Lab 11 - QAM Simulink

Edward Enriquez
ECE 4705-L

Introduction:

Background Theory:

QAM (Quadrature Amplitude Modulation) modulation makes use of the fact that any sinusoidal signal could be broken down to its quadrature (Q) and in-phase (I) components. In the complex plane, these components are represented as the projection of the signal on the y-axis (quadrature) and the x-axis (in-phase). Varying the amplitude of these components and summing the results, any point on the complex plane could be achieved. QAM assigns a certain sequence of bits to each point on its constellation diagram. When the quadrature and in-phase components' amplitude are set to correspond to that point, the QAM detector will recognize the sequence of bits. The amplitudes of the Q and I components are encoding the amplitude and phase of their sum. This amplitude and phase of the carrier will correspond to a certain bit combination of the original message signal.

For radio frequency transmission, before the Q and I components are summed together the in phase component is multiplied by $cos(2\pi f_c t)$ and the quadrature component by $sin(2\pi f_c t + \frac{\pi}{2})$. This step allows for over air transmission via the carrier while maintaining orthogonality. This produces a result similar to that of DSB-SC modulation as each component is simply multiplied by a sinusoid.

Prelab:

In the time domain, the modulated QAM signal will be a series of time shifted and scaled sinusoids. The frequency of all these symbols will be f_c, a frequency suitable for over air transmission. In the frequency domain, the QAM spectrum will appear similar to that of DSB-SC. This is because for any given symbol, the quadrature and in-phase sum are multiplied by the sinusoid carrier just like in DSB-SC. The result will be the convolution of the carrier singular frequency spectrum, and the quadrature/in-phase sum spectrum. The spectrum will simply be shifted to the carrier frequency.

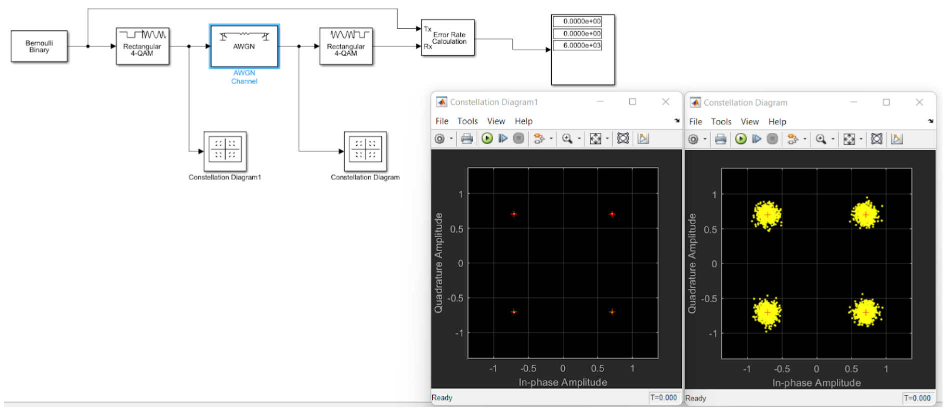
The constellation diagram for QAM is usually made in such a way to create a square like grid with its symbols. Hence the number of symbols used is usually an even power of 2.

Lab:

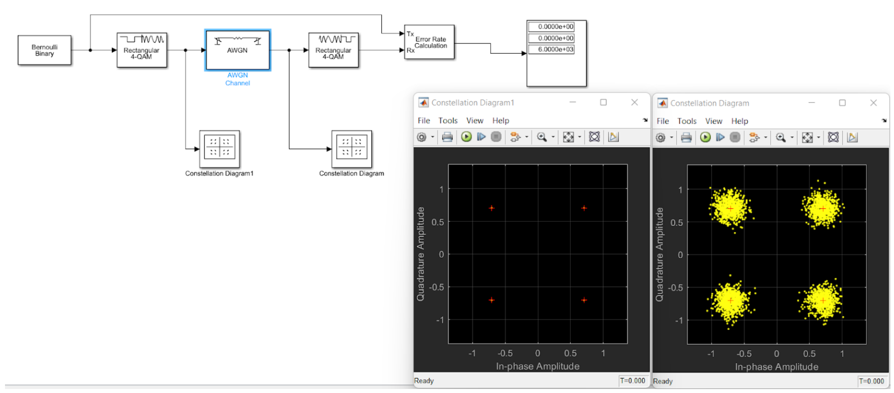
In Simulink, a digital bit stream was generated using a Bernoulli Binary Generator block. This bit stream was then modulated using a 16-bit QAM modulator. The modulated signal was sent through a AWGN (additive white gaussian noise) channel and then demodulated. The sent signal was compared with the received signal to measure the percentage of bits which were incorrectly decoded. The signal to noise ratio of the AWGN channel as well as the number of bits encoded by QAM were changed to see their effect on the bit error percentage. The percentage is taken from a total of 6000 sample bits.

Results:

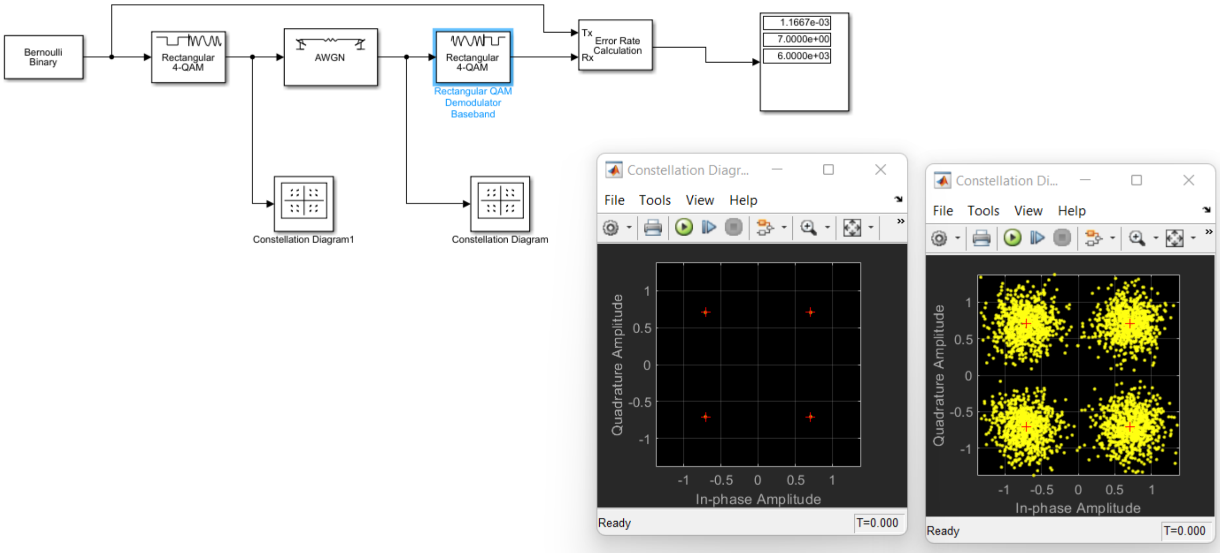
4-Ary QAM



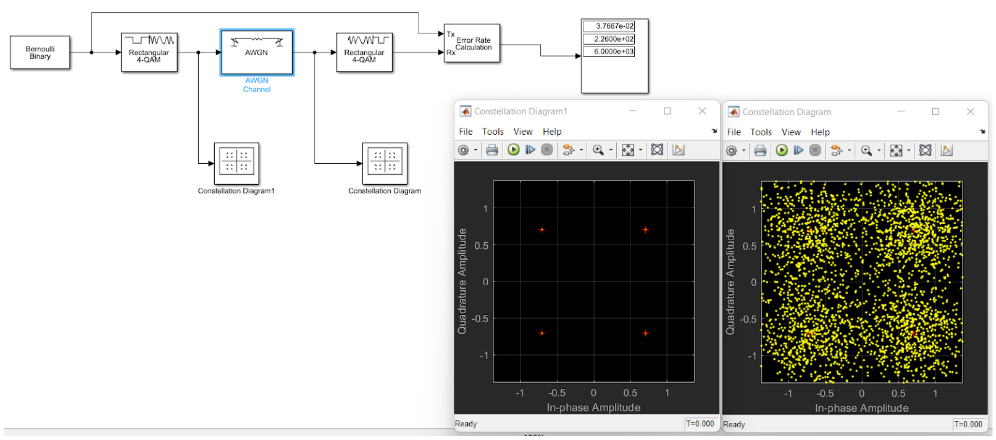
20dB SNR



16dB SNR

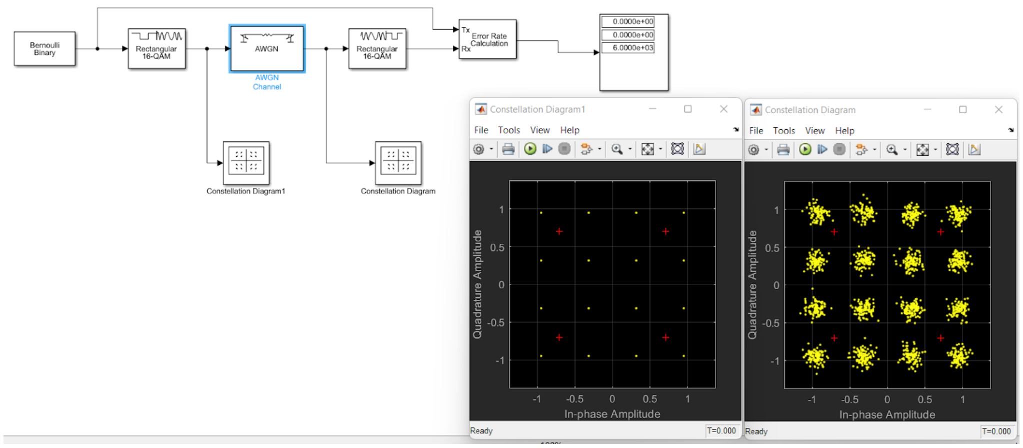


10 dB SNR

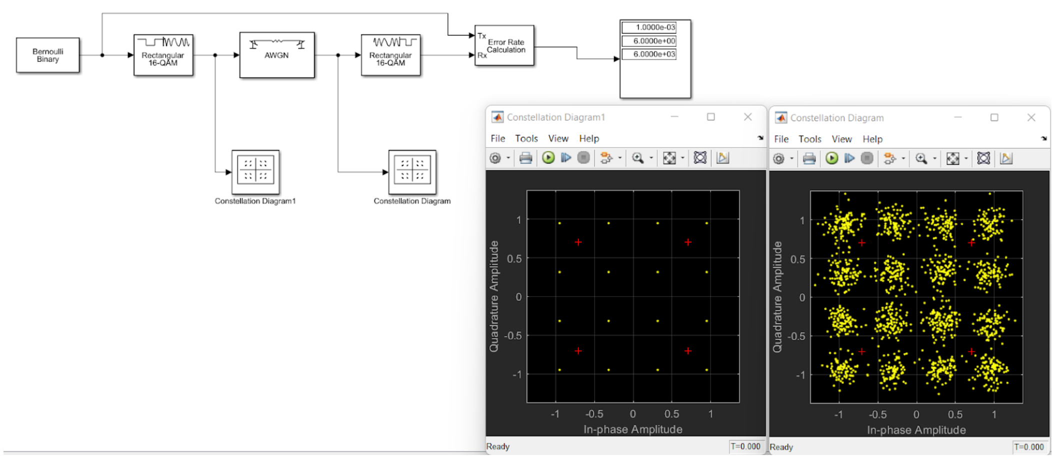


5db SNR

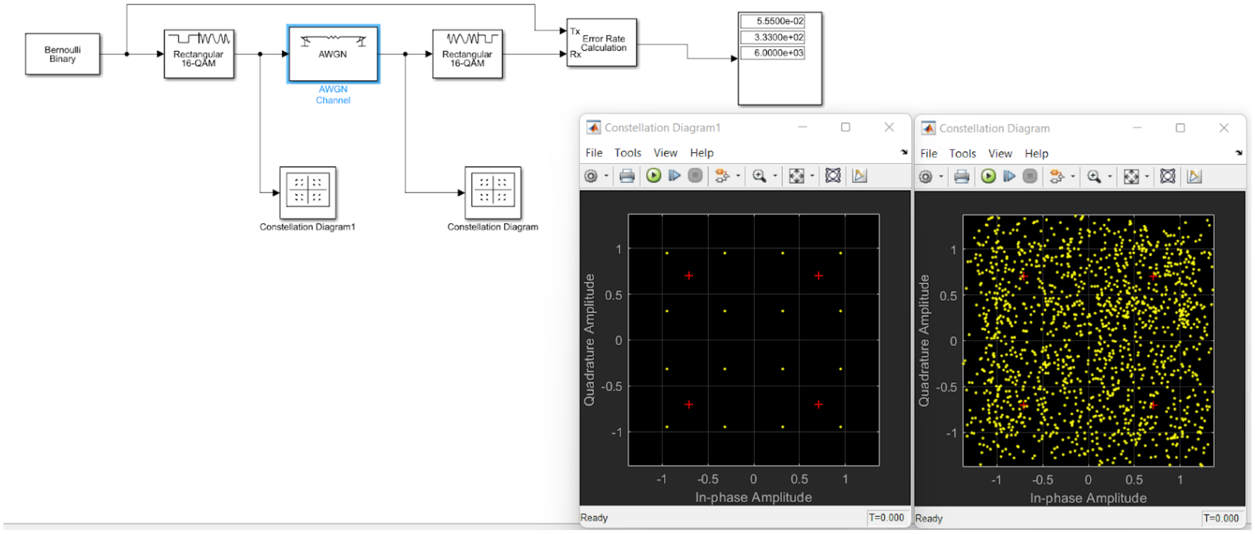
<u>16-Ary QAM</u>



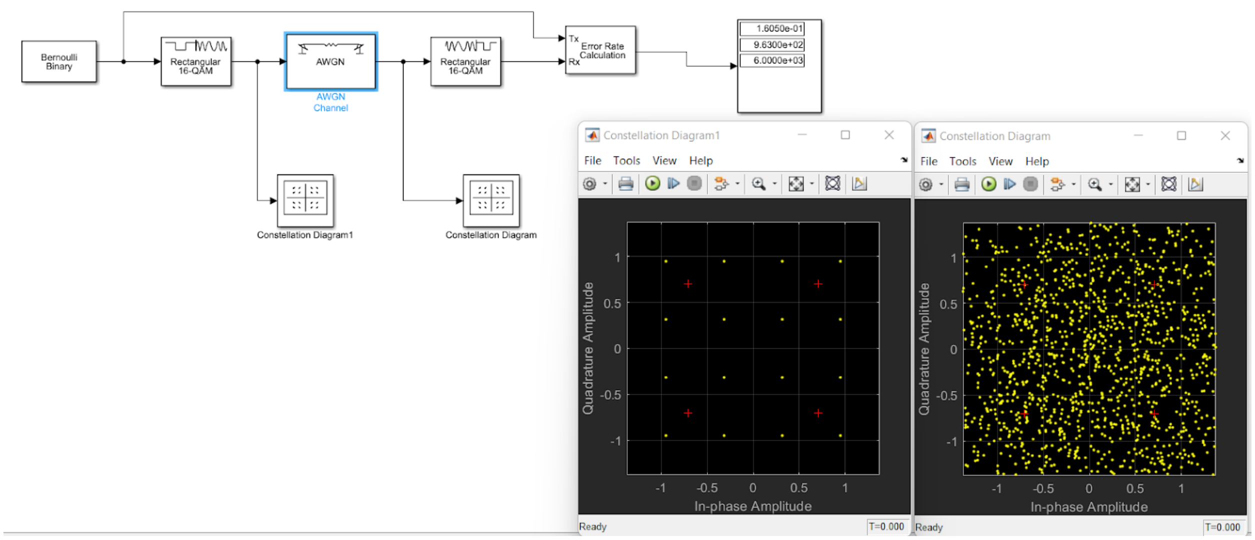
20dB SNR



16dB SNR

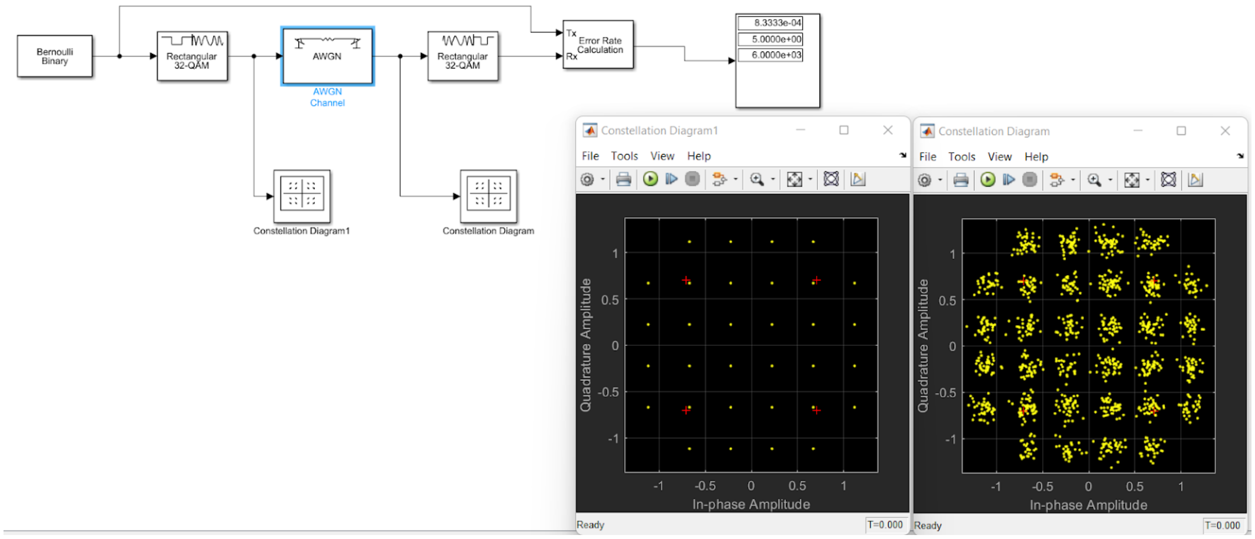


10dB SNR

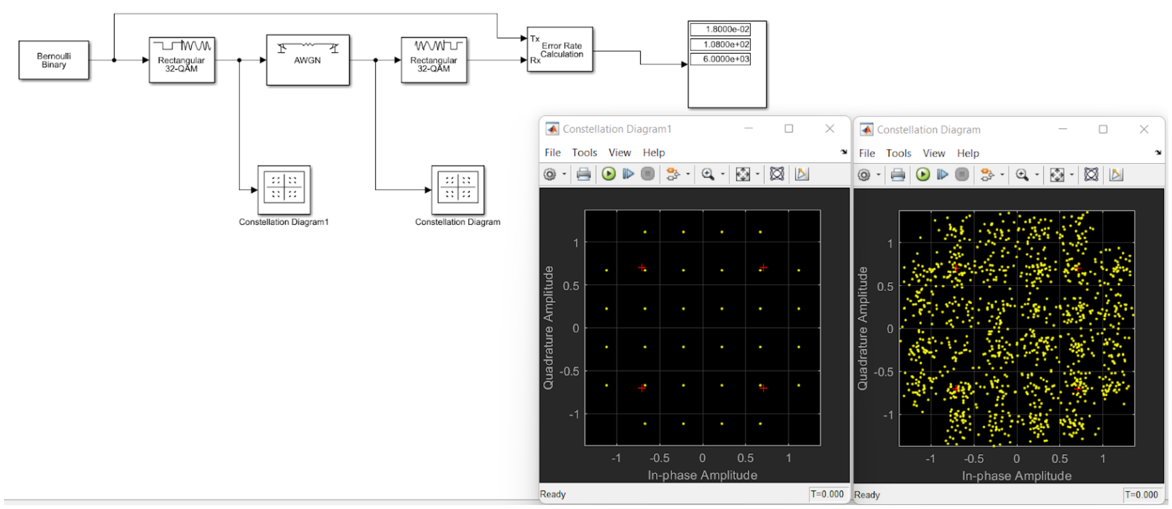


5db SNR

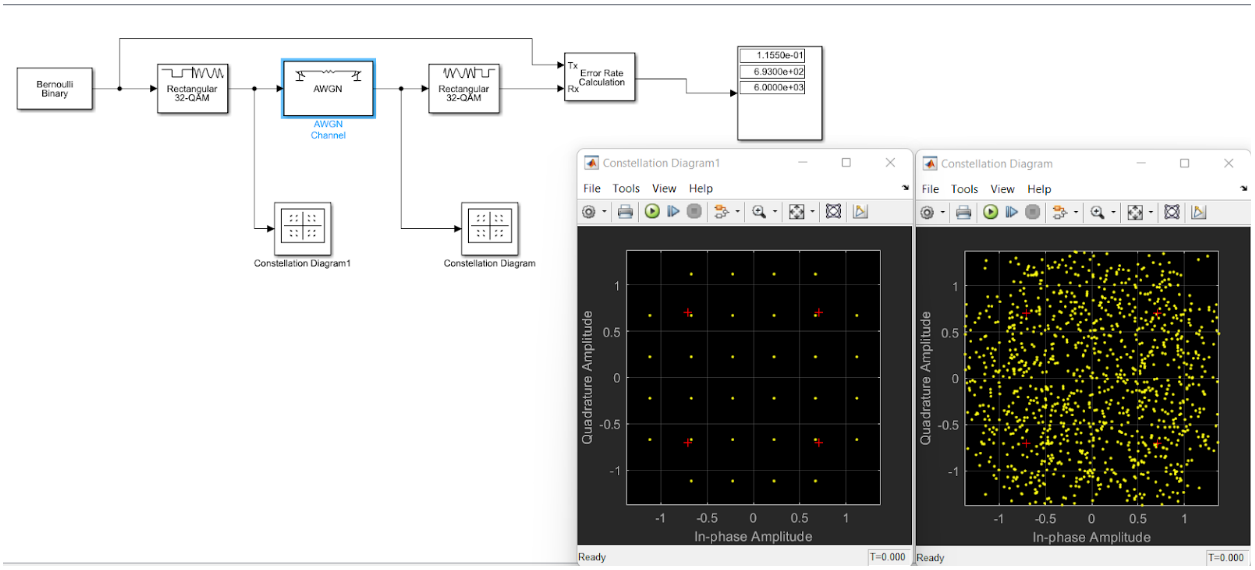
32-Ary QAM



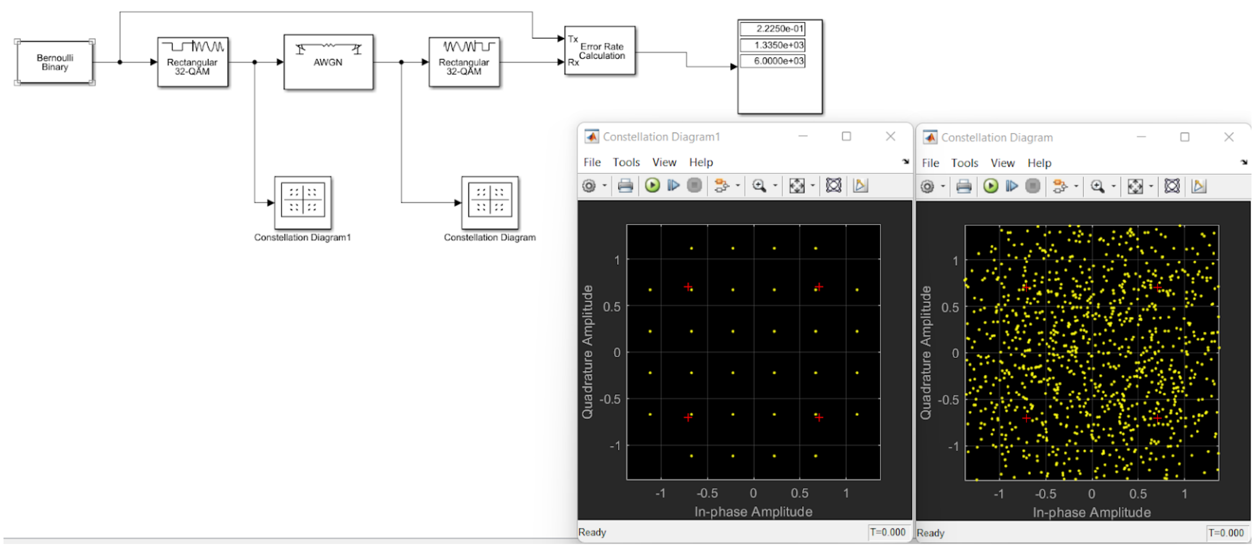
20 dB SNR



16dB SNR



10 dB SNR



5 dB SNR

Conclusion/Analysis:

The results showed that as the SNR of the AWGN channel decreased, the bit error rate increased. This was true for all QAM modulations no matter how many bits were being encoded.

Using 4 symbols (2 bits per symbol), erroneous bits became after the channel SNR was lowered from 16dB to 10dB. At 10dB, 7 out of 6000 bits were erroneous. This is around .116% bit error rate. It should be noted that any single error out of 6000 bits measured is a sign of insufficient bit error rate. 6000 is too small a sample size to assure a BER (bit error rate) of around $10^{-9} - 10^{-13}$.

At 16 symbols (4 bits per symbol), errors began to appear when the channel SNR was lowered from 20dB to 16 dB. This higher symbol rate requires higher channel SNR to provide an accurate signal. At 16dB the 16-ary QAM saw a total of 6 erroneous bits. At 10dB and 5dB the total erroneous bits increased to around 330 and 960.

With 32-ary (5 bits per symbol), not even 20dB SNR is high enough to recover an accurate signal. 5 bits were erroneously classified at this fidelity and the BER only worsened as the SNR lowered. At 5dB the 32-ary QAM modulation and demodulation yielded 1335 erroneous bits out of 6000, a BER of 22%.

It is clear that the lab demonstrates a direct relationship between the bit error rate and total amount of bits encoded by QAM. As more bits are encoded the bit error rate increases for the same level of AWGN channel SNR. As seen in all constellation diagrams the space on the complex plane on which the symbols are placed stays constant. As more symbols are introduced the closer the symbols are and the less noise is needed to move the QAM signal to another symbol threshold. This lab demonstrates the trades off in bit rate, bit error rate, SNR and power of QAM.