KEMENTERIAN PENGAJIAN TINGGI

INTRODUCTION TO COMMUNICATION SYSTEM

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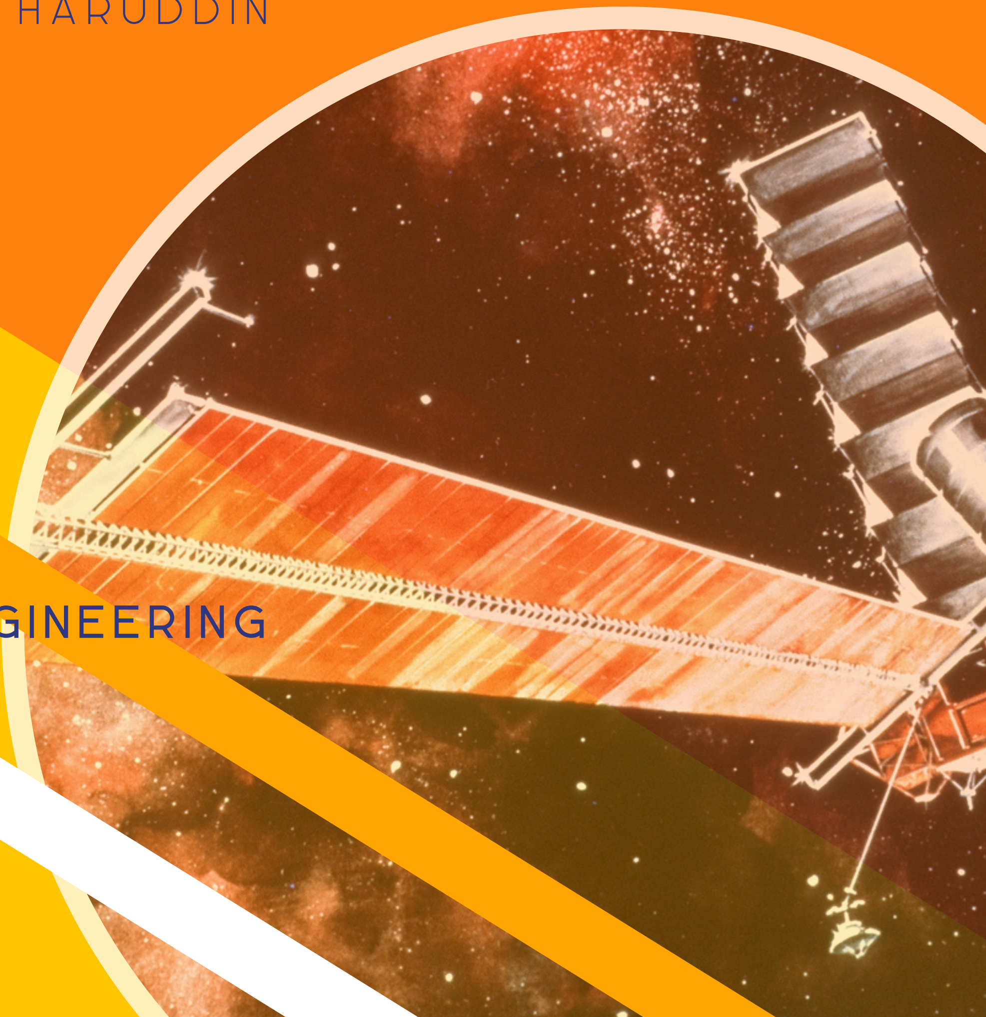

ELECTRICAL ENGINEERING

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ABSTRACT

Introduction to Communication System introduces the students to the concepts of communication system. This e-book are designed to make it particularly easy for students to understand about communications. The purpose of this e-book is to give students the knowledge and practice about communications. This e-book covers the element of basic communication system, noise, information capacity, frequency and bandwidth. It also exposes the students to the types of transmission modes and communication system. Theory, review questions and answers also provided for students in this e-book for better understanding.

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LEARNING OUTCOMES

After completing this book, you will be able to:

- [ ] Remember the element in basic communication system.
- [ ] Remember noise, interference, and distortion.
- [ ] Remember Signal-to-Noise Power Ratio, Noise Factor and Noise Figure.
- [ ] Apply SNR, Noise Factor, and Noise Figure formula.
- [ ] Understand the frequency spectrum, bandwidth, and wavelength.
- [ ] Understand Information capacity.
- [ ] Apply Shannon's limit formula.
- [ ] Apply bandwidth and wavelength formula
- [ ] Understand Transmission Modes
- [ ] Understand various types of communication system

1.0 ELEMENT IN BASIC COMMUNICATION SYSTEM.

Communication system is a process of transmission, reception and processing the information between two or more locations through transmission medium. Electrical communication systems are designed to send messages or information from a source that generates the messages to one or more destinations.

In general, a communication system can be represented by the functional block diagram shown in Figure 1.1. The information generated by the source may be of the form of voice (speech source), a picture (image source), or plain text in some language, such as English, Japanese, German, French, etc. An essential feature of any source that generates information is that its output is described in probabilistic terms, i.e., the output of a source is not deterministic. Otherwise, there would be no need to transmit the message.

A transducer is usually required to convert the output of a source into an electrical signal that is suitable for transmission. For example, a microphone serves as the transducer that converts an acoustic speech signal into an electrical signal, and a video camera converts an image into an electrical signal. At the destination, a similar transducer is required to convert the electrical signals that are received into a form that is suitable for the user, e.g., acoustic signals, images, etc.

The transmitter converts the electrical signal into a form that is suitable for transmission through the physical channel or transmission medium. For example, in radio and TV broadcast, the Federal Communications Commission (FCC) specifies the frequency range for each transmitting station. Hence, the transmitter must translate the information signal to be transmitted into the appropriate frequency range that matches the frequency allocation assigned to the transmitter. Thus, signals transmitted by multiple radio stations do not interfere with one another. Similar functions are performed in telephone communication systems where the electrical speech signals from many users are transmitted over the same wire.

The transmission medium or channel is the physical medium that is used to send the signal from the transmitter to the receiver. In wireless transmission, the channel is usually the atmosphere (free space). On the other hand, telephone channels usually employ a variety of physical media, including wirelines, optical fiber cables, and wireless (microwave radio). Whatever the physical medium for signal transmission, the essential feature is that the transmitted signal is corrupted in a random manner by a variety of possible mechanisms.

The most common form of signal degradation comes in the form of additive noise, which is generated at the front end of the receiver, where signal amplification is performed. Noise is an unwanted signal which tend to interfere with the required signal. Noise signal is always random in character. Noise may interfere with signal at any point in a communication system. However, the noise has its greatest effect on the signal in the channel.

A receiver is a collection of electronic components and circuits that accepts the transmitted message from the channel and converts it back to a form understandable by humans. Receivers contain amplifiers, oscillators, mixers, tuned circuits and filters, and a demodulator or detector that recovers the original intelligence signal from the modulated carrier. The output is the original signal, which is then read out or displayed. It may be a voice signal sent to a speaker, a video signal that is fed to an LCD screen for display, or binary data that is received by a computer and then printed out or displayed on a video monitor.

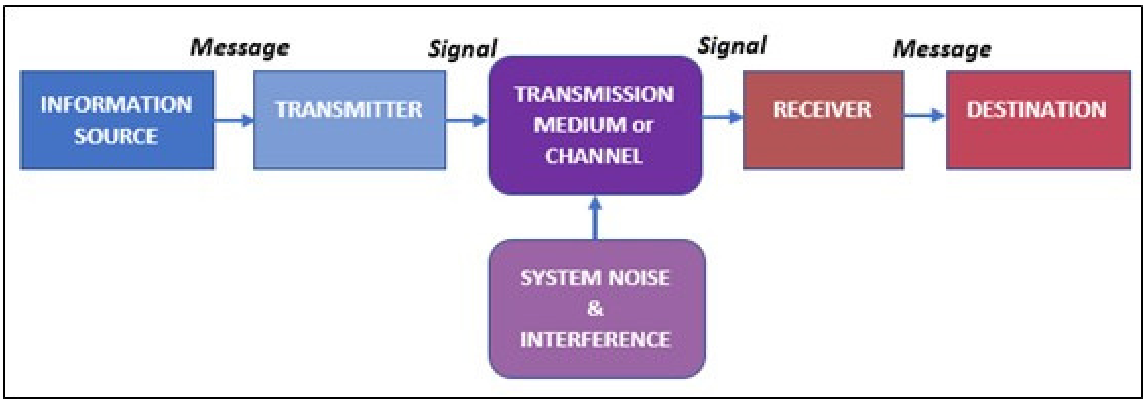
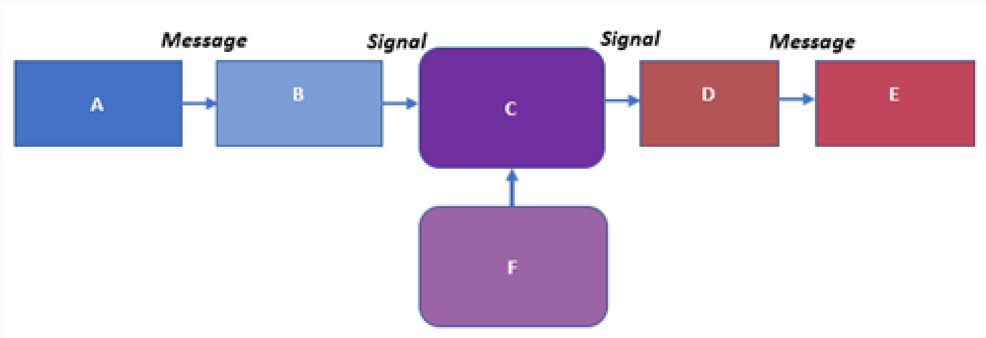


Figure 1.1: Block diagram of a communication system

TUTORIAL QUESTIONS 1

1. Define communication system and identify the element of communication system.
2. List FOUR (4) examples of destination in communication system block diagram.
3. State the process that involve in receiver part and give the examples of electronic devices that used in the process.
4. Figure below show the block diagram of a communication system. Name block A, B, C, D, E and F. Give the function of each block.



2.0 NOISE

Noise can be defined as unwanted signal from sources other than the transmitted signal source. It is a signal that does not convey any information. Electrical noise is defined as any unwanted electrical signal that falls within the passband of the signal. For example, in audio recording, any unwanted electrical signals that fall within the audio frequency band of 0 Hz to 15kHz will interfere the music will be considered as noise.

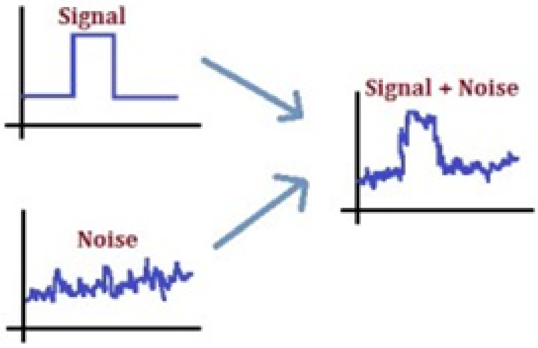


Figure 1.2: The signal with noise and the signal without noise.

Particularly noise can be divided into two general categories which is Correlated Noise and Uncorrelated Noise. Uncorrelated Noise is divided into two groups, which is External Noise and Internal Noise.

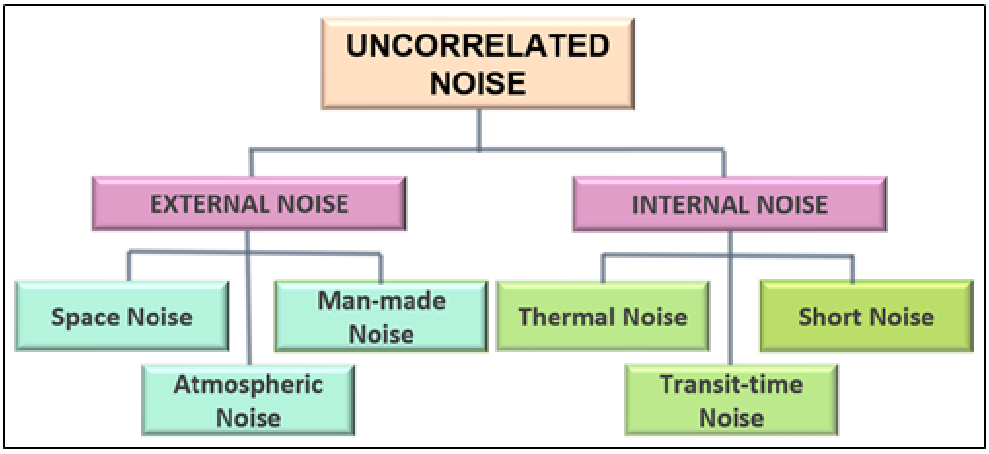
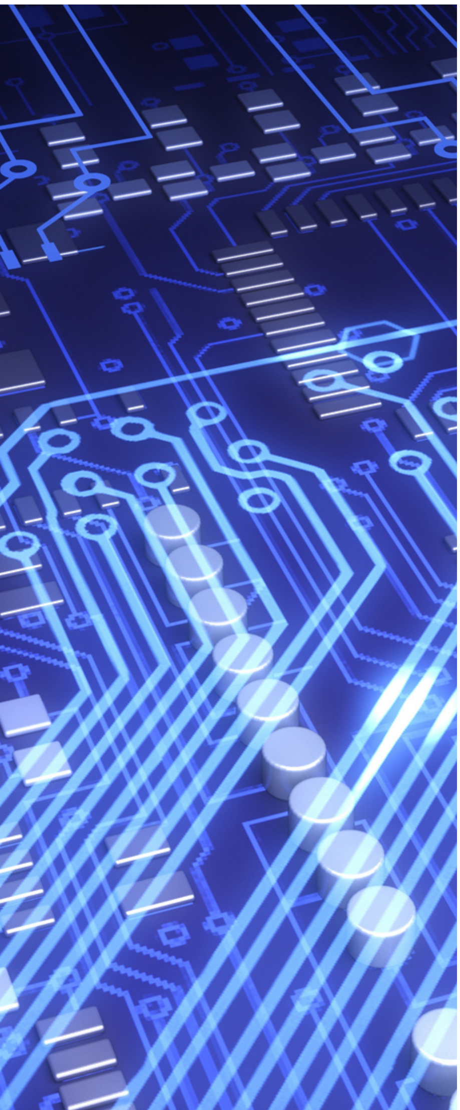


Figure 1.3: Noise Classification



2.1 EXTERNAL NOISE

External Noise is the noise which is generated outside the device or circuit system. External noises are somewhat uncontrollable, and these are:

- Atmospheric Noise
- Extra-Terrestrial/ Space Noise
- .Man-made noise or Industrial Noise

2.1.1 ATMOSPHERIC NOISE

Atmospheric Noise is caused by lighting discharge in thunderstorm and other natural disturbance in atmosphere. These electrical impulses are random in nature. Hence the energy spreads over the complete frequency spectrum which is used for radio communication. The receiving antenna not only picks up the desired signal but also the noise from thunderstorm and various disturbance causes at the output. Thus, large atmospheric noise is generated in low or medium frequency band (LF @ MF) while very little noise is generated in very high frequency (VHF) band.

2.1.2 SPACE NOISE

Space noise is divided into two categories which is solar noise and cosmic noise.

- Solar noise is an electrical noise generated from the sun heat. This is continuous radiation from sun. For example, result from large body of very high temperature (60000°C) will radiate electrical energy spectrum which is in the form of noise which spread over all the spectrum used for radio communication.
- Cosmic Noise is an electrical noise generated from the galaxies such as star. The star and distant also like a sun which have high temperature. Therefore, these stars radiate the noise in the same way as sun. The noise receives from the distant, star is known as thermal noise and distributed almost uniformly over the entire and almost effects on communication of radio waves.

2.1.3 MAN-MADE NOISE OR INDUSTRIAL NOISE

It is an electrical noise which produced by a source like automobiles such as an aircraft ignition, electric motors, switch gear leakage from higher voltage light, etc. Fluorescent light and many of man-made noise like electrical machine are intensive in industrial area and populated urban area.

2.2 INTERNAL NOISE

Internal Noise is the noise which is generated inside the communication system, within a device or circuit. It is produced by properly design of receiver circuitry and these are:

- Thermal Noise
- Shot Noise
- Transit-time Noise

2.2.1 THERMAL NOISE

The noise generated in a resistance or the resistive component is known as thermal noise. Thermal noise is present in all electronic communications system. It is due to the rapid and random motion of the molecules (atoms and electrons) inside the component itself. It is a form of additive noise which meaning that it cannot be eliminated, and it increases in intensity with the number of devices and circuit length. 'Also known as Brownian Noise, Johnson Noise, and White Noise (because the random movement of electrons is at all frequencies).

2.2.2 SHORT NOISE

Shot noise is caused by the random arrival of current carriers (holes and electrons) at the output element of an electronic device, such as a diode, field-effect transistor (FET) or bipolar transistor (BJT). These random arrival of the carriers because of the random paths and difference distance of travels. The amount of shot noise is directly proportional to the amount of dc bias flowing in a device. The bandwidth of the device or circuit is also important.

2.2.3 TRANSIT-TIME NOISE

The term transit time refers to how long it takes for a current carrier such as a hole or electron to move from the input to the output. Transit-time noise is any modification to a stream of carrier signals as they pass from the input to the output of a device (such as from the emitter to the collector of a transistor) produces an irregular, random variation. Transit-time noise in transistors is determined by carrier mobility, bias voltage, and transistor construction.

2.3 DISTORTION

Distortion is any changes in the original signal which has a corrupting effect on its form or shape. It is the modification of the original shape (or other characteristics) of original information signal. It creates unwanted frequencies (Harmonics) that interfere with the original signal and degrade the performance. It is a kind of correlated noise which the noise (distortion) is exist when the signal is exist. Some possible types of nonlinear distortion are listed below:

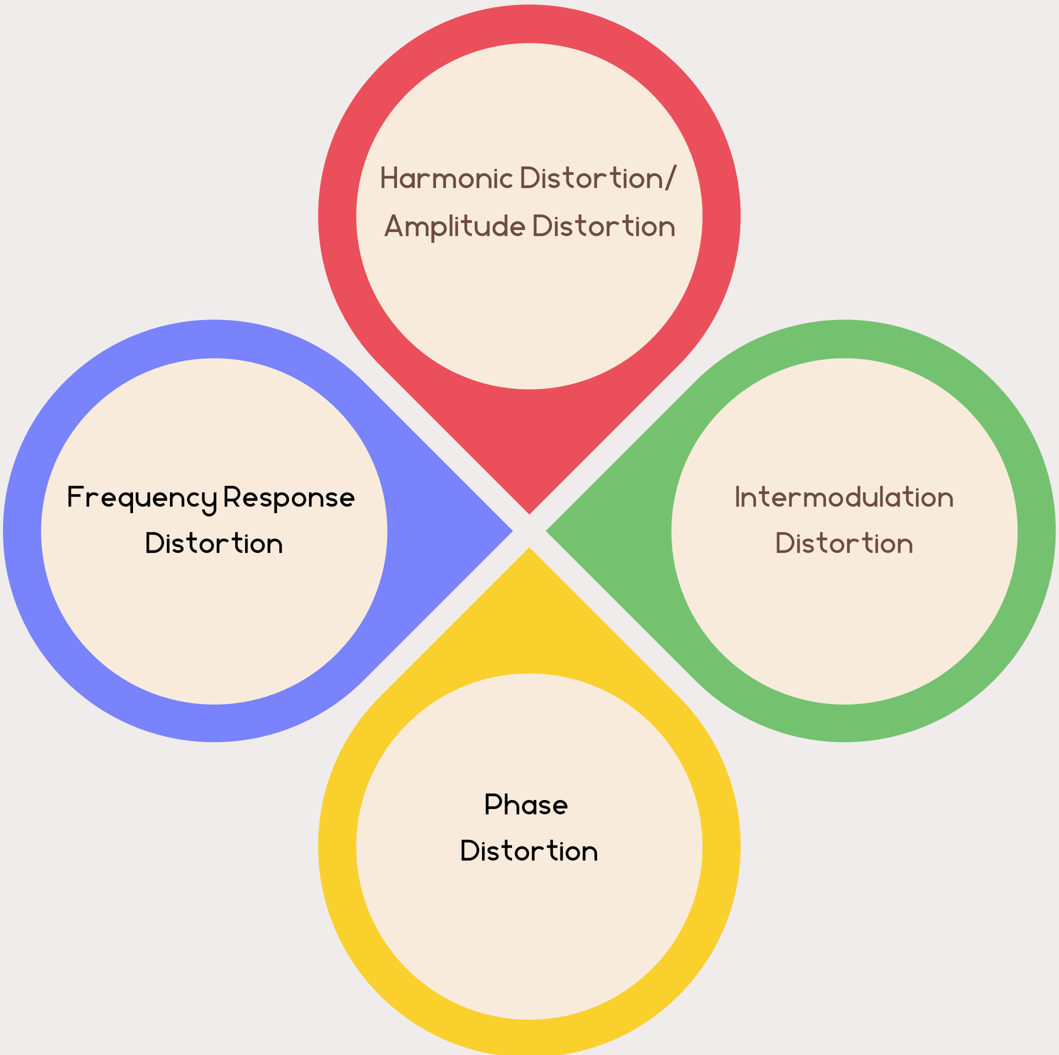


Figure 2.1: Types of Distortion

2.3.1 TYPES OF NONLINEAR DISTORTION

i) Harmonic Distortion/ Amplitude Distortion

Occurs when unwanted harmonics of a signal are produced through non-linear amplification. Figure shows the input is a single frequency (pure sine wave), but the output waveform is clipped by the amplifier. The result is that harmonic frequencies do not present in the original signal are produced at the output (harmonic distortion).

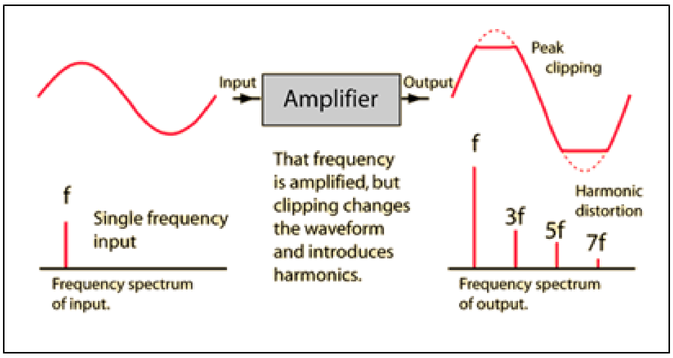


Figure 2.2: Harmonic Distortion

ii) Intermodulation Distortion

Non-linearity in amplifier components causes mixing of frequency components to form components at sum and difference frequencies. This intermodulation distortion is particularly troublesome in the reproduction of music because it generates frequencies which were not present in the original music and are thus very noticeable.

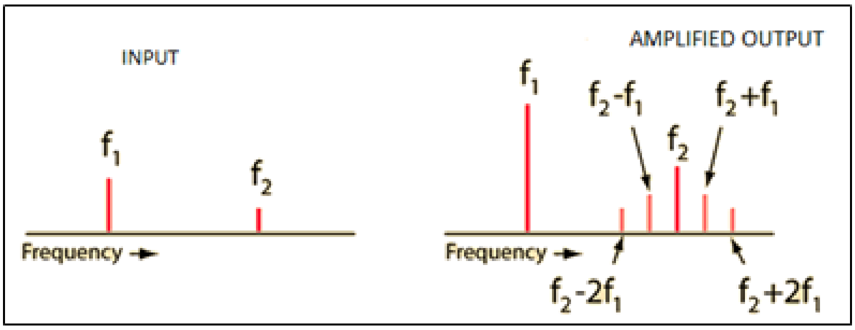


Figure 2.3: Intermodulation Distortion

iii) Frequency Response Distortion

A distortion that occurs when different frequencies are amplified by different amounts, caused by filters. Figure below shows the input waveform consists of the fundamental frequency plus a second harmonic signal. The resultant output waveform is shown on the right-hand side. The frequency distortion occurs when the fundamental frequency combines with the second harmonic to distort the output signal. Harmonics are therefore multiples of the fundamental frequency and in our simple example a second harmonic was used.

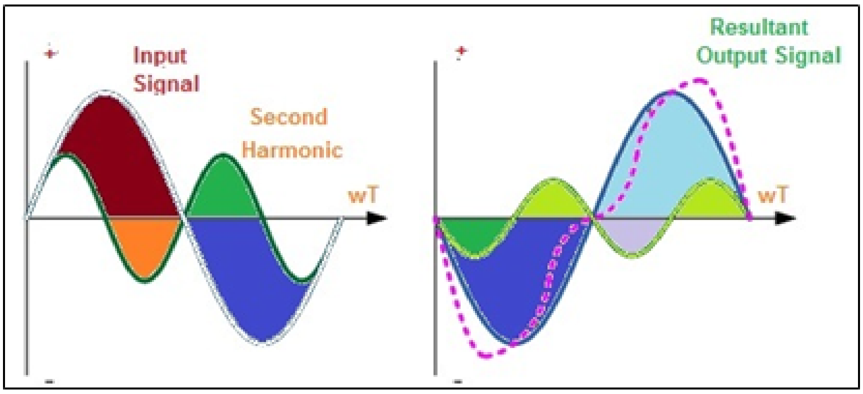


Figure 2.4: Frequency Response Distortion

iv) Phase Distortion

A distortion that occurs due to the reactive component, such as capacitive reactance or inductive reactance. As the results, a phase shift occurs between components of the original signal.

2.4 INTERFERENCE

Interference is a form of external noise which means "to disturb or detract from". Interference is when information signals from one source produce frequencies that fall outside their allocated bandwidth (Harmonics) and interfere with information signals from another source. Most interference occur when harmonics frequencies from one source fall into the passband of a neighboring channel. For example, radio channels interference where a channel is interfered by adjacent radio channel's frequencies.

Some possible types of interference are:

Adjacent-Channel Interference (ACI)
Caused by extraneous power from a signal in an adjacent channel.

Co-Channel Interference (CCI) or Crosstalk
Caused by crosstalk from two different radio transmitters using the same frequency.

Electromagnetic Interference (EMI)
Disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source.

Inter-carrier interference (ICI)
Caused by doppler shift in OFDM modulation.

TUTORIAL QUESTIONS 2

1. Define the meaning of distortion.

2. List FOUR types of nonlinear distortion in communication system.

3. Define the meaning of interference.

4. List FOUR types of interference in communication system.

3.0 SIGNAL-TO-NOISE POWER RATIO

Signal-to-Noise Power Ratio is the ratio of Signal Power (S) to the Noise Power (N) which corrupting the signal. Signal-to-Noise Power Ratio is also called as SNR or S/N.

SNR is a defining factor when it comes to quality of measurement where a high SNR guarantees clear acquisitions with low distortions caused by noise. The better your SNR, the better the signal stands out, the better the quality of your signals, and the better your ability to get the results you desire.

Noise is usually expressed as a power because the received signal is also expressed in terms of power. By knowing the signal to noise powers, the signal to noise ratio can be computed.

Rather than express the signal to noise ratio as simply a number, it can be expressed in terms of decibels (dB).

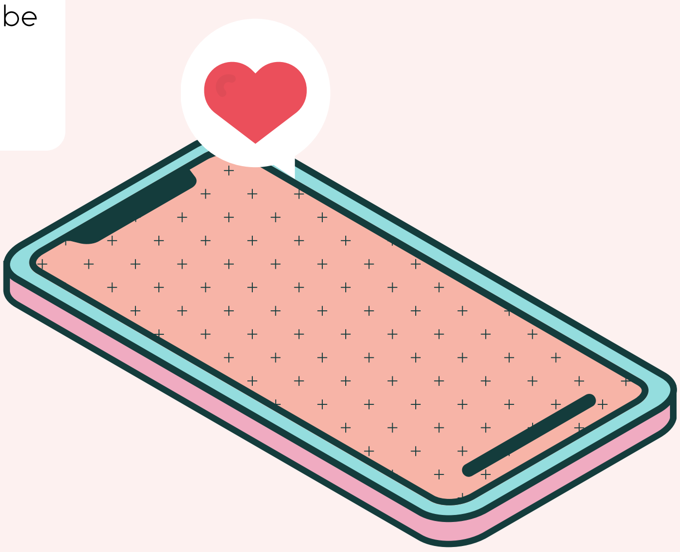
Often designated simply as S/N, the ratio is expressed mathematically at any point as,

$$\mathrm{SNR} = \frac{S}{N} = \frac{P_S}{P_N}$$

The ratio is often expressed in decibel form as:

$$\mathrm{SNR(dB)} = 10\log\left(\frac{S}{N}\right)$$

$$\mathrm{SNR(dB)} = 10\log\left(\frac{V_S^2/R_{in}}{V_N^2/R_{out}}\right)$$



3.1 NOISE FACTOR AND NOISE FIGURE

Noise Factor (F) and Noise Figure (NF) are figures of merit used to indicate how much the signal to noise ratio deteriorates as a signal passes through a circuit or series of circuits.

NOISE FACTOR

The noise factor F of a system is defined as:

$$F = \frac{\text{Input signal to Noise power ratio}}{\text{Output signal to Noise power ratio}}$$

$$F = \frac{SNR_{in}}{SNR_{out}}$$

$$F = \frac{S_{in}}{N_{in}} \text{ (unitless)}$$

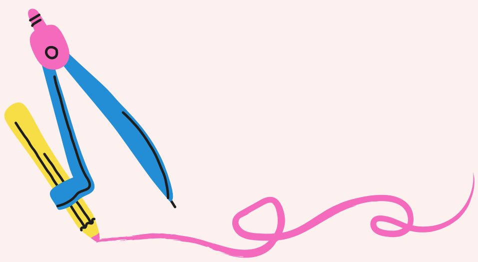
NOISE FIGURE

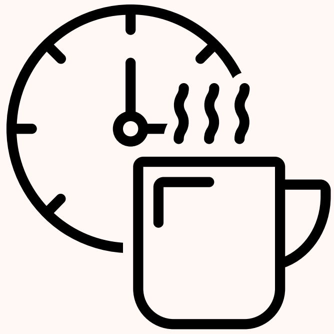
The noise figure is simply the noise factor stated in dB and is a parameter commonly used to indicate the quality of a receiver.

$$NF(dB) = 10\log F$$

$$NF(dB) = 10\log\left(\frac{SNR_{in}}{SNR_{out}}\right)$$

$$NF(dB) = 10\log\left(\frac{S_{in}/N_{in}}{S_{out}/N_{out}}\right)$$





LET'S TRY !!

EXAMPLE 1

A transistor amplifier has a measured S/N power of 10 at its input and 5 at its output.

(a)Calculate the SNR

(b)Calculate NF

Solution:

$$\text{(a)}\ \ \text{SNR} = \frac{Si/Ni}{So/No}$$

$$\text{SNR} = \frac{10}{5}$$

$$= 2$$

$$\text{(b)}\ \ \text{NF} = 10\ \log \frac{S_i/N_i}{S_o/N_o}$$

$$= 10\ \log \frac{10}{5}$$

$$= 3\text{dB}$$

EXAMPLE 2

For an amplifier with an output signal power of 10W and an output noise power of 0.01W, determine the signal to noise power ratio in dB

Solution:

$$\text{SNR} = 10 \log \frac{P_S}{P_N}$$

$$= 10 \log \frac{10}{0.01}$$

$$= 30\ \text{dB}$$

EXAMPLE 3

For an amplifier with an output signal voltage of 4V, and output noise voltage of 0.005V and an input and output resistance of 50Ω, determine the signal-to-noise power.

Solution:

$$\mathrm{SNR(dB)} = 10\log\frac{V_S^2/R_{in}}{V_N^2/R_{out}}$$

$$\mathrm{SNR(dB)} = 10\log\frac{4^2}{0.005^2}$$

$$= 58.06\mathrm{dB}$$

EXAMPLE 4

For an amplifier with an output signal power of 100W and an output noise power of 0.02W, determine the signal to noise power ratio.

Solution:

$$\mathrm{SNR} = 10\log\frac{P_S}{P_N}$$

$$= 10\log\frac{100}{0.02}$$

$$= 36.99\ \mathrm{dB}$$

EXAMPLE 5

For an amplifier with an output signal power of 1000W and an output noise power of 0.04W, determine the signal to noise power ratio.

.

Solution:

$$\mathrm{SNR} = 10\log\frac{P_S}{P_N}$$

$$= 10\log\frac{1000}{0.04}$$

$$= 43.98\ \mathrm{dB}$$

EXAMPLE 6

An amplifier has the output signal voltage 8V and output of noise voltage 0.006V. If the input resistance is 50Ω and the output resistance is 75Ω, what is the signal to noise power ratio of an amplifier?

Solution:

$$\mathrm{SNR(dB)} = 10\log\frac{V_S^2/R_{in}}{V_N^2/R_{out}}$$

$$\mathrm{SNR(dB)} = 10\log\frac{8^2/50}{0.006^2/75}$$

$$= 64.26\mathrm{dB}$$

TUTORIAL QUESTIONS 3

1. Given the Noise Figure (NF) of a non-linear amplifier is 5dB. At the input, the signal power is 500μW and the noise power is 2 μW. Calculate the Noise Factor (F) and the Output Signal to Noise Power (SNR_{out}).

2. The signal power at the input to an amplifier is 500μW and the noise power is 2 μW. At the output the signal power is 1W and the noise power is 20mW. Calculate the amplifier Noise Factor (F) as a ratio and Noise Figure (NF) in decibel.

3. The noise at the input is 4×10^{-18} W. Calculate the input signal power to the system that has noise figure 5dB and the SNR at the output is equal to 25×10^{6}.

4. An amplifier with NF = 6 dB has S_i/N_i of 25dB. Calculate the S_o/N_o in dB and as a ratio.

4.1 FREQUENCY SPECTRUM

Frequency is the number of times a particular phenomenon occurs in each period. In electronics, frequency is the number of cycles of a repetitive wave that occurs in each time. A cycle consists of two voltage polarity reversals, current reversals, or electromagnetic field oscillations. The cycles repeat, forming a continuous but repetitive wave.

The electromagnetic frequency spectrum is divided into subsections, or bands or range with each band having a different name and boundary. The International Telecommunications Union (ITU) is an international agency in control of allocation frequencies and services within the overall frequency spectrum.

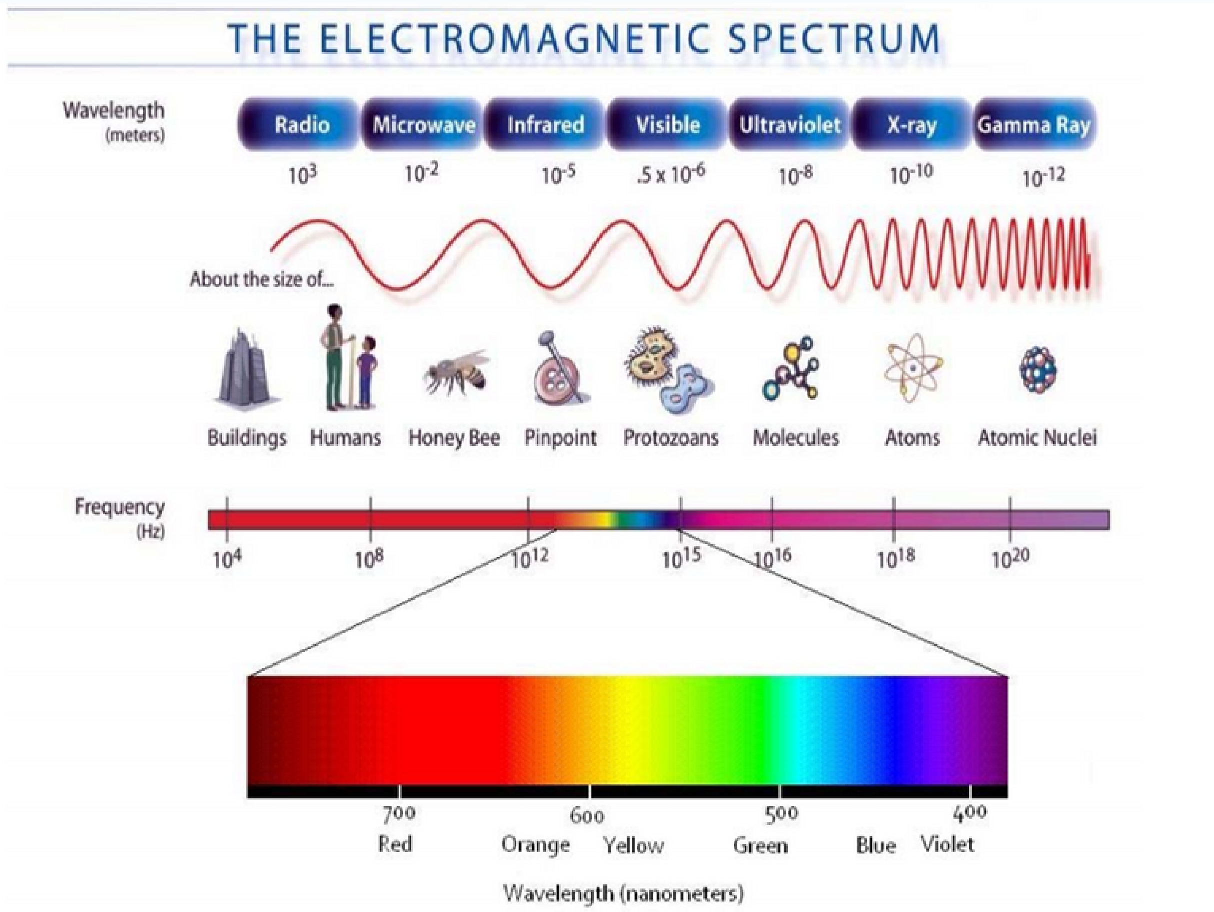


Figure 4.1: The Electromagnetic Spectrum

4.1 FREQUENCY SPECTRUM

EXTREMELY LOW FREQUENCIES (ELF)

Are signals in the 30 Hz to 300 Hz range and include ac power distribution signals (60Hz) and low frequency telemetry signals.

VOICE FREQUENCIES (VF)

Are signals in the 300 Hz to 3000 Hz range and include frequencies generally associated with human speech.

VERY LOW FREQUENCIES (VLF)

Are signals in the 3 kHz to 30 kHz range, which include the upper end of the human hearing range. VLFs are used for some specialized government and military systems, such as submarine communications.

LOW FREQUENCIES (LF)

Are signals in the 30 kHz to 300 kHz range and are used primarily for marine and aeronautical navigation.

MEDIUM FREQUENCIES (MF)

Are signals in the 300kHz to 3 MHz range and are used primarily for commercial AM radio broadcasting (535kHz - 1605kHz)

HIGH FREQUENCIES (HF)

Are signals in the 3MHz to 30 MHz range and are often referred as short waves. Most two-way radio communications use this range. Amateur radio and Citizens band (CB) radio also use signals in this range.

4.1 FREQUENCY SPECTRUM

VERY HIGH FREQUENCIES (VHF)

Are signals in the 30 MHz to 300 MHz range and are used for mobile radio, marine and aeronautical communications, commercial FM broadcasting, and commercial television broadcasting of TV1 and TV2.

ULTRA-HIGH FREQUENCIES (UHFS)

Are signals in the 300 MHz to 3 GHz range and are used by commercial television broadcasting, land mobile communication services, cellular telephones, certain radar, navigation systems, microwave, and satellite radio systems.

SUPER HIGH FREQUENCIES (SHF)

Are signals in the 3GHz to 30 GHz range and include most of the frequencies used for microwave and satellite radio communications systems.

EXTREMELY HIGH FREQUENCIES (EHF)

Are signals in the 30 GHz to 300 GHz range and are seldom used for radio communications except in very sophisticated, expensive, and specialized applications.

INFRARED

Are signals in the 0.3THz to 300 THz. Infrared signals are used in the heat-seeking guidance systems, electronic photography, and astronomy.

VISIBLE LIGHT

includes electromagnetic frequencies that fall within the visible range of humans (0.3 PHz to 3 PHz). Used with optical fiber systems.

Table 4.1 : Frequency Bands and their common uses

FREQUENCY BAND	FREQUENCY RANGE	APPLICATION
Extremely Low Frequencies (ELF)	30 Hz to 300 Hz	power distribution signals (60Hz) and low frequency telemetry signals
Voice Frequencies (VF)	300 Hz to 3000 Hz	Human speech, Telephone communication
Very Low Frequencies (VLF)	3 kHz to 30 kHz	military systems such as submarine communications
Low Frequencies (LF)	30 kHz to 300 kHz	marine and aeronautical navigation
Medium Frequencies (MF)	300kHz to 3 MHz	AM radio broadcasting
High Frequencies (HF)	3MHz to 30 MHz	two-way radio communications: Amateur Radio
Very High Frequencies (VHF)	30MHz to 300 MHz	mobile radio, marine and aeronautical communications, commercial FM broadcasting, and commercial television broadcasting of TV1 and TV2.
Ultra-High Frequencies (UHFs)	300 MHz to 3 GHz	commercial television broadcasting, land mobile communication services, cellular telephones, certain radar, navigation systems, microwave, and satellite radio systems.
Super High frequencies (SHF)	3GHz to 30 GHz	microwave links and satellite radio communications systems
Extremely High Frequencies (EHF)	30 GHz to 300 GHz	Wireless local loop
Infrared	0.3THz to 300 THz	heat-seeking guidance systems, electronic photography, and astronomy.
Visible Light	0.3 PHz to 3 PHz	Optical communications

4.2 WAVELENGTH

DEFINITION:

Wavelength is the distance occupied by one cycle (or one oscillation) of a wave, and it is usually expressed in meters.

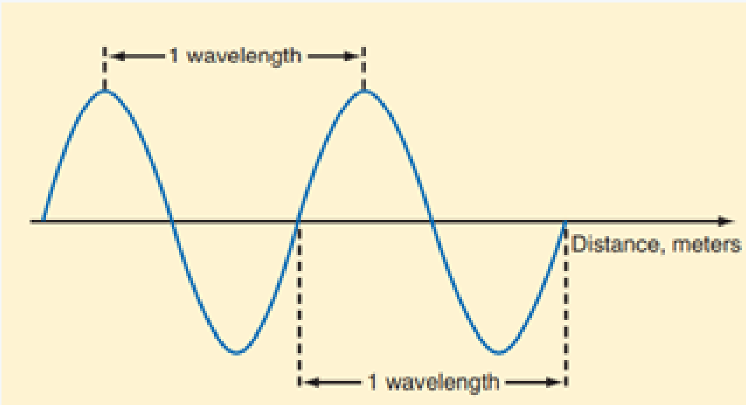


Figure 4.2 : One wavelength

If the wavelength of a signal is known or can be measured, the frequency of the signal can be calculated. The relationship among frequency f, light velocity c, and wavelength λ, is expressed mathematically as:

$$\text{wavelegth},\ \lambda = \frac{c}{f}$$

Where;

λ = wavelength (meter)

c = velocity of light (3 x 10^8 m/s)

f = frequency (Hz)

EXAMPLE :

For the frequencies of 1GHz, calculate its wavelength:

Solution:

f = 1 GHz

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3 \times 10^8}{1 \times 10^9}$$

$$\lambda = 0.3$$

4.3 BANDWIDTH

Bandwidth (BW) is the range of frequencies. The bandwidth of a signal is defined as the difference between the upper and lower frequencies of a signal generated. As seen from the figure, bandwidth (BW) of the signal is equal to the difference between the higher or upper-frequency (fH) and the lower frequency (fL). It is measured in terms of Hertz (Hz) i.e., the unit of frequency. Bandwidth indicates the capacity of data. The larger size of BW means the bigger capacity of data and more data could be transfer at one time.

BANDWIDTH FORMULA

$$BW\ (Hz) = f_H - f_L$$

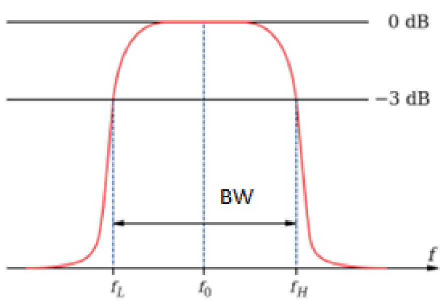
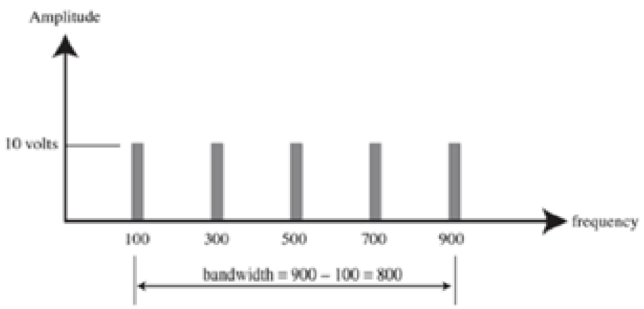


Figure 4.3 : Bandwidth of Signals

EXAMPLE 1

If a periodic signal is decomposed into five sine waves with frequencies 100,300,500,700 and 900Hz, what is the Bandwidth?

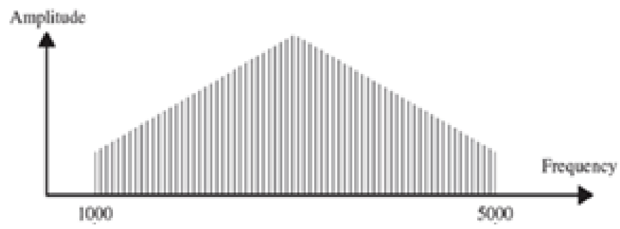


Solution:

$$BW = f_H - f_L$$
$$= (900 - 100)\ MHz$$
$$= 800Hz$$

EXAMPLE 2

Calculate the bandwidth for the given signal.



Solution:

$$BW = f_H - f_L$$
$$= (5000 - 1000)\ MHz$$
$$= 4000Hz$$

TUTORIAL QUESTIONS 4

1. Write FIVE types of frequency spectrum with their bandwidth and carry out with ONE suitable application.

2. A television signal occupies a 6-MHz bandwidth. If the low-frequency limit of channel 2 is 54 MHz, what is the upper-frequency limit?

3. Briefly explain the relationship among (f), light velocity (c) and wavelength (λ).

4. Given below frequencies, calculate its wavelength; then make a conclusion about the relationship between the wavelength and frequency.
   a) f = 1 kHz
   b) f = 1 MHz
   c) f = 1 GHz

5.0 INFORMATION CAPACITY

Information capacity is the maximum amount of information that can pass through a channel without error. It is a measure of channel "goodness." The actual amount of information depends on the code how information is represented. Information capacity is a measure of how much information can be propagated through a communications system. It is a function of bandwidth and transmission time. Information capacity represents the number of independent symbols that can be carried through a system in each unit of time. Usually expressed as a bit rate.

5.1 Apply Shannon's limit formula

In 1948, a mathematician Claude E. Shannon from Bell Telephone Laboratories developed a useful relationship among Information Capacity (I) of a communication channel, Bandwidth (BW), and signal to noise ratio (S/N). The higher the signal-to-noise ratio, the better the performance and the higher the information capacity. Mathematically stated, the Shannon Limit for information capacity is:

$$I = B \log_2\left(1 + \frac{S}{N}\right)$$

or

$$I = 3.32\, B \log_{10}\left(1 + \frac{S}{N}\right)$$

Example 1:

A standard telephone circuit has a SNR of 1000W and a bandwidth of 3KHz. Calculate the Shannon limit for the information capacity.

Solution:

$$I = 3.32\, B \log_{10}\left(1 + \frac{S}{N}\right)$$

$$I = 3.32\,(3000) \log_{10}(1 + 1000)$$

$$I = 29.9\text{Kbps}$$

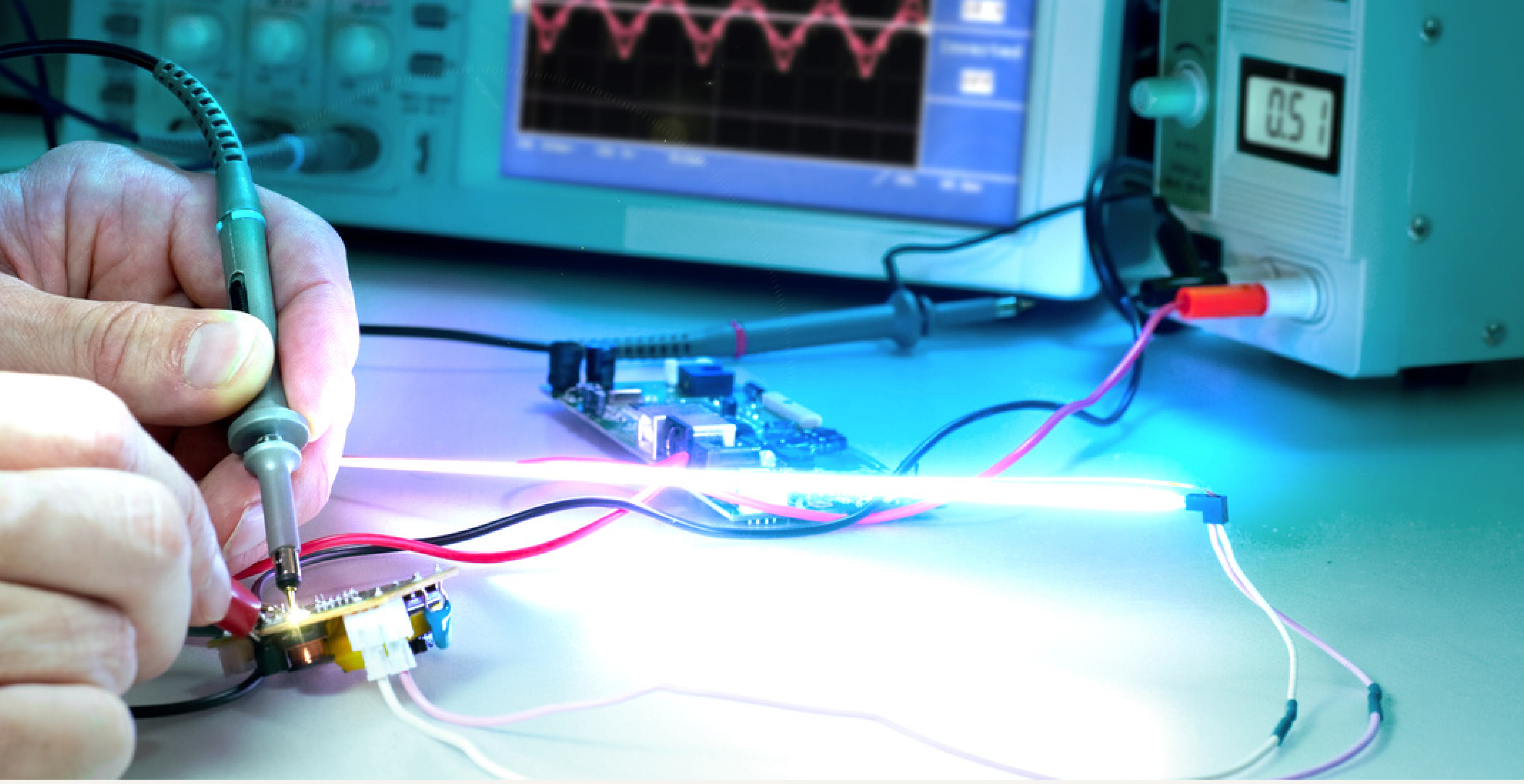
TUTORIAL QUESTIONS 5

1. The signal-to-noise ratio is often given in decibels. Assume that SNR (dB) = 36 and the channel bandwidth is 2MHz. Calculate the Shannon limit for the information capacity.

2. A telephone line normally has a bandwidth of 3000 Hz (300 to 3300 Hz) assigned for data communications. The signal-to-noise ratio is usually 3162. Calculate the information capacity for this channel.

3. For a satellite TV channel with a signal to noise ratio of 20dB and a video bandwidth of 10 MHz, find maximum data rate using Shannon's limit formula.

4. What is the information capacity for teleprinter channel with a 300Hz bandwidth and signal to noise ratio of 3dB.



6.0 TRANSMISSION MODES

Transmission mode is the flow of information signal between two devices. These modes direct the direction of flow of information signal. Buses and networks are designed to allow communication to occur between individual devices that are interconnected. The transmission modes can be characterized in the following three types based on the direction of exchange of information as shows in figure below.

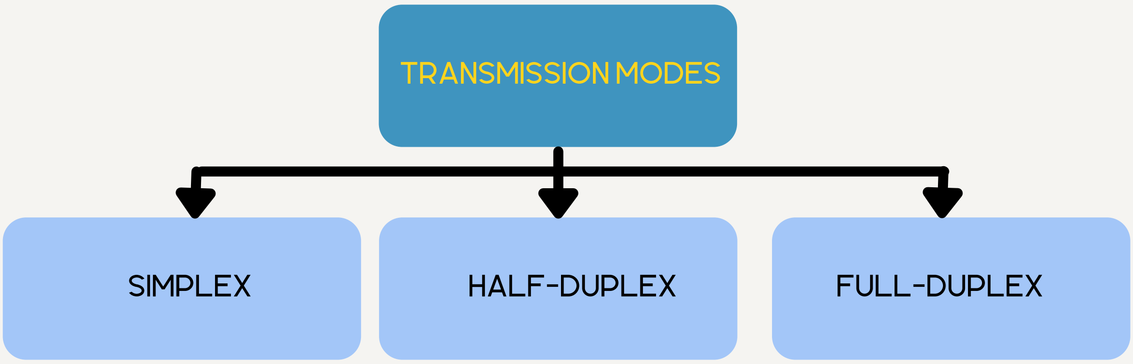


Figure 6.1: Modes of transmission

6.1 SIMPLEX MODE

In Simplex mode, the communication is unidirectional. Information signal flows only in one direction on the transmission medium. Simplex lines are also called receive- only, transmit- only, or one- way- only lines.

We can take an example of keyboard and monitor to understand transmission mode better. The keyboard can only send the data to the monitor, and the monitor can only receive data and display it on the screen. The monitor cannot send any data return to the keyboard.

Another examples for simplex are radio broadcast, television broadcast, mouse, etc. This transmission mode is not so popular because we cannot perform two-way communication between the sender and receiver in this mode. It is mainly used in the business field as in sales that do not require any corresponding reply.

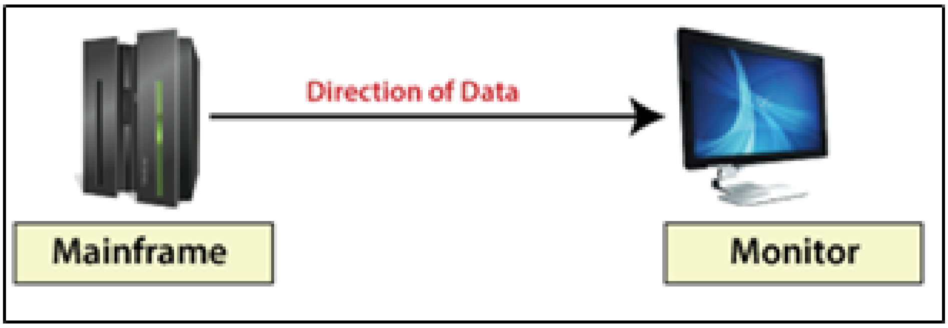


Figure 6.2 : Simplex Mode

6.2 HALF-DUPLEX MODE

In this transmission mode, the communication is done in both directions, but the communication can be done in one direction at a time. Half duplex communications lines are also called two way alternate or either way lines. For example, a conversation on walkie-talkies is a half-duplex data flow. Each person takes turns talking. If both talk at once – nothing occurs.

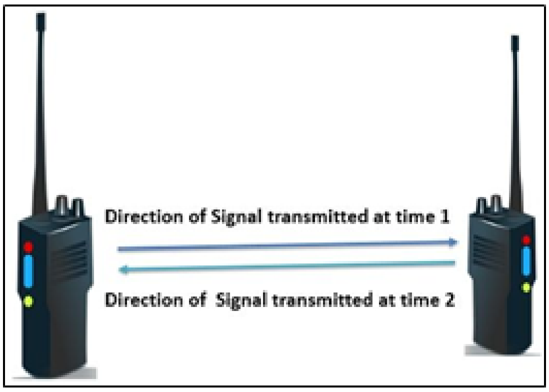


Figure 6.3 : Half-Duplex Mode

6.3 FULL-DUPLEX MODE

The full-duplex communication permits data to be sent and received by the same communication channel simultaneously. The sender and receiver both can transmit and receive simultaneously at the same time. A full-duplex mode can greatly increase the efficiency of communication. The full-duplex transmission mode is like a two-way highway road in which traffic can flow in both the direction at the same time. Here the capacity of the channel is shared by both the transmitted signal traveling in the opposite direction. For example, in the telephone system, people at both ends communicating with each other both can talk and listen at the same time.

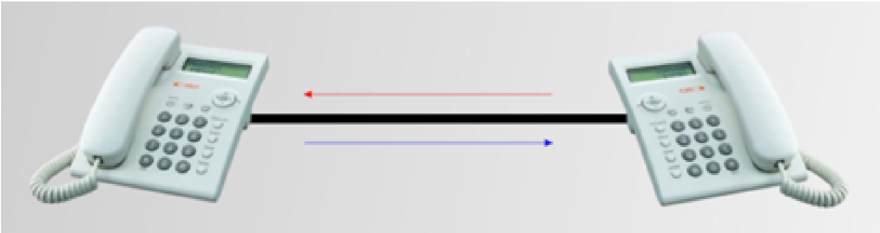


Figure 6.4: Full-Duplex Mode

Table 6.1 Differences between three modes of transmission

BASIC COMPARISON	SIMPLEX	HALF-DUPLEX	FULL-DUPLEX
Type of communication	Unidirectional	Bidirectional (one at time)	Bidirectional (simultaneously)
Exchange of data	Sender can only send data (can't receive back)	Sender can send as well as receive data (but one at time)	Sender can send and receive data (both simultaneously)
Performance	Least	less performance than the full-duplex and better the simplex mode	Better
Advantage	Is uses the entire capacity of the channel to send data in one direction. So, it is used when maximum bandwidth is required during the transmission.	It is used to conserve bandwidth as only a single communication channel is needed, which is shared alternately between the two direction.	It is used when communication in both direction is required all the time without any delays.
Application	radio broadcast, television broadcast, keyboard, mouse, etc.	Walkie-talkie	telephone network, website chat

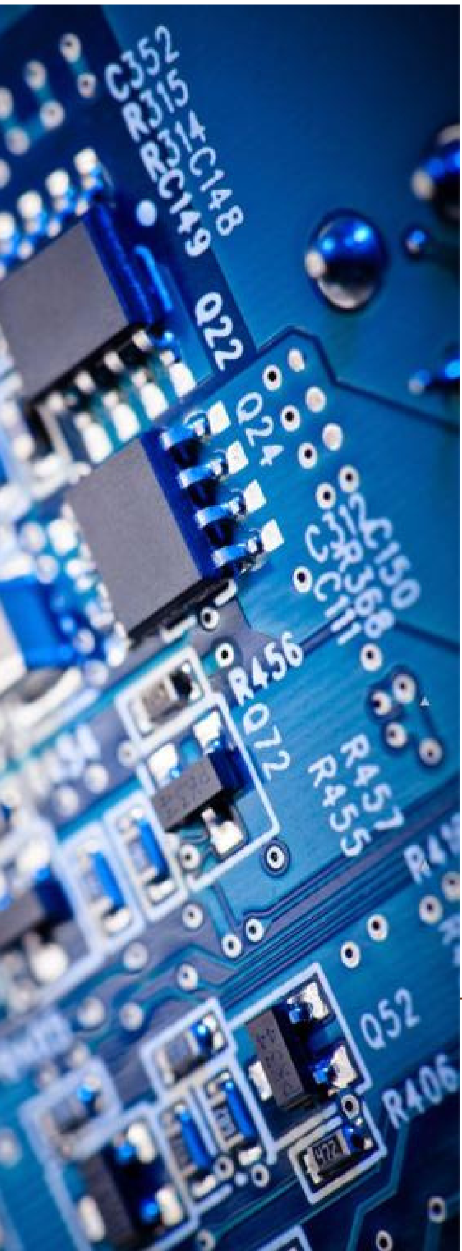
TUTORIAL QUESTIONS 6

1. List THREE (3) types of transmission mode.

2. Illustrate the differences of data transmission mode between half duplex and full duplex.

3. With the aid of suitable diagram, describe the THREE (3) transmission mode that are commonly used today.

4. What kind of transmission mode suitable for transmit data from keyboard to PC?



7.0 Types of Communication System

Communication system may be categorized based on their physical infrastructure and the specification of the signal they transmit. The physical structure pertains to the type of the channel used and the hardware design of the transmitting and receiving equipment. The signal specifications signify the nature and type of the transmitted signal. There are 4 types of communication system:

- Broadcast Communication System
- Mobile Communication System
- Fixed Communication System
- Data Communication System

7.1 BROADCAST COMMUNICATION SYSTEM

A broadcast is the wireless transmission of audio and video signal to a receiver via radio, television, or others. It is a method of sending a signal where multiple receivers may receive from a single sender. Broadcast is a type of communications called Simplex (data flow in one direction).

There is no interaction between the originator of the content and the user of the content, so if the content delivery is delayed by even a second or so, there will be little effect on the value of the communications. Historically, there have been several different types of electronic broadcasting media:

- Telephone broadcasting (1881)
- Radio broadcasting (1906)
- Television broadcasting (telecast) (1925)
- Cable radio (1928)
- Satellite television (1974) and Satellite radio (1990)
- Webcasting of video/television (1993) and audio/radio (1994) streams.

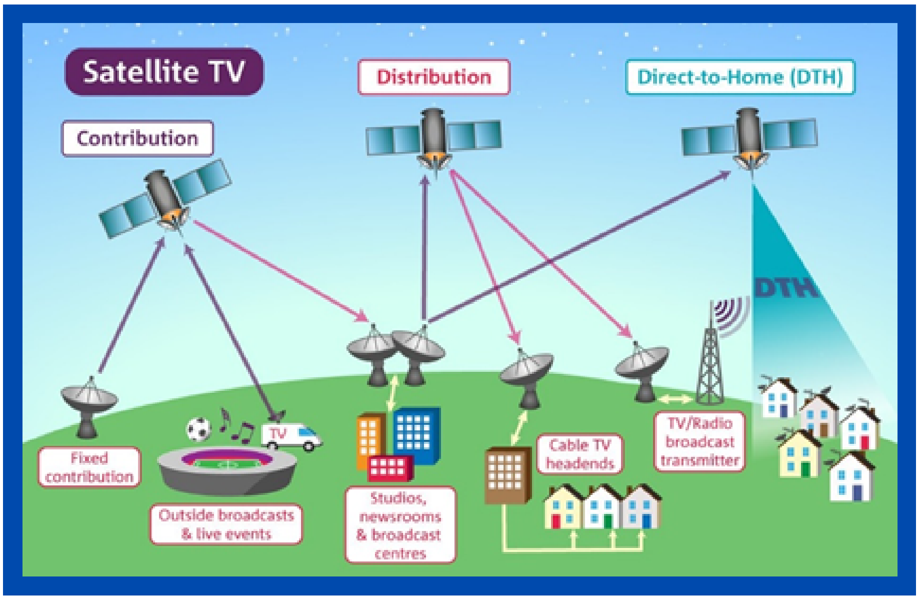


Figure 7.1: Broadcast Communication System

7.2 MOBILE COMMUNICATION SYSTEM

Mobile communication system is a wireless communication in which voice and data information is emitted, transmitted, and received via microwave signals. Example: talking on the hand phone, SMS via hand phone and so on. It is a Full Duplex communication (data flow in 2 directions simultaneously). Using GSM (Global System for Mobile) which is a standard set developed by the European Telecommunications Standards Institute (ETSI). A wireless communication link includes a transmitter, a receiver, and a channel as shown in Figure. Most links are full duplex and include a transmitter and a receiver or a transceiver at each end of the link.

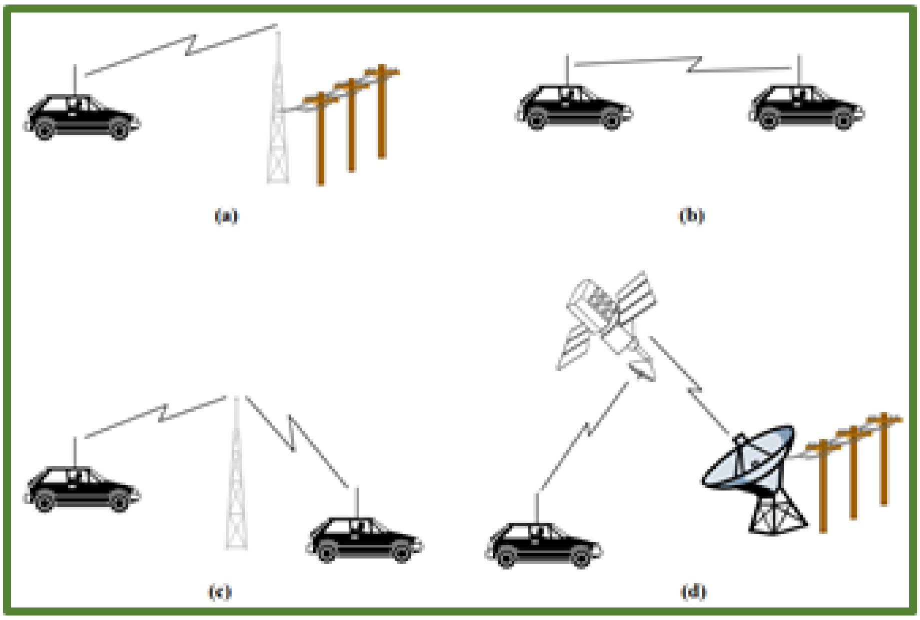


Figure 7.2 : Mobile Communication System

Figure above show the wireless mobile communication system with different system:

(a) Mobile - base station
(b) Peer-to-peer
(c) Mobile-repeater-mobile
(d) Mobile satellite

7.3 FIX COMMUNICATION SYSTEM

Fixed Communication is a full-duplex (FDX) or sometimes double-duplex system, allows communication in both directions using fixed line. Example: Land-line telephone networks Using Public Switching Telephone Network (PSTN) which is a standard set developed by ITU-T. Now, Malaysia is moving towards NGN (Next Generation Network).

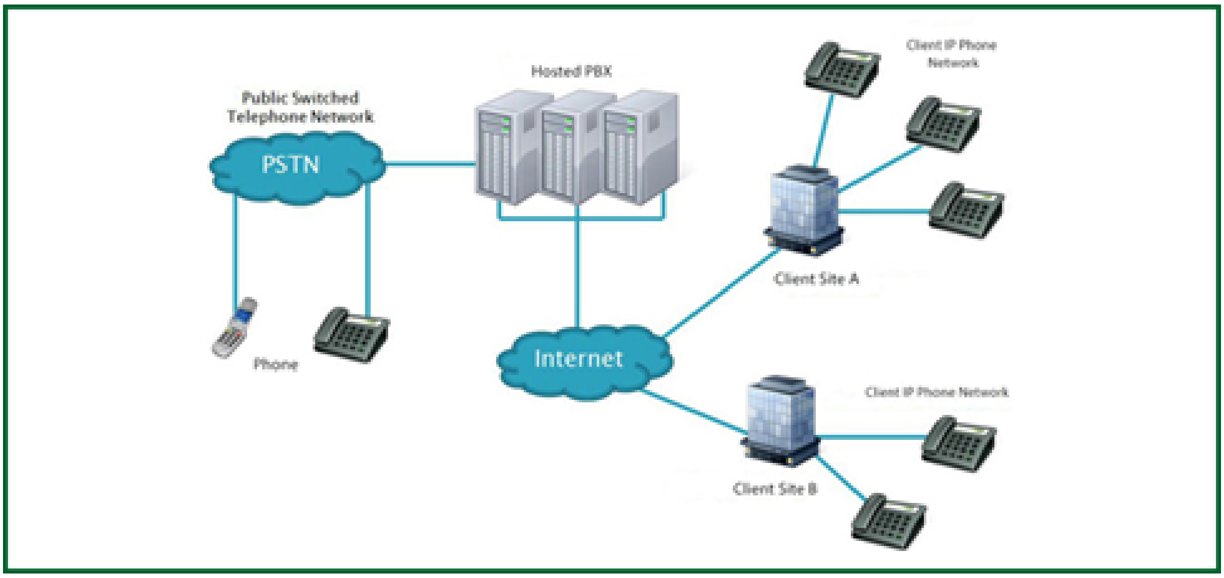


Figure 7.3 : Public Switching Telephone Network (PSTN)

7.4 DATA COMMUNICATION SYSTEM

Data communication is the process of transferring digital information (usually in binary form) between two or more points. Example: computer communications (because much of the information is exchanged between computers and peripheral devices). Data may be as simple as binary ones and zeros, or it may include complex information, such as digital audio or video.

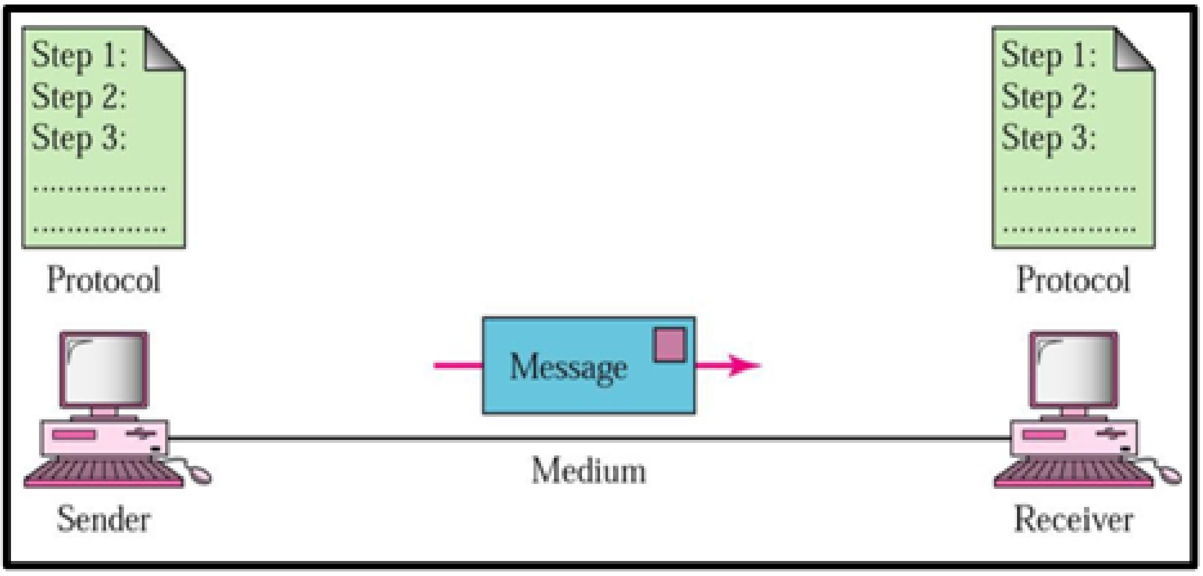


Figure 7.4 : Data Communication System Component

TUTORIAL QUESTIONS 7

1. List FOUR (4) types of communication system and relate them with ONE (1) suitable application.

2. Differentiate between Broadcast Communication System and Mobile Communication System.

3. Differentiate between Fix Communication System and Data Communication System.

4. What are the components of a data communication system?

ASNWER TO TUTORIAL QUESTIONS

ASNWER TO TUTORIAL QUESTION 1

Question 1

Communication is a process of transmission, reception, and processing the information between two or more location through transmission media. The element of communication system is:

i) Information source
ii) Transmitter
iii) Transmission medium
iv) Receiver
v) Destination

Question 2

Four examples of destination in communication system block diagram

i) People
ii) Computer
iii) Hand phone
iv) Electronic devices

Question 3

The process that involves in receiver part include the demodulation, demultiplexing and decoding. Examples: Demodulator, Demultiplexer, Transducer, Decoder, Photo detector, etc.

Question 4

Function of each block diagram of a communication system.

A= Information Source

- generates the information (audio, text, image, or video)

B= Transmitter

- Converts the original source information to a form more suitable for transmission. Ex: Modulator, Multiplexer, Transducer, Encoder, Light Source etc.

C= Transmission Medium / Channel

- media/link/path that capable to transfer the electronic signal from transmitter to receiver. Ex: Twisted Pair Cable, Coaxial Cable, Fiber Optic Cable, Waveguide, etc.

D=Receiver

- A collection of one or more electronic devices or circuits that accept the transmitted signals from the transmission medium and then convert back to their original information form.

E= Destination

- Anything that receive the transmitted information and capable to store them.

F= System Noise

- Noise is any unwanted electrical signals that interfere with the information signal.

ASNWER TO TUTORIAL QUESTION 2

QUESTION 1

Distortion is any changes in the original signal which has a corrupting effect on its form or shape

QUESTION 2

FOUR types of nonlinear distortion in communication system.

i. Harmonic distortion/amplitude distortion
ii. Intermodulation distortion
iii. Frequency response distortion
iv. Phase distortion

QUESTION 3

Interference is when information signals from one source produce frequencies that fall outside their allocated bandwidth and interfere with information signals from another source.

QUESTION 4

FOUR types of nonlinear distortion in communication system:

i. Adjacent-Channel Interference (ACI)
ii. Co-Channel Interference (CCI) or Crosstalk
iii. Electromagnetic Interference (EMI)
iv. Inter-carrier interference (ICI)

ASNWER TO TUTORIAL QUESTION 3

Question 1

$$NF(dB) = 10\log F$$
$$5dB = 10\log \text{F}$$
$$\frac{5}{10} = \log F$$
$$F = 10^{0.5}$$
$$F = 3.162$$

Output Signal to Noise Power (SNR_{out}).

$$SNR_{Out} = {SNR_{in}}/{F}$$
$$= \frac{{S_{in}}/{N_{in}}}{F}$$
$$= \frac{{500\mu}/{2\mu}}{3.16}$$
$$= 79.11$$

Question 2

$$F = \frac{{S_i}/{N_i}}{{S_o}/{N_o}}$$

$$\frac{S_i}{N_i} = \frac{500\mu W}{2\mu W} = 250$$

$$\frac{S_o}{N_o} = \frac{500\mu W}{2\mu W} = 50$$

$$F = \frac{250}{50} = 5$$

$$NF(dB) = 10\log F$$
$$= 10\log 5$$
$$= 6.98dB$$

Question 3

$$NF(dB) = 10\ \log\left(\frac{SNR_{in}}{SNR_{out}}\right)$$

$$5(dB) = 10\ \log\left(\frac{SNR_{in}}{25\times 10^6}\right)$$

$$\frac{5}{10} = \log\left(\frac{SNR_{in}}{25\times 10^6}\right)$$

$$10^{0.5} = \left(\frac{SNR_{in}}{25\times 10^6}\right)$$

$$SNR_{in} = (25\times 10^6)\times 10^{0.5}$$

$$\frac{S_{in}}{N_{in}} = 79.06\times 10^6$$

$$S_{in} = (79.06\times 10^6)(4\times 10^{-18})$$
$$= 3.16\times 10^{-10}$$

Question 4

SNR_{in} = 25dB,

Convert 25dB to ratio (unitless)

$$= 316.23$$

$$NF(dB) = 10\ \log\left(\frac{SNR_{in}}{SNR_{out}}\right)$$

$$6(dB) = 10\ \log\left(\frac{316.23}{SNR_{out}}\right)$$

$$\frac{6}{10} = \log\left(\frac{316.23}{SNR_{out}}\right)$$

$$10^{0.6} = \left(\frac{316.23}{SNR_{out}}\right)$$

$$SNR_{out} = \frac{316.23}{10^{0.6}}$$

$$\frac{S_{out}}{N_{out}} = 79.43$$

$$10\log 79.43 = 19dB$$

ASNWER TO TUTORIAL QUESTION 4

QUESTION 1

Medium Frequency (MF)	300K-3 MHz	AM radio broadcast, maritime/aeronautical mobile
High Frequency (HF)	3 - 30 MHz	Shortwave Broadcast Radio
Very High Frequency (VHF)	30 - 300 MHz	Low band: TV Band1- Channel 2-6, Mid band: FM radio, High Band: TV Band 2- Channel 7-13
Ultra-High frequency (UHF)	300M - 1GHz	Mobile phone, Channel 14 - 70
Super-High frequency (UHF)	3-30 GHz	Satellite communication, C-band, x- band, Ku-band, Ka-band.

QUESTION 2

Given; $BW = 54\,MHz$, $f_1 = 6MHZ$

$$BW = f_1 - f_2$$

$$f_2 = BW + f_1$$

$$= 6 + 54$$

$$= 60\,MHz$$

QUESTION 3

From the equation, wavelength is inversely proportional to the frequency of the wave and directly proportional to the velocity of propagation.

wavelegth, $\lambda = \frac{c}{f}$

Where:

λ = wavelength (meter)

c = velocity of light (3 x 108 m/s)

f = frequency (Hz)

QUESTION 4

a) f = 1 kHz

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3 \times 10^8}{1 \times 10^3}$$

$$\lambda = 300 \times 10^3$$

b) f = 1 MHz

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3 \times 10^8}{1 \times 10^6}$$

$$\lambda = 300$$

c) f = 1 GHz

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3 \times 10^8}{1 \times 10^9}$$

$$\lambda = 0.3$$

The conclusion is frequency and wavelength are inversely proportional to each other. The wave with the greatest frequency has the shortest wavelength.

ASNWER TO TUTORIAL QUESTION 5

Question 1

$$SNR(dB) = 10\log_{10} SNR$$

$$SNR(dB) = 10^{SNR(dB)/10}$$

$$= 10^{36/10}$$

$$= 3981$$

$$I = B\log_2(1 + SNR)$$

$$= (2 \times 10^6) \times \log_2(1 + 3981)$$

$$= 24Mbps$$

Question 2

$$I = B\ \log_2(1\ +\ SNR)$$

$$I = (3000)\ \log_2(1\ +\ 3162)$$

$$I = 34{,}860\text{bps}$$

Question 3

$$SNR(dB) = 10^{SNR(dB)/10}$$

$$= 10^{20/10}$$

$$= 10^2$$

$$I = B\ \log_2(1\ +\ SNR)$$

$$I = (10 \times 10^6)\ \log_2(1\ +\ 10^2)$$

$$I = 66M\text{bps}$$

Question 4

$$SNR(dB) = 10^{SNR(dB)/10}$$

$$= 10^{3/10}$$

$$= 10^{0.3}$$

$$I = B\ \log_2(1\ +\ SNR)$$

$$I = (300)\ \log_2(1\ +\ 10^{0.3})$$

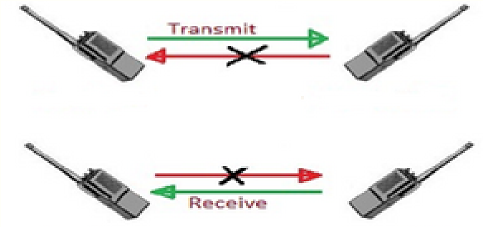
$$I = (300)\ \log_2(2995)$$

$$I = 474\text{bps}$$

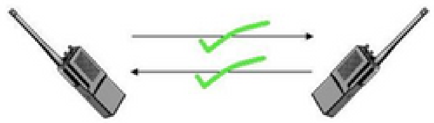
ASNWER TO TUTORIAL QUESTION 6

1. Three types of transmission mode.
i) Duplex
ii) Half duplex
iii) Full duplex

2. For half duplex mode, data can be transmitted in both direction but not at the same time. For example, walkie talkie.

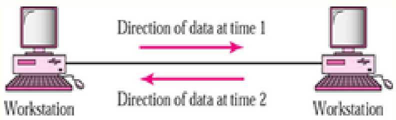


For full duplex mode, transmission of data in two direction. It allows transmitting and receiving at the same time. For example, telephone.

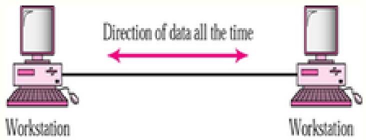


3. Diagram of THREE (3) transmission mode that are commonly used today.
i) Simplex mode

ii) Half duplex mode



iii) Full duplex mode



4. Transmission mode that suitable for transmit data from keyboard to PC is Simplex Mode

ASNWER TO TUTORIAL QUESTION 7

1. FOUR types of communication system with ONE suitable application.

i) Broadcast Communication System - Application: tv/radio broadcasting

ii) Mobile Communication System - Application: talking/SMS/WhatsApp via handphone

iii) Fixed Communication System - Application: Land-line telephone networks

iv) Data Communication System - Application: computers

2. Difference between Broadcast Communication System and Mobile Communication System.

Broadcast Communication System	Mobile Communication System
One way communication (Simplex)	Two-way communication (Full Duplex)
Using radio wave	Using microwave

3. Difference between Fix Communication System and Data Communication System.

Fix Communication System	Data Communication System
Information in analog signal (audio)	Information in digital signal
Telephone-telephone	Computer-computer

4. Components of a data communication system?

Message	Message is the information to be communicated by the sender to the receiver.
Sender	The sender is any device that is capable of sending the data (message).
Receiver	The receiver is a device that the sender wants to communicate them data (message).
Transmission Medium	It is the path by which the message travels from sender to receiver. It can be wired or wireless.
Protocol	• It is an agreed upon set or rules used by the sender and receiver to communicate data. • A set of rules that governs data communication. • A necessity in data communications without which the communicating entities are like two persons trying to talk to each other in a different language without know the other language.

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