

ANALYSIS AND SIMULATION OF DIGITAL MODULATION SCHEME

A MAJOR PROJECT REPORT

Submitted by:

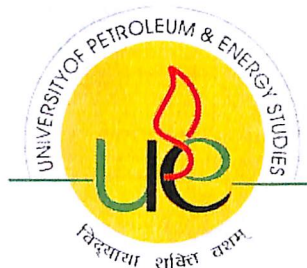
ANIRUDH SINGH PARMAR [R640209005]
MANDEEP VERMA [R640209024]
RIPUDAMAN ARYA [R640209032]

of
BACHELOR OF TECHNOLOGY
In
AVIONICS ENGINEERING

K B

2
1
3

Under the Supervision of Prof. Pavan Kumar Nanduri



Harnessing Energy through Knowledge

**DEPARTMENT OF AEROSPACE ENGINEERING
COLLEGE OF ENGINEERING STUDIES (CoES)
UNIVERSITY OF PETROLEUM & ENERGY STUDIES
DEHRADUN- 248007, INDIA
APRIL 2013**

*Dedicated to Our Guide
Prof. Pawan Kumar Nanduri
&
Our Parents.*

THESIS CERTIFICATE

We hereby certify that the work which is being presented in the project report entitled “**Analysis and Simulation of Digital Modulation Scheme**” in partial fulfillment of the requirements for the satisfactory performance for B .Tech Avionics Engineering, Major Project submitted in the Department of Aerospace Engineering, University of Petroleum and Energy Studies, Dehradun is an authentic record of our own work carried out during a period from July 2012 to April 2013.

SUBMITTED BY:

Anirudh Singh Parmar [R640209005]

Mandeep Verma [R640209024]

Ripudaman Arya [R640209032]

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

Prof. Pawan Kumar Nandan

Date:



ACKNOWLEDGEMENT

It is with a sense of great satisfaction and pride that we are sitting down to pen out our major project thesis report. First and foremost we sincerely salute our esteemed Institution **University of Petroleum & Energy Studies, Dehradun** for giving this golden opportunity for fulfilling our warm dreams of becoming a bachelor.

The first and foremost person we would like to express our deep sense of gratitude and profound thanks to our guide **Prof. Pawan Kumar Nanduri**, Department of Aerospace Engineering, UPES Dehradun for his valuable advice, suggestions, insurmountable guidance which played a vital role in carrying out our project work successfully. Our thanks to **Prof. (Dr.) Om Prakash**, (Head, Department of Aerospace Engineering, UPES, Dehradun) for his valuable guidance in our project.

We would like to specially thank **Prof. Pawan Kumar Nanduri**, for his help & encouragement during the work. We also thank all faculty, staff, and students of Department of Aerospace Engineering and for rendering help during various stages of the project work. We would like to thank our parents for their support and encouragement for carrying out our project work in a well sincere manner.

Anirudh Singh Parmar [R640209005]

Mandeep Verma [R640209024]

Ripudaman Arya [R640209032]

ABSTRACT

The invention of rocket technology has opened wide doors for the mankind to explore, enter and physically travel in space. Due to the developments in integrated circuits and fabrication technologies, huge inroads are laid into space electronics (avionics) because of which avionics itself has become an area to explore and experiment. Space communication being the important of all, advanced communication technologies are adopted and utilized to make the data secure and safer than before.

Modern digital modulations schemes like ASK, FSK, PSK, QPSK, GMSK and OFDM are employed to a good amount depending on the application, frequency and power requirements. The selection of a digital modulation scheme should be done by making the best possible use of the resources available for transmission, namely, bandwidth, power, and complexity, in order to achieve the reliability required.

This project discusses and lists all important modulation schemes that are employed for aircraft communications in detail. A deep insight is given into power requirements and their bandwidth utilization efficiency by drawing a comparison between all the modulation schemes. Performance graphs are plotted using MATLAB & SIMULINK tools. Analysis involving the bit error probability of all the modulation schemes will be carried out extensively.

TABLE OF CONTENTS

	Title	Page No.
	ACKNOWLEDGMENTS.....	I
	ABSTRACT.....	li
	TABLE OF CONTENTS.....	iii
	LIST OF TABLES.....	vi
	LIST OF FIGURES.....	vii
	ABBREVIATIONS.....	ix
CHAPTER 1 INTRODUCTION		
1.1	Challenge of digital modulation.....	1
1.2	Necessity of digital modulation.....	2
1.3	Advantages of digital modulation.....	2
1.4	Modulation Schemes.....	4
1.4.1	Coherent and Incoherent system.....	4
1.5	Type of modulation.....	5
1.6	Digital Modulation.....	5
1.6.1	Amplitude Shift Keying (ASK).....	6
1.6.2	Frequency Shift Keying (FSK).....	7
1.6.3	Minimum Shift Keying (PSK).....	8
1.6.4	Phase Shift Keying (PSK).....	9
1.6.5	Effects of going through the origin.....	10
CHAPTER 2 CONSTELLATION DIAGRAM		
2.1	I/Q Formats.....	11
2.1.1	Why use I and Q.....	11
2.1.2	I and Q in a Radio Transmitter.....	12
2.1.3	I and Q in a Receiver.....	12
2.2	Constellation Diagram.....	13

2.2.1	Quadrature Amplitude Modulation.....	14
2.3	Theoretical bandwidth efficiency limits.....	15
2.4	Digital Modulation Type-Variations.....	16
2.4.1	I/Q Offset Modulation.....	16
2.4.2	Differential Modulation.....	17
2/4/3	Constant amplitude Modulation.....	19
CHAPTER 3 BIT ERROR RATE		
3.1	Terminology.....	20
3.2	Methodology.....	22
3.3	Calculations.....	23
3.3.1	Assumed Calculations.....	23
3.3.2	Bit Error Rate Graph.....	29
CHAPTER 4 RESULTS & CALCULATIONS		
4.1	Bit Error Rate Graph.....	30
4.2	Practical Calculations.....	30
4.2.1	For Low Earth Orbit (LEO).....	31
4.2.2	For Geostationary Earth Orbit (GEO).....	28
4.2.3	Matlab Programming.....	32
4.3	Graphs.....	33
4.3.1	For Geostationary Earth Orbit (GEO).....	33
4.3.2	For Low Earth Orbit (LEO).....	35
4.4	Range Vs Received Power Graph.....	37
CHAPTER 6 CONCLUSION AND SUMMARY		
5.1	Conclusion.....	38
5.2	Future Work.....	39
REFERENCES.....		47

LIST OF TABLES

Table No	Title	Page No.
1.1	It covers the applications for different modulation formats in both wireless communications and video.....	4
2.1	Theoretical bandwidth efficiency limits for the main modulation types.....	23

LIST OF FIGURES

Figure	Title	Page No.
1.1	Coherent Generation of modulation.....	5
1.2	Types of modulation.....	6
1.3	Amplitude shift keying carrier waveform.....	8
1.4	Frequency shift keying carrier waveform.....	10
1.5	Phase shift keying technique.....	11
1.6	Different modulation schemes.....	12
2.1	I/Q Formats.....	15
2.2	I and Q in a Practical Radio Transmitter.....	16
2.3	I and Q in a Radio Receiver.....	17
2.4	PSK Constellation Diagram.....	19
2.5	QAM Constellation Diagram.....	20
2.6	Offset Modulation.....	22
2.7	Differential Modulation.....	23
2.8	Constant Amplitude Modulation.....	24
3.1	Probability Error Graph on the basis of Assumed calculation.....	37
4.1	Bit Error Rate Graph.....	41
4.2	Bit Error Rate Graph for GEO without semi log.....	48
4.3	BER graph for GEO with semi log.....	49
4.4	BER graph for LEO without semi log.....	50
4.5	BER graph for LEO with semi log.....	51
4.6	Range Vs Received Power Graph.....	53

CHAPTER 1

INTRODUCTION

In electronics and tele-communications, modulation is the process of varying one or more properties of a high-frequency periodic waveform, called the carrier signal with a modulating signal which typically contains information to be transmitted. 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 demod). A device that can do both operations is a modem (from "modulator–demodulator").

Over the past few years a major transition has occurred from simple analog Amplitude Modulation (AM) and Frequency/Phase Modulation (FM/PM) to new digital modulation techniques. Examples of digital modulation include

- QPSK (Quadrature Phase Shift Keying)
- FSK (Frequency Shift Keying)
- MSK (Minimum Shift Keying)
- QAM (Quadrature Amplitude Modulation)

Another layer of complexity in many new systems is multiplexing. Two principal types of multiplexing (or “multiple access”) are TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access). The RF spectrum must be shared, yet every day there are more users for that spectrum as demand for communications services increases. Digital modulation schemes have greater capacity to convey large amounts of information than analog modulation schemes. The choice of digital modulation scheme will significantly affect the characteristics, performance and resulting physical realization of a communication system. There is no universal 'best' choice of scheme; Consideration must be given to the required data rate, acceptable level of latency, available bandwidth, anticipated link budget and target hardware cost, size and current consumption.

1.1 The Challenge of Digital Modulation:

The selection of a digital modulation scheme should be done by making the best possible use of the resources available for transmission, namely, bandwidth, power, and complexity, in order to achieve the reliability required. There are only three characteristics of a signal that can be changed over time: amplitude, phase or frequency. However, phase and frequency are just different ways to view or measure the same signal change.

In AM, the amplitude of a high-frequency carrier signal is varied in proportion to the instantaneous amplitude of the modulating message signal.

Frequency Modulation (FM) is the most popular analog modulation technique used in mobile communications systems. In FM, the amplitude of the modulating carrier is kept constant while its frequency is varied by the modulating message signal.

Amplitude and phase can be modulated simultaneously and separately, but this is difficult to generate, and especially difficult to detect. Instead, in practical systems the signal is separated into another set of independent components: I (In-phase) and Q (Quadrature). These components are orthogonal and do not interfere with each other.

1.2 Necessity of Modulation:

There are many instances where baseband signals are incompatible for direct transmission over the medium.

- The signal gets attenuated rapidly due to its low frequency.
- Hence modulation schemes are used for transmission of baseband signal for communication.

1.3 Advantages of Modulation:

- Reduces height of Antenna
- Increases range of communication
- Avoids mixing of signals
- Allows multiplexing of signal
- Allows adjustment in bandwidth
- Improves quality of reception

Modulation format	Application
MSK, GMSK	GSM, CDPD
BPSK	Deep space telemetry, cable modems
QPSK, $\pi/4$ DQPSK	Satellite, CDMA, NADC, TETRA, PHS, PDC, LMDS, DVB-S, cable (return path), cable modems, TSTS
OQPSK	CDMA, satellite
FSK, GFSK	DECT, paging, RAM mobile data, AMPS, CT2, ERMES, land mobile, public safety
8, 16 VSB	North American digital TV (ATV), broadcast, cable
8PSK	Satellite, aircraft, telemetry pilots for monitoring broadband video systems
16 QAM	Microwave digital radio, modems, DVB-C, DVB-T
32 QAM	Terrestrial microwave, DVB-T
64 QAM	DVB-C, modems, broadband set top boxes, MMDS
256 QAM	Modems, DVB-C (Europe), Digital Video (US)

Table 1.1 Modulation Formats

The table covers the applications for different modulation formats in both wireless communications and video.

Reasons for Choosing Encoding Techniques:

- Digital data & digital signal – Equipment less complex and expensive than digital-to-analog modulation equipment
- Analog data & digital signal – Permits use of modern digital transmission and switching equipment
- Digital data & analog signal – Some transmission media will only propagate analog signals. E.g., unguided media (air)
- Analog data & analog signal – Analog data in electrical form can be transmitted easily and cheaply. E.g., AM Radio

Now there is a trend in communication system design to replace analogue techniques with digital techniques. For both voice and video, transmission coding procedures result in the digitally transmitted signal taking the same or less bandwidth than the corresponding analogue signal.

Example, a digital cellular radio system is capable to transmit two to three times the number of calls per MHz allocated bandwidth than an analogue system. For Video transmissions, same frequency allocation can be used throughout the region or country for the same programme material, so that up to approximately 350 PAL (phase alternating line) quality programmes can be broadcast on the existing UHF band.

1.4 Modulation Schemes

1.4.1 Coherent And Incoherent Systems:

The terms coherent and incoherent are used when discussing the generation and reception of digital modulation. When linked to the process of modulation the term coherence means the ability of the modulator to control the phase of the signal, not just the frequency.

Use of the term coherent with respect to the act of demodulation refers to a system that makes a demodulation decision based on the received signal phase, not frequency.

The additional 'information' available results in an improved BER performance.

The high level of digital integration now possible in semiconductor devices have made digitally based coherent demodulators common in mobile communications systems.

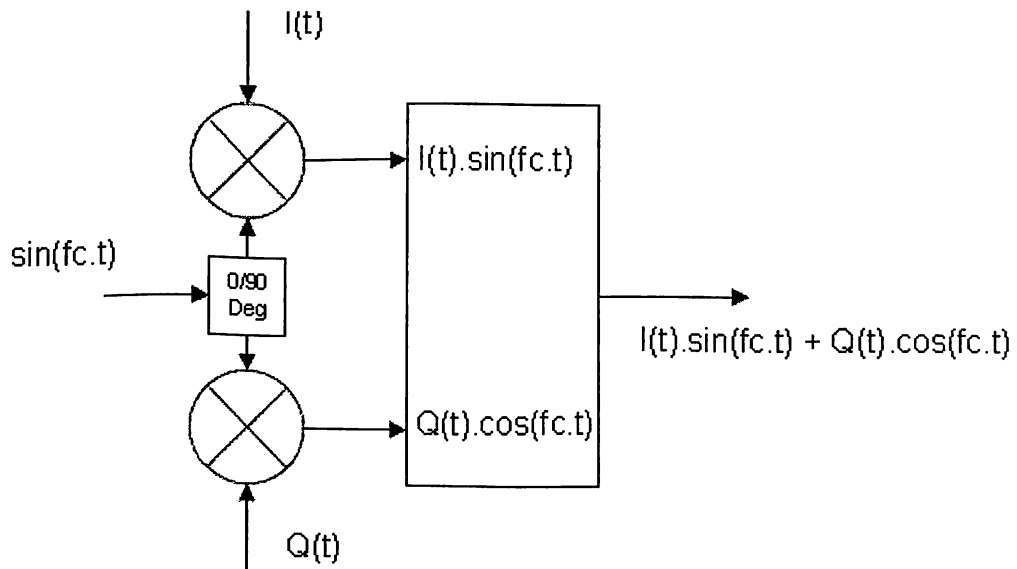


Fig.1.1 Coherent Generation of modulation.

1.5 Type Of Modulation

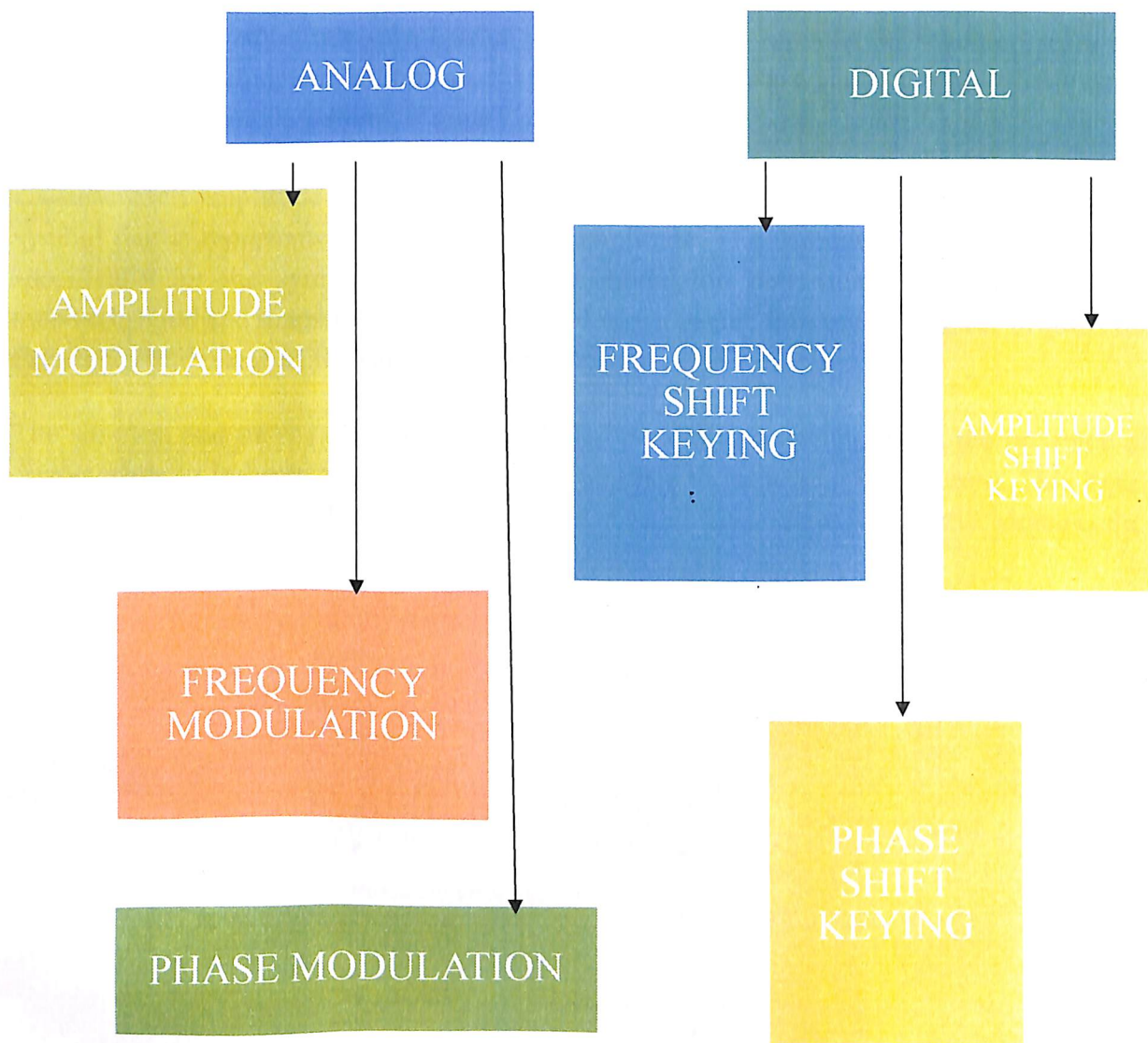


Fig.1.2 Various Kinds Of Modulation Techniques.

1.6 Digital Modulation

The basic form of 3 different digital modulation methods used for transmitting digital signals methods are:

- Amplitude Shift Keying
- Frequency Shift Keying
- Phase Shift Keying

1.6.1 Amplitude Shift Keying (ASK)

Amplitude-shift keying (ASK) is a form of modulation that represents digital data as variations in the amplitude of a carrier wave. Any digital modulation scheme uses a finite number of distinct signals to represent digital data. ASK uses a finite number of amplitudes, each assigned a unique pattern of binary digits.

Usually, each amplitude encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular amplitude. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the amplitude of the received signal and maps it back to the symbol it represents, thus recovering the original data. Frequency and phase of the carrier are kept constant.

The simplest and most common form of ASK operates as a switch, using the presence of a carrier wave to indicate a binary one and its absence to indicate a binary zero. This type of modulation is called on-off keying, and is used at radio frequencies to transmit Morse code.

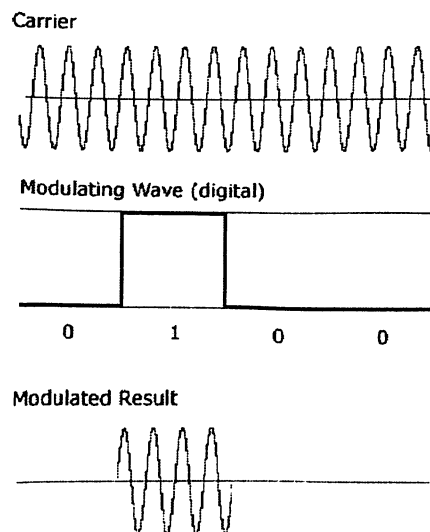


Fig. 1.3 Amplitude Modulated Carrier Wave.

Another member of the digital modulation family is Quadrature Amplitude Modulation (QAM). QAM is used in applications including microwave digital radio, DVB-C (Digital Video Broadcasting - Cable) and modems. Another variation is 32QAM. In this case there are six I values and six Q values resulting in a total of 36 possible states ($6 \times 6 = 36$). This is too many states for a power of two (the closest power of two is 32). So the four corner symbol states, which take the most power to transmit, are omitted. This reduces the amount of peak

power the transmitter has to generate. Since $2^5 = 32$, there are five bits per symbol and the symbol rate is one fifth of the bit rate.

The current practical limits are approximately 256QAM, though work is underway to extend the limits to 512 or 1024 QAM. A 256QAM system uses 16 I-values and 16 Q-values giving 256 possible states. Since $2^8 = 256$, each symbol can represent eight bits. A 256QAM signal that can send eight bits per symbol is very spectrally efficient. However, the symbols are very close together and are thus more subject to errors due to noise and distortion. Such a signal may have to be transmitted with extra power (to effectively spread the symbols out more) and this reduces power efficiency as compared to simpler schemes.

16QAM Four Bits per Symbol

Symbol Rate = 1/4 Bit Rate

32QAM Five Bits per Symbol

Symbol Rate = 1/5 Bit Rate

1.6.2 Frequency Shift Keying (FSK)

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. Frequency modulation and phase modulation are closely related. A static frequency shift of +1 Hz means that the phase is constantly advancing at the rate of 360 degrees per second (2π rad/sec), relative to the phase of the unshifted signal. FSK (Frequency Shift Keying) is used in many applications including cordless and paging systems. Some of the cordless systems include DECT (Digital Enhanced Cordless Telephone) and CT2 (Cordless Telephone 2). In FSK, the frequency of the carrier is changed as a function of the modulating signal (data) is being transmitted. Amplitude remains unchanged. In binary FSK (BFSK or 2FSK), a "1" is represented by one frequency and a "0" is represented by another frequency. The simplest FSK is binary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.

FSK and MSK produce constant envelope carrier signals, which have no amplitude variations. This is a desirable characteristic for improving the power efficiency of transmitters. Amplitude variations can exercise nonlinearities in an amplifier's amplitude-transfer function, generating spectral regrowth, a component of adjacent channel power. Therefore, more efficient amplifiers (which tend to be less linear) can be used with constant-envelope signals, reducing power consumption.

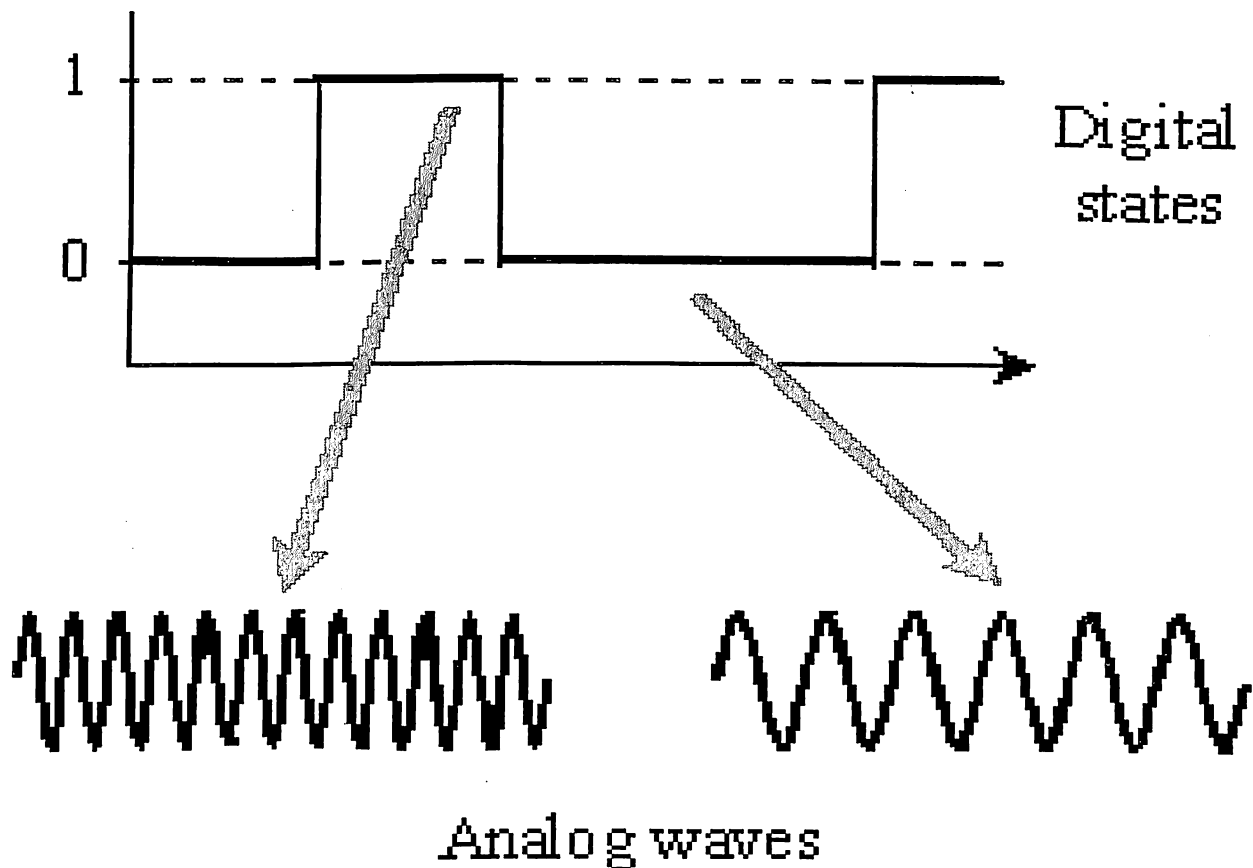


Fig.1.4 Frequency Modulated Waveform.

1.6.3 Minimum Shift Keying

Since a frequency shift produces an advancing or retarding phase, frequency shifts can be detected by sampling phase at each symbol period. Phase shifts of $(2N + 1) \frac{1}{2}$ radians are easily detected with an I/Q demodulator. At even numbered symbols, the polarity of the I channel conveys the transmitted data, while at odd numbered symbols the polarity of the Q channel conveys the data. This orthogonality between I and Q simplifies detection algorithms and hence reduces power consumption in a mobile receiver. The minimum frequency shift which yields orthogonality of I and Q is that which results in a phase shift of $\pm \frac{1}{2}$ radians per symbol (90 degrees per symbol). FSK with this deviation is called MSK (Minimum Shift Keying). The deviation must be accurate in order to generate repeatable 90 degree phase shifts. MSK is used in the GSM (Global System for Mobile Communications) cellular standard. A phase shift of +90 degrees represents a data bit equal to "1", while -90 degrees represents a "0". The peak-to-peak frequency shift of an MSK signal is equal to one-half of the bit rate.

MSK has a narrower spectrum than wider deviation forms of FSK. The width of the spectrum is also influenced by the waveforms causing the frequency shift. If those waveforms have fast transitions or a high slew rate, then the spectrum of the transmitter will be broad. In practice, the waveforms are filtered with a Gaussian filter, resulting in a narrow spectrum. In addition, the Gaussian filter has no time-domain overshoot, which would broaden the spectrum by increasing the peak deviation. MSK with a Gaussian filter is termed GMSK (Gaussian MSK).

1.6.4 Phase Shift Keying (PSK)

Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave). 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 digits. Usually, each phase encodes an equal number of 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; such a system is termed coherent (and referred to as CPSK).

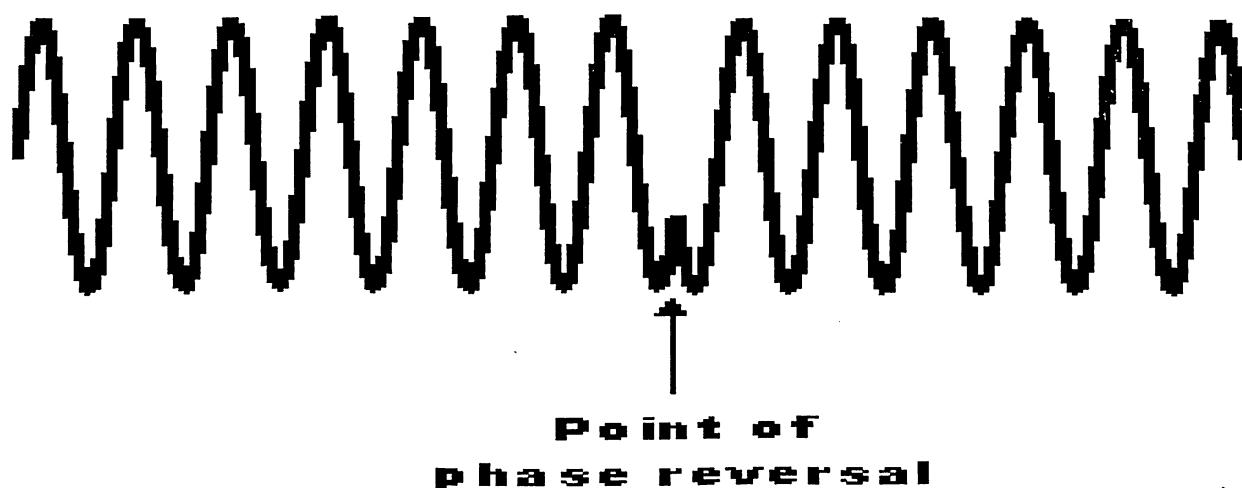


Fig.1.5 Phase Shift Keying Technique

One of the simplest forms of digital modulation is binary or Bi-Phase Shift Keying (BPSK). One application where this is used is for deep space telemetry. The phase of a constant amplitude carrier signal moves between zero and 180 degrees. On an I and Q diagram, the I state has two different values. There are two possible locations in the state diagram, so a binary one or zero can be sent. The symbol rate is one bit per symbol.

A more common type of phase modulation is Quadrature Phase Shift Keying (QPSK). It is used extensively in applications including CDMA (Code Division Multiple Access) cellular service, wireless local loop, Iridium (A voice/data satellite system) and DVB-S (Digital Video Broadcasting-Satellite). Quadrature means that the signal shifts between phase states which are separated by 90 degrees. The signal shifts in increments of 90 degrees from 45 to 135, -45, or -135 degrees. These points are chosen as they can be easily implemented using an I/Q modulator. Only two I values and two Q values are needed and this gives two bits per symbol. There are four states because $2^2 = 4$. It is therefore a more bandwidth-efficient type of modulation than BPSK, potentially twice as efficient.

1.6.5 Effects of going through the origin:

Take, for example, a QPSK signal where the normalized value changes from 1, 1 to -1, -1. When changing simultaneously from I and Q values of +1 to I and Q values of -1, the signal trajectory goes through the origin (the I/Q value of 0,0). The origin represents 0 carrier magnitude. A value of 0 magnitudes indicates that the carrier amplitude is 0 for a moment. Not all transitions in QPSK result in a trajectory that goes through the origin. If I changes value but Q does not (or vice-versa) the carrier amplitude changes a little, but it does not go through zero. Therefore some symbol transitions will result in a small amplitude variation, while others will result in a very large amplitude variation. The clock-recovery circuit in the receiver must deal with this amplitude variation uncertainty if it uses amplitude variations to align the receiver clock with the transmitter clock.

Spectral regrowth does not automatically result from these trajectories that pass through or near the origin. If the amplifier and associated circuits are perfectly linear, the spectrum (spectral occupancy or occupied bandwidth) will be unchanged. The problem lies in nonlinearities in the circuits. A signal which changes amplitude over a very large range will exercise these nonlinearities to the fullest extent. These nonlinearities will cause distortion products. In continuously-modulated systems they will cause "spectral regrowth" or wider modulation sidebands (a phenomenon related to inter modulation distortion). Another term which is sometimes used in this context is "spectral splatter". However this is a term that is more correctly used in association with the increase in the bandwidth of a signal caused by pulsing on and off.

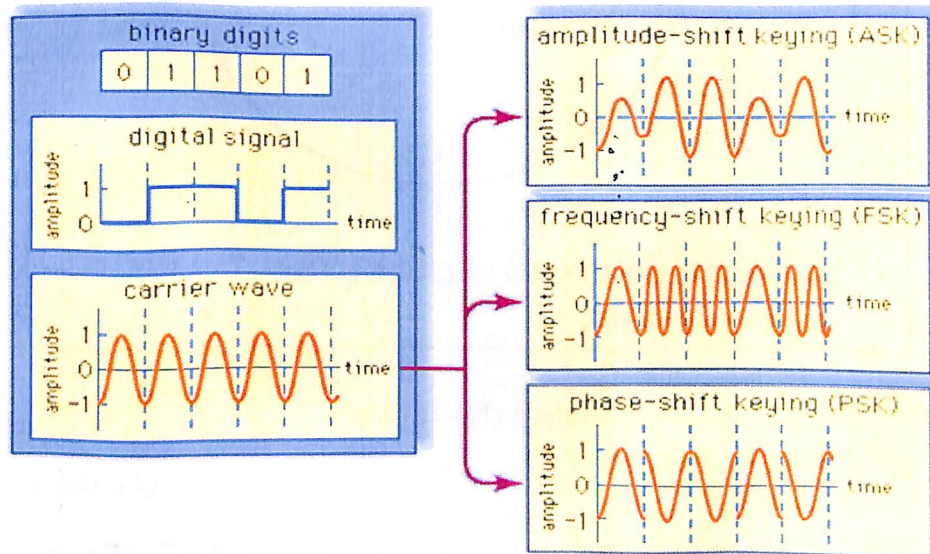


Fig. 1.7 The Different Schemes Are Explained

CHAPTER 2

CONSTITUTION DIAGRAM

2.1 I/Q Formats

In digital communications, modulation is often expressed in terms of I and Q. I axis lies on the zero degree phase reference, and the Q axis is rotated by 90 degrees. The signal vector's projection onto the I axis is its "I" component and the projection onto the Q axis is its "Q" component.

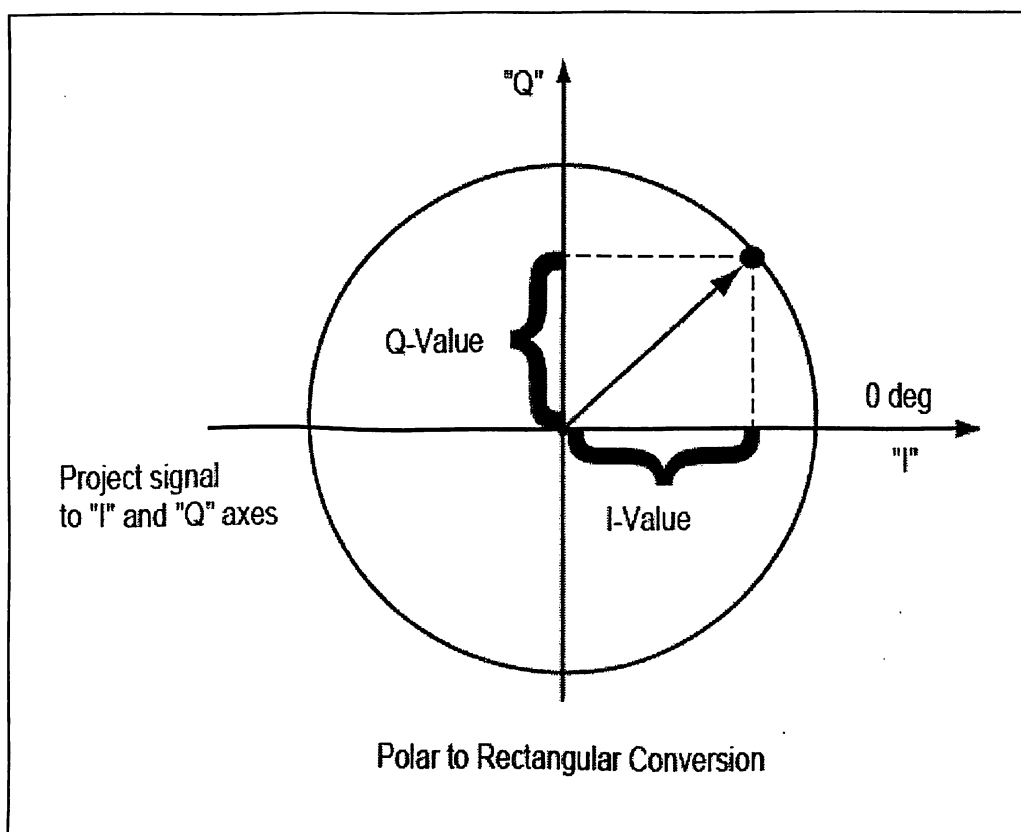


Fig.2.1 The I/Q Formats.

2.1.1 Why use I and Q?

Digital modulation is easy to accomplish with I/Q modulators. Most digital modulation maps the data to a number of discrete points on the I/Q plane. These are known as constellation points. As the signal moves from one point to another, simultaneous amplitude and phase modulation usually results. To accomplish this with an amplitude modulator and a phase modulator is difficult and complex. It is also impossible with a conventional phase modulator. The signal may, in principal, circle the origin in one direction forever, necessitating infinite phase shifting capability. Alternatively, simultaneous AM and Phase Modulation is easy with an I/Q modulator. The I and Q control signals are bounded, but infinite phase wrap is possible by properly phasing the I and Q signals.

2.1.2 I and Q in a Radio Transmitter

I/Q diagrams are particularly useful because they mirror the way most digital communications signals are created using an I/Q modulator. In the transmitter, I and Q signals are mixed with the same local oscillator (LO). A 90 degree phase shifter is placed in one of the LO paths. Signals that are separated by 90 degrees are also known as being orthogonal to each other or in quadrature. Signals that are in quadrature do not interfere with each other. They are two independent components of the signal. When recombined, they are summed to a composite output signal. There are two independent signals in I and Q that can be sent and received with simple circuits. This simplifies the design of digital radios. The main advantage of I/Q modulation is the symmetric ease of combining independent signal components into a single composite signal and later splitting such a composite signal into its independent component parts.

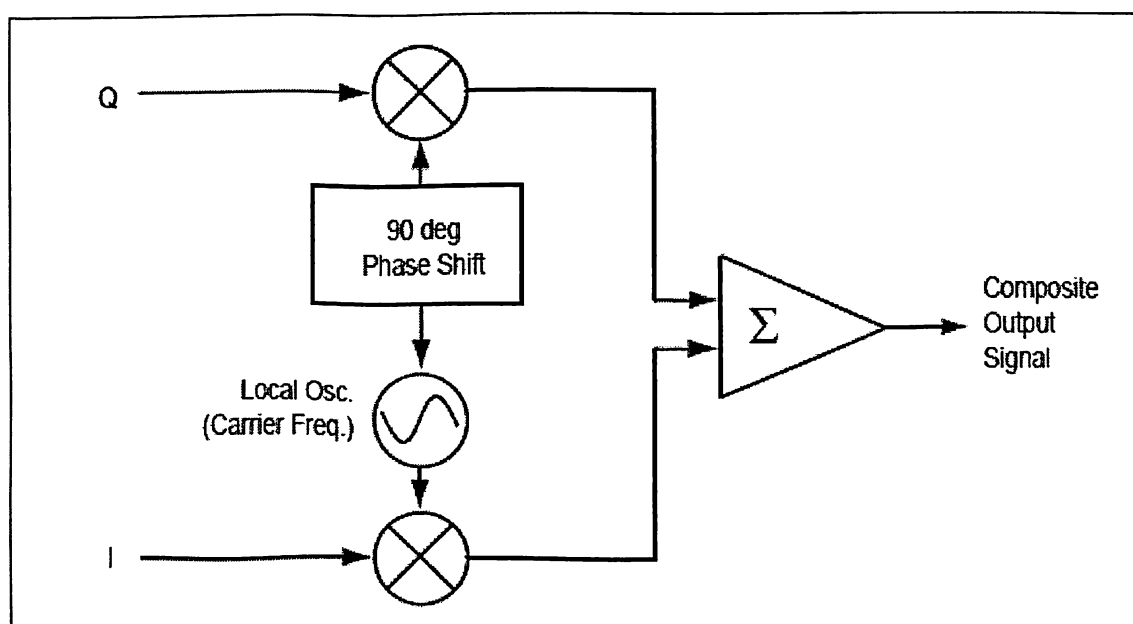


Fig. 2.1 I and Q in a Practical Radio Transmitter

2.1.3 I and Q in a radio receiver

The composite signal with magnitude and phase (or I and Q) information arrives at the receiver input. The input signal is mixed with the local oscillator signal at the carrier frequency in two forms. One is at an arbitrary zero phase. The other has a 90 degree phase shift. The composite input signal (in terms of magnitude and phase) is thus broken into an in-phase, I, and a quadrature, Q, component. These two components of the signal are independent and orthogonal. One can be changed without affecting the other.

Normally, information cannot be plotted in a polar format and reinterpreted as rectangular values without doing a polar-to-rectangular conversion.

This conversion is exactly what is done by the in-phase and quadrature mixing processes in a digital radio. A local oscillator, phase shifter, and two mixers can perform the conversion accurately and efficiently.

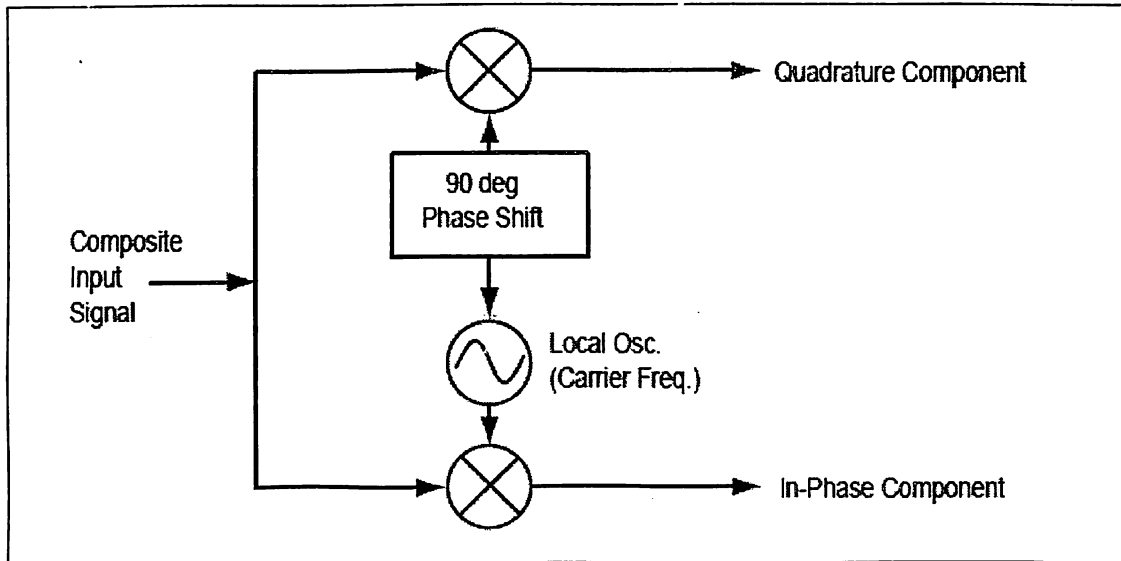


Fig.10 I and Q in a Radio Receiver

2.2 Constellation Diagram

A constellation diagram is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase-shift keying. It displays the signal as a two-dimensional scatter diagram in the complex plane at symbol sampling instants. Plotting several symbols in a scatter diagram produces the constellation diagram. The points on a constellation diagram are called constellation points. They are a set of modulation symbols which comprise the modulation alphabet. A two-dimensional diagram of the carrier magnitude and phase (a standard polar plot) can be represented differently by superimposing rectangular axes on the same data and interpreting the carrier in terms of in-phase (I) and quadrature-phase (Q) components. It would be possible to perform AM and PM on a carrier at the same time and send data this way; it is easier for circuit design and signal processing to generate and detect a rectangular, linear set of values (one set for I and an independent set for Q). The constellation diagram displays phase errors, as well as amplitude errors, at the decision points. The transition between the decision points affects transmitted bandwidth. This display shows the path the carrier is taking but does not explicitly show errors at the decision points. Constellation diagrams provide insight into varying power levels, the effects of filtering, and phenomena such as Inter-Symbol Interference. The relationship between constellation points and bits per symbol is $M=2^n$, where M = number of constellation points & n = bits/symbol or $n = \log_2(M)$ This holds when transitions are allowed from any constellation point to any other.

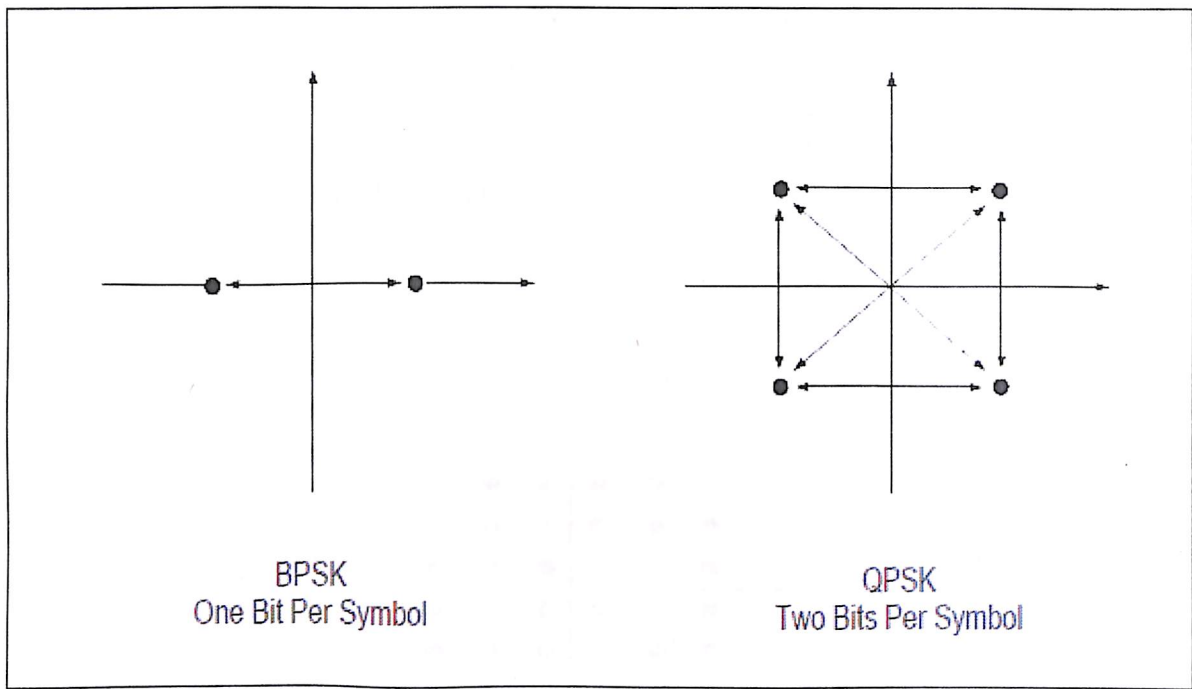


Fig. 2.4 Constellation Diagram For Bi-Phase Shift Keying And Quadrature Phase Shift Keying

BPSK: The I state has two different values. There are two possible locations in the state diagram, so a binary one or zero can be sent. The symbol rate is one bit per symbol.

QPSK: Only two I values and two Q values are needed and this gives two bits per symbol. There are four states because $2^2 = 4$. It is therefore a more bandwidth-efficient type of modulation than BPSK, potentially twice as efficient.

2.2.1 Quadrature Amplitude Modulation

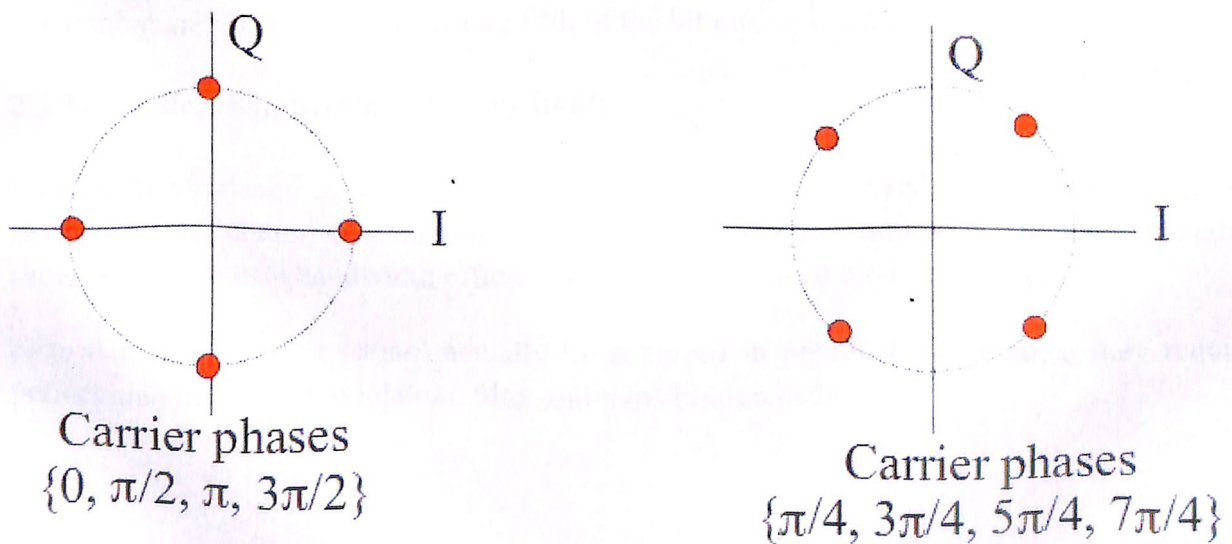


Fig. 2.5 QAM

Quadrature amplitude modulation: It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components — hence the name of the scheme.

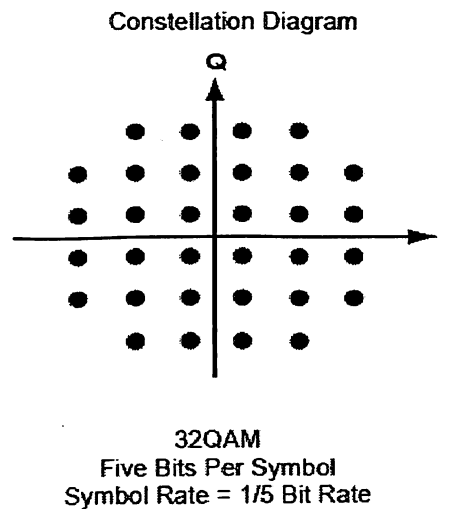


Fig. 2.5 The constellation diagram of 32 QAM

In 32 QAM there are six I values and six Q values resulting in a total of 36 possible states ($6 \times 6 = 36$). This is too many states for a power of two (the closest power of two is 32). So the four corner symbol states, which take the most power to transmit, are omitted. This reduces the amount of peak power the transmitter has to generate. Since $2^5 = 32$, there are five bits per symbol and the symbol rate is one fifth of the bit rate

2.3 Theoretical bandwidth efficiency limits

Bandwidth efficiency describes how efficiently the allocated bandwidth is utilized or the ability of a modulation scheme to accommodate data, within a limited bandwidth. This table shows the theoretical bandwidth efficiency limits for the main modulation types.

Note that these figures cannot actually be achieved in practical radios since they require perfect modulators, demodulators, filter and transmission paths.

Modulation format	Theoretical bandwidth efficiency limits
MSK	1 bit/second/Hz
BPSK	1 bit/second/Hz
QPSK	2 bits/second/Hz
8PSK	3 bits/second/Hz
16 QAM	4 bits/second/Hz
32 QAM	5 bits/second/Hz
64 QAM	6 bits/second/Hz
256 QAM	8 bits/second/Hz

Table 2.1 Theoretical Bandwidth

If the radio had a perfect (rectangular in the frequency domain) filter, then the occupied bandwidth could be made equal to the symbol rate.

Techniques for maximizing spectral efficiency include the following:

- Relate the data rate to the frequency shift (as in GSM).
- Use pre modulation filtering to reduce the occupied bandwidth.
Raised cosine filters, as used in NADC, PDC, and PHS give the best spectral efficiency.
- Restrict the types of transitions.

2.4 Digital Modulation Type-Variation

The modulation types outlined above form the building blocks for many systems. There are three main variations on these basic building blocks that are used in communications systems: I/Q offset modulation, differential modulation, and constant envelope modulation.

2.4.1 I/Q Offset Modulation

The first variation is offset modulation. One example of this is offset QPSK (OQPSK). This is used in the cellular CDMA (Code Division Multiple Access) system for the reverse (mobile to base) link.

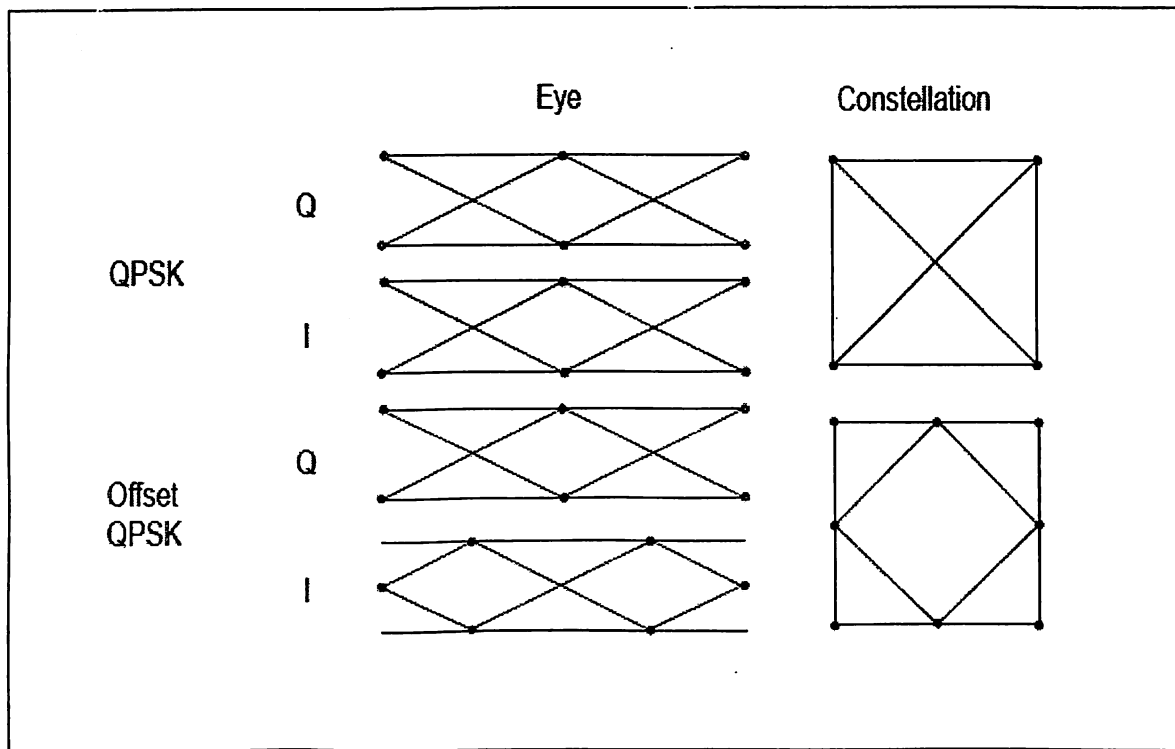


Fig. 2.6 Offset Modulation.

In QPSK, the I and Q bit streams are switched at the same time. The symbol clocks, or the I and Q digital signal clocks, are synchronized. In Offset QPSK (OQPSK), the I and Q bit streams are offset in their relative alignment by one bit period (one half of a symbol period). Since the transitions of I and Q are offset, at any given time only one of the two bit streams can change values. This creates a dramatically different constellation, even though there are still just two I/Q values. This has power efficiency advantages. In OQPSK the signals trajectories are modified by the symbol clock offset so that the carrier amplitude does not go through or near zero (the center of the constellation). The spectral efficiency is the same with two I states and two Q states. The reduced amplitude variations (perhaps 3 dB for OQPSK, versus 30 to 40 dB for QPSK) allow a more power-efficient, less linear RF power amplifier to be used.

2.4.2 Differential modulation:

The second variation is differential modulation as used in differential QPSK (DQPSK) and differential 16QAM (D16QAM). Differential means that the information is not carried by the absolute state, it is carried by the transition between states. In some cases there are also restrictions on allowable transitions. This occurs in $1/4$ DQPSK where the carrier trajectory does not go through the origin. A DQPSK transmission system can transition from any symbol position to any other symbol position. The $1/4$ DQPSK modulation format is widely used in many applications including

- Cellular
 - NADC- IS-54 (North American digital cellular)
 - PDC (Pacific Digital Cellular)

- Cordless
 - PHS (personal handy phone system)
- Trunked radio
 - TETRA (Trans European Trunked Radio)

The $\pi/4$ DQPSK modulation format uses two QPSK constellations offset by 45 degrees ($\pi/4$ radians). Transitions must occur from one constellation to the other. This guarantees that there is always a change in phase at each symbol, making clock recovery easier. The data is encoded in the magnitude and direction of the phase shift, not in the absolute position on the constellation. One advantage of $\pi/4$ DQPSK is that the signal trajectory does not pass through the origin, thus simplifying transmitter design. Another is that $\pi/4$ DQPSK, with root raised cosine filtering, has better spectral efficiency than GMSK, the other common cellular modulation type.

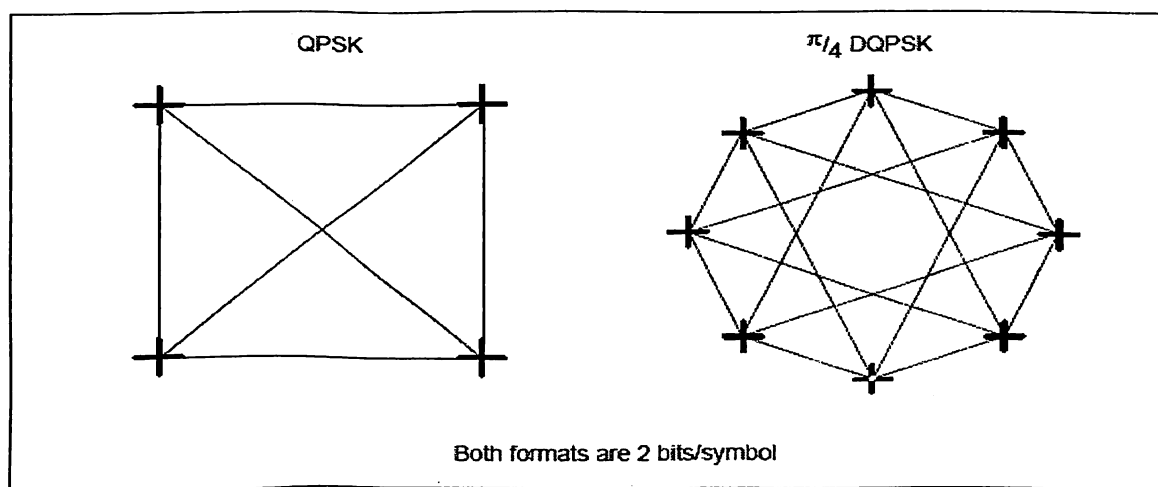


Fig. 2.7 Formats of DPQSK & QPSK

2.4.3 Constant Amplitude Modulation

The third variation is constant-envelope modulation. GSM uses a variation of constant amplitude modulation format called 0.3 GMSK (Gaussian Minimum Shift Keying).

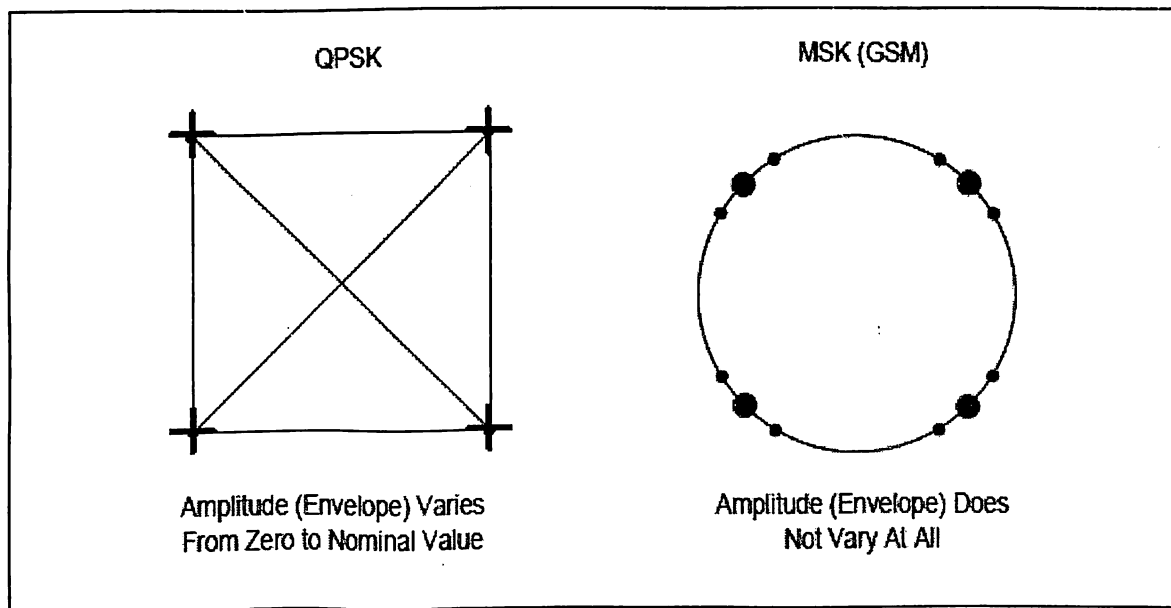


Fig. 2.8 Constant Amplitude Modulation

In constant-envelope modulation the amplitude of the carrier is constant, regardless of the variation in the modulating signal. It is a power-efficient scheme that allows efficient class-C amplifiers to be used without introducing degradation in the spectral occupancy of the transmitted signal. However, constant-envelope modulation techniques occupy a larger bandwidth than schemes which are linear. In linear schemes, the amplitude of the transmitted signal varies with the modulating digital signal as in BPSK or QPSK. In systems where bandwidth efficiency is more important than power efficiency, constant envelope modulation is not as well suited. MSK is a special type of FSK where the peak-to-peak frequency deviation is equal to half the bit rate. GMSK is a derivative of MSK where the bandwidth required is further reduced by passing the modulating waveform through a Gaussian filter. The Gaussian filter minimizes the instantaneous frequency variations over time. GMSK is a spectrally efficient modulation scheme and is particularly useful in mobile radio systems. It has a constant envelope, spectral efficiency, good BER performance and is self-synchronizing.

CHAPTER 3.

BIT ERROR RATE

3.1 Terminology

BIT RATE: Bit rate is the number of bits that are conveyed or processed per unit of time.

SYMBOL RATE: In digital communications, symbol rate (also known as baud or modulation rate) is the number of symbol changes (waveform changes or signaling events) made to the transmission medium per second using a digitally modulated signal or a line code.

- The signal bandwidth for the communications channel needed depends on the symbol rate, not on the bit rate.
- Symbol rate is sometimes called baud rate.

$$\text{Symbol rate} = \frac{\text{bit rate}}{\text{the number of bits transmitted with each symbol}}$$

BIT RATE ERROR: In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors.

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage.

$$BER = \frac{\text{Error}}{\text{Total number of bit}}$$

BER is a measure of signal quality. The bit error rate is the function of the bit energy per noise density (E_b/N_0). It is the measure of the digital link.

Maximum Power Flux Density,

$$\Psi_M = \frac{GP_S}{4\pi r^2} \tag{3.1}$$

Where G is the gain of antenna, r is the distance from antenna and P_S is the transmitting power.

EQUIVALENT ISOTROPIC RADIATED POWER:

$$EIRP = GP_S \tag{3.2}$$

GAIN OF PARABOLIC ANTENNA:

$$G = \eta (3.192fD)^2 \quad (3.3)$$

POWER RECEIVED BY MATCHED RECEIVER:

$$\begin{aligned} P_R &= \Psi_M A_{\text{eff}} \\ &= \frac{\text{EIRP}}{4\pi r^2} \frac{\lambda^2 G_R}{4\pi} \\ &= (\text{EIRP}) (G_R) \left(\frac{\lambda}{4\pi r} \right)^2 \end{aligned} \quad (3.4)$$

RECEIVED POWER IN dBW:

$$[P_R] = [\text{EIRP}] + [G_R] - 10 \log \left(\frac{4\pi r}{\lambda} \right)^2 \quad (3.5)$$

FREE SPACE LOSS:

$$[\text{FSL}] = 10 \log \left(\frac{4\pi r}{\lambda} \right)^2 \quad (3.6)$$

LOSS FOR CLEAR SKY CONDITION:

$$[\text{LOSSES}] = [\text{FSL}] + [\text{RFL}] + [\text{AML}] + [\text{AA}] + [\text{PL}] \quad (3.7)$$

Thus

$$[P_R] = [\text{EIRP}] + [G_R] - [\text{LOSSES}] \quad (3.8)$$

NOISE POWER FROM A THERMAL NOISE SOURCE

$$P_N = kT_N B_N \quad (3.9)$$

T_N = Equivalent Noise Temperature,

B_N = Equivalent Noise Bandwidth,

k = Boltzmann's Constant

$$k = 1.38 \times 10^{-23} \text{ J/K} \quad (3.10)$$

NOISE POWER SPECTRAL DENSITY, N_0 :

$$N_0 = \frac{P_N}{B_N} = kT_N \text{ joules} \quad (3.11)$$

CARRIER TO NOISE RATIO, C/N:

$$\left[\frac{C}{N} \right] = [P_R] - [P_N] \quad (3.12)$$

$$\left[\frac{C}{N_0} \right] = \left[\frac{C}{N} \right] + [B_N] \quad (3.13)$$

Where N_0 = Noise Power Spectral Density

B_N = Noise Bandwidth.

3.2 Methodology

- Detailed study of digital modulation schemes will be completed.
- Parameters required for digital modulation will be calculated.
- Calculation for efficient modulation scheme.
- Comparison of modulation scheme to find the efficient scheme.
- Simulated result & graph in MATLAB

3.3 Calculations

Formula for calculating transmitted power and BER. Carrier to Noise ratio is

A measure of the performance of a satellite link is the ratio of carrier power to noise power at the receiver input, and the link budget calculations are often concerned with determining this ratio. Conventionally, the ratio is denoted by C/N (or CNR) which is equivalent to PR/PN.

In terms of decibels,

$$\left[\frac{C}{N} \right] = [P_R] - [P_N] \quad (3.14)$$

Substituting previously derived equations

$$\left[\frac{C}{N} \right] = [EIRP] + [G_R] - [LOSSES] - [k] - [T_S] - [B_N] \quad (3.15)$$

The G/T ratio is a key parameter in specifying the receiving system performance. The antenna gain GR and the system noise temperature TS can be combined as

$$\left[\frac{G_R}{T_S} \right] = [G_R] - [T_S] \quad (3.16)$$

Therefore the link equation becomes

$$\left[\frac{C}{N} \right] = [EIRP] + \left[\frac{G_R}{T_S} \right] - [LOSSES] - [k] - [B_N] \quad (3.17)$$

The ratio of carrier power to noise power density P_R/N_0 may be the quantity actually required. Since $P_N = k \times T_N \times B_N = N_0 \times B_N$, then

$$\left[\frac{C}{N} \right] = \left[\frac{C}{N_0 \times B_N} \right] = \left[\frac{C}{N_0} \right] - [B_N] \quad (3.18)$$

And therefore

$$\left[\frac{C}{N_0} \right] = \left[\frac{C}{N} \right] + [B_N] \quad (3.19)$$

$[C/N]$ is a true power ratio in units of decibels; $[B_N]$ is in decibels relative to one hertz, or dBHz. Thus the units for $[C/N_0]$ are dBHz.

Substituting for $[C/N]$ gives

$$\left[\frac{C}{N_0} \right] = [EIRP] + \left[\frac{G_R}{T_S} \right] - [LOSSES] - [k] \quad (3.20)$$

- $E_b = P_{avg} / R_b$
- $E_b = P \cdot \tau$
- $N_0 = P_n / B_n$

3.3.1 Assumed Calculatons

Transmitted Power for PSK

$$s(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t) \quad (3.21)$$

Take $E_b = 10^6$

$$T_b = 1/f_c$$

$$F_c = 300 \text{ MHz and } 500 \text{ MHz}$$

$$t = 0.00001, 0.00002, 0.00003$$

For 300 MHz $s(t) = -12.3\text{Db}, -12.3\text{Db}, 24.6\text{Db}$

For 500 MHz $s(t) = 5.4\text{Db}, 5.4\text{Db}, -15.8\text{Db}$

Theoretical value of BER for PSK:

E_b / N_0	BER
0	0.0786 e
1	0.0562
2	0.0375
3	0.0228

$$P_e(BER) = \frac{1}{2} \operatorname{erfc} \sqrt{\frac{E_b}{N_c}} \quad (3.22)$$

4	0.0125
5	0.0059
6	0.0023
7	7.72E-4
8	1.90E-4
9	3.36E-5
10	3.87E-6
11	2.61E-7
12	9.00E-9
13	1.33E-10
14	6.81E-13
15	9.12E-16
16	2.26E-19
17	6.75E-24

Theoretical Value of BER for FSK.

$$P_e(BER)_{forFSK} = \frac{1}{2} \operatorname{erfc} \sqrt{\frac{E_b}{2N_c}} \quad (3.23)$$

E_b / N_0	BER
0	0.1482
1	0.1309
2	0.1040
3	0.0788
4	0.0564
5	0.0376
6	0.0230
7	0.0125
8	0.0060
9	0.0024
10	7.82E-4
11	1.93E-4
12	3.43E-5
13	3.96E-6
14	2.69E-7
15	9.36E-9
16	1.39E-10
17	6.92E-13
18	5.95E-16

Theoretical Value of BER for QPSK

$$P_e(BER)_{forFSK} = \frac{1}{2} \operatorname{erfc} \sqrt{\frac{E_b}{2N_c}} \quad (3.24)$$

E_b / N_0	BER
0	0.0786
1	0.0562
2	0.0375
3	0.0228
4	0.0125
5	0.0059
6	0.0023
7	7.72E-4
8	1.90E-4
9	3.36E-5
10	3.87E-6
11	2.61E-7
12	9.00E-9
13	1.33E-10
14	6.81E-13
15	9.12E-16
16	2.26E-19
17	6.75E-24
18	1.39E-29

Theoretical Value of BER for QPSK.

$$P_e(BER)_{for\ QFSK} = \frac{1}{2} \operatorname{erfc} \sqrt{\frac{E_b}{N_o}} \quad (3.25)$$

E_b / N_o	BER
0	0.0786
1	0.0562
2	0.0375
3	0.0228
4	0.0125
5	0.0059
6	0.0023
7	7.72E-4
8	1.90E-4
9	3.36E-5
10	3.87E-6
11	2.61E-7
12	9.00E-9
13	1.33E-10
14	6.81E-13
15	9.12E-16
16	2.26E-19
17	6.75E-24
18	1.39E-29

Theoretical Value of BER for MSK

$$P_e(BER)_{forMSK} = \frac{1}{2} \operatorname{erfc} \sqrt{\frac{E_b}{2N_o}} \quad (3.26)$$

E_b/N_o	BER
0	0.1449
1	0.1062
2	0.0721
3	0.0447
4	0.0246
5	0.0118
6	0.0047
7	0.0015
8	3.81E-4
9	6.72E-5
10	7.74E-6
11	5.22E-7
12	1.80E-8
13	2.66E-10
14	1.36E-12
15	1.82E-15
16	4.53E-19
17	1.35E-23
18	2.79E-29

3.3.2 Bit Error Rate Graph

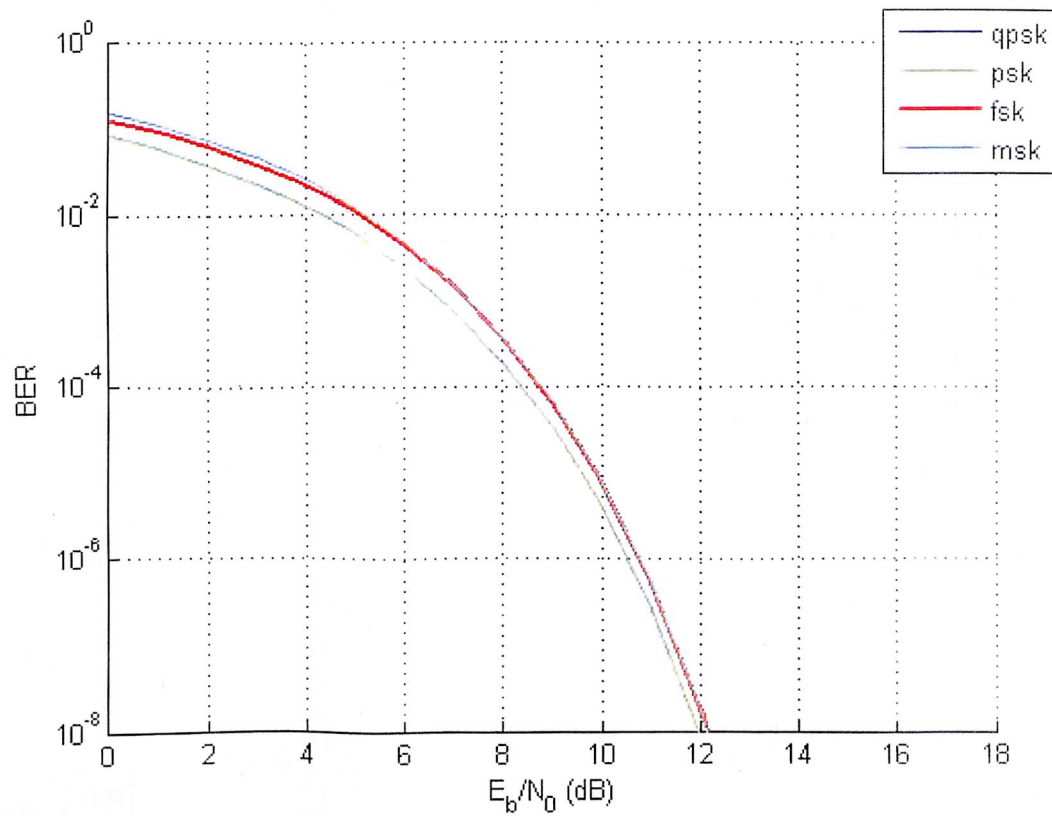


Fig. 3.1 Probability Error Graph on the basis of Assumed calculation.

CHAPTER 4

RESULTS & CALCULATIONS

4.1 Bit Error Rate Graph

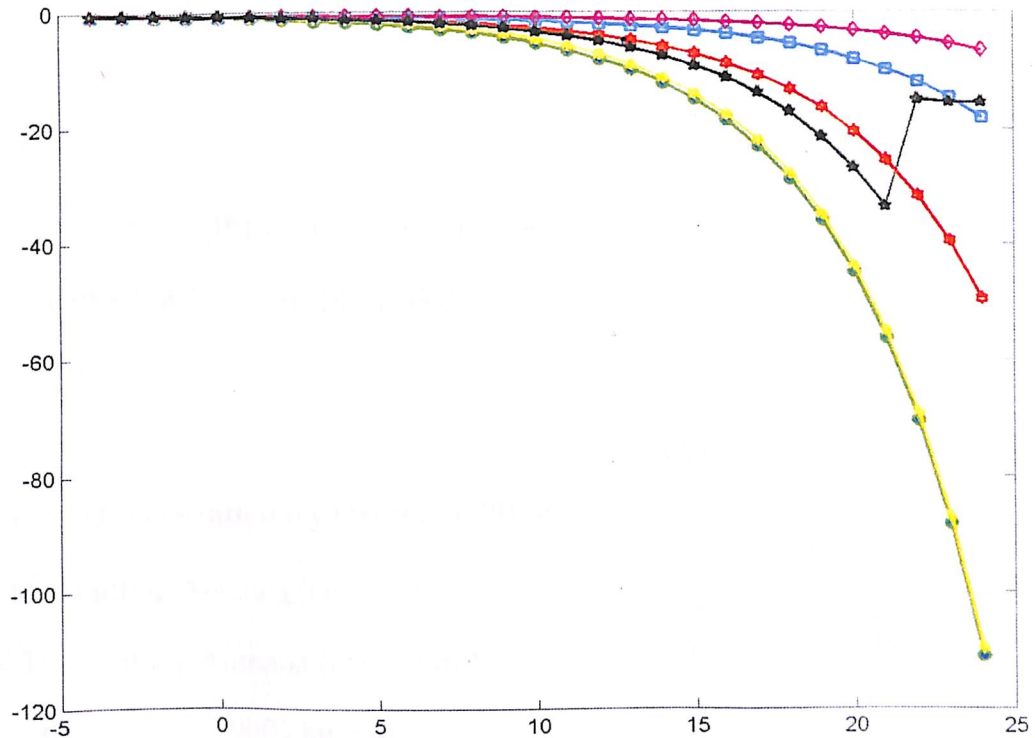


Fig. 4.1 Bit Error Rate Graph

4.2 Practical Calculations

4.2.1 For LEO (Low Earth Orbit Satellite)

Gain for transmitting Antenna (G_t) = 50dB

Power of Transmitting Antenna (P_t) = 10kw

Frequency (w) = 0.6m/sec or 0.0006 km/sec

Aperture area (A_e) = 2m

Free space loss = $10\log(4\pi/w)^2$

AML = 2dB

AML = 0

$$AA = 2\text{dB}$$

$$PL = 0$$

$$RFL = 2\text{dB}$$

$$\text{EIRP} = G_t * P_t$$

$$K = -288.6$$

$$B_n = 10 \text{ dB}$$

$$G/T = 30\text{dB}$$

$$\text{Received Power (Pr)} = [P_t] + [G_t] + [G_r] - [\text{Losses}]$$

$$[C/N] = [\text{EIRP}] + [G/T] - [\text{Losses}] - [K] - [B_n]$$

$$[C/N_o] = [C/N] + [B_n]$$

$$E_b/N_o = [C/N_o]$$

4.2.2 For GEO (Geostationary Orbit Satellite):

$$\text{Gain for transmitting Antenna (Gt)} = 50\text{dB}$$

$$\text{Power of Transmitting Antenna (Pt)} = 10\text{mW}$$

$$\text{Freq (w)} = 0.6\text{m/sec or } 0.0006 \text{ km/sec}$$

$$\text{Aperture area (Ae)} = 2\text{m}$$

$$\text{Free space loss} = 10\log(4\pi r/w)^2$$

$$AML = 2\text{dB}$$

$$AML = 0$$

$$AA = 2\text{dB}$$

$$PL = 2\text{dB}$$

$$RFL = 2\text{dB}$$

$$\text{EIRP} = G_t * P_t$$

$$K = -288.6$$

$$B_n = 10 \text{ dB}$$

$$G/T = 30\text{dB}$$

$$\text{Received Power (Pr)} = [P_t] + [G_t] + [G_r] - [\text{Losses}]$$

$$[C/N] = [EIRP] + [G/T] - [\text{Losses}] - [K] - [Bn]$$

$$[C/No] = [C/N] + [Bn]$$

$$Eb/No = [C/No]$$

4.2.3 Matlab Programing:

This Matlab Code is help to find the following Values:-

1. EIRP
2. Gain of received antenna (Gr) for LEO
3. Gain of received antenna (Gr) for GEO
4. Free Space Loss (FSL)
5. Eb/No for LEO
6. Eb/No for GEO
7. Error Function (erfc)
8. For LEO
 - i. Probability error for MSK
 - ii. Probability error for PSK
 - iii. Probability error for FSK
9. For GEO
 - i. Probability error for MSK
 - ii. Probability error for PSK
 - iii. Probability error for FSK
10. Graph for MSK, PSK, FSK with semilog and with semilog

4.3 Graphs

4.3.1 For Geostationary Earth Orbit (GEO)

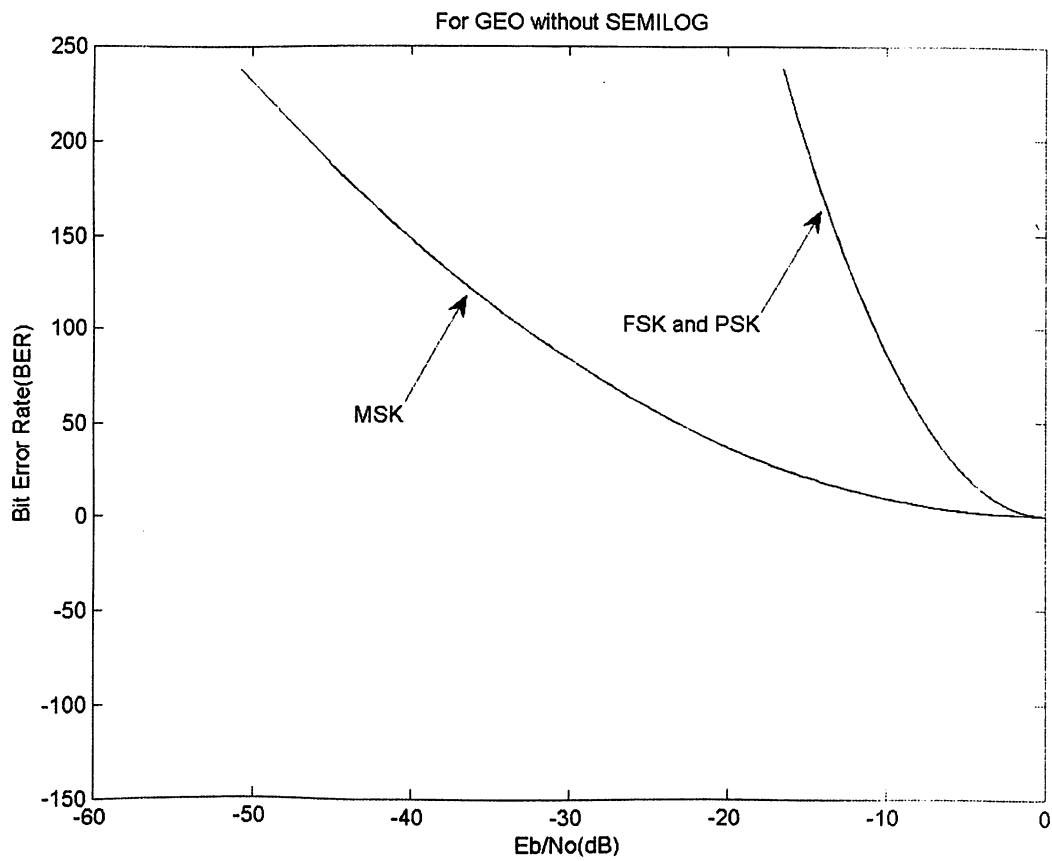


Fig. 4.2 For GEO without SEMILOG

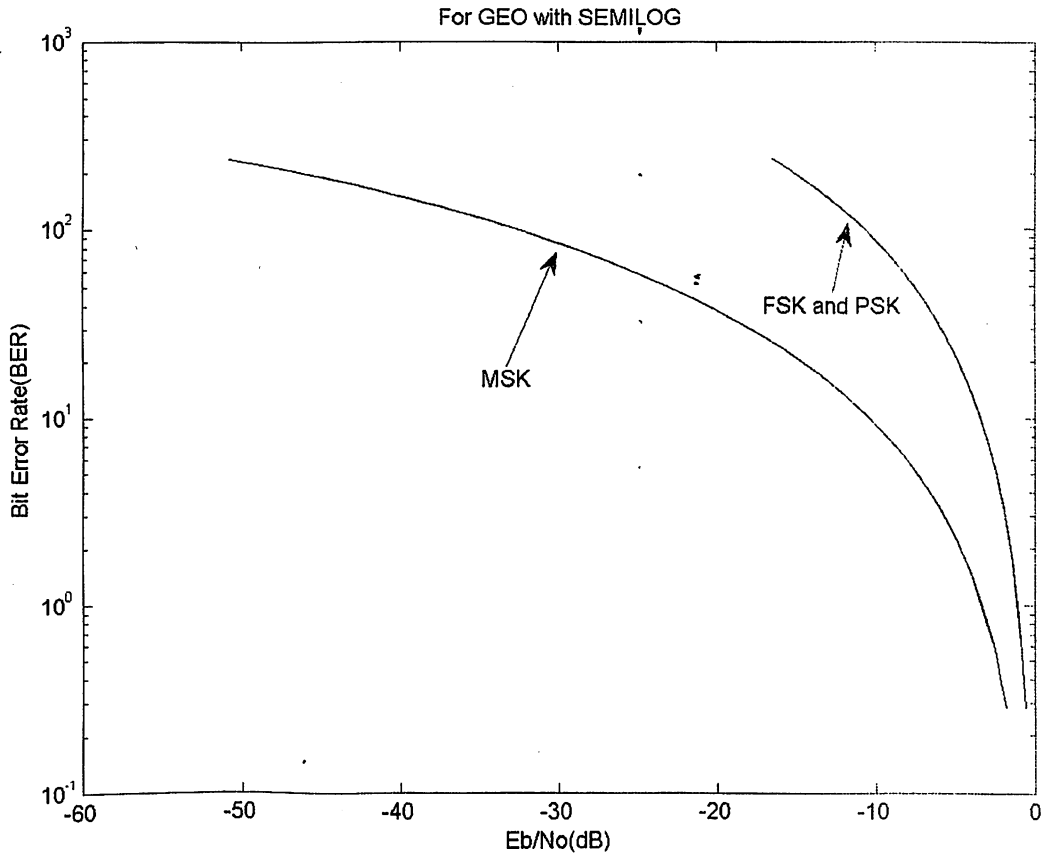


Fig.4.3 For GEO with SEMILOG

4.3.2 For Low Earth Orbit (LEO)

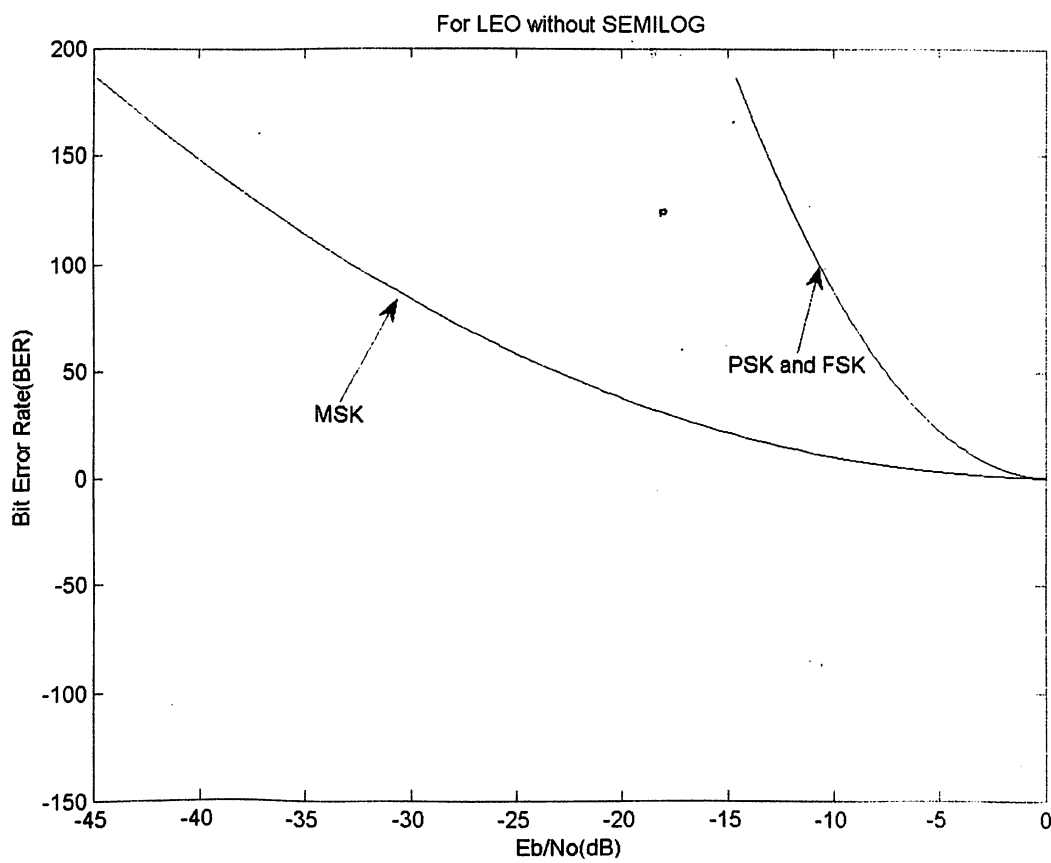


Fig. 4.4 For LEO without SEMILOG

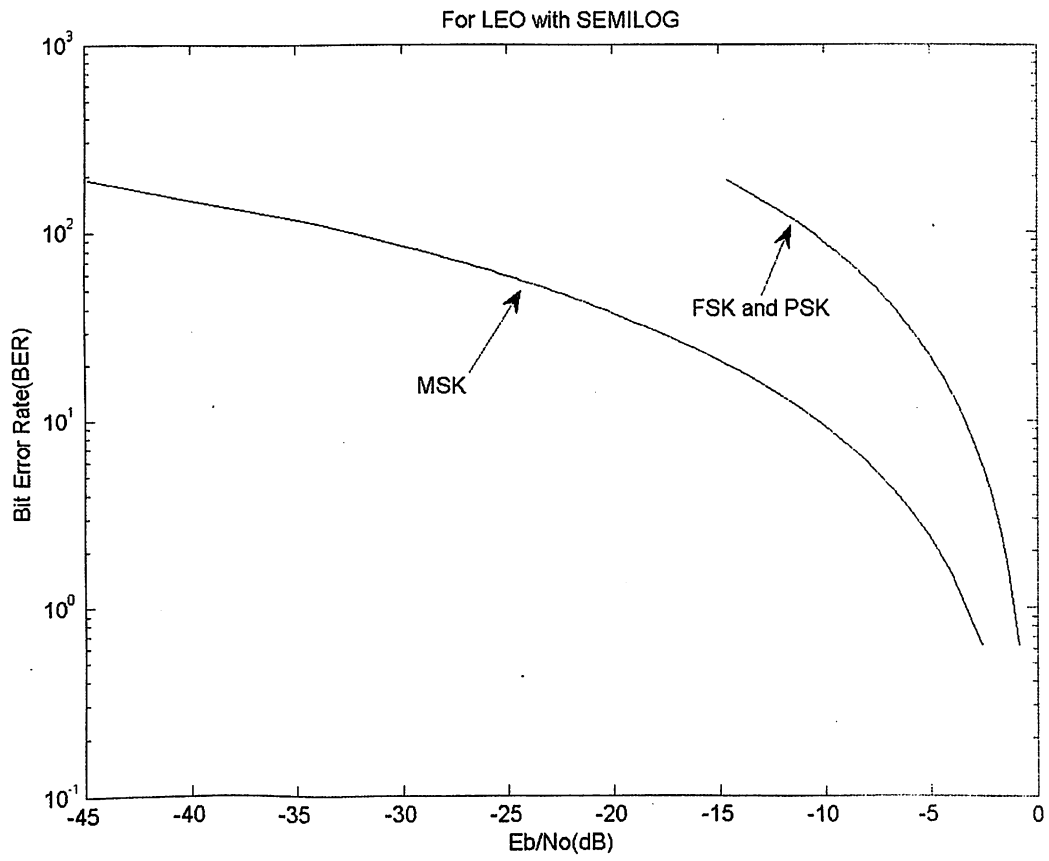


Fig. 4.5 For LEO with SEMILOG

4.4 Range Vs Power Graph

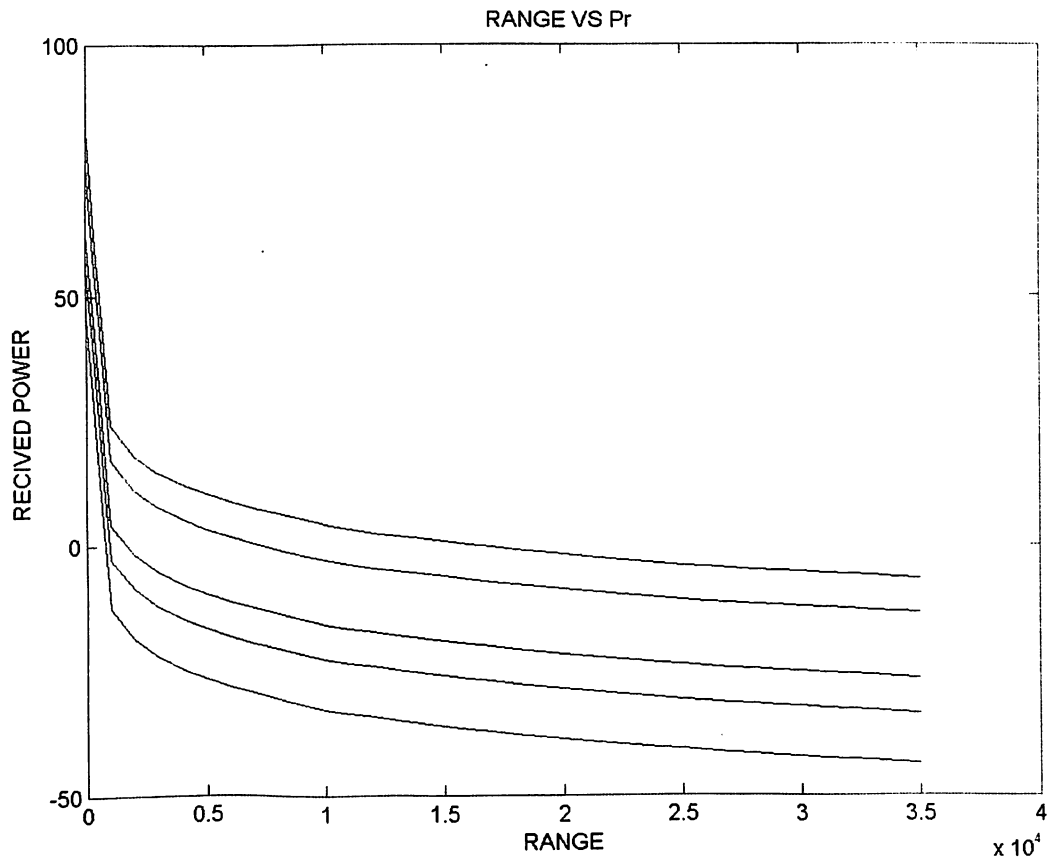


Fig. 4.6 Range vs Pr

CHAPTER 5

CONCLUSION & FUTURE WORK

5.1 Conclusion

All the types of digital modulation schemes are discussed at a stretch along with their power requirements. The resultant received power is calculated for different kinds of space links ranging for low earth orbits to geo stationary ones. Also these power calculations are made for different frequency bands namely C, Ka and Ku bands which are generally used for space communications. Power calculations are done for free space (taking into consideration free space path loss) assuming all the other losses to be negligible. As it can be concluded from the graphs that minimum shift keying (MSK) scheme is more advantageous than FSK & PSK schemes. As the free space path loss increases with frequency and range linearly at higher frequencies (Ku and Ka bands) and at geo stationary distances the loss will be even more pronounced.

It is evident from the graph that is plotted between received power and range (for different frequencies) that when distance increases because of the decrease in received power it is important to pick the modulation which has got less bit error probability to reconstruct the message properly in the exact manner.

As a matter of fact, a reference commercial BER plot is taken which is compared with the coded values for all the 3 modulation schemes. Bit Error Rate of MSK is less than FSK & PSK at low E_b/N_0 values. The plotted BER graphs indicate the above said things. It is purposefully studied and analyzed in this project the effect of un-coded modulated schemes for different values of transmitted power and range. Throughout the discussion channel (free space) existent between the transmitter and receiver is assumed to an additive white Gaussian noise one AWGN).

5.2 Future Work And Scope

This work further can be extended for deep space communication networks and also for stellar communications taking into consideration different kinds of noise sources available in the given channel space. Also the error rate can be calculated for different characteristic kinds of channels such as Rayleigh, Rician and Markov channels. Also this can further be converted into designing an efficient encoding algorithm for digital space communications. A combination of coding scheme with different modulation schemes need to be carried out to check the best combination for a given frequency. The random sources in space have to be mathematically modeled to understand their effect on the message signal.

REFERENCES

1. **Dennis, Roddy** *Space Link. Satellite Communications*. 3rd edition, McGraw Hill, USA, 2001, ISBN: 0-07-120240-4.
2. **Timothy, Prattetal** *Orbital Mechanics. Satellite Communications*. Copyright©2003, ISBN: 9814-12-684-5.
3. **Tri, T. Ha** *Digital Satellite Communication*, 2nd edition, McGraw Hill, ISBN-13: 978-0-07-007752.
4. **Gerard, Maral and Michel Bousquet** *Satellite Communication Systems*. 5th edition, John Wiley, UK, 2002.
5. **Pecar, J. A.** *The New McGraw-Hill Telecom Factbook*. McGraw-Hill, New York, 2000, ISBN: 0-07-135163-9.
6. **Bryant, Jeff and Pavlyk, Oleksandr** "Kepler's Second Law". *Wolfram Demonstrations Project*. Retrieved December 27, 2012.
7. Holton, Gerald James and Brush, Stephen G. *Physics, the Human Adventure: From Copernicus to Einstein and Beyond* (3rd paperback ed.). Piscataway, NJ: Rutgers University Press. pp. 40–41. ISBN 0-8135-2908-5. Retrieved November 15, 2012.

Website References:

1. www.radartutorial.eu/druck/Book5.pdf (12.11.2012)
2. http://www.ijens.org/vol_11_i_04/110904-3232-ijecs-ijens.pdf (24.10.2012)
3. <http://www.studymode.com/subjects/microwave-link-design-page3.html> (16.4.2013)

APPENDIX

Link Budget Analysis Graph For Space Communication

Matlab Program 1

```
EbN0dB=-4:1:24;

EbN0lin=10.^(EbN0dB/10);
colors={'b-*','g-o','r-h','c-s','m-d','y-*','k-p','b--&gt;','g.<','r-d'};
index=1;

%BPSK
BPSK = 0.5*erfc(sqrt(EbN0lin));
plotHandle=plot(EbN0dB,log10(BPSK),char(colors(index)));
set(plotHandle,'LineWidth',1.5);
hold on;

index=index+1;

%M-PSK
m=2:1:5;
M=2.^m;
for i=M,
    k=log2(i);
    berErr = 1/k*erfc(sqrt(EbN0lin*k)*sin(pi/i));
    plotHandle=plot(EbN0dB,log10(berErr),char(colors(index)));
    set(plotHandle,'LineWidth',1.5);
    index=index+1;
end

%Binary DPSK
Pb = 0.5*exp(-EbN0lin);
plotHandle = plot(EbN0dB,log10(Pb),char(colors(index)));
set(plotHandle,'LineWidth',1.5);
index=index+1;

%Differential QPSK
a=sqrt(2*EbN0lin*(1-sqrt(1/2)));
b=sqrt(2*EbN0lin*(1+sqrt(1/2)));
Pb = marcumq(a,b,1)-1/2.*besseli(0,a.*b).*exp(-1/2*(a.^2+b.^2));
plotHandle = plot(EbN0dB,log10(Pb),char(colors(index)));
set(plotHandle,'LineWidth',1.5);
index=index+1;

%M-QAM
m=2:2:6;
M=2.^m;

for i=M,
    k=log2(i);
```

```

berErr = 2/k*(1-1/sqrt(i))*erfc(sqrt(3*EbN0lin*k/(2*(i-1))));
plotHandle=plot(EbN0dB,log10(berErr),char(colors(index)));
set(plotHandle,'LineWidth',1.5);
index=index+1;
end

```

```

legend('BPSK','QPSK','8-PSK','16-PSK','32-PSK','D-BPSK','D-QPSK','4-QAM','16-
QAM','64-QAM');
axis([-4 24 -8 0]);
set(gca,'XTick',-4:2:24); %re-name axis accordingly
ylabel('Probability of BER Error - log10(Pb)');
xlabel('Eb/N0 (dB)');
title('Probability of BER Error log10(Pb) Vs Eb/N0');

```

```

grid on;

```

Practical Calculation For Link Budget Analysis

Matlab Program 2

Ps = 10 % in Kilowatt

G = 50 % in dB

EIRP = G*Ps

EIRPdB = 10*log10(EIRP)

range = 1:500

w = 0.0006 % wavelength

Ae = 2 % apperture aera

Gr1 = ((4*3.14)/w^2)*2

FSL = 10 .* (log10(((4*3.14).*range)./w).^2) % free space loss

%for leo

Pt1 = 10*log10(10)

AML1 = 2

AA = 2

RFL = 2

Pr = (Pt1) + (G) + (Gr1) - [(FSL) + (AML1) + (AA) + (RFL)]

% for geo

Pt2 = 10*log10(10^6)

AML2 = 0

PL = 0

Pr = (Pt2) + (G) + (Gr1) - [(FSL) + (AML2) + (AA) + (PL) + (RFL)]

% [C/N] for leo

G_T = 30 % it [G/T]

K = -288.6

Bn = 10

C_N1 = (Pt1) + (G) + G_T - [(FSL) + (AML1) + (AA) + (RFL)] - (K) - (Bn)

C_No1 = C_N1 + 10*log10(Bn)

EbNoleo = C_No1;

el=abs(EbNoleo);

%for geo

C_N2 = (Pt2) + (G) + (G_T) - [(FSL) + (AML2) + (AA) + (PL) + (RFL)] - (K) - (Bn)

C_No2 = C_N2 + 10*log10(Bn)

EbNogeo = C_No2

```

%BER Calculation
Eb = -225
syms t
erf = (2*sqrt(pi)) * int(exp(-t^2),t,Eb,0)
erfc = 1 - erf
MSK_leo = (erfc.*sqrt(EbNoleo)) - ((0.25) .* (erfc^2) .* sqrt(EbNoleo))
MSK_geo = (erfc.*sqrt(EbNogeo)) - ((0.25) .* (erfc^2) .* sqrt(EbNogeo))
PSK_leo = 0.5.*(erfc .* (sqrt(EbNoleo)))
PSK_geo = 0.5.*(erfc .* (sqrt(EbNogeo)))
FSK_leo = 0.5.*(erfc .* (sqrt(EbNoleo)))
FSK_geo = 0.5.*(erfc .* (sqrt(EbNogeo)))
plot(MSK_leo,EbNoleo)
hold on
plot(PSK_leo,EbNoleo)
hold on
plot(FSK_leo,EbNoleo)
title(' For LEO without SEMILOG')
xlabel('Eb/No(dB)')
ylabel('Bit Error Rate(BER)')
plot(MSK_geo,EbNogeo)
hold on
plot(PSK_geo,EbNogeo)
hold on
plot(FSK_geo,EbNogeo)
title(' For GEO without SEMILOG')
xlabel('Eb/No(dB)')
ylabel('Bit Error Rate(BER)')
figure
semilogy(MSK_leo,EbNoleo)
hold on
semilogy(PSK_leo,EbNoleo)
hold on
semilogy(FSK_leo,EbNoleo)
title(' For LEO with SEMILOG')
xlabel('Eb/No(dB)')
ylabel('Bit Error Rate(BER)')
figure
semilogy(MSK_geo,EbNogeo)
hold on
semilogy(PSK_geo,EbNogeo)
hold on
semilogy(FSK_geo,EbNogeo)
title(' For GEO with SEMILOG')

```

```
xlabel('Eb/No(dB)')
ylabel('Bit Error Rate(BER)')
```

Range Vs Received Power Graph

Matlab Program 3

```
clear all;
range=[1:1000:36000]
f=32
n=0.7
d=70
p1=100
p2=1000
p3=5000
p4=100000
p5=500000

eirp1=10*log10(p1)+10*log10(n*(10.472*f*d)^2)

eirp2=10*log10(p2)+10*log10(n*(10.472*f*d)^2)

eirp3=10*log10(p3)+10*log10(n*(10.472*f*d)^2)

eirp4=10*log10(p4)+10*log10(n*(10.472*f*d)^2)
eirp5=10*log10(p5)+10*log10(n*(10.472*f*d)^2)
gain=63.82
fsl=32.4+20*log10(f*1000)+20.*log10(range)
pr1=eirp1+gain-fsl
pr2=eirp2+gain-fsl
pr3=eirp3+gain-fsl
pr4=eirp4+gain-fsl
pr5=eirp5+gain-fsl

plot (range,pr1)
hold on
plot (range,pr2)
hold on
plot(range,pr3)
hold on
plot (range,pr4)
hold on
plot(range,pr5)
xlabel('RANGE')
ylabel('RECEIVED POWER')
title('RANGE VS Pr')
```