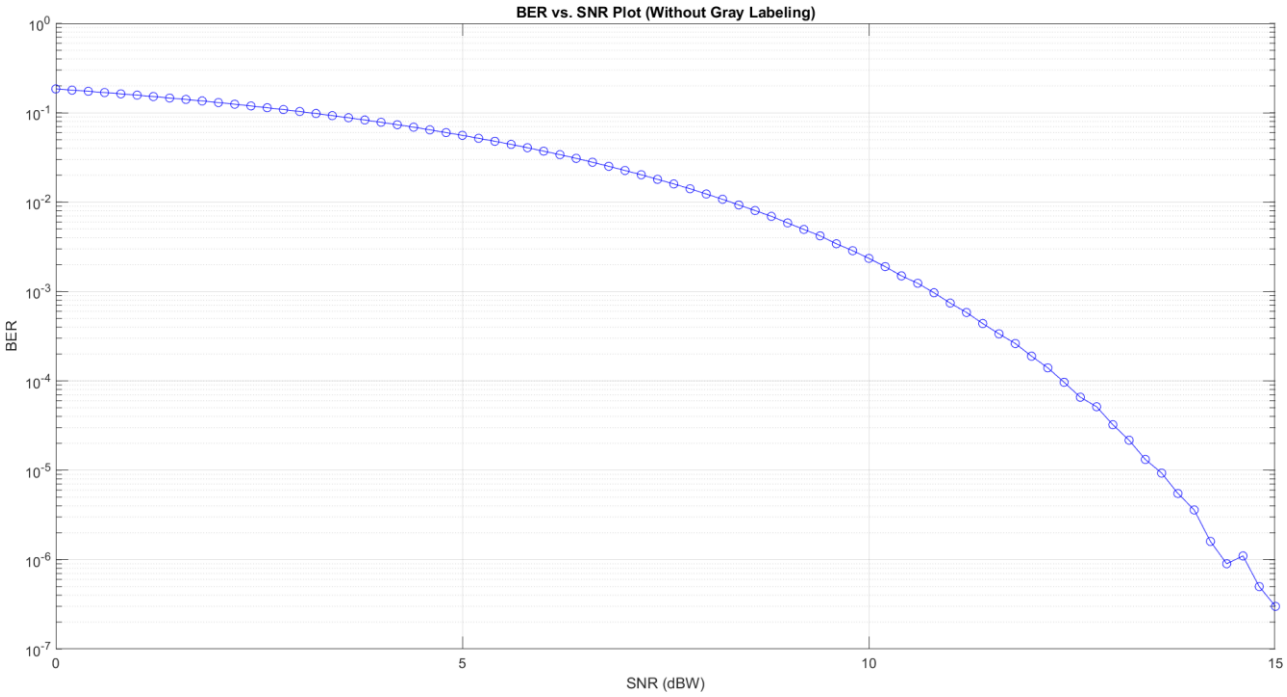
Bit Error Rate (BER) Calculation:

We run a randomly generated message signal of length 100000, for 100 iterations (we have a resolution of 10^-7) for each value of SNR from 0 to 15 dBW. The resulting bit error rate plots are as follows:

1. With Gray Labelling:



2. Without Gray Labelling:



Theoretical Calculation of Error Probability:

Theoretical value of error probability for our 16QAM communication system in both Gray labelled and not Gray labelled cases is calculated as follows:

$$SNR = \frac{E_b}{N_o}, \quad \sigma^2 = \frac{N_o}{2}$$

Where, σ^2 is the variance of the real and imaginary components of the AWGN.

We have, $E_b = 2.5$ for our choice of symbols. Therefore, standard deviation:

$$\sigma = \sqrt{\frac{5}{4SNR}}$$

We derive an expression for symbol error rate (same for with and without gray labelling), which is given as follows:

$$P_s = 3Q\left(\sqrt{\frac{4SNR}{5}}\right) - \frac{9}{4}Q\left(\sqrt{\frac{4SNR}{5}}\right)^2$$

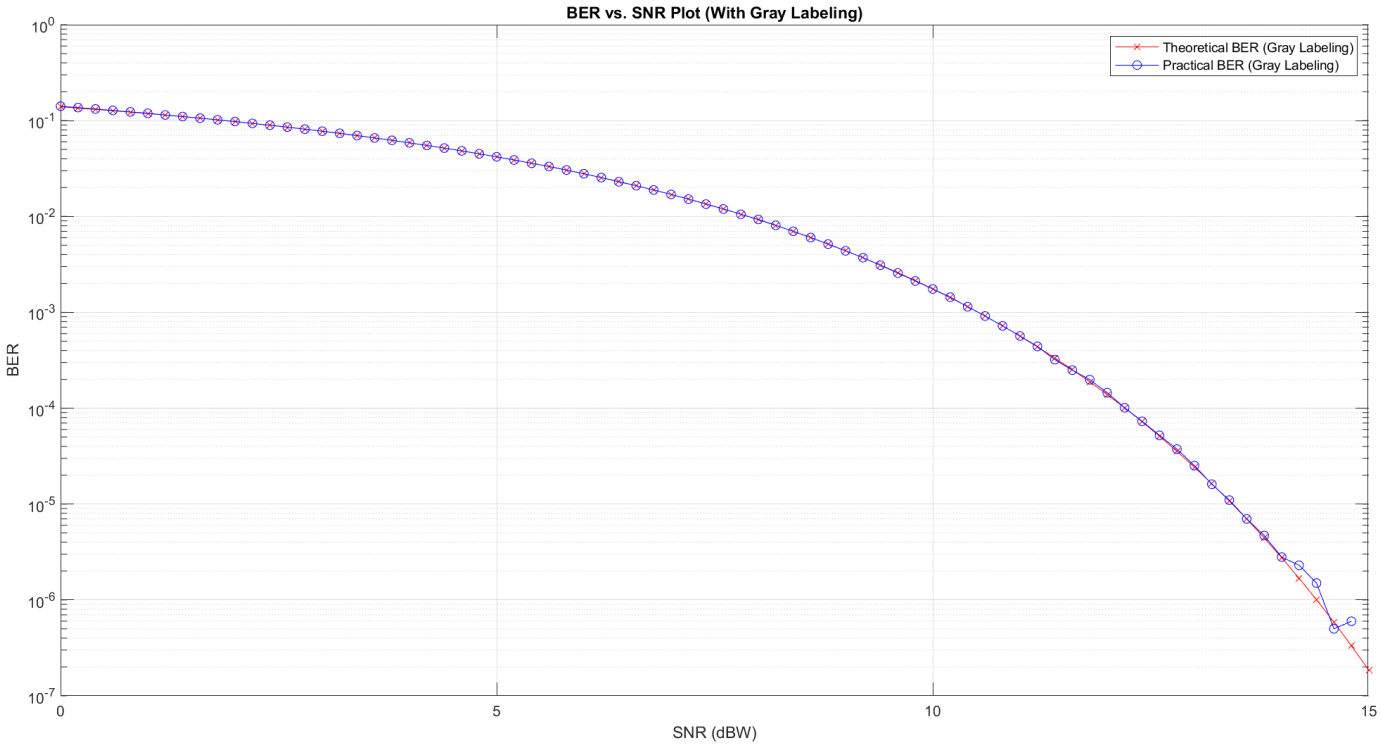
The bit error rate is given as:

1. With Gray Labelling (approximate form):

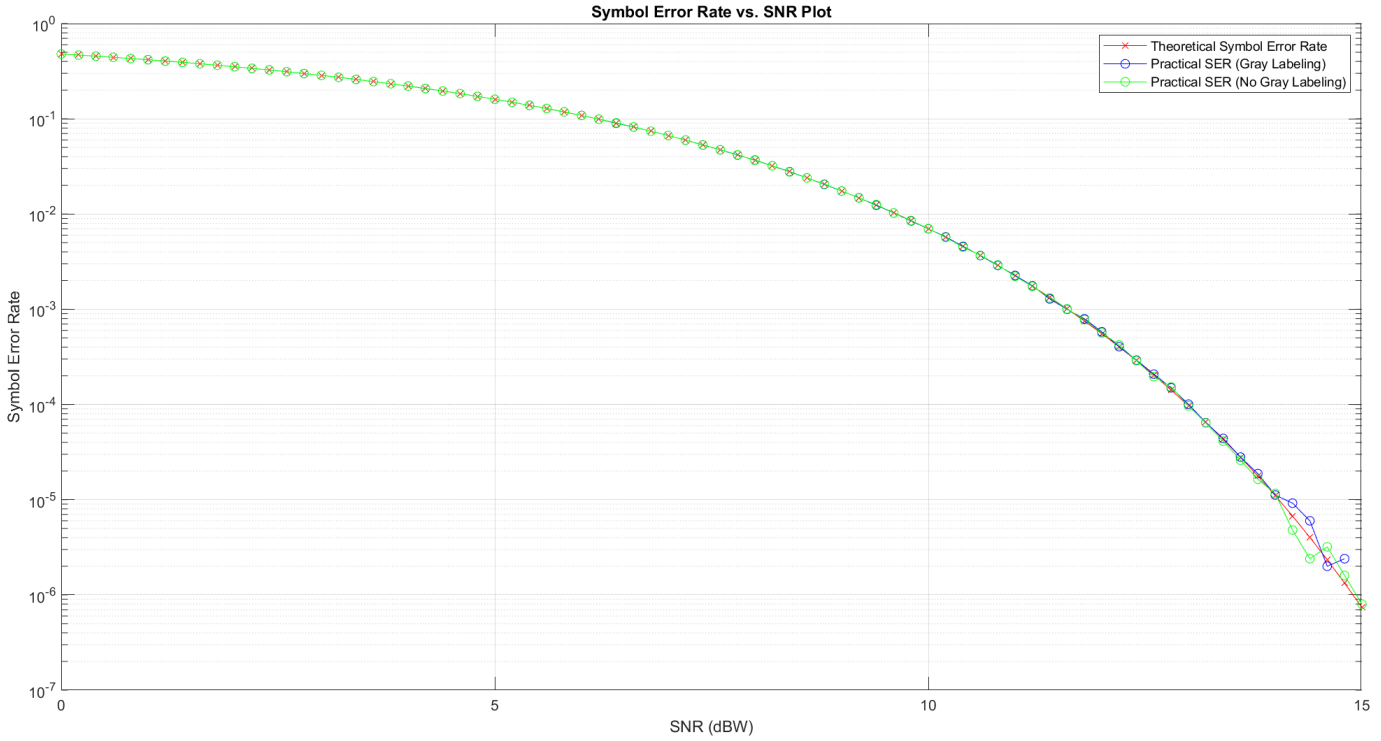
$$P_e = \frac{3}{4}Q\left(\frac{1}{\sigma}\right) = \frac{3}{4}Q\left(\sqrt{\frac{4SNR}{5}}\right)$$

2. Without Gray Labelling: We were unable to derive an expression.

The graph of theoretical and practical BER vs. SNR for the case of gray labelling is as follows. We see that both the curves match very well.



The symbol error rate (SER) vs. SNR plot for both cases along with the theoretical value is given below. We see that all 3 curves match very well.



Both theoretical and experimental curves are plotted together for comparison: