KEMENTERIAN PENGAJIAN TINGGI

BASIC CONCEPT OF DATA COMMUNICATION

NOOR AMANI SALLEH

NORAZUANA TAIB

SHAHRUL RADZI MAD ZAKI

DEPARTMENT OF ELECTRICAL ENGINEERING

BASIC CONCEPT OF DATA COMMUNICATION

Noor Amani Binti Salleh
Nor Azuana Binti Taib
Shahrul Radzi Bin Mad Zaki @ Abdullah

Editor
Noor Amani Binti Salleh
Nor Azuana Binti Taib
Shahrul Radzi Bin Mad Zaki @ Abdullah

Writer
Noor Amani Binti Salleh
Nor Azuana Binti Taib
Shahrul Radzi Bin Mad Zaki @ Abdullah

Designer
Noor Amani Binti Salleh
Nor Azuana Binti Taib
Shahrul Radzi Bin Mad Zaki @ Abdullah

First published 2021

Published by:
POLITEKNIK TUANKU SYED SIRAJUDDIN
Pauh Putra
02600 Arau
Perlis

Acknowledgement

First of all, we are grateful to Allah the Almighty for directing our team on the right path pursuing the requirement of this Basic Concept of Data Communication E-Book . With His greatness and blessings in giving us the convenience and strength, we are able to accomplish this e-book.

We would like to express our g gratitude to our Head Department of Electrical Engineering, Mr Shaffie Bin Husin, who always supported us in grabbing this opportunity. Also higher gratitude to E-Learning teams for giving endless guidance and supports throughout this E-book.

Besides that, we would also like to express our appreciation to all our friends who had supported and encouraged us in completing this E-book directly or indirectly. They also have been there for us through the difficult and crucial times upon the completion of this e-book.

Lastly, this E-book is dedicated to all students especially for electrical engineering students majoring in communication field. Hopefully with the result of this book can provide more understanding related to the basics of communication data.

Abstract

This book is published to provide an initial introduction to the basics of data communication. This book is very suitable for students in the field of communication engineering in particular and electrical engineering students in general. This book is intended as an additional note on the textbook to help students to better understand the subject of data communication. And comes with concise and clear notes to help students understand each topic clearly

This book covers basic data communication system which includes the definition of data communication, Data Terminal Equipment (DTE) and Data Communication Equipment (DCE). Next is data encoding which includes types of data encoding and explanation about digital to digital data encoding.

This book also has a details explanation of digital modulation. This topic contains Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK) and also QPSK / 4-PSK and QAM. Next, this book contains the evaluation of error detection in data transmission and the last topic is the evaluation of quality of data transmission.

List of Contents

List of Contents

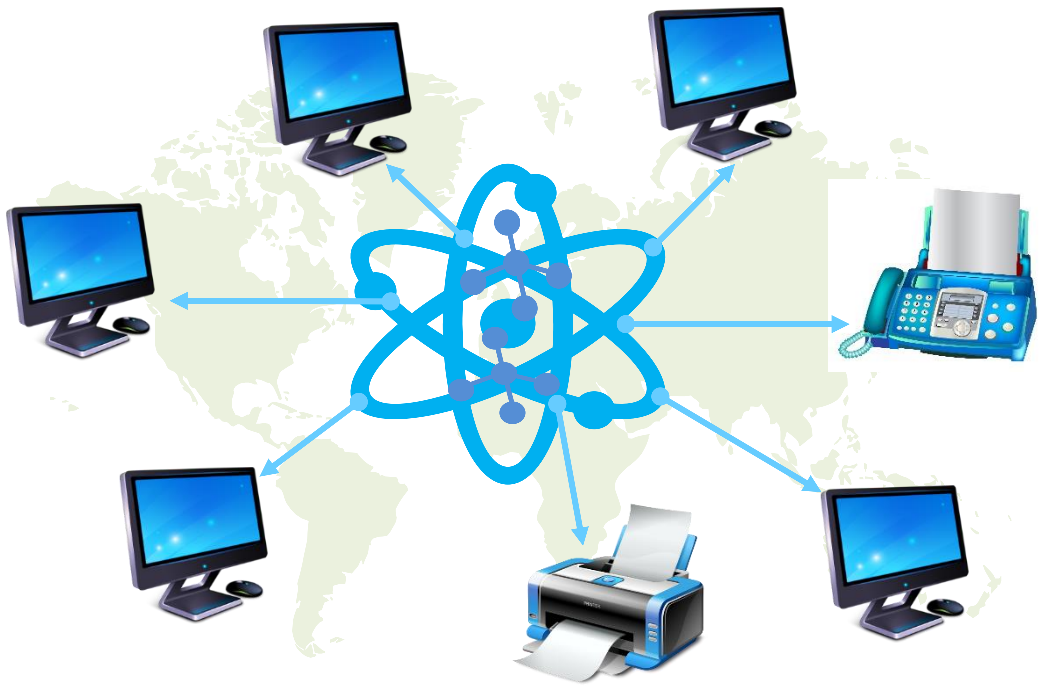
Contents | Page

CHAPTER 01

Basic of Data Communication System

Basic of Data Communication System

Definition Of Data Communication.



Communication is the process of sharing a message. A conversation between two people is an example of communication.

The term data used to describe information, quantities, characters, or symbols on which operations are performed by a computer, which may be stored and transmitted in the form of electrical signals and recorded on magnetic, optical, or mechanical recording media.

Basic of Data Communication System

Data communications refers to the sharing of a virtual message trough transmission of digital data between two or more computers and a computer. The physical connection between networked computing devices is established using either cable media or wireless media. Electronic communications, like emails and instant messages, as well as phone calls are examples of data communications.

Exchangeable of digital data coding between two devices via some form of transmission medium, + The system consists of group up the data, processing the data and transmit the data using a specified communication channel = Data Communication

A basic data communications system consists of 3 parts:

Source / Sender → Medium → Host / Receiver

Source:

It is the transmitter of data.

Examples are:

- Terminal,
- Computer
- Mainframe

Medium:

The communications stream through which the data is being transmitted. Examples are:

- Cabling,
- Microwave,
- Fiber optics,
- Radio Frequencies (RF),
- Infrared Wireless

Destination:

The receiver of the data transmitted. Examples are:

- Printer
- Terminal
- Mainframe
- Computer

Basic Data Communications System

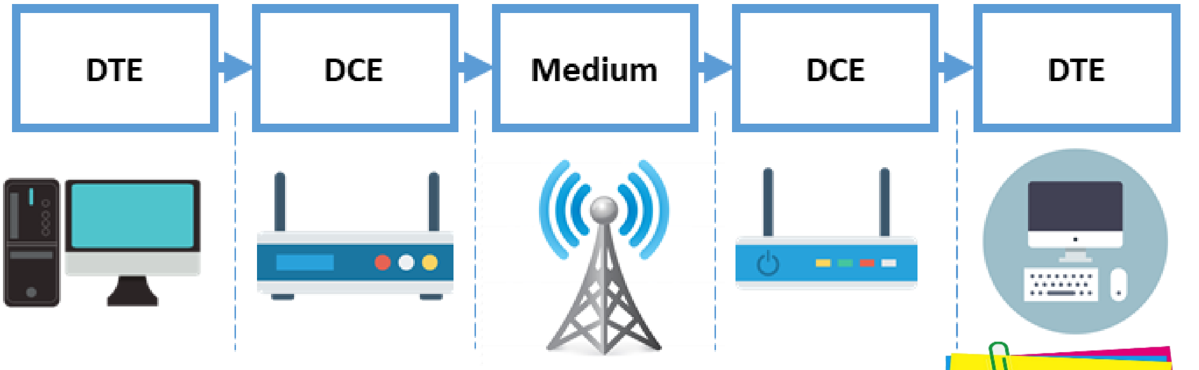
Basic of Data Communication System

The process of transferring data from one location to another is called *Data Communication*. In this process, data is transmitted from one location to another by using transmission media.

Basic of Data Communication System

Data Terminal Equipment (DTE) and Data Communication Equipment (DCE)

Data communications systems are not that simple. Often the source is not able to speak the same communication language as the medium and the data communications needs to be translated into a form that the medium can understand. Data communication is further broken down into the *__Data Communication Model__* which consists of 5 parts:



Data Communication Model

DTE

- A subscriber equipment or user's device for data communications.
- Consists of a source of data or receiving data or both.
- These tools may include an error control, synchronization and identification capabilities of the station.
- Examples of DTE is the computers, logical control, visual display units and work station.

DCE

- Provided by authorities or by client communication network itself.
- DCE is capable of implementing, operating and terminate a data communication, exchanging signals and coding needed to make the relationship between the DTE and data circuits.
- Internal or external parts of a computer.
- Example: a modem or data set

CHAPTER 1

Review Questions

1. Define data communication.

2. Figure 1a show the elements of a basic data communication system in block diagram. Name the labelled block in the figure 1.

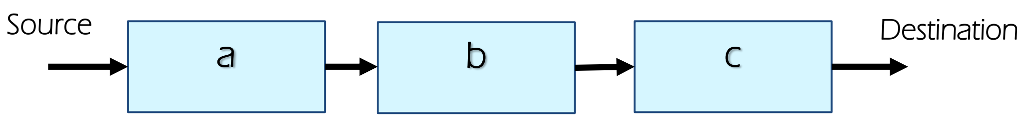


Figure 1

3. Explain the elements of basic data communication with the aids of diagram.
    - i. Source
    - ii. Transmitter
    - iii. Receiver
    - iv. Transmission medium
    - v. Destination

4. Describe Data Terminal Equipment (DTE) and Data Communication Equipment (DCE).

CHAPTER 02

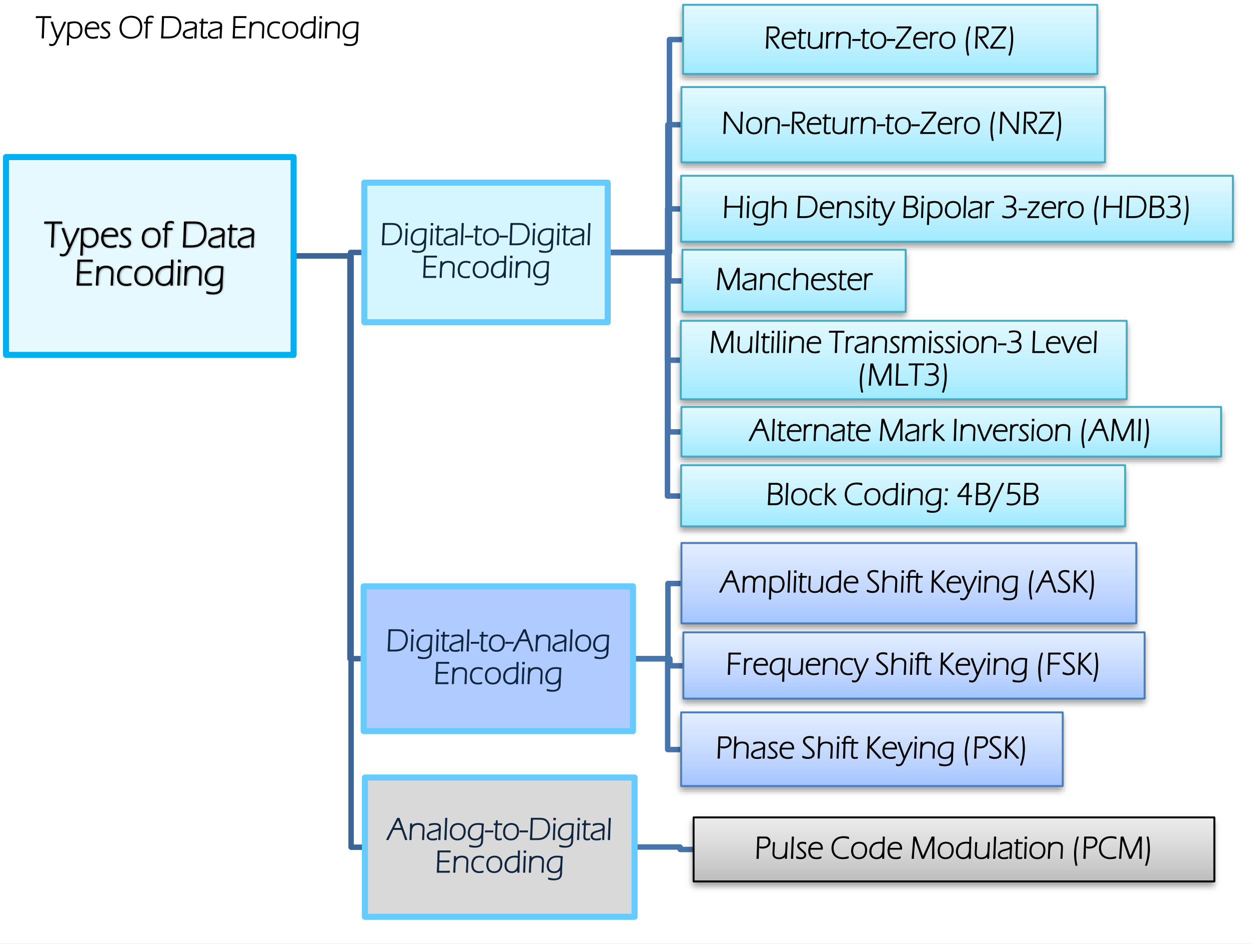
Data Encoding

Data Encoding

Data Encoding refers to the various techniques of representing data (0,1) or information on an electrical, electromagnetic or optical signal that would propagate through the physical medium making up the communication link between the two devices. It is a method by which certain communication devices (such as modems) encode digital data onto an analog signal for transmission.

A converter mechanism is necessary for computer data to be transported over a variety of networks. The most popular of these "converter mechanisms" is a modem.
In computers, encoding is the process of putting a sequence of characters (letters, numbers, punctuation, and certain symbols) into a specialized format for efficient transmission or storage. Decoding is the opposite process where the conversion of an encoded format back into the original sequence of characters. Encoding and decoding are used in data communications, networking, and storage.

Types Of Data Encoding



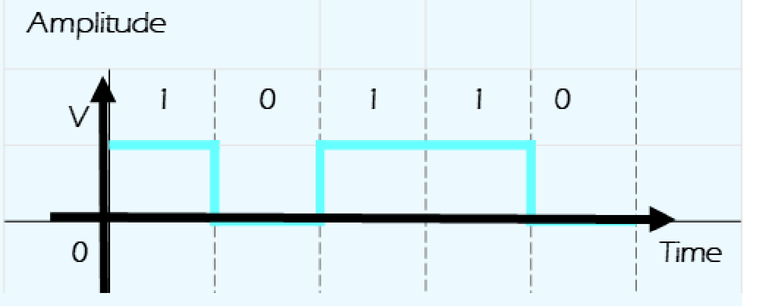
Data Encoding

Unipolar Non-Return-to-Zero (NRZ) encoding

Traditionally, a unipolar scheme was design as a NRZ. In this type of unipolar signaling, a High in data is represented by a positive pulse called as **Mark**, which has a duration T_0 equal to the symbol bit duration. A Low in data input has no pulse.

0 = Low voltage level (0V)

1 = High voltage level (+V volts)



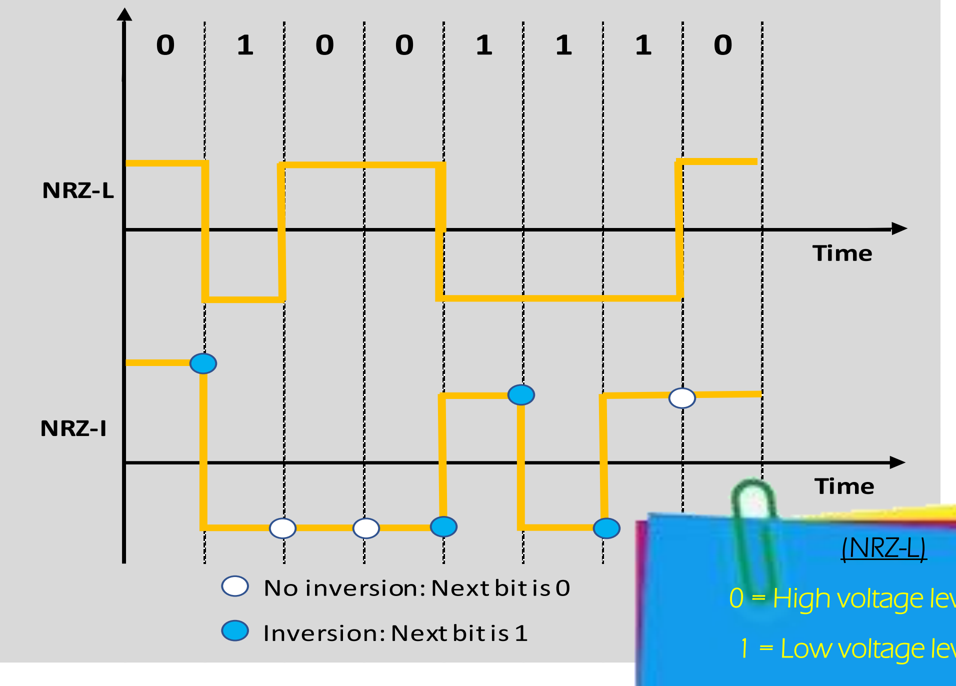
Advantages	Disadvantages
The advantages of Unipolar NRZ are: • It is simple. • A lesser bandwidth is required.	The disadvantages of Unipolar NRZ are − • No error correction done. • Presence of low frequency components may cause the signal droop. • No clock is present. • Loss of synchronization is likely to occur (especially for long strings of 1s and 0s).

Data Encoding

There are other variations of NRZ encoding; which include:

NRZ-L [Non-Return-to-Zero-Level]: In NRZ-L encoding, the polarity of the signal changes only when the incoming signal changes from a one to a zero or from a zero to a one. NRZ-L method looks just like the NRZ method, except for the first input one data bit. This is because NRZ does not consider the first data bit to be a polarity change, where NRZ-L does.

NRZI [Non-Return-to-Zero-Inverted Encoding]: A '0' is encoded as no change in the level. However a '1' is encoded depending on the current state of the line. If the current state is '0' [low] the '1' will be encoded as a high, if the current state is '1' [high] the '1' will be encoded as a low.



(NRZ-L)

0 = High voltage level (+V)

1 = Low voltage level (-V)

(NRZ-I)

next bit is 0 = No changes voltage level

next bit is 1 = Changes voltage level

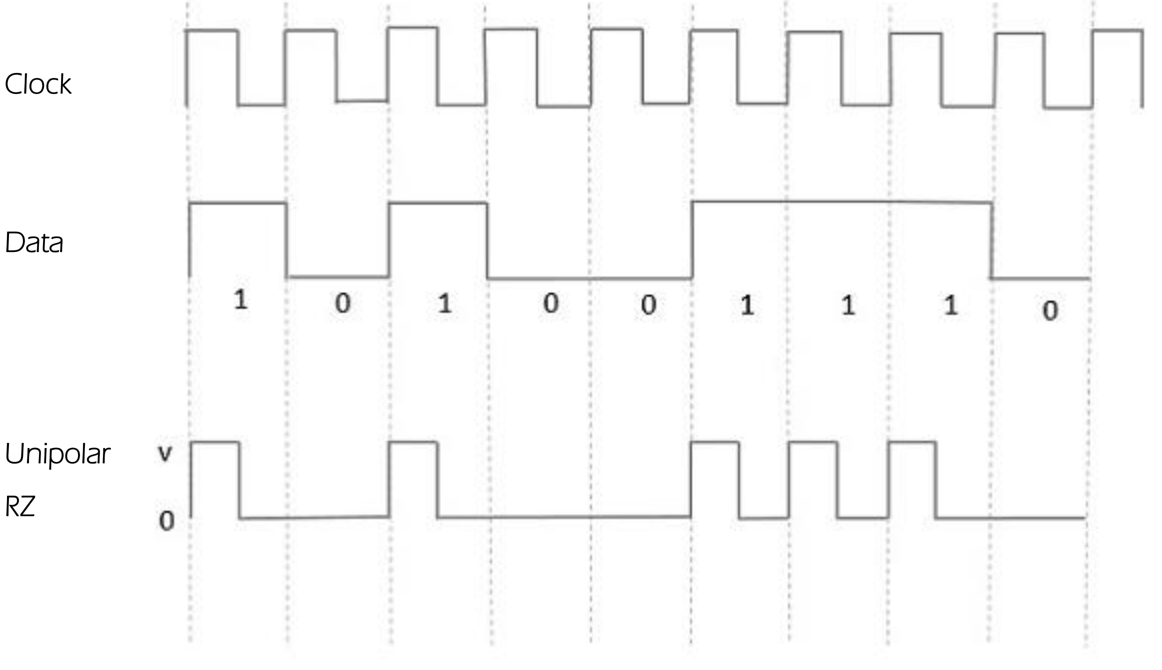
Data Encoding

Unipolar Return to Zero (RZ)

The main problem with NRZ encoding occurs when the sender and receiver clocks are not synchronized. The receiver does not know when one bit has ended and the next bit is starting. One solution is return-to-zero (RZ) scheme.

RZ uses three value: positive, negative and zero. The signal changes not between bits but during the bit.

- Bit 0 = Transition from low to high in the middle of a bit (-ve in 1st half and 0 in 2nd half).
- Bit 1= Transition from high to low in the middle of a bit (+ve in 1st half and 0 in 2nd half).



Advantages	Disadvantages
The advantages of Unipolar RZ are : • It is simple. • The spectral line present at the symbol rate can be used as a clock.	The disadvantages of Unipolar RZ are: • No error correction. • Occupies twice the bandwidth as unipolar NRZ. • The signal droop is caused at the places where signal is non-zero at 0 Hz.

RZ are require two signal changes to encode a bit. A sudden change of polarity resulting in all 0s interpreted as 1s and all 1s interpreted as 0s but no DC component problem. It also use three level of voltage which is more complex to create and discern. RZ has been replaced by better performing Manchester and Differential Manchester schemes.

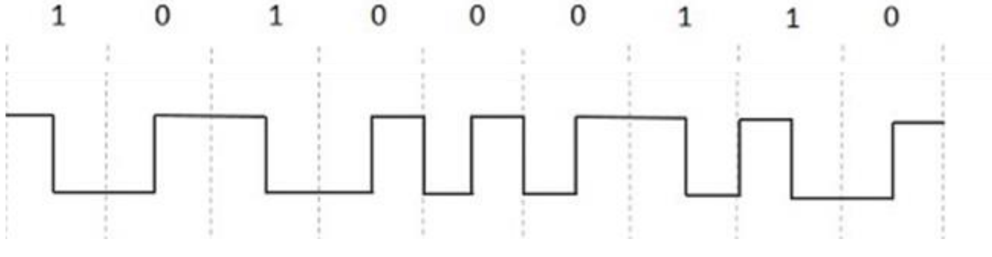
Data Encoding

Manchester Code (Also known as Bi-phase Encoding)

In this type of coding, the transition is done at the middle of the bit-interval. The duration of the bit is divided into two halves. The voltage remains at one level during the first half and moves to the other level during the second half.

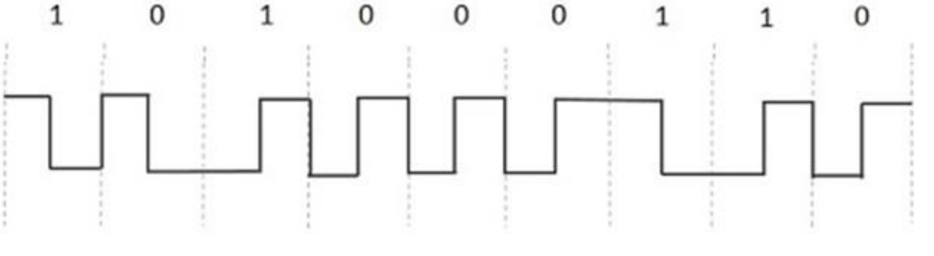
- Bit 0 = Transition from high to low in the middle of a bit (+ve in 1st half and -ve in 2nd half).
- Bit 1= Transition from low to high in the middle of a bit (-ve in 1st half and +ve in 2nd half)

Bi-phase Machaster



Another types of Manchester code is Differential Manchester. In this type of coding, there always occurs a transition in the middle of the bit interval. If there occurs a transition at the beginning of the bit interval, then the input bit is 0. If no transition occurs at the beginning of the bit interval, then the input bit is 1.

Differential Machaster



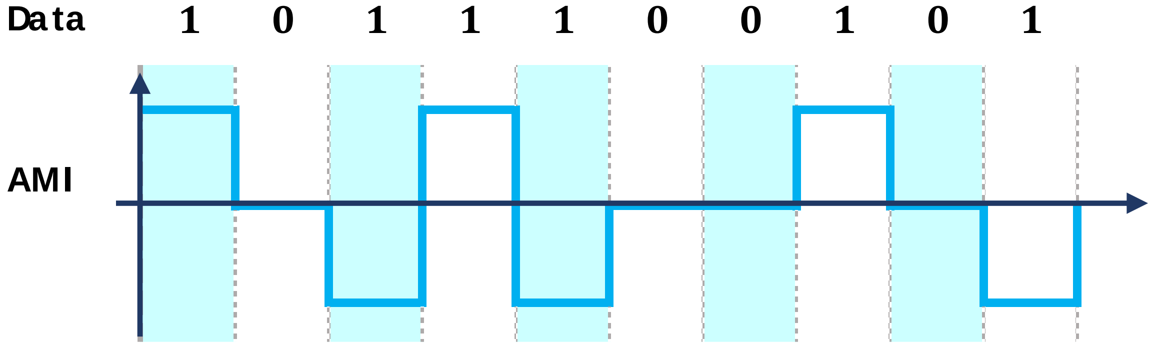
Data Encoding

AMI (Alternate Mark Inversion)

AMI (Alternate Mark Inversion) is a synchronous clock encoding technique that uses bipolar pulses to represent logical 1. The next logic 1 is represented by a pulse of the opposite polarity. Hence a sequence of logical 1s are represented by a sequence of pulses of alternating polarity in other words, the voltages go up and down.. The alternating coding prevents the build-up of a d.c. voltage level down the cable.

This code is used in long distance. This code has a problem. A long stream of 0's can cause a receiver to go out of synchronization (lose the bit boundaries) since 0's have no voltage.

Example 1



A logical 1 value is represented by high or low level - and a zero by no signal. The logical 1 by pulses use alternating polarity.

The pattern of bits "111100101" encodes to " + 0 - + - 0 0 + 0 - ".

Data Encoding

High Density Bipolar 3-zero (HDB3)

The HDB3 code is a bipolar signaling technique (relies on the transmission of both positive and negative pulses). Based on Alternate Mark Inversion (AMI), but extends this by inserting violation codes whenever there is a string of 4 or more 0's. Four consecutive zero-level voltages are replaced with a sequence of 000V or B00V. The reason for two different substitutions is to maintain the even number of nonzero pulses after each substitution.

The two rules states as follows:

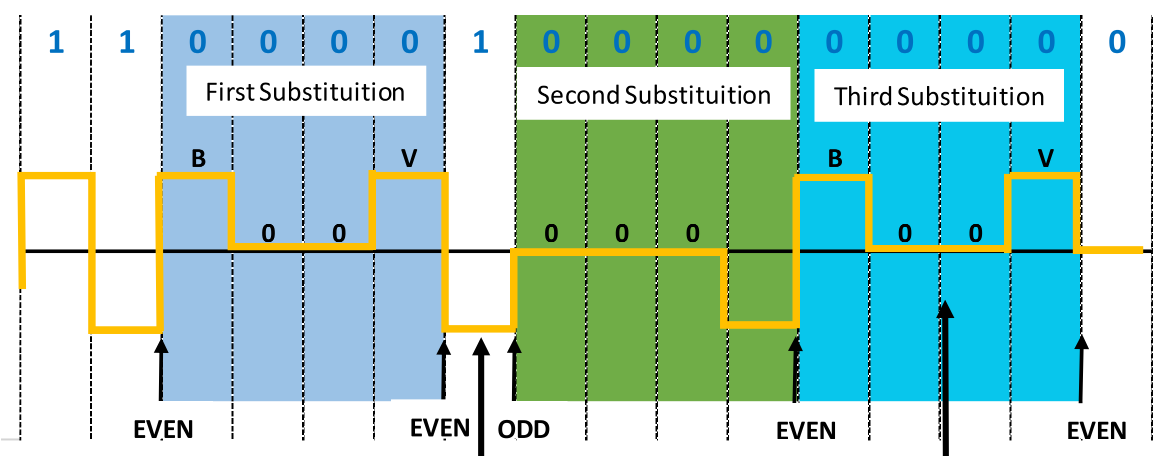
- *If the number of nonzero pulses after the last substitution is odd, the substitution pattern will be 000V, which makes the total number of nonzero pulses even.*
- *If the number of nonzero pulses after the last substitution is even, the substitution pattern will be B00V, which makes the total number of nonzero pulses even.*

Data Encoding

To determine which polarity to use in B and V, one must look at the pulse preceding the four zeros. If 000V form must be used then V simply copies the polarity of last pulse, if B00V form must be used then B and V chosen will have the opposite polarity of the last pulse.

Total + & -pulse is 2, so its even: substitution of the 4 zeros will be B00V

Here, total + &- pulse after the previous V is 1, so its odd, then next substitution of 4 zeros will be 000V



When the previous total of +&- pulse is even and the last pulse before subs. is –ve, then data '1' after subs. will follow –ve pulse. If the last pulse is +ve then data '1' after subs. will follow or copy +ve pulse

Then here, total + &- pulse after the previous V is 0, so its even : so next substitution of 4 zeros will be by B00V

When the previous total of +&- pulse is odd and the last pulse before subs. Is –ve, then data '1' after subs. will be +ve pulse (opposite). If the last pulse is +ve then data '1' after subs. will be -ve pulse

Data Encoding

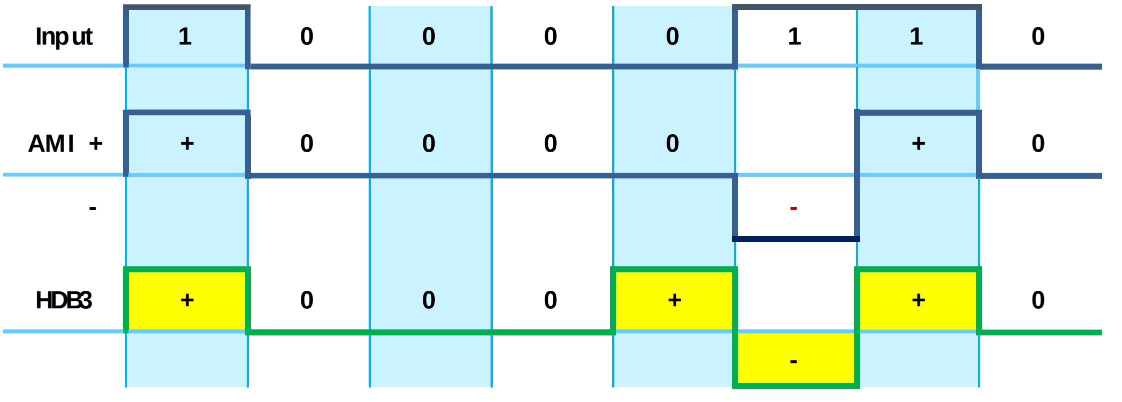
Example 1

HDB3 coding of $\mathbf{0000_2}$

Input : 10000110

AMI : +0000-+0

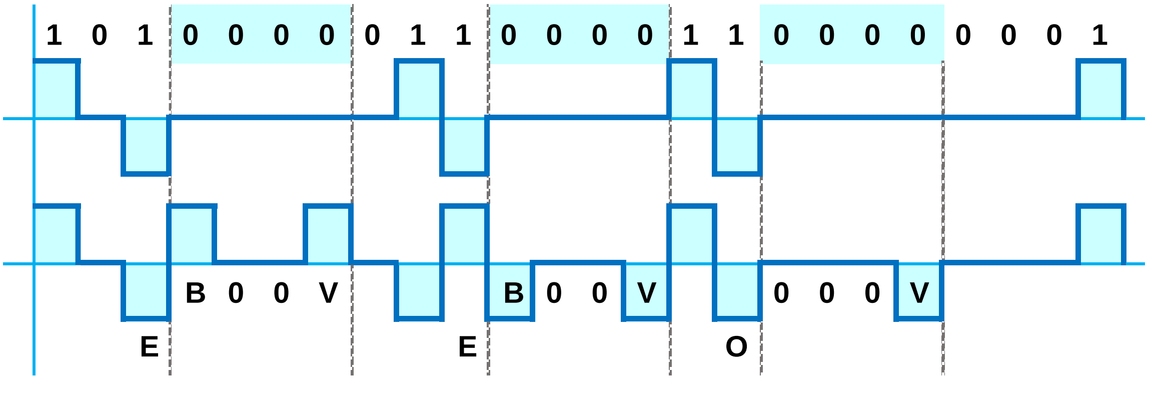
Parity of +/- bits since previous V	Pattern	Previous pulse	Coded
Even	B00V	+	-00-
		-	+00+
Odd	000V	+	000+
		-	000-



Example 2

Input : 10100000110000110000001

AMI : +0-00000+-0000+-0000000+



✓ If 000V: V simply copies the polarity of last pulse

✓ If B00V: B and V chosen will have the opposite polarity of last pulse

Data Encoding

Multiline Transmission-3 Level (MLT-3)

Similar to NRZ-I and differential Manchester with more than two transition rules.

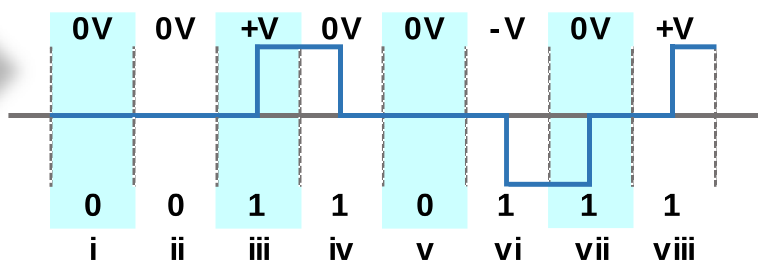
MLT-3 uses three voltage levels (+V, 0 and –V) and three transition rules to moves between the levels:

i. If the next bit is 0, there is no transition

ii. If the next bit is 1 and the current level is not 0, the next level is 0

iii. If the next bit is 1 and the current level is 0, the next level is opposite of the last nonzero level

Example 1



i. Bit 0 is sent, the previous voltage is 0V, then the voltage level will remain at 0V

ii. Bit 0 is sent, the previous voltage is 0V. Then the voltage level will remain at 0V.

iii. Bit 1 is sent according to the MLT-3 pattern (+V, 0V, -V. 0V), the level will change to the next level which is +V.

iv. Bit 1 is sent, according to the MLT-3 pattern (+V, 0V, -V. 0V), the level will change to the next level which is 0V.

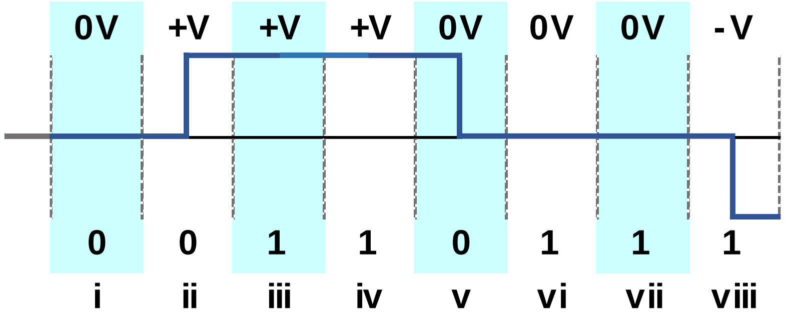
v. Bit 0 is sent, the previous voltage is 0V, then the voltage level will remain at 0V.

vi. Bit 1 is sent, according to the MLT-3 pattern (+V, 0V, -V, 0V), the level will change to the next level which is -V.

vii. Bit 1 is sent, according to the MLT-3 pattern (+V, 0V, -V, 0V), the level will change to the next level which is 0V.

viii. Bit 1 is sent, according to the MLT-3 pattern (+V, 0V, -V, 0V), the level will change to the next level which is +V.

Example 2



i. Bit 0 is sent, the previous voltage is 0V, then the voltage level will remain at 0V.
ii. Bit 1 is sent, according to the MLT-3 pattern (+V, 0V, -V, 0V), the level will change to the next level which is +V.
iii. Bit 0 is sent, the previous voltage is +V, then the voltage level will remain at +V.
iv. Bit 0 is sent, the previous voltage + V, then level the voltage will stay at +V.
v. Bit 1 is sent, according to the MLT-3 pattern (+V, 0V, -V, 0V), the level will change to the next level which is 0V.
vi. Bit 0 is sent, the previous voltage is 0V, then the voltage level will remain at 0V.
vii. Bit 0 is sent, the previous voltage is 0V, then the voltage level will remain at 0V.
viii. Bit 1 is sent, according to the MLT-3 pattern (+V, 0V, -V, 0V), the level will change to the next level which is -V.

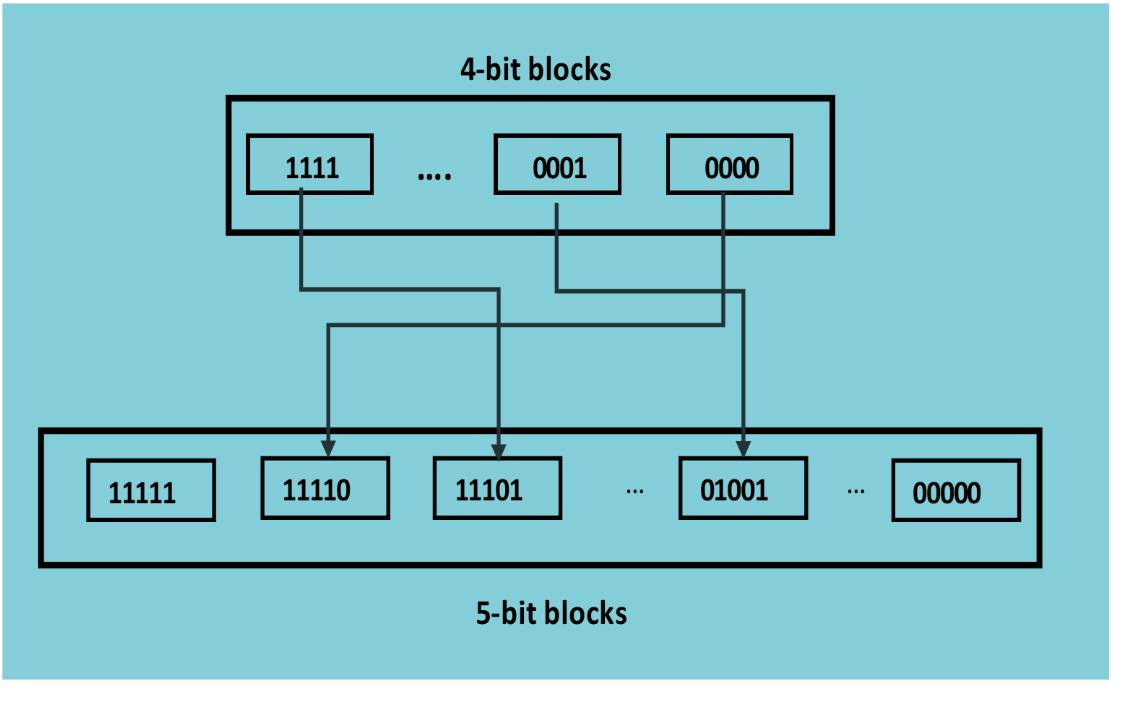
Block coding: 4B/5B

Block coding is referred to as mB/nB encoding technique. in which block coding changes a block of m bits into a block of n bits, where n is larger than m.
The four binary/five binary (4B/5B) coding scheme was designed to be used in combination with NRZ-I.

In 4B/5B encoding, we substitute a 4-bit code for 5-bit group. The 5-bit output that replace the 4-bit input has no more than one leading zero (left bit) and no more than two trailing zeros (right bit). So when different groups are combined to make new sequence, there are never more than three consecutive 0s

As a result, the 5-bit patterns can always have two '1's in them even if the data is all '0's. Block coding normally involves three step: division, substitution and combination.

The following figure shows an example of substitution in 4B/5B coding.



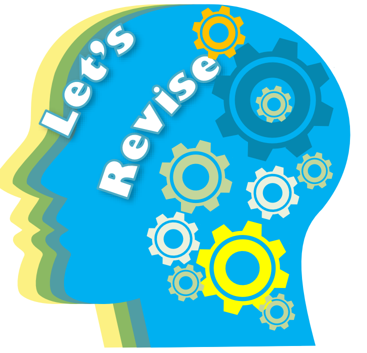
Data Encoding

Block Coding Table

The following table shows the corresponding pairs used in 4B/5B encoding. Note that the first two columns pair a 4-bit group with a 5-bit group.

DATA	CODE	DATA	CODE
0000	11110	1000	10010
0001	01001	1001	10011
0010	10100	1010	10110
0011	10101	1011	10111
0100	01010	1100	11010
0101	01011	1101	11011
0110	01110	1110	11100
0111	01111	1111	11101

CHAPTER 2



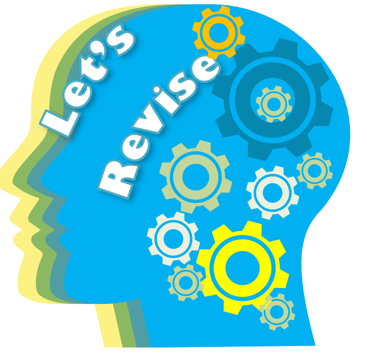
Review Questions

1. List types of data encoding:
    a) Digital-to-Digital encoding:
        i. . ...
        ii. ....
        iii. ....
        iv. ....
        v. ....
        vi. ....
    b) Analog-to-Digital encoding:
        i. ....
    c) Digital-to-Analog encoding:
        i. ....
        ii. ....
        iii. ....

2. Describe data encoding.

3. Explain the following digital-to-digital data encoding with an illustration.
    a) NRZ
    b) Manchester

CHAPTER 2



Review Questions

4. Illustrate the digital to digital encoding for NRZ-L, NRZ-I, MANCHESTER and AMI when the signal given is 01101001, Assume the start bit is at 0.

5. Illustrate the digital to digital encoding for NRZ-L, NRZ-I, MANCHESTER and AMI when the signal given is 01011011, Assume the start bit is at 0.

6. Compare the characteristic of digital-to-digital encoding

TYPE	WAVEFORM	CHARATERISTICS
NRZ		
RZ		
Manchester		
AMI		
HDB		
MLT-3		
4B/5B		

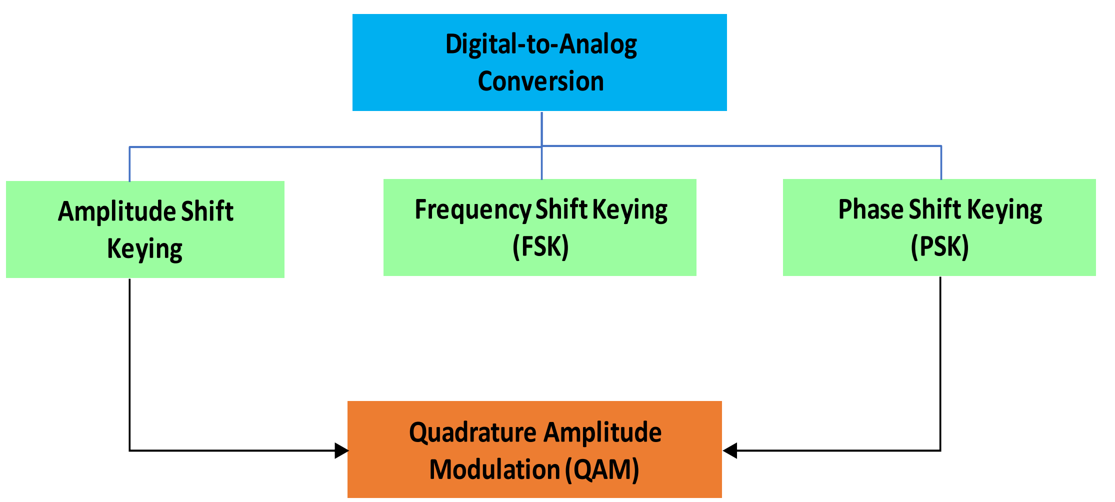
CHAPTER 03

Digital Modulation

Digital Modulation

Digital modulation methods can be considered as digital-to-analog conversion, and the corresponding demodulation or detection as analog-to-digital conversion. In electronics and telecommunications, modulation is the process of varying one or more properties of a carrier signal, with a modulating signal that typically contains information to be transmitted. Information Signal is in digital waveform. While Carrier signal is in analog waveform. The modulation of digital signals with analogue carriers allows an improvement in signal to noise ratio as compared to analogue modulating schemes. 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 bandpass filter limits the frequency range to 300–3400 Hz) or over a limited radio frequency band.

There are four basic technique for digital modulation.

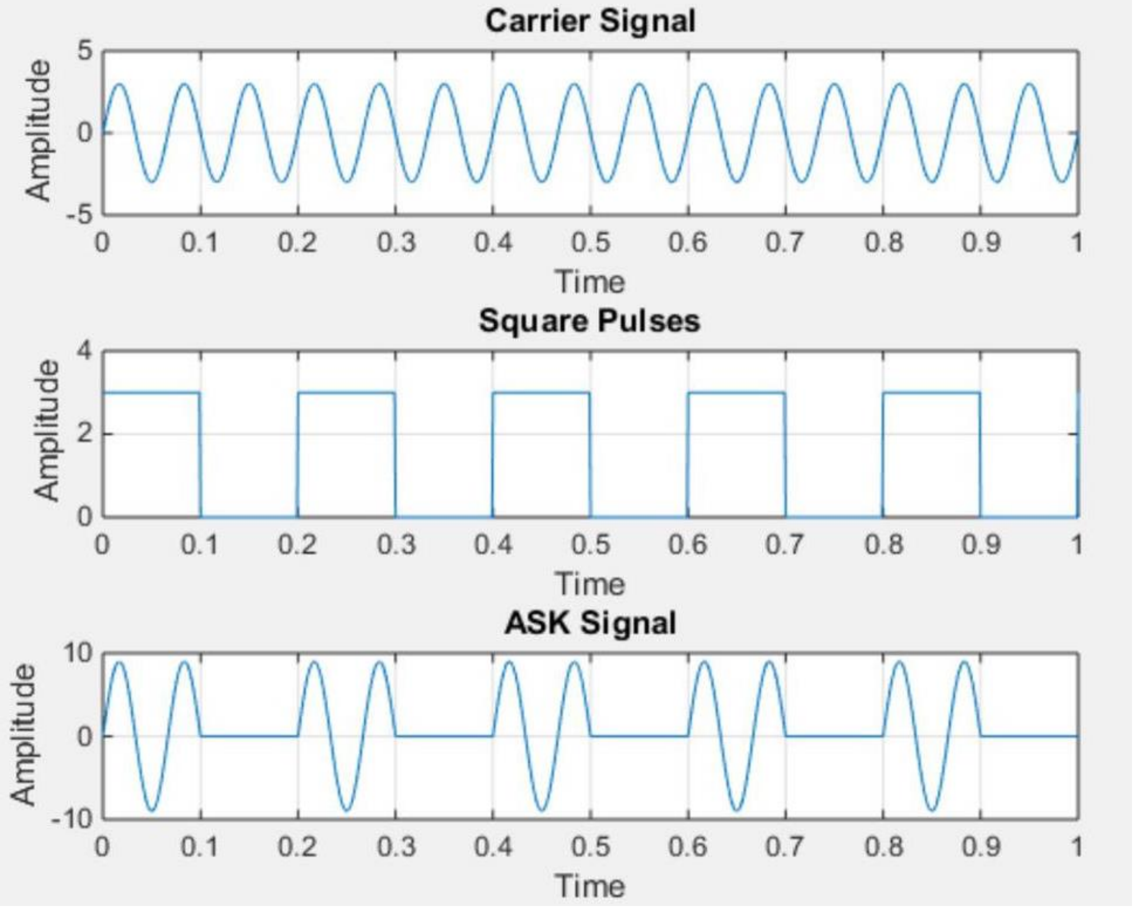


If the information signal is digital and the amplitude of the carrier is varied proportional to the information signal, a digitally modulated signal called amplitude shift keying (ASK) is produced while if the frequency (f) is varied proportional to the information signal, frequency shift keying (FSK) is produced and if the phase of the carrier (0) is varied proportional to the information signal, phase shift keying (PSK) is produced. Then If both the amplitude and the phase are varied proportional to the information signal, quadrature amplitude modulation (QAM) results.

Digital Modulation

Basic Digital Modulation: Amplitude Shift Keying (ASK)

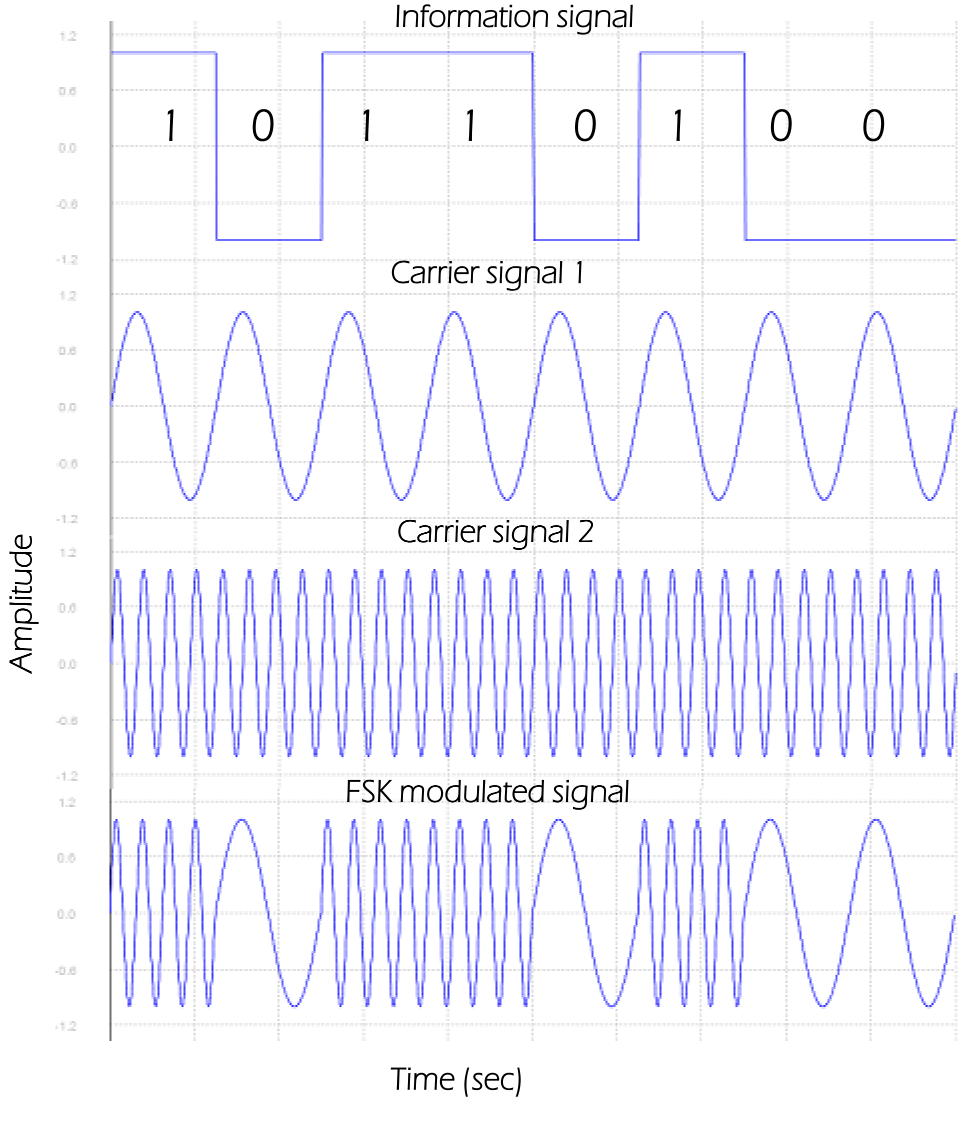
Amplitude Shift Keying (ASK) is a type of Amplitude Modulation which represents the binary data in the form of variations in the amplitude of a signal. Any modulated signal has a high frequency carrier. The binary signal when ASK modulated, gives a zero value for Low input while it gives the carrier output for High input.



Digital Modulation

Basic Digital Modulation: Frequency Shift Keying (FSK)

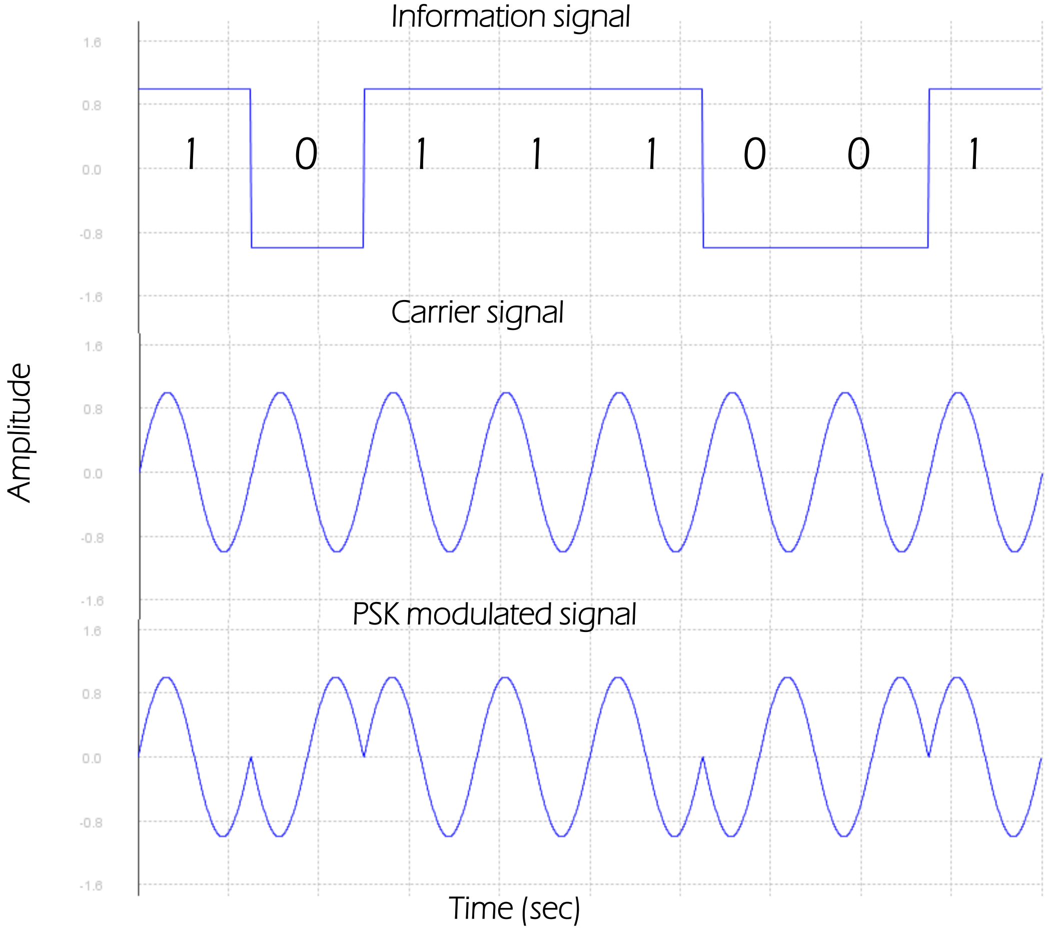
In Frequency Shift Keying (FSK) , the frequency of the carrier signal is modified. An illustration of binary FSK, or BFSK, is given . Here, bursts of a carrier wave at one frequency or bursts of a carrier wave at a second frequency are transmitted according to whether the input data is 1 or 0.



Basic Digital Modulation: Phase Shift Keying (PSK)

The third fundamental digital modulation technique, and the most widely used in one form or another, is PSK. Its simplest form is Binary Phase-Shift Keying (BPSK).

In BPSK, 0 and 1 are represented by segments of sinusoids that differ in their phase. At the receiver, distinguishing between the two segments is easier if their phases differ by as much as possible. In BPSK the phases are separated by half a cycle (equivalent to π radians or 180°)



Digital Modulation

Concept of Multi-level (M-ary)

M-ary is a term derived from the word binary. M-ary is pronounced like "em airy". An M-ary transmission is a type of digital modulation where instead of transmitting one bit at a time, two or more bits are transmitted simultaneously. M = represents a digit that corresponds to the number of conditions or levels or combinations possible for a given number of binary variables (n). For example, a digital signal with 4 possible conditions (either voltage, levels, frequencies, phases and so on) is an M-ary system where M = 4.

The number of bits that necessary to produce a given number of conditions (M) is expressed mathematically as;

$n = \log_2 M$ $\log_b x = n$ means $b^n = x$.

$\log_2 M = n$ means $2^n = M$.

For example, with two bits, $2^2 = 4$ conditions are possible.

Where; n = number of bits

M = number of conditions, levels or combinations possible with n bits

In binary coding:

- Data bit '1' has waveform 1
- Data bit '0' has waveform 2
- Data rate = bit rate = symbol rate

In M-ary coding, take M bits at a time ($M = 2^n$) and create a waveform (or symbol).

'00' → waveform (symbol) 1 '01' → waveform (symbol) 2

'10' → waveform (symbol) 3 '11' → waveform (symbol) 4

Symbol rate = bit rate/k

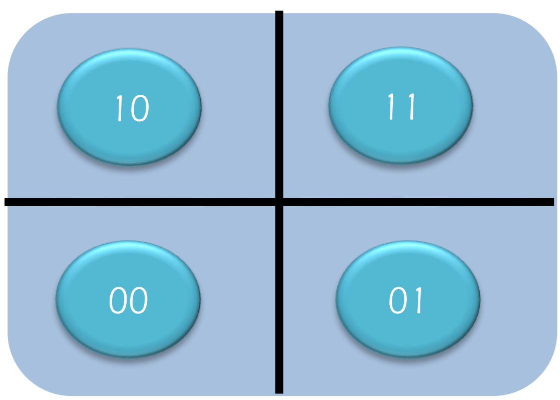
Digital Modulation

Concept Of Multi-level (M-ary) in Quadrature Phase Shift Keying (QPSK Or 4-PSK)

QPSK is an M-ary encoding scheme where N = 2 and M= 4 (hence, the name “Quadrature” or “"quaternary" meaning "4"). A QPSK modulator is a binary (base 2) signal, to produce four different input combinations: 00, 01, 10, and 11. Therefore, with QPSK, the binary input data are combined into groups of two bits, called dibits. In the modulator, each dibit code generates one of the four possible output phases (+45°, +135°, -45°, and -135°).

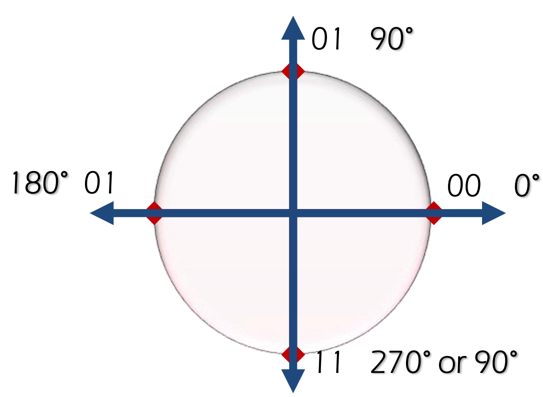
In QPSK digital data is represented by 4 points of a 2-bit binary code around a circle which correspond to 4 phases of the carrier signal. These points are called symbols.

Binary input		QPSK output phase
Q	I	
0	0	-135°
0	1	-45°
1	0	+135°
1	1	+45°



In a modulator , it could also transmits two bits in four modulation states of :

Binary input		QPSK output phase
Q	I	
0	0	0°
0	1	90°
1	0	180°
1	1	270° / -90°



Concept Of Multi-level (M-ary) in Quadrature Phase Shift Keying (QPSK Or 4-PSK)

Activity 1

$2^n=4$
$n=2$

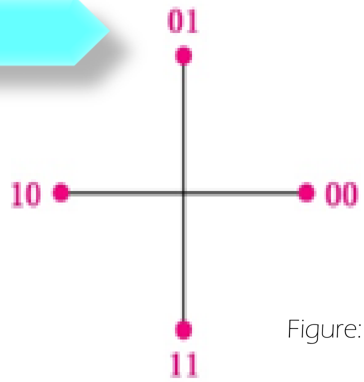


Figure: Constellation diagram of QPSK

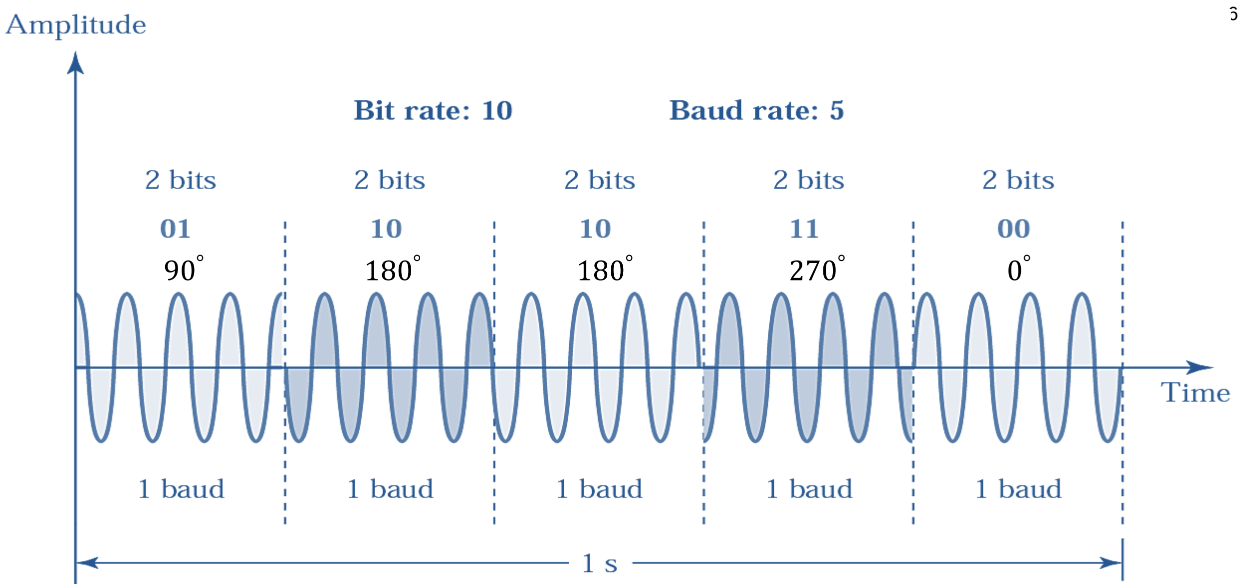
Referring to the above figure:

a. Produce the truth table.

Binary input		QPSK output phase
Q	I	
0	0	0°
0	1	90°
1	0	180°
1	1	270° / -90°

b. Illustrate the waveform of the following stream of data using QPSK digital modulation by referring the above Constellation diagram of QPSK :

Given data: 0110101100 → 01 | 10 | 10 | 11 | 00



Digital Modulation

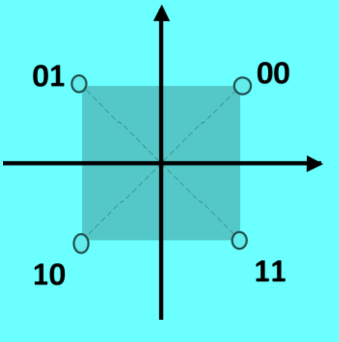
Concept Of Multi-level (M-ary) in Quadrature Amplitude Modulation (QAM)

Quadrature amplitude modulation (QAM) requires changing the phase and amplitude of a carrier sine wave which it the combination of ASK and PSK so that a maximum contrast between each signal unit is achieved. QAM involves sending digital information by periodically adjusting the phase and amplitude of a sinusoidal electromagnetic wave. Each combination of phase and amplitude is called a symbol and represents a digital bitstream. We can have x variations in phase and y variations of amplitude

x • y possible variation (greater data rates)

Example of variations: 4-QAM, 8-QAM, 16-QAM

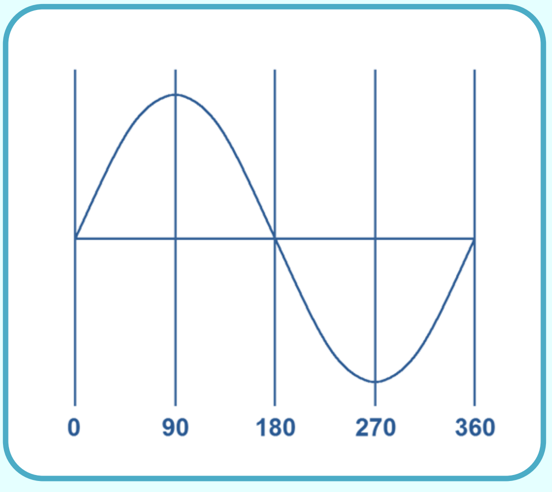
A simple QAM technique is to use 4-QAM, one form of which is QPSK, where the amplitude remains constant in the four states, and the phase is shifted for each symbol. In this example 4-QAM implementation, the constellation consists of four points, one in each quadrant around the origin. The quadrature is determined by the number of degrees needed to rotate a vector at the origin to reach each point in the constellation. For 4-QAM, you reach the points at 45°, 135°, 225°, and 315°. There being four states means that two bits of information are encoded per symbol transmitted ($2^2 = 4$).

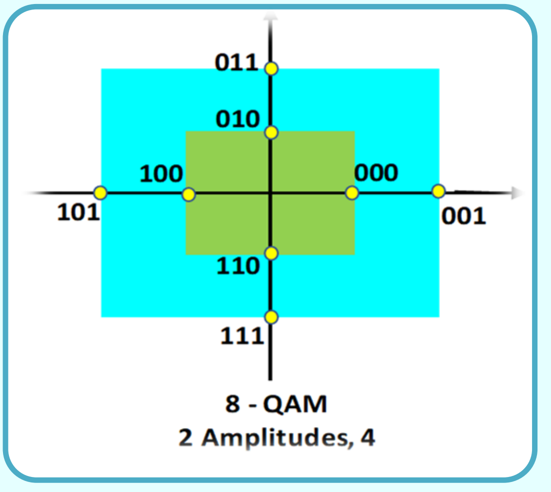


4 QAM
1 Amplitude, 4 Phases

Concept Of Multi-level (M-ary) in Quadrature Amplitude Modulation (QAM)

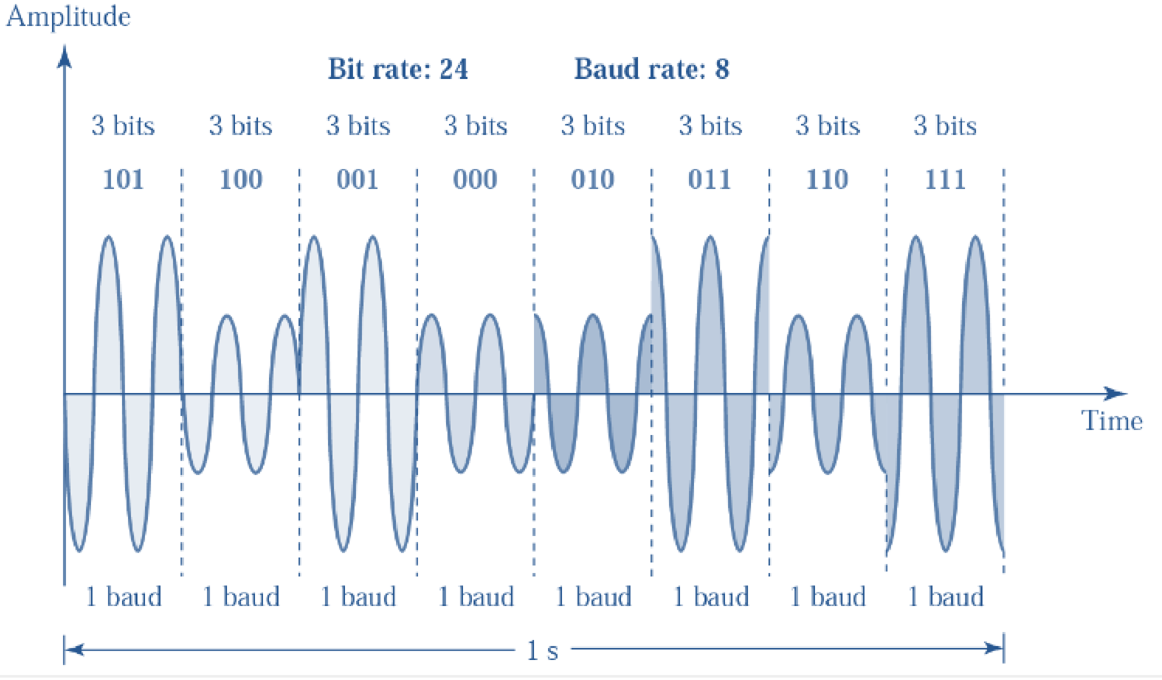
In 8QAM, three input bits generate eight modulation states using four phase angles on 90 degree boundaries and two amplitudes (4 phases X 2 amplitudes = 8 states).





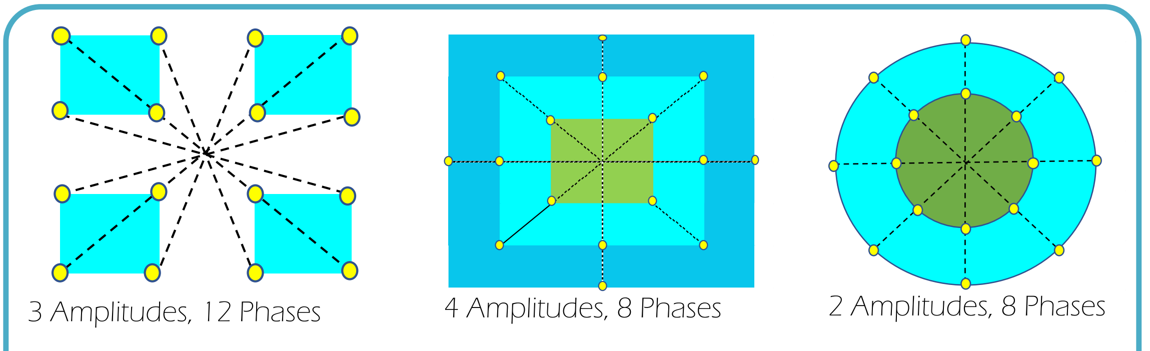
The following figure shows the waveform of the following stream of data using 8QAM digital modulation. Given data:

101100001000010011110111 ⟶ 101 | 100 | 001 | 000 | 010 | 011 | 110 | 111



Concept Of Multi-level (M-ary) in Quadrature Amplitude Modulation (QAM)

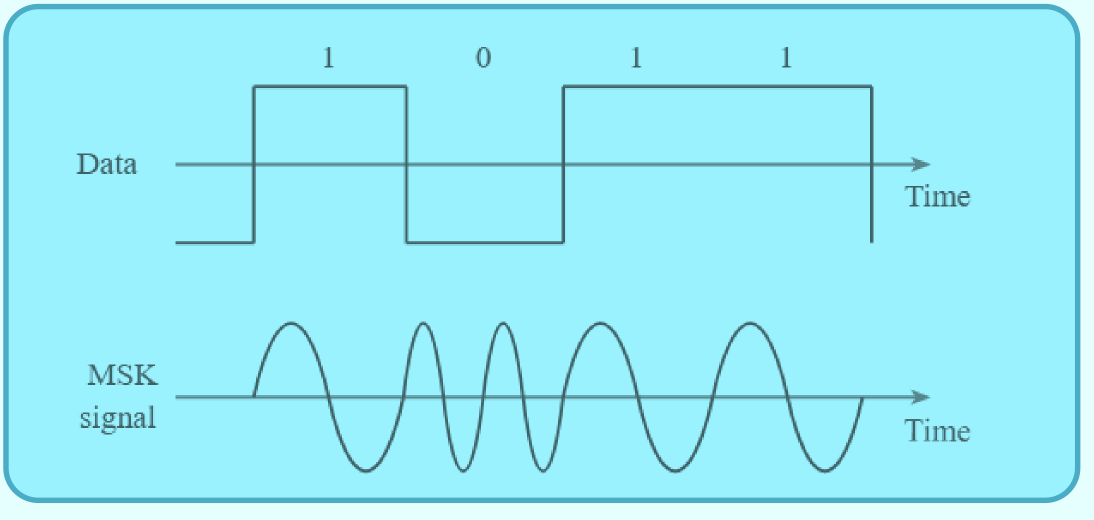
16-QAM is the next modulation that uses a square constellation (digital implementations of QAM tend to use square constellations). The 16-QAM constellation consists of 16 points, four on a side. Like 4-QAM, 16-QAM also uses the idea of quadrature, phase shifting the wave to encode various states; however, as you rotate the vector at the origin, you reveal added complexity: Rather than all points being equidistant from the origin, the distance varies. This is where the amplitude modulation makes its first real appearance in the QAM scheme. Rotating through the first quadrant, the first four points are at 18.4°, 45°, 45° and 71.6°. Because there are two points at 45°, they are differentiated by their amplitude; that is, their distance from the origin. Indeed, the amplitude of the two points at 45° are different from the amplitudes of the 18.4° and 71.6° points, meaning that there are three distinct amplitudes.



Minimum Shift Keying (MSK)

Minimum shift keying, MSK, is a form frequency modulation based on a system called continuous-phase frequency-shift keying. Minimum shift keying, MSK offers advantages in terms of spectral efficiency when compared to other similar modes, and it also enables power amplifiers to operate in saturation enabling them to provide high levels of efficiency. The advantage of MSK is known as a continuous phase scheme. Here there are no phase discontinuities because the frequency changes occur at the carrier zero crossing points.

When looking at a plot of a signal using MSK modulation, it can be seen that the modulating data signal changes the frequency of the signal and there are no phase discontinuities.

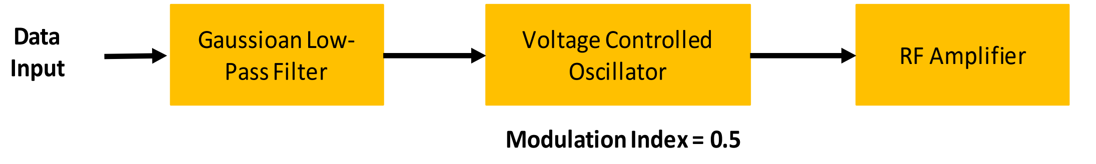


The problem can be overcome in part by filtering the signal, but is found that the transitions in the data become progressively less sharp as the level of filtering is increased and the bandwidth reduced. To overcome this problem Gaussian Minimum Shift Keying GMSK is often used and this is based on Minimum Shift Keying, MSK modulation

Gaussian Minimum Shift Keying (GMSK)

The Gaussian Minimum Shift Keying (GMSK) modulation is a modified version of the Minimum Shift Keying (MSK) modulation where the phase is further filtered through a Gaussian filter to smooth the transitions from one point to the next in the constellation. It is similar to standard minimum-shift keying (MSK); however the digital data stream is first shaped with a Gaussian filter before being applied to a frequency modulator.

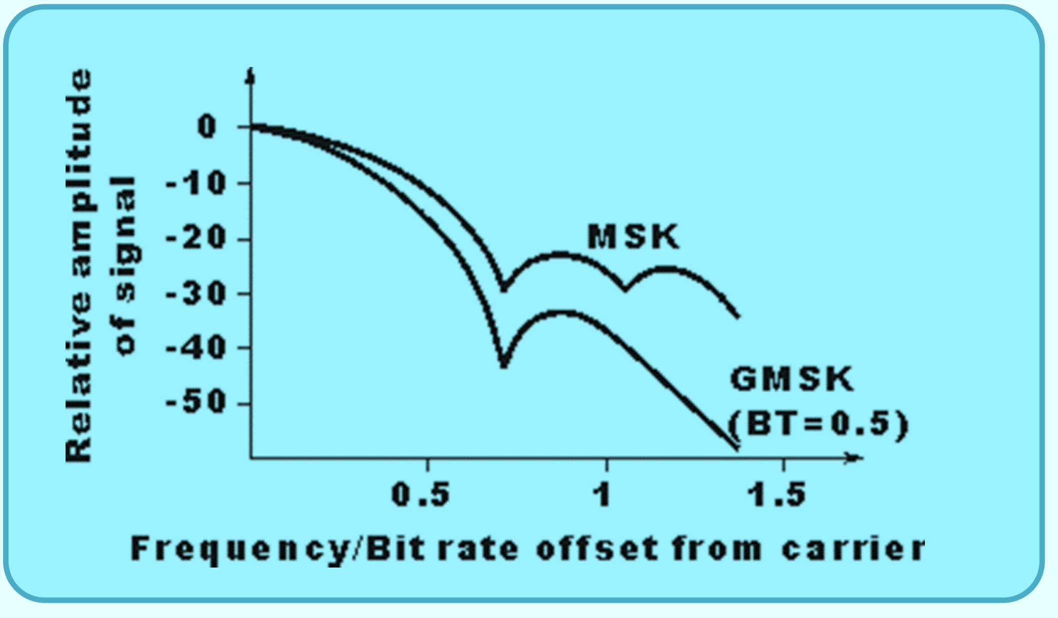
GMSK is different from MSK because a Gaussian Filter of an appropriate bandwidth is used before the modulation stage. GMSK works similarly to MSK , the main difference is on the Gaussian filter setup the digital data stream passes through before it is taken to the frequency modulator.



Generating GMSK using a Gaussian filter and VCO

Minimum Shift Keying (MSK) & Gaussian Minimum Shift Keying (GMSK)

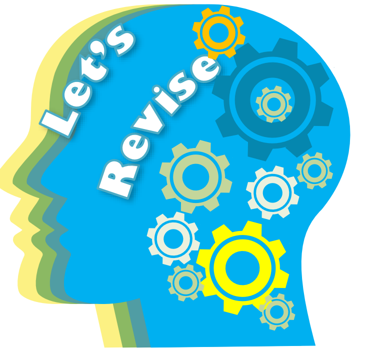
There are several advantages to the use of GMSK modulation for a radio communications system. One is obviously the improved spectral efficiency when compared to other phase shift keyed modes. GMSK, Gaussian Minimum Shift Keying proved to be a particularly successful form of modulation for GSM and some other radio communications systems. Its combination of spectral efficiency and capability to enable efficient power amplifier operation enabled it to be an excellent choice for radio communications systems of the time.



Spectral density of MSK and GMSK signals

GMSK spectral efficiency is better than MSK as shown in this figure.

CHAPTER 3



Review Questions

1. Digital modulation methods can be considered as digital-to-analog conversion and the corresponding demodulation as analog-to-digital conversion are :
   a) ______________________________
   b) ______________________________
   c) ______________________________

2. With the aid of a suitable diagram, explain TWO (2) characteristics of the digital to analogue modulation techniques.

3. Describe the concept of Multi-level (M-ary) amplitude and phase modulation.

4. Describe the following digital modulation:

TYPE	DESCRIPTION
Minimum Shift Keying (MSK)	
Gaussian Minimum Shift Keying (GMSK)	
Quadrature Phase Shift Keying (QPSK or 4-PSK)	
Quadrature Amplitude Modulation (QAM)	

CHAPTER 3

Review Questions

5. Apply QPSK/4-PSK and QAM in digital modulation for a given stream of data.

TYPE	STREAM OF DATA
Quadrature Phase Shift Keying (QPSK or 4-PSK)	
Quadrature Amplitude Modulation (QAM)	

Binary Input 2^n=8 n=3			8-QAM output	
			Amplitude	Phase
0	0	0	2V	0
0	0	1	4V	0
0	1	0	2V	90˚
0	1	1	4V	90˚
1	0	0	2V	180˚
1	0	1	4V	180˚
1	1	0	2V	270˚
1	1	1	4V	270˚

Table : Truth table of 8-QAM

6. Ilustrate the waveform of the following stream of data using 8-QAM digital modulation by referring the above truth table of 8-QAM

Given data: 010|110|101|111|001|101|000|110|001

CHAPTER 04

Error Detection And Quality Of Data Transmission

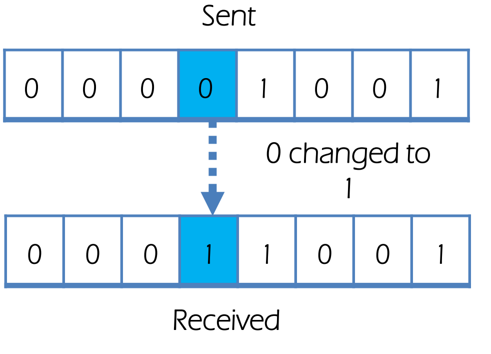
Error Detection And Quality Of Data Transmission

Error

Communication Networks must be able to transfer data from one device to another with complete accuracy with no error. Data can be corrupted during the transmission. A condition when the receiver's information does not match with the sender's information. During transmission, digital signals suffer from noise that can introduce errors in the binary bits travelling from sender to receiver. That means a 0 bit may change to 1 or a 1 bit may change to 0. There may be **three** types of errors:

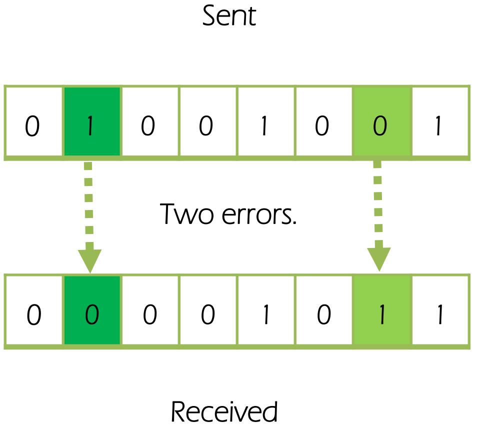
01 Single-Bit Error

The term single-bit error means that only one bit of given data unit (such as a byte, character, or data unit) is changed from 1 to 0 or from 0 to 1



02 Multiple Bit Error

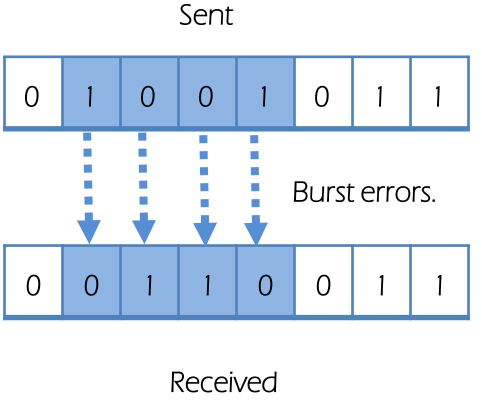
If two or more bits are differed between sending and receiving data stream, then the error is called multiple bit error. The position of the bits may differ i.e. the bits may not be consecutive. This type are errors are also common in parallel and serial communication and it leads to some difficulty in detecting and correcting. .



03

Burst Error

The term burst error means that two or more bits in the data unit have changed from 1 to 0 or from 0 to 1. The error burst is calculated from starting error bit to the ending error bit. The Burst may contain zero error items also in addition to the error bits. These errors are most common in serial communication where the noise can interfere the some amount of bits in sequence or in multiple bits.



Error Detection And Quality Of Data Transmission

Causes of Errors

Transmission Errors: These errors are occurred in the communication media due to signal distortion or attenuation.

Storage errors

These errors occurs due to data storage errors where the memory tracks will corrupt during writing of by any power supply failures.

Error Detection:

Error detection is the process of verifying the received information whether it is correct or not at the receiver end with out having any information of sent original message. In sender side some redundant bits are added to the original message based some property of message signal and in the receiver side by scanning this redundant bits, the error in the message will be predicted.

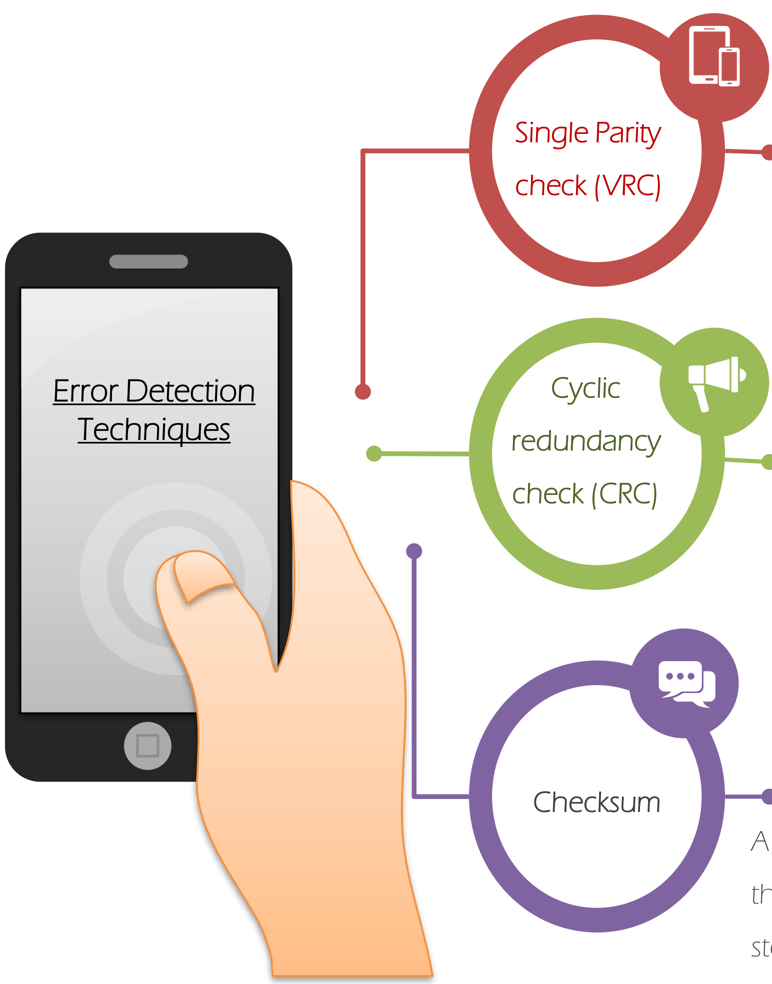
Error Correction

Error connection is the next step of error detection. Once the receiver detects the error in the message the error will be corrected by the error correcting codes. It some cases it may ask the sender to resend the data.

Error Detection And Quality Of Data Transmission

Error Detection

For reliable communication, errors must be detected and corrected. To avoid this, we use error-detecting codes which are additional data added to a given digital message to help us detect if any error has occurred during transmission of the message. Error detection and correction are implemented either at the data link layer or the transport layer of the OSI model. Some popular techniques for error detection are:



01

Vertical redundancy check is maintenance of parity bit.

02

An error-detecting code commonly used in digital networks and storage devices to detect accidental changes to raw data.

03

A digit representing the sum of the correct digits in a piece of stored or transmitted digital data, against which later comparisons can be made to detect errors in the data.

Error Detection And Quality Of Data Transmission

Error Detection : Vertical Redundancy Check (VRC)

Vertical redundancy check is maintenance of parity bit. An additional bit is added with original block to ensure that data transmitted correctly. It is also known as PARITY CHECK technique. Append a single bit at the end of data block such that the number of ones is even or odd.

Example :

Even Parity (odd parity is similar)

0110011 → 00110011

0110001 → 10110001

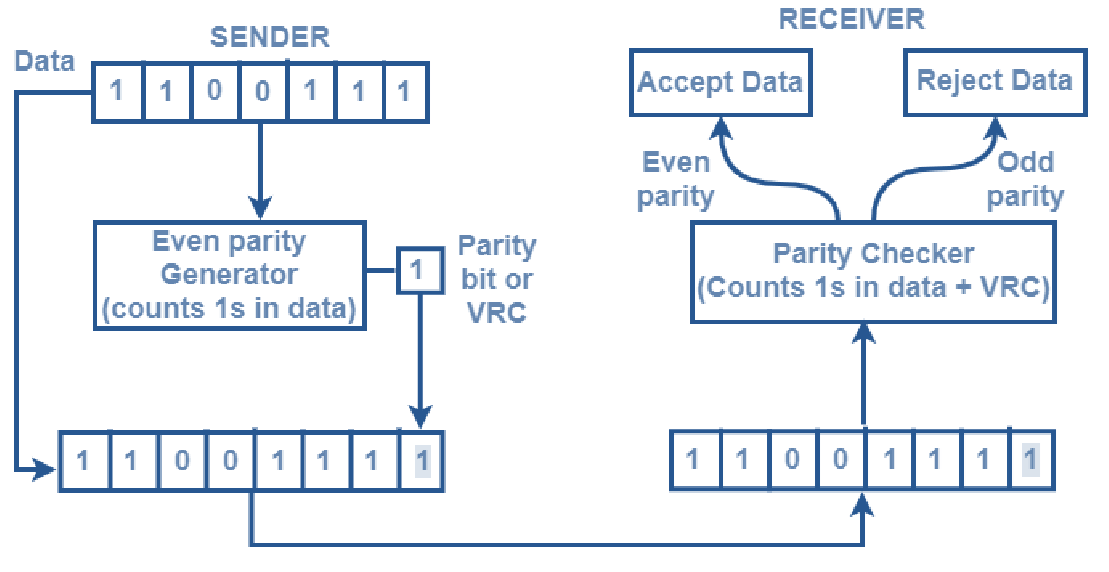
Performance:

Detects all odd-number errors in a data block VRC can detect all single bit error.

In VRC there are two types of parity bit "Even parity bit" and "Odd parity bit".

Error Detection : Vertical Redundancy Check (VRC)

If the source wants to transmit data unit 1100111 using even parity to the destination. The source will have to pass through Even Parity Generator.



Parity generator will count number of 1s in data unit and will add parity bit. In the above example, number of 1s in data unit is 5, parity generator appends a parity bit 1 to this data unit making the total number of 1s even i.e 6 which is clear from above figure.

Data along with parity bit is then transmitted across the network. In this case, 11001111 will be transmitted. At the destination, This data is passed to parity checker at the destination. The number of 1s in data is counted by parity checker.

If the number of 1s count out to be odd, e.g. 5 or 7 then destination will come to know that there is some error in the data. The receiver then rejects such an erroneous data unit.

Error Detection : Vertical Redundancy Check (VRC)

The following figure shows an example of Parity Bit:

ASCII CHARACTER	EVEN PARITY	ODD PARITY
A	$\boxed{0}$ 1 0 0 0 0 0 1	$\boxed{1}$ 1 0 0 0 0 0 1
D	$\boxed{0}$ 1 0 0 0 1 0 0	$\boxed{1}$ 1 0 0 0 1 0 0
	even parity	odd parity
8	$\boxed{1}$ 0 1 1 1 0 0 0	$\boxed{0}$ 0 1 1 1 0 0 0
DEL	$\boxed{1}$ 1 1 1 1 1 1 1	$\boxed{0}$ 1 1 1 1 1 1 1

Error Detection : Cyclic Redundancy Check (CRC)

Cyclic Redundancy Check (CRC) is a block code invented by W. Wesley Peterson in 1961. It is commonly used to detect accidental changes to data transmitted via digital telecommunications networks and storage devices. Blocks of data entering these systems get a short check value attached, based on the remainder of a polynomial division of their contents. Cyclic redundancy check (CRC) codes is a type of linear block codes. generally, not cyclic, but derived from cyclic codes. Cyclic redundancy check (CRC) codes is also a systematic error detecting code which a group of error control bits is appended to the end of the message block with considerable burst-error detection capability.

CRC uses **Generator Polynomial** which is available on both sender and receiver side. CRC generator is an algebraic polynomial represented as a bit pattern.

An example generator polynomial is of the form like $x^3 + x + 1$. This generator polynomial represents key 1011. Another example is $x^2 + 1$ that represents key 101. The power of each term gives the position of the bit and the coefficient gives the value of the bit.

$$\mathbf{1}x^7 + \mathbf{1}x^6 + \mathbf{0}x^5 + \mathbf{0}x^4 + \mathbf{1}x^3 + \mathbf{1}x^2 + \mathbf{0}x^1 + \mathbf{1}x^0$$

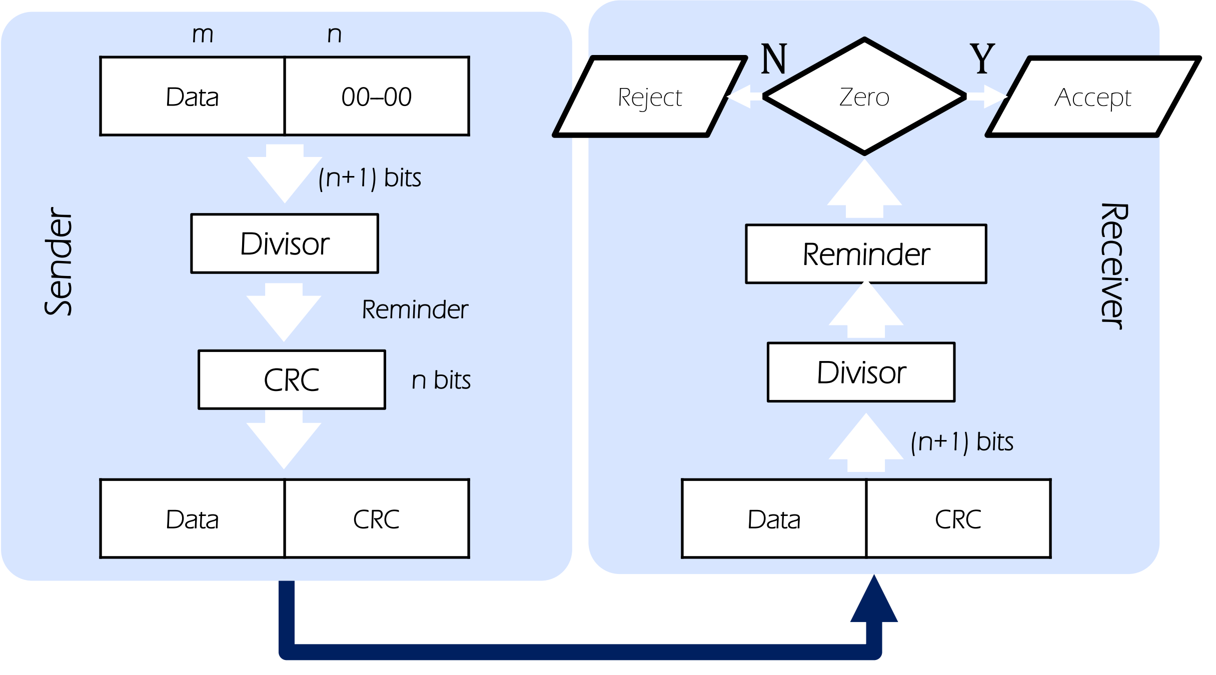
$$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow$$

1 1 0 0 1 1 0 1

Thus, for the given CRC generator, the corresponding binary pattern is <u>11001101.</u>

Error Detection And Quality Of Data Transmission

Error Detection : Cyclic Redundancy Check (CRC))



Sender Side (Generation of Encoded Data from Data (T(x))and Generator Polynomial (G(x)):

- The binary data is first augmented by adding n+1 zeros in the end of the data
- Use modulo-2 binary division to divide binary data by the key (G(x)) and store remainder of division (R(x)).
- Append the remainder at the end of the data to form the encoded data and send the same (T(x)')

Receiver Side (Check if there are errors introduced in transmission) :

- At the destination, the incoming data unit (T(x)') is divided by the same number (G(x)), (perform modulo-2 division again)
- If at this step there is no remainder (R(x)'= 0, the data unit is assumed to be correct and is therefore accepted then there are no errors.
- A remainder indicates that the data unit has been damaged in transit and therefore must be rejected.

Error Detection And Quality Of Data Transmission

Error Detection : Cyclic Redundancy Check (CRC))

Modulo 2 arithmetic uses binary addition with no carries, which is just the **EXCLUSIVE OR (XOR)** operation.

$$0 \pm 0 = 0; \qquad 0 \pm 1 = 1; \qquad 1 \pm 0 = 1; \qquad 1 \pm 1 = 0$$

For example:

$$\begin{array}{cccccc} & 1 & 1 & 1 & 1 \\ + & 1 & 0 & 1 & 0 \\ \hline & 0 & 1 & 0 & 1 \end{array} \qquad \begin{array}{cccccc} & 1 & 0 & 1 & 0 \\ + & 1 & 1 & 1 & 0 \\ \hline & 0 & 1 & 0 & 0 \end{array}$$

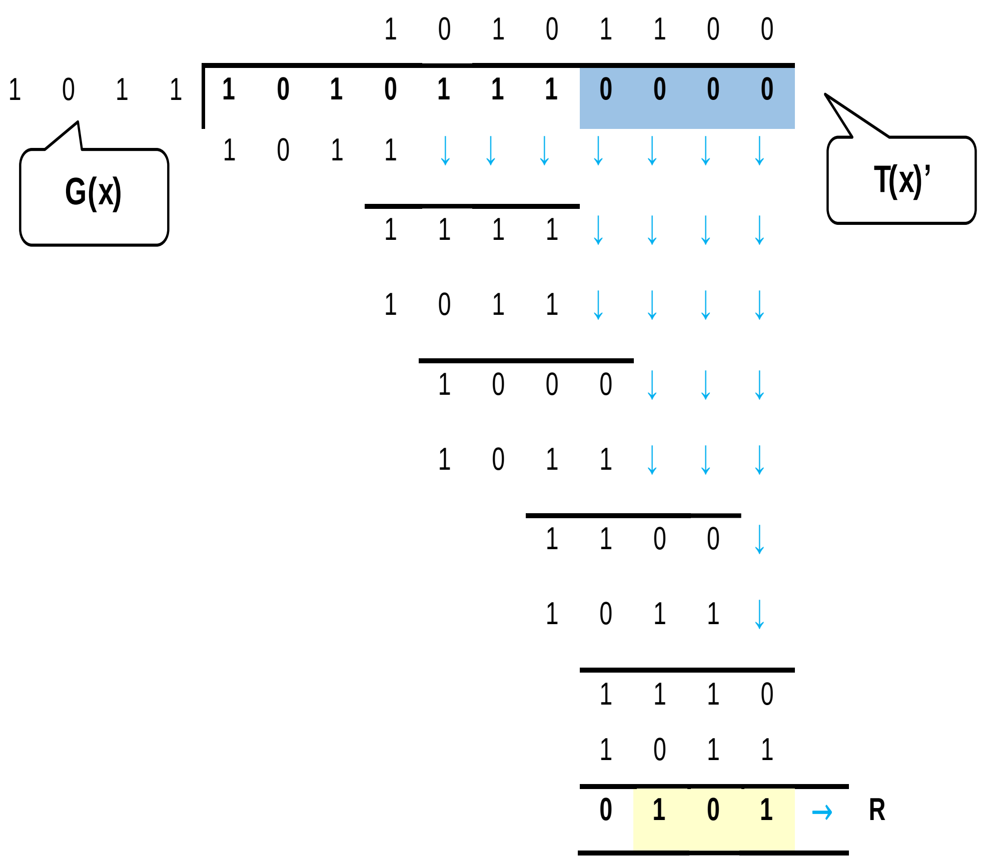
Example :

Cyclic Redundancy Check (CRC) is a systematic error detecting code technique in digital data, but this technique does not function when error detected. It is used primarily in data transmission. Given the message is 10101110 and divisor bit is 1100 which is agreed upon by transmitter and receiver. Determine the CRC check bit at both transmitter and receiver. Identify the error received at the receiver if any.

- ✓ Suppose G(x) = 1100 and T(x) = 10101110
- ✓ Since P is an agreed upon from both nodes, it will be given. Since P is 4 bits long, then n is |P|-1=4, n=3.
- ✓ T(x) will be now shifted left by 3-bits and zero will be inserted into those places, and the new pattern will be denoting by T(x)' = 10101110 000
- ✓ Now we will divide G(x) into T(x)' using an "exclusive or" operation. The remainder from the division, R, will be the bit pattern need to add to T(x)' such that the resulting bit pattern will be exactly divisible with G(x).

Error Detection And Quality Of Data Transmission

Error Detection : Cyclic Redundancy Check (CRC))



The appropriate check bit or CRC bit at the transmitter prior to data transmission is R = 101

From the answer about the resulting bit pattern when R is added to T(x) ' is T(x)"

		1	0	1	0	1	1	1	0	0	0	0
	$\oplus$									1	0	1
T(x) "	=	1	0	1	0	1	1	1	0	1	0	1

So the data will be transmitted through a communication link from the source is

T(x)" = 10101110101

Error Detection : Cyclic Redundancy Check (CRC))

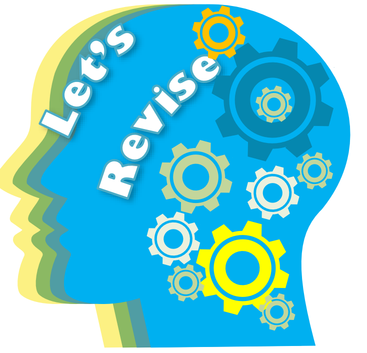
To verify the existence of error if any at the receiver, then divide G(x) into T(x)".

```
                             1   0   1   0   1   1   0   0
                 ---------------------------------------------
1   0   1   1  | 1   0   1   0   1   1   1   0   1   0   1
                 1   0   1   1   ↓   ↓   ↓   ↓   ↓   ↓   ↓
                             -------------
                             1   1   1   1   ↓   ↓   ↓   ↓
                             1   0   1   1   ↓   ↓   ↓   ↓
                                 -------------
                                 1   0   0   0   ↓   ↓   ↓
                                 1   0   1   1   ↓   ↓   ↓
                                         -------------
                                         1   1   1   0   ↓
                                         1   0   1   1   ↓
                                             -------------
                                             1   0   1   1
                                             1   0   1   1
                                             -----------------
                                             0   0   0   0   →   R
                                             -----------------
G(x)
T(x)"
```

If the answer that was computed the correct R' then the resulting remainder will be 0.

From answer that was computed, the resulting remainder, R' is equal to "0" that prove that there is NO ERROR during the transmission.

CHAPTER 4



Review Questions

1. Complete the following TWO bytes of data so that they both have ODD parity:

   A. 011100   C. 101010

   B. 101011   D. 110101

2. Which data and parity bit combination is CORRECT for an ODD parity data transmission system?

a	1	1	1	1	0	0	0
b	0	0	0	0	1	1	1

   A. a =1 , b=1   C. a =0 , b=1

   B. a =1 , b=0   D. a =0 , b=0

3. Which data and parity bit combination is CORRECT for an ODD parity data transmission system?

   A. Data = 1110 0000 : parity = 1   C. Data = 0000 0000 : parity = 0

   B. Data = 0100 1010 : parity = 1   D. Data = 1111 1111 : parity = 1

4. An even-parity checker indicates a parity error for which received data and parity bit?

   A. Data = 111 1111 : parity = 1   C. Data = 111 0000 : parity = 1

   B. Data = 100 1001 : parity = 0   D. Data = 000 0000 : parity = 0

CHAPTER 4

Review Questions

5. Describe error detection.

6. Describe type of error detection:

    i) Vertical Redundancy Check (VRC)

    ii) Cyclic Redundancy Check

7. Data to be sent, M(x) is 100100 and the CRC generator G(x) is 1101. By using Cyclic Redundancy Check (CRC) technique, show that the CRC bit is 0001.

8. Data to be sent, M(x) is 101100 and the CRC generator G(x) is 1111. By using Cyclic Redundancy Check (CRC) technique, show that the CRC bit is 0111.

REFERENCES

References

7a. The Data Communication Model - Introduction to Data Communications. (n.d.). Retrieved September 2, 2021, from http://www.telecomworld101.com/Intro2dcRev2/page28.html

Advantages of HDB3 Encoding | Disadvantages of HDB3 Scrambling. (n.d.). Retrieved September 2, 2021, from https://www.rfwireless-world.com/Terminology/Advantages-and-Disadvantages-of-HDB3-encoding.html

Amplitude Shift Keying. (n.d.). Retrieved September 2, 2021, from https://www.tutorialspoint.com/digital_communication/digital_communication_amplitude_shift_keying.htm

Cyclic redundancy check | definition and usage. (n.d.). Retrieved September 4, 2021, from https://videocide.com/glossary/cyclic-redundancy-check/

DATA COMMUNICATION AND NETWORKING TECHNOLOGY: CYCLIC REDUNDANCY CHECK (CRC). (n.d.). Retrieved September 4, 2021, from http://cedtinet.blogspot.com/2013/06/cyclic-redundancy-check-crc.html

Data Link Layer 1. 2 Single-bit error 3 Multiple-bit error ppt download. (n.d.). Retrieved September 2, 2021, from https://slideplayer.com/slide/10014670/

Different Block Coding Techniques. (n.d.). Retrieved September 2, 2021, from http://www.myreadingroom.co.in/notes-and-studymaterial/68-dcn/720-different-block-coding-techniques.htm.html

DIGITAL-TO-DIGITAL CONVERSION - ppt video online download. (n.d.). Retrieved September 2, 2021, from https://slideplayer.com/slide/6096529/

References

DIGITAL MODULATION Digitaltoanalog modulation Digitaltoanalog modulation Why Digitaltoanalog. (n.d.). Retrieved September 4, 2021, from https://slidetodoc.com/digital-modulation-digitaltoanalog-modulation-digitaltoanalog-modulation-why-digitaltoanalog/

Digital Communication - Line Codes. (n.d.). Retrieved October 11, 2021, from https://www.tutorialspoint.com/digital_communication/digital_communication_line_codes.htm

Error-Detecting Codes - Cyclic Redundancy Checks (CRCs). (n.d.). Retrieved September 28, 2021, from https://www.tutorialspoint.com/error-detecting-codes-cyclic-redundancy-checks-crcs

Exploring communications technology: 1.6 Phase-shift keying (PSK) - OpenLearn - Open University - TM355_1. (n.d.). Retrieved September 2, 2021, from https://www.open.edu/openlearn/science-maths-technology/exploring-communications-technology/content-section-1.6

Forouzan, B.A. (2012). Data Communications and Networking. 5th Edition. Mc Graw Hill

High Density Bipolar Order 3 Encoding. (n.d.). Retrieved September 2, 2021, from https://erg.abdn.ac.uk/users/gorry/course/phy-pages/hdb3.html

https://ee.eng.usm.my>eeacad>mandeep>eee436 - Bing. (n.d.). Retrieved September 3, 2021, from https://www.bing.com/search?q=https%3A%2F%2Fee.eng.usm.my%3Eeeacad%3Emandeep%3Eeee436&cvid=dc11a436bddc4e56ba3ef555ae06bdc2&aqs=edge.0.69i59j69i58.1104j0j1&pglt=43&FORM=ANSPA1&PC=NMTS

References

https://upload.wikimedia.org/wikipedia/commons/d/d8/Communication_Systems.pdf - Bing. (n.d.). Retrieved September 3, 2021, from https://www.bing.com/search?q=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2Fd%2Fd8%2FCommunication_Systems.pdf&qs=n&form=QBRE&msbsrank=0_0__0&sp=1&pq=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2Fd%2Fd8%2Fcommunication_systems.pdf&sc=0-77&sk=&cvid=039408F148D64D2A8EA7B91348278613

Jeffrey S. Beasley, Gary M. Miller (2013). Modern Electronic Communication. 10th Edition Pearson/Prentice Hall.

Jerry FitzGerald, Alan Dennis, Alexandra Durcikova (2014). Business Data Communications and Networking. 12th Edition Wiley.

Modulation - Wikipedia. (n.d.). Retrieved September 2, 2021, from https://en.wikipedia.org/wiki/Modulation

The definition of Data Encoding. (n.d.). Retrieved September 2, 2021, from https://www.itvdictionary.com/definitions/data_encoding_definition.html

Vertical Redundancy Check (VRC) or Parity Check - GeeksforGeeks. (n.d.). Retrieved September 2, 2021, from https://www.geeksforgeeks.org/vertical-redundancy-check-vrc-or-parity-check/

What is GMSK Modulation: Gaussian Minimum Shift Keying » Electronics Notes. (n.d.). Retrieved September 5, 2021, from https://www.electronics-notes.com/articles/radio/modulation/what-is-gmsk-gaussian-minimum-shift-keying.php

References

What is MSK: Minimum Shift Keying Modulation » Electronics Notes. (n.d.). Retrieved September 2, 2021, from https://www.electronics-notes.com/articles/radio/modulation/what-is-msk-minimum-shift-keying.php

What is Vertical Redundancy Check - VRC Error Detection - Propatel. (n.d.). Retrieved September 2, 2021, from https://www.propatel.com/vertical-redundancy-check-vrc/

Data Link Layer 1. 2 Single-bit error 3 Multiple-bit error ppt download. (n.d.). Retrieved September 2, 2021, from https://slideplayer.com/slide/10014670/

William Stallings (2015). Data And Computer Communications, International Edition. 10th Edition. Pearson Education Limited.

William Stallings, Thomas L. Case (2013). Business Data Communications: International Edition. 7th Edition. Pearson Education Limited.

"Reading furnishes the mind only with materials of knowledge; it is thinking that makes what we read ours."
— John Locke

Terbitan

POLITEKNIK MALAYSIA
TUANKU SYED SIRAJUDDIN

e ISBN 978-967-2258-58-2

9 7 8 9 6 7 2 2 5 8 5 8 2