İZMİR INSTITUTE OF TECHNOLOGY

ELECTRICAL AND ELECTRONICS ENGINEERING DEPARTMENT

EE451 Communication Systems II

Project Final Report

Comparison of QPSK vs π/4 Differential QPSK in AWGN channels

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1. Introduction

In this project, we will basically introduce some concepts about Quadrature Phase Shift Keying (QPSK) and π/4 Differential Quadrature Phase Shift Keying (π/4 DQPSK). Also, we will observe the differences between these two modulation techniques by looking at the Bit Error Rate (BER) for both of them for understanding which technique has more bit error rate than the other. If we examine our outputs for these two modulation techniques, it will be easy to see that π/4 DQPSK has more Bit Error Rate.

However, in this project, the reason why DQPSK is used despite of its more bit error rate will be explained. If we talk about one of the other objectives of this project, we can say that to reveal the BER analysis of QPSK and π/4 DQPSK passed through the Additive White Gaussian Noise (AWGN) channel for one high and one low SNR, preferably as 0:15 SNR in this project. Constellation diagrams have been created with noise and without noise for QPSK and π/4 DQPSK.

2. Theoretical Background Related to Our Simulation Results

2.1 Quadrature Phase-Shift Keying (QPSK)

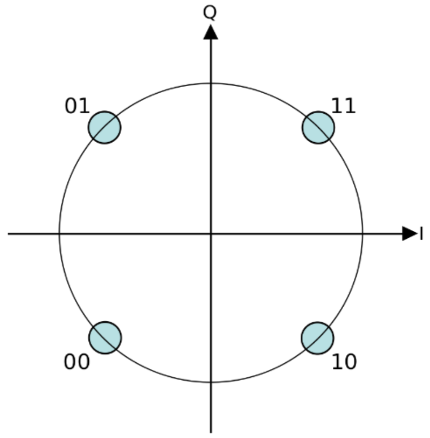

Figure 1. Constellation diagram for QPSK with Gray Coding. Each adjacent symbol only differs by one bit.

Quadrature phase shift keying (QPSK) is a type of digital modulation that is used to transmit information over a communication channel. It is a type of phase shift keying (PSK) in which the phase of the carrier signal is shifted by 0, 90, 180, or 270 degrees in response to four different digital input symbols. In QPSK, two bits of information are transmitted at a time, using four different phase shifts to represent the four possible combinations of the two bits. For example, if the two bits are 00, the phase of the carrier signal is not shifted; if the two bits are 01, the phase is shifted by 90 degrees; if the two bits are 10, the phase is shifted by 180 degrees; and if the two bits are 11, the phase is shifted by 270 degrees. QPSK is used in many different types of communication systems, including satellite communications, digital television, and mobile phone systems. It is a popular choice for these systems because it has a relatively low error rate and can be implemented using relatively simple hardware.

In QPSK, the phase of the carrier signal is changed based on the two input bits, but the amplitude of the signal remains constant. This means that the signal is only carrying information about the phase of the carrier, not the amplitude. To transmit a QPSK signal, the sender first encodes the information to be transmitted as a series of digital bits. The bits are then divided into pairs, and each pair is used to determine the phase shift that should be applied to the carrier signal. The carrier signal is then modulated with the phase shifts and transmitted over the communication channel. At the receiver end, the QPSK signal is demodulated to extract the original information. This is done by measuring the phase shifts of the received signal and comparing them to the known phase shifts used by the sender. The phase shifts are then used to decode the original information from the digital bits. QPSK is a popular choice for digital communication systems because it has a relatively low error rate and can be implemented using relatively simple hardware. It is also relatively resistant to noise and interference, which makes it well-suited for use in noisy or crowded communication environments [1].

2.2 π/4 Differential Quadrature Phase-Shift Keying (DQPSK)

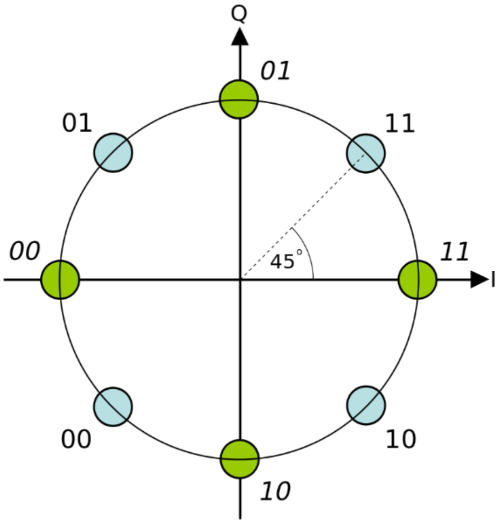

Figure 2. Dual constellation diagram for π/4-QPSK. This shows the two separate constellations with identical Gray coding but rotated by 45° with respect to each other.

Differential quadrature phase shift keying (DQPSK) is a type of digital modulation that is similar to quadrature phase shift keying (QPSK), but with one key difference: in DQPSK, the phase of the carrier signal is not directly determined by the input data bits, but rather by the difference between the current and previous input data bits. In DQPSK, the input data bits are still divided into pairs and used to determine the phase shift that should be applied to the carrier signal. However, instead of directly determining the phase shift, the input data bits are used to calculate the difference between the current and previous phase shifts. This difference is then used to determine the phase shift for the current symbol. For example, if the previous phase shift was 0 degrees and the current input data bits are 01, the difference between the previous and current phase shifts would be 90 degrees, so the current phase shift would be 90 degrees. If the previous phase shift was 90 degrees and the current input data bits are 01, the difference would be 0 degrees, so the current phase shift would be 180 degrees. DQPSK is used in many different types of communication systems, including satellite communications and mobile phone systems. It is a popular choice for these systems because it has a relatively low error rate and can be implemented using relatively simple hardware. It is also relatively resistant to noise and interference, which makes it well-suited for use in noisy or crowded communication environments.

One advantage of DQPSK over QPSK is that it is more resistant to certain types of noise and interference, such as phase jitter. In QPSK, a small change in the phase of the carrier signal can result in a significant change in the transmitted data, which can lead to errors. In DQPSK, the phase shift is determined by the difference between the current and previous phase shifts, rather than the absolute phase shift, which makes it less sensitive to phase jitter. Another advantage of DQPSK is that it allows for higher data rates than QPSK. To transmit a DQPSK signal, the sender first encodes the information to be transmitted as a series of digital bits. The bits are then divided into pairs, and the difference between the current and previous phase shifts is calculated based on the current and previous input data bits. The carrier signal is then modulated with the phase shifts and transmitted over the communication channel. At the receiver end, the DQPSK signal is demodulated to extract the original information. This is done by measuring the phase shifts of the received signal and comparing them to the known phase shifts used by the sender. The phase shifts are then used to decode the original information from the digital bits.

2.3 Implementation (QPSK - DQPSK)

Writing the symbols in the constellation diagram in terms of the sine and cosine waves used to transmit them:

$$s_n(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right), \quad n = 1, 2, 3, 4.$$

The four phases π/4, 3π/4, 5π/4 and 7π/4 as needed. This results in a two-dimensional signal space with unit basis functions as shown.

$$\phi_1(t) = \sqrt{\frac{2}{T_s}} \cos(2\pi f_c t)$$

$$\phi_2(t) = \sqrt{\frac{2}{T_s}} \sin(2\pi f_c t)$$

The first basis function is intended to be used as the in-phase component of the signal. The second basis function is used as the quaternary component of the signal. For this reason, the constellation diagram will be represented by 4 points in the signal space [3].

$$\left(\pm\sqrt{\frac{E_s}{2}} \quad \pm\sqrt{\frac{E_s}{2}} \right).$$

Since the total power is divided equally in the two carriers, the 1/2 terms are multiplied by E_s in the expression.

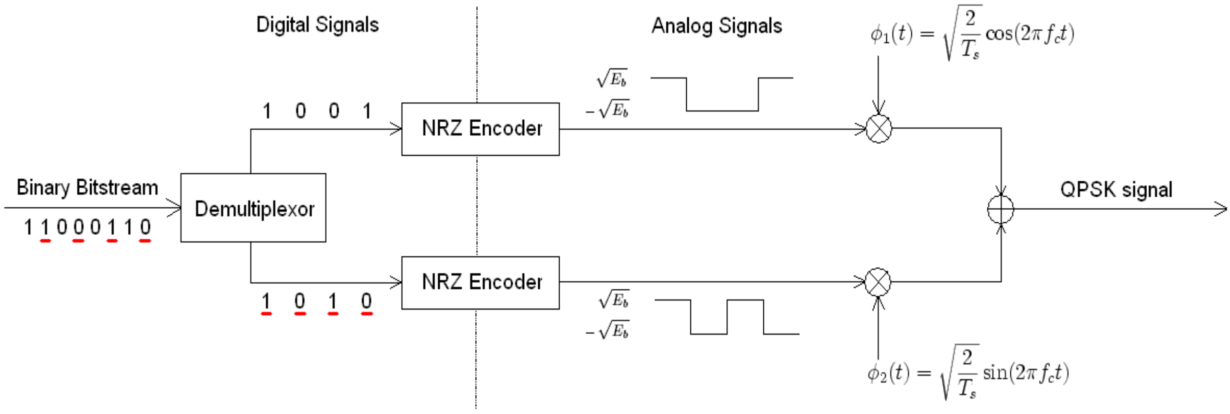

Figure 3. Transmitter Structure for QPSK

Here you can see the transmitter circuit diagram of the QPSK modulation structure shown in Figure 3. First of all, binary data are separated by co-phased and quaternary components. These data are then modulated on two orthogonal basis functions to be modulated. Two sinusoids are used in this modulation type. First, the two signals are superimposed and the QPSK signal is generated. Then, although encoders can be placed first, they are placed later in the diagram in order to focus and understand the conceptual differences between digital and analog signals.

A conceptual transmitter structure for Quadrature Phase Shift Keying (QPSK) can be explained as follows [4],

Data generation: The first step in the transmitter is the generation of the data to be transmitted. This can be achieved by using a data source such as a computer or a sensor.

Data encoding: The data is then encoded using a suitable coding scheme to improve the reliability of the transmission. This can be done using techniques such as error correction coding or forward error correction.

Modulation: The encoded data is then modulated using QPSK. In QPSK, the phase of the carrier signal is changed based on the data being transmitted. This is achieved by dividing the data into two streams, each representing one of the two bits in a symbol. These two streams are then used to modulate the phase of the carrier signal in quadrature.

Up-Conversion: The modulated signal is then up-converted to the desired frequency band using a mixer and a local oscillator.

Power amplification: The up-converted signal is then amplified using a power amplifier to increase its strength.

Antenna: The amplified signal is then transmitted using an antenna.

This is a basic outline of the transmitter structure for QPSK. The actual implementation may vary depending on the specific requirements of the system.

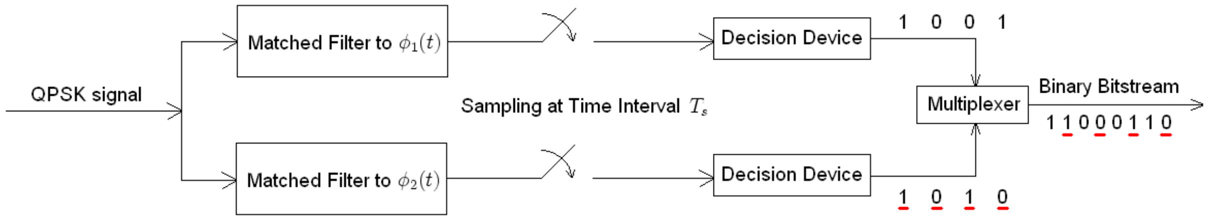

Figure 4. Receiver structure for QPSK

In more detail, the receiver structure for QPSK, shown in Figure 4, involves several steps to recover the original data from the received signal.

Down-conversion: The amplified signal is then down-converted to a lower frequency band using a mixer and a local oscillator. The mixer combines the received signal with a sinusoidal signal from the local oscillator to produce sum and difference frequencies. The difference frequency is typically in a lower frequency band than the original signal, and it can be filtered out using a band pass filter. This process, known as down-conversion, reduces the complexity of the following stages of the receiver.

Filtering: The down-converted signal is then passed through a band pass filter to remove any unwanted frequencies and improve the signal-to-noise ratio (SNR). The SNR is a measure of the strength of the signal relative to the noise present in the signal. A higher SNR makes it easier to recover the original data.

Demodulation: The filtered signal is then demodulated to recover the original data. In QPSK, this is achieved by using a pair of mixers, a local oscillator, and a low pass filter. The mixers are used to multiply the received signal by the local oscillator signal, producing sum and difference frequencies. The low pass filter is used to remove the sum frequencies, leaving only the difference frequencies, which contain the data streams that were used to modulate the carrier signal in quadrature.

Data decoding: The demodulated data is then decoded using the same coding scheme that was used at the transmitter to improve the reliability of the transmission. This can involve techniques such as error correction coding or forward error correction, which allow the receiver to detect and correct errors that may have occurred during the transmission.

Data processing: The decoded data is then passed to a data sink, such as a computer or a display, for further processing or display.

2.4 Probability of Error (P_b)

We can view QPSK modulation as a quadrature modulation type, but in fact it is easier to view it as two independently modulated quadratic carriers. In this way, even or odd bits will be used to modulate the in-phase component of the carrier, while odd or even bits will be used to modulate the quadrature component of the carrier.

As a result, the probability of bit-error for QPSK,

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

The symbol error rate is given by,

$$\begin{aligned} P_s &= 1 - (1 - P_b)^2 \\ &= 2Q\left(\sqrt{\frac{E_s}{N_0}}\right) - \left[Q\left(\sqrt{\frac{E_s}{N_0}}\right)\right]^2. \end{aligned}$$

If the signal-to-noise ratio is high (as is necessary for practical QPSK systems) the probability of symbol error may be approximated,

$$P_s \approx 2Q\left(\sqrt{\frac{E_s}{N_0}}\right) = \operatorname{erfc}\left(\sqrt{\frac{E_s}{2N_0}}\right) = \operatorname{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$$

The following image shows a diagram of a modulated signal represented by an arbitrary binary data stream. Two carrier waves, one cosine wave and the other sine wave, are shown by signal-space analysis [5]. Here, odd-numbered bits are assigned to the in-phase component and even-numbered bits are assigned to the quadrature component (the first bit is taken as 1).

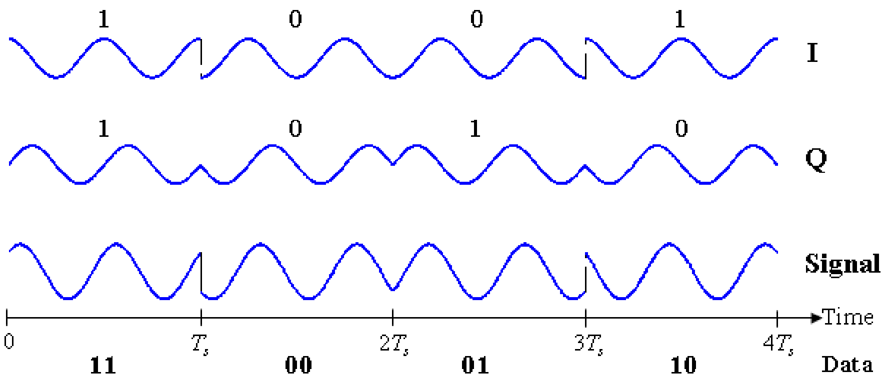

Figure 5. Timing diagram for QPSK

The binary data stream is shown under the time axis in Figure 5. The two signal components with their bit assignments are shown at the top, and the total combined signal at the bottom. Note the abrupt changes in phase at some of the bit-period boundaries.

The binary data that is conveyed by this waveform is: 11000110.

- The odd bits, highlighted here, contribute to the in-phase component: 11000110
- The even bits, highlighted here, contribute to the quadrature-phase component: 11000110

If we briefly mention other factors that affect the probability of error in QPSK and DQPSK, it will enable us to understand the probability of error in this modulation type and other factors that determine this probability.

QPSK (Quadrature Phase Shift Keying) is a type of digital modulation in which two bits of information are transmitted at a time by shifting the phase of a carrier signal by one of four possible values: 0, 90, 180, or 270 degrees. The probability of error in QPSK depends on a number of factors, including the signal-to-noise ratio (SNR) of the channel, the level of interference present, and the distance between the transmitter and receiver.

In general, the probability of error in QPSK decreases as the SNR increases. This means that as the signal becomes stronger relative to the noise, the probability of an error occurring during the transmission of the data decreases. The probability of error also decreases as the distance between the transmitter and receiver decreases, because the signal has less distance to travel and is therefore less likely to be affected by noise or interference.

The probability of error in DQPSK depends on a number of factors, including the signal-to-noise ratio (SNR) of the channel, the level of interference present, and the distance between the transmitter and receiver. The SNR is a measure of the strength of the signal relative to the noise in the channel. A high SNR means that the signal is strong compared to the noise, while a low SNR means that the noise is strong relative to the signal. The probability of error in DQPSK tends to decrease as the SNR increases, because a stronger signal is less likely to be affected by noise or interference.

There are various ways to calculate the probability of error in QPSK, but one common method is to use the bit error rate (BER) formula. The BER is defined as the number of bits that are received incorrectly divided by the total number of bits transmitted. The BER can be expressed as a function of the SNR and the distance between the transmitter and receiver. For example, if the SNR is 10 dB and the distance between the transmitter and receiver is 1 kilometer, the BER might be on the order of 10^-5.

Interference is any extraneous signal that can disrupt the transmission of data. Interference can come from a variety of sources, including other communications systems, electrical equipment, and even natural phenomena such as lightning. The probability of error in QPSK can be increased by interference, because the presence of extraneous signals can cause the receiver to misinterpret the transmitted data.

Also, the distance between the transmitter and receiver can also affect the probability of error in QPSK and DQPSK. As the distance between the two increases, the signal has more distance to travel and is therefore more likely to be affected by noise or interference. The probability of error in QPSK can be reduced by decreasing the distance between the transmitter and receiver, or by using techniques such as error correction to compensate for errors that do occur.

It's important to note that the probability of error in QPSK is not a fixed value, but rather a function of the SNR and other factors. As such, it can vary widely depending on the specific conditions of the transmission.

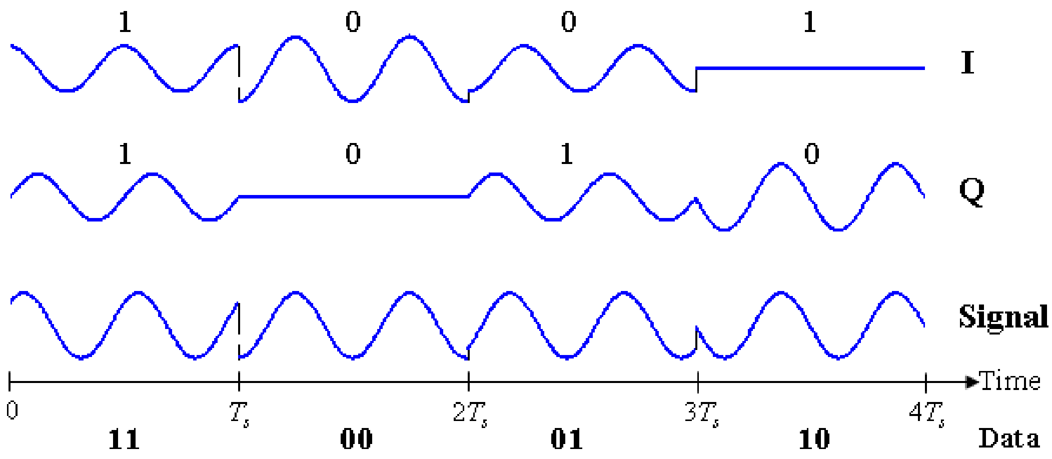

Figure 6. Timing diagram for DQPSK

In this diagram we see a random binary data stream of a modulated signal. This build is the same as an ordinary QPSK build. The sequential symbols here are taken from the sequential symbols in the DQPSK constellation diagram. Thus the first symbol (1 1) is taken from the constellation "blue" and the second symbol (0 0) is taken from the constellation "green". Note that the amplitudes of the bi component waves change as you switch between constellations, but the amplitude of the total signal remains constant (constant envelope). The phase shifts are between those of the two previous timing diagrams. Here we see the binary data stream below the time axis in the timing diagram for π/4-QPSK. The two signal components with their bit assignments are shown at the top and the total combined signal at the bottom. Note that the consecutive symbols are taken alternately from the two constellations, starting with the "blue" one.

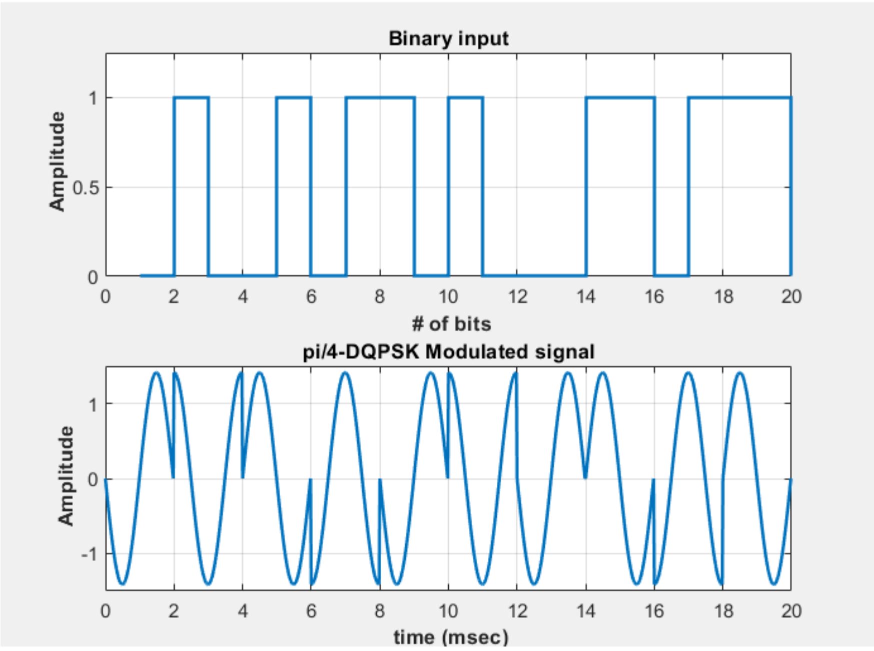

Figure 7. Phase Transitions in π/4 DQPSK

When looking at Figure 7, the phase transitions between the first 20 symbols can be easily seen. Where bit pairs change in the constellation, for example from 11 to 01, we can talk about the change of phase of the sine wave representing the new bit pair in modulation.

2.5 QPSK and DQPSK Constellations

Constellation diagrams are graphical representations of possible points a signal can take in the complex plane. They are often used to visualize and analyze the behavior of digital modulation schemes such as quaternary amplitude modulation (QAM), phase shift keying (PSK), and frequency shift keying (FSK). In a constellation diagram, points in the complex plane correspond to different symbols that can be transmitted by the modulation diagram. The distance between dots represents the signal-to-noise ratio (SNR) of the transmission, and smaller distances correspond to higher SNR. Constellation diagrams can be used to visualize the performance of a digital modulation scheme under different channel conditions such as varying SNR or interference. They can also be used to design and optimize the modulation scheme for a particular application or communication system. Overall, constellation diagrams are a useful tool for understanding and analyzing the behavior of digital modulation schemes and can help designers and engineers optimize the performance of communication systems.

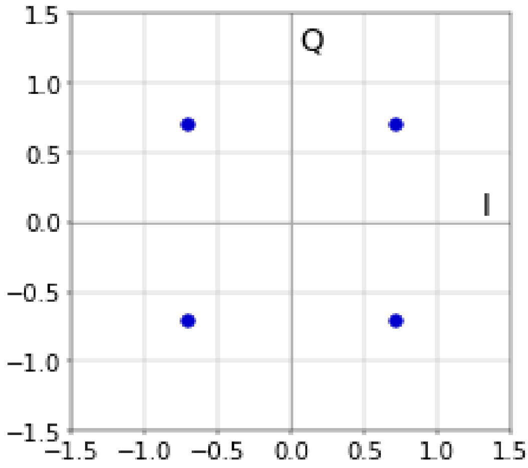

Figure 8. QPSK Constellation

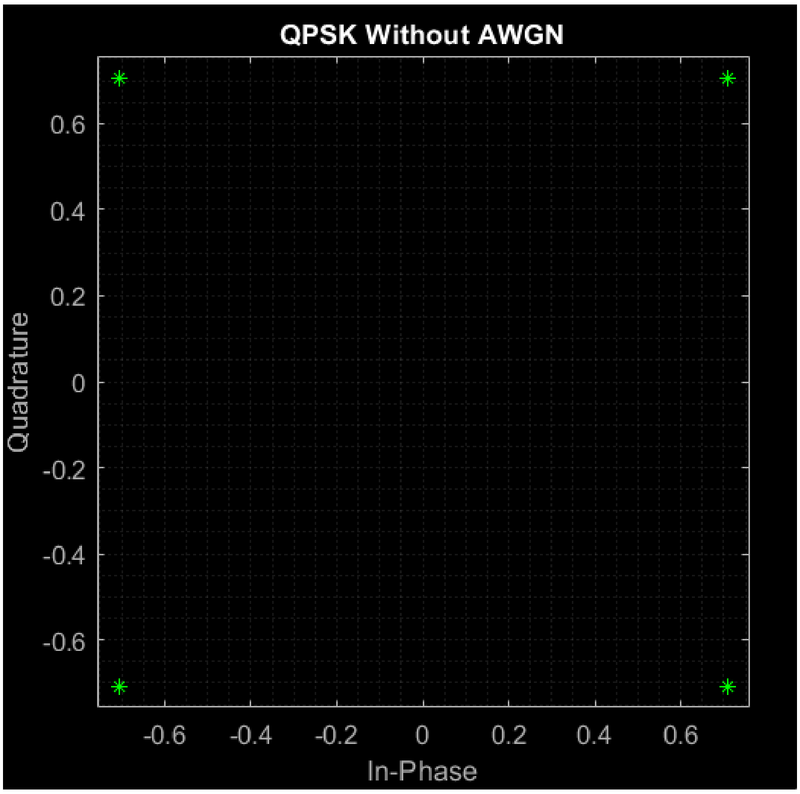

Figure 9. Our Simulation Result for QPSK without AWGN

In a constellation diagram, the complex plane is divided into a grid, and each point on the grid represents a symbol that can be communicated by the modulation diagram. The distance between points in the constellation diagram represents the signal-to-noise ratio (SNR) of the transmission. By analyzing the constellation diagram, it is possible to understand how the modulation scheme performs under different channel conditions. For example, if the SNR is low, the points in the constellation diagram may be closer together, indicating that the symbols are more difficult to distinguish. On the other hand, if the SNR is high, the points in the constellation diagram will be farther apart, indicating that the symbols are easier to distinguish [6]. Constellation diagrams can also be used to optimize the performance of a communication system. For example, if the SNR of a transmission is too low, a different modulation scheme with larger distances between points in the constellation diagram can be used to improve the performance of the system. Overall, constellation diagrams are a useful tool for understanding and analyzing the behavior of digital modulation schemes and can help designers and engineers optimize the performance of communication systems.

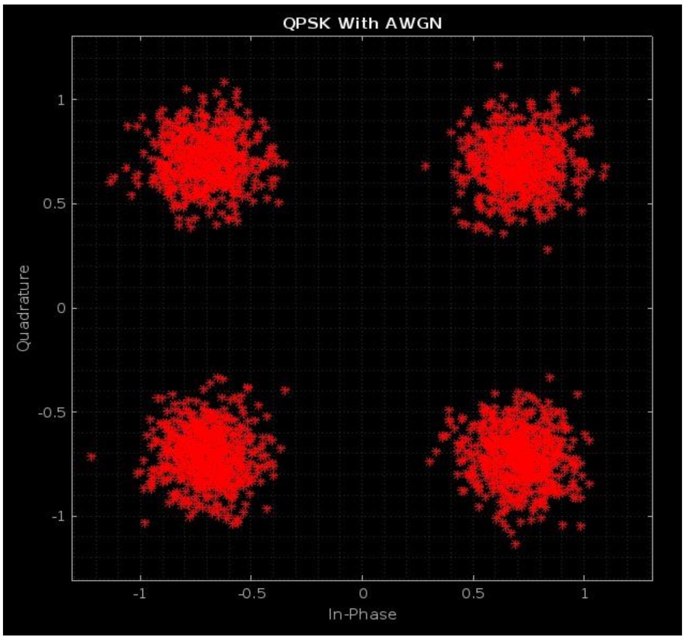

Figure 10. Our Simulation Result for QPSK SNR of 15 dB with AWGN

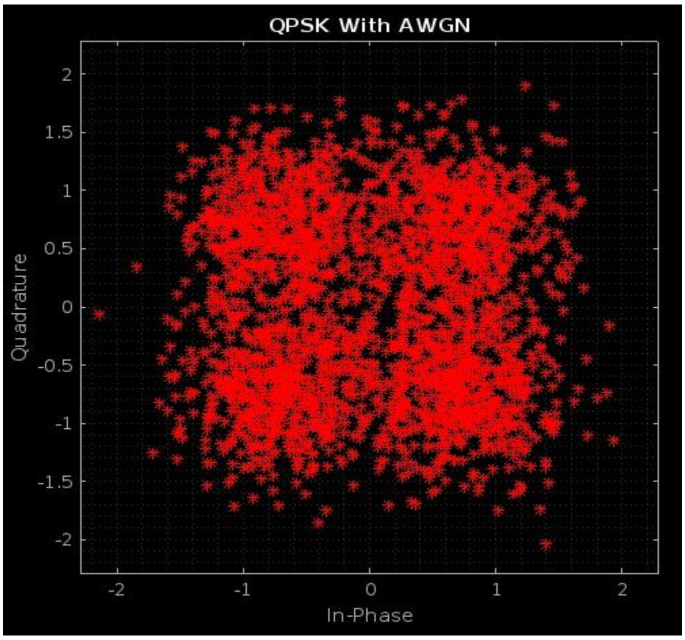

Figure 11. Our Simulation Result for QPSK SNR of 5 dB with AWGN

If we briefly summarize the diagrams, we observe the distribution of the stars in the constellation diagrams in the symbol space of the SNR value in dB in the range of 5-15 dB. At 15 dB SNR, the symbols are positioned very close to each other. This is because the strength of the noise does not outweigh the strength of the signal. However, at 5 dB SNR, the power of the noise is greatly increased compared to the power of the signal. This means that the rate of being affected by noise will increase for the symbol representing each bit pair sent. For this reason, at 5dB SNR, the symbols are fringed in the symbol space.

Quadrature Phase Shift Keying (QPSK) is a digital modulation scheme that transmits information by changing the phase of a carrier signal. It encodes two bits of data per symbol, allowing a higher data rate than simpler schemes such as Binary Phase Shift Keying (BPSK). In QPSK, the phase of the carrier signal is changed in 90 degree increments. There are four possible phase shifts: 0 degrees, 90 degrees, 180 degrees and 270 degrees. These phase shifts correspond to four possible combinations of symbols: 00, 01, 10, and 11. Symbols are represented in a constellation diagram, with each symbol represented by a dot on the diagram. For example, consider a QPSK signal with a carrier frequency of 1 Hz and a symbol rate of 1 symbol per second. The first symbol transmitted can be 00, which corresponds to a phase shift of 0 degrees. The second symbol could be 01, which corresponds to a phase shift of 90 degrees. The third symbol could be 10, corresponding to a 180 degree phase shift, and so on. QPSK is widely used in wireless communication systems such as cellular networks and satellite communications because of its ability to transmit data at high speeds with relatively low error rates. It is also used in other communication systems such as cable modems and digital audio broadcasting.

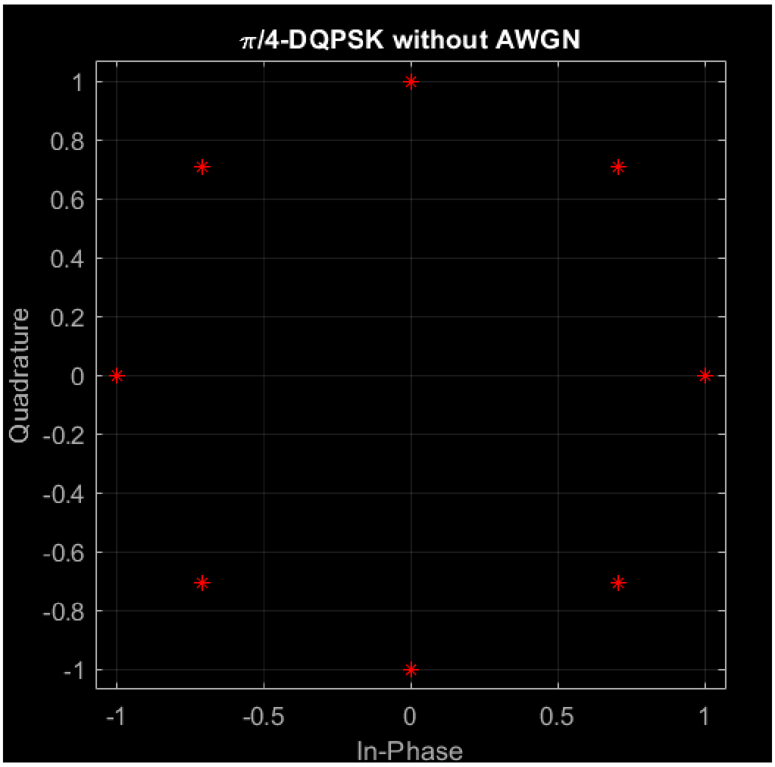

Figure 12. Our Simulation Result for π/4 DQPSK without AWGN

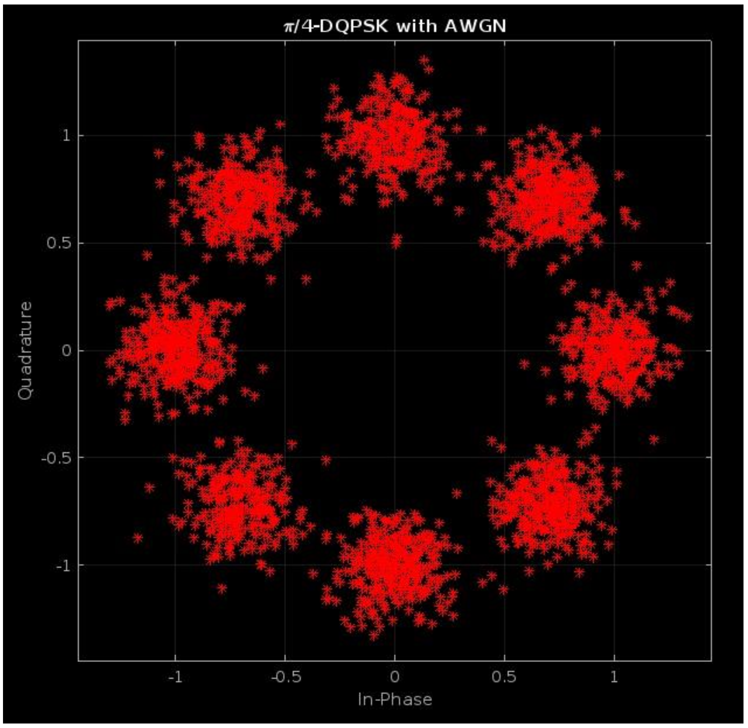

Figure 13. Our Simulation Result for π/4 DQPSK SNR of 15 dB with AWGN

Differential Quadruple Phase Shift Keying (DQPSK) is a variation of the Quadruple Phase Shift Keying (QPSK) digital modulation scheme. It is similar to QPSK in that it encodes two bits of data per symbol and uses phase shifts of 0, 90, 180, and 270 degrees to represent four possible symbol combinations. However, in DQPSK, the phase shift of each symbol is determined by the phase shift of the previous symbol. Specifically, the phase shift of each symbol is equal to the difference between the phase shifts of the previous and current symbols. This allows the receiver to determine the phase shifts of symbols based on the phase shifts of the previous symbols without needing a reference signal. Like QPSK, DQPSK is widely used in wireless communication systems due to its ability to transmit data at high speeds with relatively low error rates. It is especially useful when the signal-to-noise ratio is low, as it is more noise-tolerant than QPSK. In the constellation diagram, the symbols in the DQPSK signal are represented by dots on the diagram, just as in the QPSK. However, the dots are combined with lines to indicate the relationship between the phase shifts of the symbols. The lines in the diagram form a spiral pattern, with each dot representing a symbol and each line representing the phase shift between two consecutive symbols.

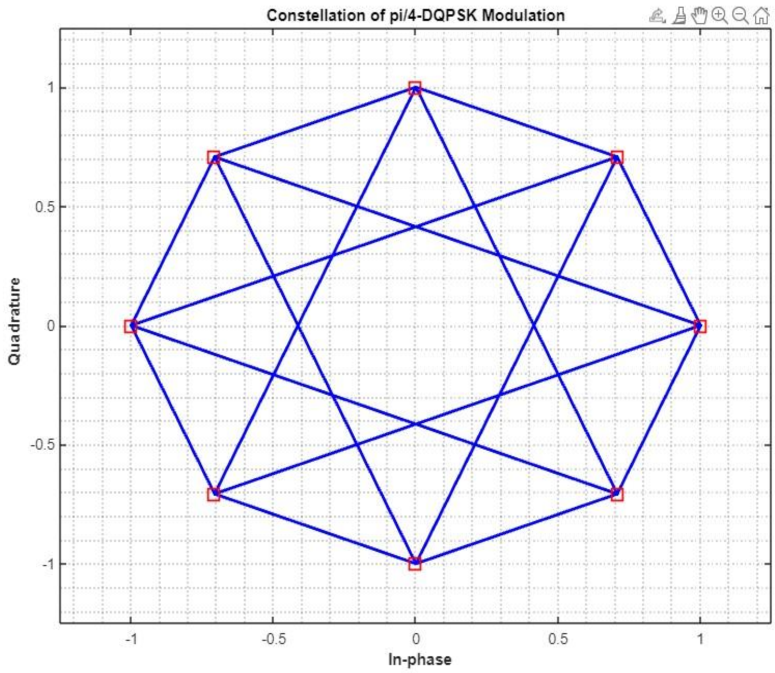

Figure 14. Spiral Modeling of Phase Shifts for DQPSK BER Analysis

Several parameters can be used to analyze the performance of a QPSK system, including: bit error rate (BER) and symbol error rate (SER). BER is a measure of the number of errors in transmitted data, expressed as a fraction of the total number of bits transmitted. Other parameters that can be used to analyze the performance of a QPSK system include signal-to-noise ratio (SNR), signal to interference ratio (SIR), and signal to noise and interference ratio (SNR). These parameters are used to evaluate the quality of the received signal and can be used to optimize the performance of the QPSK system. In general, the analysis of QPSK systems involves evaluating the performance of the system under different conditions, such as different noise and interference levels, to optimize the system design and ensure reliable data transmission.

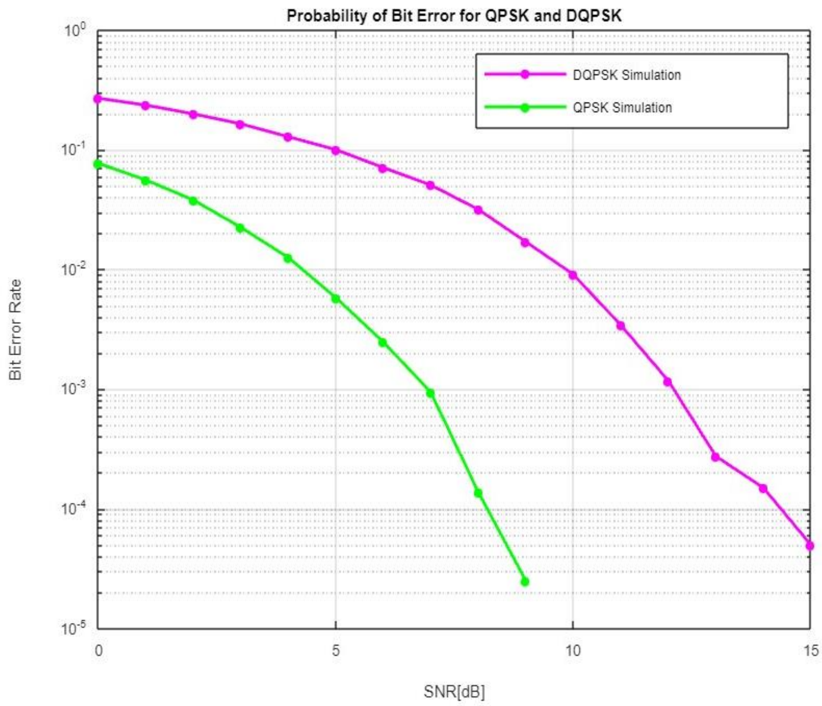

Figure 15. Our Simulation Result for Probability of Bit Error for QPSK and DQPSK

One advantage of QPSK is that it is relatively robust against noise and interference when compared to other types of phase shift keying (PSK) modulation. This is because QPSK uses four different phase shifts that allow it to transmit more data per symbol and therefore achieve a higher data rate.

The BER values of a QPSK system can be calculated using analytical models or simulated using computer models. These models take into account various factors that can affect the performance of the system, such as signal-to-noise ratio (SNR), signal-to-interference ratio (SIR), and signal-to-noise-and-.

SNR is a measure of the strength of the received signal relative to the noise present in the system. A higher SNR means the signal is stronger relative to noise, which can result in a lower BER.

DQPSK (Differential Quadruple Phase Shift Keying) is a type of digital modulation similar to QPSK (Quad Phase Shift Keying) but uses differential coding to improve system performance. In DQPSK, the phase of the carrier signal changes according to the transmitted digital data, but the phase shifts are not directly encoded. Instead, phase shifts are determined by comparing the current symbol with the previous symbol, allowing the receiver to detect and correct any errors that may occur during transmission. Various parameters, including bit error rate (BER) and symbol error rate (SER), can be used to analyze the performance of a DQPSK system. BER is a measure of the number of errors in transmitted data, expressed as a fraction of the total number of bits transmitted. SER is a measure of the number of errors in transmitted symbols, expressed as a fraction of the total number of symbols transmitted.

One advantage of DQPSK is that it is more resistant to errors from noise and interference than QPSK. This is because DQPSK uses differential coding, which allows the receiver to detect and correct any errors that may occur during transmission. Quadrature Phase Shift Keying (QPSK) and Differential Quadrature Phase Shift Keying (DQPSK) are two types of digital modulation techniques used in communication systems. Both techniques are used to transmit digital data over a wireless or wired channel by modulating a carrier signal. In QPSK, the phase of the carrier signal is shifted in four different states to represent two bits of data. For example, if the carrier signal is a sinusoidal wave, the phase of the wave can be 0 degrees, 90 degrees, 180 degrees, or 270 degrees to represent the four possible states. In DQPSK, the phase of the carrier signal is shifted in two different states to represent one bit of data, and the phase shift is determined by the previous bit. DQPSK requires more complex hardware and processing to implement, compared to QPSK. This makes it more expensive and less practical to use in some applications.

Why we are using Gray Coding Technique?

Quadrature phase-shift keying (QPSK), is sometimes referred to as quadriphase PSK, 4-PSK, or 4-QAM. (Although the fundamental ideas behind QPSK and 4-QAM are dissimilar, the modulated radio waves that arise are the same.) On the constellation diagram, QPSK makes use of four evenly spaced points. The graphic uses Gray coding to reduce the bit error rate and illustrates how QPSK can encode two bits per symbol with four phases (BER). Using gray code reduces the overall error rate with respect to the case of using normal-binary code. And of course, makes the error correction process much easier. The mathematical study demonstrates that QPSK may be used to either maintain the data rate of BPSK while halving the required bandwidth or to maintain the data rate of BPSK while retaining the same bandwidth of the signal. The BER of QPSK in this latter scenario is identical to the BER of BPSK, despite popular misconceptions about QPSK that lead many to believe otherwise. Numerous phase variations can occur in the transmitted carrier.

But, basically there is a single bit difference between two consecutive symbols in gray coding because there is the highest probability of bit error rate between consecutive bits. That's why we change a single bit in successive bits so that when there is an error, there is only one bit of error. That’s why we use gray coding technique.

2.6 Important Differences Related To Main Concepts, Advantages and Usage Areas of QPSK and DQPSK

QPSK (Quadrature Phase Shift Keying) and DQPSK (Differential Quadrature Phase Shift Keying) modulation techniques are modulation techniques used in digital data transfer. These techniques transmit data by modulating it to a carrier signal. However, there are important differences between these two techniques, and in the final report of this project, we would rather focus on and explain the differences, advantages and usage areas of these two modulation schemes.

Data Rate: QPSK modulation has a lower data rate than DQPSK modulation.

Therefore, QPSK modulation is more suitable for applications that require low data rates.

Signal-to-noise ratio: QPSK modulation has a higher signal-to-noise ratio than DQPSK modulation. Therefore, QPSK modulation performs better in low noise environments.

Error correction: DQPSK modulation has better error correction ability than QPSK modulation. Therefore, DQPSK modulation is more suitable for applications that require error correction.

Modulation technique: QPSK modulation takes data bits in pairs and applies a phase change for each group separately. DQPSK modulation, on the other hand, takes data bits one by one and applies a phase change from the previous data bit. Therefore, DQPSK modulation requires less data rate [7].

QPSK (Quadrature Phase Shift Keying) modulation takes data bits in pairs and applies a phase shift for each group separately. For example, if the data bits are considered as 00, 01, 10, and 11, then QPSK modulation takes these data bits in pairs and applies a phase change according to the data bits in each group.

Therefore, QPSK modulation uses two different phase changes relative to the data bits. DQPSK (Differential Quadrature Phase Shift Keying) modulation takes the data bits one by one and applies a phase shift relative to the previous data bit. For example, if the data bits are considered as 0101, DQPSK modulation takes these data bits one by one and applies a phase change relative to the previous data bit. Therefore, DQPSK modulation does not apply a phase change for each data bit, but a phase change with respect to the previous data bit [8].

They are commonly used in communication systems, including cellular networks, satellite systems, and other wireless communication systems.

QPSK is used in a variety of applications [9], including:

- Digital television and radio broadcasting
- Wireless local area networks (WLANs)
- Digital subscriber line (DSL)
- Global positioning systems (GPS)
- Digital audio broadcasting (DAB)

DQPSK is also used in a variety of applications [10], including:

- Cellular networks, including GSM and 3G
- Satellite systems

- Wireless local area networks (WLANs)
- Digital subscriber line (DSL)
- Global positioning systems (GPS)

Both QPSK and DQPSK are widely used because they offer a good balance between spectral efficiency and robustness against noise and interference. They are also relatively easy to implement and can be used in a variety of frequency bands and transmission environments.

3. Conclusion

In Quadrature Phase Shift Keying (QPSK), two bits are modulated simultaneously while choosing one of four potential carrier phase shifts (0, 90, 180, or 270 degrees).

DQPSK is a kind of differential QPSK that employs differential modulation. In this case, bits are chosen for a specific symbol depending on the phase shift from a preceding symbol. The four potential states are 0,+/2, and -/2. Consequently, each sign stands for two pieces of information. The binary pattern splitting here is identical to QPSK with the exception that one chain of bits is phase-shifted to about /4 or /2 depending on the design need. The advantage of this modulation as compared to conventional QPSK or offset QPSK systems is that pi/4 DQPSK can be detected coherently or non-coherently. Non-coherent detection techniques include differential detection as well as receivers using a limiter-discriminator followed by an integrate-and-dump filter. The choice of this modulation for digital cellular systems is appropriate because of the phase-incoherent nature of cellular communication channels.

In this project, QPSK and DQPSK are examined by looking at the outputs both with less signal-to-noise ratio and more signal-to-noise ratio. By looking at the output graphs, At 15 dB SNR, the symbols are positioned very close to each other. This is because the strength of the noise does not outweigh the strength of the signal. However, at 5 dB SNR, the power of the noise is greatly increased compared to the power of the signal. This means that the rate of being affected by noise will increase for the symbol representing each bit pair sent. For this reason, at 5dB SNR, the symbols are fringed in the symbol space.

One of the other important analyses of this project is BER Analysis for QPSK and DQPSK. By looking at the outputs, it is observed that DQPSK has more BER. Then, although BER is more when DQPSK is used, the reason why DQPSK is still used was explained.

To sum up, in this project we observed QPSK and QPSK with BER and SNR analyses and taking into consideration of their disadvantages and advantages their usage areas were explained.

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