$3140 = 3.14\times 2\times h_T\times 6400$
h_T = 0.078125 km = 78.125 m

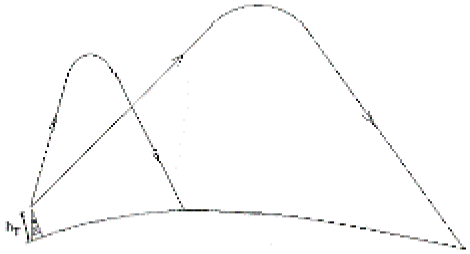
Q) A transmitting antenna at the top of a tower has a height of 50m and the height of the receiving antenna is 32m. What is the maximum distance between them for satisfactory communication is LOS mode? Give radius of earth R = 6400km

Solution:
h_R = 32m, h_T = 50 m,
From formula

$$d_m = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$
$$d_m = \sqrt{2\times 6400\times 10^3\times 50} + \sqrt{2\times 6400\times 10^3\times 32}$$
$$d_m = 25.29\times 10^3 + 20.23\times 10^3 = 45.5\ km$$

Sky wave propagation

The propagation of radio waves (frequency 2MHz to 30 MHz) is due to sky waves. The electromagnetic waves emitted by the transmitter, return to the earth after getting reflected by the ionosphere at a height of about 80 -300km. A receiver at large distance can receive these reflected waves. The ionosphere behaves like a mirror for these radio waves.



Ionosphere of earth atmosphere contains electrons anions produced due to radiation from sun. There are different layers at various heights, depending on the density of gas, intensity of radiation and selective ionization of gases by various radiation. Electron density of all layers are different. So the radio waves with different frequencies get reflected from the ionosphere of diffident height. Due to total internal reflection phenomenon waves can be received at far distance from the transmitter on the earth Frequency from 2MHz to 30MHz are used above 30MHz frequency wave penetrate the ionosphere and cannot be reflected by ionosphere.

Modulation and its necessity

Most of the signals of information have low frequency and they are not able to travel long distance in free space. Because of flowing factors

(1)Length of antenna: A transmitter converts audio frequency electrical signal into electromagnetic radiation through an antenna and radiates in the space

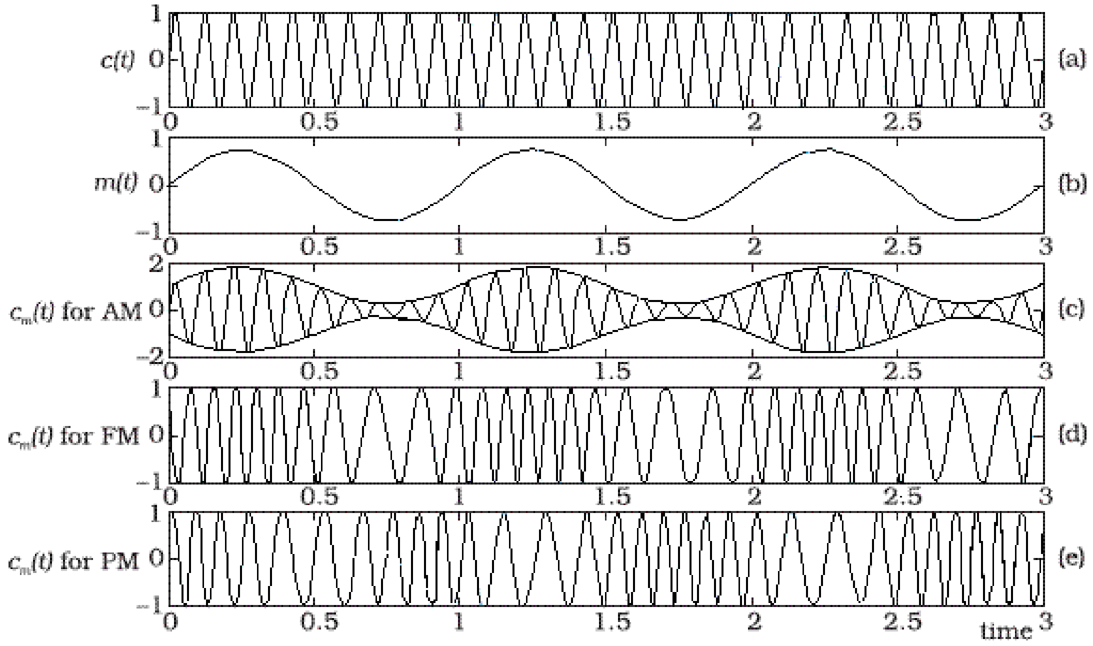
For effective transmission of electromagnetic radiation of audio signal, the minimum length of antenna must be $\lambda/4$. Where λ is the wavelength of the audio signal
If transmitted wavelength is 300 km whose frequency is about 1kHz then minimum length of antenna would be
300/4 = 75 km, which impractical as well as very costly
This shows that for effective transmission of high frequency signals, required antenna length is small and hence an antenna can be easily constructed.

(2)Power radiated from antenna: Transmitted power by an antenna of a given length is inversely proportional to the square of the wavelength λ i.e. $P \propto 1/\lambda^2$.
This indicates that an antenna can transmit short wavelength or high frequency radiation with more efficiency.

(3) Mixing up of signals from different transmitters: If there is more than one transmitter in a region and if these transmit the information using audio signals, then all such signals get mixed. It is not possible to separate information of one transmitter from the information of other transmitter. Such situation can be avoided if every transmitter is assigned different high frequencies for information.

Modulation

The process of superposing low frequency audio signals on waves with high frequency is called modulation.
Here, low frequency signal is called the modulating and the high frequency wave, since it carries the information is called a carrier wave.
A sinusoidal carrier wave can be represented as $c(t) = A_c \sin(\omega_c t + \phi)$
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 figure



Amplitude modulation

A modulation in which the amplitude of carrier wave C(t) is varied in accordance with the instantaneous value of the modulating wave is called amplitude modulation (AM). The frequency and initial phase remains constant

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.

Amplitude of carrier wave changes according to modulating signal but frequency and phase of the carrier wave remains constant thus

The modulated signal $c_m(t)$ can be written as

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

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

$C_m(t) = A_c(1 + \mu sin\omega_m t) sin\omega_c t \; ------ eq(1)$

Above equation is a mathematical form of AM wave

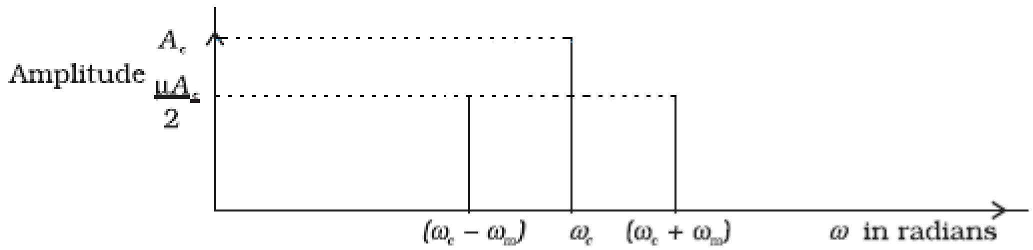
Here $\mu = A_m/A_c$ is the *modulation index*; in practice, μ is kept ≤ 1 to avoid distortion.

$$C_m(t) = A_c sin\omega_c t + A_c \mu sin\omega_m t sin\omega_c t$$

Using the trigonometric relation $\sin A \sin B = ½ (\cos(A - B) - \cos(A + B)$, above equation can be wrote as

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

Here $\omega_c - \omega_m$ and $\omega_c + \omega_m$ are respectively called the lower side frequency band (LSB) and upper side frequency band (USB). 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



.

Amplitude of USB and LSB is $\mu A_c/2$

From eq(1) When sinωt = 1 Amplitude modulated wave have maximum amplitude

$A_{max} = A_C + A_m$

When sinωt = -1. Amplitude modulated wave have minimum amplitude

$A_{min} = A_c - A_m$

From above equations

$$A_c = \frac{A_{max} + A_{min}}{2} \text{ and } A_m = \frac{A_{max} - A_{min}}{2}$$

According to definition of modulation index

$$\mu = \frac{A_m}{A_C} = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

$$\mu(\%) = \frac{A_{max} - A_{min}}{A_{max} + A_{min}} \times 100$$

Solved numerical

Q) A 10 MHz sinusoidal carrier wave of amplitude 10 mV is modulated by a 5 kHz sinusoidal audio signal wave of amplitude 6 mV. Find the frequency components of the resultant modulated wave and their amplitude.

Data: Frequency of the carrier = fc = 10 MHz

Frequency of the signal = fs= 5 kHz = 0.005 MHz

Amplitude of the carrier signal = Ec = 10 mV

Amplitude of the audio signal = Es = 6 mV

Frequency components of modulated wave = ?

Amplitude of the components in the modulated wave = ?

Solution :

The modulated carrier wave contains the following frequencies :

(i) Original carrier wave of frequency = fc = 10 MHz

(ii) Upper side band frequency, $fc + fs$ = 10 + 0.005 = 10.005 MHz

(iii) Lower side band frequency $fc – fs$ = 10 − 0.005 = 9.995 MHz

The modulation factor is,

$$\mu = \frac{A_m}{A_C} = \frac{6}{10} = 0.6$$

∴Amplitude of USB = Amplitude of LSB

$$\frac{\mu A_c}{2} = \frac{0.6 \times 10}{2} = 3mV$$

Q) The equation of AM wave is C = 100(1 +0.6sin6280t) sin2π×10^6 t. Calculate (i)Modulation Index (ii) Frequency of carrier wave (iii) frequency of modulating wave (iv) frequency of LSB and USB

Solution:

Comparing given equation with standard equation

$$C_m(t) = A_c(1 + \mu sin\omega_m t) sin\omega_c t$$

We get (i) modulation index μ = 0.6

(ii) Frequency of carrier wave $\omega_C = 2\pi\times10^6$

∴ $2\pi f_c = 2\pi\times10^6$

∴$f_c = 10^6$ Hz= 1MHz

(iii) Frequency of modulating wave

$\omega_m = 6280$

∴ $2\pi f_m = 6280$

∴$2\times3.14\times f_m = 6280$

∴f_m = 1000 Hz=1kHz

(iv) frequency of LSB

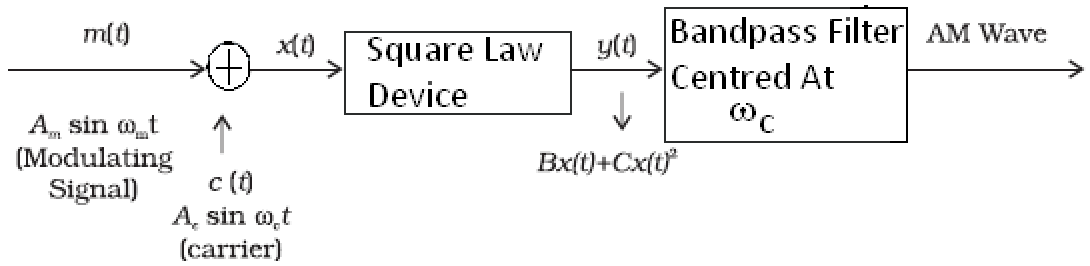
$f = f_c - f_m$ = 1MHz - 1kHz = 0.999 MHz

frequency USB

$f = f_c + f_m$ = 1MHz + 1kHz = 1.001 MHz

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.



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

$y(t) = B\,x(t) + Cx^2(t)$

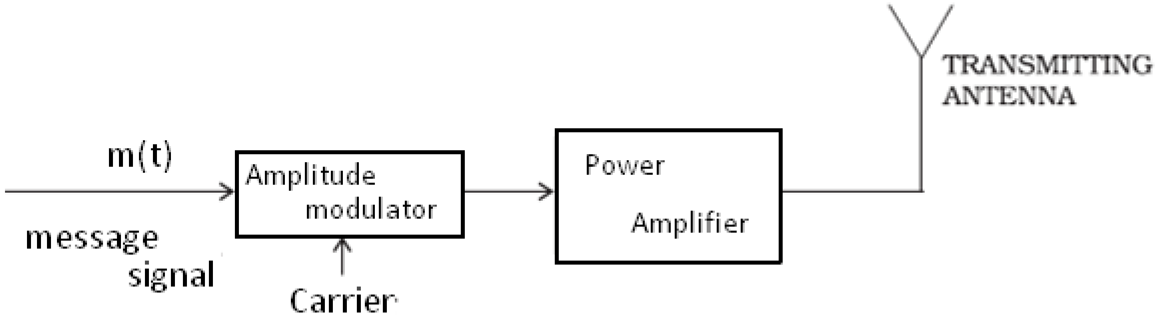
where *B* and *C* are constants. Thus,

$y(t) = BA_m \sin \omega_m t + BA_c \sin \omega_c t + C[A^2{}_m \sin^2{}_m \omega_m t + A^2{}_c \sin^2{}_c \omega_c t + 2A_m A_c \sin\omega_c t \sin\omega_c t]$

From trigonometry formula $\sin^2 A = (1-\cos2A)/2$ we get

$$y\,(t) = \mathrm{BAm}\sin\omega\mathrm{mt} + \mathrm{BAc}\sin\omega\mathrm{ct} + \frac{\mathrm{CA}_\mathrm{m}^2}{2} + \mathrm{A}_\mathrm{c}^2 - \frac{\mathrm{CA}_\mathrm{m}^2}{2}\cos 2\omega_\mathrm{m}\mathrm{t} - \frac{\mathrm{CA}_\mathrm{c}^2}{2}\cos 2\omega_\mathrm{c}\mathrm{t} + \mathrm{CA}_\mathrm{m}\mathrm{A}_\mathrm{C}\cos(\omega_\mathrm{c} - \omega_\mathrm{m})\mathrm{t} - \mathrm{CA}_\mathrm{m}\mathrm{A}_\mathrm{C}\cos(\omega_\mathrm{c} + \omega_\mathrm{m})\mathrm{t}$$

In above equation dc term is C/2(A^2_m + A^2_c) and sinusoids of frequencies $\omega_{m,}$2 ω_m, ω_c , 2ω_C, ω_c - ω_m,and $\omega_c + \omega_m$ this signal passes through a band filters which rejects dc and the frequencies of $\omega_{m,}$2 ω_m, 2ω_C and retains frequencies ω_c , ω_c - ω_m,and $\omega_c + \omega_m$. the out put therefore is amplitude modulated waves

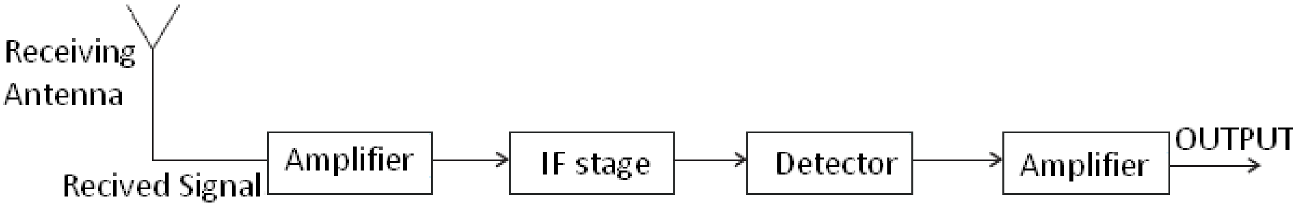


Modulated signals cannot be transmitted as such. The modulator is followed by a power amplifier which provides the necessary power and then modulated signals is forwarded to an antenna of appropriate size for radiation as shown in figure

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.

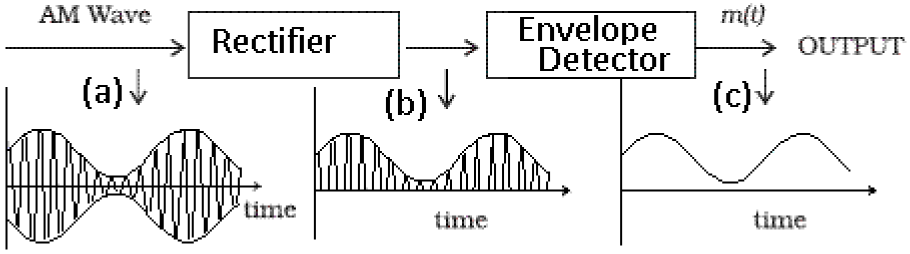
In addition, to facilitate further processing, the carrier frequency is usually changed to a lower frequency by what is called an *intermediate frequency (IF) stage* preceding the detection.



The detected signal may not be strong enough to be made use of and hence is required to be amplified. A block diagram of a typical receiver is shown in Detection is the process of recovering the modulating signal from the modulated carrier wave.

We know 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.



AM input wave Rectified wave Output (without RF component)

The modulated signal of the form given in (a) of fig. 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).