ECE 4705 Lab
Experiment 12 – PSK Modulation and Demodulation
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ECE4705L_04

ECE 4705L **EXPERIMENT 12**

PSK MODULATION AND DEMODULATION: Simulink Simulation[1]

INTRODUCTION

As introduced in Lab 10, Phase Shift Keying, or PSK for short, is a form of digital modulation where the phase of a carrier signal is manipulated by changing the cosine and sine of the signal, and is used most commonly to wirelessly transfer digital data. While basic PSK only involves two phases 180 degrees apart on a circle to represent data shifting states, i.e. switching between a binary one to a binary zero, there exists various other PSK schemes that allow for even larger quantities of data to be sent at once. More phase states can be added to represent a greater number of scenarios, such as a one remaining a one or a zero remaing a zero. To get a better idea of how this kind of modulation works, a tool known as a constellation diagram is used to represent the phase of the signal by the angle around the circle, and the amplitude by the distance from the center of the circle. Because the amplitude of the signal remains unchanged, each of the phase states can be represented as equidistance points on the circle with constant radius that represents the constant amplitude. The most simple form of PSK, Binary Phase Shift Keying (BPSK), can be represented on a constellation diagram as two points on the circle and other PSK modulation schemes that encode more bits of data per signal utilize more points in their respective constellation diagrams. Other higher order schemes of PSK, such as Quaternary Phase Shift Keying (QPSK), 8-PSK and 16-PSK, are utilized to modulate at higher data rates within a certain bandwidth.

When demodulatting the PSK modulated signal, errors can be detected on the receiving end by comparing the resulting phase position of the signal at the receiving demodulator to the ideal phase state. Such errors occur due to innaccuracies during modulation and transmission, and a constellation diagram helps to see how great the discrepency in measured position versus ideal position attributes to a larger error in the data of the received signal. The error rate of this type of modulation is also heavily affected by the Signal-to-Noise Ratio (SNR) experienced during transmission. For this lab, an AWGN block was placed and modified to simulate the noise experienced during transmission so we could see the effects of varying the SNR. When working with higher order PSK schemes, a higher SNR is required to prevent the error rate from becoming too high and allows the received data to be accurately matched to the appropriate bits that represent the state of the signal.

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

LAB

In this lab, we aimed to investigate Phase Shift Keying (PSK) 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 various PSK modulation schemes, including the modulation, demodulation, and error rate of the signal. As mentioned previously, there are different variations of PSK, but for the purposes of this lab we will begin by simulating 16-PSK. The following circuit was constructed in order to achieve the desired simulation.

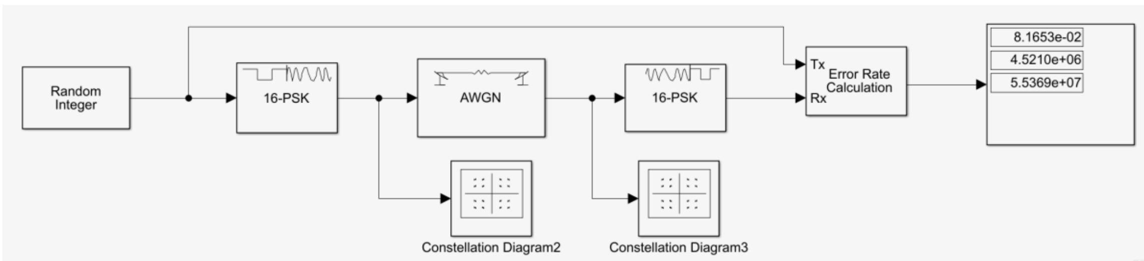

Fig 1a – Block Diagram for 16-PSK Modulation and Demodulation (Error = 8.17e-2)

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. The second and third box in the display block shows the amount of errors detected and the number of samples taken, respectively .The number of samples taken was kept close to the same for all simulations to allow for better comparisons across the different PSK modulation schemes. 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, after demodulation the system aims to correct the distorted signals by matching the signal to the closest corresponding value during demodulation. The default SNR used for the AWGN block was 16 dB. In theory, the higher the SNR ratio, the more distortion and innacuracy there is in the data being sent, thus also increasing the error rate. The various constellation diagrams confirming this theory are shown below.

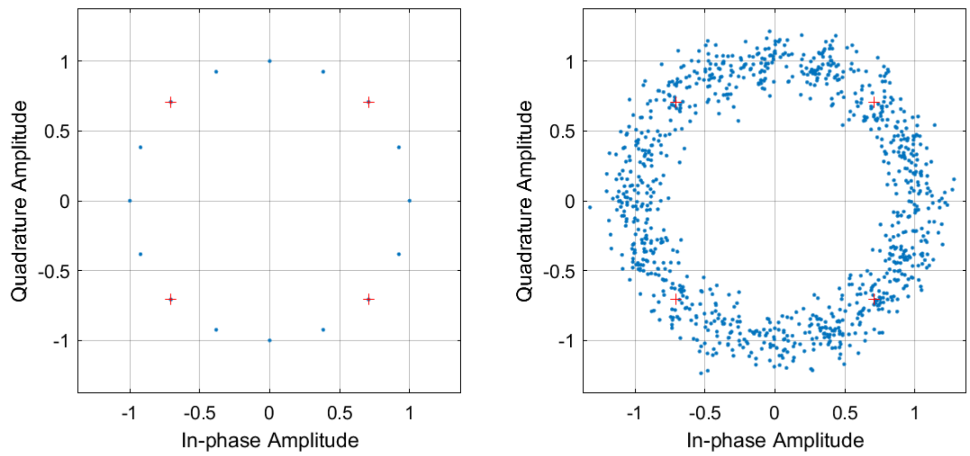

Fig. 1b – Constellation Diagram for 16-PSK Signal after Modulation

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 PSK signal. By changing the SNR, we can observe how it changes the resulting constellation diagrams and error rate. With a higher SNR, we expect both the spread of points on the constellation diagrams and the error rate to increase, and vice versa with a lower SNR.

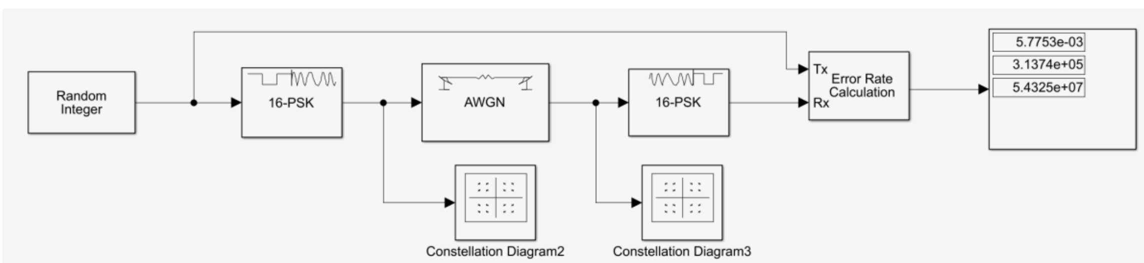

Fig. 2a – 16-PSK Block Diagram showing Error Rate when SNR = 20 (Error = 5.78e-3)

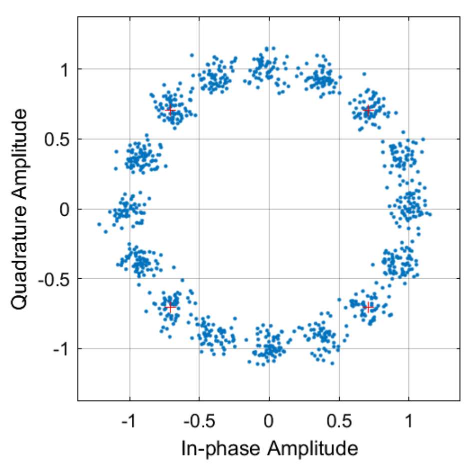

Fig. 2b – 16-PSK Constellation Diagram with SNR = 20

Note: The 16-PSK modulated signal's constellation diagram goes unchanged for the constellation diagram following the modulation block after modifying the SNR.

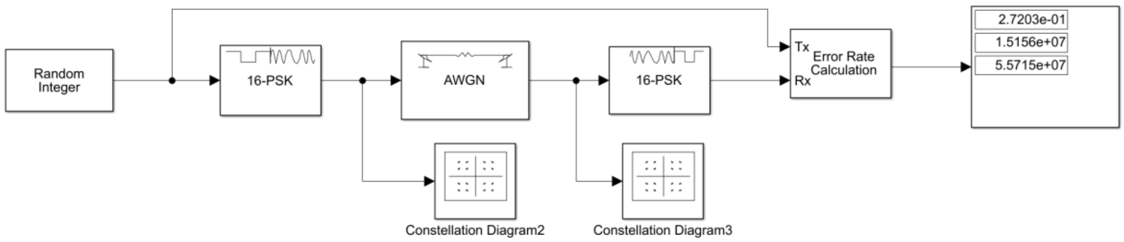

Fig. 3a – 16-PSK Block Diagram showing Error Rate with SNR = 12 (Error = 2.72e-1)

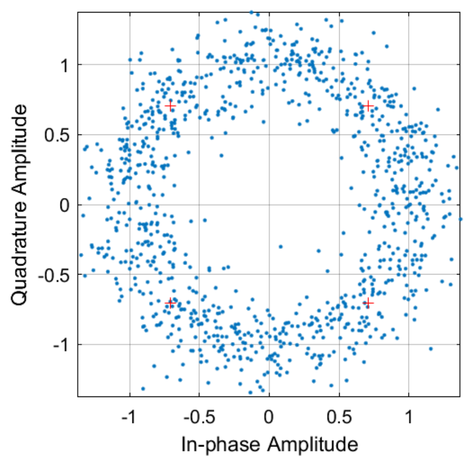

Fig. 3b – 16-PSK Constellation Diagram after Demodulation with SNR = 12

After changing the SNR, we see that the error rate and spread do indeed increase upon lowering the SNR, and a practically nonexisting error rate and diminished spread upon increasing the SNR. Another important property to note about PSK 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 confirming the predictions regarding the effect changing the array size on a PSK modulator and demodulator has on the error rate.

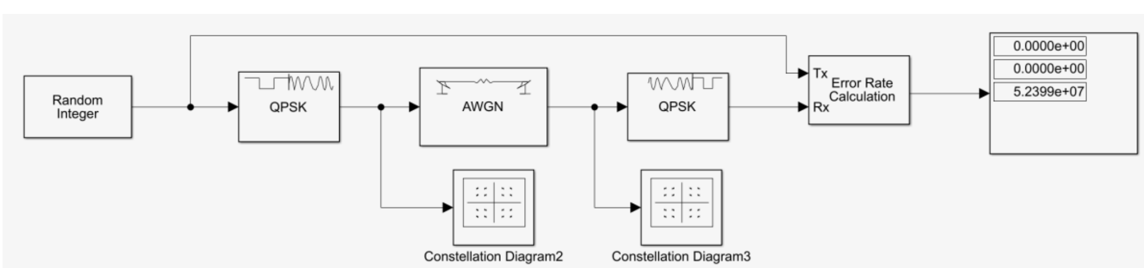

Fig 4a – QPSK Block Diagram with SNR = 16 (Error = 0.00)

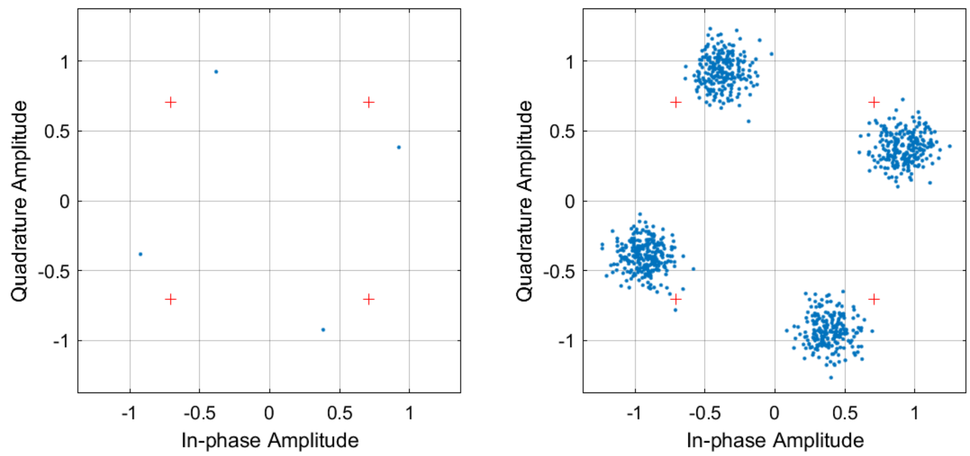

Fig 4b – QPSK Constellation Diagrams when SNR = 16

QPSK encodes two bits to each signal and once it is sent it is matched to one of four equidistant points around a circle representing four different phases. If we look at the two figures above, we can see that the random signals are so close to the points that there is practically no error in matching the modulated signal to their respective symbol on the constellation diagram. Another point to take note of is that because the error rate reads as zero for QPSK when the SNR is greater than or equal to 16dB, only the constellation diagram for scenarios when the SNR for QPSK is less than the default 16dB will be shown.

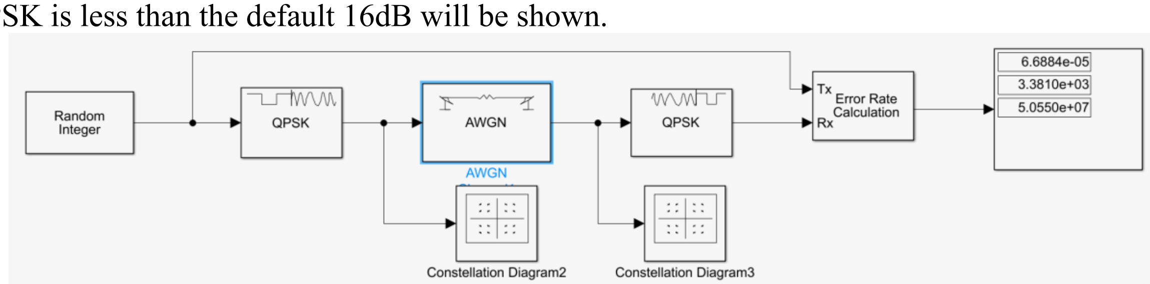

Fig 5a – QPSK Block Diagram showing Error Rate when SNR = 12 (Error = 6.69e-5)

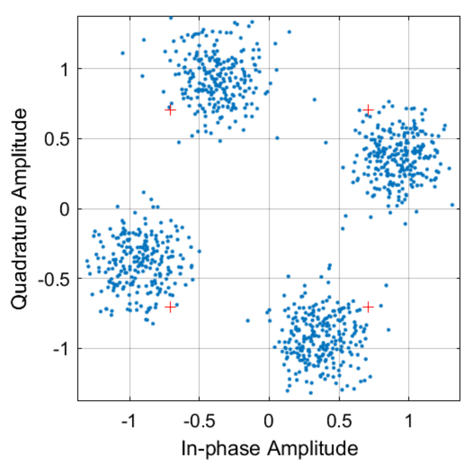

Fig 5b – QPSK Constellation Diagram when SNR = 12

We continue to see a pattern of lower SNR values resulting in greater error rates detected. After viewing how the error is affected by the SNR in a quadrature type PSK modulation scheme, let us now look at how changing the array of the data being modulated affects the constellation diagrams and error rate.

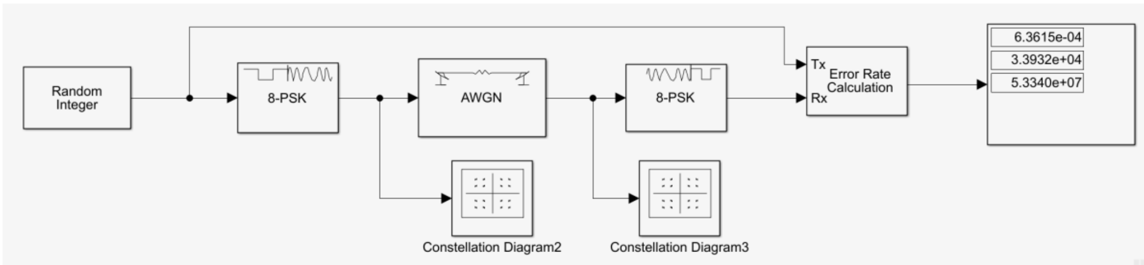

Fig 6a – 8-PSK Block Diagram showing Error Rate when SNR = 16 (Error = 6.36e-4)

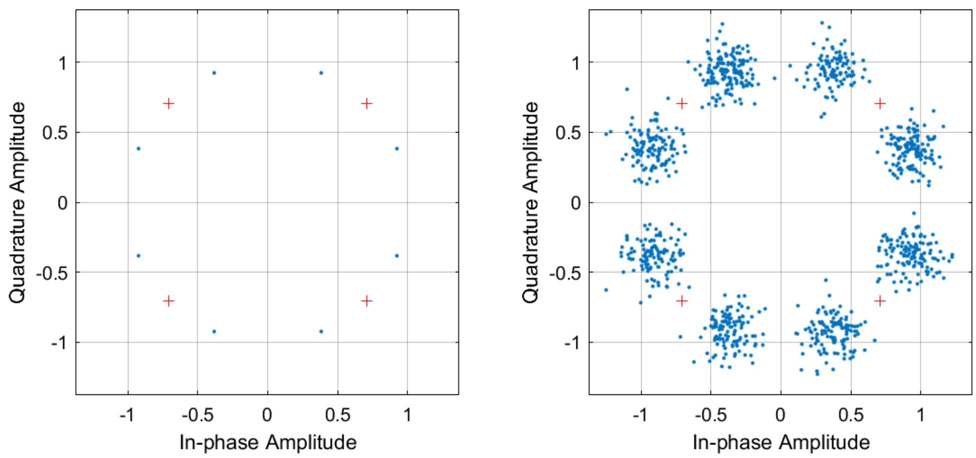

Fig 6b – 8-PSK Constellation Diagram when SNR = 16

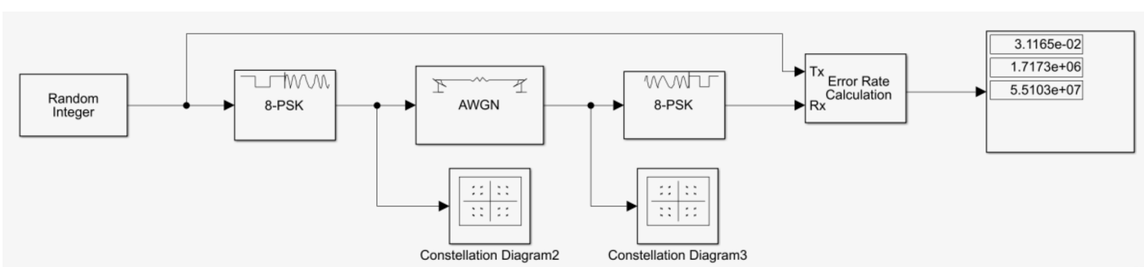

Fig 6c – 8-PSK Block Diagram showing Error Rate when SNR = 12 (Error = 3.12e-2)

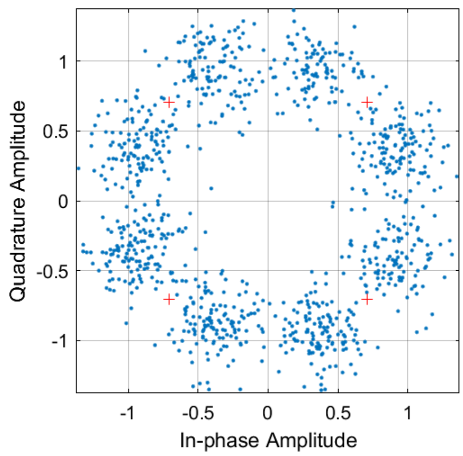

Fig 6d – 8-PSK Constellation Diagram when SNR = 12

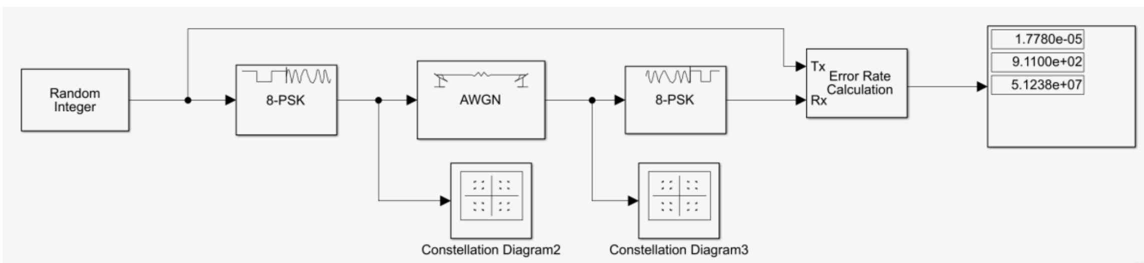

Fig 6e – 8-PSK Block Diagram showing Error Rate when SNR = 18 (Error = 1.79e-5)

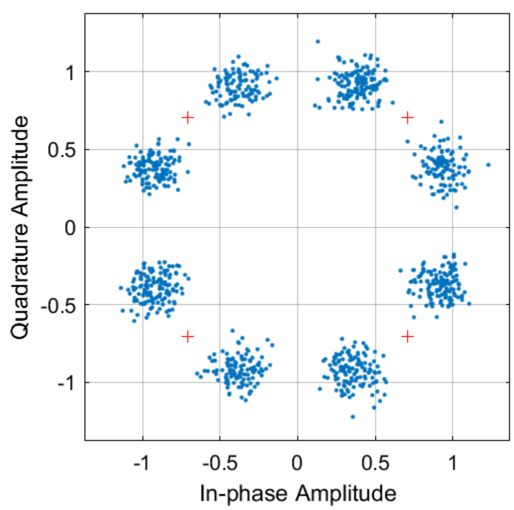

Fig 6f – 8-PSK Constellation Diagram when SNR = 18

It is interesting to note that the error rate increases by almost a factor of 500 after increasing the data rate size for the same SNR. After examining PSK schemes that utilize lower data rates, we will see what increasing the data rate size further does to the error rate and the corresponding constellation diagrams.

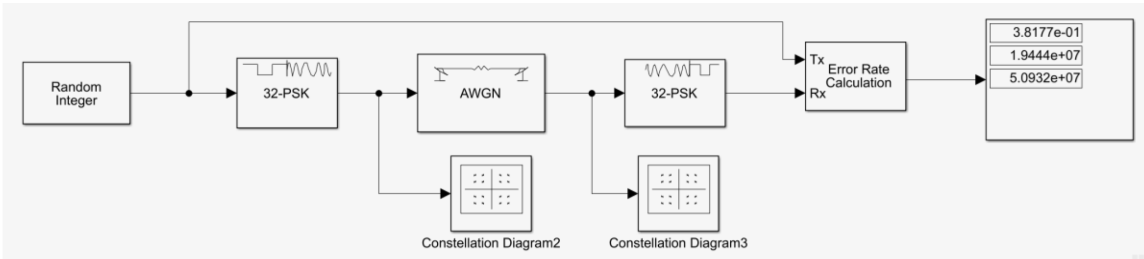

Fig 7a – 32-PSK Block Diagram showing Error Rate when SNR = 16 (Error = 3.82e-1)

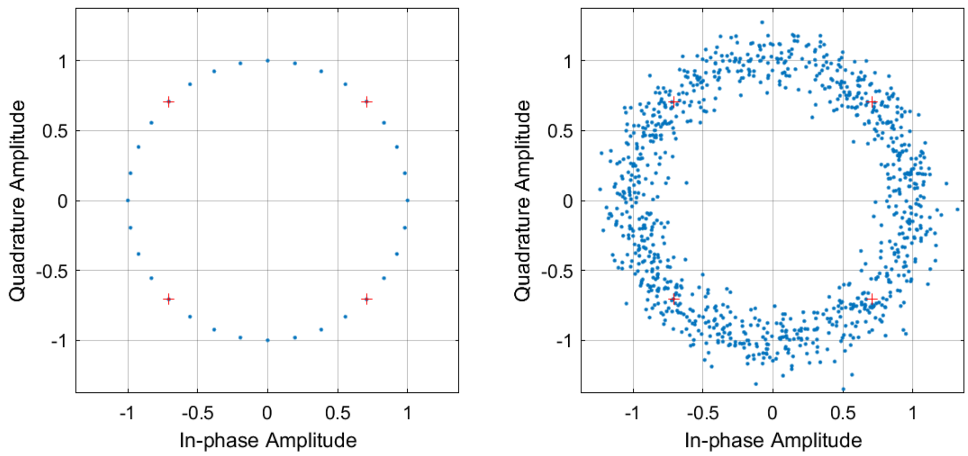

Fig 7b – 32-PSK Constellation Diagram when SNR = 16

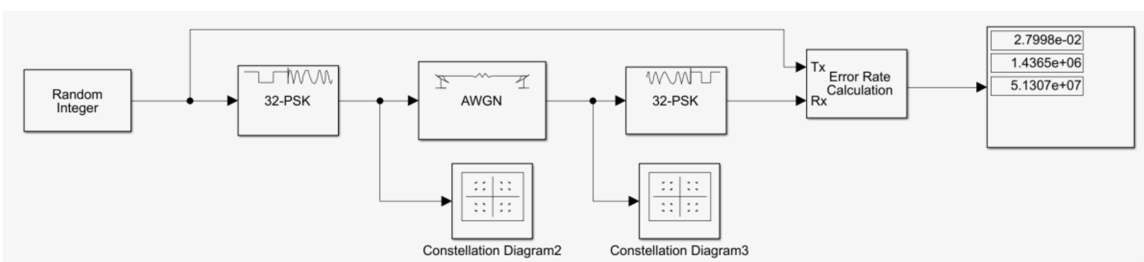

Fig 7c – 32-PSK Block Diagram showing Error Rate when SNR = 24 (Error = 2.80e-2)

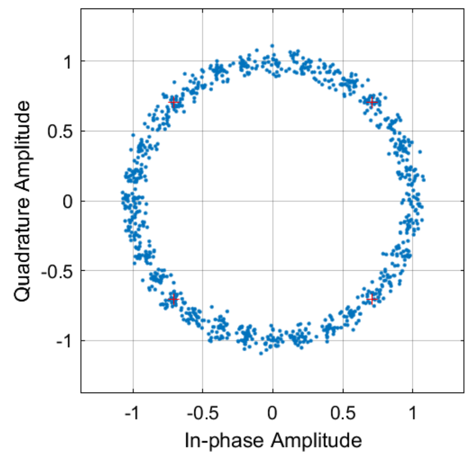

Fig 7d – 32-PSK Constellation Diagram when SNR = 24

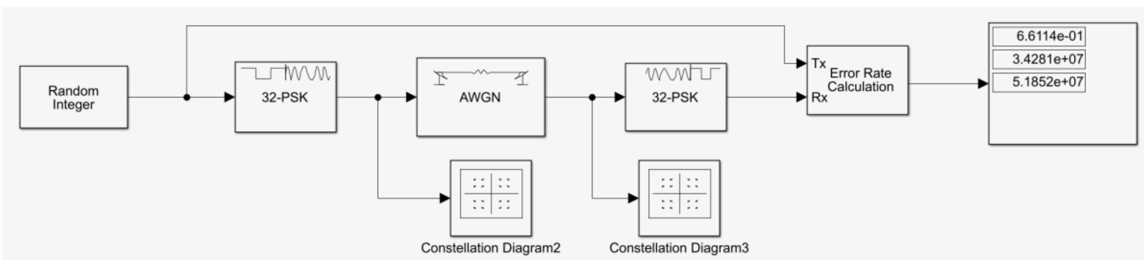

Fig 7e – 32-PSK Block Diagram showing Error Rate when SNR = 10 (Error = 6.61e-1)

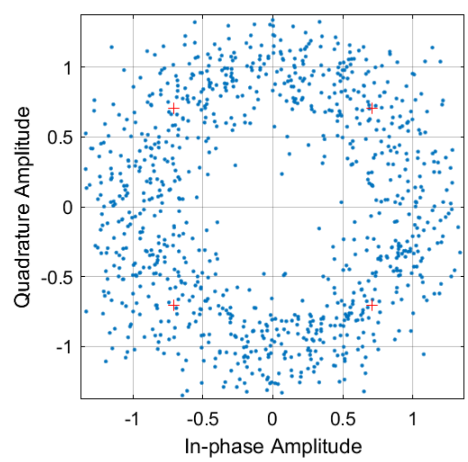

Fig 7f – 32-PSK Constellation Diagram when SNR = 10

After running the 32-PSK modulation simulations, 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, in the case of PSK modulation schemes, the modulation data rate has a greater influence over the error rate than the SNR of modulation/demodulation. We can see that the error rate of PSK modulation with higher data sizes is greater, even for schemes utilizing a higher SNR.

CONCLUSION

Using the Simulink program provided in MATLAB, we were able to succesfully simulate and see the results of variations of different PSK modulation schemes.We were able to obtain results that fall in line with what we expected when modifying the various different PSK modulation schemes. We also became familiar with constellation diagrams for the different PSK modulations and how to interpret them. By modifying various elements of the block diagram simulation, we were able to analyze the resulting constellation diagrams and their relationship with the error rate. Following the simulation results after changing the PSK data array size and signal-to-noise ratio (SNR), we confirmed what we expected to happen with each variation. We found that by either increasing the PSK data rate array, i.e. the amount of information sent over a modulated signal, or decreasing the SNR, the error rate of the demodulated signal increases; however, as opposed to with QAM, which we investigated in the last lab, the error rate is much more influenced by the data rate size than by the SNR. On the other hand, we can reduce the error rate by decreasing the array or increasing the SNR to more effectively transmit digital data, but it is important to note that this comes at the cost of other factors, such as power consumption and efficiency.