

DATA-AIDED CARRIER RECOVERY WITH QPSK MODULATION

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ABSTRACT

Digital communication has proven to be the most efficient method of data transmission especially where long distances are involved. This led to the invention of more sophisticated methods of communication ranging from mobile handset communication to more advanced satellite communication. The speeds of passing information have been improving over the years and real time video communication has been made possible with digital devices. Various methods of digital data transmission are employed based on the information to be transmitted. This paper focuses on carrier recovery in digital communication systems, especially those based on Quadrature Phase Shift Keying (QPSK) modulation and demodulation scheme. The design being implemented is that of coherent demodulation for QPSK scheme using SIMULINK design tool. Performance of QPSK is also investigated to make a comparison and the suitability of the scheme to use in digital data transmission applications.

KEYWORDS:

Data-aided carrier recovery, digital modulation, QPSK modulation

1. Introduction

Communication describes the art of passing information from one person (sender) to another (recipient). This is a field that has undergone significant evolution from the analog mode of communication to the recent digital communication. The large volumes of data to be transmitted and distance involved has necessitated for sophisticated modes of communication such as satellite communication and the use of fiber optic cables for transmission (Jain et al., 2017).

Digital communication has seen significant application in modern society such as in television broadcasting, mobile

phone communication and data transfer using internet. The signal which is mainly in analog format is converted into binary strings of zeros and ones. This digital signal is then modulated using a carrier signal which is essential to limit the bandwidth required for the transmission. The modulated signal is then transmitted using a desired channel. This could either be point-to-point communication or broadcasting. The receiver is designed to be able to isolate the transmitted signal from the noise in the channel. The received signal is then demodulated to recover the transmitted signal (Chowdhury et al., 2017; Niaz et al., 2018).

The success and preference of digital modulation to the analog modulation is due to high information capacity, immunity to noise, high quality communication and information security. Therefore, knowledge of various forms of digital modulation and demodulation is key in the optimization of the limited bandwidth. The challenge in digital communication is noise, especially when air is used as the channel of transmission. The design should also be robust, lie within permissible power and have high immunity to noise, irrespective of whether the receiver is stationary or in motion as in mobile handsets (Agarwal & Bhardwaj, 2018, pp. 135-139).

2. Design procedure

The design and simulations we done using the Math Work Simulink for modeling and evaluating the performance of the QPSK system. Simulink is a block-oriented modeling tool that utilizes well tested MATLAB code to enable rapid development of the simulations for communication systems modeling. This block-oriented approach obviates the need for writing new software routines. The Simulink library provides an extensive array of Math-Works-verified blocks available for assembling any specific model

2.1. Modulator design

The Simulink design of QPSK modulator is shown in Figure no. 1 and each block is explained in the following subsequent sections.

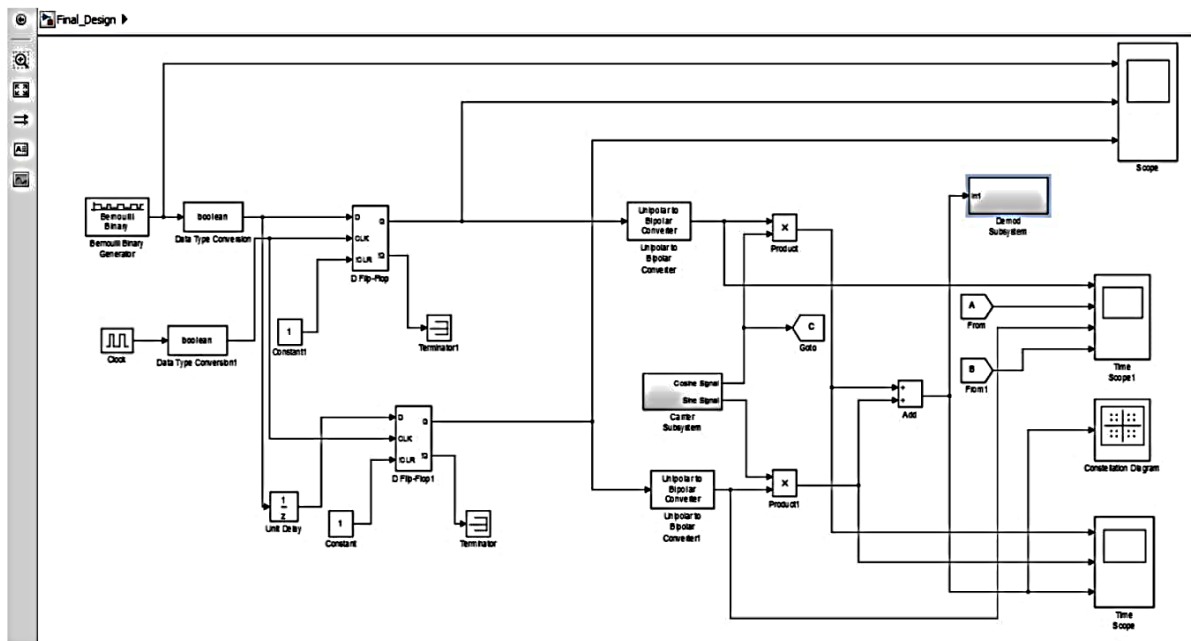


Figure no. 1. Simulink design of QPSK modulator

2.1.1. Bernoulli binary generator

This is used to represent the digital signal that is to be transmitted. The data generated is random serial sequence of 1's and 0's which is essentially the type of data that a QPSK modulation scheme works with. The Bernoulli binary generator block generates random binary numbers using a Bernoulli distribution.

2.1.2. Clock

The clock is used to trigger the D-flip flops used in the design of serial to parallel convertor. It is set to generate clock pulses at a period of 0.05 seconds.

2.1.3. Data type conversion

Data type conversion block converts an input signal of any Simulink data type to

the data type specified by the designer for the output data type parameter. The input can be any real or complex valued signal. If the input is real, the output is real and if the input is complex, the output is complex. The data type for this design is set to Boolean.

2.1.4. Serial to parallel converter

Serial to parallel converter shown in Figure no. 2 is basically a sequential circuit

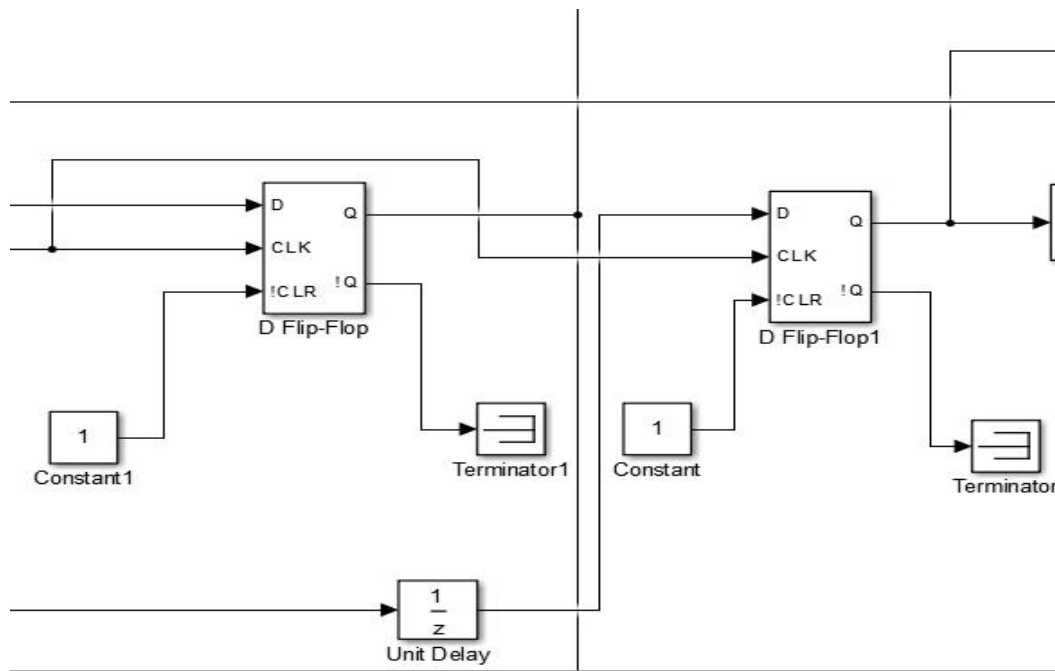


Figure no. 2. Serial to parallel converter

The serial to parallel converter utilizes blocks such as constant which has a value 1 to disable the active low clear terminal of the D-flip flop. The terminal block ensures that the circuit does not generate error during simulation due to floating output. For the design to generate odd and even numbered bits from the serial binary input, a unit delay block is used to ensure that the input to the next D flip flop is delayed by one. This ensures that this D-flip flop only outputs even bits, and the D-flip flop with no delay gives odd numbered bits only. These are then fed to the Q- and I-channel respectively.

constructed using flip flops but, in this case D-flip flops are used. The binary data from the Bernoulli binary generator passes through the serial to parallel converter which separates the even and odd binary data signal. The even data and odd data is passed into the in-phase and quadrature part of the transmitter where they are separately mixed with the cosine and the sine wave generated by the local carrier generator.

2.1.5. Unipolar to bipolar converter

QPSK design that is implemented in this paper utilizes the non-return-to-zero (NRZ) design. This means that binary data streams in the Q- and I-channel are 1 and -1. The unipolar converter shown in Figure no. 3 hence serves to convert a unipolar, single sided signal to a bipolar double side signal. Whereas the unipolar had 1's presented by a positive signal and 0's represented by zero signal, the bipolar has the 1's represented by a positive signal and the 0's represented by negative signal of equal magnitude.

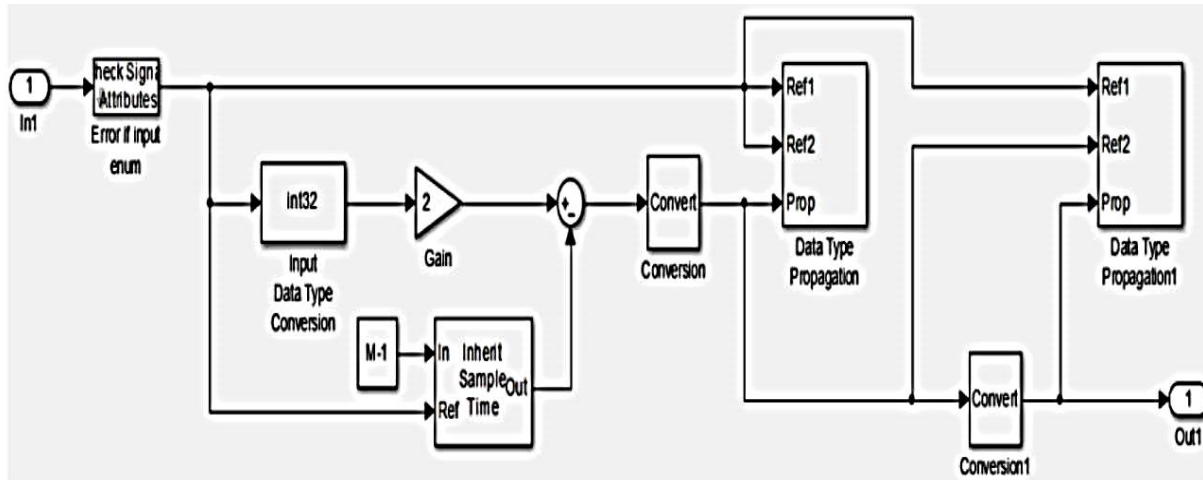


Figure no. 3. Simulink design of unipolar to bipolar convertor

2.1.6. Carrier generator

The carrier signal is the transmitted pulse at a base frequency of alteration on which the information can be imposed in the process of modulation. For QPSK modulation, the carrier is a sinusoidal signal, one on the I-channel having a phase shift of 0° while the carrier signal on the Q-channel has a phase shift of 90° . These two carriers, which can be regarded as cosine and sine signal respectively, are modulated by the incoming message signal of the channel, which is transmitted to the receiver with the carrier frequency.

This paper focuses on QPSK modulation and therefore for each channel, that is the Q- and the I-channel, the carrier phase is shifted by 0° or 180° resulting in a form of BPSK modulated signal. This is the theory behind QPSK modulation which is essentially a summation of two BPSK modulated signals from two channels.

The carrier generator consists of the discrete sine generator and a block for complex converter. The discrete sine signal is passed through the complex converter to give the sine signal at the imaginary output and a cosine signal at the real output.

2.1.7. Product

This is used as the mixer to modulate the carrier with the modulating message signal. Its set depending on the number of the inputs for the particular use and multipliers the inputs element-wise. All the products used in the design are set to have the same parameters with only two inputs.

2.1.8. Adder

This sums up various inputs to give a combined output. It is used for deriving the QPSK modulated signal by summing the BPSK modulated signals from the Q- and I-channel of the modulator. The functionality of the block remains the same throughout the design, although in different applications.

2.2. Demodulator and re-modulator design

The modulated signal is passed through an Additive White Gaussian Noise (AWGN) channel to the QPSK demodulator. The AWGN channel is set to give a high signal to noise ratio (SNR) to ensure there is no bit error at the demodulated signal. The demodulation design that is implemented in Simulink is as shown in Figure no. 4.

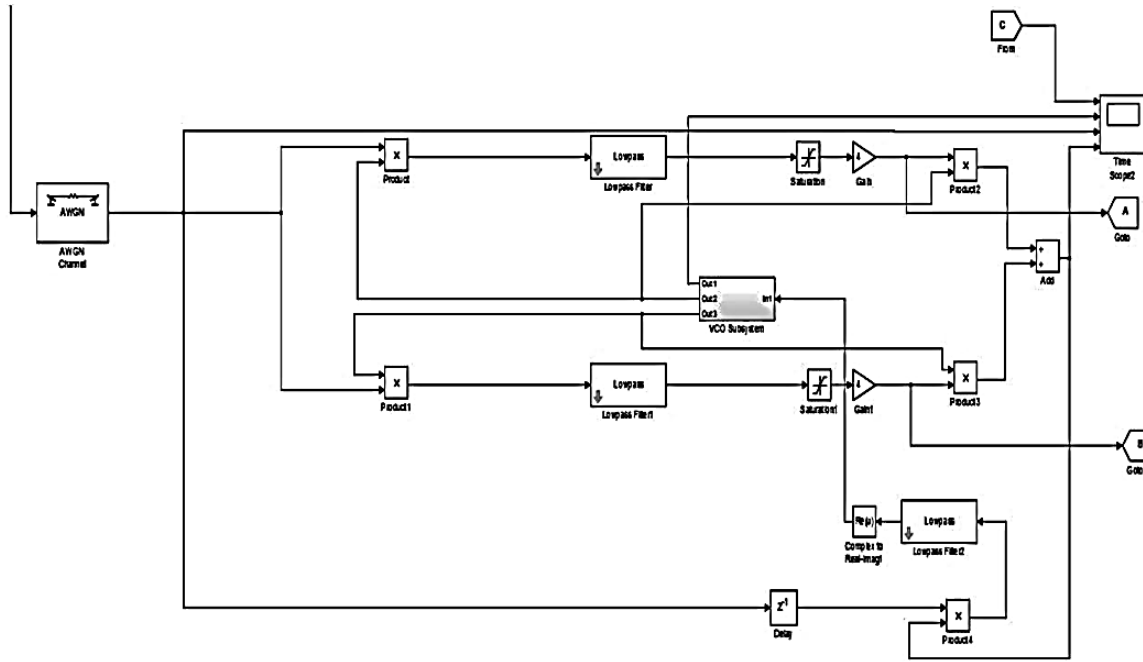


Figure no. 4. QPSK demodulation and re-modulation design

The basic blocks such as the product and adder have then same parameters and functionality as are used in the modulation design. The receiver generates a carrier signal that is similar to the transmitter carrier, which is then multiplied by the incoming modulated signal to start the process of demodulation. The resultant signal which has a double frequency element is passed through low pass filters to remove this high frequency component.

The demodulation process occurs at the Q- and I-arm of the demodulator resulting in recovery of the message signal at both the Q- and I- arm. After filtering the high frequency component, the signal passes through a limiter which attenuates the high spikes of the demodulated signal that may be due to the presence of noise in the channel. To obtain the recovered signal having some desired magnitude, the demodulated signal is multiplied by a desired gain. The two recovered signals at the Q- and I- arm are used for re-modulation and this loop aids in recovery of the carrier especially when the carrier is below intermediate frequency (IF) signal.

2.2.1. Low pass filter (LPF)

The modulated signal reaching the receiver is multiplied by a signal similar to that of the transmitter carrier. This result into a signal with a double frequency component which has to be filtered hence the need for the LPF which is implemented on both arms of the demodulator.

2.2.2. Saturation

The saturation blocks are used to impose upper and lower limits of the input signal for each demodulation arm. This block accepts real signals of floating point, built-in integer and fixed point data types.

2.2.3. Gain

The gain block is used to amplify the clipped signal from the saturation block. The amplification is to ensure that the output data had a unity magnitude. This is essential for observability of the demodulated signal and has no significant effect on this signal.

2.2.4. Delay

The delay block is used to ensure phase match between the transmitted QPSK signal and the re-modulated QPSK signal.

2.2.5. Phase/frequency offset

The signal from the voltage controlled oscillator (VCO) which is essentially a cosine signal similar to that of the carrier needed to be shifted 90° to obtain the sine waveform to be used for the demodulation purpose in the Q-arm. This phase shift is achieved using a phase/frequency offset with parameters set shift the phase while maintaining the frequency to match that of the carrier.

2.2.6. Discrete-time VCO

The VCO generates a discrete-time output signal whose frequency changes in response to the amplitude variations of the input signal. The input signal must be scalar.

3. Results

3.1. QPSK modulation results

The input serial data stream, which is a random sequence of 1's and 0's is as in Figure no. 5.

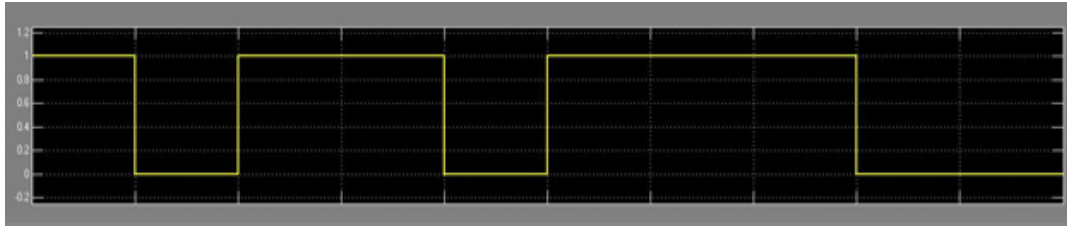


Figure no. 5. Input serial digital data

For the modulation purposes, this input data which is in serial form is converted to parallel using the serial-to-parallel converter. The data is then split into

even numbered bits and odd numbered bits which are then modulated in the Q- and the I-channel respectively, as shown in Figure no. 6 and Figure no. 7.

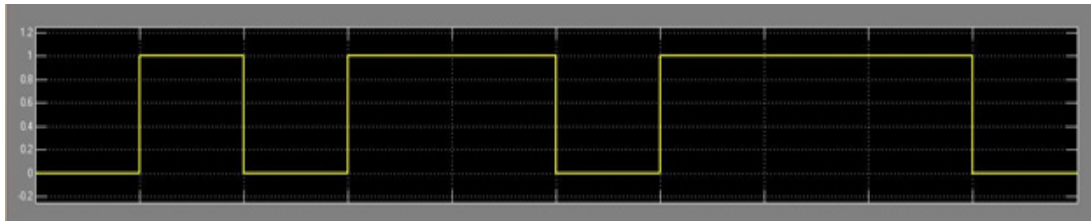


Figure no. 6. Odd numbered bits for I-channel

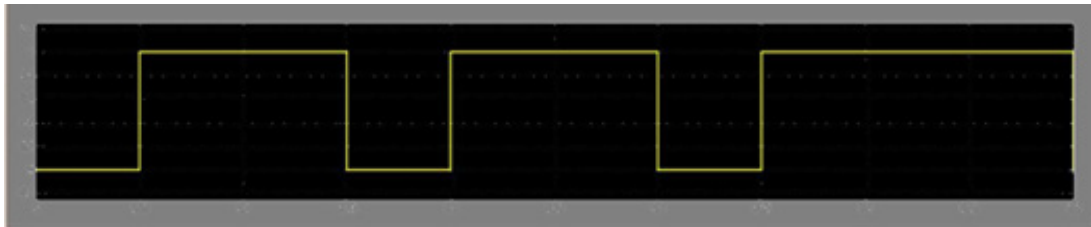


Figure no. 7. Even numbered bits for Q-channel

The carrier signal shown in Figure no. 8, which is a cosine and sine signal, is

used to modulate the data in the I- and Q-channel respectively.

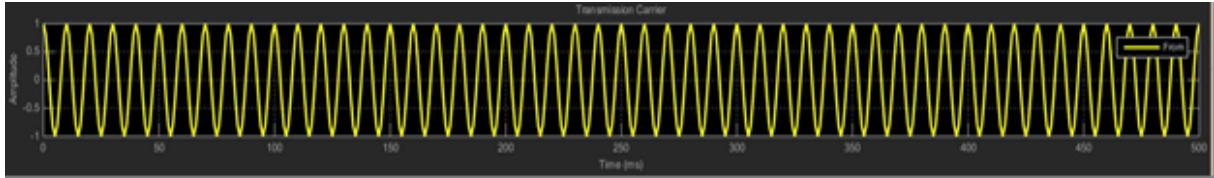


Figure no. 8. Carrier signal

The carrier modulates the data in the I- and Q- channel which is then summed up

to give the QPSK signal to be transmitted as shown in Figure no. 9.

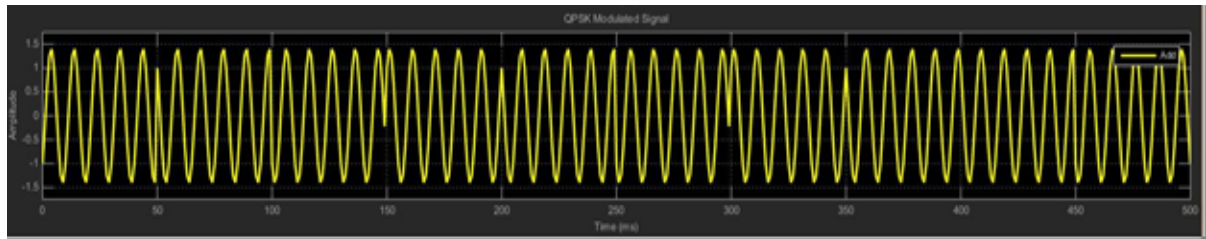


Figure no. 9. QPSK modulated signal

The signal constellation diagram for the QPSK modulation scheme as observed

from the simulations is as shown in Figure no. 10.

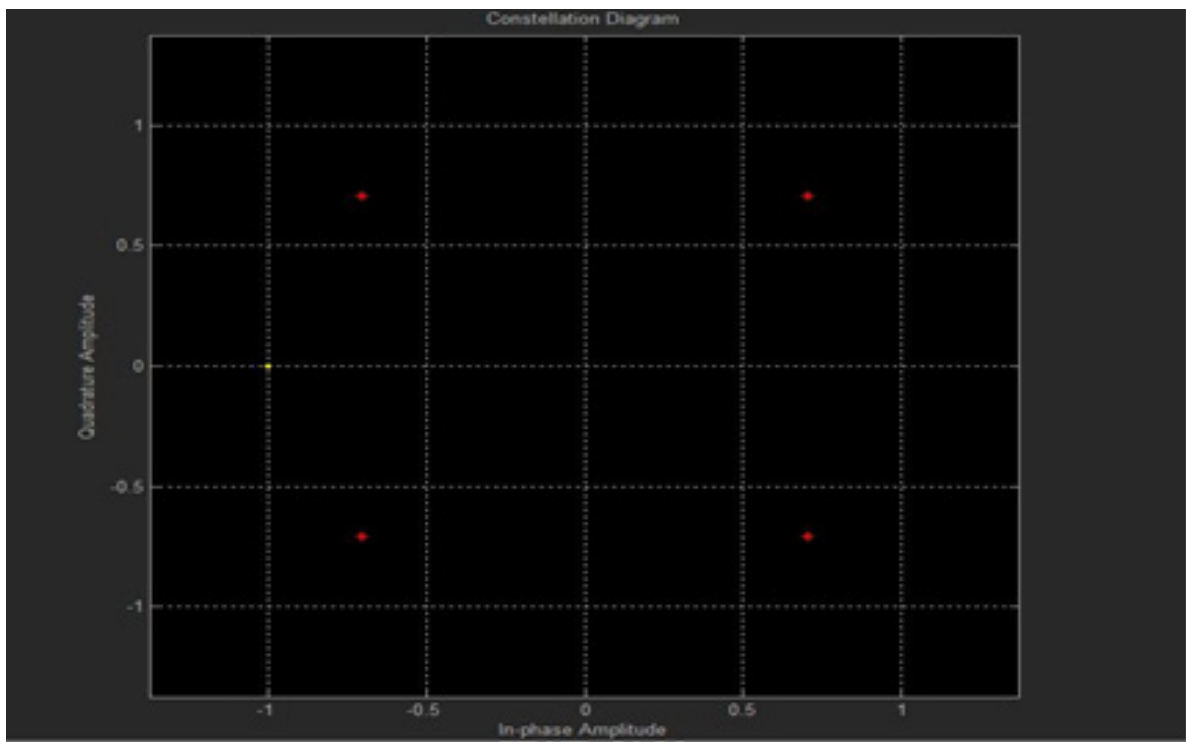


Figure no. 10. Signal constellation diagram

3.2. QPSK demodulation results

For the demodulation process, a comparison is made between the

transmission-end results and the receiver-end results. The waveforms shown in Figure no. 11 are obtained.

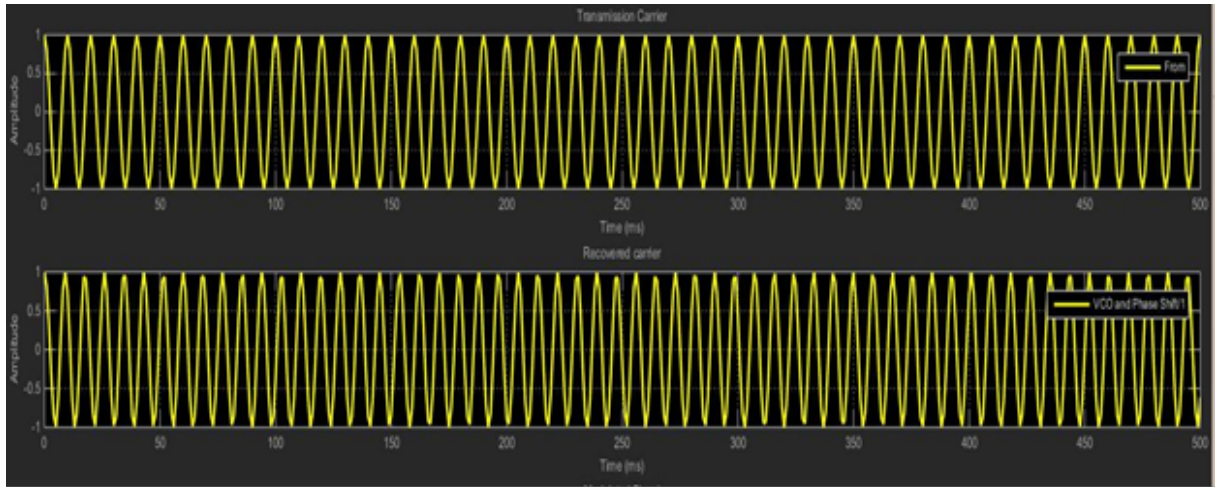


Figure no. 11. Comparison between transmission carrier and recovered carrier

The modulated and re-modulated waveforms obtained from the simulations

are as shown in Figure no. 12.

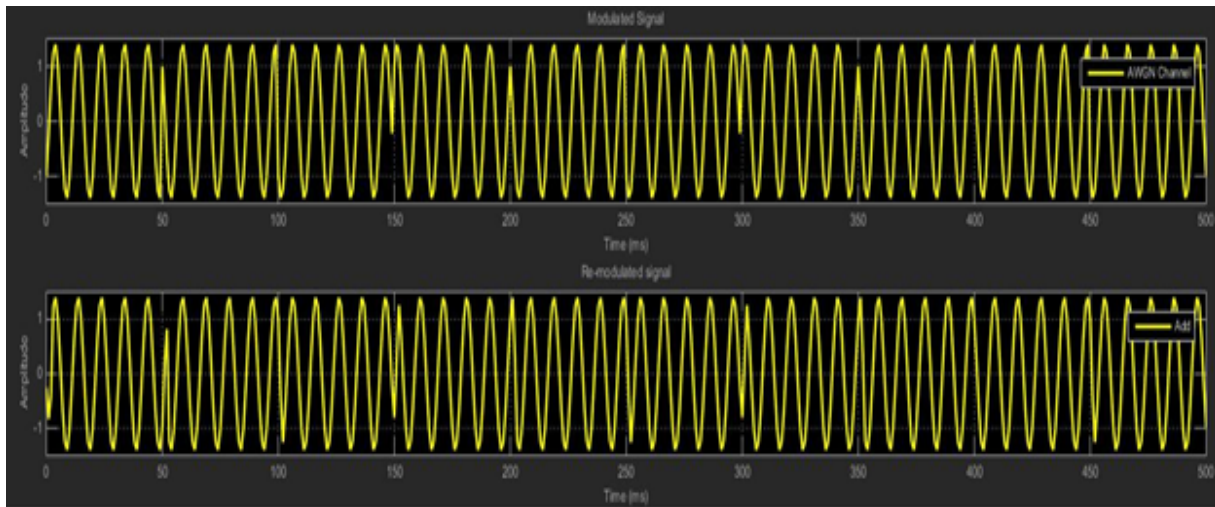


Figure no. 12. Comparison of modulated and re-modulated signals

The received data after demodulated at both the I-channel and the Q-channel is

compared with the transmitted data and the results shown in Figure no. 13 are obtained.

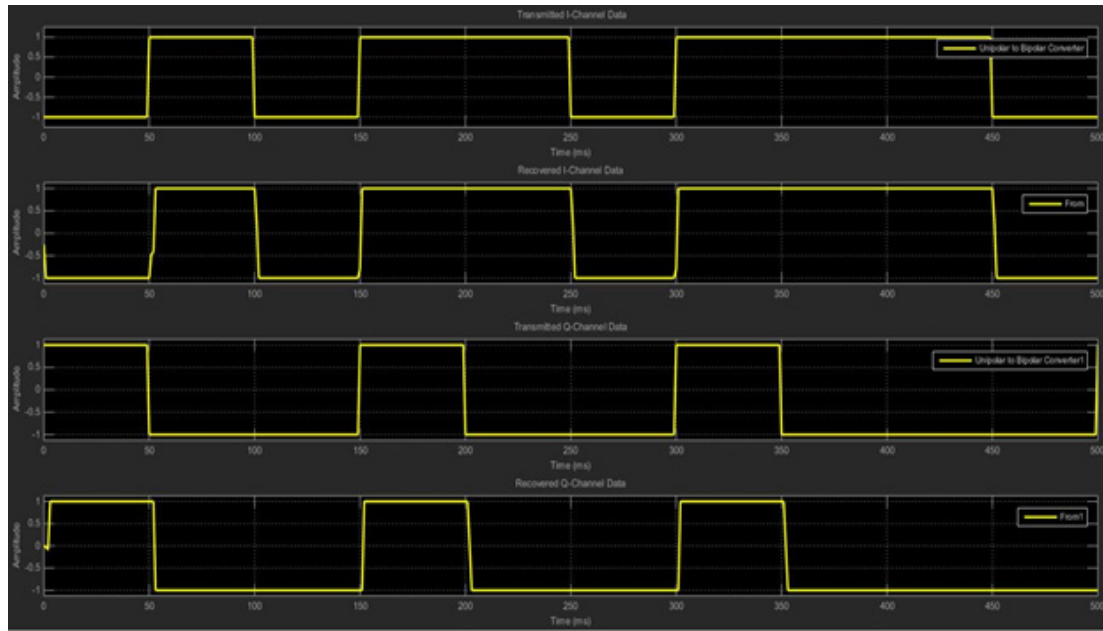


Figure no. 13. Comparison of the transmitted and recovered data for both channels

4. Conclusion

The theory behind QPSK modulation and demodulation was well demonstrated taking into account the required process such as the conversion of the serial data to even and odd numbered bits as well as the simulation of noise using AWGN channel which would be expected in real world transmission of data especially when using air as the medium of transmission. The use

of Simulink for simulation had various constraints in that the frequency of the carrier could not be set at the standard MHz ranges used in real world application of the QPSK modulation. Some of the blocks used such as the VCO and the filters were lumped blocks and do not give a clear picture of the analogue circuitry that can be used to achieve the QPSK modulation scheme.

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