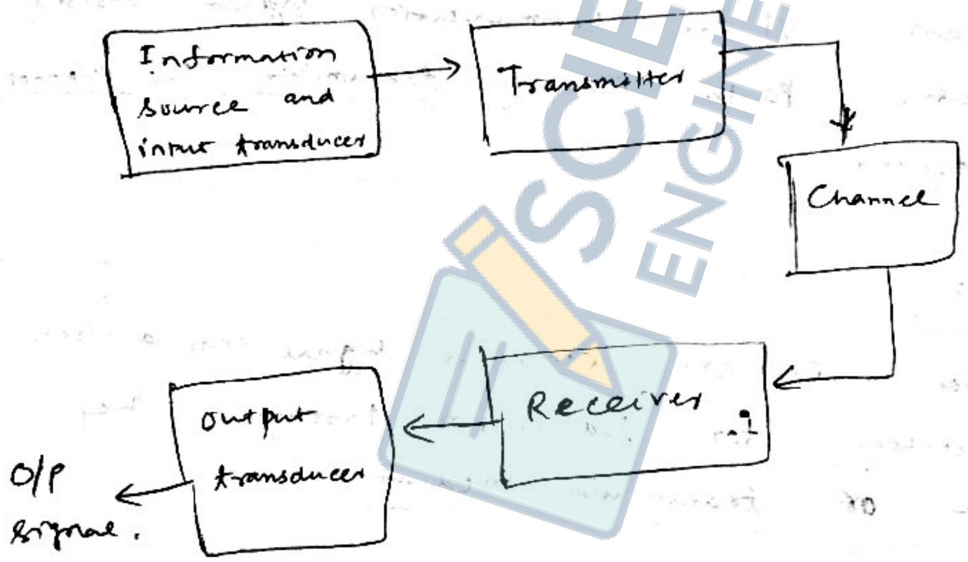
# Introduction (Module-I)

Everyday, in our work and in our leisure time, we come in contact with and use variety of modern communication systems and communication media, the most common being the telephone, radio, T.V and internet. Through these media we are able to communicate instantaneously with people on different continents, transact our daily business and receive information about various developements and events of note that occure all around the world.

## Elements of an electrical communication system:-

Electrical communication system are designed to send message or information from a source that generates the message to one or more destination.




(fig.- Functional block diagram of a communication system)

Description :- (Information source & i/p transducer)

(i) The information generated by the source may be of the form of voice (speech source), a picture (image source) or plain text in some particular language (ex:- English).

(ii) An essential feature of any source that generates information is that its o/p is described in probabilistic term: i.e the o/p of a source is not deterministic.

(iii) A transducer is usually required to convert the o/p of a source into an electrical signal that is suitable for transmission.

e.g:- A microphone serves as the transducer that converts an acoustic speech signal into electrical.

Video camera converts images → electrical signal.

(iv) At the destination, a similar transducer is required to convert electrical signals that are received into a form that is suitable for user e.g acoustic signals, images etc.

(v) The heart of the communication system consists of three basic parts namely transmitter, the channel, and the receiver.

## The transmitter:-

→ The transmitter converts electrical signal into a form that is suitable for transmission through the physical channel or transmission medium.

e.g:- In radio and T.V broadcast, the Federal Communication Commission (FCC) specifies the frequency range for each transmitting station. Hence the transmitter must translate the information signal to be transmitted into appropriate frequency range that matches the frequency allocation assigned to the transmitter. Thus signal transmitted by multiple radio stations don't interfere with one another.

(In general, Carrier modulation such as AM, FM, PM is performed at the transmitter, to convert the information signal to a form that matches the characteristics of the Channel.) Thus, through the process of modulation, the information signal is translated in frequency to match the allocation for the channel.

(In addition to modulation, other functions like filtering of information bearing signal, amplification of modulated signal and in case of wireless communication, radiation of signal by means of transmitting antenna are performed.)

The channel :-

(The Communication channel is the physical medium that is used to send the signal from the transmitter to the receiver.)

e.g:- 1) Wireless transmission the channel is usually the atmosphere (free space)

2) Telephone channels use -> wirelines, optical fiber Cables and wireless medium (Microwave radio).

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 end of receiver, where signal amplification is performed. This noise is often called thermal noise.

(4)

(In wireless transmission, additional additive disturbances are man-made noise and atmospheric noise picked up by the receiving antenna.)

In such cases, the system designer may design a communication system that is robust to the variety of signal distortions.

## The receiver :-

(The function of the receiver, is to recover the message signal contained in the received signal.)

If the message signal is transmitted by carrier modulation, the receiver performs carrier demodulation in order to extract message from the sinusoidal carrier.

Since the signal demodulation is performed in the presence of additive noise and possibly other signal distortion, the demodulated signal is generally degraded to some extent.

(The receiver also performs a number of peripheral functions including signal filtering and noise supression.)

(*)→ Digital Communication System (After 6 page)

## Communication Channels and their Characteristics :-

Communication channel provides the connection between the transmitter and receiver. Different types of channel are

(a) Wireline channels
(b) Fiber optic channels.
(c) Wireless Electromagnetic channels
(d) Underwater Acoustic channels.

(e) Storage Channels.

## (a) Wireline Channels:-

The telephone n/w makes extensive use of wire lines for voice signal transmission, as well as data and video transmission.

Twisted-pair wire-lines and co-axial cable are basically guided electromagnetic channels which provide relatively modest bandwidths.

- ✓ → Telephone lines → several hundred KHZ
- ✓ → Co-axial cable → several MHZ (Mega Hertz)
- ✓ → wave guide → several GHZ. (Giga Hertz)

Signals transmitted through such channels are distorted in both amplitude and phase and further corrupted by additive noise.

→ Twisted-pair wireline channels are also prone to cross talk interference from physically adjacent channels.

## (b) Fiber optic channel:-

→ Fiber optic channel gives bandwidth much larger than co-axial cable channels.

→ It has low signal attenuation.

→ The transmitter or modulator in a fiber optic communication system is light source, either a LED or LASER.

→ Information is transmitted by varying the intensity of light source with the message signal.

→ The light propagates through the fiber as light wave and is amplified periodically.

(by repeaters) along the transmission path to compensate for signal attenuation.

→ At the receiver, the light intensity is detected by a photodiode, whose output is an electrical signal that varies in direct proportion to the power of the light impinging on the photodiode.

## (c) Wireless Electromagnetic Channels:-

→ In radio communication systems, electromagnetic energy is coupled to the propagation medium by an antenna which serves as the radiators. To obtain efficient radiation of ~~[illegible]~~ electromagnetic energy, the antenna must be longer than $\frac{1}{10}$ of the wavelength.

→ ex:- Am freq band, say 1 MHz $\lambda = \frac{c}{f} = \frac{3\times10^8}{1\times10^6} = 300\,m$.

antenna length $= \frac{300}{10} = 30\,m$.

→ The mode of propagation of electromagnetic wave in atmosphere and free space may be divided into 3 categories:

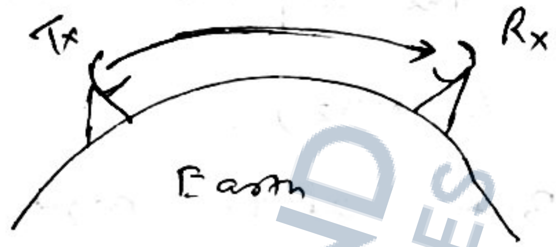
(i) Ground wave propagation

(ii) Sky wave propagation

(iii) Line of sight (LOS) propagation.

(i) Ground Wave propagation:-

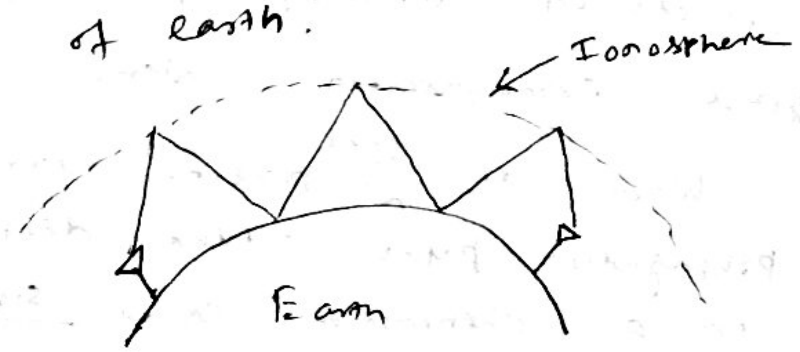
→ In ELF (Extremely low freq) (3-30 Hz) and VLF (very low frequency) ($3\times10^{3}$-30 kHz) freq. bands (where the wavelength exceeds 10 km) the earth and the ionosphere act as a wave guide for electromagnetic wave propagation. In these frequency ranges, communication signals practically propagate around the globe. The channel band widths available in these ~~frequencies~~ frequency bands are small and hence the information that is transmitted through these channels is relatively slow speed and generally confined to digital communication.




→ This mode is the dominant mode of propagation for frequencies in MF (Medium frequency) band (0.3 – 3 MHz). This is the frequency band used for A.M broadcasting and maritime radio broadcasting. But the signals can not be transmitted to larger distance. In AM broadcasting, the range of ground wave propagation is limited to 100 miles only.

(ii) Sky wave propagation:-

This wave results from transmitted signals being reflected from the ionosphere, which consist of several layers of charged particles ranging from 30-250 miles above the surface of earth.



In the day time hours the heating of the lower atmosphere by the sun causes the formation of lower layer at altitude below 75 miles. These lower layers (D layer) serve to absorb frequencies below 2 MHz thus limits the sky wave propagation of AM Broadcast (~1 MHz)

But at the night hours, the electron density in the lower layer of the ionosphere drops sharply and the freq absorption occurs during the day time is significantly reduced. Therefore powerful AM radio broadcast stations can propagate over large distances via skywave over F layer of the ionosphere, which ranges from 90-250 miles above the surface of the earth.

Imp Signal fading:-

The problem with electromagnetic wave propagation via sky wave in the HF (High frequency) (3 to 30 MHz) range is signal multipath. Signal multipath occurs when the transmitted signal arrives at the receiver via multiple propagation paths at different delays. Signal multipath generally results in intersymbol interference (ISI) in digital communication system.

(When the signal components arriving via different propagation paths added destructively, resulting in a phenomenon called signal fading)

→ Sky-wave propagation ceases to exists at frequencies above approximately 30 MHz, which is end of HF band.

## (iii) Line of Sight (LOS) propagation:-

Frequencies above 30 MHz propagate through the ionosphere with relatively little loss and make satellite and extraterrestrial communication possible. Hence at frequencies in VHF band and higher, the dominant mode of electromagnetic propagation is LOS (Line of Sight) propagation. For terrestrial communication systems, this means that the transmitter and receiver antennas must be in direct LOS with relatively little or no obstruction. For this reason T.V stations transmitting in the VHF and UHF frequency bands mount their antennas on high towers in order to achieve a broad coverage area.

The coverage area is limited by curvature of earth.

| Coverage Distance $(d) = \sqrt{2h}$ miles. |
|---|

h = height above the surface of earth where the antenna mounted.

e.g.

↳ If $h = 1000\,ft$, $d = \sqrt{2h}$

$= \sqrt{2 \times 1000} = 44.72$

Coverage distance $\simeq 50$ miles.

## (d) Underwater Acoustic Channels :-

Electromagnetic wave don't propagate over long distances underwater, except at extremely low frequencies. (The attenuation of electromagnetic waves in water can be expressed in terms of the skin depth, which is the distance a signal is attenuated by $\frac{1}{e}$.)

ex : For sea water, skin depth ( δ ) $(e = 2.718)$

$$\boxed{\delta = \frac{250}{\sqrt{f}}}$$

f in Hertz, δ in meter.

At 10 KHz, $\delta = \frac{250}{\sqrt{10 \times 10^3}} = \frac{250}{10^2} = 2.5\,m$

A shallow water acoustic channel is characterized as multipath channel due to signal reflections from the surface and the bottom of the sea. Due to wave motion, the signal multipath components undergo time-varying propagation delays which results in signal fading.

$$\boxed{\text{(freq-dependent) attenuation} \propto f^2}$$

i.e if freq increases, attenuation increases.

Also noise presents, in the propagation.

Ambient noise → Due to fish, shrimp and various mamals.

Also man-made noise exist in addition to ambient noise- ①

$\delta \propto \frac{1}{\sqrt{f}}$ & $f \propto \sqrt{\text{attenuation}}$.

$\delta \propto \frac{1}{\sqrt{\sqrt{\text{attenuation}}}}$, $\delta \propto \frac{1}{(\text{atten})^{1/4}}$

## (e) Storage channels:-

Information storage and retrieval systems constitute a very significant part of our data-handling activities on a daily basis. Magnetic tape, including digital audio tape and video tape, magnetic disks used for ~~data~~ ~~storage~~ storing large amount of computer data and optical disks used for computer data storage, music, video.

The process of storing data on a magnetic tape or a magnetic or optical disk is equivalent to transmitting a signal over a telephone or radio channel.

The readback process and the signal processing involved in a storage systems is equivalent to recover the stored information by a receiver in to the functions performed by a telephone or radio communication system to recover the transmitted information.

## Digital Communication System:-

Analog signals can be transmitted directly via carrier modulation over the communication channel and demodulated accordingly at the receiver. ~~the~~ Such a communication system is called Analog communication system.

An analog source O/P may be converted into digital form and the message can be transmitted via digital modulation and demodulated as a digital signal at the receiver

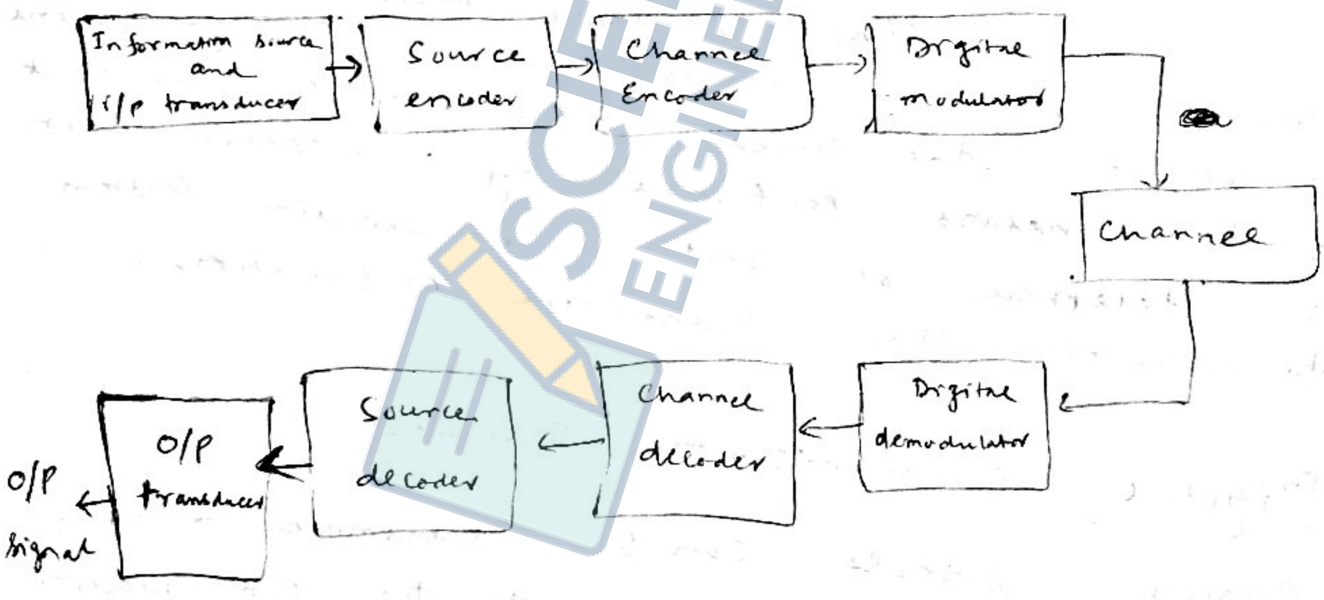
## Advantage of digital communication over analog:-

1) The signal fidelity (reliability) is better controlled through digital transmission than analog.

2) Digital transmission allows us to regenerate the digital signal in long-distance transmission, thus eliminating effect of noise at each regeneration point. (which happens in analog system)

3) Redundancy, may be removed prior to modulation, thus conserving channel bandwidth.

4) Digital communication system are often cheaper to implement.




(fig:- Basic Elements of digital communication system)

### Information source and i/p transducer:-

The source output may be either an analog signal such as audio or video signal or digital signal such as o/p of a computer which is discrete in time and has a finite number of

Output characters.

## Source encoder:-

(In digital communication system the messages produced by the source are usually converted into sequence of binary digits.) That means the source o/p represented by few binary digits. (The process of efficiency converting the o/p of either an analog or digital source into a sequence of binary digits is called source encoding or data compression.)

(ADC)

## Channel encoder:-

The sequence of binary digits from the source encoder which call the information sequence is passed through the channel encoder. (The purpose of channel encoder is to introduce in a controlled manner some redundancy in the binary information sequence which can be used at receiver to overcome the effects of noise and interference encountered in the transmission of the signal through the channel.) Thus the added redundancy serves to increase the reliability of the received data and improves the fidelity of the received signal.

(ASK, FSK, PSK)

## Digital Modulator:-

The binary sequence at the o/p of the channel encoder is passed to the digital modulator, which serves as the interface to the communication channel. (The primary purpose of the digital modulator is to map the binary information sequence into signal waveforms.) For example:- Suppose the coded information sequence is to be transmitted one bit at a time at some uniform rate R bits/second. The digital modulator may simply map the binary digit '0' onto a waveform $s_0(t)$ and the binary digit 1 onto a waveform $s_1(t)$. In this manner, each bit from the channel encoder is transmitted separately. This scheme is called 'binary modulation'.

The modulator may transmit 'b' coded information bits at a time by using $M = 2^b$ distinct waveforms $s_i(t)$, $i = 0, 1, 2 \ldots M-1$, one waveform for each of $2^b$ possible b-bit sequences. We call this M-ary modulation. $(M > 2)$

ex: $b = 2$, $M = 2^2 = 4$.

$s_0(t), s_1(t), s_2(t), s_3(t)$

4-ary modulation. (QPSK)



## Digital demodulator:-

(At the receiving end of a digital communication system, the digital demodulator processes the channel-corrupted transmitted waveform and reduces each waveform to a single number that represents an estimate of the transmitted data symbol.)

e.g:- When binary modulation is used, the demodulator may process the received waveform and decide on whether the transmitted bit is 0 or 1. In such case, the demodulator has made a binary decision. Alternatively, the demodulator may make a ternary (3) decision. i.e it decodes that the transmitted bit is either a 0 or 1 or it makes no decision at all. When no decision is made on a particular bit, we say the demodulator has inserted an erasure in the demodulated data.

## Channel decoder:-

When there is no redundancy in the transmitted information, the demodulator must decide which of the M waveforms was transmitted in any given time interval. Consequently Q = M and since there is no redundancy in the transmitted information, no discrete channel decoder is used following the ~~Channel~~ demodulator.

On the other hand, when there is redundancy introduced by a discrete channel encoder at the transmitter, the Q-ary o/p from the demodulator occuring every b/R seconds is fed to the decoder, which attempts to reconstruct the original information sequence from knowledge of the code used by the channel encoder and the redundancy contained in the received data. (Removes the redundancy)

## Source decoder:-

(When an analog o/p is required, the source decoder accepts the o/p sequence from the channel decoder and from the knowledge of the source encoding method used, tries to reconstruct the original signal from the source) The signal at the o/p of the source decoder is an approximation to the original source o/p. (DAC)

## Mathematical Models for communication channels:-

The mathematical model reflect the most important characteristics of the medium. There after, the mathematical model for the channel is used in the design of the channel encoder, modulator at the transmitter and demodulator, channel decoder at the receiver.

### Additive noise channel:-

The simplest mathematical model for a communication channel is the additive noise channel.


fig:- The additive noise channel.

In this model, the transmitted signal S(t) is corrupted by an additive random noise process n(t). The additive noise process may arise from electronic components and amplifiers at the receiver of the communication system or from the interference encountered in the transmission.

If the noise is introduced primarily by electronic components and amplifiers at the receiver, it may be characterized as thermal noise. This type of noise is also called Gaussian noise process. So the resulting mathematical model for the channel is called additive Gaussian noise channel. When the signal undergoes attenuation in transmission through the channel, the received signal is

$$\gamma(t) = a\, s(t) + n(t)$$

Where 'a' represents attenuation factor.

## The Linear filter channel:-

In some physical channels such as wireline telephone channels, filters are used to ensure that the transmitted signal don't exceed specified bandwidth limitation and thus don't interfere with one another.

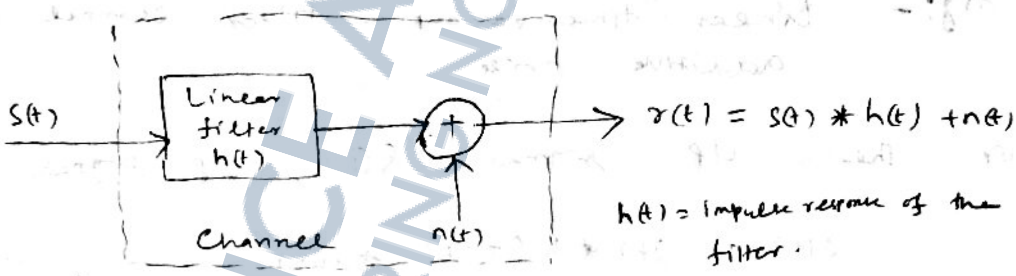



fig:- The Linear filter channel with additive noise.

In the channel i/p signal is $S(t)$ and the channel o/p is

$$\gamma(t) = S(t) * h(t) + n(t)$$

$$\gamma(t) = \int_{-\infty}^{\infty} h(\tau)\, s(t-\tau)\, d\tau + n(t)$$

Where $h(t)$ is the impulse response of the linear filter and $*$ denotes the convolution.

## The Linear Time-Variant Filter Channel:-

Physical channels such as under-water acoustic channels and ionosphere radio channels which result in time-variant multipath propagation of the transmitted signal may be characterized mathematically as time-variant linear filters. Such linear filters are characterized by time-variant channel impulse response $h(\tau;t)$ where $h(\tau;t)$ is the response of the Channel at time t, due to an impulse applied at time $t-\tau$. Thus, $\tau$ represents "age" (elapsed time) variable.

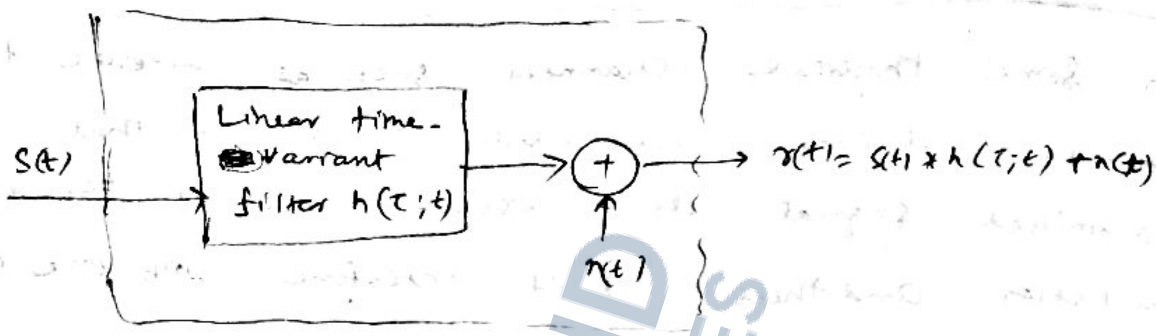



fig:- Linear time-variant filter channel with additive noise.

For the i/p signal $s(t)$, o/p signal is

$$r(t) = s(t) * h(\tau;t) + n(t)$$

$$r(t) = \int_{-\infty}^{\infty} h(\tau;t)\, s(t-\tau)\, d\tau + n(t) \quad \text{--- (1)}$$

→ For signal propagation through physical channels such as ionosphere and mobile cellular radio channels the time variant impulse response has the form

$$h(\tau;t) = \sum_{k=1}^{L} a_k(t)\, \delta(\tau-\tau_k) \quad \text{--- (2)}$$

where $\{a_k(t)\}$ → represents the possibly time-variant attenuation factor for the 'L' multipath propagation paths.

If we substitute eqn (2) in eqn (1), we have

$$r(t) = \sum_{k=1}^{L} a_k(t)\, s(t-\tau_k) + n(t) \quad \text{--- (3)}$$

[∵ $\int x(t)\, \delta(t)\, dt = x(0)$ since $\tau$ is variable 't' will remain]

So, the received signal consists of 'L' multipath components. where each component is attenuated by $\{a_k\}$ and delayed by $\{\tau_k\}$.

## Probable questions:—

1) What are the elements of ~~channel~~ electrical communication system?
2) Explain the function of channel in communication system.
3) Explain the function of source encoder in digital communication system.
4) What is the advantage of fiber optic channel?
5) What are the modes of propagation of e.m wave in atmosphere.
6) What is the freq range of ground wave propagation?
7) What is skin depth?
8) What is signal fading?
9) What is Gaussian noise process?
10) What are the uses of filter in wireline telephone channels?

## Long questions:—

1) State & explain the elements of electrical communication system.
2) Explain the various functions of digital communication system.
3) What are characteristics of communication channel.
4) Describe the mathematical model for communication channel.
5) Write down the freq. range for various wireline electromagnetic channel.