BRIEF REVIEW

Communication The transfer of information from one point to another may be termed as communication. In order to convey the information over a long distance, a communication system is required. Within a communication system the information transfer is achieved usually by superimposing or modulating the information on to an electromagnetic wave (carrier). The modulated carrier is then transmitted to the required destination where it is received and original information is retrieved by means of demodulation or detection. Sophisticated techniques have been developed for this process, using electromagnetic carrier waves operating at radio frequencies as well as microwave and millimeter wave frequencies or even infrared rays in optical communication.

Transducer It is a device which converts a physical quantity varying with time into electrical signal or vice versa. It is of two types: input transducer and output transducer. Input transducer converts a physical quantity varying with time into electrical signal. For example, microphone converts sound into electrical signal, thermocouple or thermistor convert temperature into electrical signal. An output transducer converts electrical signal back to a physical quantity varying with time. For example, a speaker converts electrical signal back to sound. A heater converts electrical signal back to thermal variations.

Passive transducers require a source of emf to operate while Active transducers do not require any electrical energy to work. For example microphone and thermistor are passive transducers while solar cell is an active transducer.

Channel is used to refer to the frequency range allocated to a particular transmission, for example, a TV channel.

Noise is the introduction of unwanted signal or some distortion in the process of transmission and reception. The signal gets deteriorated. Since the noise will be received along with the signal and if noise is several times the signal, it may mask the signal making it unineligible.

Modulation is of two types: analog and digital. In analog modulation some characteristic of high frequency sine wave (called carrier) is varied in accordance with the instantaneous value of modulating signal. If amplitude of carrier wave is varied in accordance with the instantaeous value of the modulating signal then amplitude modulation (AM) results. If the frequency of the carrier is varied in accordance with the instantaneous value of the modulating signal then frequency modulation (FM) results. If phase of the carrier wave is varied in accordance to the instantaneous value of the modulating signal then phase modulation (PM) results. FM and PM may be categorized as angle modulation.

Modulation is required for long distance communication. If we transmit sound wave directly say at 20 kHz (largest frequency of sound) then the length of antenna required = $\frac{\lambda}{2} = 7.5\text{ km} \left(\lambda = \frac{c}{f} = \frac{3\times10^8}{20\times10^3} = 15\ km\right)$ which is impractical in present day technology. The other reason in favour of modulation is that if all the radio stations transmit at 20 kHz (or same frequency) their signal will mix up and nothing audible will be heard.

Amplitude Modulation (AM) Let $e_c = E_c \sin \omega_c t$ be the carrier wave and $e_m = E_m \sin \omega_m t$ be the modulating signal. Then modulated signal e is given by

$$e = (E_c + E_m \sin \omega_m t) \sin \omega_c t.$$

$$e = E_c\left(1+\frac{E_m}{E_c}\sin\omega_m t\right)\sin\omega_c t$$

$$= E_c\ (1 + m_a \sin \omega_m t)\ \sin \omega_c t \text{ where } m_a = \frac{E_m}{E_c}$$

is modulation index. It is normally expressed in % and should be less than 100%.

From Fig. 20.1 $m_a = \frac{E_{max} - E_c}{E_c} = \frac{E_c - E_{min}}{E_c} = \frac{E_{max} - E_{min}}{2E_c}$

$$= \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$

$$e = E_c\ (1 + m_a \sin \omega_m t)\ \sin \omega_c t$$

$$= E_c \sin \omega_c t + \frac{m_a}{2} E_c \cos(\omega_c + \omega_m) t - \frac{m_a}{2} \cos(\omega_c - \omega_m) t.$$

shows that spectrum of AM will consist of carrier wave, lower slide band (LSB) or component of $(\omega_c - \omega_m)$ and upper side band (USB) or component of $(\omega_c + \omega_m)$ as illustrated in Fig. 20.2.

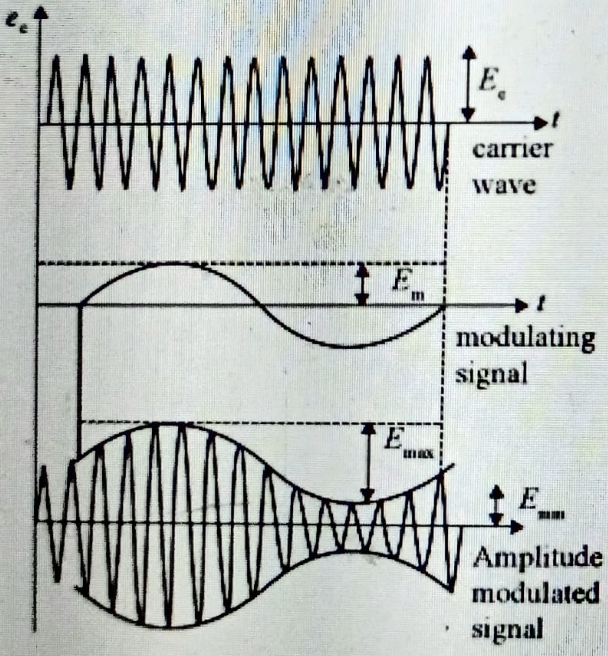


Fig. 20.1 Amplitude Modulation illustration

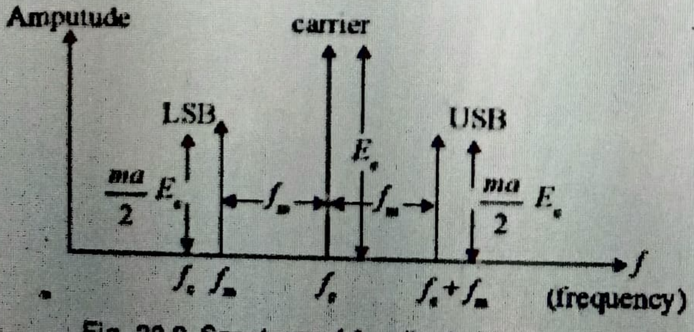


Fig. 20.2 Spectrum of Amplitude Modulation

$$P_{Total} = P_{Carrier} + P_{LSB} + P_{USB}$$

$$= P_{Carrier}\left[1+\frac{m_a^2}{2}\right]$$

or $\frac{P_{Total}}{P_{Carrier}} = 1 + \frac{m_a^2}{2}$

$$\frac{I_{Total}}{I_{Carrier}} = \sqrt{1+\frac{m_a^2}{2}}$$

If several modulating signals are present then

$$m_{total} = \sqrt{m_1^2 + m_2^2 + m_3^2 + ...}$$

Moreover, total modulation index should not exceed unity. Collector and base modulation are two methods of modulation. Collector modulation is preferred as it results in better linearity and more power output.

Types of AM

A3 → double side band full carrier.

A3A → single side band reduced carrier.

A3H → single side band full carrier.

A3J → single side band suppressed carrier called SSB (Single Side band) transmission.

A3B → two independent side bands with suppressed carrier.

A5C → vestigial side band transmission (used for video transmission in TV)

Frequency Modulation Mathematically, the instantaneous frequency of the frequency modulated signal is given by $f = f_c\ (1 + k E_m \cos \omega_m t)$ where f_c is unmodulated or average carrier frequency, k is a conversion factor which converts voltage to frequency. Since $\cos \omega_m t$ will lie between ±1, therefore, f lies between $f_c\ (1 \pm k E_m)$ maximum frequency deviation $\delta = k f_c E_m$

We may also write $\omega = \omega_c\ (1 + k E_m \cos \omega_m t)$ and angle θ is given by

$$\theta = \int \omega dt = \omega_c t + \frac{\omega_c k E_m \sin \omega_m t}{\omega_m}$$

$$= \omega_c t + \frac{f_c K E_m \sin \omega_m t}{f_m}$$

$$= \omega_c t + \frac{\delta}{f_m} \sin \omega_m t$$

The instantaneous voltage of *FM* signal 'thus' becomes

$$e = A \sin\left[\omega_c t + \frac{\delta}{f_m} \sin \omega_m t\right]$$

$$= A \sin\ [\omega_c t + m_f \sin \omega_m t]$$

Where m_f is frequency modulation index and

$$m_f = \frac{\delta}{f_m} = \frac{k E_m f_c}{f_m}$$

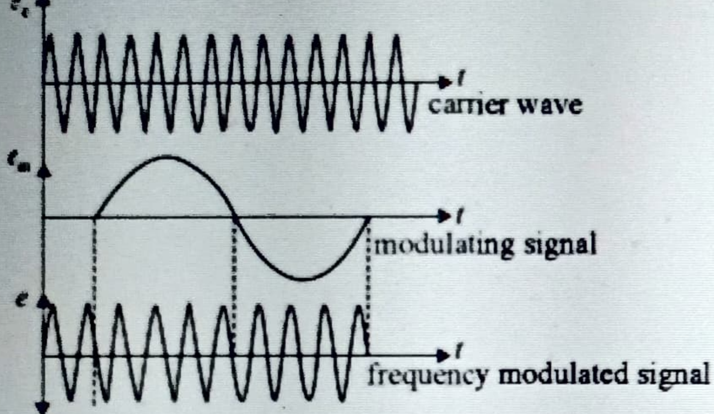


Fig. 20.3 FM illustration

Figure 20.3 shows *FM* signal illustration. To describe *FM* spectrum, Bessels function are required. It has been found that for $m_f = 2.4, 5.5, 8.6$ and 11.8 and so on carrier component completely vanishes. These values are called eigen values. These help in finding bandwidth and measuring deviation δ.

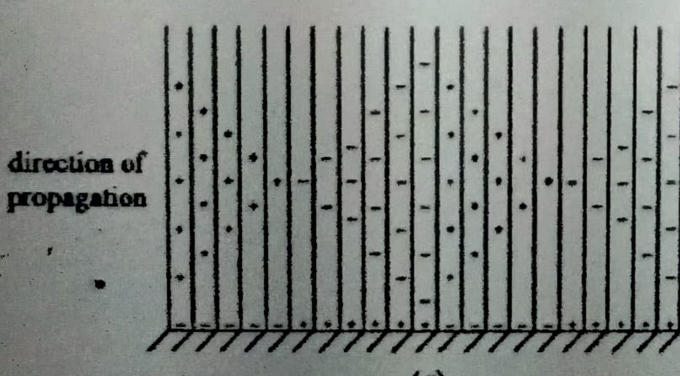
To a good approximation for $m_f > 6$, bandwidth $\Delta = 2\,(f_m + \delta)$. Otherwise, look into the table for a given m_f. Find the highest J coefficient for which modulation index has values < 0.01 then $\Delta = 2 \times f_m \times$ highest needed side band.

Note *AM* is a long distance transmission as it operates on frequencies which are reflected by ionosphere. Moreover, its circuits are simpler. However, *AM* is noise prone.

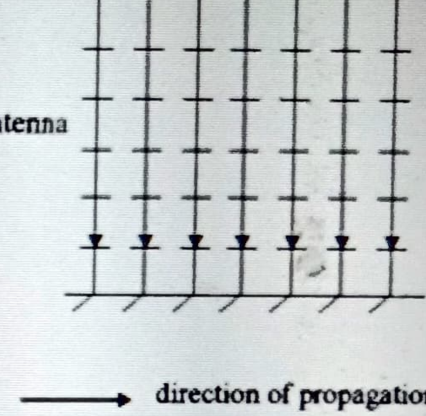
FM is short distance transmission. Repeaters are required for long distance *FM* communication. Its circuits are complex. However, it is noise immune because it is detected from frequency deviation and not from amplitude variation (where noise resides).

Ground or Surface Waves These waves are vertically polarised and progress along the surface of the earth. Vertical polarization prevents short circuiting of electric component. A wave induces current in the ground over which it passes and thus, loses some energy by absorption. However, this is made up by energy diffracted downwards from a wavefront and act like a leakage capacitor as illustrated in Fig. 20.4 (a) and (b).

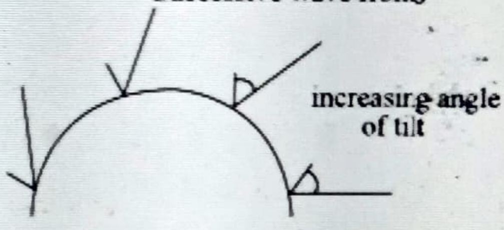
Attenuation also occurs due to diffraction as angle of tilt of successive wavefronts increases as shown in Fig. 20.4 (c).



(a)



Successive wave fronts



(c)

Fig. 20.4 Ground wave propagation

Electric field at a distance d from antenna due to ground waves is given by

$$E = \frac{120\pi h_t I}{\lambda d}$$

and the signal received by the receiving antenna of height h_r in volts is given by

$$V\ (\text{volts}) = \frac{120\pi h_t h_r I}{\lambda d}$$

where $120\,\pi = 377\ \Omega$ is characteristic impedance; I is antenna current, h_t = effective height of transmitting antenna and λ is wavelength.

VLF Propagation When propagation is over a good conductor like sea water at frequencies below 100 kHz attenuation is small. Ship communication uses frequency 10 Hz – 110 kHz. The VLF antennas are inefficient, high powered and use tallest mast.

Sky wave propagation – the ionosphere Ionosphere is the upper portion of the atmosphere, which continually absorbs large quantities of radiant energy from the sun, thus, becoming heated and ionized. Temperature, density, composition and type of radiation received stratify the ionosphere. The most important ionizing agent are uv, α, β, γ radiations from the sun as well as cosmic rays and meteors. The overall result as shown in Fig. 20.5 is a range of four main layers. D, E, F_1 and F_2 in ascending order. The last two combine at night to form a single layer.

The *D* layer is the lowest existing at an average height of 70 km with an average thickness of 10 km. The degree of its ionization depends upon the altitude of the sun. It disappears at night. It reflects LF and VLF rays and absorbs MF and HF waves to a certain extent.

The *E* layer is a thin layer of very large density. Like *D* layer it also disappears at night. If reflects MF and surface waves and some HF waves in day time.

The F_1 layer exists at a height of 180–200 km and combines with F_2 at night. F_1 layer absorbs HF waves.

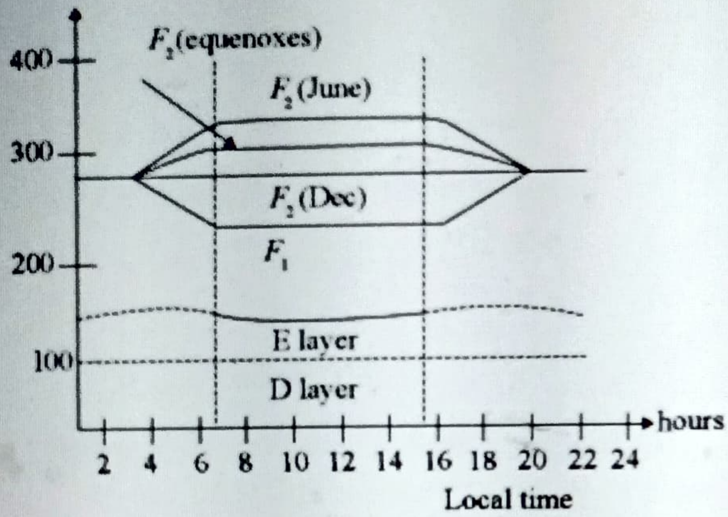


Fig. 20.5 Illustration of ionosphere layers

F_2 layer is most important reflecting layer for HF. Its height is 250-400 km with an average thickness of 200 km and average height 300 km.

Reflection Mechanism As the ionization density increases the refractive index of the layer decreases. The incident ray is gradually bent and suffers total internal reflection as illustrated in Fig. 20.6. Figure 20.7 illustrates skip distance and effect of ionosphere on rays of varying angle of incidence. Large angle rays are bent while short angle of incidence rays escape.

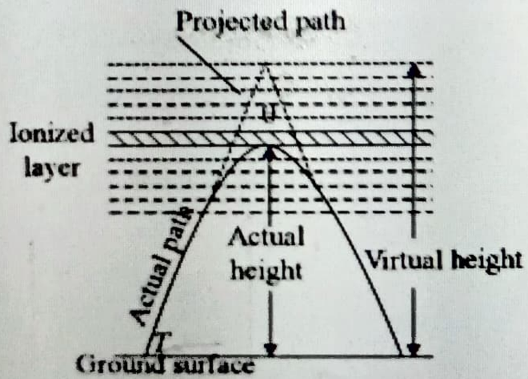


Fig. 20.6 Actual and virtual heights of an ionized layer

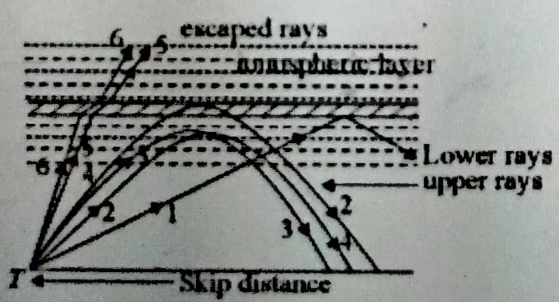


Fig. 20.7 Effect of ionosphere on rays of varying incidence

Skip distance is the shortest distance from a transmitter *T*, measured along the surface of the earth at which a sky wave of fixed frequency ($> f_c$) will be returned to the earth. Note that it is frequency specific and depends upon angle of incidence.

Critical frequency (f_c) For a given layer, it is the highest frequency that will be returned to earth by having been beamed straight up at it $f_c = 9\sqrt{N}$.

Maximum usable frequency (*muf*) Maximum limiting frequency is the frequency of the ray incident at some specific angle of incidence which will return to the earth from ionosphere.

$muf = f_c \sec\theta$ also known as secent law.

Space waves travel in straight lines. They depend upon line of sight. Their propagation is limited by the curvature of the earth. They are not reflected from ionosphere.

Radio horizon for space waves $= \frac{3}{4}$ optical horizon. The emperical formula gives the radio horizon. $d_r(k) = 4\sqrt{h_r}$ Where d_t is distance from transmitting antenna and h_t is height of transmitting antenna. This formula applies to receiving antenna also. Thus, $d = d_t + d_r = 4\sqrt{h_t} + 4\sqrt{h_r}$. For, example, if $h_t = 225$ m then radio horizon $= 4\sqrt{h_t} = 60$ km. Figure 20.8 illustrates radio horizon for space waves. Links longer than 100 km are hardly used in commercial communication that is, repeaters are then required.

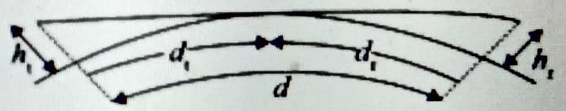


Fig. 20.8 Height of transmitting and receiving antenna

Super refraction or duct The microwaves due to decreasing refractive index just 30 m above the ground bend complete bending takes place as illustrated in Fig. 20.9. Microwaves are, thus, continuously refracted from the duct and reflected from the ground can travel 1000 km.

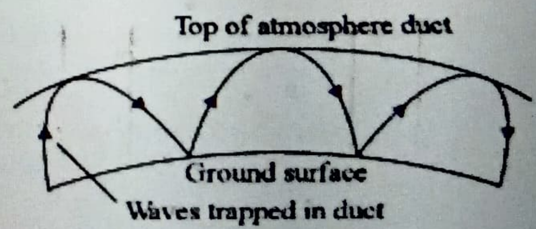


Fig. 20.9 Wave propagation and duct illustration

Tropospheric scattering As shown in Fig. 20.10, two directional antennas are pointed so that their beams intersect midway between them above the horizon. If they are UHF transmitting and receiving antenna then sufficient radio

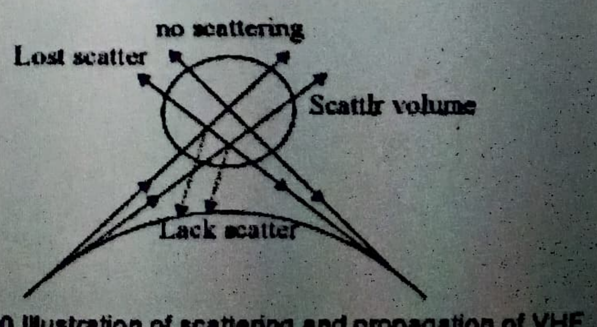


Fig. 20.10 Illustration of scattering and propagation of VHF

energy reaches to receiving antenna. Best results are seen if frequencies are 900 MHz, 2000 MHz and 5000 MHz. This tropospheric scattering occurs within 15 km above the ground.

Satellite and Probe tracking The requirement of tracking and communicating with satellites in close orbits involve the use of fast rotating circularly polarized antennas together with fairly low noise and medium power transmitter and receivers.

Detection Systems The simplest detector uses a peak detector (rectifier + capacitor filter) to detect AM wave. The diode will rectify and give either positive or negative half cycle and capacitor filter gives only peak value. Thereby detecting information from the carrier. The simple circuit and output is shown in Fig. 20.11. However, the information is slightly distorted as we cannot retrieve exact input because capacitor charges or discharges nearly linearly for short intervals. But to a large extent it is replica of input. Normally, we use negative part of the input for detection (in the figure positive part is shown), as it helps in achieving AGC (Automatic gain control).

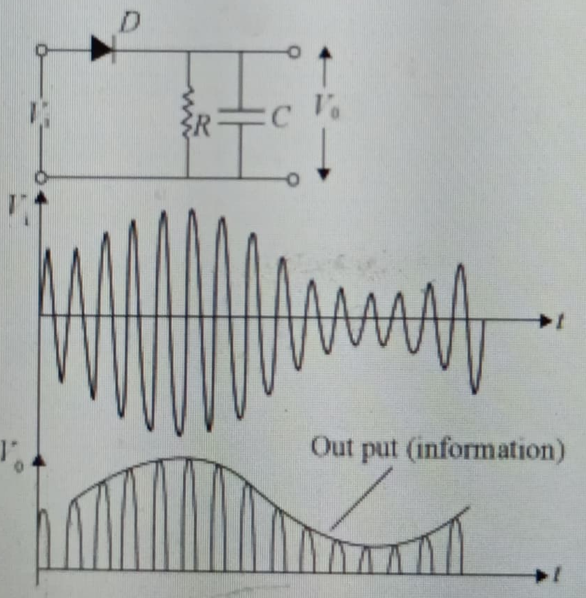


Fig. 20.11 AM detection

FM can be generated using balanced modulator or varactor diode.

FM detection The simplest FM detection is achieved using an LC circuit operated at OFF resonant frequency as shown in Fig. 20.12. See how simple it is to convert

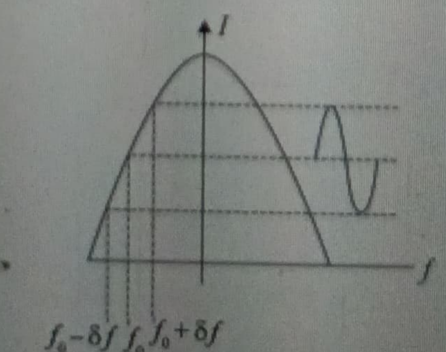


Fig. 20.12 FM detection illustration

frequency variation into voltage variation using LC oscillator. The frequency variation is converted to current variation and hence, voltage variation (if taken across a resistor).

ASK (Amplitude Shift Keying) Binary ASK is also called OOK (ON OFF keying). As is clear from Fig. 20.13.

When '1' is transmitted wave is present and when a '0' is transmitted wave is absent Fig. 20.13 (a). shows transmission of binary 10 110.

FSK (Frequency Shift Keying) During transmission of a '1', frequency increases (say doubles as shown in Fig. 20.13 (b). It remains unchanged during transmission of a '0'. It is another way of frequency modulation.

PSK (Phase Shift Keying) Phase shift of 180° or change of half wavelength is observed during a transition $0 \rightarrow 1$ or $1 \rightarrow 0$ as illustrated in Fig. 20.13 (c).

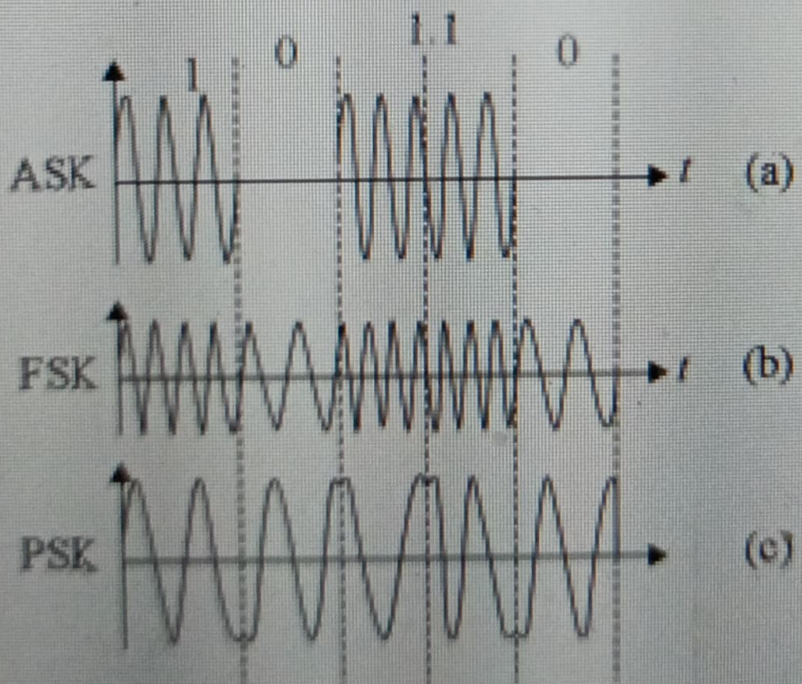


Fig. 20.13 ASK, FSK and PSK illustration

PSK may be used in Telex or Telegraphy. The carrier may be phase shifted by +90° for a mark, and by −90° for a space. In the four phase systems possible phase shifts are +135°, +45°, −45°, −135° so that two bit of information can be indicated instead of one as in the other systems.