Course code: ICT 3103
Course Title: Analog and Digital Communication
Semester: V (March-June 2022)

Course Teacher

Dr. Monir Morshed

Professor, Dept. of ICT

Email:monirmorshed.ict@mbstu.ac.bd

Course Contents

▪Radio Wave Propagation: Surface and space wave propagation, Sky wave through Ionosphere. Pulse method for measuring height and electron concentration of Ionospheric region; Chapman theory of layer formation, Ionospheric storm.

▪Modulation and Demodulation: Linear modulation - AM, SSB, DSB, and SSB generation, PLL Circuit to generate linear modulated signals, low and high power modulators, Exponential modulation- FM and PM, demodulation of AM, FM.

▪Broadcasting Transmitter: Transmitter classification, Elements of transmitter, AM and FM transmitters, SSB transmitter, stabilized master oscillator, Frequency multipliers, Mixer circuits, RF power amplifier, Pre-emphasis circuits, Transmitter performance-carrier frequency requirements, audio frequency response, distortion, and signal to distortion ratio.

▪Radio Receiver: Receiver classification, Elements of receiver, AM and FM receivers, SSB receiver, Comparison of AM and FM receivers, Noise in receiver, AGC circuits, AFC circuits, Noise limiters, Receiver sensitivity, Cross modulation, Spurious responses.

▪Representation of Random Signals and Noise in Communication System: Signal Power and Spectral Representations, White noise, Thermal noise, PSDF of White Signals. Input and Output Relationship for Random Signals and Noise Passed Through a Linear Time Invariant System, Band Limited White Noise, ARC Filtering of White Noise.

Course Contents

▪Elements of Digital Communication Systems: Elements of Digital Communication Systems: Model of Digital Communication Systems, Digital Representation of Analog Signal, Certain issues in Digital Transmission, Advantages of Digital Communication Systems, Bandwidth-S/N tradeoff, Hartley Shannon Law.

▪Pulse Code Modulation: Pulse Code Modulation: PCM Generation and Reconstruction, Quantization noise, Non uniform Quantization and Companding, DPCM, Adaptive DPCM, DM and Adaptive DM. Noise in PCM and DM.

▪Digital Modulation Techniques: Digital Modulation Techniques: Introduction, ASK, ASK Modulator, Coherent ASK Detector, Non-Coherent ASK Detector, FSK, Bandwidth and Frequency Spectrum of FSK. Non coherent FSK Detector, Coherent FSK Detector, FSK Detection Using PLL, BPSK, Coherent PSK Detection, QPSK, Differential PSK.

▪Line Coding: Techniques and Analysis.

▪Required Text Books:

▪B.P.Lathi, "Modern Digital & Analog Communication", Prison Books Pvt Ltd., 1989

▪Sanjay Sharma, "Communication Systems, Analog & Digital

▪Reference Books:

▪Simon Haykin, "Communication System", John Wiley & Sons, 4th Edition, 1991

▪K.Sam Shanmugam, "Digital & Analog Communication System", John Wiley & Sons

Course Objectives

- To introduce with basic communication systems.

- Various Amplitude modulation and demodulation systems

- Various Angle modulation and demodulation systems

- Basics of Noise theory and performance of various receivers.

- Design modulation and optimum demodulation and detection methods for digital communications over an AWGN channel.

- Calculate the error rate performance for a number of modulation schemes in AWGN environments

Course Outcomes

- Understand basic elements of a communication system

- Conduct analysis of baseband signals in time domain and in frequency domain

- Demonstrate understanding of various analog and digital modulation and demodulation techniques.

- Analyze the performance of modulation and demodulation techniques in various transmission environments

- Understand the importance of noise considerations in communication systems.

- Baseband and band-pass transmission techniques

- Detection & Estimation of signal

Communication Engineering concerned with the sending and receiving of signals especially by means of electrical devices and electromagnetic waves.
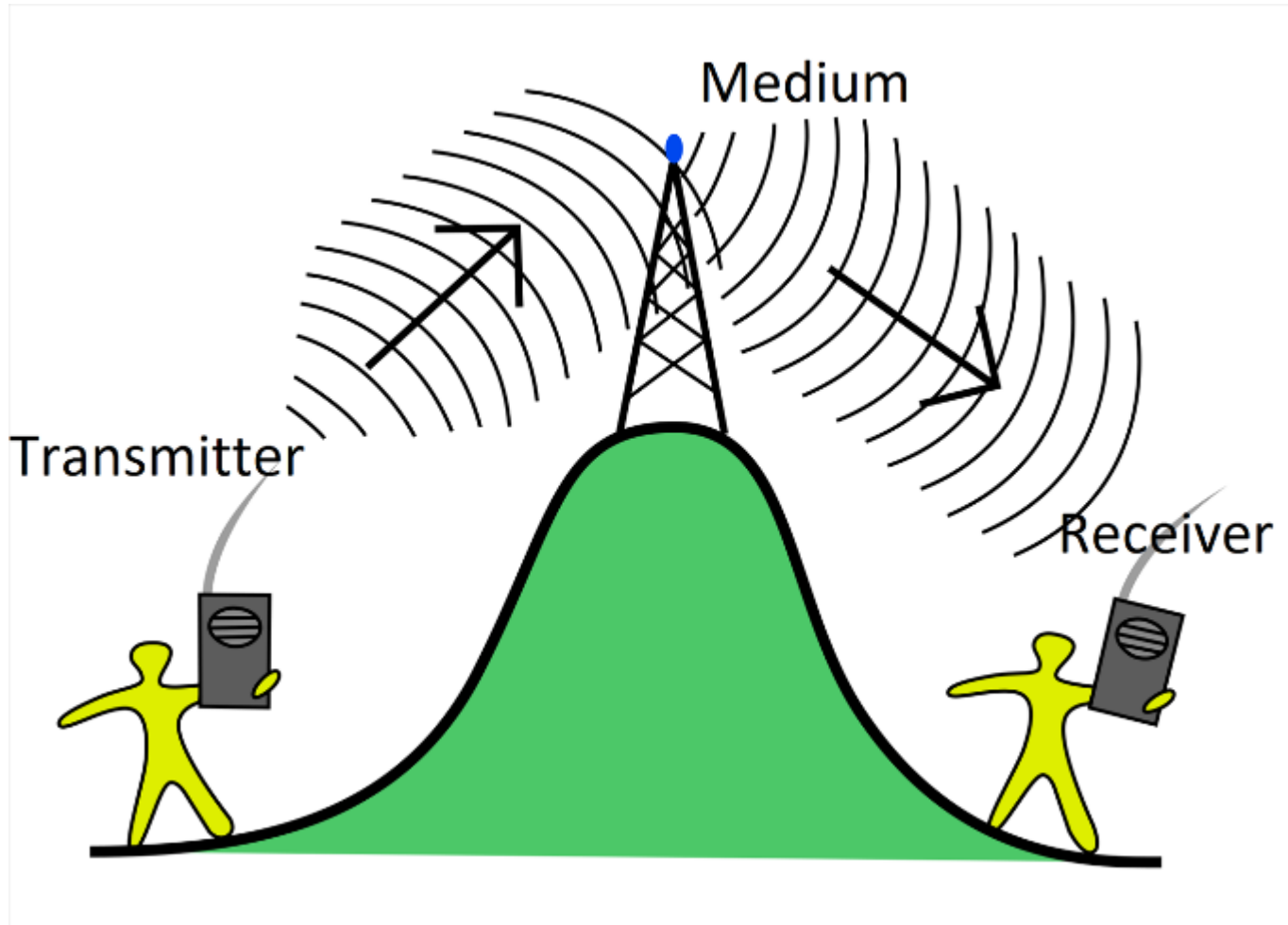
Introduction

"Communication is the process of establishing connection or link between two points for information exchange"

The examples of communication:

1. Ancient communication
2. Telegraph
3. Line telephony
4. Radio telephony
5. Radio telegraph
6. Point to point communication
7. Mobile communication
8. Computer communication
9. Radar communication
10. Television broadcasting
11. Radio telemetry
12. Radio aids to navigation
13. Radio aids to aircraft landing

Ancient Communications

Harkara

Pigeons

Fire and Smoke

Telegraph (1836)

Invention Of Telegraph: First Wireless Communication

Telephone (1876)

Invention Of Telephone By Alexander Graham Bell: The Beginning of Electricity Based Analog Communication

FM Radio(1933)

Edwin Howard Armstrong

- Perhaps the **greatest** EE in history.
- Inventor of the:
  - feedback **amplifier**
  - electronic **oscillator**
  - super-hetrodyne **receiver**
  - **FM** radio.
- These inventions allowed for the transmission of **voice and music**.
- His ideas are still **widely used** today!
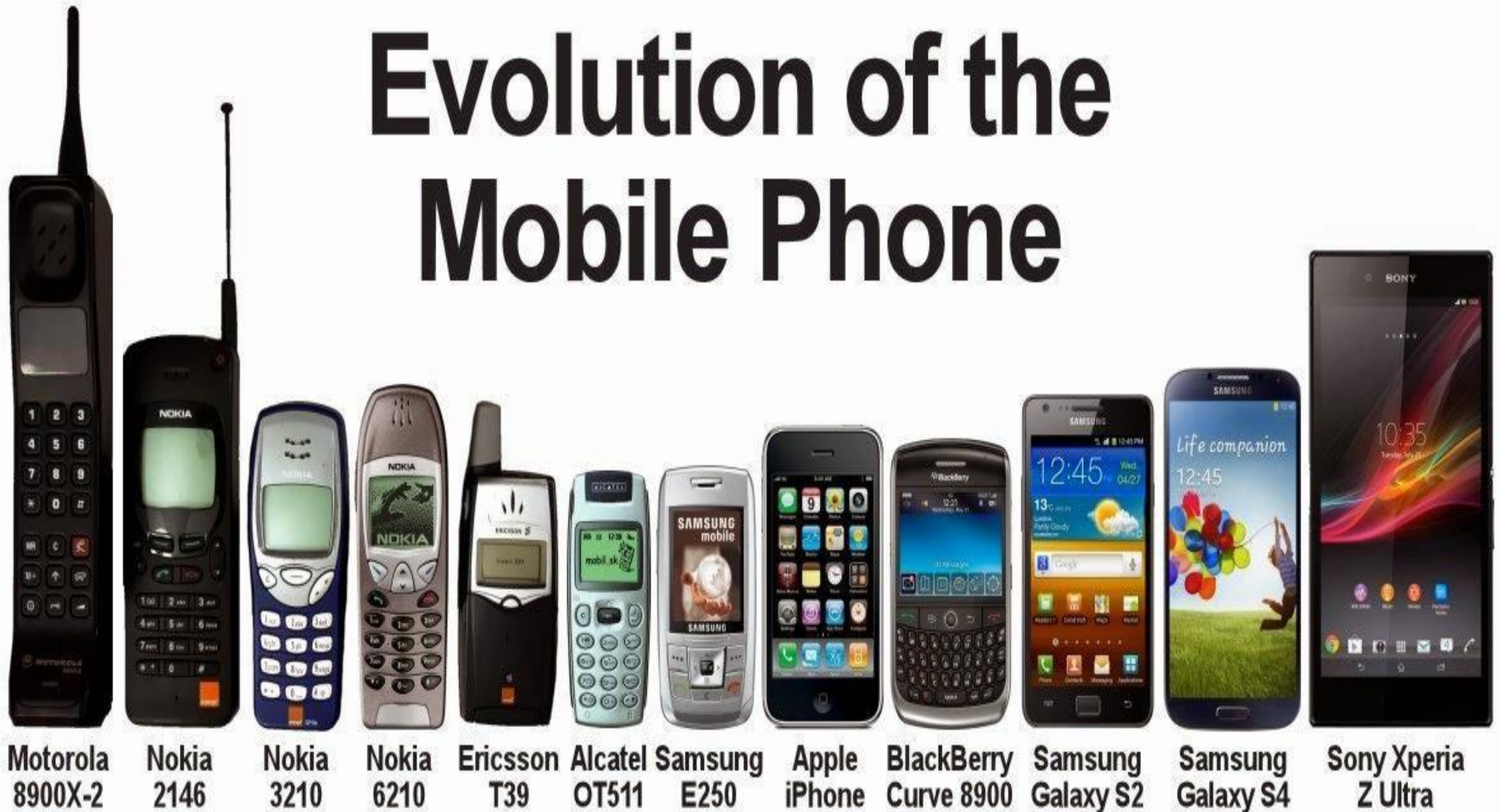
Edwin H. Armstrong (1890-1954)

Mobile Phones (1983)

Mobile phone was first available commercially in 1983. This indicated the beginning of the large commercialization of communication systems.

Contribution of Electronics in Communication Devices
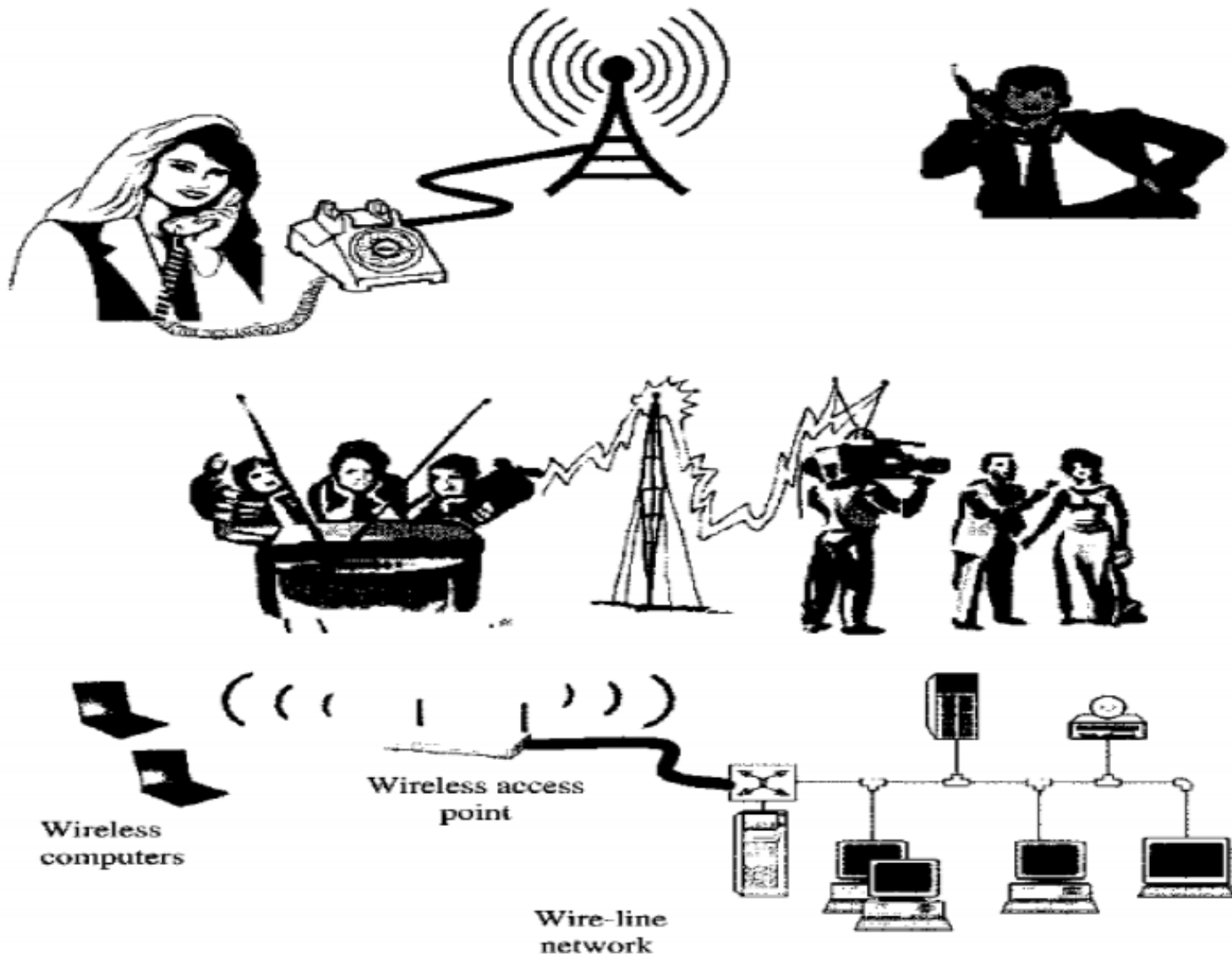

Evolution of the Mobile Phone

Motorola 8900X-2 — Nokia 2146 — Nokia 3210 — Nokia 6210 — Ericsson T39 — Alcatel OT511 — Samsung E250 — Apple iPhone — BlackBerry Curve 8900 — Samsung Galaxy S2 — Samsung Galaxy S4 — Sony Xperia Z Ultra

Fig: Some Examples of Modern Communication System

Modern Communication System

Message: sounds (voice, music), pictures, words, codes, light, temperature, pressure, etc.

Information in electrical signal/ modulating signal

Modulated signal in RF range (transmitted through channel)

Modulated signal in RF range (received from the channel)

Reconstructed electrical signal/ modulating signal

| Information source | → | Input transducer | → | Transmitter (Modulator) | → | Channel | → | Receiver | → | Output transducer | → |

Noise

Microphone, camera, scanner, etc.

Modulator (Analog: AM,FM.PM. Digital: ASK, FSK, PSK, DM)

Information in the original form

Figure: Block diagram of a communication system

Information source:

• The message produced by the information source is not an electrical in nature.
•Such as voice, music pictures, words, codes, lights, temperature etc.
•So we need transducer to convert from physical message to electrical signal.

Input transducer:

• It converts one form of energy into another form.
•It is used to convert physical message signal into time varying electrical signal.

Transmitter:

• Here, restriction of range of audio frequencies, amplification, and modulation are achieved.
•Modulation is the superimposed of audio signal upon the high-frequency carrier signal.

Modern Communication System

The channel and the Noise:

• It is the path through which the signal propagates from transmitter to receiver.

•It may be a pair of wires, a coaxial cable, microwave links or radio waves or space.

•In the channel, the signal gets distorted due to noise introduced in the system.

•Noise signals are always random in character.

Receiver:

• It receives information from the modulated signal available at the transmission channel.

•The main function of the receiver is to extract the original message signal from the degraded version of the transmitted signal.
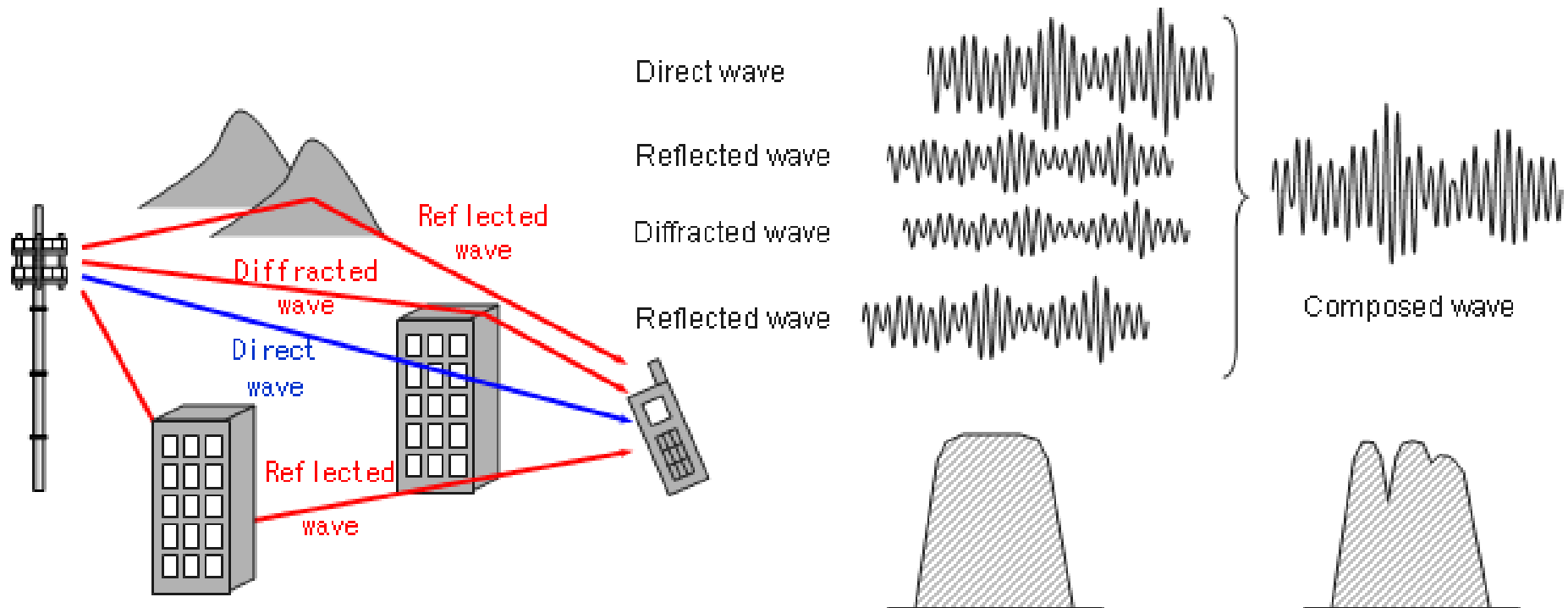
•Example: TV sets and Radio set are example for receivers

Destination:

• Destination is the final stage where electrical message signal is converted into its original form, such as voice, message, etc.

•For example, in radio broadcasting, loudspeaker which works as a transducer.

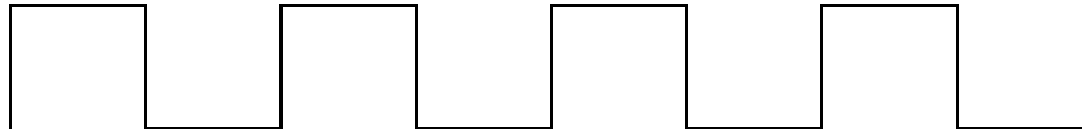# Modern Communication System
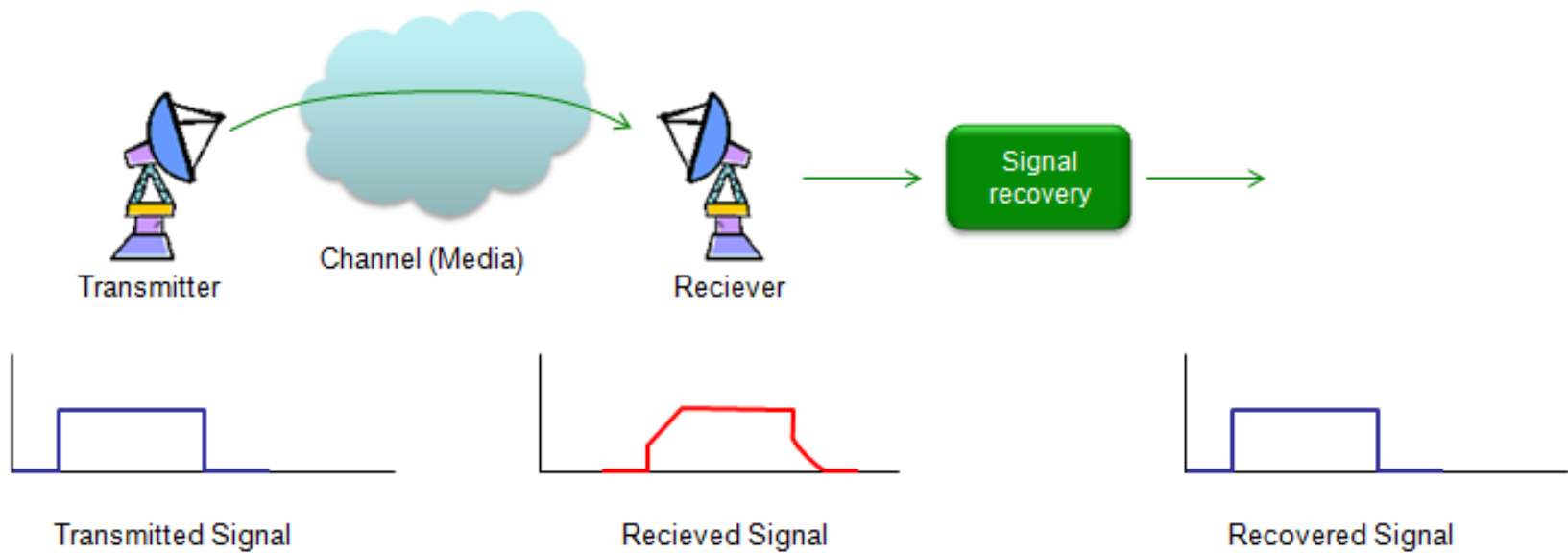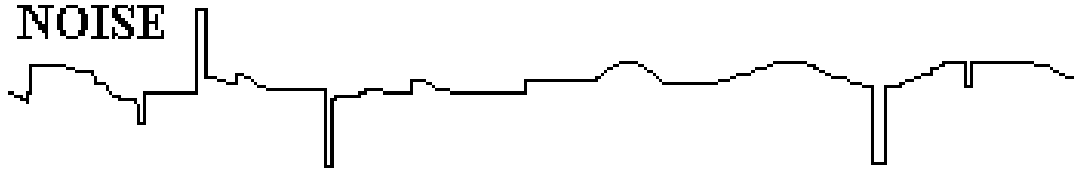
Modern Communication System

Noise

Noise in a communication system is basically undesirable or unwanted signals that get randomly added to the actual information carrying signal
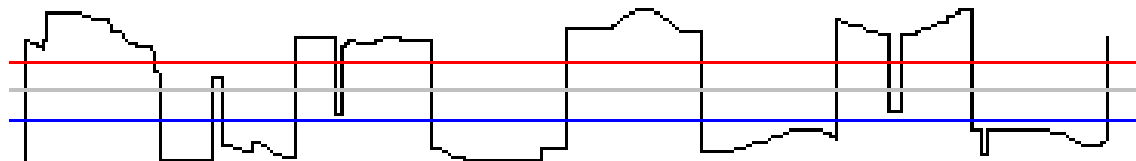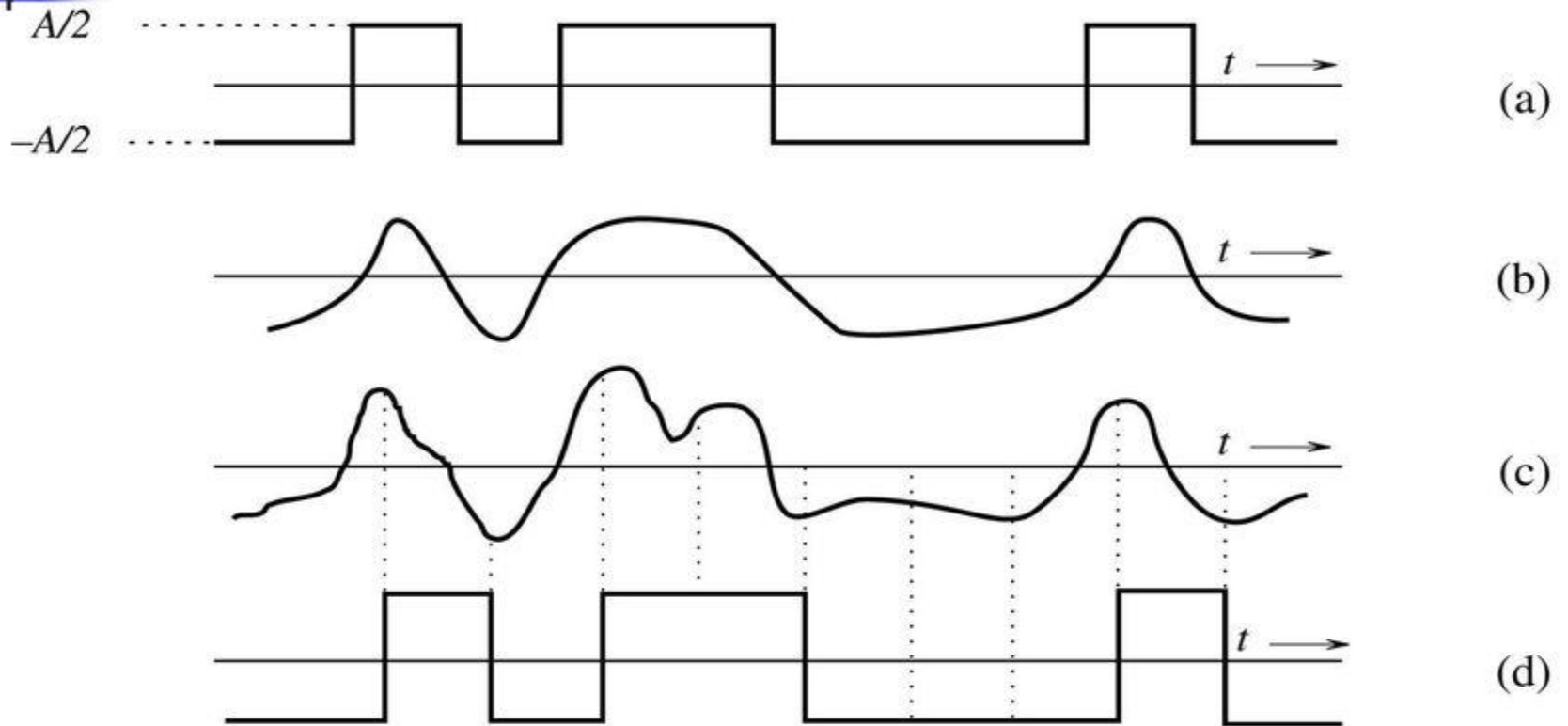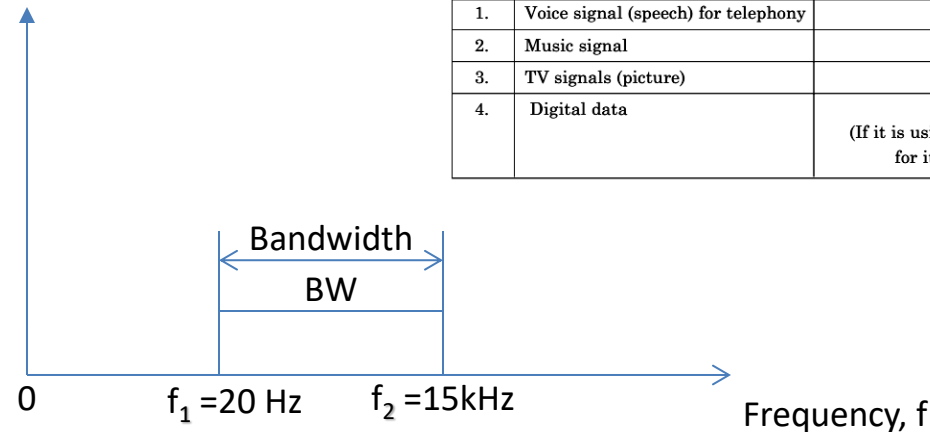
SIGNAL

NOISE

SIGNAL + NOISE

Regeneration digital signal

(a) Transmitted signal. (b) Received distorted signal (without noise).
(c) Received distorted signal (with noise). (d) Regenerated signal (delayed).

Bandwidth

▪The bandwidth is the frequency range over which an information signal is transmitted

▪We may also say that bandwidth is the difference between the upper and lower frequency limits of the signal.

S.No.	Type of the signal	Range of frequency in Hz	Bandwidth in Hz
1.	Voice signal (speech) for telephony	300 – 3400	3,100
2.	Music signal	20 – 15000	14, 980
3.	TV signals (picture)	0 – 5 MHz	5 MHz
4.	Digital data	300 – 3400 (If it is using the telephone line for its transmission)	3,100

Bandwidth

BW

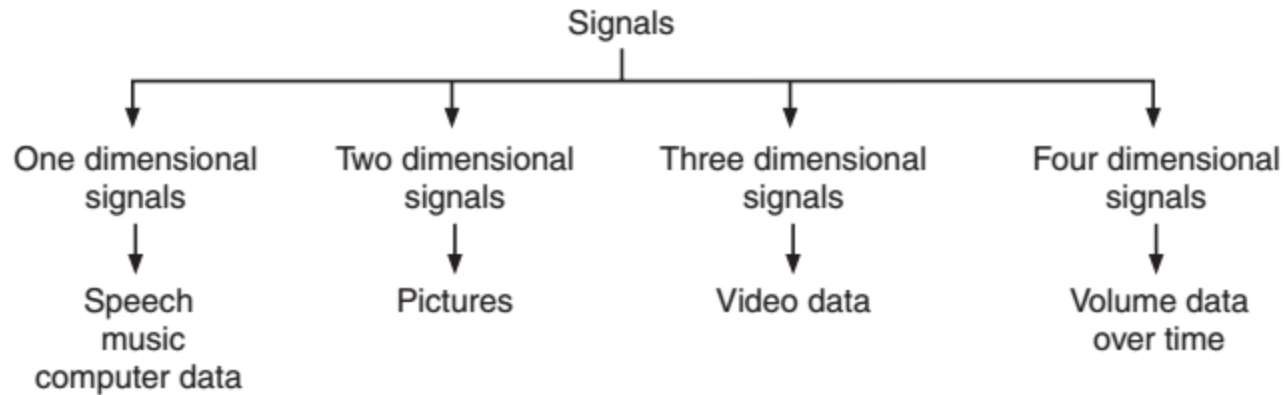0 f_1 =20 Hz f_2 =15kHz   Frequency, f

For example, the range of music signal is 20 Hz to 15 kHz, therefore, as shown in the above figure, the bandwidth is

$$BW = f_2 - f_1$$
$$BW = 15000 - 20 = 14980 \text{ Hz.}$$

Signal

A signal may be defined as the single valued function of time.

Speech: The band of frequencies required for the speech communication is 300 Hz to 3100 Hz. This band is utilized for the commercial telephonic communication.

Music: Music signal is a bipolar signal and it requires a bandwidth of about 15 kHz.

Video: The bandwidth required for this video signal is 0 to 5 MHz.

Computer Data: The text transmitted by a computer is encoded using American Standard Code for Information Interchange (ASCII)
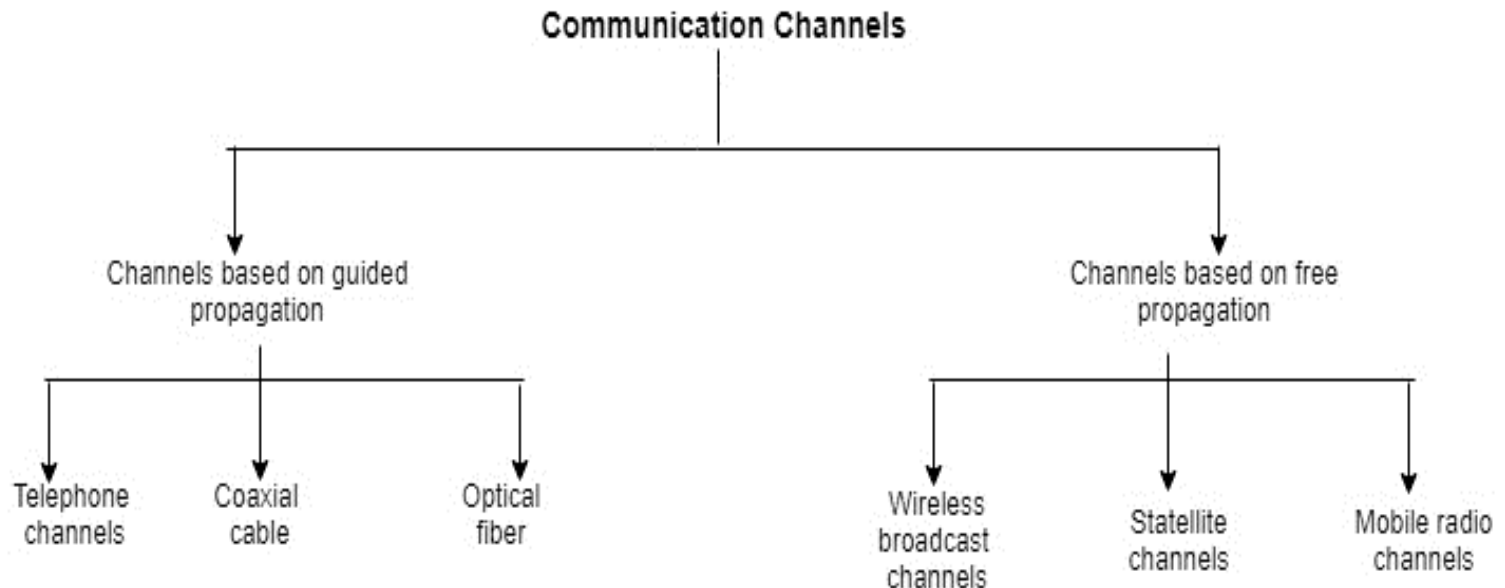
ASCII code set

Hex	Value	Hex	Value	Hex	Value	Hex	Value	Hex	Value	Hex	Value	Hex	Value	Hex	Value
00	NUL	10	DLE	20	SP	30	0	40	@	50	P	60	`	70	p
01	SOH	11	DC1	21	!	31	1	41	A	51	Q	61	a	71	q
02	STX	12	DC2	22	"	32	2	42	B	52	R	62	b	72	r
03	ETX	13	DC3	23	#	33	3	43	C	53	S	63	c	73	s
04	EOT	14	DC4	24	$	34	4	44	D	54	T	64	d	74	t
05	ENQ	15	NAK	25	%	35	5	45	E	55	U	65	e	75	u
06	ACK	16	SYN	26	&	36	6	46	F	56	V	66	f	76	v
07	BEL	17	ETB	27	'	37	7	47	G	57	W	67	g	77	w
08	BS	18	CAN	28	(	38	8	48	H	58	X	68	h	78	x
09	HT	19	EM	29	)	39	9	49	I	59	Y	69	i	79	y
0A	LF	1A	SUB	2A	*	3A	:	4A	J	5A	Z	6A	j	7A	z
0B	VT	1B	ESC	2B	+	3B	;	4B	K	5B	[	6B	k	7B	{
0C	FF	1C	FS	2C	,	3C	<	4C	L	5C	\	6C	l	7C		
0D	CR	1D	GS	2D	-	3D	=	4D	M	5D	]	6D	m	7D	}
0E	SO	1E	RS	2E	.	3E	>	4E	N	5E	^	6E	n	7E	~
0F	SI	1F	US	2F	/	3F	?	4F	O	5F	_	6F	o	7F	DEL

Communication Channels

Some important characteristics of a channel are:
- Power required to achieve the desired S/N ratio.
- Bandwidth of the channel.
- Amplitude and phase response of channel.
- Type of channel (linear or non-linear).
- Effects of external interference on the channels.

Communication Channels

- Channels based on guided propagation
  - Telephone channels
  - Coaxial cable
  - Optical fiber
- Channels based on free propagation
  - Wireless broadcast channels
  - Statellite channels
  - Mobile radio channels

Communication Channels

Telephone channels:

- It is designed for providing service to voice signals such as telephones
- Bandpass characteristics over 300 to 3400 Hz.
- High signal to noise ratio of about 30 dB.
- Approximately linear response.
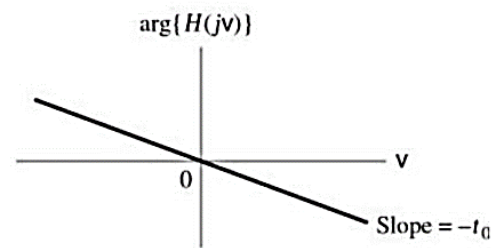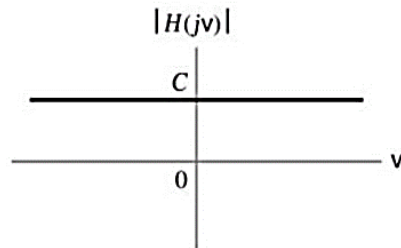
Example of telephone channels: A common examples is twisted pair cable.
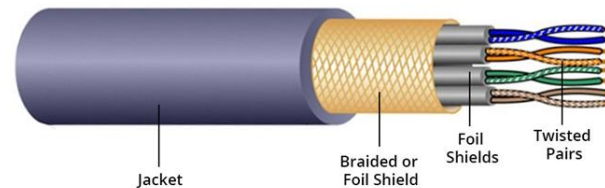
Advantages: It is quite cheaper.

Communication Channels

Co-axial cables:

- It was initially developed as the backbone of analog telephone networks
- A single cable would be used to carry more than 10,000 voice channels.
- Two types of cables having 75 Ω and 50 Ω impedance are available.
- Because of shielding, this cable has noise immunity.
- It has large bandwidth and low losses
- This cable is suitable for both point to point or point to multipoint applications.
- It expensive than twisted pair cable however, cheaper than optical fiber.
- Repeaters are used after every 1 km to achieve data rates 8.5 Mb/s to 274 Mb/s

COAXIAL CABLE

braided shield   foil shield   center conductor   outer jacket   dielectric

Advantages: co-axial cables provide higher immunity to electromagnetic interference and higher bandwidth compared with twisted pair cables.

Communication Channels

Optical fiber cables:

- An optical fiber is a very thin strand of plastic or glass that is used to transmit messages via light.
- It consist of an inner glass core. High bandwidth
- Long distance
- Immunity to electromagnetic interference required
- It can transmit voice, video, and telemetry through LAN, computer networks, or across long distances.
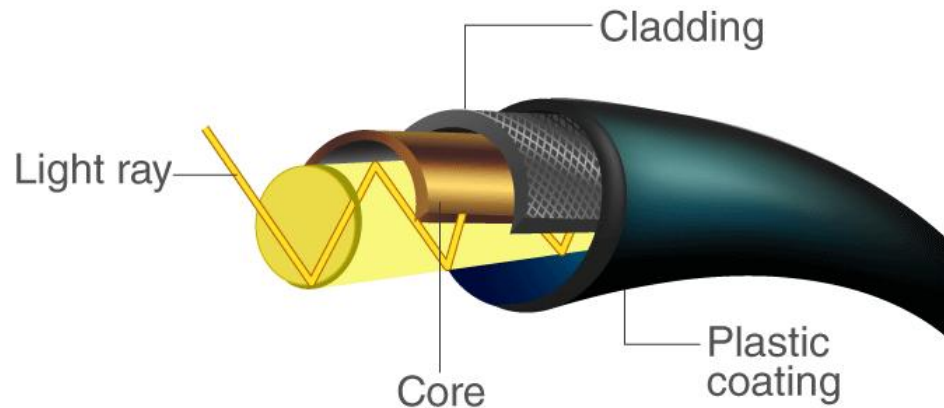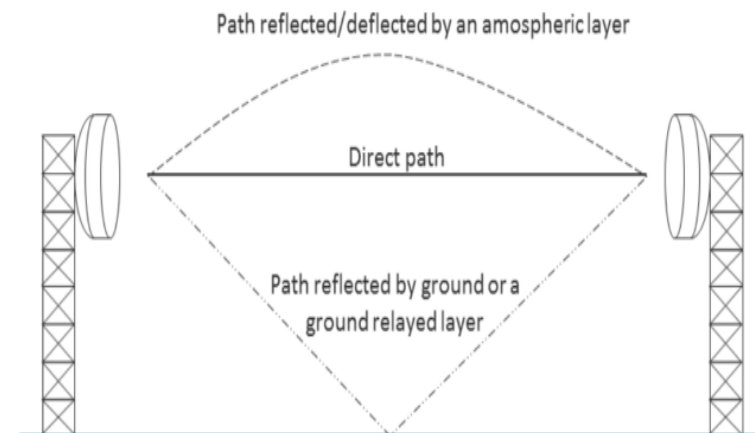

Advantages: Small size and light weight, easy availability and low cost, no electrical or electromagnetic interference, large bandwidth.

Disadvantages: High initial cost, Maintenance and repairing cost, Jointing and test procedures, Tensile stress, Fiber losses.

Communication Channels

Terrestrial microwave channel:

- Terrestrial microwave channel requires a line of sight path between a sender and a receiver.
- Unidirectional
- Repeaters are needed for long distance communication.
- No adverse effects such as cable breakage etc.
- Very high frequency microwave cannot penetrate walls
- Less maintenance compared with cables.
- Microwave waves are used for cellular networks, satellite and wireless networks.

MICROWAVES TRANSMISSION

Main Microwave

Microwave Relay Station

Microwave Relay Station

Line of Sight (about 30 miles)

Earth

Microwave Relay Stations
- ✓ Height of 40-50ft
- ✓ Spaced at least 20-30miles apart

Path reflected/deflected by an amospheric layer

Direct path

Path reflected by ground or a ground relayed layer

Advantages: No cables needed, multiple channel available, wide bandwidth.

Disadvantages: Signal strength at the receiving antenna reduces due to multipath reception.

Communication Channels

Satellite channel:

- A communication satellite is a microwave relay station.
- Used to link two or more ground stations
- It uses frequency range between 11 GHz and 14 GHz.
- The message signal transmitted by the earth station to the satellite is called as an uplink frequency.
- It is amplified and down converted in frequency by the transponder.
- The signal from satellite to earth is called downlink frequency.
- It receives signal on one frequency (uplink=6 GHz) and transmits on another frequency (downlink= 4 GHz).
- Rotation match occurs at a height of 35,683 km at the equator.
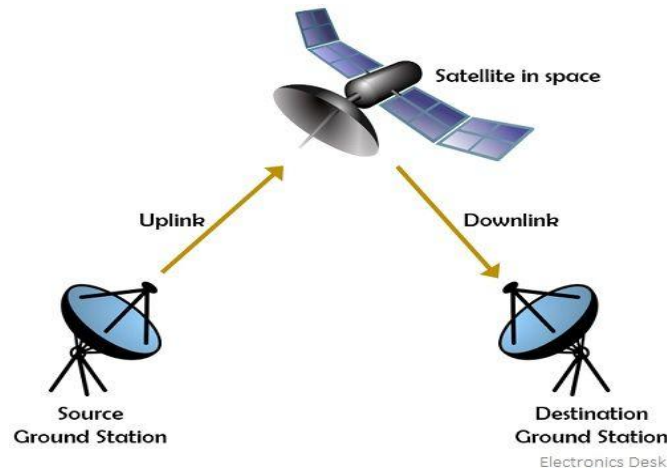
Disadvantages: The cost of building and launching is very high.

Electronic communication systems

Classification: The electronic communication may be classified into three groups based on

- whether the system is unidirectional or bidirectional.
- Whether it uses an analog or digital information signal/modulating signal.
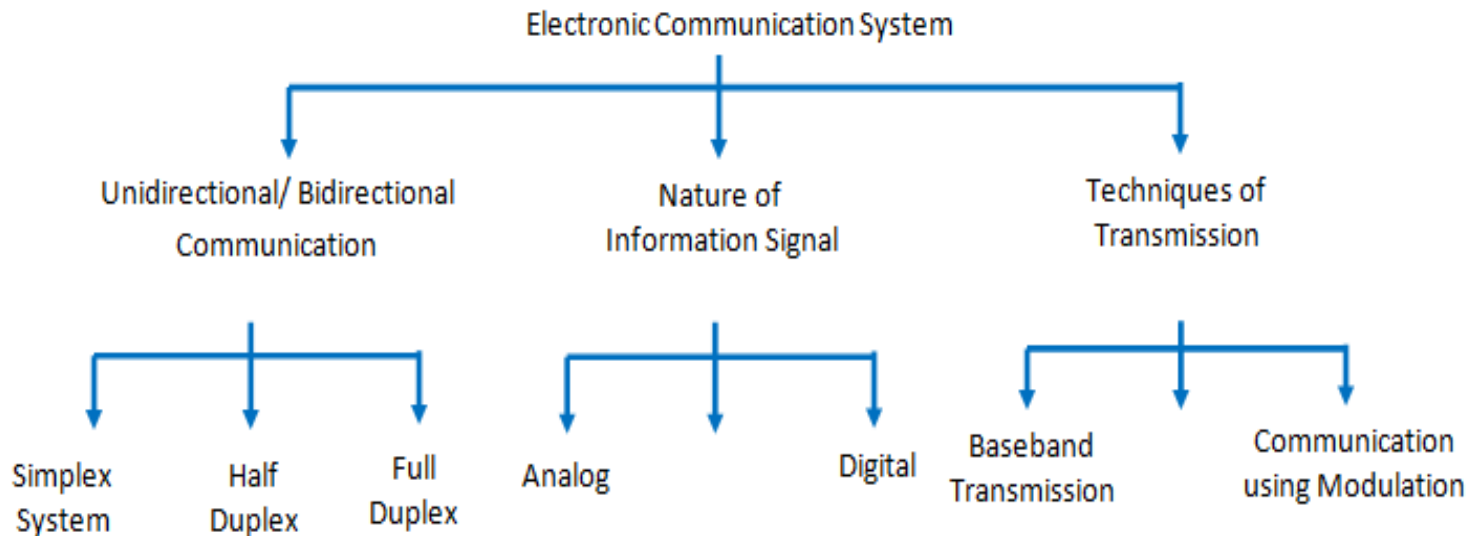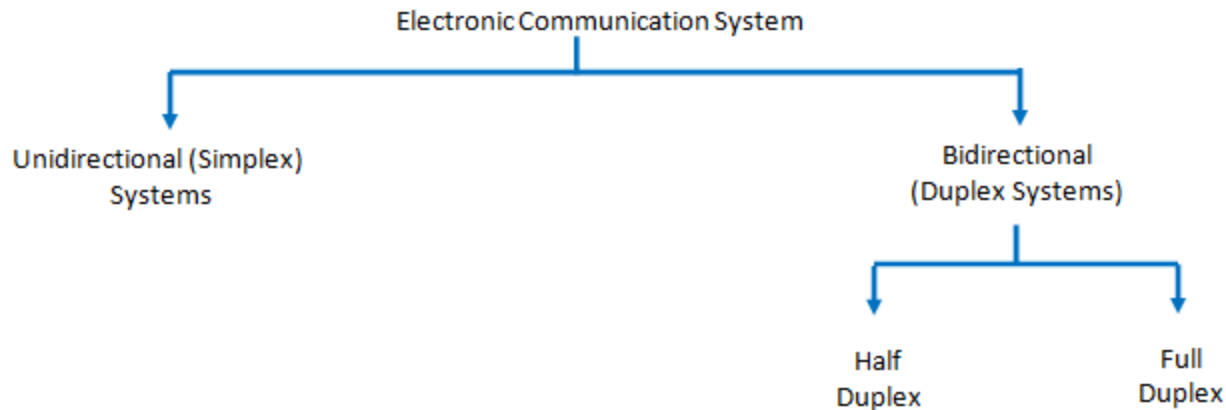- Whether the system uses baseband transmission or use some kind of modulation.

Fig. Classification of electronic communication system

Based on direction of communication

Based on the direction of communication, the communication systems are:

i.   Simplex systems
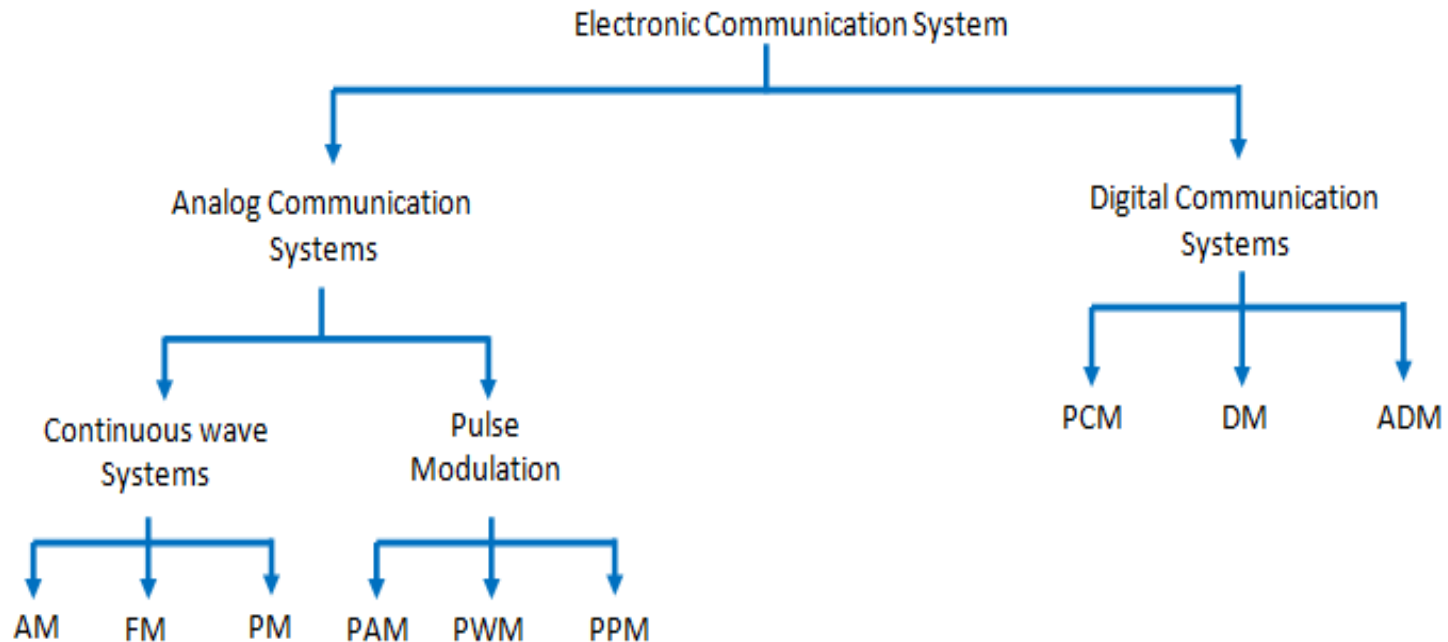ii. Half duplex systems
iii. Full duplex systems

Simplex systems: The information is communicated in only one direction such as the radio and TV broadcasting.

Half duplex systems: The information is communicated in bi-direction but one at a time such as walky-talky.

Full duplex systems: The information is communicated in both direction simultaneously such as telephone.

Based on nature of information signal

Based on the nature of information signal the communication systems are:

```
                        Electronic Communication System
                                       |
              ┌────────────────────────┴────────────────────────┐
              ↓                                                  ↓
      Analog Communication                            Digital Communication
           Systems                                          Systems
              |                                                  |
      ┌───────┴───────┐                          ┌───────────────┼───────────────┐
      ↓               ↓                          ↓               ↓               ↓
 Continuous wave    Pulse                       PCM             DM             ADM
    Systems       Modulation
      |               |
 ┌────┼────┐     ┌────┼────┐
 ↓    ↓    ↓     ↓    ↓    ↓
 AM   FM   PM   PAM  PWM  PPM
```

Analog communication: The modulation systems or techniques in which one of the characteristics (amplitude, phase or frequency) of the carrier is varied in proportion with the instantaneous value of modulating signal is called as analog modulation system.

Examples of analog modulation: Following are the examples of analog modulation systems :

- Amplitude modulation (AM)
- Frequency modulation (FM)
- Phase modulation (PM)
- Pulse Amplitude Modulation (PAM)
- Pulse Width Modulation (PWM)
- Pulse Position Modulation (PPM)

Advantages of analog communication:

- Transmitters and receivers are simple
- Low bandwidth requirement
- FDM (Frequency division multiplexing) can be used

Drawbacks of analog communication:

- Noise affects the signal quality
- It is not possible to separate noise and signal
- Repeaters can not be used between transmitter and receiver
- Coding is not possible
- It is not suitable for the transmission of secret information

Applications:

- Radio broadcasting (AM and FM)
- TV broadcasting
- Telephones

Digital communication

The modulation system or technique in which the transmitted signal is in the form of digital pulses of constant amplitude, constant frequency and phase is called as digital modulation system : The common applications are: Long distance, communication between earth and space ships , Satellite communication, Military communication, Telephone systems, Data and computer communications

Examples of digital modulation: Following are the examples of analog modulation systems :
- Pulse code modulation (PCM)
- delta modulation (DM)

Advantages of analog communication:
- Reliable communication, less sensitivity to changes in environmental conditions (such as temperature)
- Easy multiplexing, easy signaling
- Voice and data integration
- Easy processing like encryption and compression
- Integration of transmission and switching
- FDM (Frequency division multiplexing) can be used

Drawbacks of Digital Communication:
- The bit rates of digital systems are high . Therefore, they require a larger channel bandwidth as compared to analog system .
- Digital modulation needs synchronization in case of synchronous modulation .

Classification based on technique of transmission

Based on the technique used for the signal transmission, we can categorize the electronic communication system as under :
- Baseband transmission system
- Communication systems using modulation

Baseband transmission systems: In baseband transmission systems, the baseband signals (original information signals/modulating signal) are directly transmitted such as telephone network
Limitations:
- It cannot be used for free space communication because it gets suppressed after a short distance.
  Note: we can overcome this limitations using modulation

Communication systems using modulation:
- In the modulation process, two signals are used namely the modulating signal and the carrier .
- The modulating signal is nothing but the baseband signal or information signal while the carrier is a high frequency sinusoidal signal .

What is modulation

Modulation is the process of varying one or more properties of a high frequency periodic waveform, called the *carrier signal*, with a separate signal called the *modulation signal* that typically contains information to be transmitted.
For example, the modulating signal might be an audio signal, a video signal etc.
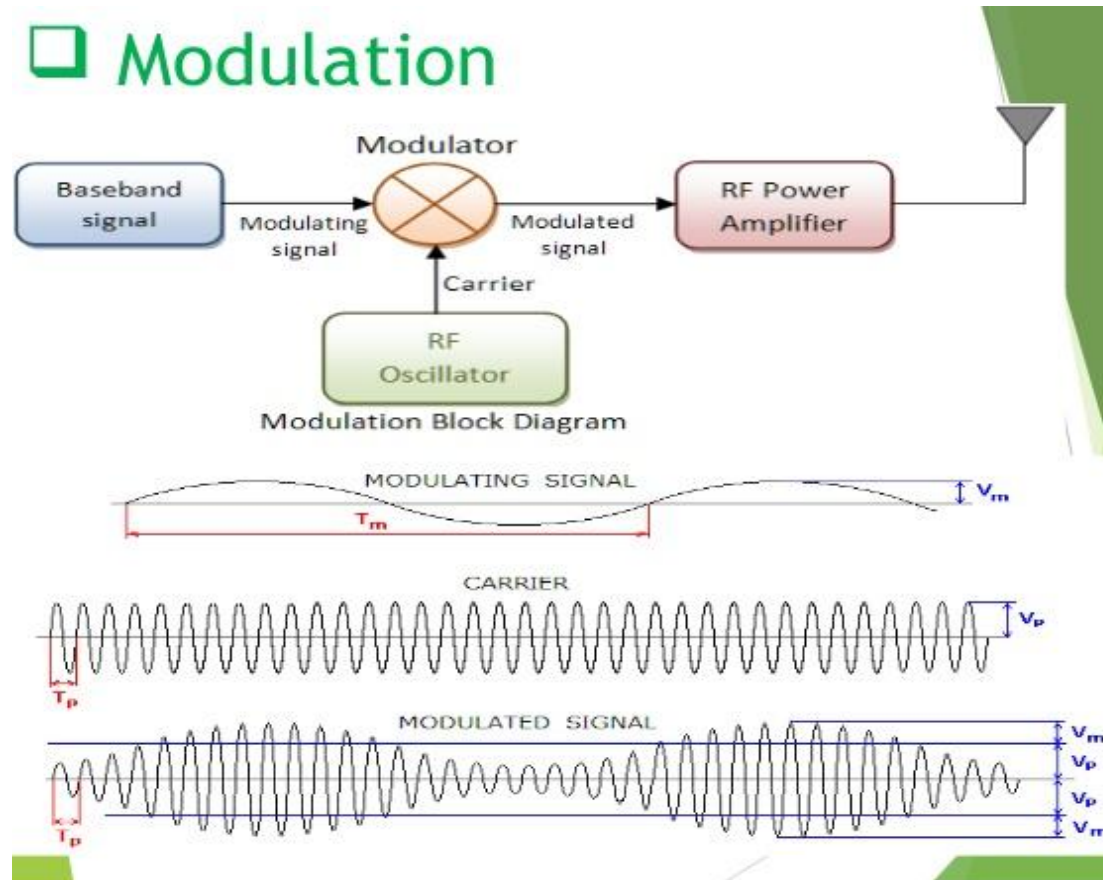
Why do we need modulation

The modulation is necessary for the following reasons:
- Reduction in the height of the antenna
- Avoids mixing of signals
- Increases the range of communication
- Multiplexing is possible
- Improve quality of reception

Reduction in the height of antenna : For the transmission of radio signals, the antenna height must be a multiple of $(\lambda/4)$. where λ is the wavelength $(\lambda = c/f)$.

The minimum antenna height required to transmit a base-band signal of f = 10KHz is calculated as follows:

Minimum antenna height = $\lambda/4 = C/4f = 3 \times 10^8 /(4 \times 10 \times 10^3)$ **= 7500 m i.e. 7.5 km**

The antenna of this height is practically impossible to install.

Now consider a modulated signal at f = 1MHz

The minimum height is given by $= \lambda/4$

$= c/4f$

$= 3 \times 10^8 /(4 \times 10 \times 10^6)$

= 75 m

This size antenna can be installed practically.

Avoid mixing of signals
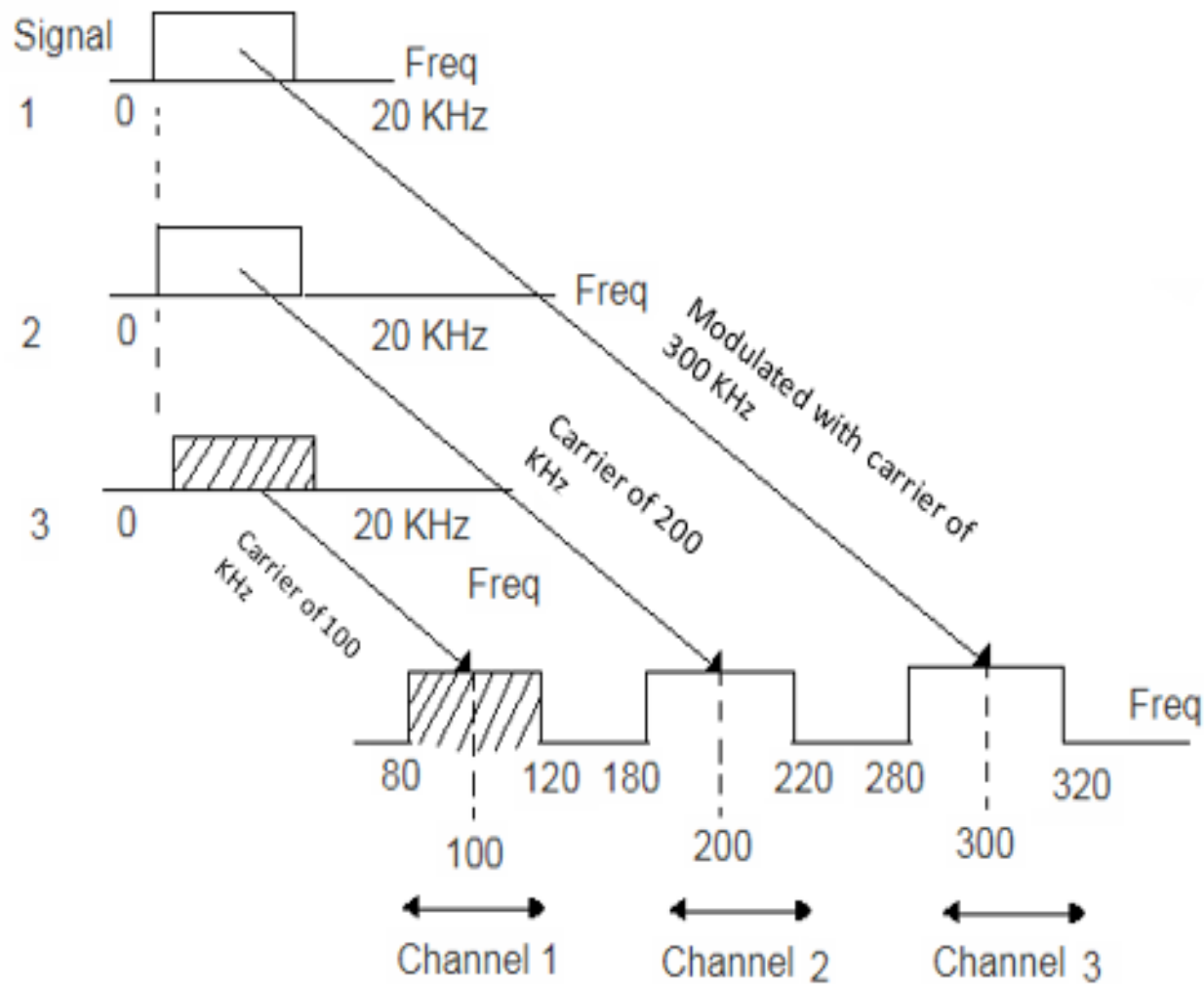
Different types of modulation systems
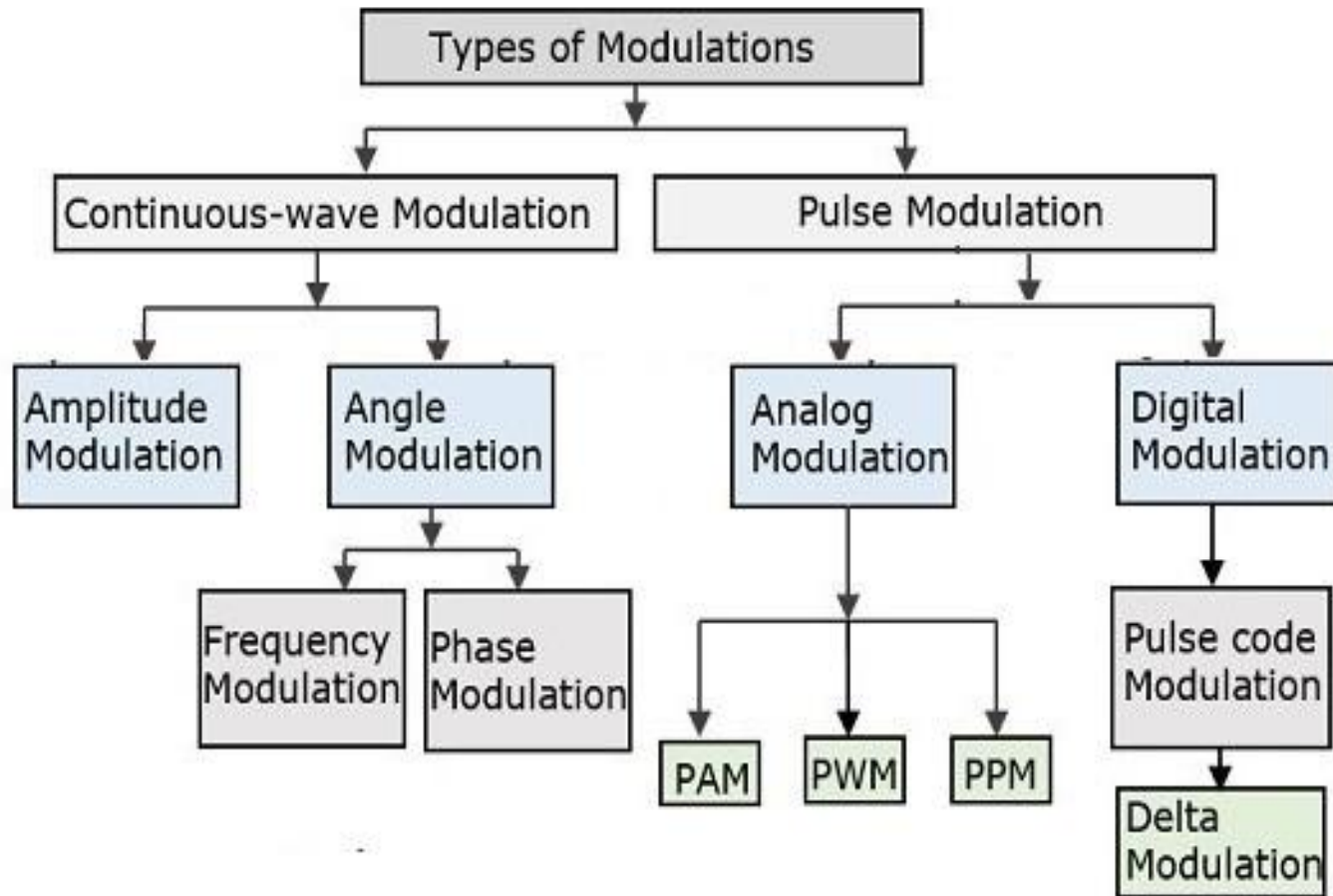
Amplitude modulation (AM)

- The carrier is a sine wave frequency
- The carrier frequency is much higher than the frequency of modulating signal.
- Here, the information is contained in its amplitude variation.
- The frequency of the carrier remains constant.
- AM is used in radio and TV broadcasting applications.
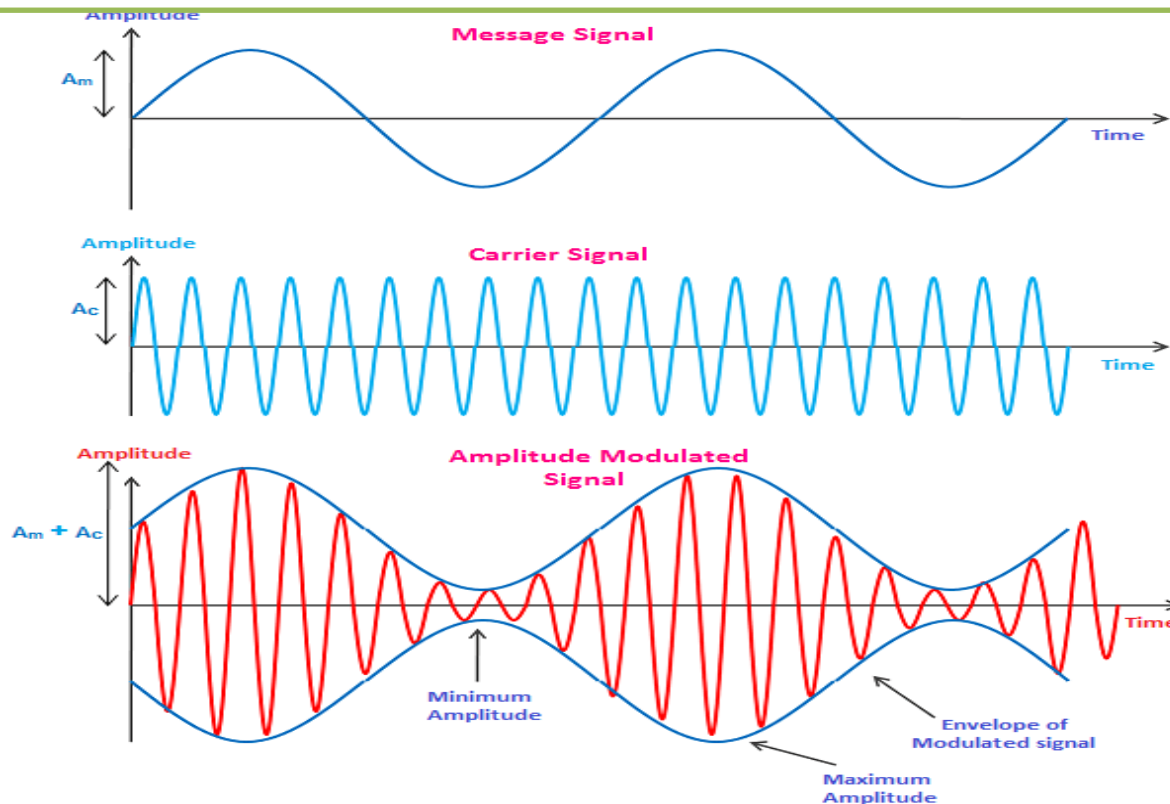
Frequency modulation (FM)

- The frequency of the carrier is changed in proportion with the amplitude of the modulating signal.
- The amplitude of the carrier remains constant.
- FM is used for TV, sound, FM radio and police wireless transmission.
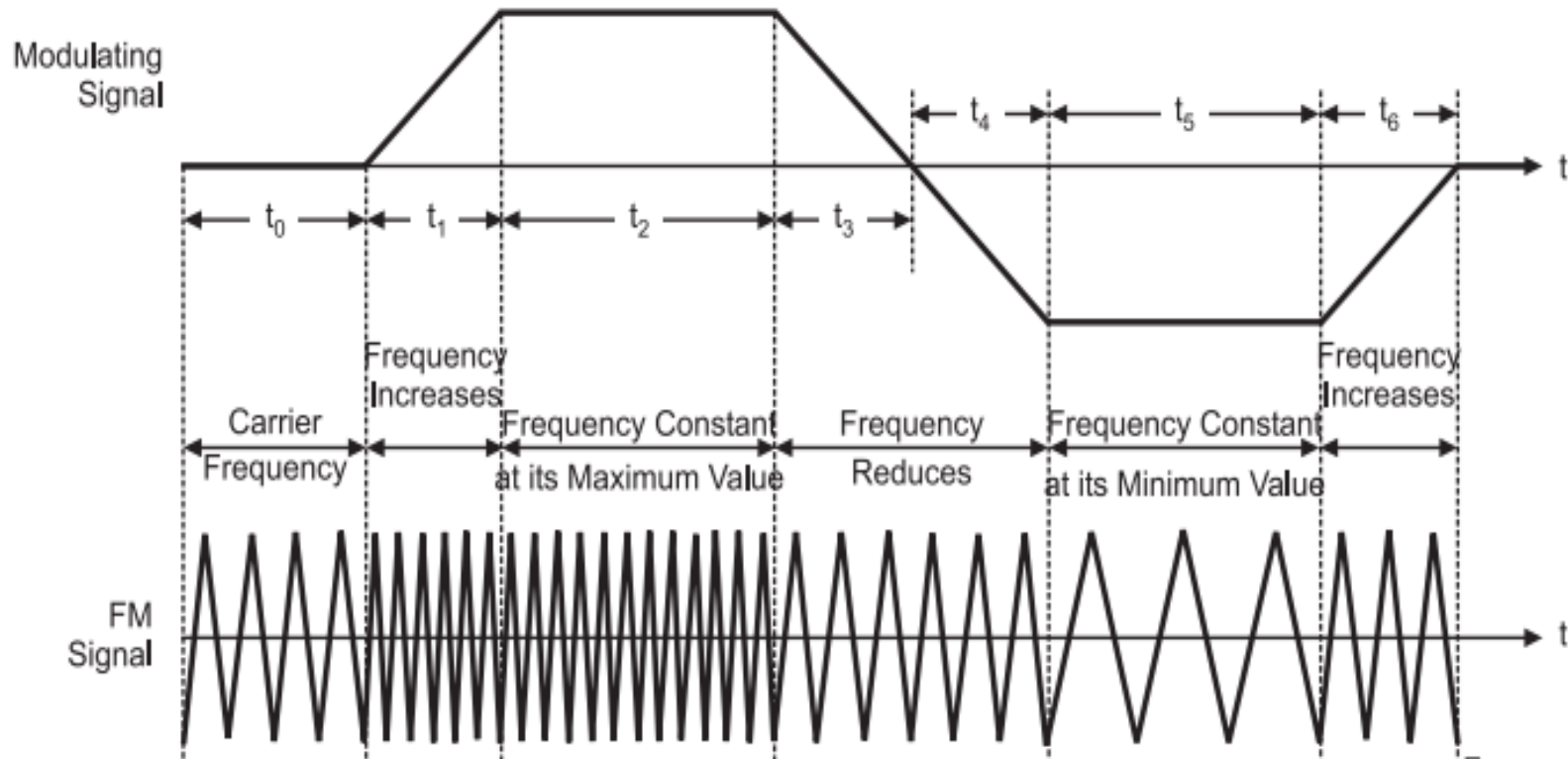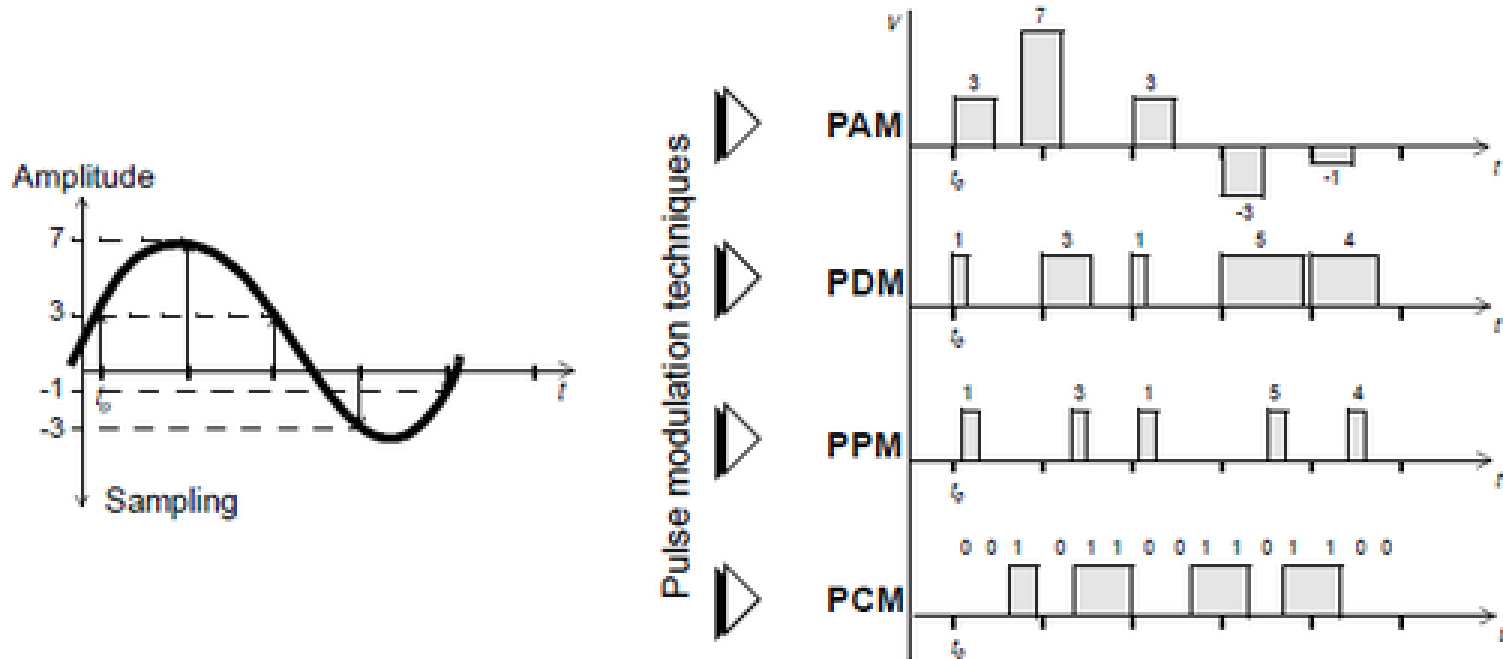
Phase modulation (PM)

▪The phase shift of the carrier is changed in proportion with the amplitude of the modulating signal.
▪The amplitude of the carrier remains constant.
▪PM is used for generation of FM.
▪FM signal produced from PM signal is very stable.
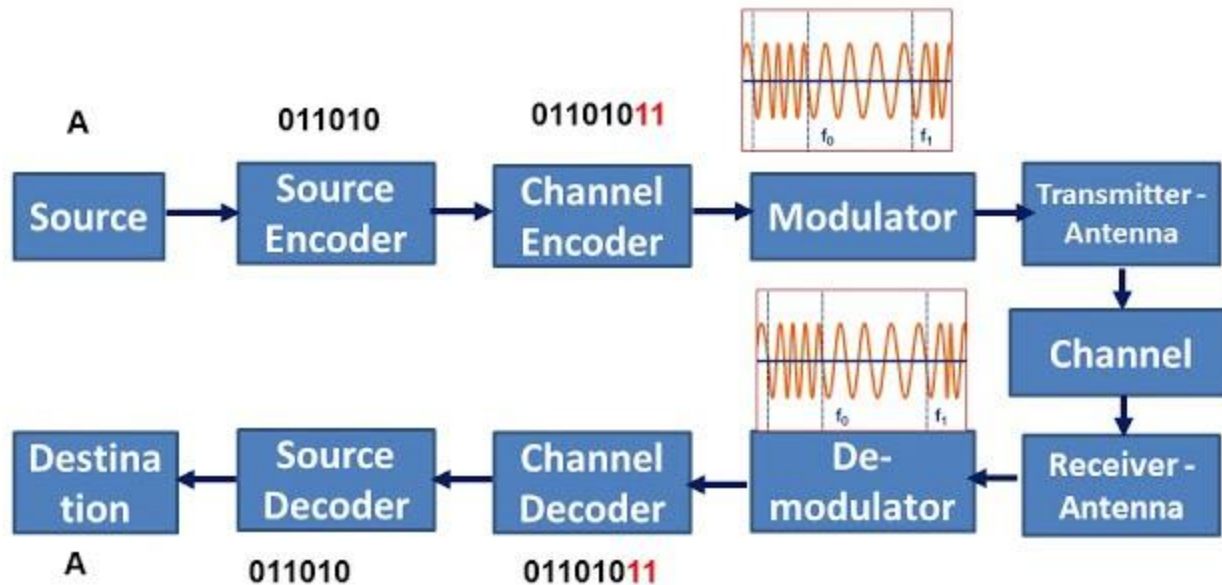▪The centre frequency called resting frequency is extremely stable.
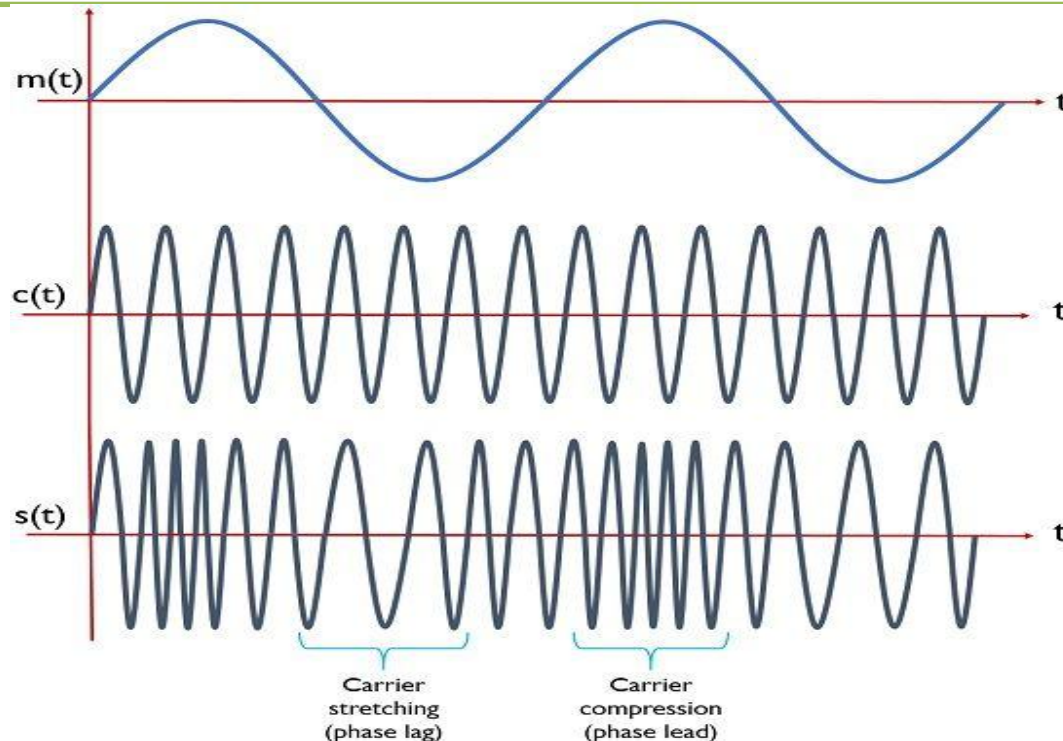
Waveform for Phase Modulation
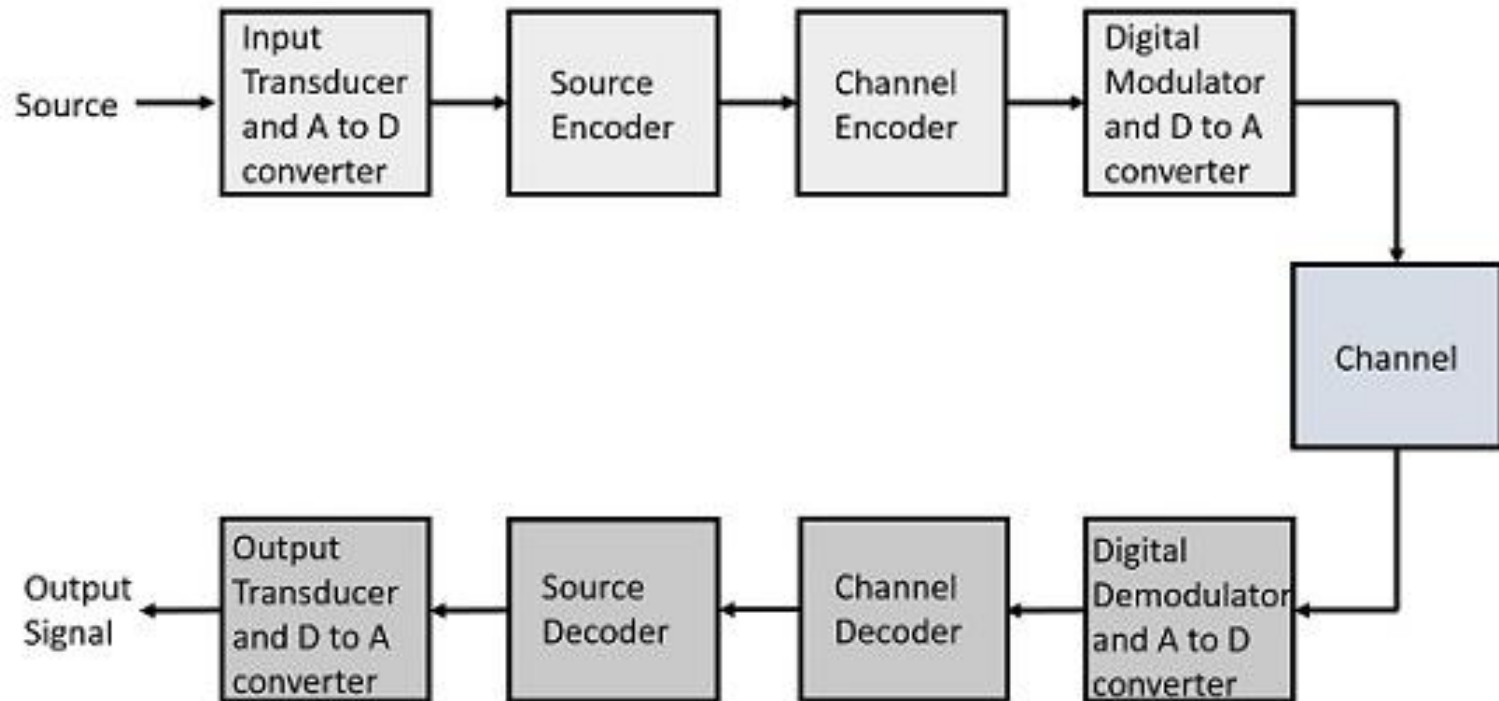
Pulse analog modulation

- The carrier is in the form of pulses instead of being a sinewave.
- In PAM, the amplitude of the carrier is varied.
- In PWM, the width of the carrier is varied.
- In PPM, position of the pulses is varied with the amplitude of modulating signal.

Digital Communication System

A   **011010**   **0110101 1**

| Source | → | Source Encoder | → | Channel Encoder | → | Modulator | → | Transmitter - Antenna |

↓

| Channel |

↓

| Destination | ← | Source Decoder | ← | Channel Decoder | ← | De-modulator | ← | Receiver - Antenna |

A   **011010**   **0110101 1**

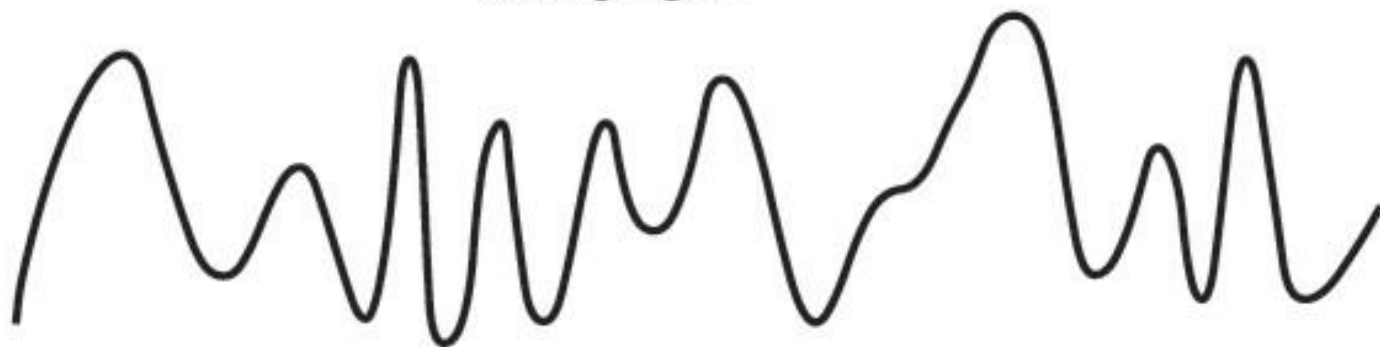# Digital Communication System

Basic Elements of a Digital Communication System

A/D Converter: Analog to Digital Converter
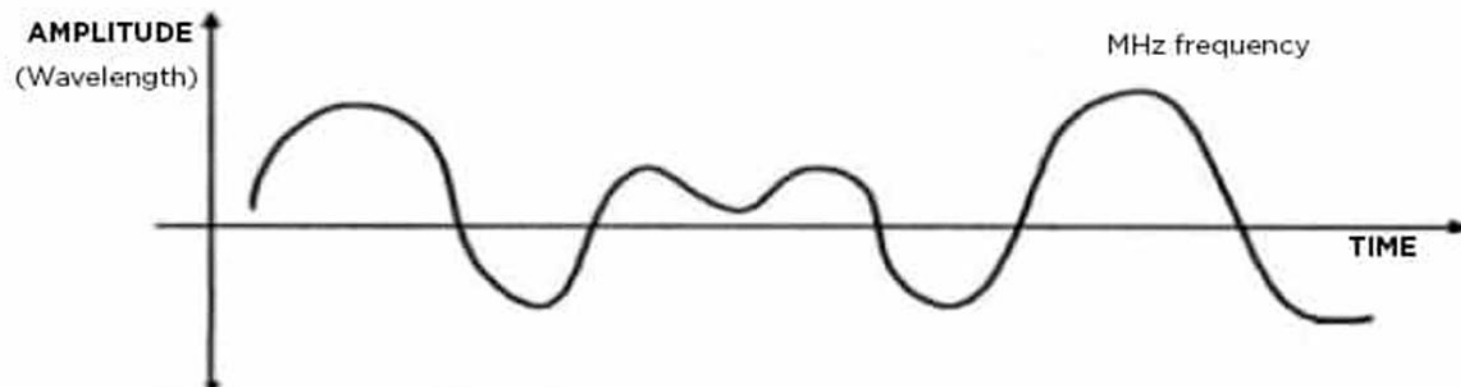
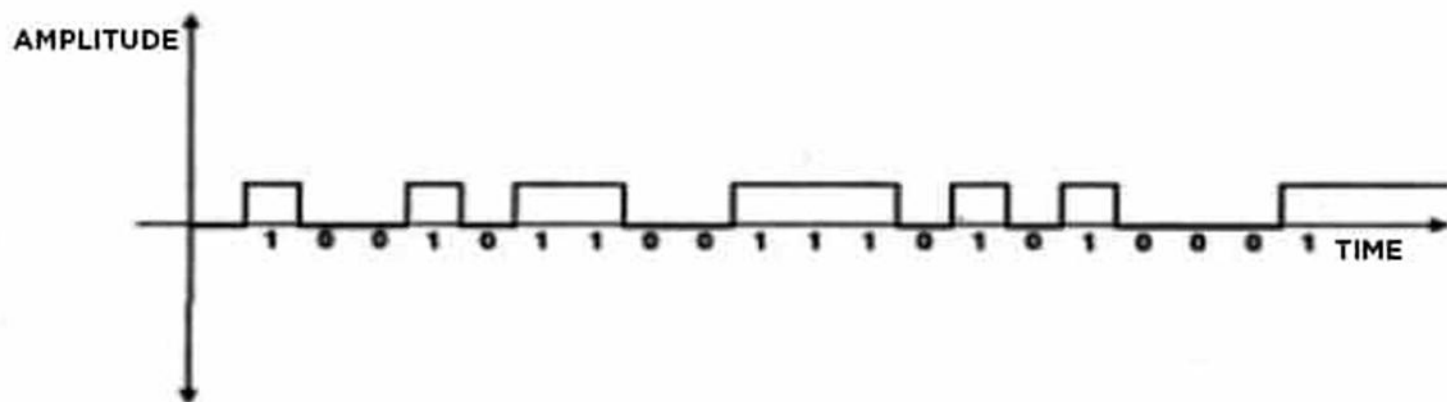D/A Converter: Digital to Analog Converter

analog signal

digital signal

Comparison of Analog and Digital Modulation

Analog	Digital
Less bandwidth(**Advantage**)	Large bandwidth(**Disadvantage**)
More accurate (**Advantage**)	Less accurate due to the Quantization error that can not be avoided or corrected. (**Disadvantage**)
Low noise immunity (**Disadvantage**).	High noise immunity as the amplitude of the digital has two levels only and channel coding (error correcting codes) can be used. (**Advantage**)
Low level of security. (**Disadvantage**)	High level of security as you can use Encryption (Ciphering) and Authentication. (**Advantage**)
No signal conditioning and processing are used (**Disadvantage**)	Support complex signal conditioning and processing techniques such as source coding, encryption, and equalization((**Advantage**)
Low QOS. (**Disadvantage**)	High QOS. (**Advantage**)
You can use FDM only(**Disadvantage**)	You can use FDM, TDM, CDM, OFDM multiplexing techniques. (**Advantage**)
In mobile communications, analog supports voice service only. (**Disadvantage**)	In mobile communications, digital supports voice, SMS, data (you can access the internet), images and video call. (**Advantage**)
More difficult to design than Digital. (**Disadvantage**)	Easily designed using software (**Advantage**).

Limitation of communication systems

Physical limitations:
- Bandwidth limitations
  - Measure of speed
  - The system ability to follow signal variations depends on the transmission bandwidth
  - Available bandwidth determines the maximum signal speed.
- Noise limitations
  - Unavoidable
  - The kinetic theory
  - Noise relative to information signal is measured in terms of signal to noise ratio (SNR)

Compromise within:
- Transmission time and power
- SNR performance
- Cost of equipments
- Channel capacity
- bandwidth