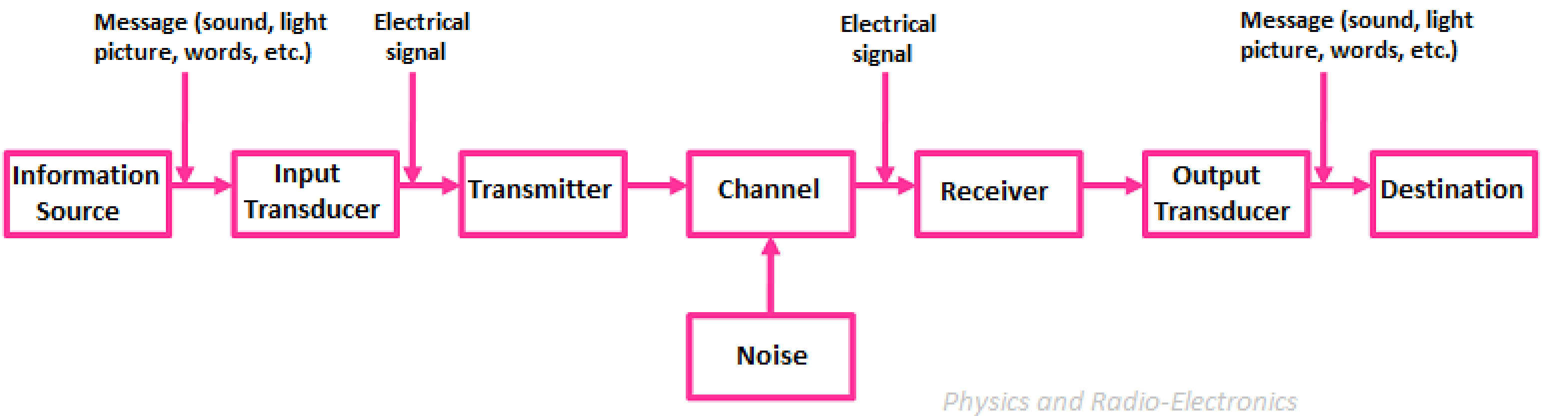
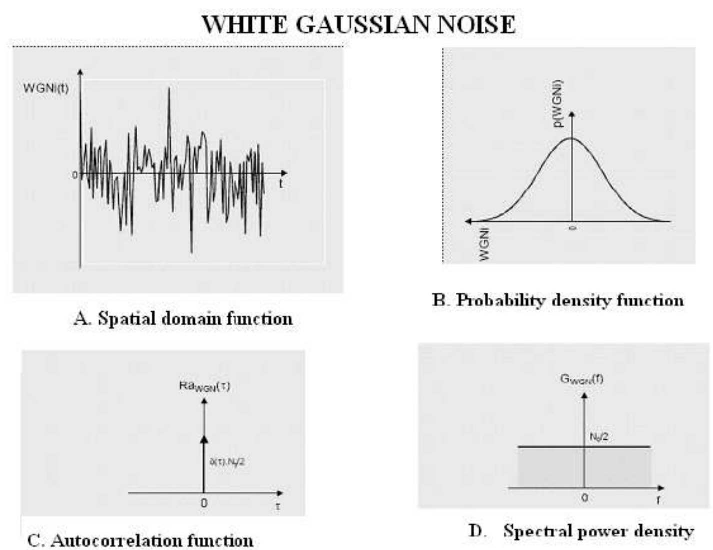
Module 1.1

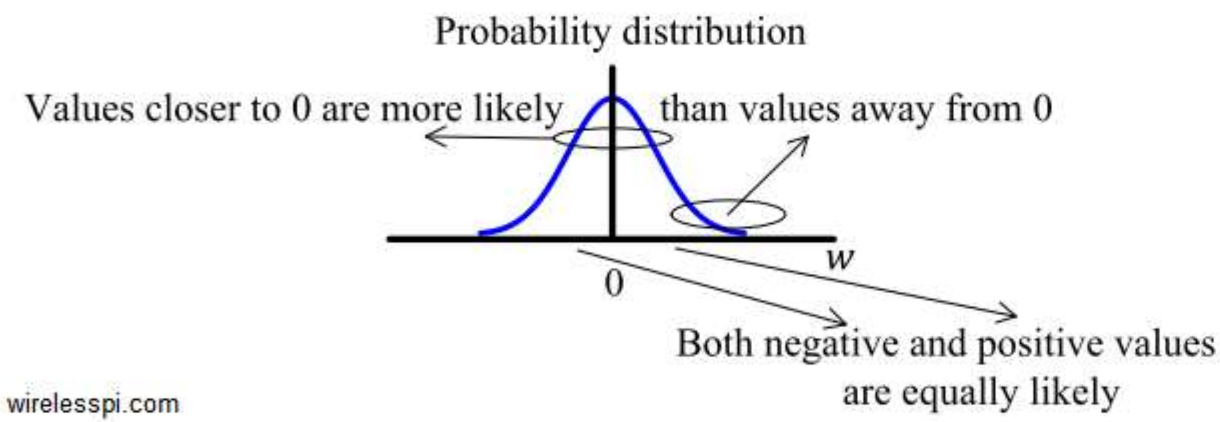
Basic Communication



Noise: White noise has zero mean, constant variance, and is uncorrelated in time. As its name suggests, white noise has a power spectrum which is uniformly spread across all allowable frequenciesGaussian white noise (GWN) is a stationary and ergodic random process with zero mean.



Properties of White Noise



$$\text{PDF} = f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

$$\text{CDF} = F(x) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{t} e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx$$

where,

σ = Standard deviation of random variable

σ^2 = Variance of random variable

x = Random variable (current, voltage, power, phase angle)

μ = Mean value of random variable

$f(x)$ = Probability density function (PDF).

Need of Modulation

Baseband Transmission

The electrical equivalent of original information is known as the baseband signal.

The communication system in which the baseband signals are transmitted directly is known as **baseband transmission**.

Baseband transmission is effective only for wire communication.

Example, Telephone network, data communication in computer networks through coaxial cable.

But it is inefficient for wireless or radio communication.

Need of Modulation

Limitations of Baseband Transmission

1)Baseband signal having small frequency range from 20 Hz to 20 KHz only
(so no large channel accommodation, mixing of signals).

2)Due to small frequency range, baseband signal cannot travel long distance in free space or air.

3)After a travel of short distance signal gets suppressed. So not used for radio communication. i.e. wireless communication.

To make the baseband signal efficient for radio communication modulation technique is used.

Need of Modulation

Need of Modulation

Need of Modulation

Modulation Technique

To overcome the drawbacks of baseband transmission and to transmit baseband signals by radio, modulation techniques must be used.

Baseband signal (Information signal) is a low-frequency signal and cannot travel longer distance. Just like we cannot walk at longer distance.

Definition:

Modulation is the process of superimposing low-frequency information signal on a high-frequency carrier signal

Need of Modulation

Need of Modulation

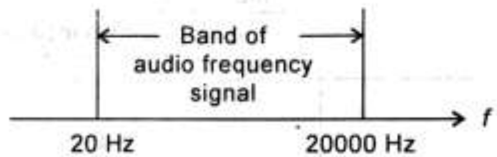
Baseband signal transmission cannot be used for radio communication. To transmit the baseband signal for radio communication, modulation must be used.

Modulation is necessary because of following advantages:

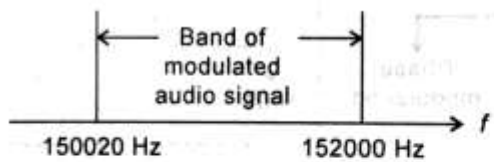
1. Reduction in height of antenna.
2. Avoids mixing of signals.
3. Increase the range of communication.
4. Multiplexing is possible.
5. Improves quality of reception

Need of Modulation

Lets take the normal audio signal which consists of frequencies from 20 Hz to 20 kHz. Thus, the lowest frequency is 20 Hz and highest frequency is 20 kHz. The frequency band of the audio signal is



Now, if this audio signal modulates a carrier of 1.5 MHz then the band of the modulated audio signal is as follows.



This is how baseband signal of a low frequency spectrum is translated to a high frequency spectrum.

Let us discuss the problem's which may be encountered if modulation is not used in a system and how modulation solves those problems.

Need of Modulation

According to a study on antennas, for proper transmission and reception of radio waves, the height of antenna should be the order of one fourth or half the wavelength of the frequency of the transmitted signal.

i.e. $h = \frac{\lambda}{4}$ or $h = \frac{\lambda}{2}$

where h : Height of antenna

λ : Wavelength of the transmitted signal

Also $\lambda = \frac{c}{f}$

$\therefore \boxed{h = \frac{c}{4f}}$ $\left(\text{by considering } h = \frac{\lambda}{4} \text{ (for e.g.)}\right)$

Without Modulation :

Lowest frequency = 20 Hz

Highest frequency = 20000 Hz

$\therefore$ Height $h_L = \frac{3 \times 10^8}{4 \times 20} = 3750$ km $(\because c = 3 \times 10^8$ m/s$)$

and $h_H = \frac{3 \times 10^8}{4 \times 20 \times 10^3} = 3.75$ km

h_L : Height corresponding to lowest frequency

h_H : Height corresponding to highest frequency

Thus without modulation the antenna height should lie between 3.75 km to 3750 km which is practically not feasible.

With Modulation :

Lowest frequency = 1500020 Hz

Highest frequency = 1520000 Hz

$\therefore h_L = 49.999333$ m

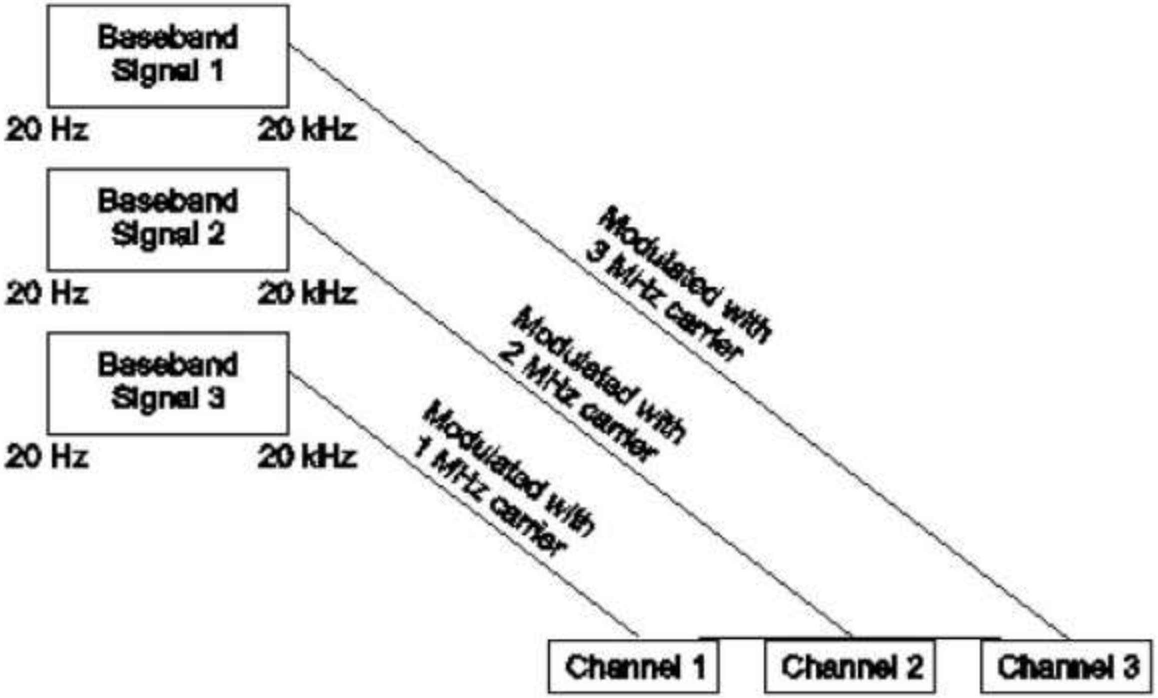
and $h_H = 49.342$ m

thus $h_L \approx h_H \approx 50$ m

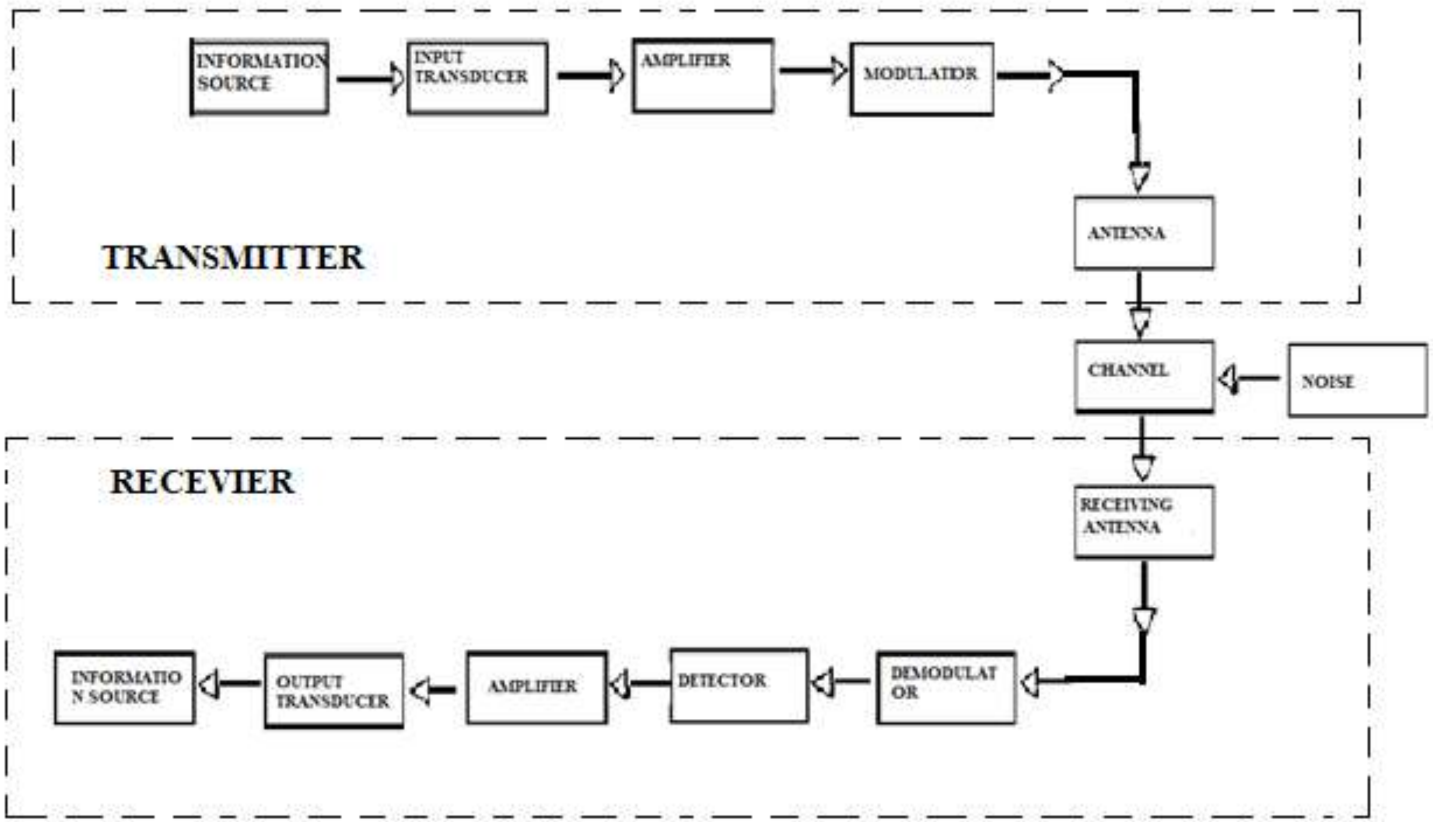
Thus we need an antenna of height 50 m which is practically available.

Need of Modulation

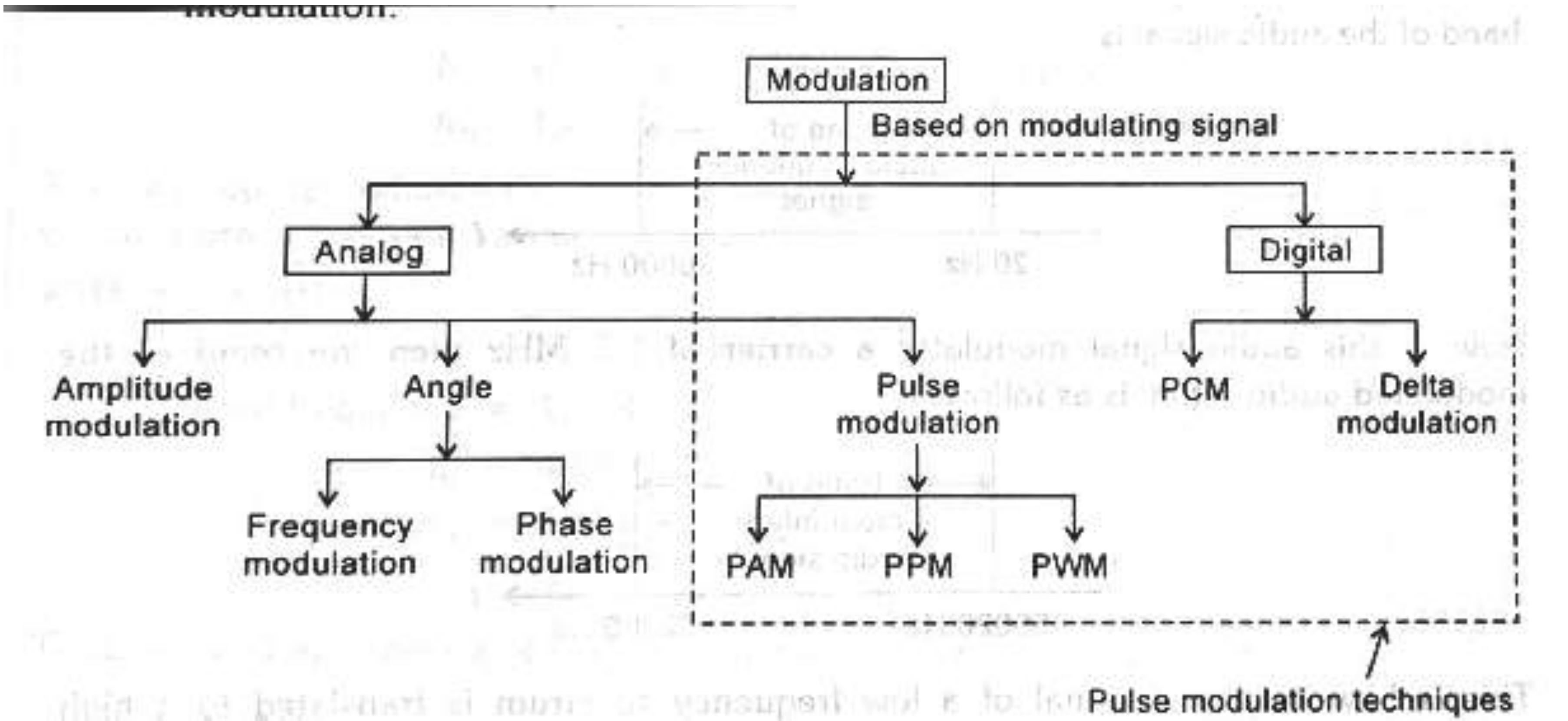
Avoids Mixing of Signal



Detailed Block diagram



Type of Modulation



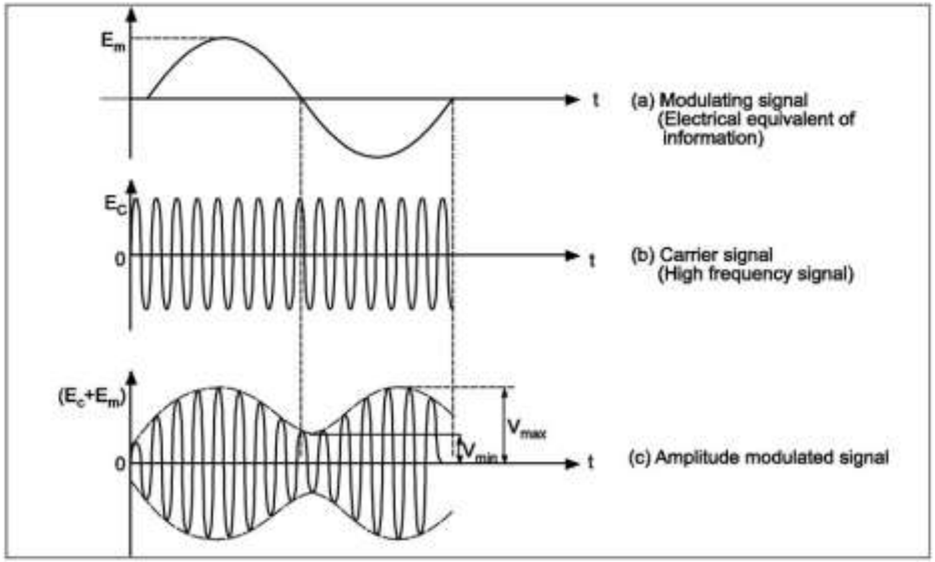
Amplitude Modulation

Definition:

Amplitude modulation, is a technique of modulation in which the instantaneous amplitude of carrier signal varies in accordance with amplitude of modulating signal.

While **frequency** and **phase** of carrier **remains constant**. Nature of Amplitude Modulated waveform shown in Fig. below.

Continued....



Modulation Index

Definition:

In AM, the modulation index (m) is defined as the ratio of amplitudes of modulating signal to the carrier signal.

$$M.I. = \frac{\text{Modulating Signal Amplitude}}{\text{Carrier Signal Amplitude}}$$

$$\boxed{m = \frac{E_m}{E_c}} \qquad \ldots (2.4)$$

If modulation index is expressed in percentage, it is called **'percentage modulation'.**

i.e.

$$\boxed{\%m = \frac{E_m}{E_c} \times 100} \qquad \ldots (2.5)$$

Referring to Fig. 2.6, the modulation index is

$$\boxed{m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}}$$

Effect of Modulation Index on Modulated Signal

1. For m < 1,

i.e. $E_m < E_c$

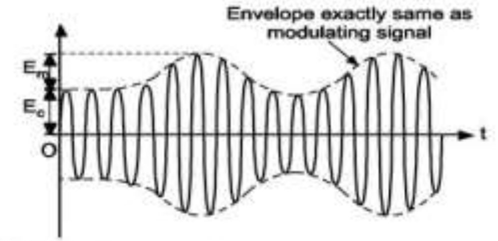


Fig. 2.9 (b) AM Wave for m < 1 (Under Modulation)

2. For m = 1

i.e. $E_m = E_c$, i.e. m = 100%.

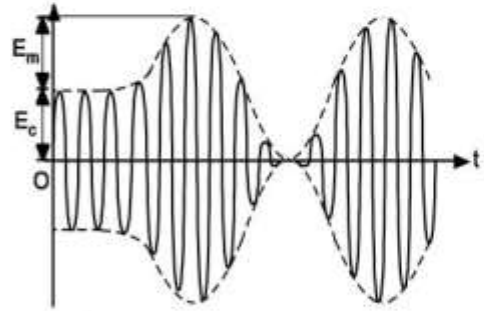


Fig. 2.9 (c) AM Wave for m = 1 (Fully Modulated)

Continued….

3. For m > 1

i.e. $E_m > E_c$

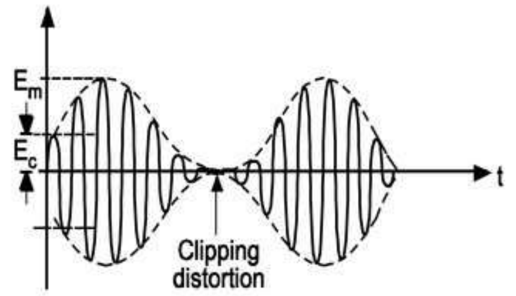


Fig. 2.9 (d) AM Wave at m > 1 (Over Modulation)

For m = 0

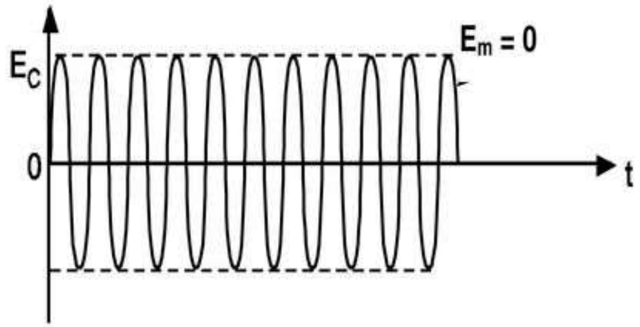
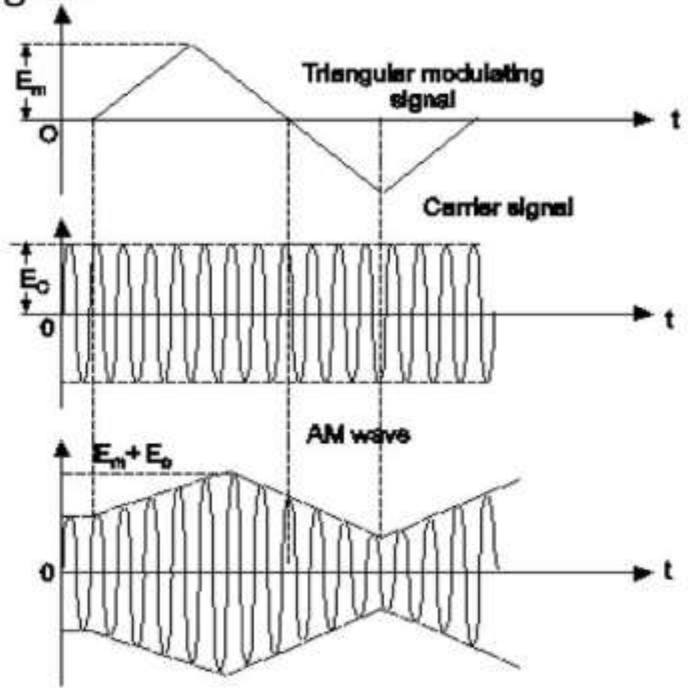


Fig. 2.9 (e) AM Wave at m = 0 (No Modulation Takes Place)

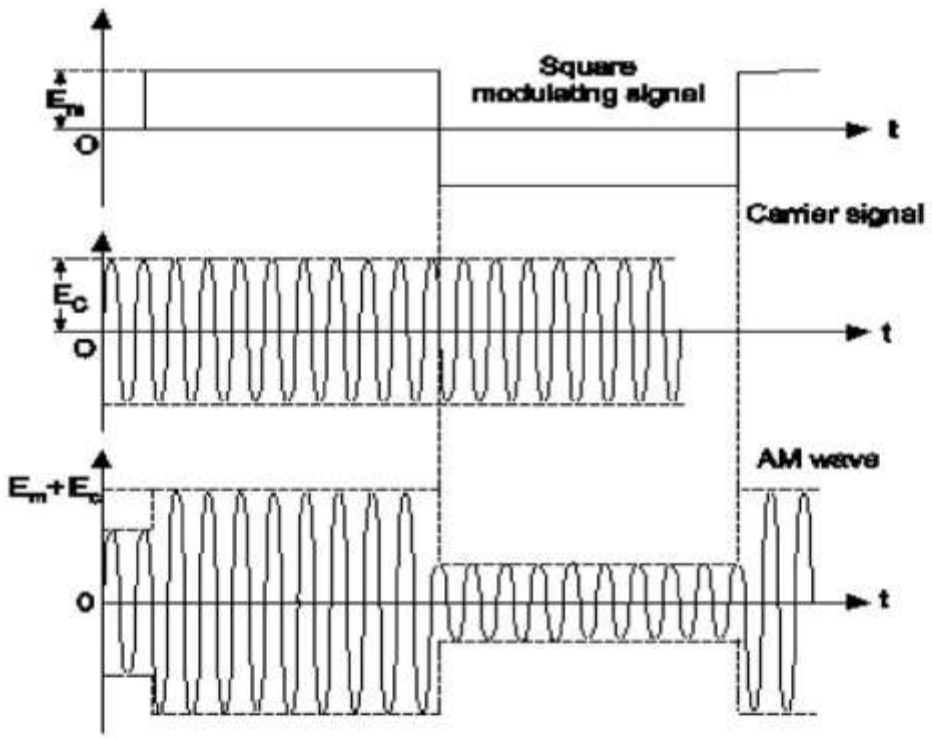
Example

Draw the AM wave for triangular and square wave modulating signal.

Solution:

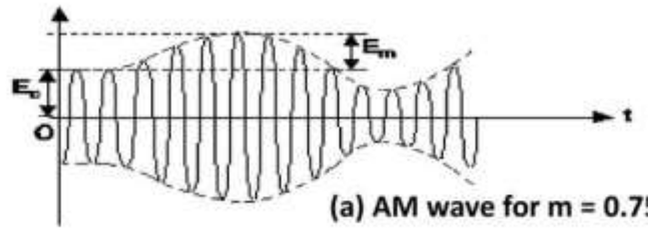


For square wave input.



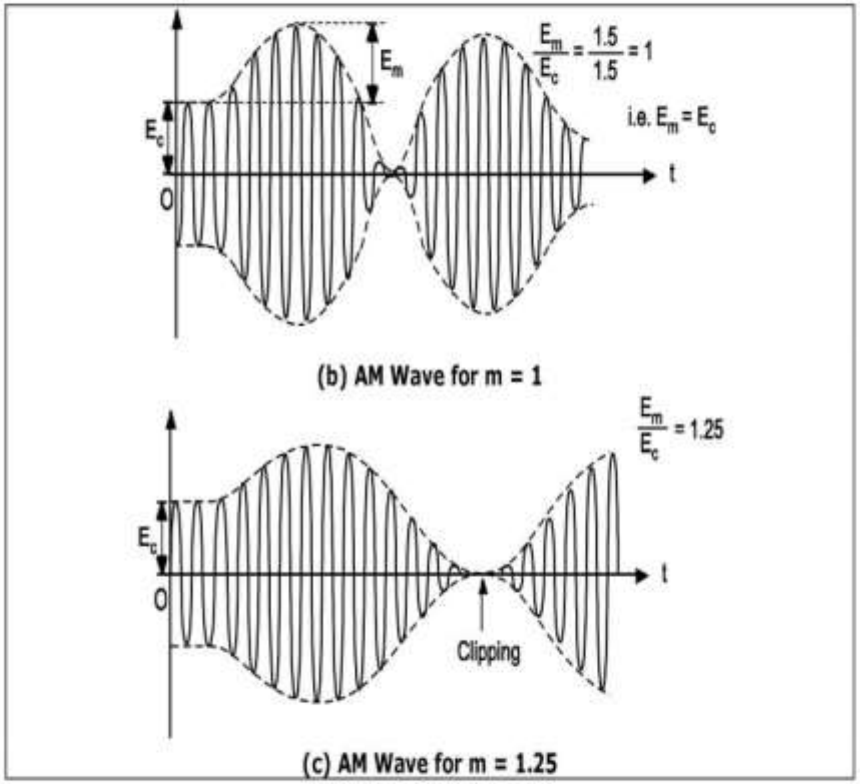
Example 2 Draw the AM waveform for the modulation index m = 0.75, m = 1 and m = 1.25.

Take a graph paper and adjust the value of E_m and E_C in such a way that $\frac{E_m}{E_c} = 0.75$, $\frac{E_m}{E_c} = 1$, $\frac{E_m}{E_c} = 1.25$.



(a) AM wave for m = 0.75

Continued…

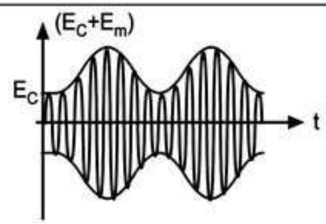
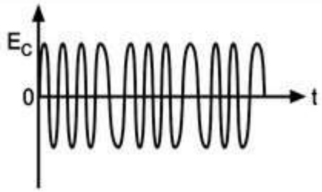
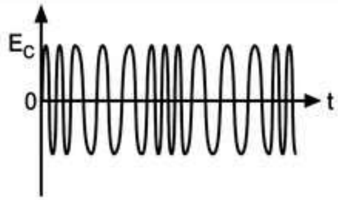


(b) AM Wave for m = 1

(c) AM Wave for m = 1.25

https://slideplayer.com/slide/12185195/

Types AM, FM, PM Definition, Waveforms

Sr. No.	Parameter	AM	FM	PM
1.	Definition	Amplitude modulation is a technique of modulation, in which amplitude of carrier varies in accordance with amplitude of modulating signal. Keeping frequency and phase constant.	Frequency modulation is a technique of modulation, in which frequency of carrier varies in accordance with amplitude of modulating signal. Keeping amplitude and phase constant.	Phase modulation is a technique of modulation in which phase of carrier varies in accordance with amplitude of modulating signal. Keeping amplitude and frequency constant.
1.	Definition	Amplitude modulation is a technique of modulation, in which amplitude of carrier varies in accordance with amplitude of modulating signal. Keeping frequency and phase constant.	Frequency modulation is a technique of modulation, in which frequency of carrier varies in accordance with amplitude of modulating signal. Keeping amplitude and phase constant.	Phase modulation is a technique of modulation in which phase of carrier varies in accordance with amplitude of modulating signal. Keeping amplitude and frequency constant.
2.	Waveforms	 **Fig. 2.3**	 **Fig. 2.4**	 **Fig. 2.5**

AM Generation

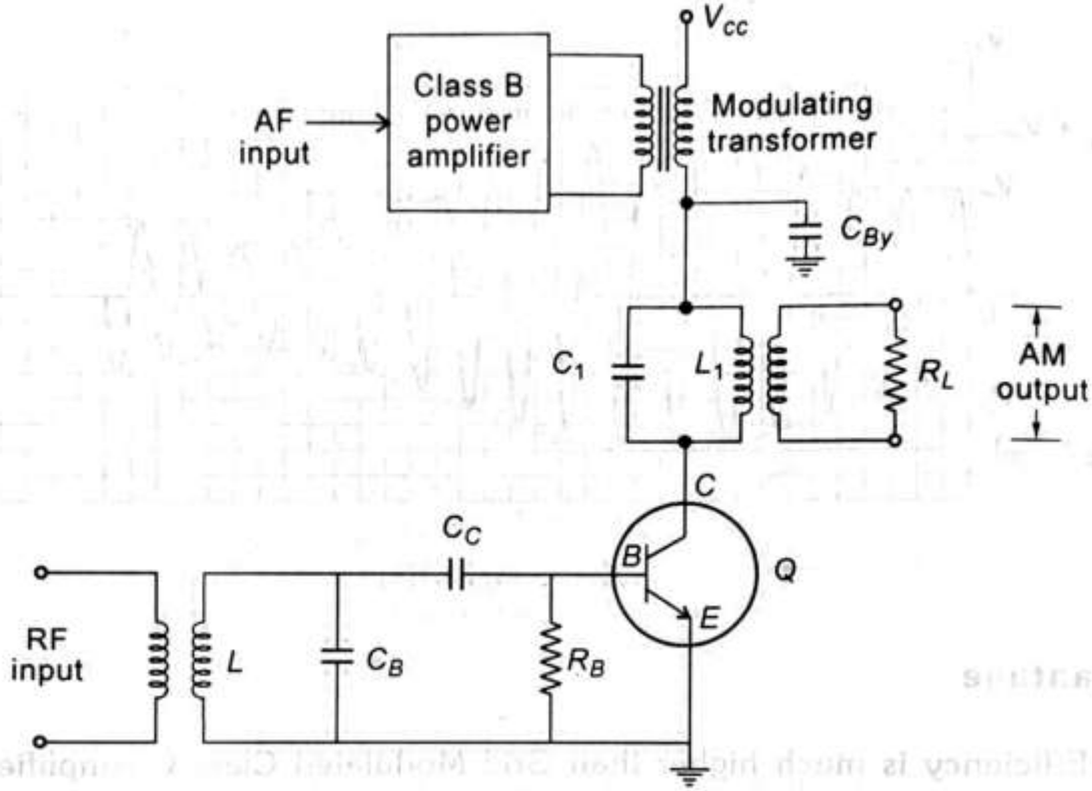


Fig. 3.9(a)

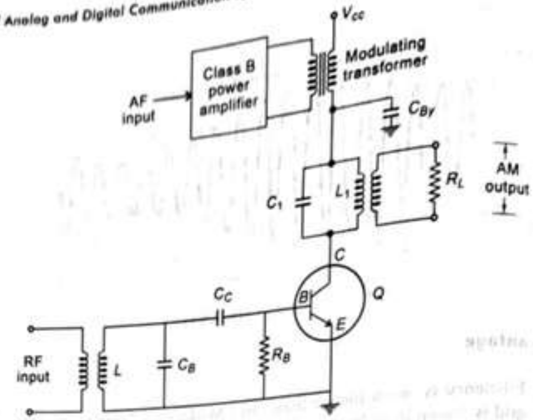


Fig. 3.9(a)

Operation

- RF carrier signal is applied at the base of transistor Q.

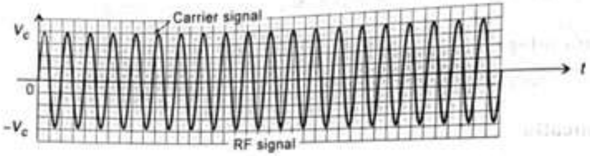


Fig. 3.9(b)

- The transistor will conduct only for positive half cycle of carrier signal.
- The AF input is given to the class B amplifier which increases power level of AF signal.
- This modulating signal is the applied in series with V_{CC}.

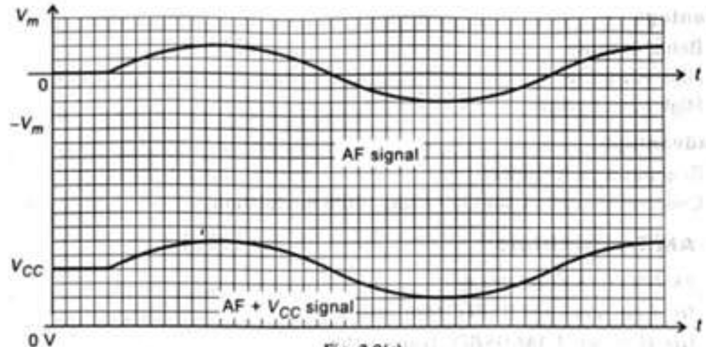


Fig. 3.9(c)

- Therefore the supply voltage varies according to the amplitude of modulating signal.
- Such varying voltage is applied to the collector which results in variation in amplitude of current pulses at the collector of transistor.

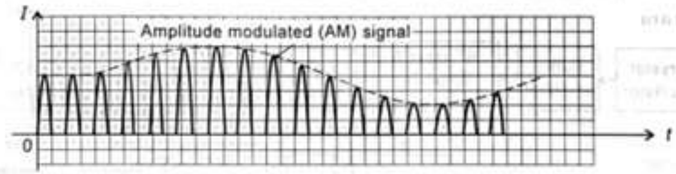


Fig. 3.9(d)

- These pulses are applied to the tank circuit and we get the AM signal across load resistor R_L.

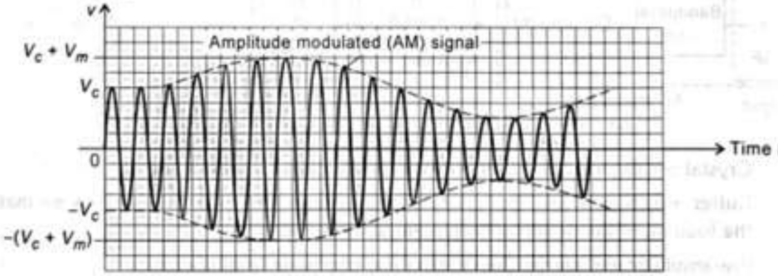


Fig. 3.9(e)

3.7.1 Low Level Modulated AM Transmitter

- The block diagram of low level AM transmitter is as shown in *figure 3.10*.

Diagram

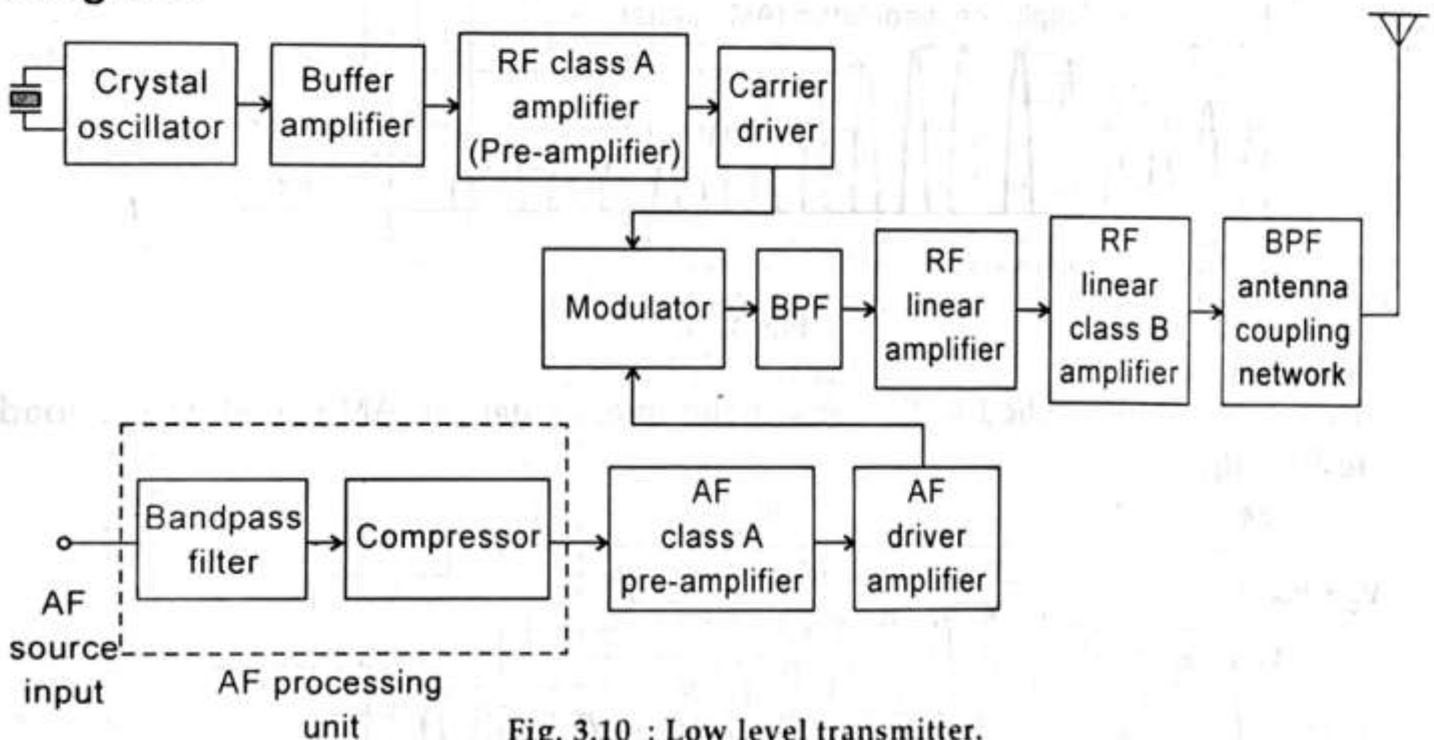


Fig. 3.10 : Low level transmitter.

- AF processing unit filters AF so as to occupy the current bandwidth (generally 10 kHz).
- AF pre-amplifier and driver raises the amplitude level of AF signal.

Operation

- The carrier generated by the oscillator and the amplified modulating signal is applied to the modulator.
- At the output of modulator we get AM wave.
- This AM signal is then amplified using chain of linear amplifiers to raise its power level.
- The amplitude modulated signal is then transmitted using transmitting antenna.
- The low level transmitter does not require a large AF modulator power so its design is simplified.
- However, the efficiency is much lower compared to high level modulation.

3.7.2 High Level Modulated AM Transmitter

- The block diagram of high level AM transmitter is as shown in *figure 3.11*.

Diagram

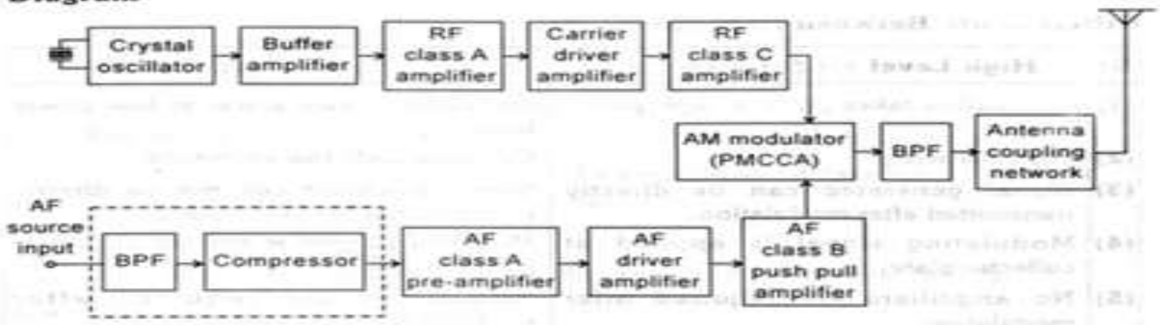


Fig. 3.11 : High level transmitter.

- Crystal oscillator is used as it provides better stability of frequency.
- Buffer amplifier is used to isolate oscillator from high power amplifiers so that the loading of the oscillator by pre-amplifier is divided.
- Pre-amplifier and carrier driver raises the amplitude level of carrier.
- AF source can be microphone, magnetic tape or CD etc.

AM Envelop Detector

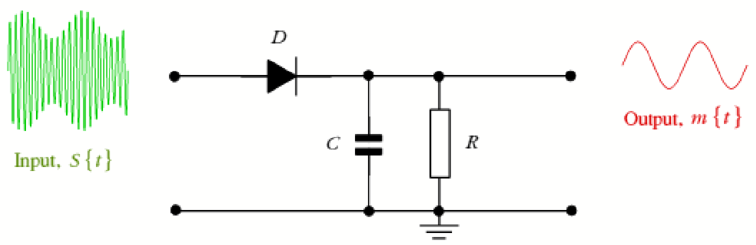
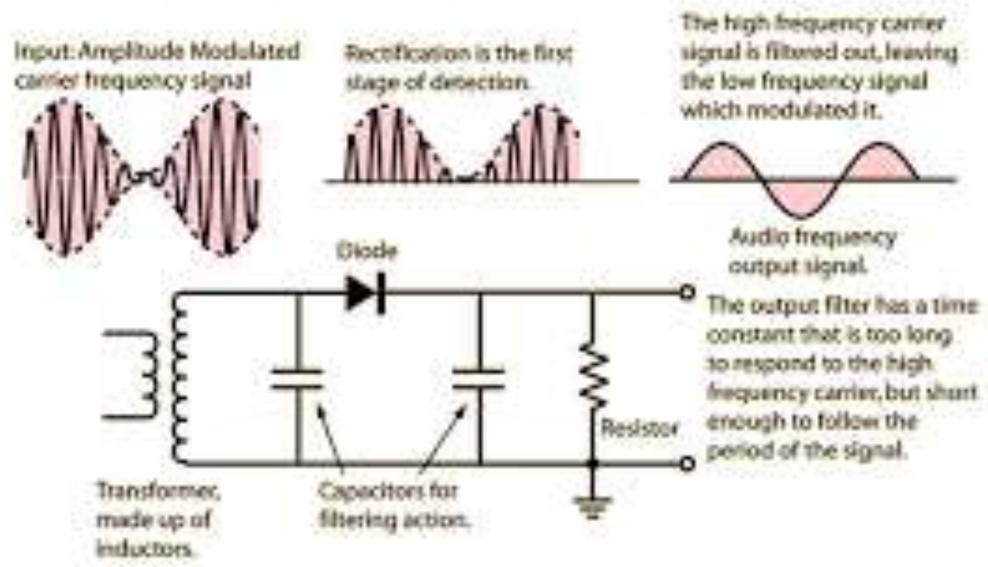
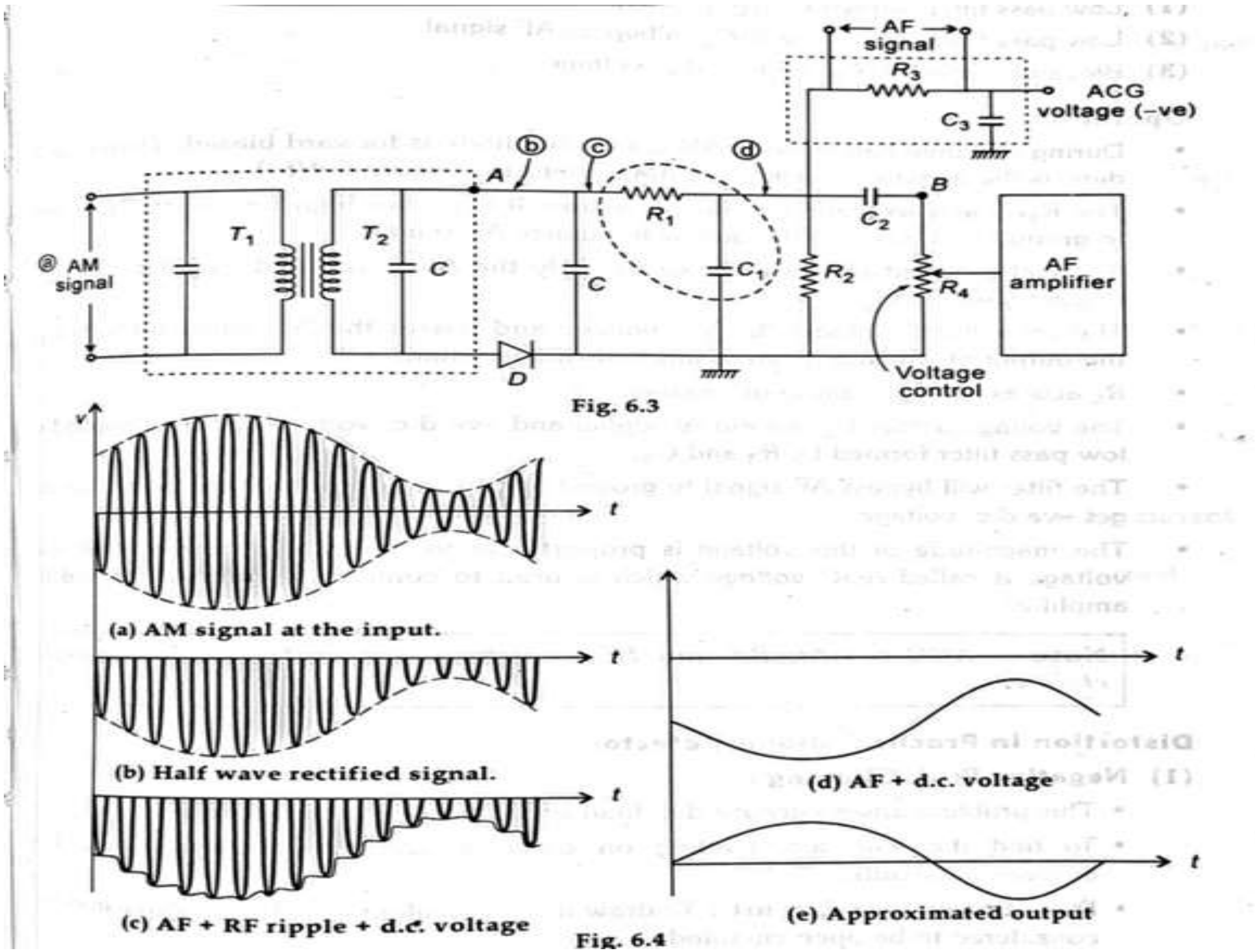


Figure 9.2 Envelope Detector (AM Demodulator/Detector).



Practical AM Demodulation



Detection

Circuit Description

Circuit diagram of practical diode detector is shown in *figure 6.3.*

Here detector diode *D* is connected such that –ve d.c. voltage is available for Gain Control of amplifier.

The detector consists of

(1) Low pass filter formed by R_1C_1 to bypass RF ripples.

(2) Low pass filter formed by R_3C_3 to bypass AF signal.

(3) Blocking capacitor C_2 to block d.c. voltage.

Operation

- During negative half cycle of AM wave, the diode is forward biased. Therefore it detects the negative envelope of AM waveform. [*Figure 6.4(b)*]
- The R_1C_1 acts as low pass filter. Therefore it bypasses high frequency RF signal to ground and passes only the low frequency AF signal.
- So, at the output of this filter we get only the AF signal and –ve d.c. voltage. [*Figure 6.4(d)*]
- The capacitor C_2 blocks the d.c. voltage and passes the AF signal towards R_4, the output of which is given to input of AF amplifier..
- R_4 acts as voltage control of receiver.
- The voltage across R_2 contain AF signal and –ve d.c. voltage which is applied o low pass filter formed by R_3 and C_3.
- The filter will bypass AF signal to ground and at the output of low pass filter we get –ve d.c. voltage.
- The magnitude of this voltage is proportional to strength of carrier. This -ve voltage is called *AGC voltage* which is used to control the gain of RF and IF amplifier.

Note : *AGC circuit, RF and IF amplifiers are explained in the next chapter.*

Distortion in Practical diode detector

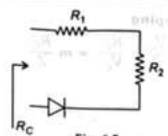
Distortion in Practical Diode Detector

(1) Negative Peak Clipping :

- This problem arises because d.c. load of diode *D* is not equal to a.c. load.
- To find d.c. and a.c. loading on detector, lets first draw a.c. and d.c. equivalent circuits.

- **D.C. Equivalent Circuit :** To draw d.c. equivalent circuits, all capacitors are considered to be open circuited

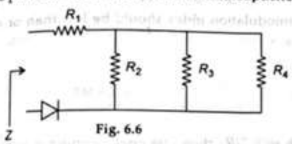
Negative peak clipping



$\therefore R_C = R_1 + R_2$

Fig. 6.5

- **A.C. Equivalent Circuit :** To draw a.c. equivalent circuit, capacitor C and C_1 acts as open circuit for AF and capacitor C_2 and C_3 acts as short circuit.



$\therefore Z = R_1 + (R_2 \,||\, R_3 \,||\, R_4)$

Fig. 6.6

- From above equations, it is seen that

$$\therefore R_C > Z \qquad \text{..... (1)}$$

- As we already know, modulation index is

$$m = \frac{V_m}{V_C}$$

- The demodulation index at the receiver is defined as

$$m_d = \frac{I_m}{I_C} \quad \text{where } I_m = \frac{V_m}{Z} = \text{Modulating current}$$

$$I_C = \frac{V_C}{R_C} = \text{Carrier current}$$

From equation (1), we can say that if $V_m \approx V_c$ then,

$$I_m > I_C$$

Therefore we get –ve peak clipping as shown in *figure 6.7*.

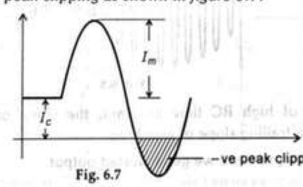


Fig. 6.7

Diagonal Clipping

To avoid −ve peak clipping

$$m_d = \frac{I_m}{I_C} = \frac{V_m}{Z} \times \frac{R_C}{V_C} = m\frac{R_C}{Z}$$

$$\because \; R_C > Z$$

$$\therefore \; m_d > m$$

- It means after detection, the demodulation index increases, i.e. if m is 100%, then $m_d > 100\%$.
- Therefore during −ve half cycle, AF signal gets clipped.
- To avoid −ve peak clipping demodulation index should be less than or equal to 1 i.e. $m_d \leq 1$

$$\therefore \; m\frac{R_C}{Z} < 1$$

$$\therefore \; m \leq \frac{Z}{R_C}$$

- If the signal is transmitted with $m \leq Z/R_C$ then −ve peak clipping is avoided.

(2) Diagonal Clipping :

- In diode detectors, the RC time constant should be small such that the capacitor does not discharge by large amount.
- The capacitor's charging and discharging should follow the envelope of AM wave.
- If the RC time constant is too high, then the output of detector does not follow the fast changes in envelope of AM wave.
- This results in diagonal clipping as shown in *figure 6.8*.

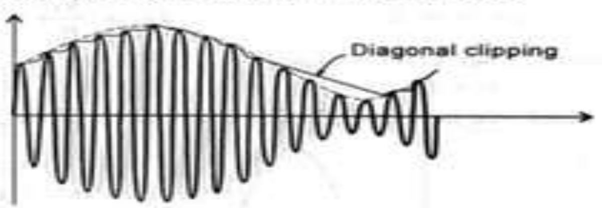


Fig. 6.8

- Because of high RC time constant, the slope of output waveform cannot follow the trailing slope of envelope.
- Due to this problem, we get distorted output.

Diagonal Clipping

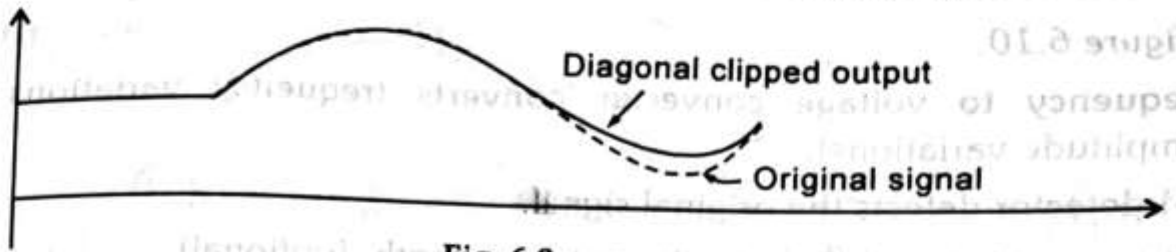


Fig. 6.9

- To avoid diagonal clipping, the discharging time constant should not be too high.
- Also, the modulating index used at transmitter should be less than 60%.

FM Detectors