Television broadcast, microwave links and satellite communication are some examples of communication systems that use space wave mode of propagation. Figure 15.6 summarises the various modes of wave propagation discussed so far.

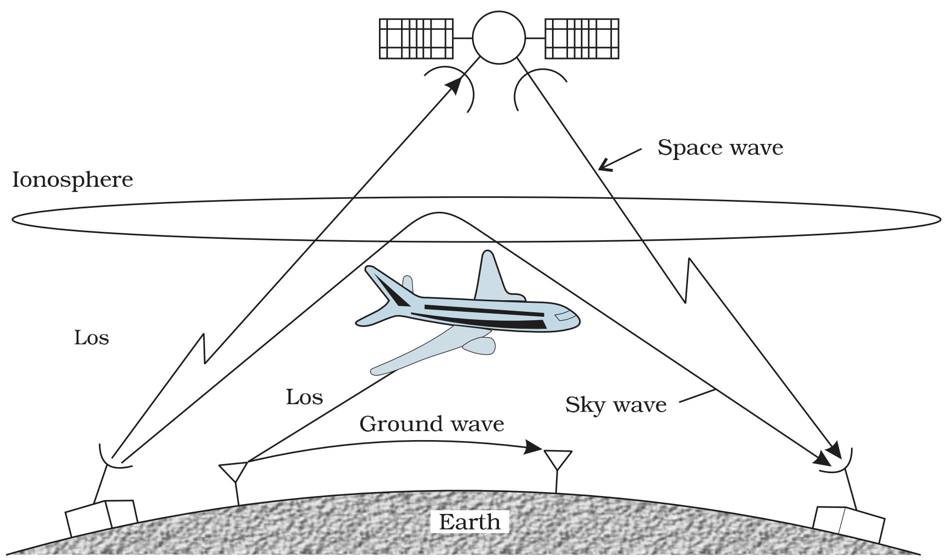

FIGURE 15.6 Various propagation modes for em waves.

EXAMPLE 15.1

Example 15.1 A transmitting antenna at the top of a tower has a height 32 m and the height of the receiving antenna is 50 m. What is the maximum distance between them for satisfactory communication in LOS mode? Given radius of earth 6.4×10^6 m.

Solution

$$d_m = \sqrt{2 \times 64 \times 10^5 \times 32} + \sqrt{2 \times 64 \times 10^5 \times 50} \text{ m}$$

$$= 64 \times 10^2 \times \sqrt{10} + 8 \times 10^3 \times \sqrt{10} \text{ m}$$

$$= 144 \times 10^2 \times \sqrt{10} \text{ m} = 45.5 \text{ km}$$

15.7 Modulation and its Necessity

As already mentioned, the purpose of a communication system is to transmit information or message signals. Message signals are also called *baseband signals*, which essentially designate the band of frequencies representing the original signal, as delivered by the source of information. No signal, in general, is a single frequency sinusoid, but it spreads over a range of frequencies called the signal *bandwidth*. Suppose we wish to transmit an electronic signal in the audio frequency (AF) range (baseband signal frequency less than 20 kHz) over a long distance directly. Let us find what factors prevent us from doing so and how we overcome these factors,

15.7.1 Size of the antenna or aerial

For transmitting a signal, we need an antenna or an aerial. This antenna should have a size comparable to the wavelength of the signal (at least $\lambda/4$ in dimension) so that the antenna properly senses the time variation of the signal. For an electromagnetic wave of frequency 20 kHz, the wavelength λ is 15 km. Obviously, such a long antenna is not possible to construct and operate. Hence direct transmission of such baseband signals is not practical. We can obtain transmission with reasonable antenna lengths if transmission frequency is high (for example, if ν is 1 MHz, then λ is 300 m). Therefore, there is a need of *translating the information contained in our original low frequency baseband signal into high or radio frequencies before transmission.*

15.7.2 Effective power radiated by an antenna

A theoretical study of radiation from a linear antenna (length l) shows that the power radiated is proportional to $(l/\lambda)^2$. This implies that for the same antenna length, the power radiated increases with decreasing λ, i.e., increasing frequency. Hence, the effective power radiated by a long wavelength baseband signal would be small. For a good transmission, we need high powers and hence this also points out to *the need* of using high frequency transmission.

15.7.3 Mixing up of signals from different transmitters

Another important argument against transmitting baseband signals directly is more *practical* in nature. Suppose many people are talking at the same time or many transmitters are transmitting baseband information signals simultaneously. All these signals will get mixed up and there is no simple way to distinguish between them. This points out towards a possible solution by using communication at high frequencies and allotting a *band* of frequencies to each message signal for its transmission.

The above arguments suggest that there is a *need for translating the original low frequency baseband message or information signal into high frequency wave before transmission such that the translated signal continues to possess the information contained in the original signal.* In doing so, we take the help of a high frequency signal, known as the *carrier wave*, and a process known as modulation which attaches information to it. The carrier wave may be continuous (sinusoidal) or in the form of pulses as shown in Fig. 15.7.

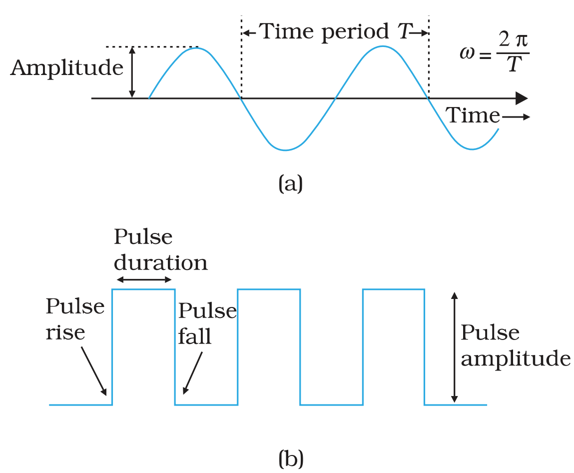

FIGURE 15.7 (a) Sinusoidal, and (b) pulse shaped signals.

A sinusoidal carrier wave can be represented as

$$c(t) = A_c \sin(\omega_c t + \phi) \qquad (15.2)$$

where $c(t)$ is the signal strength (voltage or current), A_c is the amplitude, ω_c ($= 2\pi\nu_c$) is the angular frequency and ϕ is the initial phase of the carrier wave. During the process of modulation, any of the three parameters, *viz* A_c, ω_c and ϕ, of the carrier wave can be controlled by the message or information signal. This results in three types of modulation: (i) Amplitude modulation (AM), (ii) Frequency modulation (FM) and (iii) Phase modulation (PM), as shown in Fig. 15.8.

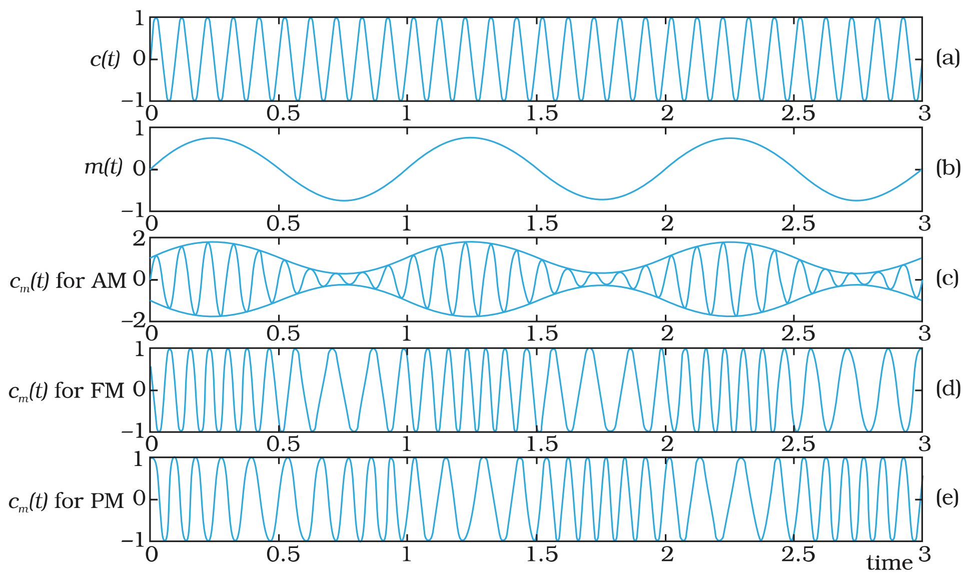

FIGURE 15.8 Modulation of a carrier wave: (a) a sinusoidal carrier wave; (b) a modulating signal; (c) amplitude modulation; (d) frequency modulation; and (e) phase modulation.

Modulation and Demodulation
http://www.williamson labs.com/480_mod.htm

Similarly, the significant characteristics of a pulse are: pulse amplitude, pulse duration or pulse Width, and pulse position (denoting the time of *rise* or *fall* of the pulse amplitude) as shown in Fig. 15.7(b). Hence, different types of pulse modulation are: (a) pulse amplitude modulation (PAM), (b) pulse duration modulation (PDM) or pulse width modulation (PWM), and (c) pulse position modulation (PPM). In this chapter, we shall confine to amplitude modulation on ly.

15.8 Amplitude Modulation

In amplitude modulation the amplitude of the carrier is varied in accordance with the information signal. Here we explain amplitude modulation process using a sinusoidal signal as the modulating signal.

Let $c(t) = A_c \sin \omega_c t$ represent carrier wave and $m(t) = A_m \sin \omega_m t$ represent the message or the modulating signal where $\omega_m = 2\pi f_m$ is the angular frequency of the message signal. The modulated signal $c_m(t)$ can be written as

$$c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$$

$$= A_c \left(1 + \frac{A_m}{A_c} \sin \omega_m t\right) \sin \omega_c t \qquad (15.3)$$

Note that the modulated signal now contains the message signal. This can also be seen from Fig. 15.8(c). From Eq. (15.3), we can write,

$$c_m(t) = A_c \sin \omega_c t + \mu A_c \sin \omega_m t \sin \omega_c t \qquad (15.4)$$

Here $\mu = A_m/A_c$ is the *modulation index;* in practice, μ is kept ≤ 1 to avoid distortion.

Using the trignomatric relation $\sin A \sin B = ½ (\cos(A-B) - \cos(A+B)$, we can write $c_m(t)$ of Eq. (15.4) as

$$c_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2}\cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2}\cos(\omega_c + \omega_m)t \qquad (15.5)$$

Here $\omega_c - \omega_m$ and $\omega_c + \omega_m$ are respectively called the lower side and upper side frequencies. The modulated signal now consists of the carrier wave of frequency ω_c plus two sinusoidal waves each with a frequency slightly different from, known as side bands. The frequency spectrum of the amplitude modulated signal is shown in Fig. 15.9.

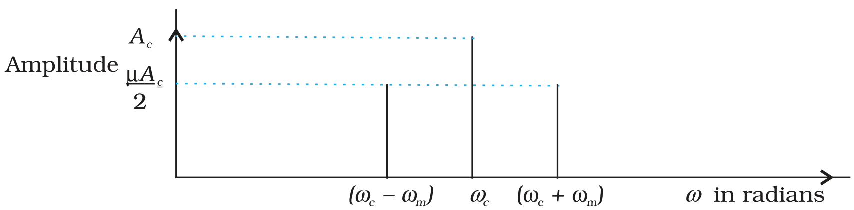

FIGURE 15.9 A plot of amplitude versus ω for an amplitude modulated signal.

As long as the broadcast frequencies (carrier waves) are sufficiently spaced out so that sidebands do not overlap, different stations can operate without interfering with each other.

Example 15.2 A message signal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 volts. Determine (a) modulation index, (b) the side bands produced.

Solution

(a) Modulation index =10/20 = 0.5

(b) The side bands are at (1000+10 kHz)=1010 kHz and (1000 –10 kHz) = 990 kHz.

EXAMPLE 15.2

15.9 PRODUCTION OF AMPLITUDE MODULATED WAVE

Amplitude modulation can be produced by a variety of methods. A conceptually simple method is shown in the block diagram of Fig. 15.10.

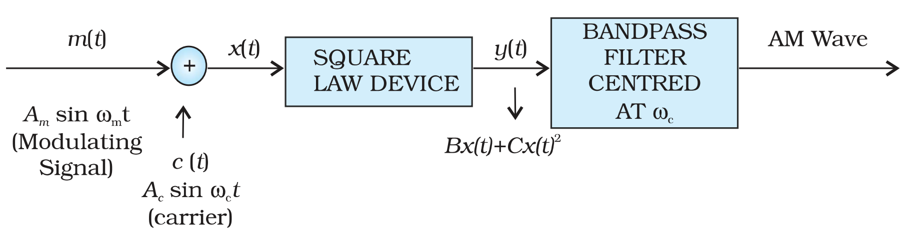

FIGURE 15.10 Block diagram of a simple modulator for obtaining an AM signal.

Here the modulating signal $A_m \sin \omega_m t$ is added to the carrier signal $A_c \sin \omega_c t$ to produce the signal $x(t)$. This signal $x(t) = A_m \sin\omega_m t + A_c \sin\omega_c t$ is passed through a square law device which is a non-linear device which produces an output

$$y(t) = B\,x(t) + Cx^2(t) \tag{15.6}$$

where B and C are constants. Thus,

$$y(t) = BA_m \sin \omega_m t + BA_c \sin \omega_c t$$

$$+C\left[A_m^2 \sin^2 \omega_m t + A_c^2 \sin^2 \omega_c t + 2A_m A_c \sin \omega_m t \sin \omega_c t\right] \tag{15.7}$$

$$= BA_m \sin \omega_m t + BA_c \sin \omega_c t$$

$$+\frac{C\,A_m^2}{2} + A_c^2 - \frac{C\,A_m^2}{2}\cos 2\omega_m t - \frac{C\,A_c^2}{2}\cos 2\omega_c t$$

$$+ CA_m A_c \cos(\omega_c - \omega_m)\,t - CA_m A_c \cos(\omega_c + \omega_m)\,t \tag{15.8}$$

where the trigonometric relations $\sin^2 A = (1 - \cos 2A)/2$ and the relation for $\sin A \sin B$ mentioned earlier are used.

In Eq. (15.8), there is a dc term $C/2\left(A_m^2 + A_c^2\right)$ and sinusoids of frequencies ω_m, $2\omega_m$, ω_c, $2\omega_c$, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. As shown in Fig. 15.10 this signal is passed through a band pass filter* which rejects dc and the sinusoids of frequencies ω_m, $2\omega_m$ and $2\,\omega_c$ and retains the frequencies ω_c, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. The output of the band pass filter therefore is of the same form as Eq. (15.5) and is therefore an AM wave.

It is to be mentioned that the modulated signal cannot be transmitted as such. The modulator is to be followed by a power amplifier which provides the necessary power and then the modulated signal is fed to an antenna of appropriate size for radiation as shown in Fig. 15.11.

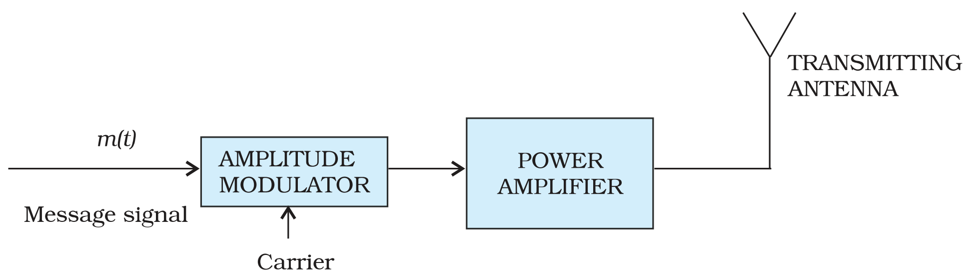

FIGURE 15.11 Block diagram of a transmitter.

15.10 Detection of Amplitude Modulated Wave

The transmitted message gets attenuated in propagating through the channel. The receiving antenna is therefore to be followed by an amplifier and a detector. In addition, to facilitate further processing, the carrier frequency is usually changed to a lower frequency by what is called an *intermediate frequency (IF) stage* preceding the detection. The detected signal may not be strong enough to be made use of and hence is required

* A band pass filter rejects low and high frequencies and allows a band of frequencies to pass through.

to be amplified. A block diagram of a typical receiver is shown in Fig. 15.12

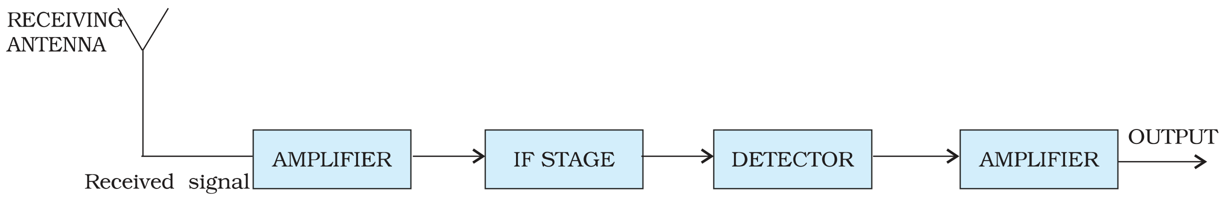

FIGURE 15.12 Block diagram of a receiver.

Detection is the process of recovering the modulating signal from the modulated carrier wave. We just saw that the modulated carrier wave contains the frequencies ω_c and $\omega_c \pm \omega_m$. In order to obtain the original message signal $m(t)$ of angular frequency ω_m, a simple method is shown in the form of a block diagram in Fig. 15.13.

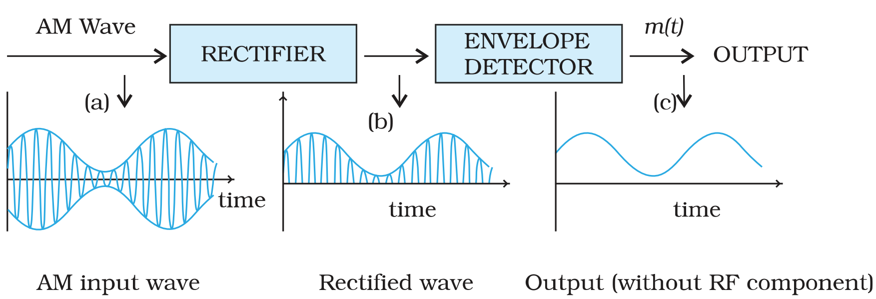

FIGURE 15.13 Block diagram of a detector for AM signal. The quantity on y-axis can be current or voltage.

The modulated signal of the form given in (a) of fig. 15.13 is passed through a rectifier to produce the output shown in (b). This envelope of signal (b) is the message signal. In order to retrieve $m(t)$, the signal is passed through an envelope detector (which may consist of a simple RC circuit).

In the present chapter we have discussed some basic concepts of communication and communication systems. We have also discussed one specific type of analog modulation namely Amplitude Modulation (AM). Other forms of modulation and digital communication systems play an important role in modern communication. These and other exciting developments are taking place everyday.

So far we have restricted our discussion to some basic communication systems. Before we conclude this chapter, it is worth taking a glance at some of the communication systems (see the box) that in recent times have brought major changes in the way we exchange information even in our day-to-day life: