COMMUNICATION SYSTEMS

COMMUNICATION SYSTEMS:

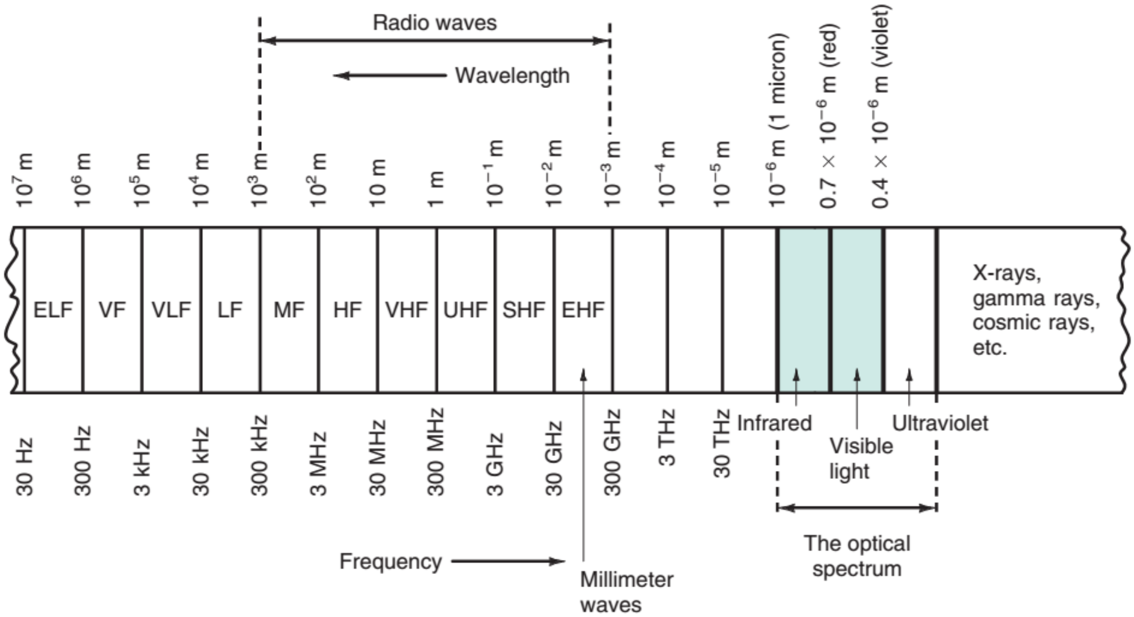
Introduction, Elements of Communication system, Modulation- AM, FM (Only concepts, working principle, waveform and Comparison), Super heterodyne receiver, Digital Communication block diagram.

INTRODUCTION TO MICROPROCESSOR AND MICROCONTROLLER:

Microprocessor, Microcontroller (Only concepts, working principle, and Comparison)

Introduction:

The Electromagnetic Spectrum



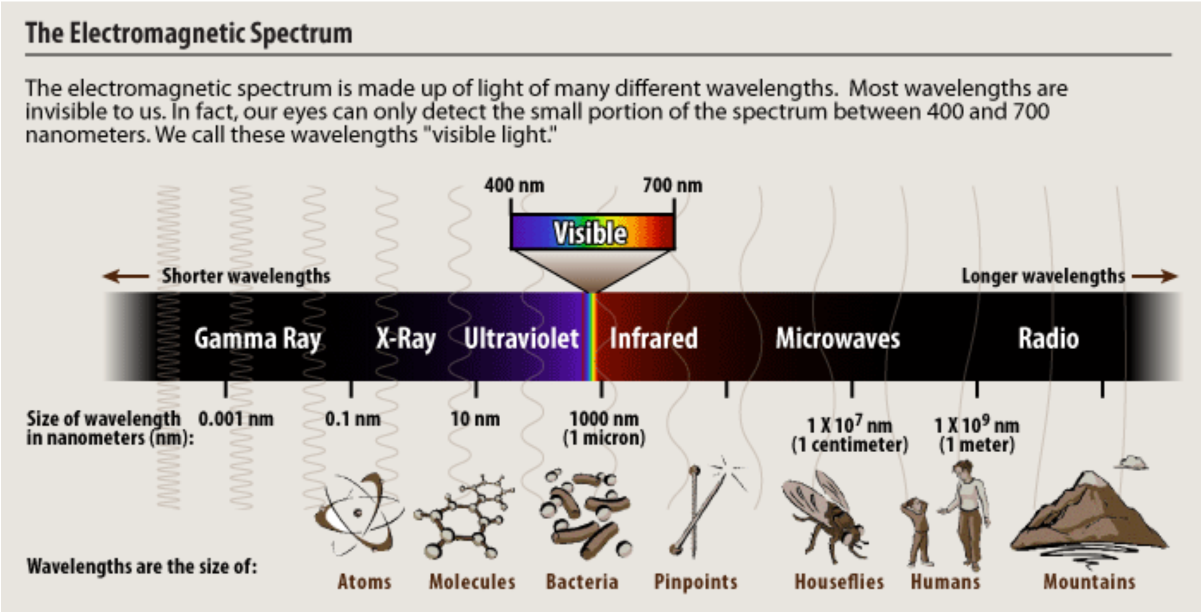


Figure 1: The Electromagnetic Spectrum

Electromagnetic waves are signals that oscillate; i.e., the amplitudes of the electric and magnetic fields vary at a specific rate. The field intensities fluctuate up and down, and the polarity reverses a given number of times per second. The electromagnetic waves vary sinusoidally. Their frequency is measured in cycles per second (cps) or hertz (Hz). These oscillations may occur at a very low frequency or at an extremely high frequency. The range of electromagnetic signals encompassing all frequencies is referred to as the electromagnetic spectrum.

All electrical and electronic signals that radiate into free space fall into the electromagnetic spectrum. Not included are signals carried by cables. Signals carried by cable may share the same frequencies of similar signals in the spectrum, but they are not radio signals. Fig. 1 shows the entire electromagnetic spectrum, giving both frequencies and wavelength. Within the middle ranges are located the most commonly used radio frequencies for two-way communication, TV, cell phones, wireless LANs, radar, and other applications. At the upper end of the spectrum is infrared and visible light. Fig. 2 is a listing of the generally recognized segments in the spectrum used for electronic communication and other applications.

Name	Frequency	Wavelength
Extremely low frequencies (ELFs)	30–300 Hz	10^7-10^6 m
Voice frequencies (VFs)	300–3000 Hz	10^6-10^5 m
Very low frequencies (VLFs)	3–30 kHz	10^5-10^4 m
Low frequencies (LFs)	30–300 kHz	10^4-10^3 m
Medium frequencies (MFs)	300 kHz–3 MHz	10^3-10^2 m
High frequencies (HFs)	3–30 MHz	10^2-10^1 m
Very high frequencies (VHFs)	30–300 MHz	10^1-1 m
Ultra high frequencies (UHFs)	300 MHz–3 GHz	$1-10^{-1}$ m
Super high frequencies (SHFs)	3–30 GHz	$10^{-1}-10^{-2}$ m
Extremely high frequencies (EHFs)	30–300 GHz	$10^{-2}-10^{-3}$ m
Infrared	—	$0.7-10$ μm
The visible spectrum (light)	—	$0.4-0.8$ μm

Units of Measure and Abbreviations:

kHz = 1000 Hz

MHz = 1000 kHz = 1×10^6 = 1,000,000 Hz

GHz = 1000 MHz = 1×10^6 = 1,000,000 kHz = 1×10^9 = 1,000,000,000 Hz

m = meter

$\mu m = \text{micrometer} = \frac{1}{1{,}000{,}000}\, m = 1 \times 10^{-6}\, m$

Figure: 2 The Electromagnetic spectrum

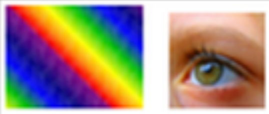
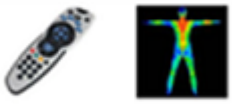
Gamma Rays	• kill bacteria in food • sterilise medical equipment • treat tumours	
X-Ray	• imaging internal structures in the body • studying the atomic structure of materials	
Ultraviolet (UV)	• fluorescent tubes • tanning • security marking	
Visible Light	• seeing • optical fibres communication	
Infrared (IR)	• radiant heaters • grills • remote controls • thermal imaging	
Microwaves	• satellite communication • cooking	
Radio Waves	• communication • broadcasting • radar	

Figure 3: Application of Electromagnetic waves

General block diagram of a Communication System

All electronic communication systems have a transmitter, a communication channel or medium, and a receiver. These basic components are shown in Fig. 4. The process of communication begins when a human being generates some kind of message, data, or other intelligence that must be received by others. A message may also be generated by a computer or electronic current. In *electronic communication systems,* the message is referred to as *information,* or an intelligence signal. This message, in the form of an electronic signal, is fed to the transmitter, which then transmits the message over the communication channel. The message is picked up by the receiver and relayed to another human. Along the way, noise is added in the communication channel and in the receiver. *Noise* is the general term applied to any phenomenon that degrades or interferes with the transmitted information.

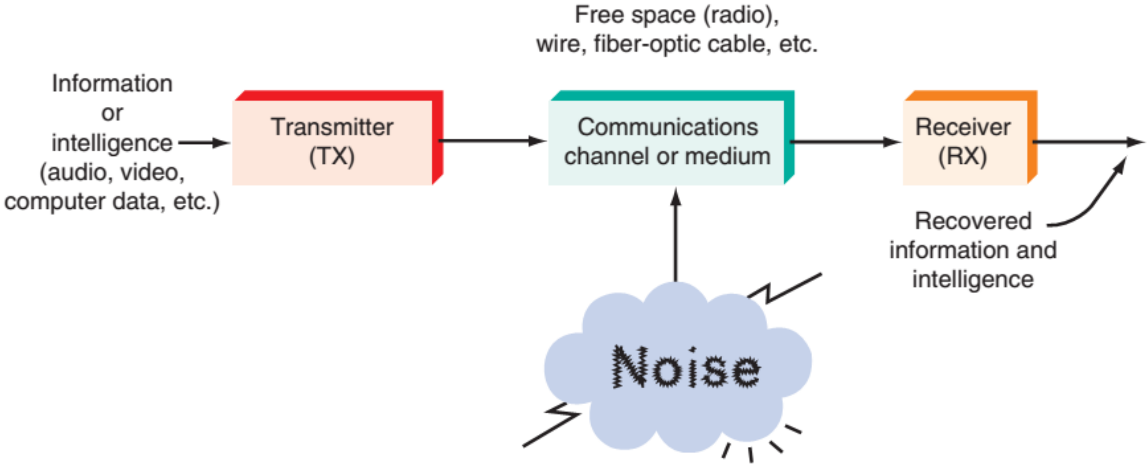


Fig.4: **General block diagram of all communication system**

Transmitter

The first step in sending a message is to convert it into electronic form suitable for transmission. For voice messages, a microphone is used to translate the sound into an electronic *audio* signal. For TV, a camera converts the light information in the scene to a video signal. In computer systems, the message is typed on a keyboard and converted to binary codes that can be stored in memory or transmitted serially. Transducers convert physical characteristics (temperature, pressure, light intensity, and so on) into electrical signals.

The *transmitter* itself is a collection of electronic components and circuits designed to convert the electrical signal to a signal suitable for transmission over a given communication medium. Transmitters are made up of oscillators, amplifiers, tuned circuits and filters, modulators, frequency mixers, frequency synthesizers, and other circuits. The original intelligence signal usually modulates a higher-frequency carrier sine wave generated by the transmitter, and the combination is raised in amplitude by power amplifiers, resulting in a signal that is compatible with the selected transmission medium.

Communication Channel

The *communication channel* is the medium by which the electronic signal is sent from one place to another. Many different types of media are used in communication systems, including wire conductors, fiber-optic cable, and free space.

Receivers

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 fed to an LCD screen for display, or binary data received by a computer and then printed out or displayed on a video monitor.

Attenuation

Signal *attenuation,* or degradation, is inevitable no matter what the medium of transmission. Attenuation is proportional to the square of the distance between the transmitter and receiver.

Thus considerable signal amplification, in both the transmitter and the receiver, is required for successful transmission.

Noise

Noise is mentioned here because it is the bane of all electronic communications. Its effect is experienced in the receiver part of any communications system. While some noise can be filtered out, the general way to minimize noise is to use components that contribute less noise and to lower their temperatures.

Need for Modulation

1. **Practical Antenna length-**theory shows that in order to transmit a wave effectively the length of the transmitting antenna should be approximately equal to the wavelength of the wave.

$$Wavelength = \frac{Velocity}{frequency} = \frac{3*10^8}{frequency}\frac{meters}{sec}$$

The audio frequencies range from 20 Hz to 20Khz, if they are transmitted directly into space, the length of the transmitting antenna required would be extremely large. For example to radiate a frequency of 20 KHz directly into space we would need an antenna length of $3x10^{8} / 20x10^{3} \approx 15{,}000$ meters. This is too long to be constructed practically.

2. **Operating Range:** The higher- frequency signals radiate into space more efficiently than the low frequency signals. The high frequency electromagnetic signals are able to travel through space for long distances, since they undergo less attenuation.

3. **Improves Quality of Reception:** Using modulation techniques like FM, PCM, reduces the effect of noise to great extent. Reduction in noise improves the quality of reception.

4. **Avoids mixing of the signals, allows multiplexing of the signal:** The use of modulation also permits another technique, known as multiplexing, to be used. Multiplexing is the process of allowing two or more signals to share the same medium or channel.

Significance of Bandwidth

Bandwidth (BW) is that portion of the electromagnetic spectrum occupied by a signal. It is also the frequency range over which a receiver or other electronic circuit operates. More specifically, bandwidth is the difference between the upper and lower frequency limits of the signal or the equipment operation range. Fig. 5 shows the bandwidth of the voice frequency range from 300 to 3000 Hz. The upper frequency is f_2 and the lower frequency is f_1. The bandwidth, then, is **$BW = f_2 - f_1$**.

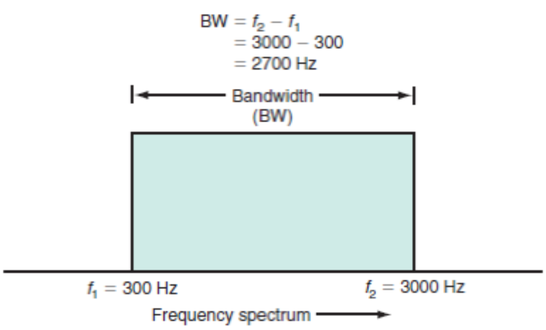


Fig. 5 voice frequency bandwidth

AM and FM Systems

Types of modulation-

1. Amplitude modulation
2. Frequency modulation
3. Phase modulation

The three ways to make the baseband signal change the career sine wave are to vary its amplitude, vary its frequency or vary its phase angle. The two most common methods of modulation are amplitude modulation (AM) and frequency modulation (FM). In AM, the baseband information signal called modulating signal varies the amplitude of the high frequency carrier signal as shown in fig. 6.a. In FM, the information signal varies the frequency of the carrier, as shown in fig. 6.b.

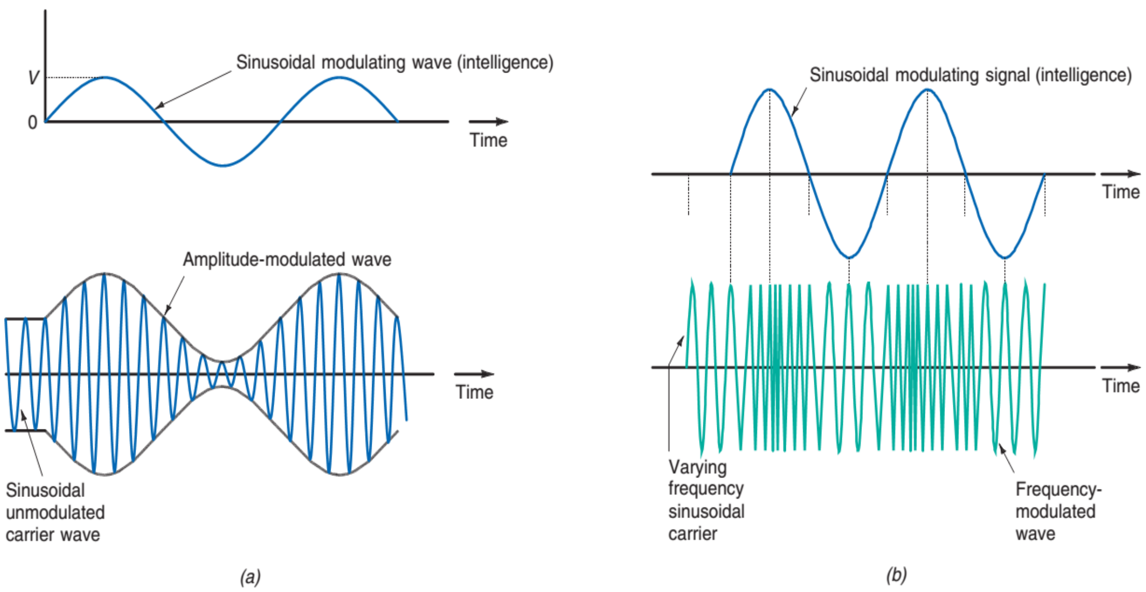


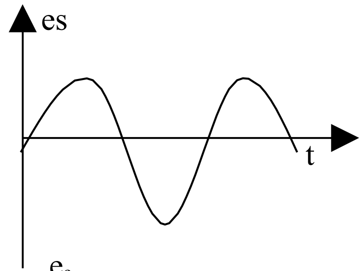
Fig. 6: **Types of Modulation. a) Amplitude Modulation b) Frequency Modulation**

Amplitude modulation:

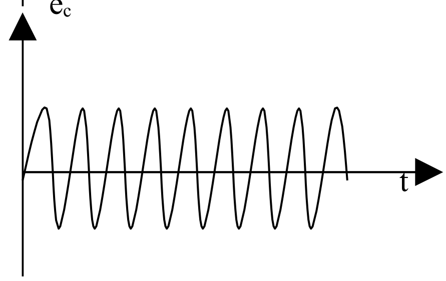
When the amplitude of a high-frequency carrier wave is changed in accordance with the intensity of the signal, it is called amplitude modulation.

The following points are to be noted in amplitude modulation.

1. The amplitude of the carrier wave changes according to the instantaneous amplitude of the message signal.
2. The amplitude variations of the carrier wave are at the signal frequency f_m.
3. The frequency of the amplitude-modulated wave remains the same as the unmodulated carrier frequency f_C.



Modulating signal



Carrier Wave

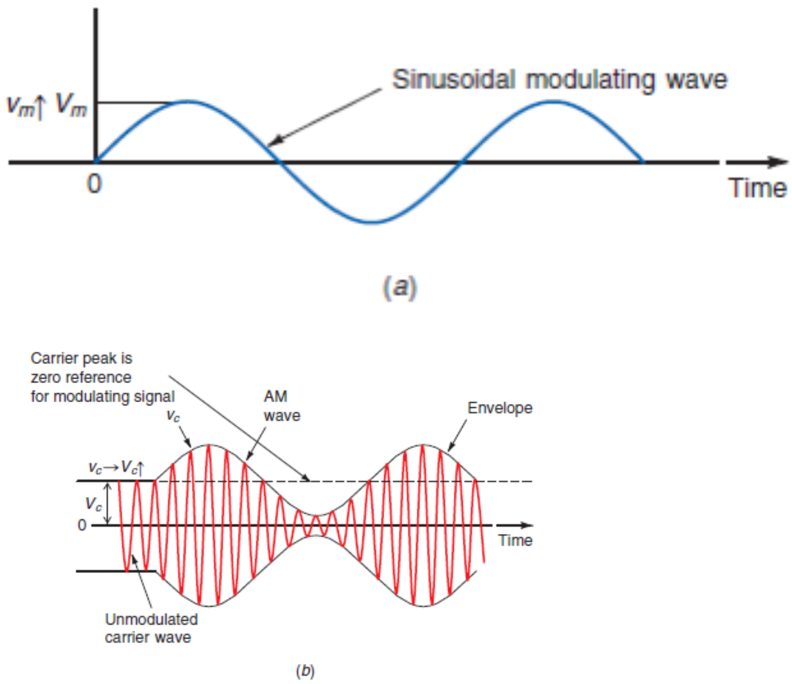


Fig. 7 (a) Message signal (b) AM signal

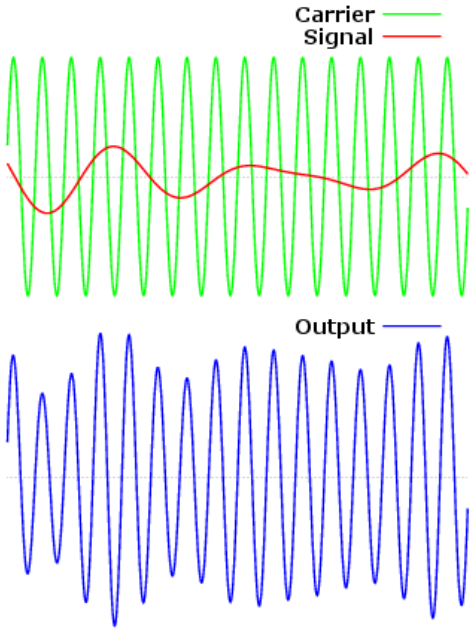


Fig. 7(c) Modulating signal (Non-sinusoidal / Audio) and modulated carrier

AM derivation

A sine wave carrier signal is of the form $c(t) = A_c \sin\omega_c t$ and a sine wave message signal is of the form $m(t) = A_m \sin\omega_m t$.

Notice that the amplitude of the high frequency carrier takes on the shape of the lower frequency modulation signal forming what is called a modulation envelope.

The modulation index is defined as the ratio of the modulation signal amplitude to the carrier signal amplitude. $m = \frac{A_m}{A_c}$ where $0 \le m \le 1$. The overall signal can be described by:

$$\begin{aligned} S_{AM}(t) &= (A_c + A_m \sin\omega_m t)\sin\omega_c t \\ &= (A_c + mA_c \sin\omega_m t)\sin\omega_c t \end{aligned}$$

A note on frequency multiplication:

The product of two sine waves produces sum and difference frequencies:

$$\sin\omega_1 t \sin\omega_2 t = \frac{1}{2}\cos(\omega_1 - \omega_2)t - \frac{1}{2}\cos(\omega_1 + \omega_2)t$$

As a result, expanding the instantaneous AM expression results in:

$$
\begin{aligned}
S_{AM}(t) &= A_c \sin\omega_c t + mA_c \sin\omega_m t \sin\omega_c t \\
&= \underbrace{A_c \sin\omega_c t}_{\text{Carrier}} + \underbrace{\frac{mA_c}{2}\cos(\omega_c - \omega_m)}_{\text{LSB}} - \underbrace{\frac{mA_c}{2}\cos(\omega_c + \omega_m)}_{\text{USB}}
\end{aligned}
$$

From this we observe that upper and lower sidebands are created when using amplitude modulation. The sideband amplitude is: $\frac{mA_c}{2}$, and the total occupied spectrum is twice the bandwidth of the modulation signal or $2f_m$.

AM signals are often characterized in terms of power, since it is power, which is used to drive antennas. The total power in a 1 Ω resistor is given by:

$$
\begin{aligned}
P_T &= P_C + P_{LSB} + P_{USB} \\
&= A_c^2 + \left(\frac{mA_c}{2}\right)^2 + \left(\frac{mA_c}{2}\right)^2 \\
&= P_c + \frac{m^2}{4}P_c + \frac{m^2}{4}P_c \\
&= P_c\left(1 + \frac{m^2}{2}\right)
\end{aligned}
$$

From this we observe that with a modulation index of 0, the transmitted power is equal to the carrier power. However, when the modulation index is 1, the total transmitted power increases to 1.5 times the carrier power.

At 100% modulation, only 1/3 of the total power is in the sidebands or only 1/2 of the carrier power is in the sidebands.

In terms of voltages and currents:

$$V_T = V_c\sqrt{1 + \frac{m^2}{2}} \qquad I_T = I_c\sqrt{1 + \frac{m^2}{2}}$$

If the carrier is modulated by a complex signal, the effective modulation can be determined by the combining the modulation index of each component.

$$m_{eff} = \sqrt{m_1 + m_2 + m_3 + \cdots}\ (\text{must not exceed } 1)$$

Modulation Index

Modulation factor is very important since it determines the strength and quality of the transmitted signal. The greater the degree of modulation, the stronger and clearer will be the audio signal. It should be noted that if the carrier is over modulated (ie $m>1$) distortion will occur at reception. Typically m lies between 0 and 1.

Limitations of Amplitude Modulation

1. **Noisy Reception-** In an AM wave, the signal is in the amplitude variations of the carrier. Practically all the natural and man-made noises consist of electrical amplitude disturbances. As a radio receiver cannot distinguish between amplitude variations that represent noise and those that contain the desired signal. Therefore reception is very noisy.

2. **Low efficiency-** In AM useful power is in the sidebands as they contain the signal. An AM wave has low sideband power.

   For example even if modulation is 100% ie $m=1$, the efficiency is 33.33%. Practically efficiency will be lesser than 33.33%.

   The carrier itself conveys no information. The carrier can be transmitted and received, but unless modulation occurs, no information will be transmitted. When modulation occurs, sidebands are produced. It is easy to conclude, therefore, that all the transmitted information is contained within the sidebands. Only one-third of the total transmitted power is allotted to the sidebands, and the remaining two-thirds is literally wasted on the carrier.

3. **Lack of audio quality-** The audio signals that are AM modulated has poor audio quality.
4. **Low Spectrum efficiency-** The real information is contained within the sidebands. One way to improve the spectral efficiency of amplitude modulation is to suppress the carrier and eliminate one sideband.

Frequency modulation:

When the frequency of carrier wave is changed in accordance with the intensity of the signal, it is called frequency modulation.

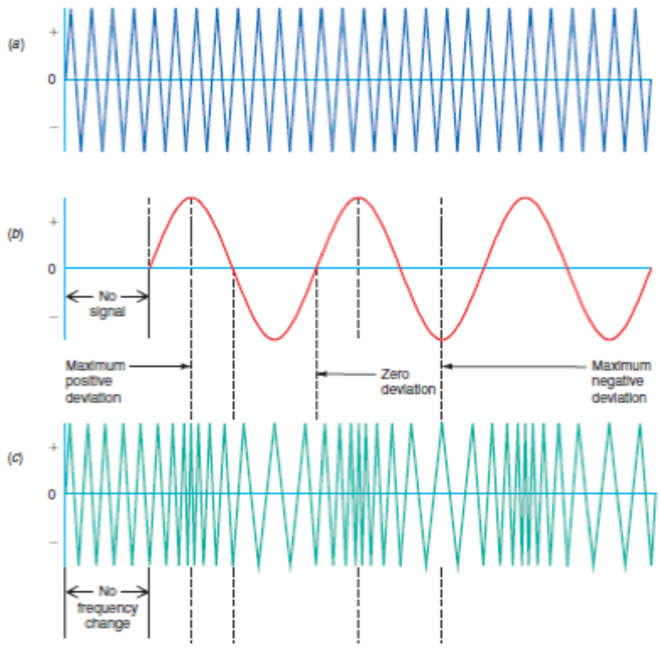


Fig. 8: Frequency modulation waveforms

- Here the amplitude of the modulated wave remains the same ie carrier wave amplitude.
- The frequency variations of carrier wave depend upon the instantaneous amplitude of the signal.
- When the signal approaches positive peaks, the carrier frequency is increased to maximum and during negative peak, the carrier frequency is reduced to minimum as shown by widely spaced cycles.

Advantages of FM

1. It gives noiseless reception.
2. The operating range is quite large.
3. The efficiency of transmission is very high.

Comparison between Amplitude Modulation and Frequency Modulation

AMPLITUDE MODULATION	FREQUENCY MODULATION
Amplitude of the carrier varies while its frequency remain constant	Frequency of the carrier varies while its Amplitude remain constant

Modulation index can have values from 0 to 1 only	Modulation index is much greater than one
AM has only two side bands	FM has infinite side bands
BW is twice the highest modulating frequency	BW is much larger than AM
Susceptible to noise	More immune to noise
Range: 500KHz to 3MHz	Range: 88MHz to 108M Hz
AM covers long distances	FM covers short distance
Propagation is by ground waves and sky waves	Propagation is by space waves
Requires less complex and less expensive equipment	Requires more complex equipment

Digital Communication Block diagram:

The elements which form a digital communication system is represented by the following block diagram for the ease of understanding.

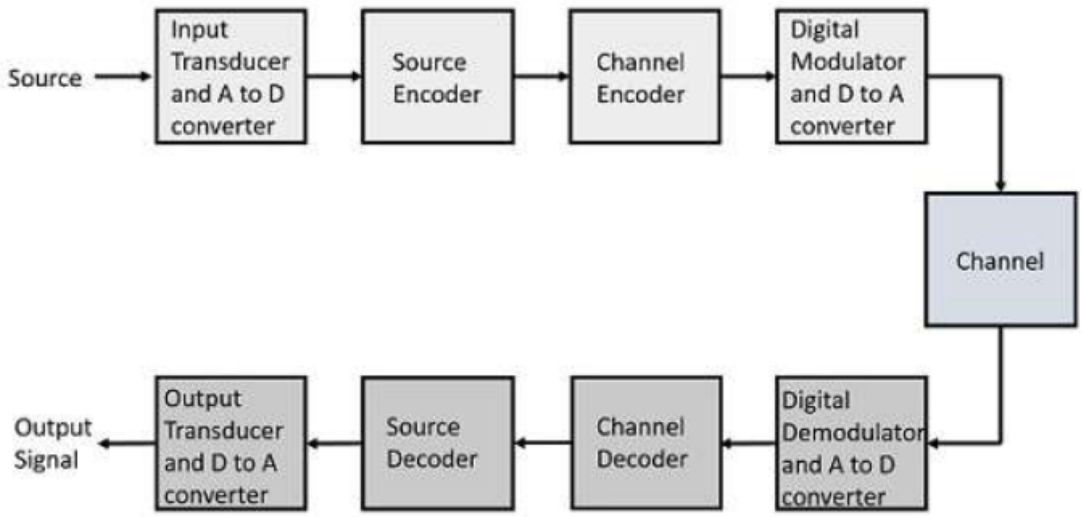


Fig 9: Elements of digital communication system

Following are the sections of the digital communication system.

Source: The source can be an analog signal. Example: A Sound signal

Input Transducer: This is a transducer which takes a physical input and converts it to an electrical signal (Example: microphone). This block also consists of an analog to digital converter where a digital signal is needed for further processes. A digital signal is generally represented by a binary sequence.

Source Encoder: The source encoder compresses the data into minimum number of bits. This process helps in effective utilization of the bandwidth. It removes the redundant bits (unnecessary excess bits, i.e., zeroes).

Channel Encoder: The channel encoder, does the coding for error correction. During the transmission of the signal, due to the noise in the channel, the signal may get altered and hence to avoid this, the channel encoder adds some redundant bits to the transmitted data. These are the error correcting bits.

Digital Modulator: The signal to be transmitted is modulated here by a carrier. The signal is also converted to analog from the digital sequence, in order to make it travel through the channel or medium.

Channel: The channel or a medium, allows the analog signal to transmit from the transmitter end to the receiver end.

Digital Demodulator: This is the first step at the receiver end. The received signal is demodulated as well as converted again from analog to digital. The signal gets reconstructed here.

Channel Decoder: The channel decoder, after detecting the sequence, does some error corrections. The distortions which might occur during the transmission are corrected by adding some redundant bits. This addition of bits helps in the complete recovery of the original signal.

Source Decoder: The resultant signal is once again digitized by sampling and quantizing so that the pure digital output is obtained without the loss of information. The source decoder recreates the source output.

Output Transducer: This is the last block which converts the signal into the original physical form, which was at the input of the transmitter. It converts the electrical signal into physical output (Example: loud speaker).

Output Signal: This is the output which is produced after the whole process. Example − The sound signal received.