

DESIGN AND IMPLEMENTATION OF A QPSK DEMODULATOR

Supervisor

Dr. Satya Prasad Majumder

Submitted by

Md Mubeenul Haq Khan

Student ID: 07110009

Mahabubul Hasan

Student ID: 07110077

Farzana Akhter

Student ID:07110099

Department of Electronic and Electrical Engineering

August 2010



BRAC University, Dhaka, Bangladesh

DECLARATION

This is to certify that the thesis contains our original work towards the degree of Bachelor of Science in Electronics and Communication Engineering at BRAC University. Materials of work found by other researcher are mentioned by reference. Furthermore, this thesis has not been submitted elsewhere for a degree.

.....

(Dr. Satya Prasad Majumder)

Acknowledgement

First of all I'm grateful to Allah for giving me strength and wisdom throughout all my life. I thank my family for their love, their moral and financial support they had given me. This helped me a lot. We would like to give my gratitude for our supervisor Dr. Satya Prasad Majumder, who has given us significant suggestions and inspections during the whole process of the work. From the form of primary, we really acquire much knowledge about how to organize a well-structured report step by step. I would like to give my great appreciation to our Co-Supervisor Nazmus Saquib, Lecturer, Dept. of EEE, BRAC University. He always stays beside us, encourage and sustain us when we feel tired and confused.

We give our gratefully acknowledge to Fariah Mahzabeen, lecturer, Dept. of EEE, BRAC University, who gave her valuable time & overview about the project.

Last but not least we are really grateful to Tarem Ahmed, Rumana Rahman for their enormous help during the work session in each and every aspect. We are really fortunate to have nice human being like them beside us.

I thanks all my friends, both here and back home, who have been there for me when I needed them. They are NOT ordered according to their importance to me; it's just the order they came to my mind.

TABLE OF CONTENTS

CHAPTER-1

| | |
|--|----|
| INTRODUCTION | 10 |
| 1.1 Initials | 10 |
| 1.2 Analysis of Modulation | 10 |
| 1.3 Purposes of Modulation | 11 |
| 1.3.1 Ease of radiation | 11 |
| 1.3.2 Simultaneous transmission of several signals | 11 |
| 1.4 Analog Modulation Methods | 15 |
| 1.5 Digital Modulation Methods | 15 |
| 1.6 Digital base-band Modulation or Line Coding | 19 |
| 1.7 Pulse Modulation Methods | 19 |
| 1.8 Analysis of Demodulation | 20 |

CHAPTER – 2

| | |
|--|----|
| ANALYSIS OF QUADRATURE PHASE SHIFT KEYING (QPSK) | 21 |
| 2.1 Phase-Shift Keying | 21 |
| 2.2 Binary Phase-Shift Keying (BPSK) | 23 |
| 2.2.1 Implementation | 24 |
| 2.3 QPSK Demodulation | 25 |
| 2.4 QPSK Signal In The Time Domain | 27 |
| 2.5 Offset QPSK (OQPSK) | 28 |

| | |
|---------------------------------------|----|
| 2.6 $\pi/4$ QPSK | 31 |
| 2.7 Higher-Order PSK | 32 |
| 2.8 Differential Encoding | 35 |
| 2.9 Differentially Encoded BPSK | 36 |
| 2.10 Differential Phase-Shift Keying | 38 |
| CHAPTER 3 | |
| IMPLEMENTATION OF A QPSK DEMODULATOR | 41 |
| 3.1 QPSK Demodulator | 41 |
| 3.1.1 Multiplier for QPSK demodulator | 42 |
| 3.1.2 Low pass filter | 43 |
| 3.1.3 Pulse shaper | 44 |
| 3.1.4 Parallel to serial converter | 45 |
| 3.2 Experimental Circuit Diagram | 47 |
| 3.3 Experimental Wave Shapes | 49 |
| CHAPTER 4 | |
| SIMULATION | 57 |
| CHAPTER 5 | |
| CONCLUSION | 69 |
| REFERENCES | 70 |
| MATLAB CODE | 72 |

LIST OF FIGURES

CHAPTER 2

| | |
|---|----|
| Fig 2.1 Constellation diagram for BPSK | 23 |
| Fig. 2.2 Block diagram of QPSK demodulator | 27 |
| Fig.2.3 Timing diagram for QPSK | 28 |
| Fig.2.4 Difference of the phase between QPSK and OQPSK | 29 |
| Fig.2.5 Timing diagram for OQPSK | 30 |
| Fig.2.6 Dual constellation diagram for $\pi/4$ -QPSK | 31 |
| Fig.2.7 Timing Diagram for $\pi/4$ -QPSK | 32 |
| Fig. 2.8 Constellation diagram for 8-PSK with Gray coding | 32 |
| Fig.2.9 Bit error rate curves for BPSK, QPSK,8-PSK and 16-PSK | 34 |
| Fig.2.10 Timing diagram for DBPSK AND DQPSK | 35 |
| Fig.2.11 Differential encoding decoding system diagram | 36 |
| Fig.2.12 BER comparisons between BPSK and DBPSK with gray coding | 37 |
| Fig. 2.13 BER comparison between DBPSK, DQPSK and their non-differential forms using gray-coding and operating in white noise | 38 |

CHAPTER 3

| | |
|--|----|
| Fig.3.1 Basic demodulator block diagram | 42 |
| Fig. 3.2 Balance Modulator | 43 |
| Fig.3.3 Low pass filter | 44 |
| Fig.3.4 Voltage comparator and Schmitt Trigger | 45 |

| | |
|---|----|
| Fig.3.5 Parallel to serial converter | 46 |
| Fig.3.6 QPSK demodulator | 47 |
| Fig.3.7 QPSK demodulator (backend labeled) | 48 |
| Fig.3.8 Carrier (sine wave) | 49 |
| Fig.3.9 Sine wave and 90 degree shifted sine wave (cosine wave) | 50 |
| Fig.3.10 Data clock | 51 |
| Fig. 3.11 QPSK signal | 52 |
| Fig. 3.12 I-data and demodulated data | 53 |
| Fig.3.13 Q-data and demodulated Q-data | 54 |
| Fig. 3.14 Demodulated I-data after passing diode, low pass filter and Schmitt trigger | 55 |
| Fig. 3.15 Parallel to serial converter | 56 |

CHAPTER 4

| | |
|---|----|
| Fig. 4.1 QPSK Demodulator | 57 |
| Fig.4.2 Multiplier circuit | 58 |
| Fig. 4.3 Low pass filter and opamp | 59 |
| Fig.4.4 Parallel to Serial Converter | 60 |
| Fig. 4.5 QPSK signal multiplied with cosine carrier | 61 |
| Fig. 4.6 QPSK signal multiplied with sine carrier | 62 |
| Fig. 4.7 Original I-data and output signal after diode and low pass filter (I-data) | 63 |
| Fig.4.8 Output signal after diode and low pass filter (Q-data) | 64 |
| Fig. 4.9 Output after OPAMP and inverter (I-data) | 65 |
| Fig. 4.10 Output after OPAMP and inverter (Q-data) | 66 |

Fig. 4.11 Demodulated I and Q data67

Fig.4.12 Output of parallel to serial converter (original data)68

LIST OF ACRONYMS

| | |
|--------|--|
| QPSK | Quadrature Phase Shift Keying |
| BPSK | Binary Phase Shift Keying |
| PSK | Phase Shift Keying |
| DPSK | Differential Phase Shift Keying |
| OQPSK | Offset Quadrature Phase Shift Keying |
| SNR | Signal to Noise Ratio |
| ASK | Amplitude Shift Keying |
| FSK | Frequency Shift Keying |
| AM | Amplitude Modulation |
| FM | Frequency Modulation |
| QAM | Quadrature Amplitude Modulation |
| PPM | Pulse-Position Modulation |
| PDM | Pulse-Duration Modulation |
| PAM | Pulse- Amplitude Modulation |
| DSB-SC | Double–Sideband Supperessed–Carrier Transmission |
| DSB-RS | Double–Sideband Reduced–Carrier Transmission |
| SSB | Single-Sideband Modulation |
| AMI | Alternate Mark Inversion |
| AWGN | Additive White Gaussian Noise |

CHAPTER-1

INTRODUCTION

1.1 Initials

A technique employed in telecommunications transmission systems whereby an electromagnetic signal(the modulating signal) is encoded into one or more of the characteristics of another signal (the carrier signal) to produce a third signal (the modulated signal), whose properties are matched to the characteristics of the medium over which it is to be transmitted. The encoding preserves the original modulating signal in that it can be recovered from the modulated signal at the receiver by the process of demodulation.

1.2 Analysis of Modulation

It is not suitable to transmit base band signals ,produced by more than one information sources, directly over a given channel. In order to transmit these signals , some modification has to be done and this conversion process is called modulation. During modulation the base band signal is used to modify some parameter of a high frequency carrier signal.

This is achieved by varying any one of the parameters, such as amplitude, frequency or phase of the carrier which is a sinusoid of high frequency, in proportion to the base band signal. Depending on the parameter being varied we have amplitude modulation, frequency modulation or phase modulation.

1.3 Purposes of Modulation

1.3.1 Ease of radiation

Efficient radiation of electromagnetic energy is dependent on the size of the radiating antenna. For efficient radiation, the antenna from which the signal is being radiated should be of the order of one-tenth or more the wavelength of the wavelength of the signal radiated. In case of multiple base-band signals, the wavelengths are too large for reasonable antenna dimensions. For instance, it is required to transmit a speech signal. The power in a speech signal is concentrated at frequencies in the range of 100 to 3000Hz the corresponding wavelength is 100 to 3000km. In order to transmit this signal a huge antenna of the order of at least 10km would be required which is impractical. Instead, we modulate a high frequency carrier, this translating the signal spectrum to the region of carrier frequencies that corresponds to a much smaller wavelength. For example, a 1-MHz carrier frequencies that corresponds to a much smaller wavelength of only 300m and requires an antenna whose size in order of 30m in this aspect, modulation is like letting the base-band signal hitch-hike on a high frequency sinusoid (carrier) the carrier and the base-band signal may be compared to a stone and a piece of paper. If we wish to throw a piece of paper, it cannot go too far by itself but by wrapping it around a stone, it can be thrown over a longer distance.

1.3.2 Simultaneous transmission of several signals

Consider the case of several radio stations broadcasting audio base-band signals directly, without any modification. This will cause interference between the transmitted signals as the spectra occupied by all the signals have bandwidths whose sizes are almost the same. This means that only one radio or television station can broadcast at a time, which is wasteful because the channel bandwidth may be much larger than that of the signal. One way to solve this problem is to use modulation.

Different audio signals could be used to modulate different carrier frequencies, thus translating each signal to separate frequency range. If the carrier frequencies for various carriers are chosen such that there is a sufficient gap between their frequencies, the spectra of the modulated signals will not overlap and hence there will be no interference in transmission. On the receiving end, a tunable band pass filter could be used to select the desired station or signal. This method of transmitting several signals simultaneously is known as Frequency Division Multiplexing. Here the bandwidth of the channel is shared by various signals without any overlapping. When the signal is in the form of a pulse train time division multiplexing is used.

- Effecting the Exchange of SNR with Bandwidth
- Randomness, Redundancy and Coding

Modulation is advantageous as it allows to shift the modulating signal to a part of the frequency spectrum where the characteristics of the medium such as such as its attenuation, interference and noise level are favorable.

There are two forms of modulation in general which shares some common properties. The first one being analog modulation. In this case the modulating signal's amplitude varies continuously with time, which is why it is said to be an analog signal and the modulation is referred to as analog. In the case where the modulating signal may vary its amplitude only between a finite number of values and the change may occur only at discrete moments in time , the modulating signal is said to be a digital signal and the modulation is referred to as digital.

In most applications of modulation the carrier signal is a sine wave, which is completely characterized by its amplitude, its frequency, and its phase relative to some point in time. In order to modulate the carrier it is required to vary one or more of these parameters in direct proportion to the amplitude of the modulating signal. In analog modulation systems, varying the amplitude, frequency. or phase of the carrier signal results in amplitude modulation (AM). Frequency modulation (FM), or phase

modulation(PM), respectively. Since the frequency of a sine wave expressed in radians per second equals the derivative of its phase, frequency modulation and phase modulation are sometimes subsumed under the general term "angle modulation" or "exponential modulation".

If the modulating signal is digital, the modulation is termed amplitude-shift keying (ASK), frequency shift keying (FSK) or phase shift keying (PSK), since in this case the discrete amplitudes of the digital signal can be said to shift the parameter of the carrier signal between a finite number of values. For a modulating signal with only two amplitudes, "binary" is sometimes added before these terms.

Digital modulating signals with more than two amplitudes are sometimes encoded into both the amplitude and phase of the carrier signal. For example, if the amplitude of the modulating signal can vary between four different values, each such value can be encoded as a combination of one of two amplitudes and one of two phases of the carrier signal. Quadrature Amplitude Modulation (QAM) is an example of such a technique.

In certain applications of modulation the carrier signal, rather than being a sine wave, consists of a sequence of electromagnetic pulses of constant amplitude and time duration, which occur at regular points in time. Changing one or the other of these parameters gives rise to three modulation schemes known as pulse-position modulation (PPM), pulse-duration modulation (PDM), and pulse-amplitude modulation(PAM), in which the time of occurrence of a pulse relative to its nominal occurrence, the time duration of a pulse, or its amplitude are determined by the amplitude of the modulating signal.

In telecommunications, modulation is the process of varying a periodic waveform, i.e. a tone, in order to use that signal to convey a message, in a similar fashion as a musician may modulate the tone from a musical instrument by varying its volume, timing and pitch. Normally a high frequency sinusoid waveform is used as carrier signal. The three key parameters of a sine wave are its amplitude("volume"),its phase ("timing") and its frequency("pitch"),all of which can be modified in accordance with a low frequency information signal to obtain the modulated signal.

A device that performs modulation is known as a modulator and a device that performs the inverse operation of modulation is known as a demodulator (sometimes detector or demodulator). A device that can do both operations is a modem (a contraction of the two terms).

A simple example: A telephone line is designed for transferring audible sounds, for example tones, and not digital bits (zeros and ones). Computers may however communicate over a telephone line by means of a modems, which are representing digital bits by tones, called symbols. You could say that modems play music for each other. If there are four alternative symbols (corresponding to a musical instrument that can generate four different tones, one at a time), the first symbol may represent the bit sequence 00, the second 01, the third 10 and the fourth 11. If the modem plays a melody consisting of 1000 tones per second, the symbol rate is 1000 symbols/second, or baud. Since each tone represents a message consisting of two digital bits in this example, the bit rate is twice the symbol rate, i.e. 2000 bit per second.

The aim of digital modulation is to transfer a digital bit stream over an analog bandpass channel, for example over the public switched telephone network (where a filter limits the frequency range to between 300 and 3400 Hz) or a limited radio frequency band.

The aim of analog modulation is to transfer an analog low pass signal, for example an audio signal or TV signal, over an analog band pass channel, for example a limited radio frequency band or a cable TV network channel.

Analog and digital modulation facilitate frequency division multiplex(FDM), where several low pass information signals are transferred simultaneously over the same shared physical medium, using separate band pass channels.

The aim of digital base-band modulation methods, also known as line coding, is to transfer a digital bit stream over a low pass channel, typically a non-filtered copper wire such as a serial bus or a wired local area network.

The aim of pulse modulation methods is to transfer a narrowband analog signal, for example a phone call over a wideband low pass channel or, in some of the schemes, as a bit stream over another digital transmission system.

1.4 Analog Modulation Methods

In analog modulation, the modulation is applied continuously in response to the analog information signal. Common analog modulation techniques are:

- Angular modulation
- Phase modulation(PM)
- Frequency modulation (FM)
- Amplitude modulation (AM)
- Double-sideband modulation with unsuppressed carrier
- Double-sideband suppressed-carrier transmission (DSB-SC)
- Double-sideband reduced carrier transmission (DSB-RC)
- Single-sideband modulation(SSB, or SSB-AM)
- Quadrature amplitude modulation (QAM)

1.5 Digital Modulation Methods

In digital modulation, an analog carrier signal is modulated by a digital bit stream of either equal length signals or varying length signals. This can be described as a form of analog-to-digital conversion. The changes in the carrier signal are chosen from a finite number of alternative symbols (the modulation alphabet). These are the most fundamental digital modulation techniques. In the case of CW, groupings of On Off keying of varying length signals are used. In the case of PSK, a finite number of phases are used. In the case of FSK, a finite number of frequencies are used. In the case of ASK, a finite number of amplitudes are used.

In the case of QAM, as in phase signal (the I signal, for example a cosine waveform) a quadrature phase signal (the P signal, for example a sine wave) are amplitude modulated with a finite number of amplitudes. It can be seen as a two channel system. The resulting signal is a combination of PSK and ASK, with a finite number of at least two phases, and a finite number of at least two amplitudes.

Each of these phases, frequencies or amplitudes are assigned a unique pattern of binary bits. Usually, each phase, frequency or amplitude encodes an equal number of bits. This number of bits comprises the symbol that is represented by the particular phase.

If the alphabet consists of $M = 2^N$ alternative symbols, each symbol represents a message consisting of N bits. If the symbol rate (also known as the baud rate) is f_s symbols/second (or baud), the data rate is Nf_s bit/second.

For example, with an alphabet consisting of 16 alternative symbols, each symbol represents 4 bit. Thus, the data rate is four times the baud rate.

In the case of PSK, ASK and QAM, the modulation alphabet is often conveniently represented on a constellation diagram, showing the amplitude of the I signal at the x-axis, and the amplitude of the Q signal at the y-axis, for each symbol.

PSK and ASK, and sometimes also FSK, can be generated and detected using the principle of QAM. The I and Q signals can be combined into a complex valued signal called the equivalent low pass signal or equivalent base-band signal. This is a representation of the valued modulated physical signal (the so called pass band signal or RF signal). These are the general steps used by the modulator to transmit data.

Group the incoming data into code words:

1. Map the code words to attributes, for example amplitudes of the I and Q signals (the equivalent low pass signal), or frequency or phase values.
2. Adapt pulse shaping or some other filtering to limit the bandwidth and form the spectrum, typically using digital signal processing.
3. Digital-to-analog conversion (DAC) of the I and Q signals (since today all of the above is normally achieved using digital signal processing, DSP)

Sometimes the next step is also achieved using DSP, and then the DAC should be done after that.

4. Modulate the high frequency carrier waveform, resulting in that the equivalent low pass signal is frequency shifted into a modulated pass band signal or RF signal.

5. Amplification and analog band pass filtering to avoid harmonic distortion and periodic spectrum.

At the receiver, the demodulator typically performs :

- Band pass filtering
- Automatic gain control, AGC (to compensate for attenuation)
 - + Frequency shifting of the RF signal base-band I and Q signals, or to an intermediate frequency (IF) signal, or
 - + Sampling and analog-to-digital conversion (ADC) (Sometimes before the above point)
 - + Equalization filtering
 - + Detection of the amplitudes of the I and Q signals, or the frequency or phase of the IF signal;
 - + Quantization of the amplitudes, frequencies or phases to the nearest allowed values, using mapping
 - + Map the quantized amplitudes, frequencies or phases to code words (bit groups)
 - + Parallel-to-serial conversion of the code words into a bit stream
 - + Pass the resultant bit stream on for further processing such as removal of any error-correcting codes.

As is common to all digital communication systems, the design of both the modulator and demodulator must be done simultaneously. Digital modulation schemes are possible because the transmitter-receiver pair have prior knowledge of how data is encoded and represented in the communications system.

In all digital communication systems, both the modulator at the transmitter and the demodulator at the receiver are structured so that they perform inverse operations.

The most common digital modulation techniques are:

- Phase-shift keying (PSK)
- Frequency-shift keying (FSK) (see also audio frequency-shift keying)
- Amplitude-shift keying (ASK) and its most common form, (OOK)
- Quadrature amplitude modulation(QAM) a combination of PSK and
- Polar modulation like QAM a combination of PSK and ASK
- Continuous phase modulation (CPM) Minimum-shift keying (MSK)
- Gaussian minimum-shift keying (GMSK)
- Orthogonal Frequency division multiplexing (OFDM) modulation.
- Trellis coded modulation (TCM) also known as trellis modulation

MSK and GMSK are particular cases of continuous phase modulation (CPM).

Indeed, MSK is a particular case of the sub-family of CPM known as continuous-phase frequency-shift keying (CPFSK) which is defined by a rectangular frequency pulse (i.e. a linearly increasing phase pulse) of one symbol-time duration (total response signaling).

OFDM is based on the idea of Frequency Division Multiplex (FDM), but is utilized as a digital modulation scheme. The bit stream is split into several parallel data streams, each transferred over its own sub-carrier using some conventional digital modulation scheme. The sub-carriers are summarized into an OFDM symbol. OFDM is considered as a modulation technique rather than a multiplex technique, since it transfers one bit stream over one communication channel using one sequence of so-called OFDM symbols.

OFDM can be extended to multi-user channel access method in the Orthogonal Frequency Division Multiple Access (OFDMA) and MCOFDM schemes, allowing several users to share the same physical medium by giving different sub-carriers to different users.

1.6 Digital base-band Modulation or Line Coding

The term digital base-band modulation is synonymous to line codes, which are methods to transfer a digital bit stream over an analog low pass channel using a discrete number of signal levels, by modulating a pulse train (a square wave instead of a sinusoidal waveform). Common examples are unipolar, non-return-to-zero (NRZ), Manchester and alternate mark inversion (AMI) coding.

1.7 Pulse Modulation Methods

Pulse modulation schemes aim at transferring a narrowband analog signal over an analog low pass channel as a two-level quantized signal, by modulating a pulse train. Some pulse modulation schemes also allow the narrowband analog signal to be transferred as a digital signal (i.e. as a quantized discrete-time signal) with a fixed bit rate, which can be transferred over an underlying digital transmission system, for example some line code. They are not modulation schemes in the conventional sense since they are not channel coding schemes, but should be considered as source coding schemes, and in some cases analog-to-digital conversion techniques.

- Pulse-code modulation (PCM) (Analog-over-digital)
- Pulse-width modulation (PWM) (Analog-over-analog)
- Pulse-amplitude modulation (PAM) (Analog-over-analog)
- Pulse-position modulation (PPM) (Analog-over-analog)
- Pulse-density modulation (PDM) (Analog-over-analog)
- Sigma-delta modulation ($\Sigma\Delta$) (Analog-over-digital)
- Adaptive modulation

1.8 Analysis of Demodulation

Demodulation refers to the act where the modulation is stripped off from an analog signal in order to get the original base-band signal which was modulated. It is important, because the receiver system receives a modulated signal with certain characteristics and it needs to turn it to base-band.

Depending on the parameters of the base-band signal which are being transmitted in the carrier signal, there are several methods in which demodulation can be achieved. For instance- the parameters of the carrier signals are amplitude, frequencies or phase and based on any one of this a particular demodulation approach will be used.

For example, if we have a signal modulated with a lineal modulation, like AM (Amplitude Modulated), we can use a synchronous detector. On the other hand, if we have a signal modulated with an angular modulation, we must use a FM (Frequency Modulated) demodulator or a PM (Phase Modulated) demodulator respectively. There are different kinds of circuits that make these functions.

CHAPTER – 2

ANALYSIS OF QUADRATURE PHASE SHIFT KEYING (QPSK)

2.1 Phase-Shift Keying

Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases, each assigned a unique pattern of binary bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data. This requires the receiver to be able to compare the phase of the received signal to a reference signal thus erecting a system which is termed coherent.

Alternatively, instead of using the bit patterns to set the phase of the wave, it can instead be used to change it by a specified amount. The demodulator then determines the changes in the phase of the received signal rather than the phase itself. Since this scheme depends on the difference between successive phases, it is termed differential phase-shift keying (DPSK). DPSK can be significantly simpler to implement than ordinary PSK since there is no need for the demodulator to have a copy of the reference signal to determine the exact phase of the receiver signal (it is a non-coherent) scheme. In exchange, it produces

more erroneous demodulations. The exact requirements of the particular scenario under consideration determine which scheme is used.

In PSK, the constellation points chosen are usually positioned with uniform angular spacing around a circle. This gives maximum phase –separation between adjacent points and thus the best immunity to corruption. They are positioned in a circle so that they can all be transmitted with the same energy. In this way, the module of the complex numbers they represent will be the same and thus so will be the amplitudes of needed for the cosine and sine waves. Two common examples are “binary phase-shift keying” (BPSK) which uses two phases, and “quadrature phase-shift keying (QPSK)” which uses four phases, although any number of phases may be used. Since, the data to be conveyed is usually binary, the PSK scheme is usually designed with the number of constellation points being a power of 2.

For determining error rates mathematically, some definitions will be needed:

- E_b = Energy –per- bit
- E_s = Energy – per –symbol = kE_b with k bits per symbol
- T_b = Bit duration
- T_s = Symbol duration
- $N_0/2$ = Noise power spectral density (W/Hz)
- P_s = Probability of symbol – error

$Q(x)$ will give the probability that single sample taken from a random process with zero-mean and unit – variance Gaussian probability density function will be greater or equal to x . It is a scaled form of the complementary Gaussian error function

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{t^2}{2}} dt = 1/2 \operatorname{erfc} \left(\frac{x}{\sqrt{2}} \right), x \geq 0 \quad (2.1)$$

The error rates quoted here are those in additive white Gaussian (AWGN). These error rates are lower than those computed in fading channels, hence are a good theoretical benchmark to compare with,

2.2 Binary Phase-Shift Keying (BPSK)

BPSK is the simplest form of PSK. It uses two phases which are represented by 180 degrees and so can also be termed 2 – PSK. It does not particularly matter exactly where the constellation points are positioned, and in this figure they are shown on the real axis at 0 degrees and 180 degrees. This modulation is the most robust of all the PSKs since it takes serious distortion to make the demodulator reach an incorrect decision. It is, however only able to modulate at 1 bit/symbol (as seen in the figure) and is so suitable for high data-rate applications when bandwidth is limited.

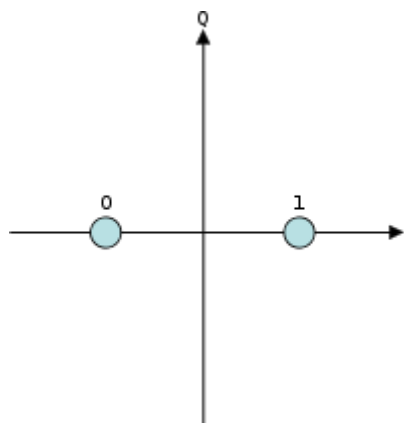


Fig 2.1 Constellation diagram for BPSK

The bit error rate (BER) of BPSK in AWGN can be calculated as:

$$P_b = Q\left(\frac{\sqrt{2E_b}}{\sqrt{N_0}}\right) \quad (2.2)$$

Since there is only one bit per symbol, this is also the symbol error rate.

In the presence of an arbitrary phase-shift introduced by the communications channel, the demodulator is unable to tell which constellation point is which. As a result, the data is often differentially encoded prior to modulation.

2.2.1 Implementation

Binary data is often conveyed with the following signals:

$$s_0(t) = \frac{\sqrt{2E_b}}{\sqrt{T_b}} \cos(2\pi f_c t + \pi) = -\frac{\sqrt{2E_b}}{\sqrt{T_b}} \cos(2\pi f_c t) \quad (2.3)$$

for binary "0"

$$s_1(t) = \frac{\sqrt{2E_b}}{\sqrt{T_b}} \cos(2\pi f_c t) \quad (2.4)$$

for binary "1"

where f_c is the frequency of the carrier wave. Hence, the signal-space can be represented by the single basis function:

$$\phi(t) = \frac{\sqrt{2}}{\sqrt{T_b}} \cos(2\pi f_c t) \quad (2.5)$$

where 1 is represented by $\sqrt{E_b} \phi(t)$ and 0 is represented by $-\sqrt{E_b} \phi(t)$. This assignment is, of course, arbitrary.

2.3 QPSK Demodulation

The proof of how phase modulation, and hence QPSK, is demodulated is shown below. The proof begins by defining Euler's relations, from which all the trigonometric identities can be derived. Euler's relations state the following:

$$\sin \omega t = \frac{e^{j\omega t}}{2j} - \frac{e^{-j\omega t}}{2j} \qquad \cos \omega t = \frac{e^{j\omega t}}{2} + \frac{e^{-j\omega t}}{2} \qquad (2.6)$$

Now considering the multiplication of two sine waves together, thus:

$$\begin{aligned} \sin^2 \omega t &= \left(\frac{e^{j\omega t}}{2j} - \frac{e^{-j\omega t}}{2j} \right) \times \left(\frac{e^{j\omega t}}{2j} - \frac{e^{-j\omega t}}{2j} \right) = \frac{e^{2j\omega t} - 2e^0 + e^{-2j\omega t}}{-4} \\ &= \frac{1}{2} - \frac{1}{2} \cos 2\omega t \qquad (2.7) \end{aligned}$$

From equation 2.7, it can be seen that multiplying two sine waves together (one sine being the incoming signal while the other being the local oscillator at the receiver mixer) results in an output frequency $\frac{1}{2} \cos 2\omega t$ double that of the input (at half the amplitude) superimposed on a dc offset of half the input amplitude.

Similarly, multiplying $\sin \omega t$ by $\cos \omega t$ gives :

$$\begin{aligned} \sin \omega t \cdot \cos \omega t &= \frac{e^{2j\omega t} - e^{-2j\omega t}}{4j} \\ &= \frac{1}{2} \sin 2\omega t \qquad (2.8) \end{aligned}$$

which gives an output frequency $\sin 2\omega t$ double that of the input, with no dc offset. It is now fair to make the assumption that multiplying $\sin\omega t$ by any phase-shifted sine wave ($\sin\omega t + \varphi$) yields a demodulated waveform with an output frequency double that of the input frequency, whose dc offset varies according to the phase shift, φ .

To prove this,

$$\begin{aligned} \sin \omega t \cdot \sin(\omega t + \varphi) &= \frac{e^{j\omega t} - e^{-j\omega t}}{2j} \times \frac{e^{j(\omega t + \varphi)} - e^{-j(\omega t + \varphi)}}{2j} \\ &= \frac{e^{j(2\omega t + \varphi)} - e^{j(\omega t - \omega t - \varphi)} + e^{j(\omega t + \varphi - \omega t)} + e^{-j(2\omega t + \varphi)}}{-4} \\ &= \frac{\cos(2\omega t + \varphi)}{-2} - \frac{e^{j\varphi} + e^{-j\varphi}}{-4} \\ &= \frac{\cos(2\omega t + \varphi)}{-2} + \frac{\cos \varphi}{2} \\ &= \frac{\cos \varphi}{2} - \frac{\cos(2\omega t + \varphi)}{2} \end{aligned}$$

Thus, the above proves the supposition that the phase shift on a carrier can be demodulated into a varying output voltage by multiplying the carrier with a sine-wave local oscillator and filtering out high-frequency term. Unfortunately, the phase shift is limited to two quadrants; a phase shift of $\frac{\pi}{2}$ cannot be distinguished from a phase shift of $-\frac{\pi}{2}$. Therefore, to accurately decode phase shifts present in all four quadrants, the input signal needs to be multiplied by both sinusoidal and co-sinusoidal waveforms, the high frequency filtered out, and the data reconstructed.

$$\begin{aligned} \cos\omega t \cdot \sin(\omega t + \varphi) &= \frac{e^{j\omega t} + e^{-j\omega t}}{2} \cdot \frac{e^{j(\omega t + \varphi)} - e^{-j(\omega t + \varphi)}}{2j} \\ &= \frac{e^{j(2\omega t + \varphi)} - e^{j(-\varphi)} + e^{j(\varphi)} - e^{-j(2\omega t + \varphi)}}{4j} \end{aligned}$$

$$\begin{aligned}
 &= \frac{\sin(2\omega t + \varphi)}{2} + \frac{e^{j\varphi} - e^{-j\varphi}}{4j} \\
 &= \frac{\sin(2\omega t + \varphi)}{2} + \frac{\sin\varphi}{2}
 \end{aligned} \tag{2.9}$$

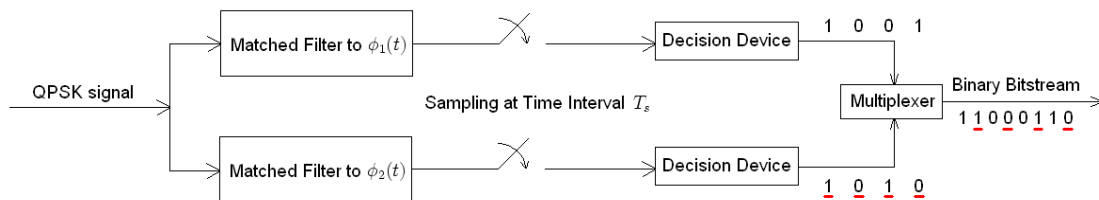


Fig. 2.2 Block diagram of QPSK demodulator

The matched filters can be replaced with correlations. Each detection device uses a reference threshold value to determine whether a 1 or 0 is detected.

2.4 QPSK Signal In The Time Domain

The modulated signal is shown below for a short segment of a random binary data-stream. The two carrier waves are a cosine wave and a sine wave, as indicated by the signal-space analysis above. Here, the odd-numbered bits have been assigned to the in-phase component and the even-numbered bits to the quadrature component (taking the first bit as number 1). The total signal — the sum of the two components — is shown at the bottom. Jumps in phase can be seen as the PSK changes the phase on each component at the start of each bit-period. The topmost waveform alone matches the description given for BPSK.

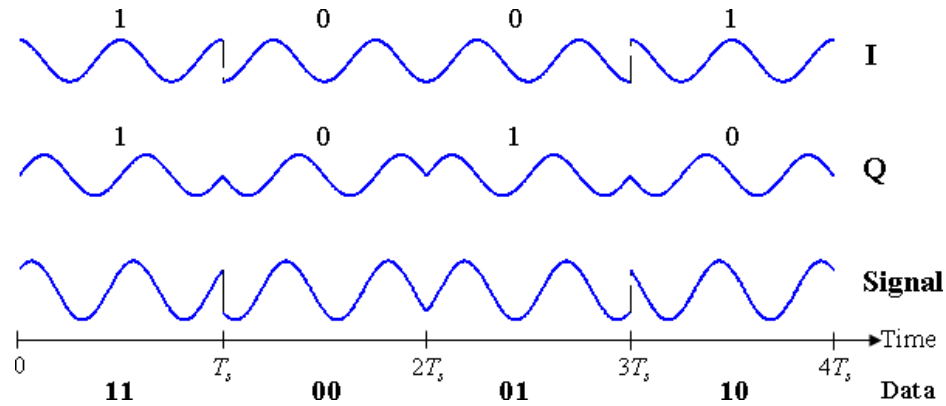


Fig.2.3 Timing diagram for QPSK

The binary data stream is shown beneath the time axis. The two signal components with their bit assignments are shown 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: 1 1 0 0 0 1 1 0.

- The odd bits, highlighted here, contribute to the in-phase component: **1 1 0 0 0 1 1 0**
- The even bits, highlighted here, contribute to the quadrature-phase component: 1 **1** 0 **0** 0 **1** 1 **0**

2.5 Offset QPSK (OQPSK)

Offset quadrature phase-shift keying (OQPSK) is a variant of phase-shift keying modulation using 4 different values of the phase to transmit. It is sometimes called Staggered quadrature phase-shift keying (SQPSK).

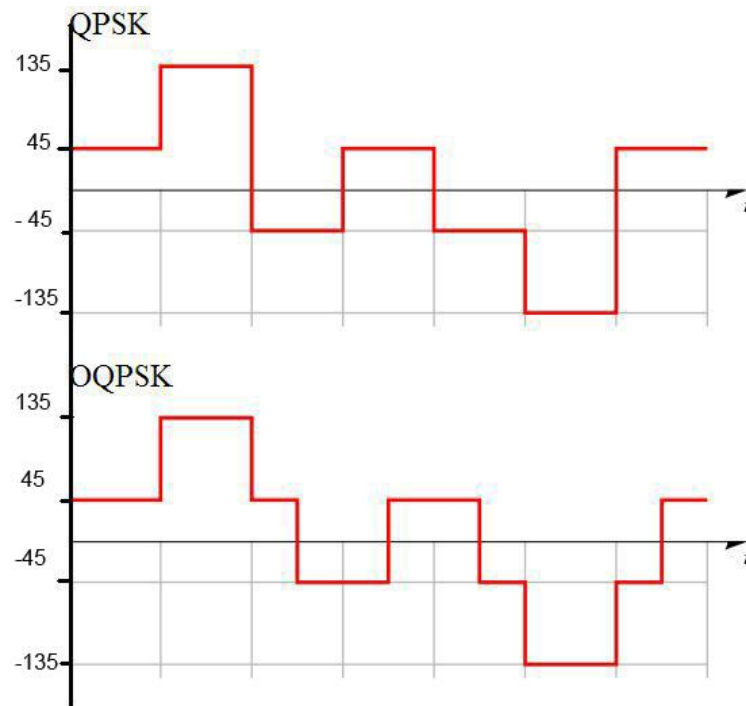


Fig.2.4 Difference of the phase between QPSK and OQPSK

Taking four values of the phase (two bits) at a time to construct a QPSK symbol can allow the phase of the signal to jump by as much as 180° at a time. When the signal is low-pass filtered (as is typical in a transmitter), these phase-shifts result in large amplitude fluctuations, an undesirable quality in communication systems. By offsetting the timing of the odd and even bits by one bit-period, or half a symbol-period, the in-phase and quadrature components will never change at the same time. In the constellation diagram shown on the right, it can be seen that this will limit the phase-shift to no more than 90° at a time. This yields much lower amplitude fluctuations than non-offset QPSK and is sometimes preferred in practice.

The picture above shows the difference in the behavior of the phase between ordinary QPSK and OQPSK. It can be seen that in the first plot the

phase can change by 180° at once, while in OQPSK the changes are never greater than 90° .

The modulated signal is shown below for a short segment of a random binary data-stream. Note the half symbol-period offset between the two component waves. The sudden phase-shifts occur about twice as often as for QPSK (since the signals no longer change together), but they are less severe. In other words, the magnitude of jumps is smaller in OQPSK when compared to QPSK.

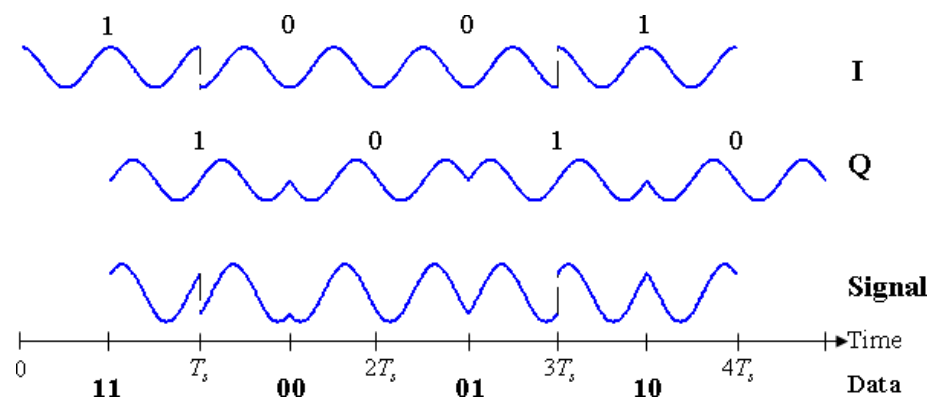


Fig.2.5 Timing diagram for OQPSK

The binary data stream is shown beneath the time axis. The two signal components with their bit assignments are shown the top and the total, combined signal at the bottom. Note the half-period offset between the two signal components.

2.6 $\pi/4$ QPSK

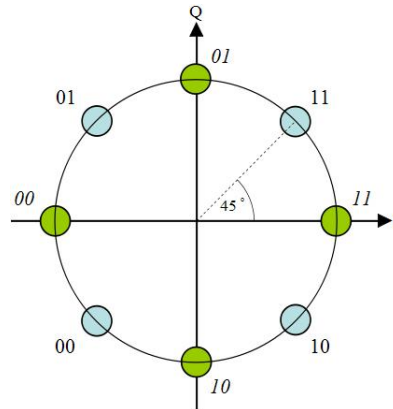


Fig.2.6 Dual constellation diagram for $\pi/4$ -QPSK

This shows the two separate constellations with identical Gray coding but rotated by 45° with respect to each other.

This final variant of QPSK uses two identical constellations which are rotated by 45° ($\pi/4$ radians, hence the name) with respect to one another. Usually, either the even or odd symbols are used to select points from one of the constellations and the other symbols select points from the other constellation. This also reduces the phase-shifts from a maximum of 180° , but only to a maximum of 135° and so the amplitude fluctuations of $\pi/4$ -QPSK are between OQPSK and non-offset QPSK.

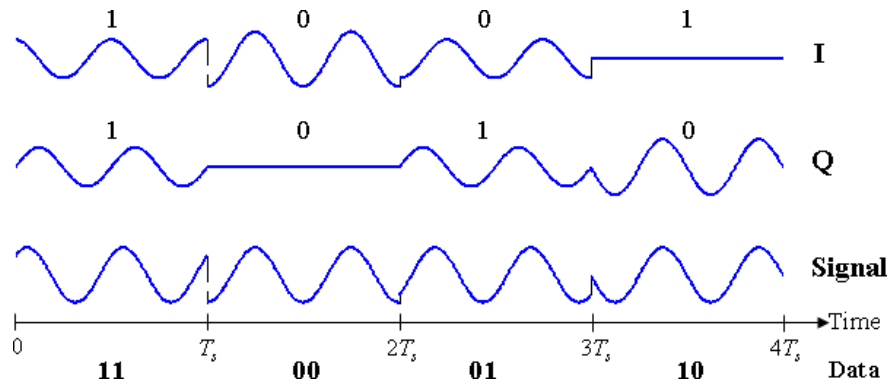


Fig.2.7 Timing Diagram for $\pi/4$ -QPSK

The binary data stream is shown beneath the time axis. The two signal components with their bit assignments are shown the top and the total, combined signal at the bottom. Note that successive symbols are taken alternately from the two constellations, starting with the 'blue' one.

2.7 Higher-Order PSK

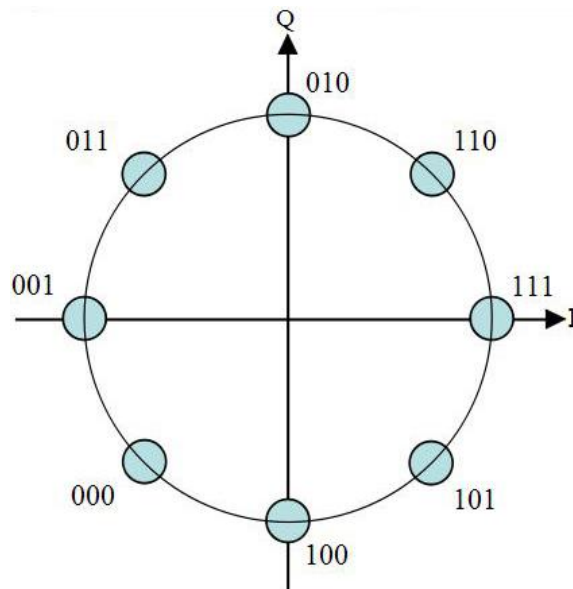


Fig. 2.8 Constellation diagram for 8-PSK with Gray coding

Any number of phases may be used to construct a PSK constellation but 8-PSK is usually the highest order PSK constellation deployed. With more than 8 phases, the error-rate becomes too high and there are better, though more complex, modulations available such as quadrature amplitude modulation (QAM). Although any number of phases may be used, the fact that the constellation must usually deal with binary data means that the number of symbols is usually a power of 2 — this allows an equal number of bits-per-symbol.

For the general M-PSK there is no simple expression for the symbol-error probability if $M > 4$. Unfortunately, it can only be obtained from:

$$P_s = 1 - \int_{-\pi/M}^{\pi/M} p_{\theta_r}(\theta_r) d\theta_r \quad (2.10)$$

Where,

$$p_{\theta_r}(\theta_r) = \frac{1}{2\pi} e^{-2\gamma_s \sin^2 \theta_r} \int_0^{\infty} V e^{-(V - \sqrt{4\gamma_s} \cos \theta_r)^2 / 2}$$

$$V = \sqrt{r_1^2} + \sqrt{r_2^2}$$

$$\theta_r = \tan^{-1}(r_2/r_1)$$

$$\gamma_s = E_s/N_0$$

$r_1 \sim N\left(\sqrt{E_s}, \frac{N_0}{2}\right)$ and $r_2 \sim N\left(0, \frac{N_0}{2}\right)$ are jointly – Gaussian random variables

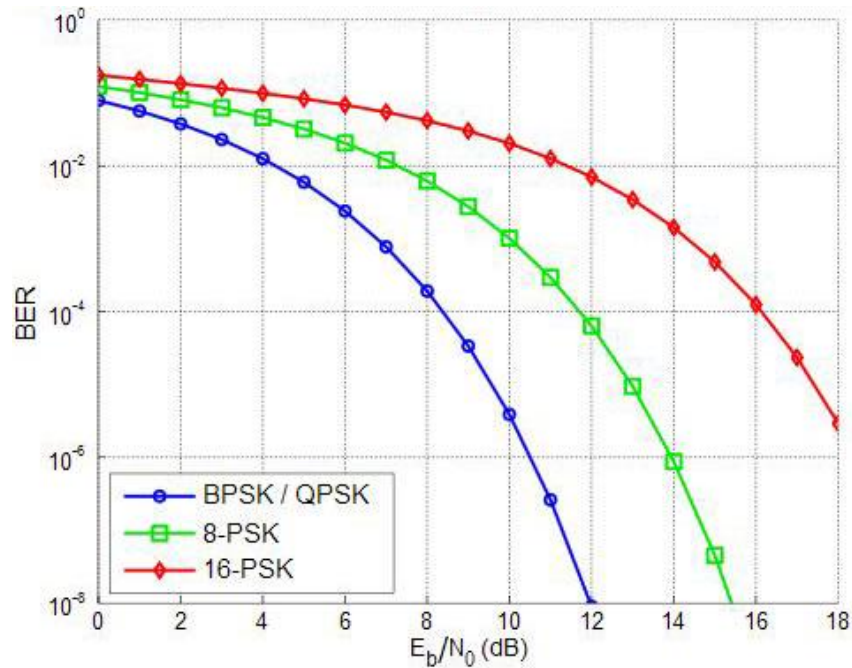


Fig.2.9 Bit error rate curves for BPSK, QPSK,8-PSK and 16-PSK

This may be approximated for high M and high E_b/N_0 by:

$$P_s \approx 2Q\left(\frac{\sqrt{2\gamma_s} \sin\pi}{M}\right) \quad (2.11)$$

The bit-error probability for M -PSK can only be determined exactly once the bit-mapping is known. However, when Gray coding is used, the most probable error from one symbol to the next produces only a single bit-error and

$$P_b \approx \frac{1}{k} P_s \quad (2.12)$$

The BER graph compares the bit-error rates of BPSK, QPSK (which are the same), 8-PSK and 16-PSK. It is seen that higher-order modulations exhibit higher error-rates; in exchange however they deliver a higher raw data-rate. Bounds on the error rates of various digital modulation schemes can be computed with application of the union bound to the signal constellation.

2.8 Differential Encoding

Differential phase shift keying (DPSK) is a common form of phase modulation that conveys data by changing the phase of the carrier wave. As mentioned for BPSK and QPSK there is an ambiguity of phase if the constellation is rotated by some effect in the communications channel through which the signal passes. This problem can be overcome by using the data to change rather than set the phase.

For example, in differentially-encoded BPSK a binary '1' may be transmitted by adding 180° to the current phase and a binary '0' by adding 0° to the current phase. In differentially-encoded QPSK, the phase-shifts are 0° , 90° , 180° , -90° corresponding to data '00', '01', '11', '10'. This kind of encoding may be demodulated in the same way as for non-differential PSK but the phase ambiguities can be ignored. Thus, each received symbol is demodulated to one of the M points in the constellation and a comparator then computes the difference in phase between this received signal and the preceding one. The difference encodes the data as described above

The modulated signal is shown below for both DBPSK and DQPSK as described above. In the figure, it is assumed that the signal starts with zero phase, and so there is a phase shift in both signals at $t = 0$.

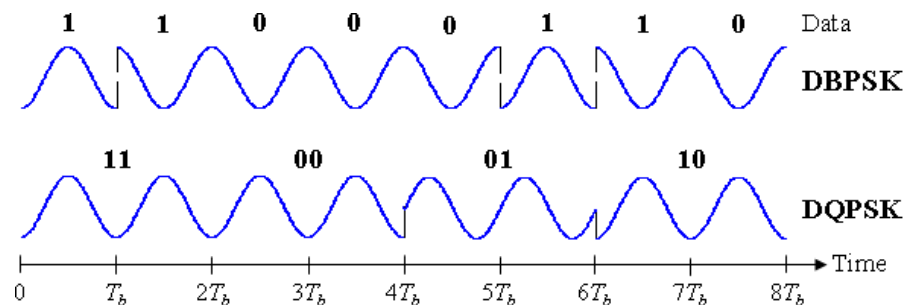


Fig.2.10 Timing diagram for DBPSK AND DQPSK

The binary data stream is above the DBPSK signal. The individual bits of the DBPSK signal are grouped into pairs for the DQPSK signal, which only changes every $T_s = 2T_b$.

Analysis shows that differential encoding approximately doubles the error rate compared to ordinary M-PSK but this may be overcome by only a small increase in E_b/N_0 . Furthermore, this analysis (and the graphical results below) are based on a system in which the only corruption is additive white Gaussian noise(AWGN). However, there will also be a physical channel between the transmitter and receiver in the communication system. This channel will, in general, introduce an unknown phase-shift to the PSK signal; in these cases the differential schemes can yield a better error-rate than the ordinary schemes which rely on precise phase information.

2.9 Differentially Encoded BPSK

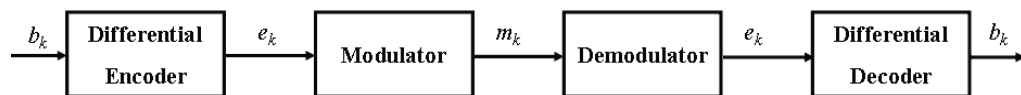


Fig.2.11 Differential encoding decoding system diagram

At the k^{th} time-slot call the bit to be modulated b_k , the differentially-encoded bit e_k and the resulting modulated signal $m_k(t)$. Assume that the constellation diagram positions the symbols at ± 1 (which is BPSK). The differential encoder produces

$$e_k = e_{k-1} \oplus b_k$$

where \oplus indicates binary or modulo-2 addition

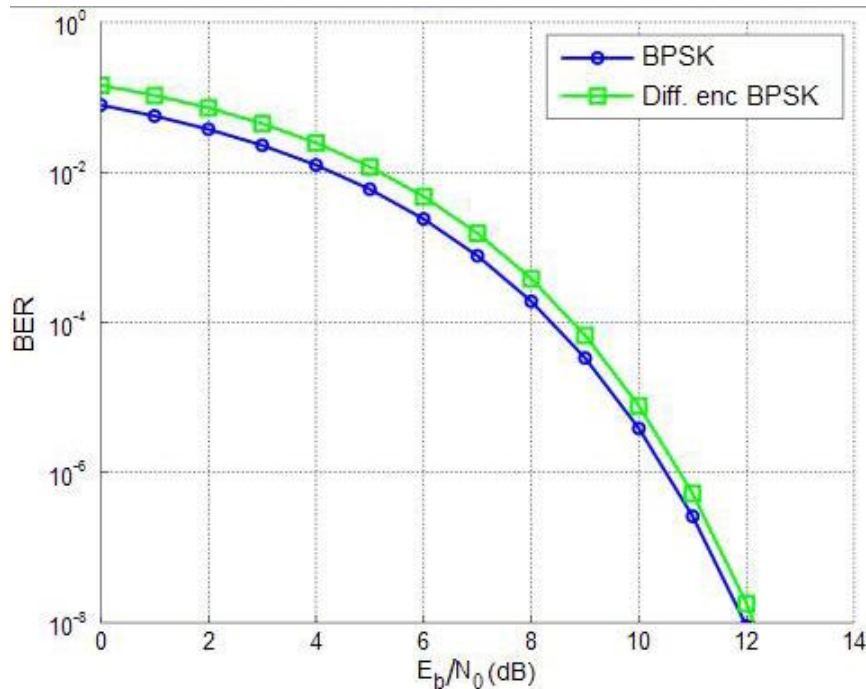


Fig.2.12 BER comparisons between BPSK and DBPSK with gray coding

So e_k only changes state (from binary '0' to binary '1' or from binary '1' to binary '0') if b_k is a binary '1'. Otherwise it remains in its previous state. This is the description of differentially-encoded BPSK shown earlier. The received signal is demodulated to yield $e_k = \pm 1$ and then the differential decoder reverses the encoding procedure and produces:

$$b_k = e_k \oplus e_{k-1}$$

Since binary subtraction is the same as binary addition. Therefore, $b_k=1$ if e_k and e_{k-1} differ and $b_k = 0$ if they are the same. Hence, if both e_k and e_{k-1} are inverted, b_k will still be decoded correctly. Thus, the 180° phase ambiguity does not matter. Differential schemes for other PSK modulations may be devised along similar lines. The waveforms for DPSK are the same as for differentially – encoded PSK given above since the only change between the two schemes is at the receiver. The BER curve for this example is compared to ordinary BPSK. As mentioned earlier, whilst the error-rate is approximately doubled, the increase needed in E_b/N_0 to overcome this is small. The performance degradation is a

result of non-coherent transmission – in this case it refers to the fact that tracking of the phase is completely ignored.

2.10 Differential Phase-Shift Keying

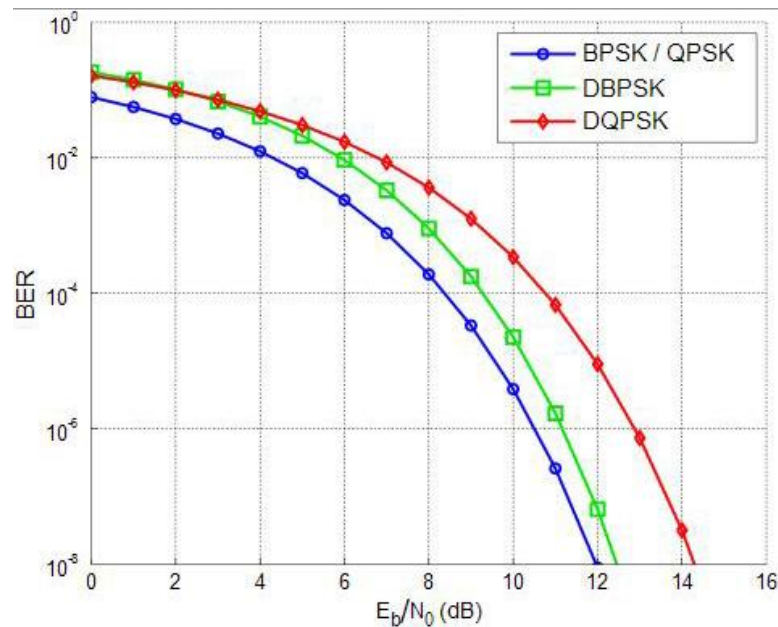


Fig. 2.13 BER comparison between DBPSK, DQPSK and their non-differential forms using gray-coding and operating in white noise

For a signal that has been differentially encoded, there is an obvious alternative method of demodulation. Instead of demodulating as usual and ignoring carrier-phase ambiguity, the phase between two successive received symbols is compared and used to determine what the data must have been. When differential encoding is used in this manner, the scheme is known as differential phase-shift keying (DPSK). Note that this is subtly different to just differentially-encoded PSK since, upon reception, the received symbols are not

decoded one-by-one to constellation points but are instead compared directly to one another.

Calling the received symbol in the k^{th} timeslot r_k and let it have phase φ_k . Assume without loss of generality that the phase of the carrier wave is zero. Denoting the AWGN term as n_k . Then

$$r_k = \sqrt{E_s} e^{j\varphi_k} + n_k \quad (2.13)$$

The decision variable for the $(k-1)^{\text{th}}$ symbol and the k^{th} symbol is the phase difference between r_k and r_{k-1} . That is projected onto r_{k-1} , the decision is taken on the phase of the resultant complex number.

$$r_k r_{k-1}^* = E_s e^{j(\theta_k - \theta_{k-1})} + \sqrt{E_s} e^{j\theta_k} n_{k-1}^* + \sqrt{E_s} e^{-j\theta_{k-1}} n_k + n_k n_{k-1} \quad (2.14)$$

where superscript * denotes complex conjugation. In the absence of noise, the phase of this is $\theta_k - \theta_{k-1}$, the phase shift between two receiver signals which can be used to determine the data transmitted. The probability of error for DPSK is difficult to calculate in general, but in the case of DBPSK it is :

$$P_b = \frac{1}{2} e^{-\frac{E_b}{N_0}} \quad (2.15)$$

which, when numerically evaluated, is only slightly worse than ordinary BPSK, particularly at higher E_b/N_0 values. Using DPSK avoids the need for possibly complex carrier-recovery schemes to provide an accurate phase estimate and can be an attractive alternative to ordinary PSK.

In optical communications, the data can be modulated onto the phase of a laser in a differential way. The modulation is a laser which emits a continuous wave, and a Mach-Zehnder modulator which receives electrical binary data. For the case of BPSK for example, the laser transmits the field unchanged for binary '1', and with reverse polarity for '0'. The demodulator consists of a delay line interferometer which delays one bit, so two bits can be compared at one time. In further processing, a photo diode is used to transform the optical field into an electric current, so the information is changed back into its original state.

The bit-error rates of DBPSK and DQPSK are compared to their non-differential counterparts in the graph to the right. The loss for using DBPSK is small enough compared to the complexity reduction that it is often used in communications systems that would otherwise use BPSK. For DQPSK though, the loss in performance compared to ordinary QPSK is larger and the system designer must balance this against the reduction in complexity.

CHAPTER 3

IMPLEMENTATION OF QPSK DEMODULATOR

3.1 QPSK Demodulator

It might appear the QPSK offers advantages over ASK, PSK and FSK. However, the demodulation of these signals requires various degrees of difficulty and hence expense. The method of demodulation is an important factor in determining the selection of a modulation scheme. There are two types of demodulation which are distinguished by the need to provide knowledge of the phase of the carrier. Demodulation scheme requiring the carrier phase are termed coherent. Those that do not need the phase are Non-coherent. Non-coherent modulation is expensive and performs poorly. Coherent modulation requires more complex circuitry, but has better performance.

The demodulator of QPSK is quite complex. In our project, we have used coherent detection for obtaining the original data signal. Fig. 3.1 shows the basic blocks for a practical QPSK demodulator.

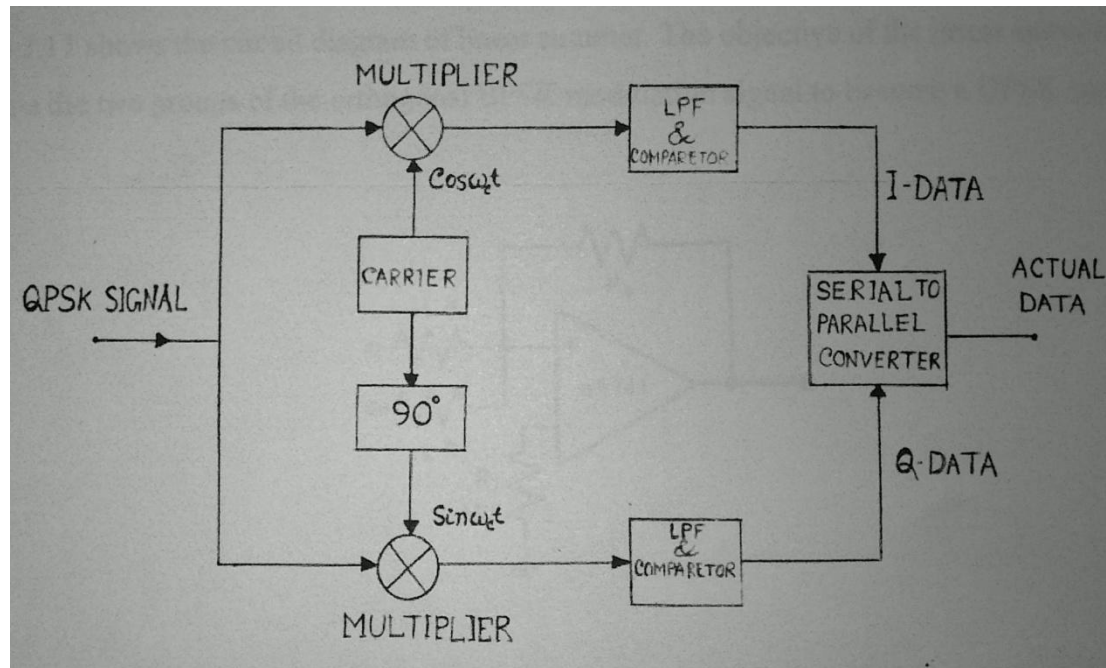


Fig.3.1 Basic demodulator block diagram

In coherent detection, the carrier has to be recovered from the QPSK signal. Then the QPSK signal is multiplied with two carriers. By multiplying the cosine carrier with QPSK modulated data, we can get the raw I-data. Similarly, by multiplying the sine carrier with QPSK modulated data, we can get the raw Q-data. These raw data are then passed through low pass filter and through a comparator to get well shaped data. Then the I-data and Q-data can be found. The parallel I-data and Q-data are then converted to serial data to achieve the actual signal.

3.1.1 Multiplier for QPSK demodulator

In a coherent detection system, multiplier has great significance. It is the prerequisite to obtain raw data from the modulated signal. A lot of ICs may be

used for the purpose of multiplication. We have used LM1596 to multiply the QPSK signal with sine and cosine carriers.

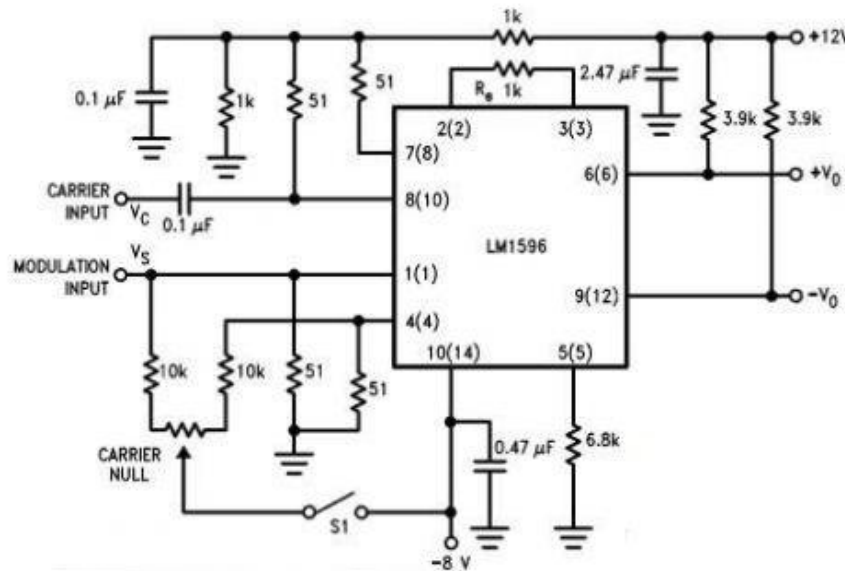


Fig. 3.2 Balance Modulator

3.1.2 Low pass filter

Low pass filter is another essential part of a demodulator. In coherent detection it plays a vital role. A low pass filter is an RC tuned circuit which allows certain frequencies to pass through. For the filter circuit, variable resistor can be used for the variability of the filter circuit. After passing through the diode, the raw data are given to the filter circuit. The basic equation of a low pass filter is shown below:

$$f_{oh} = \frac{1}{2\pi RC} \quad (3.1)$$

and the gain of the filter is

$$A_v = 1 + R_f/R_g \quad (3.2)$$

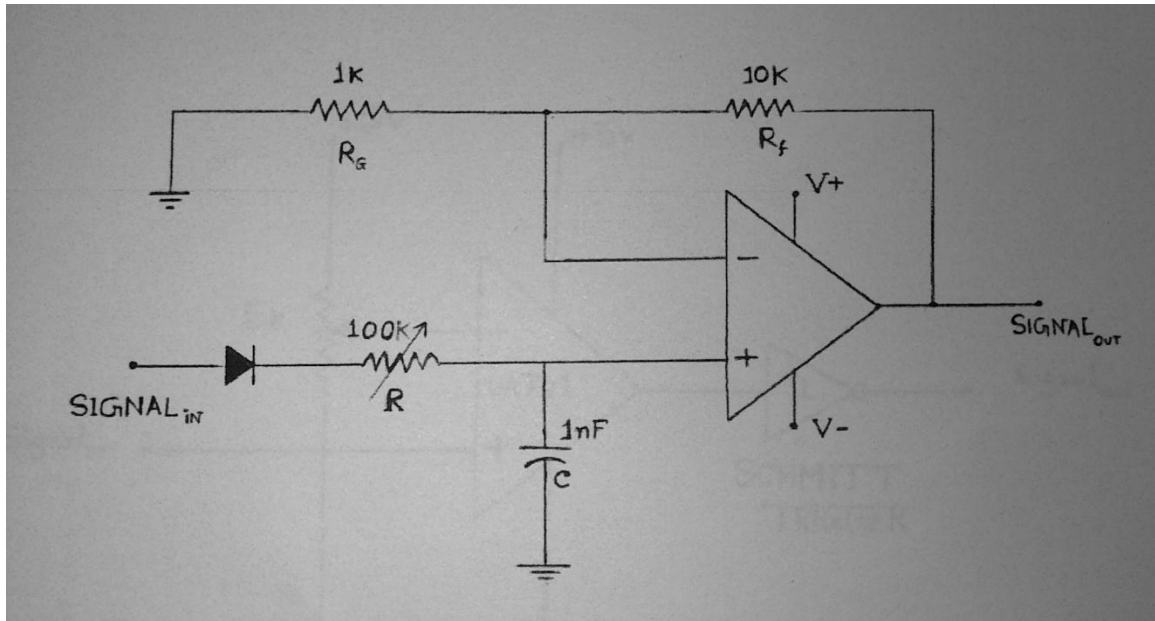


Fig.3.3 Low pass filter

3.1.3 Pulse shaper

After passing through the LPF, the signal is obtained having certain voltage levels varying with the phase. To make it TTL comparable, the data is passed through a comparator. A uA741 is used as a comparator and certain levels are set by changing the reference voltage given to the negative pin of uA741.

The output of uA741 is passed through a Schmitt Trigger to get well shaped data with no slope at the transition period. A 7414 is used for this purpose.

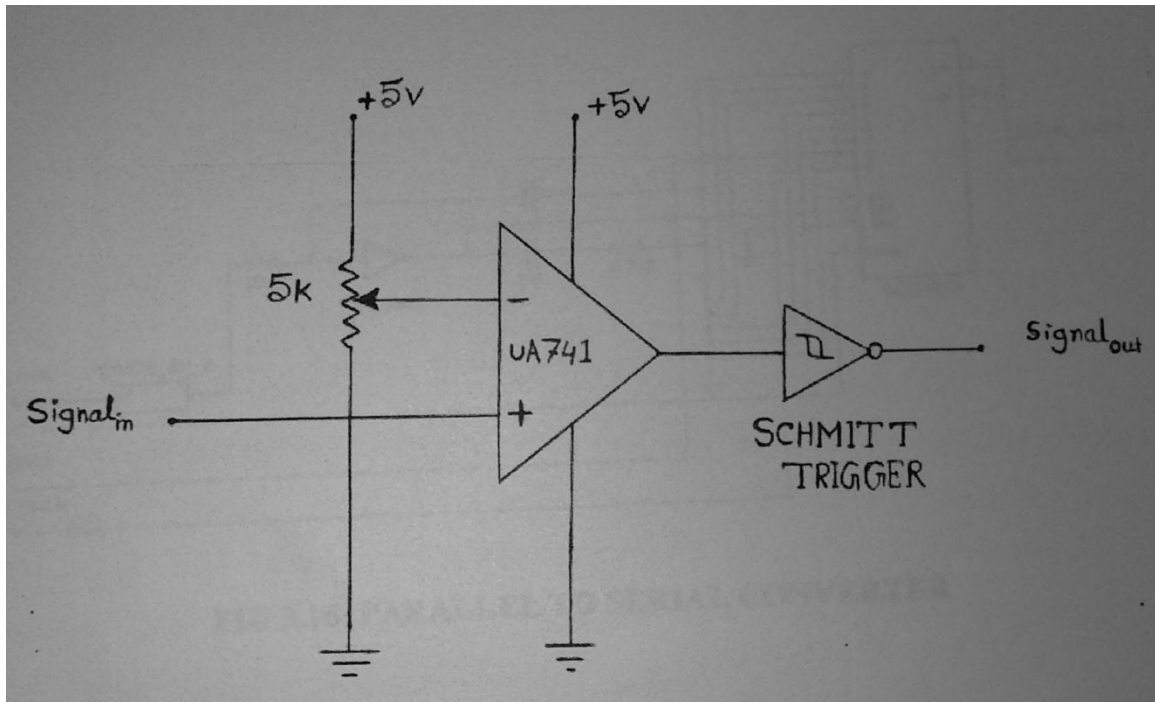


Fig.3.4 Voltage comparator and Schmitt Trigger

3.1.4 Parallel to serial converter

After getting the parallel I-data and Q-data, it is combined in order to get the actual data. For this reason, we use shift register (IC-74165) as a parallel to serial converter. The clock pulse recovered from the QPSK signal is needed here. A frequency divider is also needed (divide by 2) which can be made by a counter IC-74390.

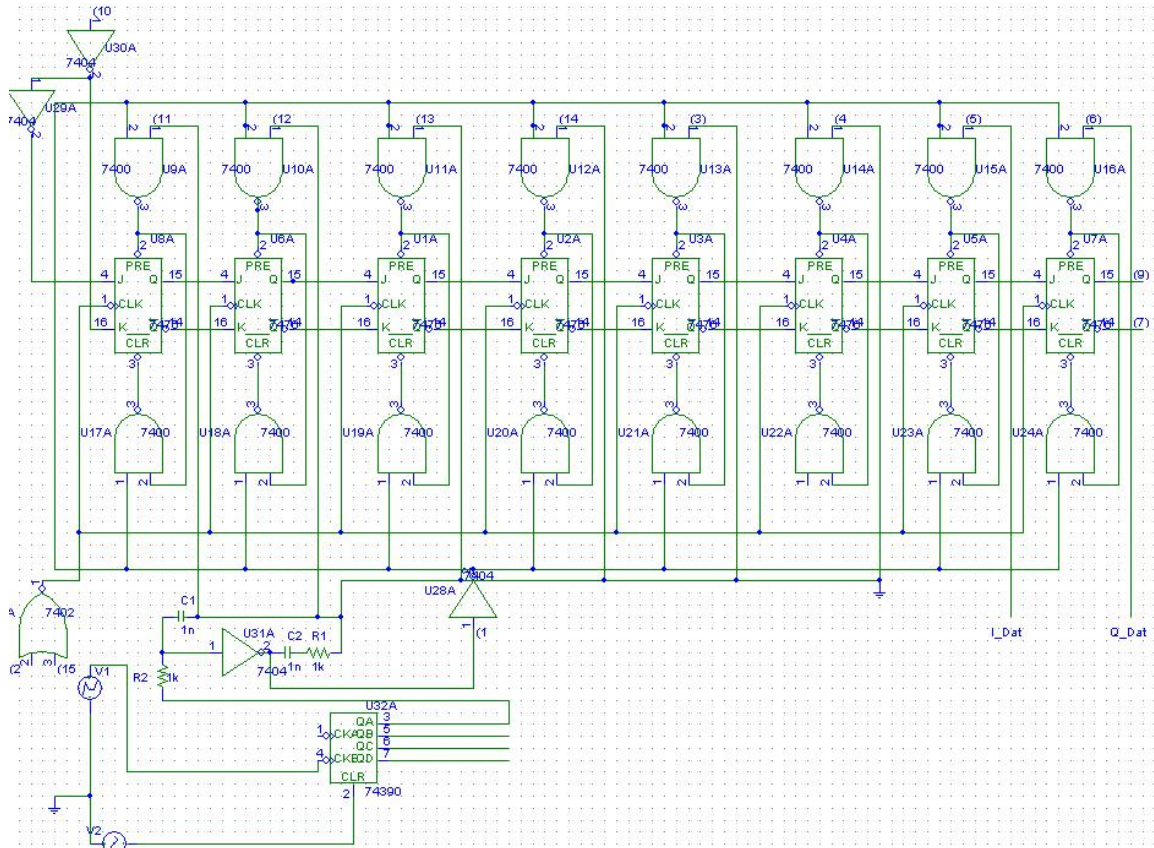


Fig.3.5 Parallel to serial converter

3.2 Experimental Circuit Diagram

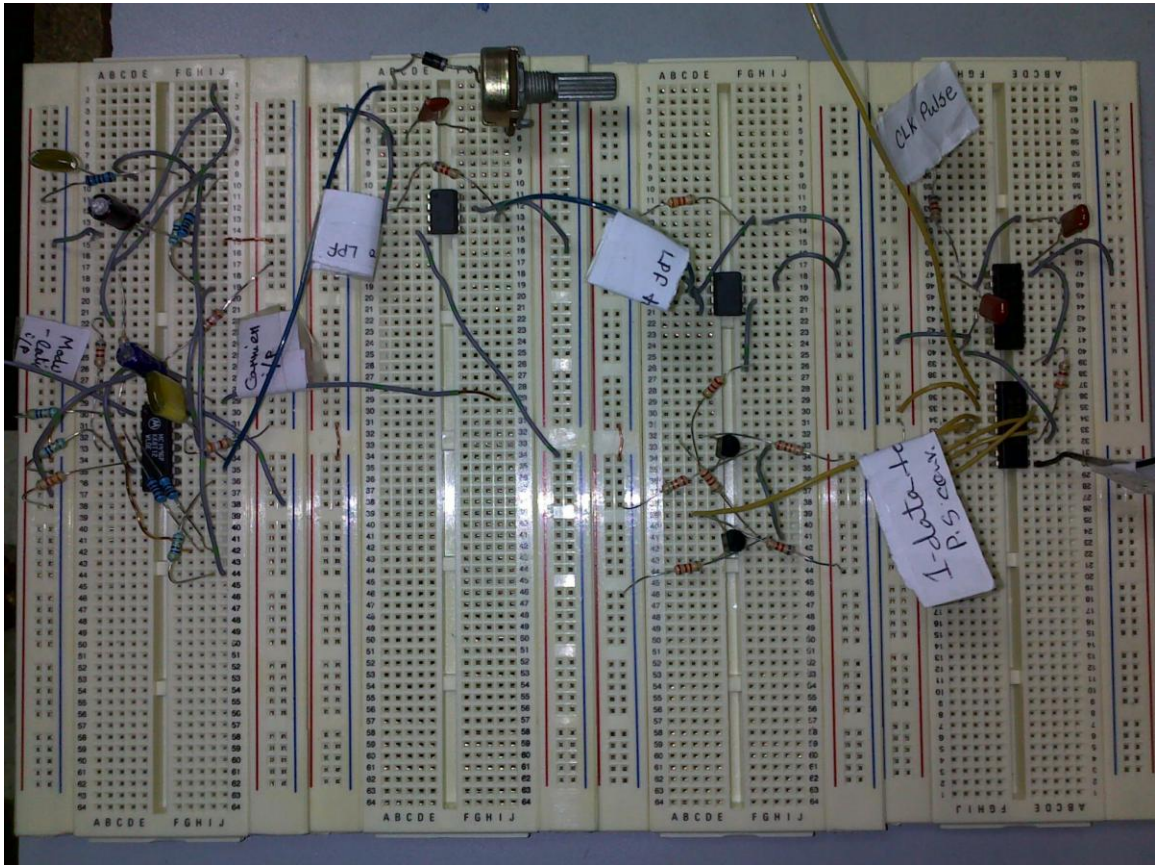


Fig.3.6 QPSK demodulator

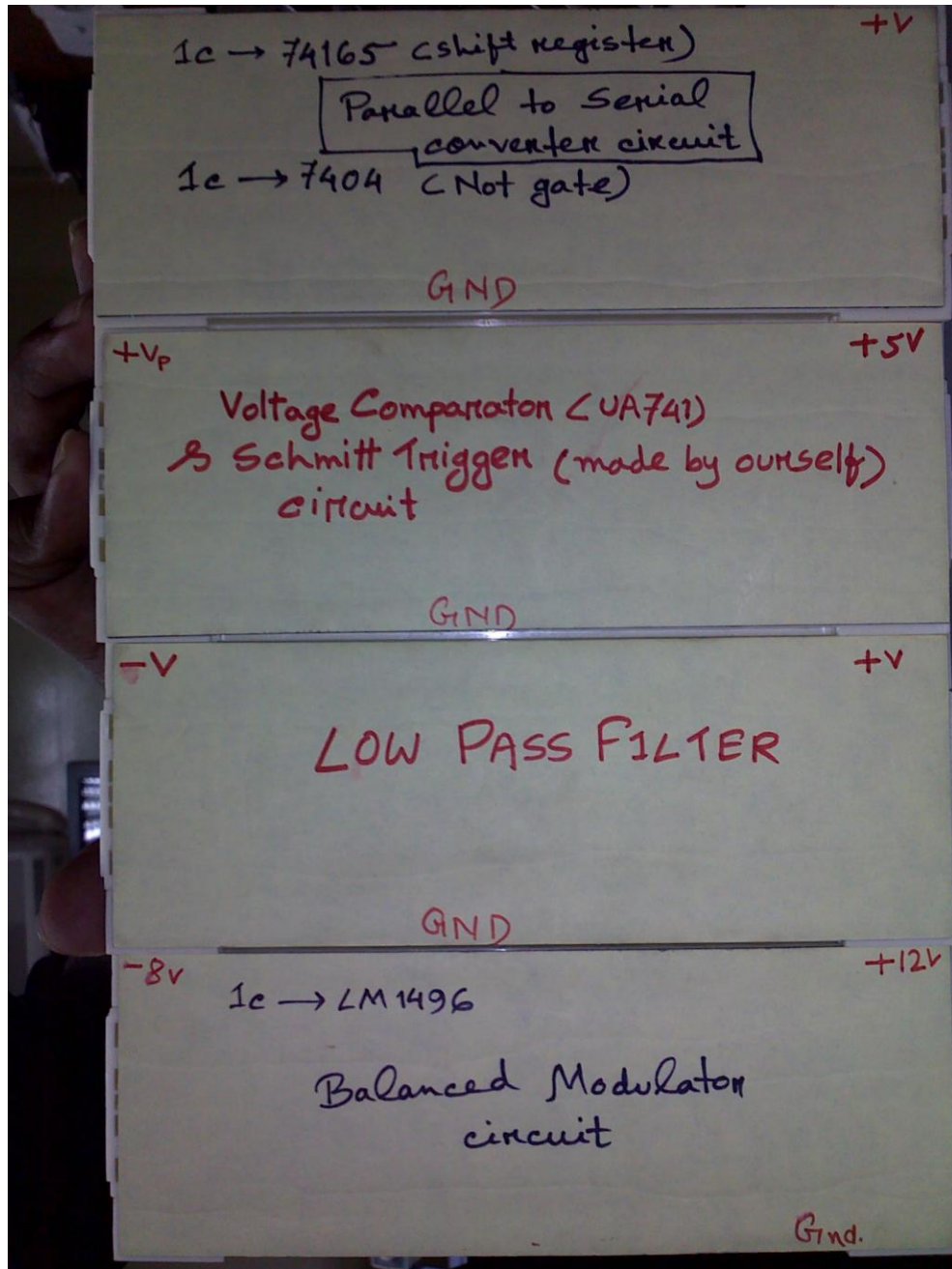


Fig.3.7 QPSK demodulator (backend labeled)

3.3 Experimental Wave Shapes

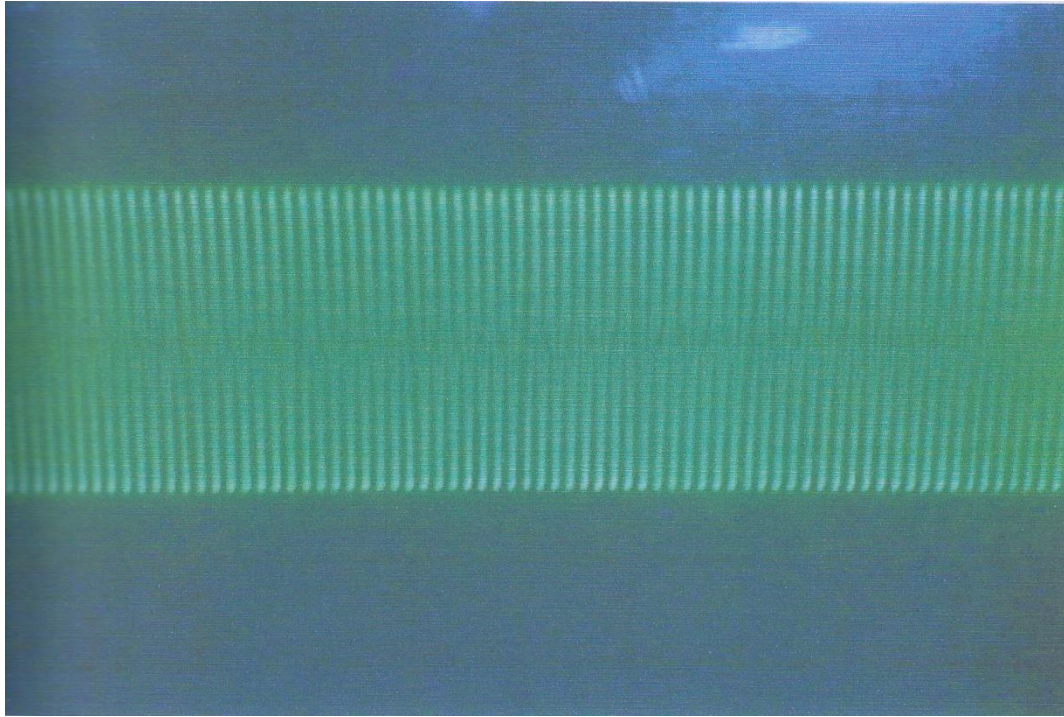


Fig.3.8 Carrier (sine wave)

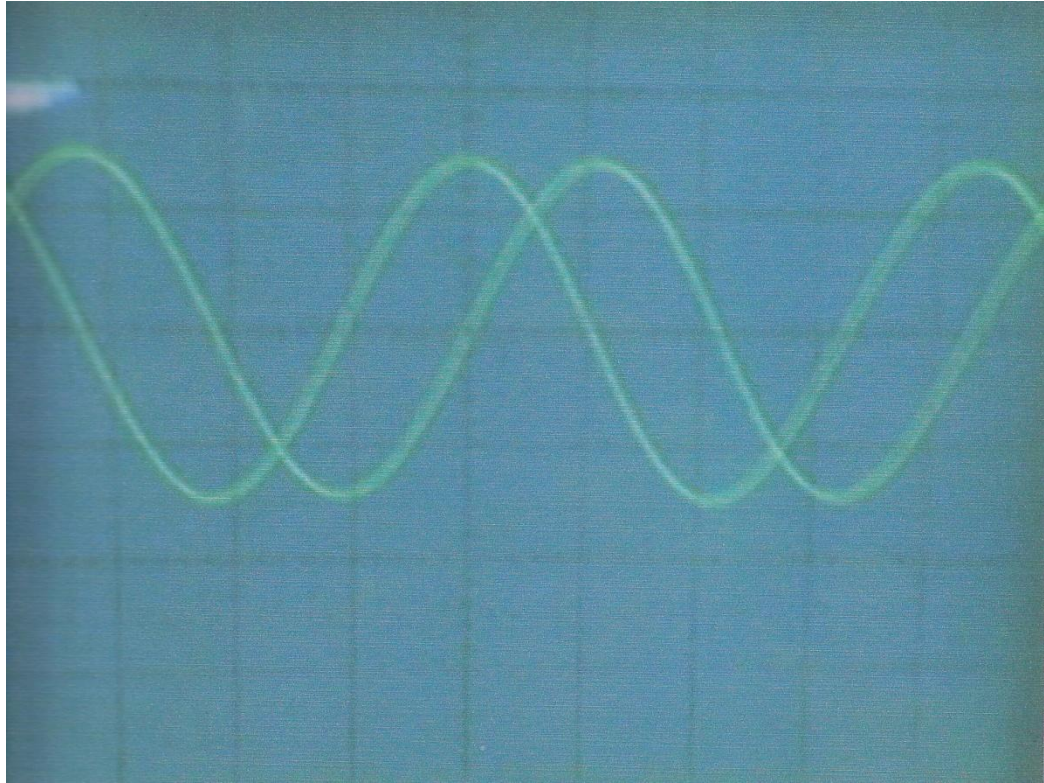


Fig.3.9 Sine wave and 90 degree shifted sine wave (cosine wave)

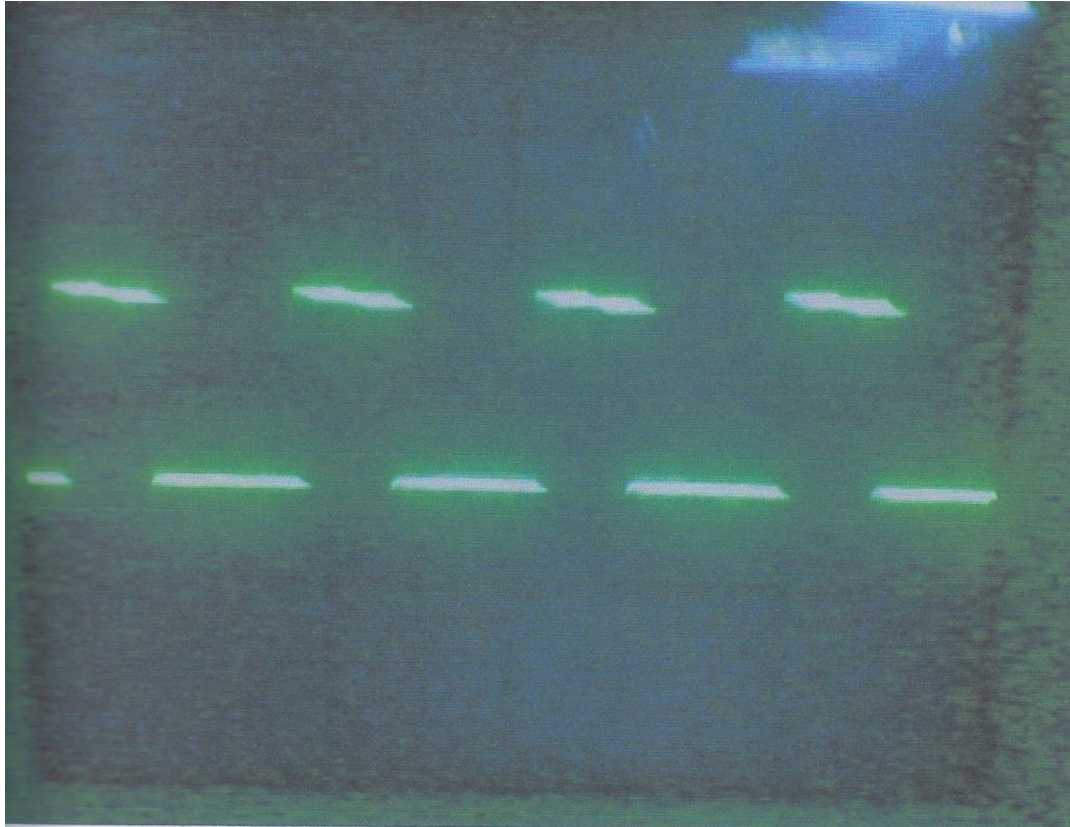


Fig.3.10 Data clock

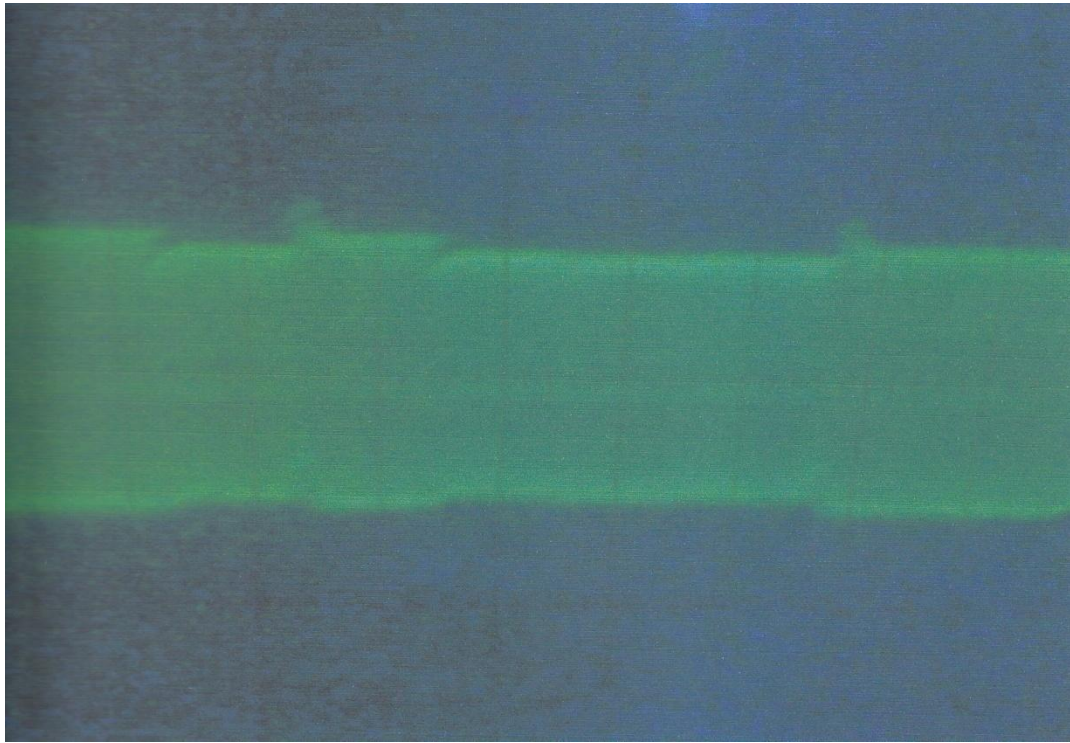


Fig. 3.11 QPSK signal

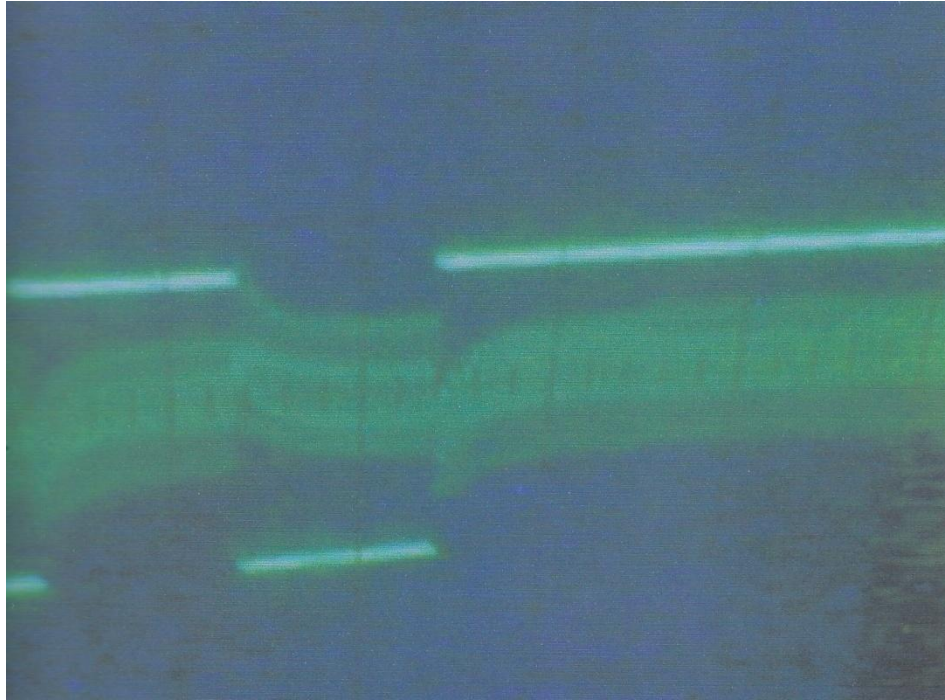


Fig. 3.12 I-data and demodulated data

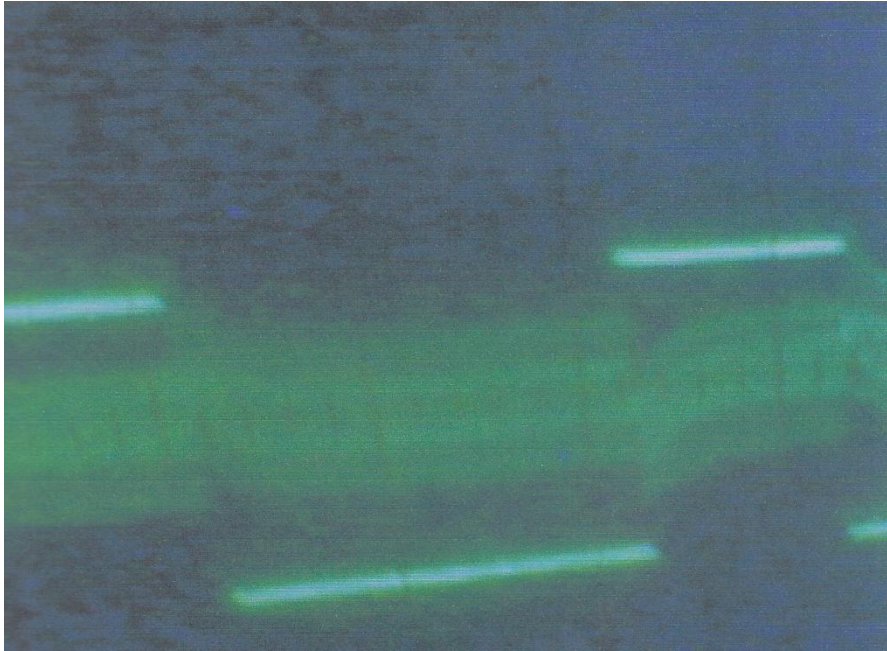


Fig.3.13 Q-data and demodulated Q-data

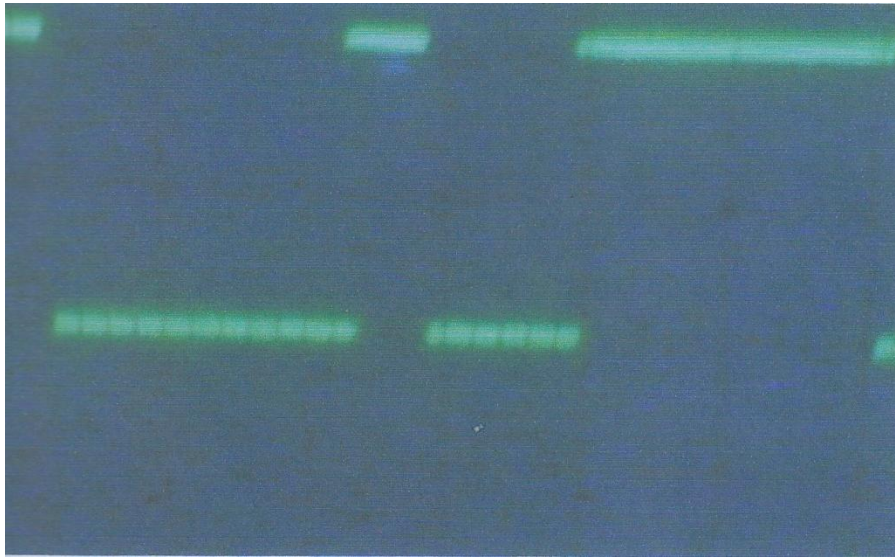


Fig. 3.14 Demodulated I-data after passing diode, low pass filter and Schmitt trigger

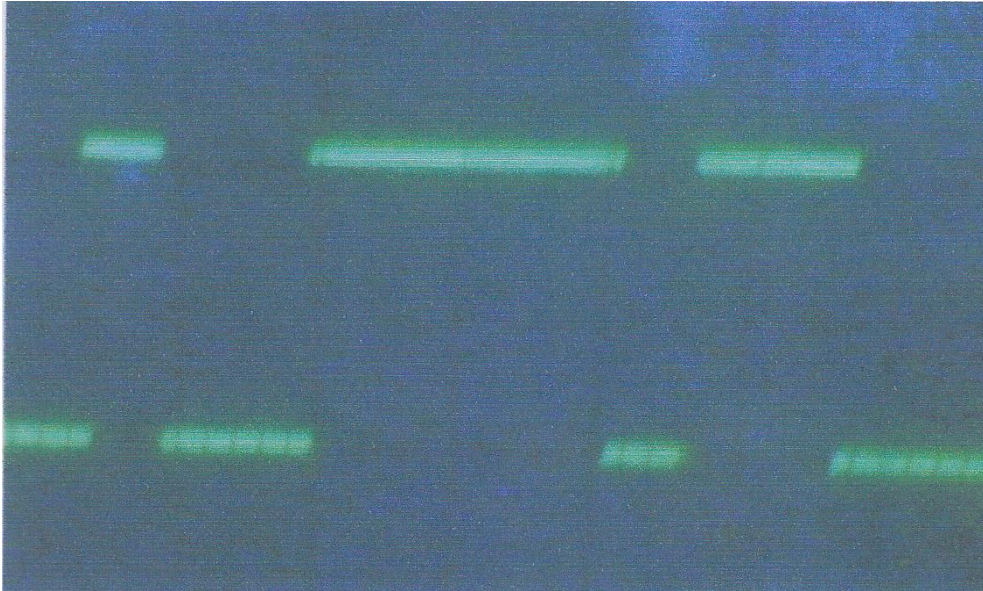


Fig. 3.15 Parallel to serial converter

CHAPTER-4

SIMULATION AND SIMULATION DIAGRAM OF QPSK BY PSPICE Schematic
version 9.2

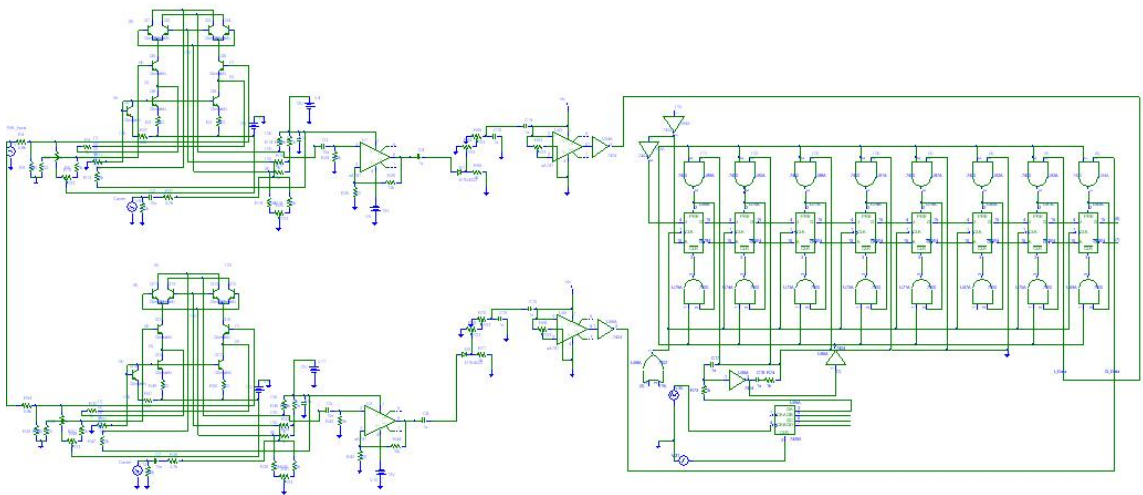


Fig. 4.1 QPSK Demodulator

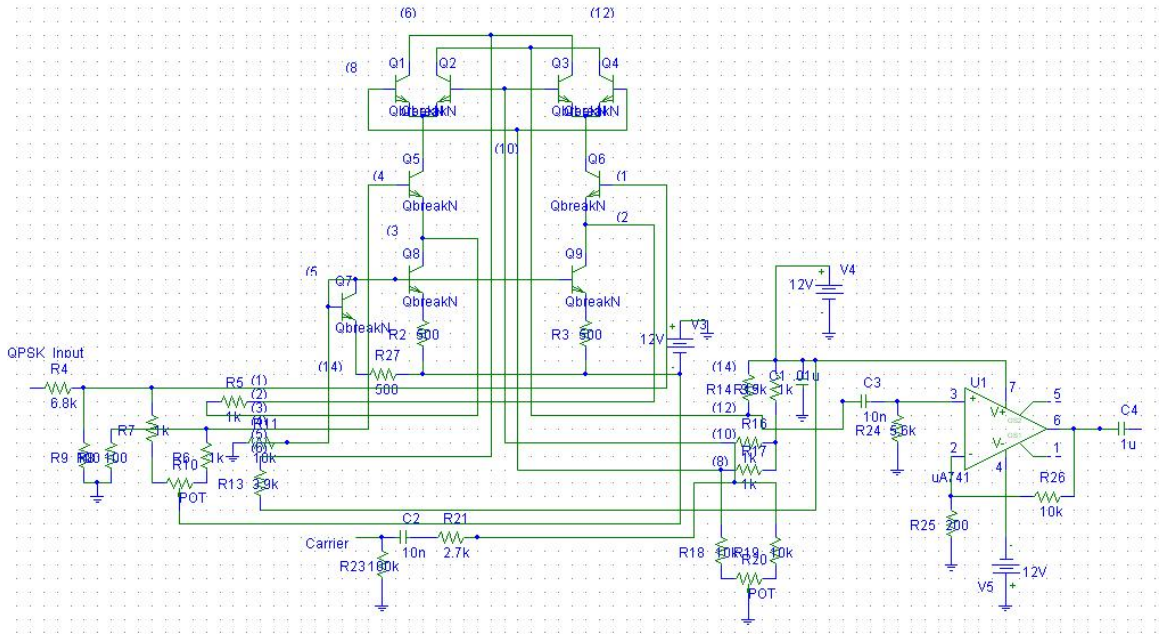


Fig.4.2 Multiplier circuit

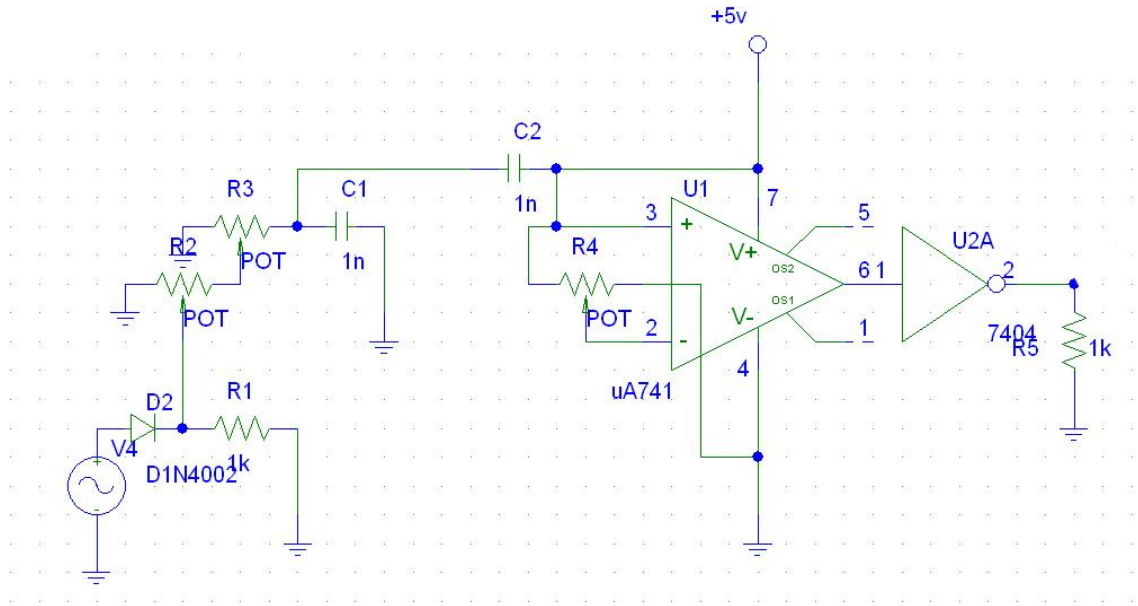


Fig. 4.3 Low pass filter and opamp

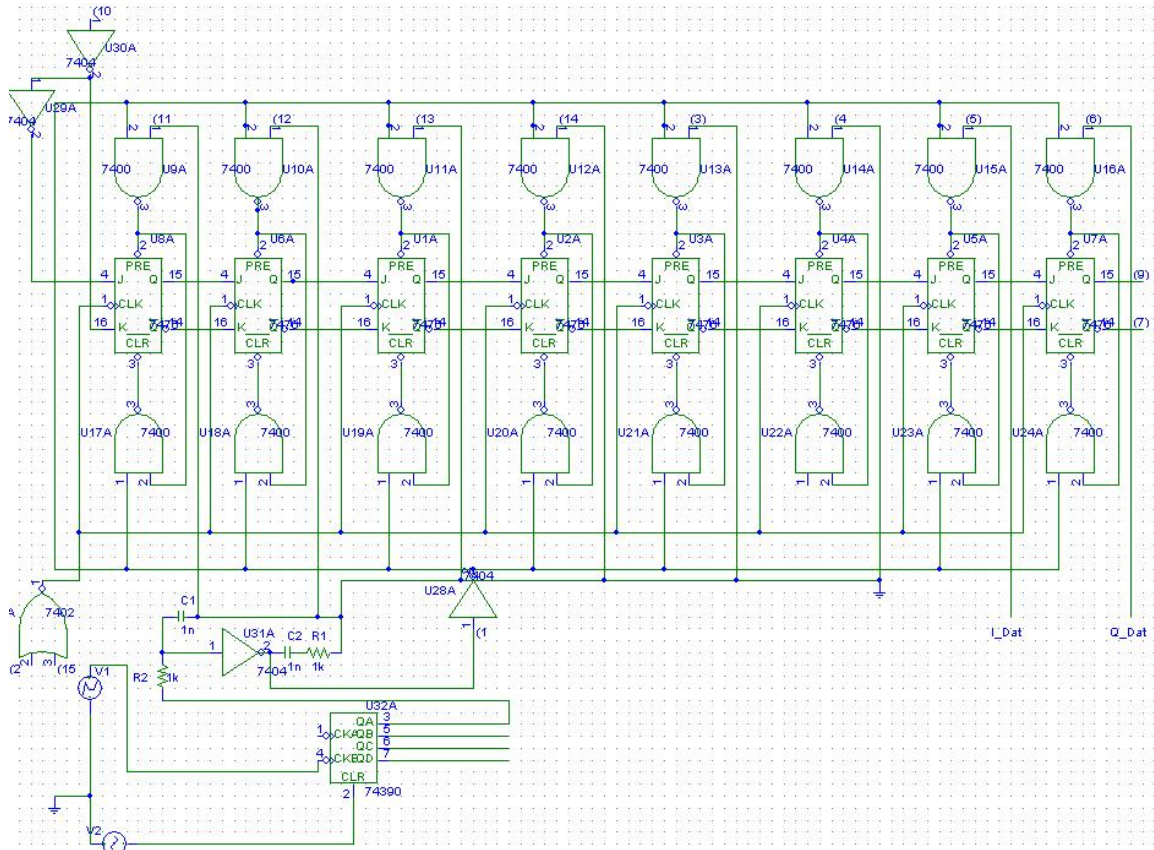


Fig.4.4 Parallel to Serial Converter

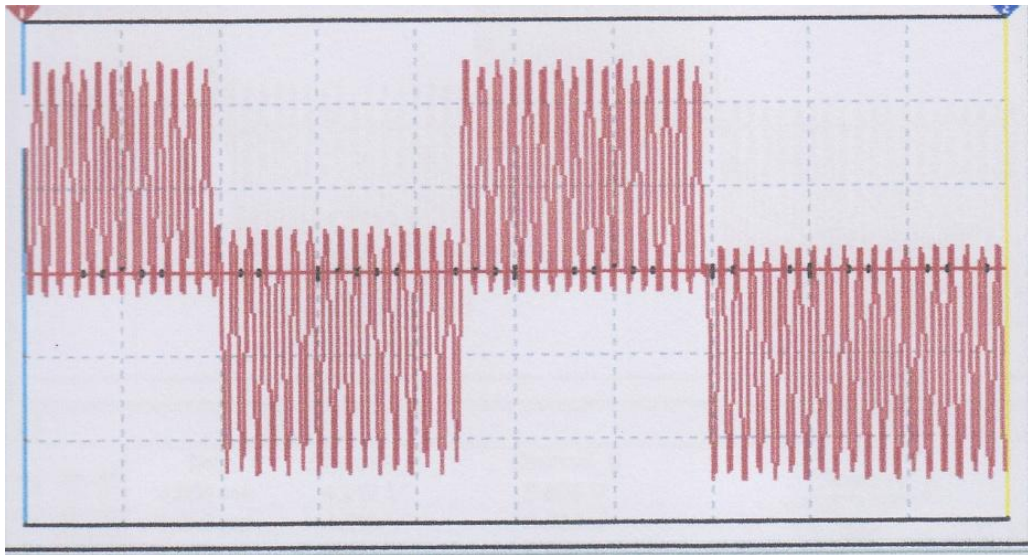


Fig. 4.5 QPSK signal multiplied with cosine carrier

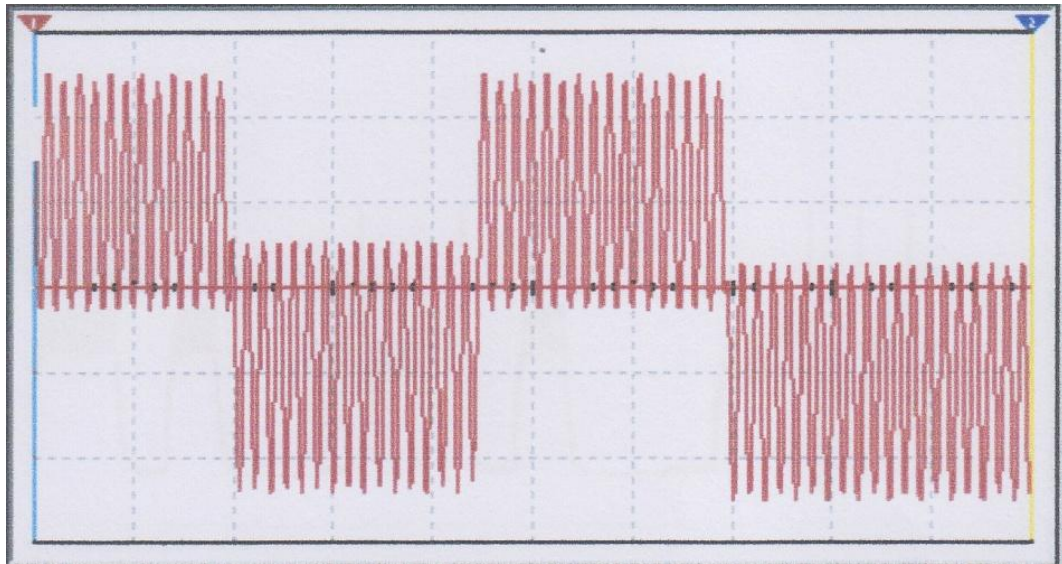


Fig. 4.6 QPSK signal multiplied with sine carrier

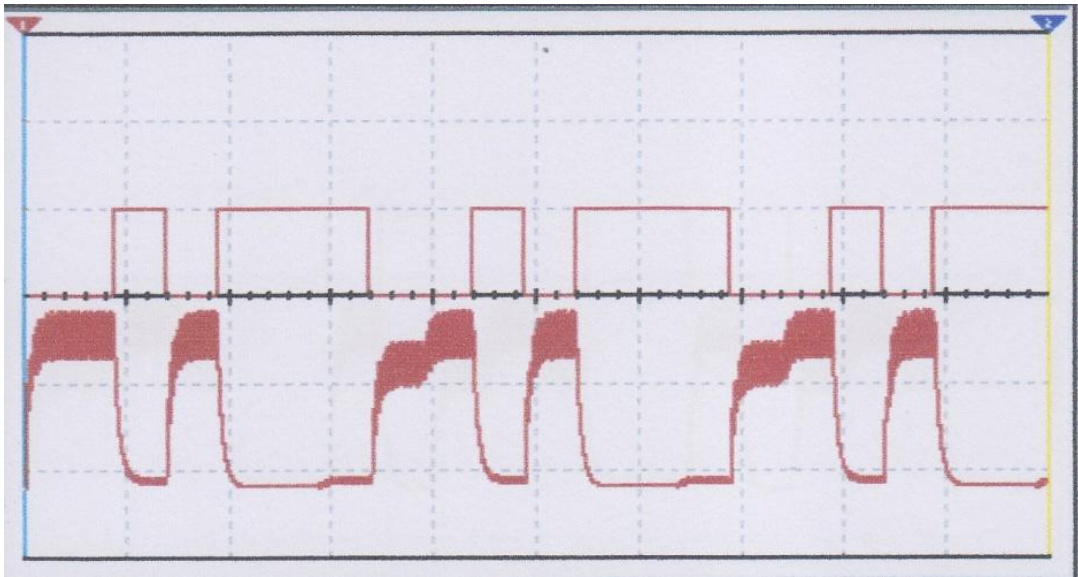


Fig. 4.7 Original I-data and output signal after diode and low pass filter (I-data)

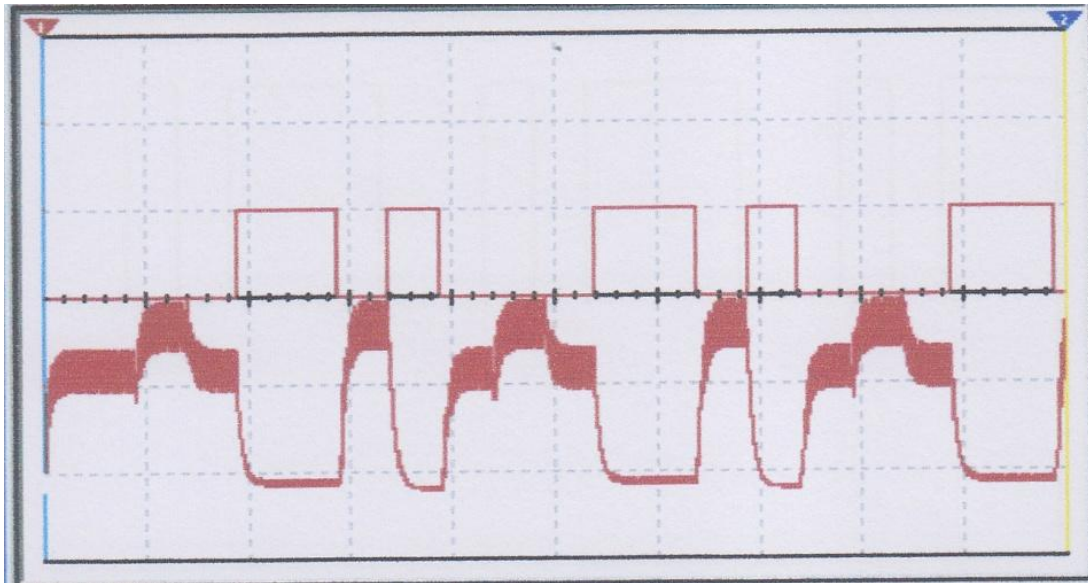


Fig.4.8 Output signal after diode and low pass filter (Q-data)



Fig. 4.9 Output after OPAMP and inverter (I-data)

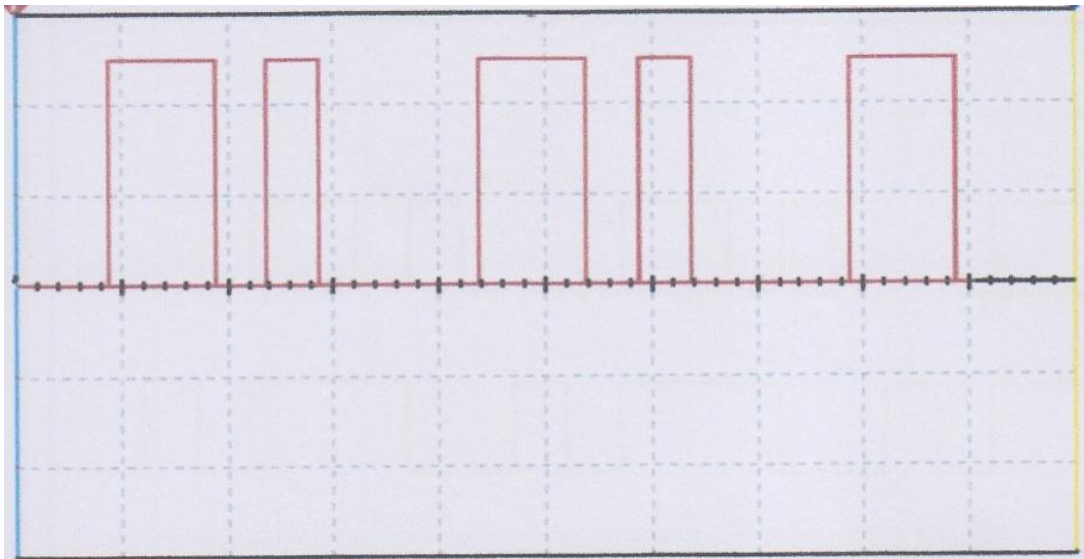


Fig. 4.10 Output after OPAMP and inverter (Q-data)

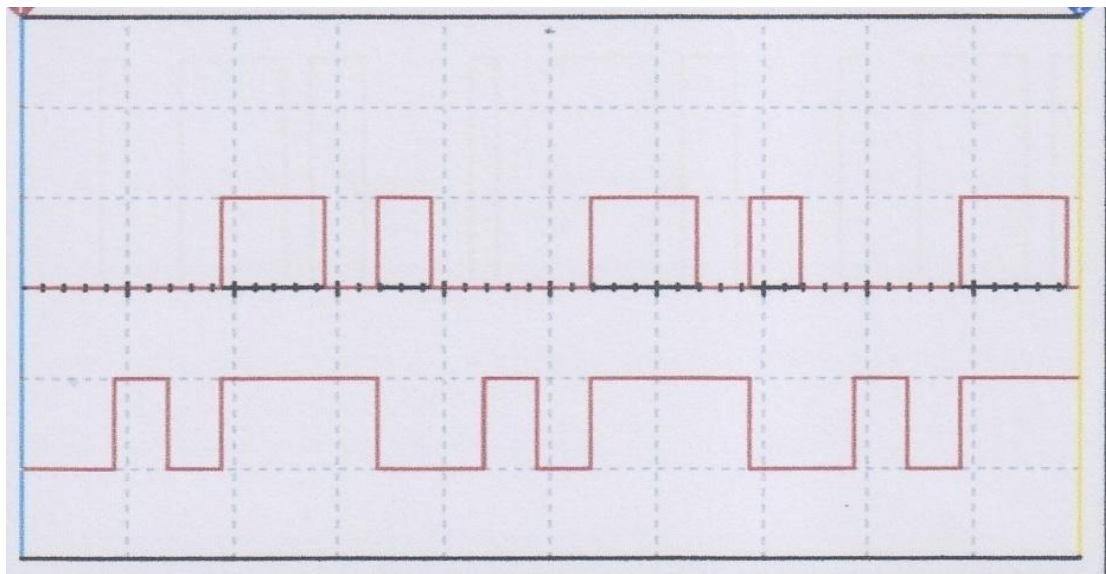


Fig. 4.11 Demodulated I and Q data

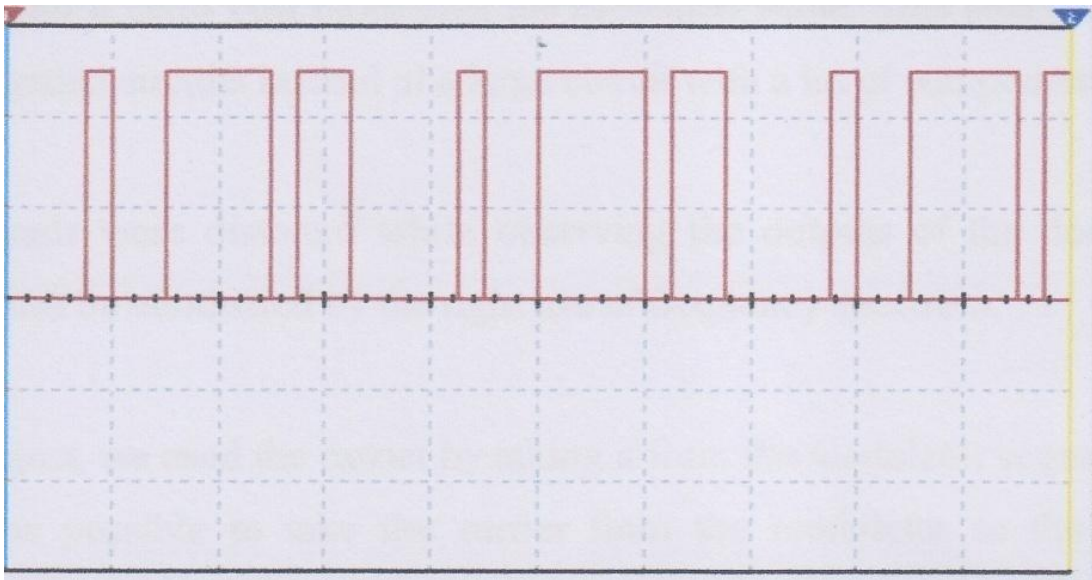


Fig.4.12 Output of parallel to serial converter (original data)

CHAPTER 5

CONCLUSION

The project that is being submitted can be improved at the following sides:

- Within our limitations, we tried to construct a simple QPSK demodulator of low cost. Still it takes cost more than the estimated value. This cost can be reduced by using integrated circuits instead of a large circuit with a lots of components.
- Some signals were distorted while observing the outputs of the demodulator. This distortion can be eliminated by the right use of frequency spectrum.
- In our project, we used the carrier by taking it from the modulated segment. In practical, it won't be possible to take carrier from the modulator as the modulator & demodulator segments will have certain distance from each other. So we can produce carrier recovery circuits. We can use PLL (Phase Locked Loop) for the purpose or we can use Costas loop so the carrier is generated from the demodulator segment.
- In our project we took the QPSK signal from the modulator to the demodulator with the help of a wire for shortage of time. It is possible to upgrade the system as wireless with the help of an Antenna. For using antenna, we have to use mixer circuit to convert the signal to intermediate signals as well as to radio signal.

LIST OF REFERENCES

- [1]. Ana García Armada, Member, IEEE, Understanding the Effects of Phase Noise in Orthogonal Frequency Division Multiplexing (OFDM)
- [2]. Ana García Armada and Miguel Calvo, Member, IEEE. Phase Noise and Sub-Carrier Spacing Effects on the Performance of an OFDM Communication System
- [3]. MIMO Block Spread OFDMA System for Next Generation Mobile Communications A thesis submitted in partial fulfilment of the requirements for the award of the Degree Master of Engineering by Research from UNIVERSITY OF WOLLONGONG
- [4]. Dr. Ing. L. “OFDM Transmission Technique”. Haring University of DUISBURG ESSEN
- [5]. Ender Bolat .“STUDY OF OFDM PERFORMANCE OVER AWGN CHANNELS” .Electrical and Elctronic Engineering Department Eastern Mediterranean University
- [6]. Alan C. Brooks , Stephen J. Hoelzer . “Design and Implementation of Orthogonal Frequency Division Multiplexing”
- [7]. Implementing OFDM Modulation for Wireless Communications
- [8]. An Introduction to Orthogonal Frequency Division Multiplex Technology from www.keithley.com

- [9] Measurement Challenges for OFDM Systems from Agilent Technology.
- [10]. Orthogonal Frequency Division Multiplexing for Wireless Networks, Standard IEEE 802.11a, UNIVERSITY OF CALIFORNIA SANTA BARBARA.
- [11]. Schwartz, M. "Information Transmission, Modulation and Noise". McGraw Hill New York,1990.
- [12]. Blanchard,A. "Phase Locked Loops", Wiley, New York,1994.
- [13]. B.P. Lathi. "Modern Digital and Analog Communication Systems".2004
- [14].Dennis Roddy. "Electronic Communication"

MATLAB CODE

```
%QPSK simulation with Gray coding
%Run from editor debug(F5)
%JC 2/16/07

%The purpose of this m-file is to show a baseband simulated version of QPSK
with
%Gray coding which may give valid results (still trying to figure out if it is correct)
%when compared to theoretical analysis.

%The simulation assumes a perfect system. I have kluged this together from
%various programs that I have seen on the internet and hope it may be
%somewhat useful to others to play with. I have provided comments and notes
for review.

clear

%randn('state',0);%keeps bits the same on reruns

nr_data_bits=64000;% 0's and 1's, keep even number-Takes ~1 minute for a run
of 1 million

%64000 allows bits and complex values to be shown in array editor

nr_symbols=nr_data_bits/2;

b_data = (randn(1, nr_data_bits) > .5);%random 0's and 1's

b = [b_data];

% Map the bits to be transmitted into QPSK symbols using Gray coding. The
```


% resulting QPSK symbol is complex-valued, where one of the two bits in each
 % QPSK symbol affects the real part (I channel) of the symbol and the other
 % bit the imaginary part (Q channel). Each part is subsequently
 % modulated to form the complex-valued QPSK symbol.

%

% The Gray mapping resulting from the two branches are shown where
 % one symbol error corresponds to one bit error going counterclockwise.

% imaginary part (Q channel)

% ^

% |

% 10 x | x 00 (odd bit, even bit)

% |

% -----+-----> real part (I channel)

% |

% 11 x | x 01

% |

% Input:

% b = bits {0, 1} to be mapped into QPSK symbols

%

% Output:

% d = complex-valued QPSK symbols 0.70711 + 0.70711i, etc

d=zeros(1,length(b)/2);

%definition of the QPSK symbols using Gray coding.

```
for n=1:length(b)/2
    p=b(2*n);
    imp=b(2*n-1);
    if (imp==0)&(p==0)
        d(n)=exp(j*pi/4);%45 degrees
    end
    if (imp==1)&(p==0)
        d(n)=exp(j*3*pi/4);%135 degrees
    end
    if (imp==1)&(p==1)
        d(n)=exp(j*5*pi/4);%225 degrees
    end
    if (imp==0)&(p==1)
        d(n)=exp(j*7*pi/4);%315 degrees
    end
end
end
qpsk=d;
figure(1);
plot(d,'o');%plot constellation without noise
axis([-2 2 -2 2]);
grid on;
xlabel('real'); ylabel('imag');
title('QPSK constellation');
```

```

SNR=0:12;
BER1=[];
SNR1=[];
SER=[];
SER1=[];
sigma1=[];

%AWGN(additive white Gaussian noise)
for SNR=0:length(SNR);%loop over SNR
sigma = sqrt(10.0^(-SNR/10.0));
sigma=sigma/2;%Required a division by 2 to get close to exact solutions(Notes)-
WHY?
%Is dividing by two(2) legitimate?
sigma1=[sigma1 sigma];
%add noise to QPSK Gray coded signals
snqpsk=(real(qpsk)+sigma.*randn(size(qpsk)))
+i.*(imag(qpsk)+sigma*randn(size(qpsk)));

figure(2);
plot(snqpsk,'o'); % plot constellation with noise
axis([-2 2 -2 2]);
grid on;
xlabel('real'); ylabel('imag');
title('QPSK constellation with noise');

```

```

%Receiver
r=snqpsk;%received signal plus noise

%Detector-When Gray coding is configured as shown, the detection process
%becomes fairly simple as shown. A system without Gray coding requires a
much
%more difficult detection method
bhat=[real(r)<0;imag(r)<0];%detector
bhat=bhat(:)';
bhat1=bhat;%0's and 1's

ne=sum(b~=bhat1);%number of errors
BER=ne/nr_data_bits;
SER=ne/nr_symbols;%consider this to be  $P_s = \log_2(4) * P_b = 2 * P_b$ 
SER1=[SER1 SER];
BER1=[BER1 BER];
SNR1=[SNR1 SNR];
end
figure(3);
semilogy(SNR1,BER1,'*',SNR1,SER1,'o');
grid on;
xlabel('SNR=Eb/No(dB)'); ylabel('BER or SER');
title('Simulation of BER/SER for QPSK with Gray coding');
legend('BER-simulated','SER-simulated');

```

%Notes: Theoretical QPSK EXACT SOLUTION for several SNR= E_b/N_0 points on BER/SER plot

%Assuming Gray coding

% $P_b=Q(\sqrt{2SNR_{bit}})$

% $P_s=2Q(\sqrt{2SNR_{bit}})[1-.5Q(\sqrt{2SNR_{bit}})]$

%SNR=7dB

% $SNR_{bit}=10^{(7/10)}=5.0118$ get ratio

% $P_b=Q(\sqrt{2*SNR_{bit}})=Q(\sqrt{10.0237})=7.7116e-4$ (bit error rate)

%where $Q=.5*erfc(\sqrt{10.0237}/1.414)$

% $P_s=2*Q-Q^2=2*(7.7116e-4)-(7.7116e-4)^2=1.5e-3$ (symbol error rate)

%SNR=9dB

% $SNR_{bit}=10^{(9/10)}=7.943$ get ratio

% $P_b=Q(\sqrt{2*SNR_{bit}})=Q(\sqrt{15.866})=3.37e-5$ (bit error rate)

% $P_s=2*Q-Q^2=2*(3.37e-5)-(3.37e-5)^2=6.74e-5$ (symbol error rate)

%0,1,2,3,4,5,6,8,10,11,12 You do the rest of these and plot if so inclined