UNIT -1

1.1 Introduction of Communication Systems:
“Communication is a process of establishing connection or link between two points for sharing information.”
The development in electronics communication system by which signals moves with the speed of light is changing the phase of human civilization. Only with a click we can visualize our desire which was very hard years ago.

1.1.1 Block Diagram: The fig represents the basic block diagram of electronic communication system. Communication is a process of transferring information from one place to another. The information generated at source side may need to travel hundreds or thousands of miles via channel to reach destination.
Communication system contains basic three parts:
1. Transmitter: It is used to transfer or send the information into channel. Transmitter is a set of many types of equipment.
2. Channel: Channel is used to convey message from transmitter to receiver. The channel could be wired line such as copper wire or wireless. Wired line is costlier than wireless line but the distortion becomes less in wired line (optical fiber has minimum distortion 2dB/km).
3. Receiver: It is the device that receives information from channel and extract intended electrical message from it. The receivers demodulate or de-multiplex the signal and amplify the signal. It also removes noise, distortion and attenuation from the received signal.
4. Noise: Noise can be defined as random, unwanted interference or transmitted signal. The major portion of noise which affects communication is external noise like lightning, electrical switching, automobile ignition, etc.
5. Transducer: Transducers converts the form of energy e.g. input transducer converts message into electrical signal and output transducer converts electrical signal into message e.g. microphone and loudspeaker.

1.1.2 Types of Communication:
Analog Communication: The electrical message signals that need to be communicated can be analog when it is continuously varying with time. Speech, video, variations in temperature with time all are analog in nature. The proposed block diagram for analog communication is presently all the AM, Fm radio transmission and TV transmission is analog communication. It needs lower bandwidth compared to digital communication but the noise interference is more in analog communication.

Digital Communication: The electrical message signal that need to be communicated can be digital when it has finite number of discrete levels. Text and data are primarily digital signals. The block diagram for digital communication is proposed here. The source and destinations are two physically separate points. Digital communication is less affected by noise and for long distance communication can be effectively used regenerative repeaters.
1.1.3 Transmission Media:

1. Open wire Lines: The original telephone and telegraph transmission lines are still in use today but on their way of phasing out. They have low attenuation (0.04 dB/km).

2. Paired Cables: This is used in telephone networks within short distances e.g. inside buildings, local office etc. The loss typically is 0.05dB/km.

3. Co-axial Cables: It consists of single wire conductor at the center of cylindrical cable and an outer conductor typically a wire mesh separated by dielectric. The attenuation is relatively high.

4. Waveguide: This is a hollow conductor of rectangular circular or elliptical cross section receiving signal from transmitter. It offers very high bandwidth and attenuation around 5dB/km.

5. Optical Fiber: Optical fiber cable has two parts: core and cladding. Signal propagates in core and cladding is for protection purpose. It is used where signal is in form of light. It offers minimum attenuation 0.2 – 0.4 dB/km but require high bandwidth.

### Channel Frequency Range

1. Telephone 300 to 3400 Hz
2. Co-axial Cable up to 400 MHz
3. Optical Fiber Cable $10^{14}$ to $10^{15}$ Hz
4. Microwave Radio Channel 1 to 3 GHz
5. Satellite Channel 0.25 to 65 GHz

1.1.4 Communication Parameters:

1. Signal to Noise Ratio: A quantity that gives relative strength of the signal to noise is called signal to noise ratio (SNR). It is expressed in decibels.

   \[
   \text{SNR in dB} = 10 \log_{10}\left(\frac{\text{Signal Energy}}{\text{Noise Energy}}\right)
   \]

2. Bandwidth: It is range of frequencies which can be transmitted through it, with acceptable degradation.

3. Capacity: The capacity of a channel to support a particular rate of information is defined as channel capacity.

   \[
   C = B \log_2 (1 + \text{SNR}) \text{ bits/sec}
   \]

   \[
   B = \text{Bandwidth}
   \]

   \[
   \text{SNR} = \text{Signal to Noise Ratio}
   \]

1.2 Modulation: Modulation is a process of superimposing a low frequency signal on a high frequency carrier signal. It is also defined as the process by which some characteristics usually amplitude, frequency or phase of a carrier is varied in accordance with instantaneous value of some other voltage, called the modulating voltage.

1.2.1 Need of Modulation:

1. Frequency Multiplexing: Multiplexing means transmission of two or more signals simultaneously over the same channel. The common examples of multiplexing are the number of television channels operating simultaneously. The different signals from different stations can be separated in the receiver since the carrier frequencies for these signals are different.

2. Practicability of Antennas: The height of antennas required for transmission and reception of radio waves in radio transmission is a function of wavelength of frequency used.
3 **Narrow banding:** Bandwidth of a modulated signal may be made smaller or larger than the original signal. SNR in the receiver which is a function of signal bandwidth can thus be improved by proper control of bandwidth at the modulating stage.

4 **Common Processing:** Common processing undergoes the different requirements of modulations like avoids mixing of signals. Modulation increases the range of communication; it improves quality of reception and many more.

1.2.2 **Baseband Signals:** The message signal generated from the information source is also called baseband signal. It can be analog or digital in nature. The baseband transmission is preferred at low frequencies and for short distances. PSI is the major issue with this.

**Pass band Signals:** If modulated signal is transmitted over the channel, it is called pass band transmission. When baseband signal is impressed upon a carrier, the modulated signal generated which have fixed band of frequencies. This signal is called Pass band Signal.

1.2.3 **Types of Modulation:**

![Diagram of Types of Modulation](image)

1.3 **Amplitude Modulation:** A modulation process in which amplitude of the carrier is varied in accordance with the instantaneous value of the modulating signal is known as Amplitude Modulation.

The types of Amplitude Modulation are:

1.3.1 **DSB – SC (Double Side Band – Suppressed Carrier):** A signal modulated to a new spectral range by multiplying the signal with a sinusoidal signal. But the representation deals with frequency domain only e.g. if we have any baseband signal \( m(t) \) having amplitude \( A_m \) and frequency \( f_m \), then

\[
m(t) = A_m \cos(\omega_m t) = A_m \cos(2\pi f_m t)
\]

\[
m(t) = A_m \left( e^{j\omega_m t} + e^{-j\omega_m t} \right)
\]

\[
m(t) = A_m \left( e^{j2\pi f_m t} + e^{-j2\pi f_m t} \right)
\]

Now this baseband signal is going to modulate and multiply with a carrier frequency \( f_c \) and amplitude \( A_c \).

so,

\[
m(t) = A_c \cos(\omega_c t) = A_m A_c \cos(\omega_m t) \cos(\omega_c t)
\]

\[
= \frac{A_m A_c}{2} \{ \cos(\omega_m + \omega_c)t + \cos(\omega_m - \omega_c)t \}
\]

\[
= \frac{A_m A_c}{2} \{ e^{j(\omega_c + \omega_m)t} + e^{-j(\omega_c + \omega_m)t} + e^{j(\omega_c - \omega_m)t} + e^{-j(\omega_c - \omega_m)t} \}
\]

Now the frequency domain representation in generalized form is
Generation of DSB – SC Signal: Modulation can be achieved by two methods:

1) Linear Circuits:
   a) Switching Modulator: In switching modulator the baseband signal \( f(t) \) is multiplied by any periodic wave having the carrier frequency \( \omega_c \). By using a band pass filter (BPF), the spectrum centered around \( \pm \omega_c \) can be separated. This generate DSB – SC signal.

   After passing BPF, only band exists which is around \( \pm \omega_c \). So we get DSB-SC signal.

   b) Ring Modulator: The message signal \( f(t) \) can be designed by a switching circuit using diode which is called Ring Modulator. The circuit is as follows:

   Working: As per circuit when \( Acos\omega_c t \) apply at positive half cycle, all the diodes short circuits. So a path is generated for \( f(t) \) and no output is received. When diodes are open circuit at negative cycle, the output obtained is \( f(t) \). This received signal is passed through a BPF which is centered at \( \pm \omega_c \) and we receive a DSB-SC signal.

   e.g. in switching circuit, a pulse train works as a carrier signal which is

   \[
   \frac{1}{2} + \frac{2}{\pi} \left( \cos \omega_c t - \frac{1}{3} \cos 3\omega_c t + \frac{1}{5} \cos 5\omega_c t + \cdots \right)
   \]

   so, after BPF, \( O/P = K \, m(t) \cos \omega_c t \)

2) Non – Linear Circuits:
a) **Balanced Modulator:** A balanced modulator using two diodes as non linear elements is shown in fig.

As circuit shows here two diodes, a BPF and RLC circuit exists.

\[ e_1 = \cos \omega_c t + f(t) \]
\[ e_2 = \cos \omega_c t - f(t) \]

\[ i_1 = a e_1 + b e_1^2 \]
\[ i_1 = a [\cos \omega_c t + f(t)] + b[\cos \omega_c t + f(t)]^2 \]
\[ i_2 = a e_2 + b e_2^2 \]
\[ i_2 = a [\cos \omega_c t - f(t)] + b[\cos \omega_c t - f(t)]^2 \]

![Balanced Modulator Diagram](image)

The velocity \( V_0 \) at the input of the band pass filter is given by,

\[ V_0 = V_1 - V_2 = i_1R - i_2R = 2R[a f(t) + 2b f(t) \cos \omega_c t] \]

The output of BPF centered around \( \pm \omega_c \) is given by

\[ O/P = 2bRf(t) \cos \omega_c t \]
\[ O/P = Kf(t) \cos \omega_c t \]; which is desired.

**Detection of DSB – SC:**

1) **Coherent Detection:** This is the best and the most demandable detection process. It is also called synchronous detection because the carrier frequencies are same.

![Coherent Detection Diagram](image)

As per block diagram, DSB – SC = \( m(t) \cos \omega_c t \)

at point \( a \),

\[ = [m(t) \cos \omega_c t] \cos \omega_c t \]
\[ = m(t) \cos^2 \omega_c t \]
\[ = \frac{m(t)}{2} (1 + \cos 2\omega_c t) \]

O/P will be received after LPF, so O/P = \( \frac{m(t)}{2} \)

The output shows that the strength of the signal diminishes or reduces up to 50%. The original signal was \( m(t) \) and at the destination it is received as \( \frac{m(t)}{2} \).
2) **Squaring Synchronizer:**

![Diagram of Squaring Synchronizer]

This is used for the signals where common auxiliary signals are not feasible. So just follow the instructions as given on blocks:

\[
\text{DSB-SC} = m(t) \cos \omega_c t
\]

at point a,

\[
= A \cos \omega_m t \cos \omega_c t
\]

\[
= A^2 \cos^2 \omega_m t \cos^2 \omega_c t
\]

\[
= \frac{A^2}{2} [1 + \cos 2\omega_m t] [1 + \cos 2\omega_c t]
\]

\[
= \frac{A^2}{2} [1 + \frac{1}{2} \cos 2(\omega_c + \omega_m) t + \frac{1}{2} \cos 2(\omega_c - \omega_m) t + \cos 2\omega_m t + \cos 2\omega_c t]
\]

at point b,

\[
= \cos 2\omega_c t
\]

Now, for O/P, this signal has to be divided by 2 which are accomplished by a bistable multivibrator. The O/P of divider is used to multiply the incoming signal and then recover the baseband signal \(\cos 2\omega_c t\).

Here, we can use a phase locked loop (PLL) inspite of filter centered at 2\(f_c\) for better synchronization.

### 1.3.2 DSB – C (Double Side Band – with Carrier)

It represents one category of amplitude modulation of double side band with carrier, so the carrier signal also exists with baseband signal.

\[
v(t) = A_c [1 + m(t)] \cos \omega_c t
\]

\[
= A_c m(t) \cos \omega_c t + A_c \cos \omega_c t
\]

So, the resultant waveform is one in which the carrier \(A_c \cos \omega_c t\) is modulated in amplitude. The destination “carrier” for the auxiliary signal \(A_c \cos \omega_c t\) seems especially appropriate in the present connection since this signal now carries the baseband signal as its envelope.

#### Generation (Modulator):

1) **Switching Modulator:** Consider the following modulator with only one diode and BPF passes frequency ‘\(\omega_c \pm \omega_m\)’.

![Diagram of Switching Modulator]

Consider the diode is ideal and carrier signal is stronger than message signal. So diode will conduct when it is positive or forward bias. So we receive a pulse wave O/P which can be mathematically represented as:

\[
s(t) = \frac{1}{2} + \frac{1}{2} \left(\cos \omega_c t - \frac{1}{3} \cos 3\omega_c t + \frac{1}{5} \cos 5\omega_c t + \cdots\right)
\]

(1)

Now, at y(t), the combine signal appears like, y(t) = \[m(t) + A_c \cos \omega_c t\] s(t)

\[
y(t) = [m(t) + A_c \cos \omega_c t] s(t)
\]

\[
y(t) = \left[\frac{m(t)}{2} \cos \omega_c t + \frac{A_c}{2} \cos \omega_c t + \frac{2A_c}{3} \cos 3\omega_c t + \frac{2A_c}{5} \cos 5\omega_c t + \cdots\right]
\]

here, \(\frac{m(t)}{2}\) = baseband signal, \(\frac{A_c}{2} \cos \omega_c t\) = carrier signal
After passing through a BPF centered at $\omega_e + \omega_m$, the output will be $\frac{m(t)}{2} \cos \omega_c t + \frac{1}{\pi} m(t) \cos \omega_0 t$ which a DSB-C or AM signal is clearly.

Detection (Demodulator):
1) Envelope Detector: The recovery of the baseband signal is a process referred as demodulation or detection. An envelope detector consists of a diode and RC circuit to recover from the AM or DSB-C signal.

![Envelope Detector Diagram](image)

Working: Let us assume initially resistor R is not present, so the capacitor charges to the peak positive voltage and diode will not again conduct. The capacitor holds the peak voltage and falls with the wave. Now suppose the input carrier amplitude is increased the diode again conducts and capacitor charges for the new higher peak. The R is used to discharge the capacitor and this process follows till the whole waveform. So it looks like an envelope.

Rectifier Detection: From this resultant $V_c$, we detect the baseband signal and rectify the other components using LPF having Frequencies $\pm \omega_m$. So the new final circuitry is
1.3.3 SSB (Single Side Band) Modulation: In DSB-SC, the baseband ranges between 0 & \( \omega_m \) having bandwidth \( \omega_m \), thus the bandwidth becomes \( 2\omega_m \), because the message signal appears twice in the DSB-Sc signal and is unnecessarily increases the bandwidth. Lower the bandwidth of modulated signal, more the number of channels that can be accommodated in the given frequency space. SSB is desirable to transmit only one sideband.

Now, let us find the mathematical representation of SSB signal.

For SSB there are two parts: SSB-L and SSB-R which can be derived from DSB-SC.

Mathematical Representation

\[
M_{\text{DSB-SC}}(\omega) = 0.5[ M(\omega + \omega_c) + M(\omega - \omega_c) ]
\]

\[
M_{\text{DSB-L}}(\omega) = 0.5 M_{\text{DSB-SC}}(\omega) [ \text{sgn}(\omega + \omega_c) - \text{sgn}(\omega + \omega_c) ]
\]

\[
= 0.25 \left[ M(\omega + \omega_c) \text{sgn}(\omega + \omega_c) + M(\omega - \omega_c) \text{sgn}(\omega + \omega_c) - M(\omega + \omega_c) \text{sgn}(\omega - \omega_c) - M(\omega - \omega_c) \text{sgn}(\omega - \omega_c) \right]
\]

\[
\text{Now, } -\text{sgn}(\omega - \omega_c) = 1 \text{ for } (\omega < \omega_c)
\]

\[
\text{sgn}(\omega + \omega_c) = 1 \text{ for } (\omega > -\omega_c)
\]

\[
M_{\text{DSB-L}}(\omega) = 0.25[M(\omega + \omega_c) + M(\omega - \omega_c)] + 0.25 [M(\omega + \omega_c) \text{sgn}(\omega + \omega_c) - M(\omega - \omega_c) \text{sgn}(\omega - \omega_c)]
\]

Here \( 0.5 [ M(\omega + \omega_c) + M(\omega - \omega_c) ] = m(t) \cos \omega_c t \)

But for any signal \( m(t) \) when delayed by a phase of \( \pi/2 \), it undergoes Hilbert Transform.

Hilbert Transform.

\[
-j \text{sgn}(\omega) M(\omega) \leftrightarrow m_h(t), \text{ delay of } \pi/2.
\]

Using frequency shifting property,

\[
-j \text{sgn}(\omega - \omega_c) M(\omega - \omega_c) = m_h(t) e^{j\omega_c t}
\]

\[
-j \text{sgn}(\omega - \omega_c) M(\omega - \omega_c) = m_h(t) e^{-j\omega_c t}
\]

So,

\[
M_{\text{SSB-L}}(t) = 0.5 m(t) \cos \omega_c t + 0.5 \left[ \frac{m_h(t) e^{-j\omega_c t} - m_h(t) e^{j\omega_c t}}{2j \sin \omega_c t} \right]
\]

\[
= 0.5 m(t) \cos \omega_c t + 0.5 \frac{m_h(t) e^{-j\omega_c t} - m_h(t) e^{j\omega_c t}}{2j \sin \omega_c t}
\]

\[
M_{\text{SSB-L}}(t) = 0.5 m(t) \cos \omega_c t + 0.5 m_h(t) \sin \omega_c t
\]

\[
M_{\text{SSB-L}}(t) = 0.5 m(t) \cos \omega_c t - 0.5 m_h(t) \sin \omega_c t
\]
Generation of SSB:

1). Frequency Discrimination Method:

As per the block diagram the audio baseband signal (range 300Hz to 3kHz) and a carrier of frequency 100kHz are applied to a balanced modulator. The output of BM bears both the upper and lower side bands which is selected by Band pass Filter (BPF). The first carrier frequency is selected to be of 100 kHz, so the upper sideband of the output will be 100.3 kHz to 103 kHz and lower sideband is about 97 kHz to 99.7 kHz. The separation is about 600Hz and 40dB with a percentage change of 0.6% which is very hard to separate, so we use another oscillator and BPF of around 10 kHz, after that the separation becomes 200.6kHz and percentage change of 2%, then we receive a proper SSB.

2). Phase Discrimination Method: In this method, the time domain description for lower SSB is

$$\phi_{SSB}(t) = f(t) \cos \omega_c t + f_n(t) \sin \omega_c t$$

The block diagram is
Demodulation:

Coherent Detection:

The coherent detection is the simplest and best method for recovering baseband signal.
\[ M_{\text{SSB}}(t) = 0.5 m(t) \cos \omega_c t \pm 0.5 m_h(t) \sin \omega_c t \]
\[ y(t) = M_{\text{SSB}}(t) \cos \omega_c t \]
\[ y(t) = [0.5 m(t) \cos \omega_c t \pm 0.5 m_h(t) \sin \omega_c t] \cos \omega_c t \]
\[ y(t) = 0.5 m(t) \cos^2 \omega_c t \pm 0.5 m_h(t) \sin \omega_c t \cos \omega_c t \]
\[ y(t) = 0.25 m(t) [1 + 2 \cos \omega_c t] \pm 0.25 m_h(t) \sin 2\omega_c t \]

After passing through LPF of \( \omega_m \) centered,
\[ \text{O/P} = 0.25 m(t) \text{ or } \frac{m(t)}{4} \]

1.3.4 Vestigial Sideband (VSB): VSB is something in between SSB and DSB which provides certain advantages at small cost. This is so called because a vestige is added here to SSB spectrum. Here, the generation of SSB is removed, because no sharp cut off is required in VSB. The additional spectrum required is usually less than one fourth of SSB requirement. The mathematical representation of VSB is
\[ M_{\text{DSB}}(\omega) = 0.5[M(\omega + \omega_c) + M(\omega - \omega_c)] \]
then, VSB spectrum,
\[ M_{\text{VSB}}(\omega) = 0.5 H(\omega) [M(\omega + \omega_c) + M(\omega - \omega_c)] \]
Here, \( H(\omega) \) represents the portion of filter.

Modulation and Demodulation:
Advantages:
1. Easy to generate from DSB-SC signal.
2. No specific filtration is required.
3. If loss occurs then also we will recover the original signal because vestigial part will waste.

Application: TV Broadcasting

1.3.5 Quadrature Amplitude Modulation: QAM is similar to DSB-SC but sends two messages over the same spectrum. One of the message signal is sent in phase and other message signal is sent in quadrature by multiplying with phase shifter, finally we add both signals to design QAM.

The block diagram is

The demodulation uses coherent detection method.

The mathematical expression is:

\[ m_{QAM}(t) \cos \omega_c t = m_1(t) \cos^2 \omega_c t + m_2(t) \sin \omega_c t \cos \omega_c t \]
\[ = m_1(t) \left( 1 + 2 \cos \omega_c t \right) + \frac{m_2(t)}{2} \sin 2 \omega_c t \]

After passing through LPF, O/P = \[ \frac{1}{2} \left( m_1(t) + m_2(t) \right) \]

1.4 Mathematical Parameter:
Modulation Index: The extent of amplitude variation in AM about an unmodulated carrier amplitude is measured in terms of modulation Index.

\[ m_a = \frac{|f(t)|_{\text{max}}}{\text{Carrier Amp} \cdot (A)} \quad \text{or} \quad m_a = \frac{E_m}{E_c} \]

Experimental, \[ m_a = \frac{E_{\text{max}} - E_{\text{min}}}{2E_c} \]

\[ E_m = E_{\text{max}} - E_c \]
\[ E_m = E_c - E_{\text{min}} \]
so, \[ E_c = \frac{E_{\text{max}} - E_{\text{min}}}{2} \]

Conditions for modulation:
1. \( m_a < 1 \) : Here the amplitude of baseband signal is less than \( A \), so the baseband signal is fully preserved.
2. \( m_a = 1 \) : \(|f(t)|_{\text{max}} = A\), the waveform envelope just touches the zero amplitude axis. The baseband signal is still preserved.
3. \( m_a > 1 \) : This is a condition of over modulation, where \(|f(t)|_{\text{max}} > A\), the envelope breaks and is called envelope distortion.

**Power Contents:** Total Power \( P_t \) = Sideband Power + Carrier Power
\[
P_t = P_c + P_s
\]
\[
P_t = \frac{1}{2} A^2 + \frac{1}{2} f^2(t)
\]
\[
P_t = \frac{1}{2} \left( A^2 + f^2(t) \right)
\]
\[
P_t = \frac{1}{2} \left( A^2 + \frac{E_{\text{max}}^2}{A^2} \right)
\]
\[
P_t = \frac{1}{2} \left( 1 + \frac{m_a^2}{2} \right)
\]

\[ P_t = P_c \left( 1 + \frac{m_a^2}{2} \right) \]

\[ m_a = \frac{E_{\text{max}}}{A} \]

1.5 **Radio Transmitter & Receiver:** The radio frequency achieved by translation of a baseband signal by a modulation process which is then amplified by a power amplifier and radiated through antenna assembly.
**AM Transmitter:** The AM broadcast transmitter occupy 10 kHz bandwidth, around frequency range 595-605 kHz. The oscillator used to generate carrier signal generally made up from crystal as LC oscillations tend to drift the time. The oscillator output passes through a buffer amplifier which increases its power level but serves as an isolator that prevents variations of load affecting frequency of the oscillator.

**AM Receiver:** A radio receiver is an electronic circuit that pick up a desired modulated radio frequency signal, and recovers the baseband signal from it. A receiver performs the following functions which are explained with the help of block diagram of a simple receiver known as TRF and other is super heterodyne receiver.

At the receiving antenna, the signal receives that is attenuated during transmission hence need amplification. This signal after amplification passed on a mixer, in which the modulated RF carrier is mixed by a sinusoidal waveform generated by a local oscillator ($f_{osc}$). This process is also called heterodyning, and this system is called superheterodyne receiver. The difference of frequencies generated ($f_{osc} - f_{r}$) and applied to RF amplifier. In this process a modulated RF carrier is replaced by a modulated IF carrier, is also called “conversion”. The IF output is passed through an IF carrier filter to the demodulation in which the baseband signal is recovered a baseband filter.

**Features of a Receiver:**
1. Selectivity: Selectivity is receiver’s ability to distinguish between two adjacent carrier frequencies. By this feature it is decided how perfectly the receiver is able to select the desired carrier frequency and reject the other.
2. Sensitivity: The ability of a receiver to detect the weakest possible signal is known as sensitivity. The sensitivity of a receiver is decided by the gain of its amplifying stages.
3. Fidelity: The ability of a receiver to reproduce faithfully all frequency components present in the baseband signal is known as fidelity. This feature is mainly decided by the abndwidth of audio amplifier which amplifies the baseband signal.