ECE 4705 Lab
Experiment 11 – QAM Modulation and Demodulation
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ECE4705L_04

ECE 4705L EXPERIMENT 11

QAM MODULATION AND DEMODULATION: Simulink Simulation[1]

INTRODUCTION

Quadrature Amplitude Modulation, QAM for short, is another type of modulation that allows digital data to be transmitted between two points. More specifically, QAM makes it so that analog signals can be more accurately represented as digital data through transmitting more bits in the same period. Instead of one bit being used, as in Binary Phase Shift Keying, normal QAM assigns a signal I and a signal Q with their own respective bit, allowing for four different combinations, or levels, that provide more accuracy when translating analog data to digital data. Doing so effectively increases the amplitudes of the signal being sent which effectively increases the bandwidth of the signal at the cost of being less power efficient. With this method of modulation there is no longer an envelope in which the data is contained. There are various types of QAM that depend on the number of bits being transmitted in a certain period, such as 16 QAM, 256 QAM, and 1024 QAM that correspond to 4, 8, and 10 bits respectively. For QAM to be implemented, the two signals are modulated by sine and cosine, then combined to produce the final QAM signal. Below is a block diagram representing both the modulation and demodulation of the signals in QAM.

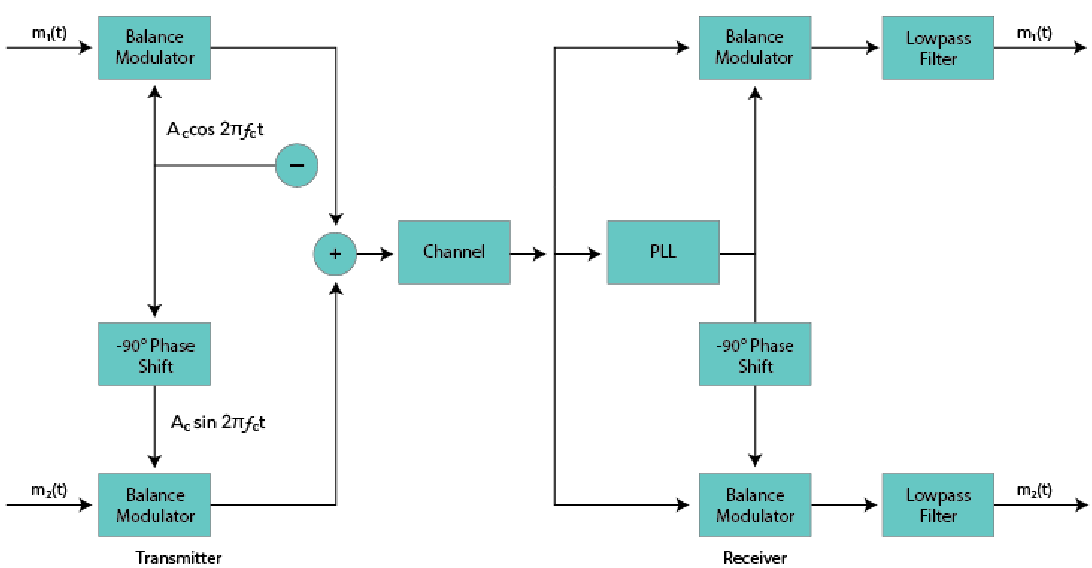

Fig. 1 – Block Diagram for Quadrature Amplitude Modulation and Demodulation

Each signal can be thought of as a distinct bit so by adding more signals we can transmit more data in the form of having a higher amount of bits to represent that data. The input signals combine after being modulated themselves with a sine or cosine wave,

[1] Based on a lab from Dr. Thomas Ketseoglou

generating a modulated QAM output signal. The signal can then be demodulated by passing it through a phase locked loop (PLL), then applying the same phase shift as before it was modulated to each signal, after which each signal is combined in a balance modulator to produce the original signals at the receiving end. With QAM, the message or information being sent now corresponds to different amplitude levels instead of being carried in an envelope as with other methods of modulation. The following figure shows the QAM signal represented in the time and frequency domain.

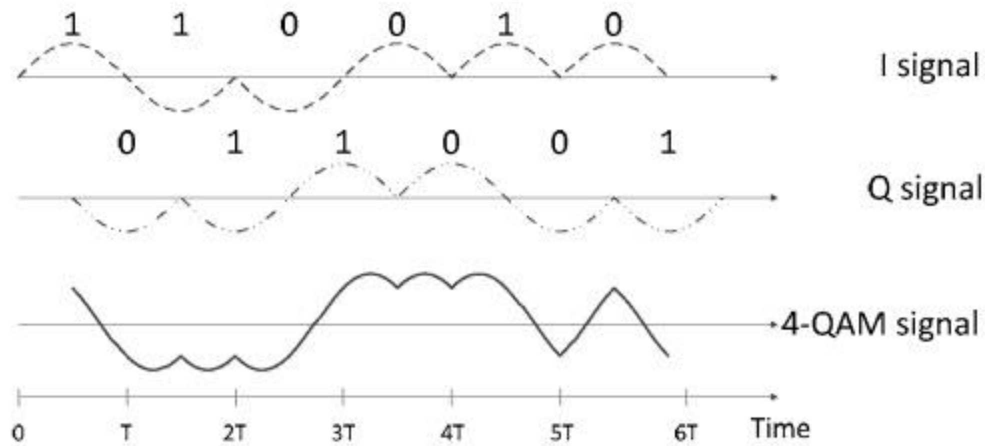

Fig. 2 – I and Q Signals and Resulting QAM Signal in the Time Domain

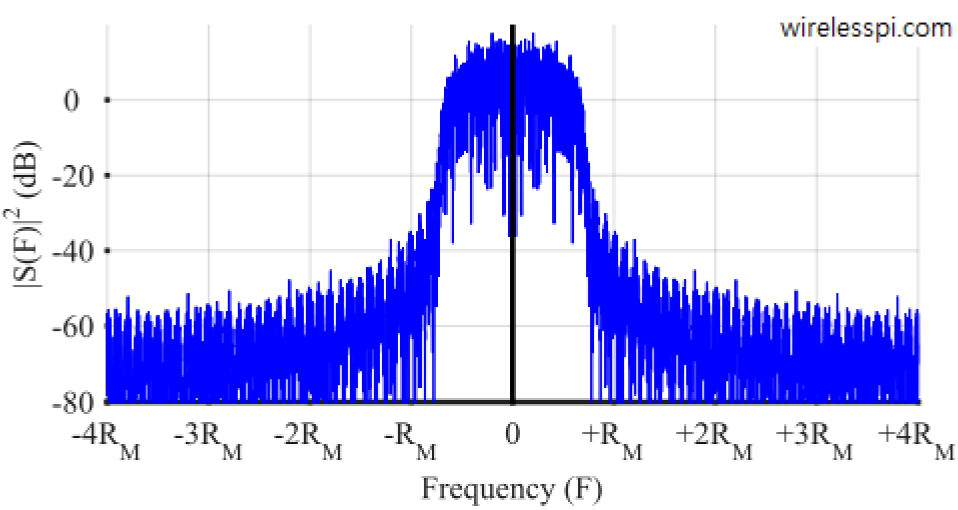

Fig . 3 – QAM Signal in the Frequency Domain

As you can see, the modulation due to combining the two signals doubles the bandwidth through which the signal can transmit data. For the simplest form of QAM, called Quadrature Phase Shift Keying (QPSK), there are four different combinations of bits to which analog data can be asssigned to represent digital data. The analog signal amplitude is matched to the nearest digital amplitude level to recreate a more accurate replicate of the analog data signal, while simultaneously increasing the bandwidth. Higher level QAM schemes that combine more than two signals increase the bandwidth even more with each signal in the modulation process. Furthermore, there is a type of plot used to represent the digital data that can be created called a Constellation Diagram. A constellation diagram can represent analog data being sent and how close its amplitude is to the level corresponding with each bit combination. The following figure shows the constellation diagrams for QPSK, 16-QAM, and 64-QAM schemes.

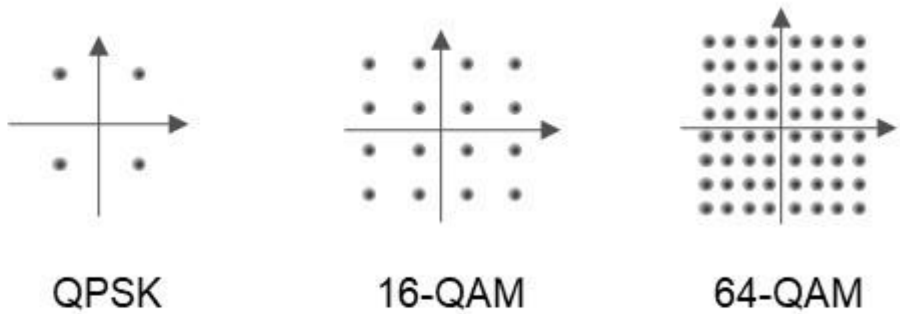

Fig 4 – Constellation Diagrams for QPSK, 16-QAM, and 64-QAM

LAB

In this lab, we aimed to investigate the properties of Quadrature Amplitude Modulation (QAM) modulation in the time and frequency domains, using Matlab's simulator software: Simulink. Simulink provides a wide array of blocks and circuit components, and, by using Simulink, we constructed a circuit that would simulate the transimission of a QAM signal, including the modulation, demodulation, and error rate. As mentioned previously, there are different variations of QAM, but for the purposes of this lab we will be simulating 16-QAM. Placing a block that can generate multiple single binary digits allows us to emulate sending larger amounts of information in a given signal. The following circuit was constructed in order to achieve the desired simulation.

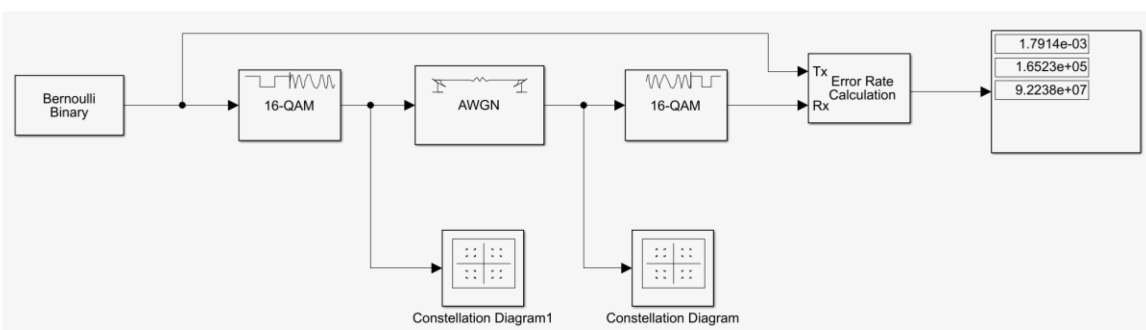

Fig 5a – Simulink Block Diagram for 16QAM Modulation and Demodulation

The first value displayed in the 3-display block at the end of the block diagram shows calculated error rate between the original signal and the demodulated signal. Constellation Diagram blocks were also placed along the circuit at the point of modulation, as well as before demodulation, to properly observe the behavior of the signal. Once modulated, the signal is sent through the AWGN block, which mimics the noise experienced during transmission of the signal. Given a certain signal-to-noise ratio

(SNR), the signal's information gets distorted, and, so, demodulation aims to correct the distorted signals by matching the signal to the closest corresponding value during demodulation. The initial SNR used for the AWGN block was 16 (no units). The higher the SNR ratio, the more distortion and innacuracy there is in the data being sent, thus also increasing the error rate. The constellation diagrams for the circuit simulation are shown below.

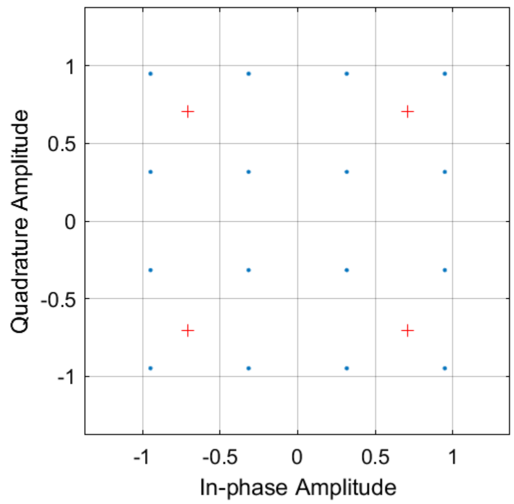

Fig. 5b – Constellation Diagram for 16QAM Signal after Modulation

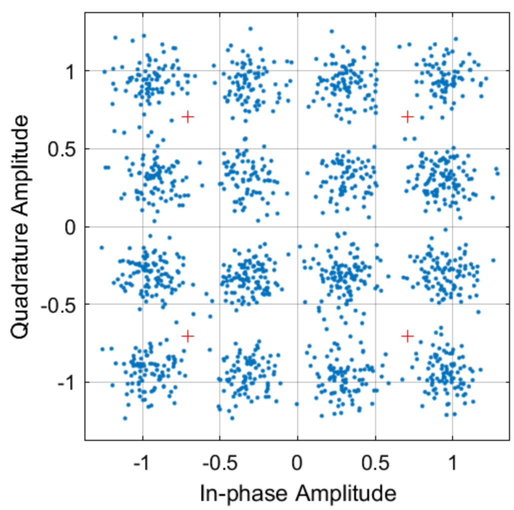

Fig. 5c – 16QAM Constellation Diagram after Demodulation

An important observation to note is how, after modulation and transmission, each point of data is closest to at least one of the original 16 constellation point. As mentioned before, the SNR affects how accurately the data can be recovered after transmitting a QAM signal. By changing the SNR, we can observe how it changes the resulting constellation diagrams and error rate. With a higher SNR, the points on the constellation diagram both the spread of points and the error rate should increase, and vice versa with a lower SNR.

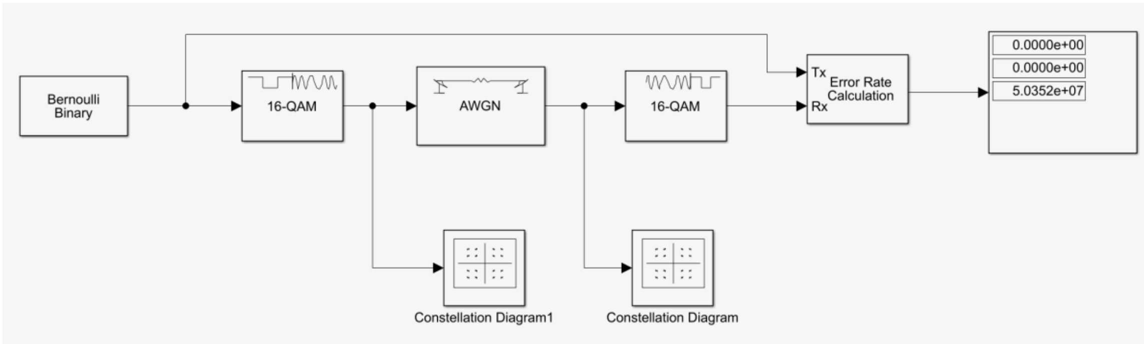

Fig. 6a – 16QAM Block Diagram showing Error Rate with SNR = 24 (Error = 0.0)

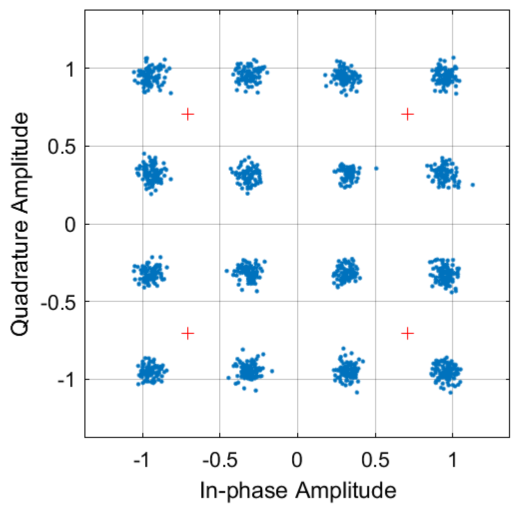

Fig. 6b – 16QAM Constellation Diagram with SNR = 24

Note: The 16QAM constellation diagram goes unchanged for the modulated signal after modifying the SNR.

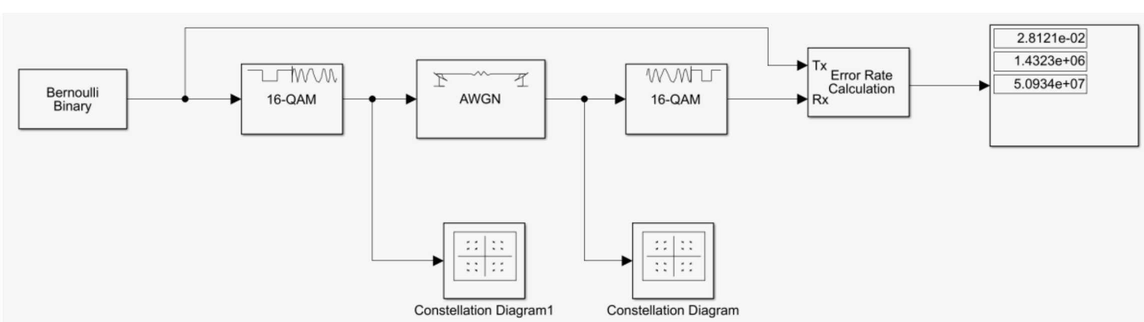

Fig. 7a – 16QAM Block Diagram showing Error Rate with SNR = 12 (Error = 2.81e-2)

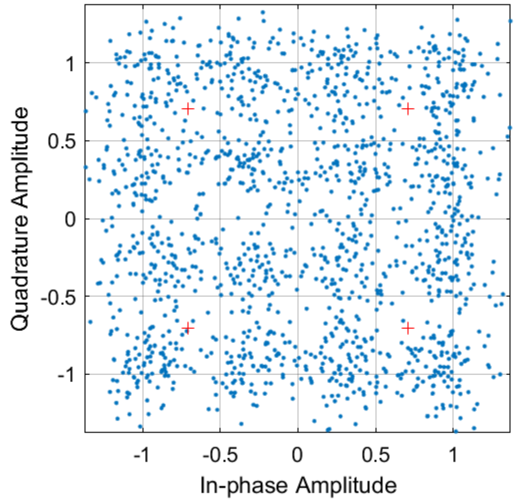

Fig. 7b – 16QAM Constellation Diagram with SNR = 12

After changing the SNR, we see that the error rate and spread do indeed increase upon lowering the SNR, and practically a nonexisting error rate and diminished spread upon increasing the SNR. Another important property to note about QAM is that for a larger array of data, a signal can still be modulated, however this comes at the cost of increased error rate as well. Below are more figures portraying the effect changing the array size on a QAM modulator and demodulator has on the error rate.

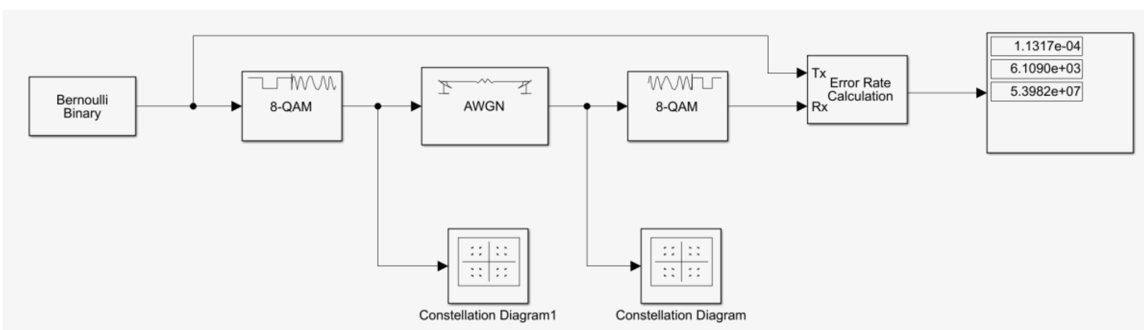

Fig 8a – 8QAM Block Diagram showing Error Rate with SNR = 16 (Error = 1.13e-4)

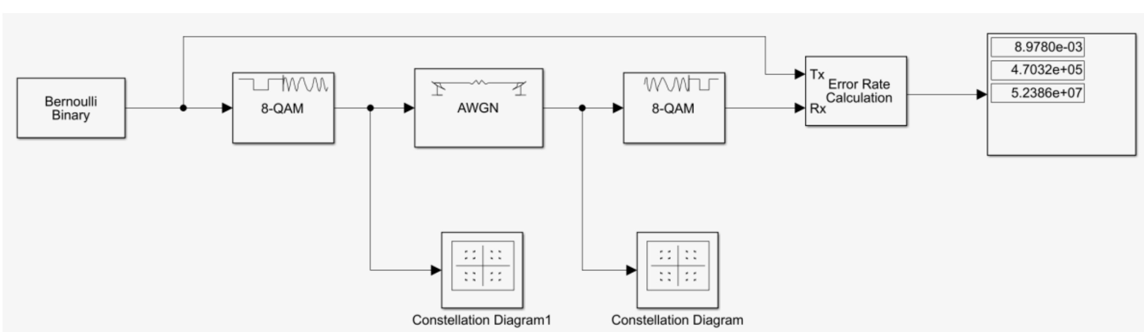

Fig 8b – 8QAM Block Diagram showing Error Rate with SNR = 12 (Error = 8.98e-3)

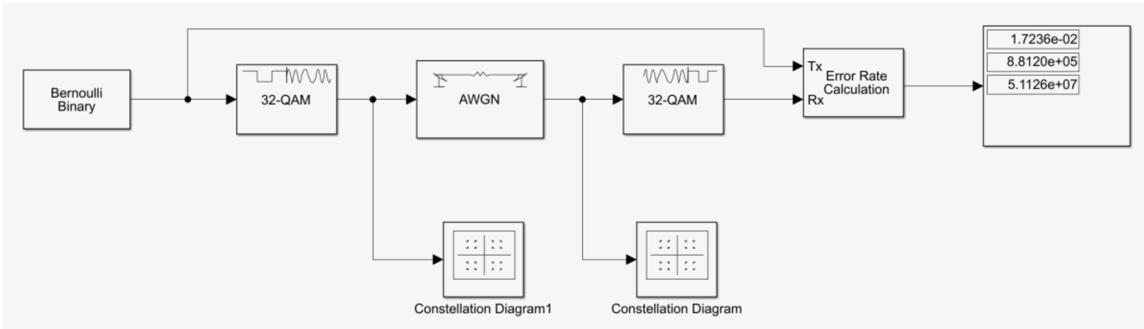

Fig 8c – 32QAM Block Diagram showing Error Rate with SNR = 16 (Error = 1.72e-2)

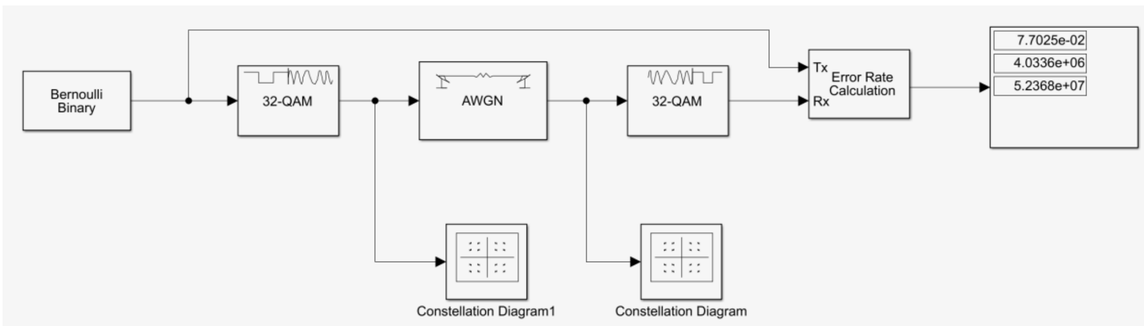

Fig 8d – 32QAM Block Diagram showing Error Rate with SNR = 12 (Error = 7.70e-2)

Here, again, we can see that larger array sizes results in a much bigger error rate, and smaller arrays lead to smaller error rates. However, it appears that the SNR still has a greater influence over the error rate than the array size of modulation/demodulation.

CONCLUSION

Using the Simulink program provided in MATLAB, we were able to succesfully simulate and see the results of variations of different QAM modulation schemes.We were able to obtain results that fall in line with the expected results when utilizing QAM. Following the simulation results after changing the QAM array and SNR, we confirmed what we expected to happen with each variation. We found that by either increasing the QAM array, i.e. the amount of information sent in a digital signal, or decreasing the signal-to-noise ratio (SNR), the error rate of the demodulated signal increases. On the other hand, we can reduce the error rate by decreasing the array or increasing the SNR to more effectively transmit digital data.