Unit 2: Modulation and Demodulation

2.1 Introduction

Radio waves can carry audio, video, and digital information over great distances by using changes in a carrier wave's amplitude, frequency, or phase to represent the information being transmitted.

Information can be sent from a transmitter to a receiver by means of modulation and demodulation, respectively, whether those signals are light waves moving through optical cables, radio waves through metallic cables, or radio waves propagating through the air. The electromagnetic (EM) waves that transport the information are referred to as carrier signals, while the information they carry may be in the form of audio, video, or data. There are numerous such systems such as radio and TV broadcasting system, mobile communication system, and satellite communication.

By changing the amplitude, frequency, or phase of carrier signal, information can be added as modulation to a signal. Due to the increased amount of information for transmission and reception, signal-modulation techniques have advanced in their capabilities to handle more data for a given amount of occupied bandwidth.

2.2 Need for modulation:

There are three major difficulties in transmitting low frequency signal such as audio signal(20Hz – 20 KHz) without modulation, namely-

1. Poor reception
2. Signal interference
3. Height of Antenna

1. Poor reception

Low frequency signals cannot travel over a long distance as they get attenuated and degraded within a short distance. The signal reaching the receiver will be very weak thereby leading to poor reception

2. Signal interference

Modulation enables us more efficient use of transmission media .Modulation prevents the interference of message signals from other signals. By using a carrier signal of high frequency, the mixing of signals can be prevented. In other words, modulation ensures that the signals received by the receiver are perfect.

3. Height of Antenna (Length)

For good transmission and reception antenna should have size of about quarter wavelength ($\lambda/4$) of signal transmitted. If the signal frequency is low, then required antenna size is much higher. In some cases it goes beyond practical limits.

$$\text{If } f = 15 \text{ KHz}, \quad \lambda = \frac{C}{f} = \frac{3\times 10^{8} \text{ m/s}}{15 \times 10^{3} \text{ Hz}} = 20 \text{ Km}$$

$$\therefore \text{Antenna size} = \frac{\lambda}{4} = 5 \text{ Kms}$$

Thus antenna size becomes impracticable.

$$\text{If } f = 1 \text{ MHz}, \quad \lambda = \frac{C}{f} = \frac{3\times 10^{8} \text{ m/s}}{10^{6} \text{ Hz}} = 300 \text{ m}$$

$$\therefore \text{Antenna size} = \frac{\lambda}{4} = 75 \text{ m}$$

Thus, antenna size comes within practicable limits.

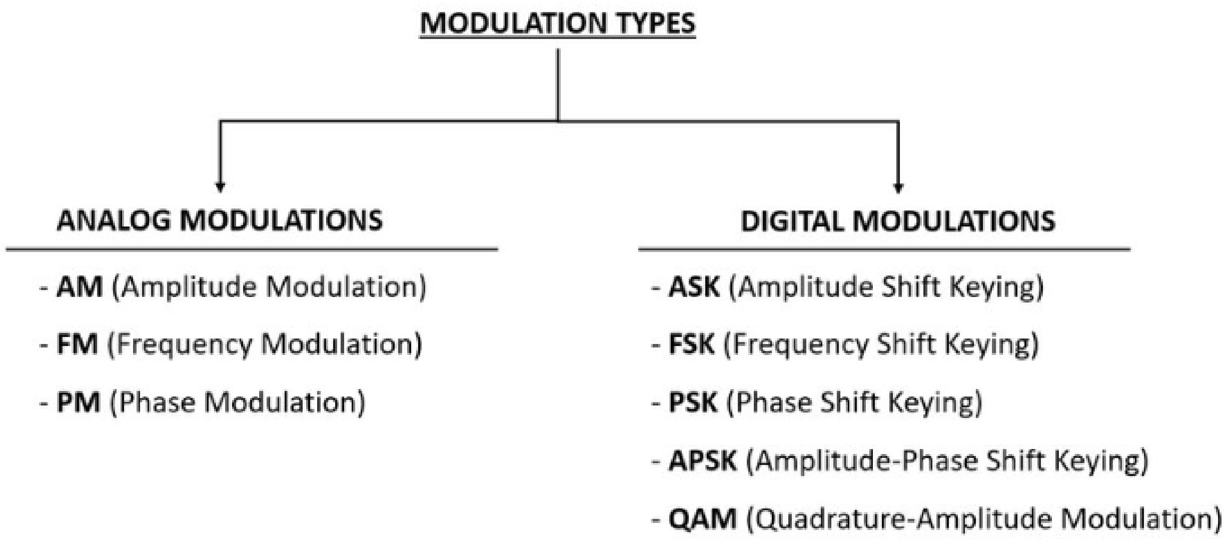
Thus if we attempted to radiate a 15 KHz speech signal, we would need an antenna of size 5 km. To build an antenna of this size is expensive, impracticable to construct and not suitable for portable applications (like say mobile). Instead if we transmit 15 KHz speech signal modulated on 1 MHz carrier signal, it can be efficiently radiated using very small and hence affordable antenna of minimum size, of 75 m.

2.3 Modulation:

Modulation is a process of changing the characteristics of a carrier signal like amplitude,frequency and phase in accordance with the amplitude of modulating signal.

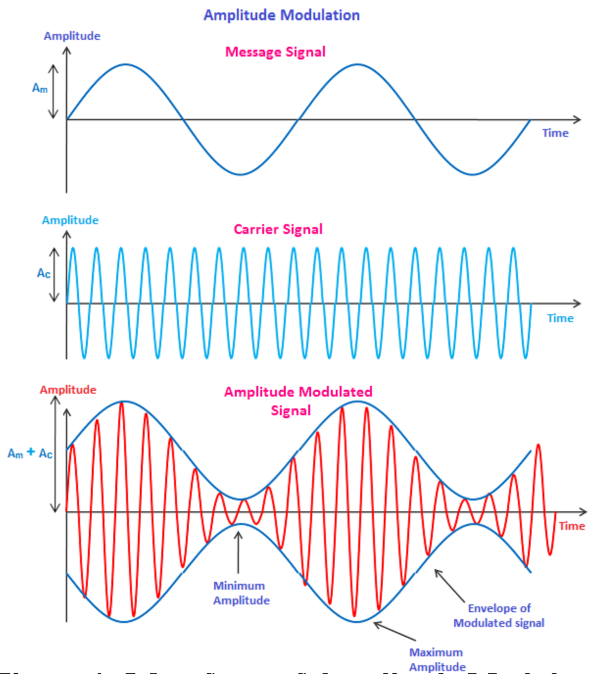
Types of Modulation

Modulation is categorized into two types depending on the type of signal.



2.4 Amplitude Modulation:

Amplitude Modulation is the process in which amplitude of carrier signal is change in accordance with amplitude of modulating signal. During this **frequency and phase** of carrier signal remains constant.



The first figure shows the modulating wave, which is the message signal. The next one is the original carrierwave, which is a high frequency signal taken for modulation and contains no information. While, the last one is the resultant modulated wave.

Figure 1: Waveform of Amplitude Modulated wave.

2.4.1 Expression for Amplitude Modulated Wave

Using trigonometric functions, we can express the sine wave modulating signal with the simple expression

$$v_m = V_m \sin 2\pi f_m t \qquad \text{----------------------- (1)}$$

Where,
ϑm =instantaneous value of information signal.
V_m=peak amplitude of information signal.
f_m=frequency of modulating signal

A carrier signal can be expressed with a similar formula as

$$v_c = V_c \sin 2\pi f_c t \qquad \text{----------------------- (2)}$$

Where,
ϑc =instantaneous value of carrier signal.
V_c=peak amplitude of carrier signal.
f_c=frequency of carrier signal

In amplitude modulation process, the amplitude of the carrier wave changes in accordance with the amplitude of the modulating signal. ϑ1 will be the amplitude of the modulated radio wave and it is given as

$$v_1 = V_c + v_m = V_c + V_m \sin 2\pi f_m t$$ --------- (this is the amplitude of the modulated wave).

Thus, we can write the instantaneous value of the complete modulated wave $\vartheta 2(\vartheta_{am})$ by substituting $\vartheta 1$ for the peak value of carrier voltage Vc as follows:

$$\vartheta_2(\vartheta_{am}) = \upsilon_1 \sin 2\pi f_c t$$

Now substituting the previously derived expression for $\vartheta 1$ and expanding, we get the following:

$$\upsilon_2 = (V_c + V_m \sin 2\pi f_m t) \sin 2\pi f_c t = V_c \sin 2\pi f_c t + (V_m \sin 2\pi f_m t)(\sin 2\pi f_c t)$$

By using the trigonometric identity that says that the product of two sine waves is

$$\sin A \sin B = \frac{\cos(A - B)}{2} - \frac{\cos(A + B)}{2}$$

and substituting this identity into the expression a modulated wave, the instantaneous amplitude of the signal becomes

$$\boxed{\upsilon_{AM} = V_c \sin 2\pi f_c t + \frac{V_m}{2}\cos 2\pi t(f_c - f_m) - \frac{V_m}{2}\cos 2\pi t(f_c + f_m)}$$

This is equation for amplitude modulated wave. This equation shows that the amplitude modulated wave consists of three terms. First term is the carrier; the second term, containing the difference fc - fm, is the lower sideband; and the third term, containing the sum fc +fm, is the upper sideband.

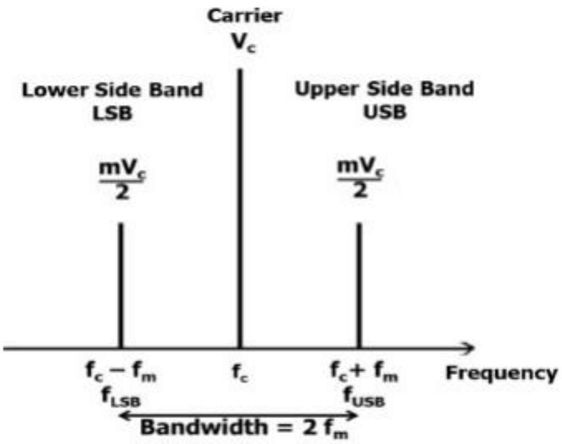


Figure 2: AM Spectra and Bandwidth

2.4.2 Band width: (B.W)

The bandwidth is the difference between lowest and highest frequencies of the signal. For amplitude modulated wave, the bandwidth is given by

B.W = upper side band frequency – lower side band frequency

$= (f_{USB} - f_{LSB}) = fc + fm - (fc - fm) = 2\ fm$

B.W = 2fm = twice the frequency of modulating signal.

Hence we got to know that the bandwidth required for the amplitude modulated wave is twice the frequency of the modulating signal.

2.4.3 Modulation Index (*m*)

The relationship between the information signal amplitude, Vm , and the unmodulated carrier amplitude, Vc, is expressed as a ratio called the modulation index (m), defined as:

The ratio of change of amplitude of carrier wave to the amplitude of normal carrier wave is called the modulation index (factor) ***m*** i.e.

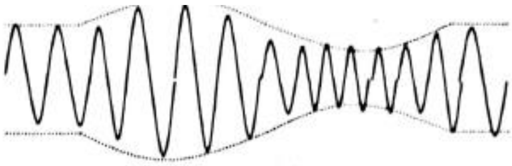
$$m = \frac{V_m}{V_c}$$

In short, in an AM signal, the percentage of modulation is a measure how strongly the carrier wave is being changed by the information.

2.4.5 SIGNIFICANCE OF Modulation Index (*m)*

The modulation factor (*m)* plays a very important role in the modulation process. This will be made clear by calculating the value of *m* for different amplitude of signal and the carrier.

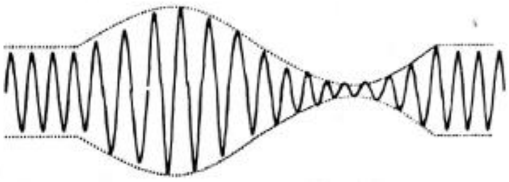
and quality of transmitted signal.



Case I : $m_a < 1$: Carrier signal is modulated to a smaller degree. This results in to smaller carrier amplitude variations as shown in figure.

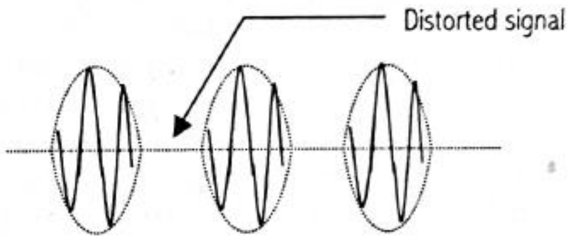
AM wave contains low transmitting power. It is a case of under-modulation.

Case II: $m_a = 1$



The carrier wave is modulated to greater degree. This results into carrier amplitude variations equal to peak amplitude of modulating signal as shown in figure.

AM wave contains higher transmitting power. This is a case of perfect or cent percent modulation.

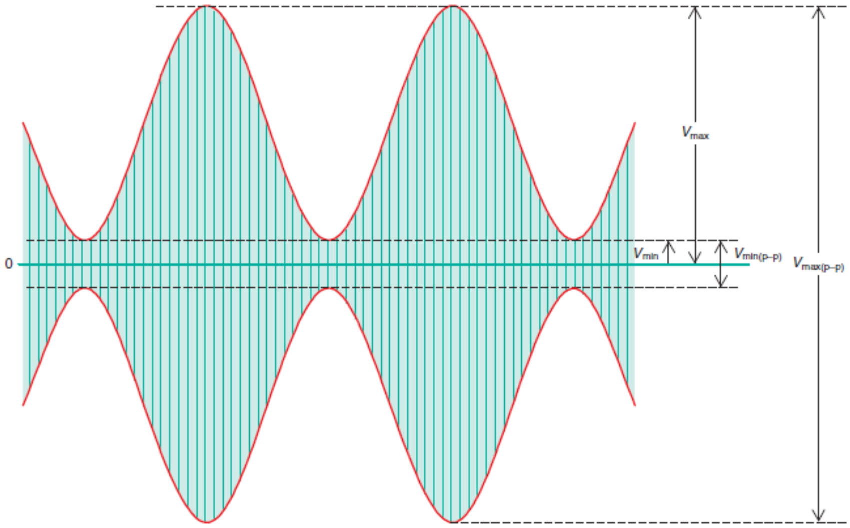


Case III: $m_a > 1$: Since variations in the carrier amplitude cannot be more then its peak value, with $V_m > V_c$, the AM wave becomes discontinuous. This results into a distortion as shown in figure.

Though the transmitting power is large some information is lost with $m_a > 1$ and hence ***practically m_a should not be greater than one***. This is the case of over-modulation.

2

Determination of modulation index from AM-wave:



We can also mathematically determine the modulation index m from the maximum and minimum values of the amplitude modulated envelope as follows, where Vmax is the maximum value of the envelope and Vmin is the minimum value:

$$V_m = \frac{V_{\max} - V_{\min}}{2}$$

$$V_c = \frac{V_{\max} + V_{\min}}{2}$$

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

Example:

Suppose that on an AM signal, the $V_{\max(p-p)}$ value read from the graticule on the oscilloscope screen is 5.9 divisions and $V_{\min(p-p)}$ is 1.2 divisions.

a. What is the modulation index?

$$m \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} = \frac{5.9 - 1.2}{5.9 + 1.2} = \frac{4.7}{7.1} = 0.662$$

2.5.6 Power distribution of AM Wave:

The AM signal is really a composite of several signal voltages, namely, the carrier and the two sidebands, and each of these signals produces power in the antenna. The total transmitted power P_T is simply the sum of the carrier power Pc and the power in the two sidebands P_{USB} and P_{LSB}:

$$P_t = P_c + P_{USB} + P_{LSB}$$

You can see how the power in an AM signal is distributed and calculated by going back to the original AM equation:

$$v_{AM} = V_c \sin 2\pi f_c t + \frac{V_m}{2} \cos 2\pi t (f_c - f_m) - \frac{V_m}{2} \cos 2\pi t (f_c + f_m)$$

where the first term is the carrier, the second term is the lower sideband, and the third term is the upper sideband.

Now, remember that Vc and Vm are peak values of the carrier and modulating sine waves, respectively. For power calculations, rms values must be used for the voltages

$$v_{AM} = \frac{V_c}{\sqrt{2}} \sin 2\pi f_c t + \frac{V_m}{2\sqrt{2}} \cos 2\pi t(f_c - f_m) - \frac{V_m}{2\sqrt{2}} \cos 2\pi t(f_c + f_m)$$

$$P_T = \frac{(V_c/\sqrt{2})^2}{R} + \frac{(V_m/2\sqrt{2})^2}{R} + \frac{(V_m/2\sqrt{2})^2}{R} = \frac{V_c^2}{2R} + \frac{V_m^2}{8R} + \frac{V_m^2}{8R}$$

Remembering that we can express the modulating signal V_m in terms of the carrier V_c by using the expression given earlier for the modulation index $m = V_m/V_c$; we can write

$$V_m = mV_c$$

If we express the sideband powers in terms of the carrier power, the total power becomes

$$P_T = \frac{(V_c)^2}{2R} + \frac{(mV_c)^2}{8R} + \frac{(mV_c)^2}{8R} = \frac{V_c^2}{2R} + \frac{m^2V_c^2}{8R} + \frac{m^2V_c^2}{8R}$$

Since the term $V_c^2/2R$ is equal to the rms carrier power P_c, it can be factored out, giving

$$P_T = \frac{V_c^2}{2R}\left(1 + \frac{m^2}{4} + \frac{m^2}{4}\right)$$

Finally, we get a handy formula for computing the total power in an AM signal when the carrier power and the percentage of modulation are known:

$$P_T = P_c\left(1 + \frac{m^2}{2}\right)$$

Advantages of amplitude modulation:

- Transmission and reception of Amplitude modulated signal is comparatively easy.
- The components used in building the AM transmitter and AM receiver are very cheap.
- The circuit used in this is very simple.

Disadvantages of amplitude modulation

- AM requires a bandwidth which is double to the audio frequency.
- Transmission and reception of Amplitude modulated waves are very noisy.
- Since the efficiency of Amplitude Modulation is very low, the messages cannot be transmitted over a particular distance.
- In the transmission of Amplitude modulated signal two sidebands and carrier signal have to be sent. So it requires a high range of bandwidth and more power.
- It is not efficient in terms of its power usage.

2.6 Double Sideband Suppressed Carrier (DSB-SC) Modulation

Definition: **DSB-SC** is an amplitude modulated wave transmission scheme in which only **sidebands** are **transmitted** and the **carrier** is not transmitted as it gets **suppressed**. DSB-SC is an acronym for **D**ouble **S**ideband **S**uppressed **C**arrier.

The carrier does not contain any information and its transmission results in loss of power. For 100% modulation, about 67% of the total power is required for transmitting the carrier which does not contain any information. Hence, if the carrier is suppressed, only the sidebands remain and in this way a saving of two-third power may be achieved at 100% modulation. This type of suppression of carriers does not affect baseband signal. The resulting signal is DSB-SC signal.

As we know that transmission power and bandwidth are the two important parameters in a communication system. Thus, in order to save power and bandwidth, DSB-SC modulation technique is adopted.

As we know,

$$P_t = \left(1 + \frac{{m_a}^2}{2}\right)P_c$$

$$Put\ m_a = 1$$

$$P_t = \left(1 + {}^1/_2\right)P_c$$

$$=> \ P_t = {}^3/_2\, P_c$$

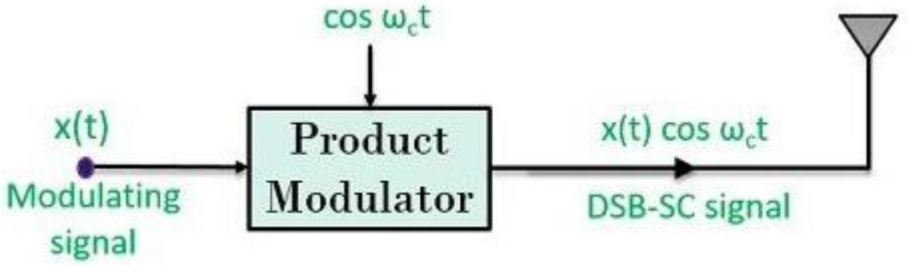
$$=> \ P_c = {}^2/_3\, P_t$$

$$=> P_c = 0.67 P_t$$

$$So, P_c\ is\ 67\%\ of\ the\ transmitted\ power.$$

Generation of DSB-SC signal

Let's have a look at the block diagram of the DSB-SC system shown below:



$$s(t) = A_x A_c \cos(2\pi f_x t) \cos(2\pi f_c t)$$

$$s(t) = \frac{Ax\ Ac}{2}\cos[2\pi(f_c + f_x)t] + \frac{Ax\ Ac}{2}\cos[2\pi(f_c - f_x)t]$$

Advantages of DSB-SC modulation

1. It provides 100% modulation efficiency.
2. Due to suppression of carrier, it consumes less power.
3. It provides a larger bandwidth.

Disadvantages of DSB-SC modulation

1. It involves a complex detection process.
2. Using this technique it is sometimes difficult to recover the signal at the receiver.
3. It is an expensive technique when it comes to demodulation of the signal.

2.7 Single -sideband suppressed-carrier transmission (SSB-SC)

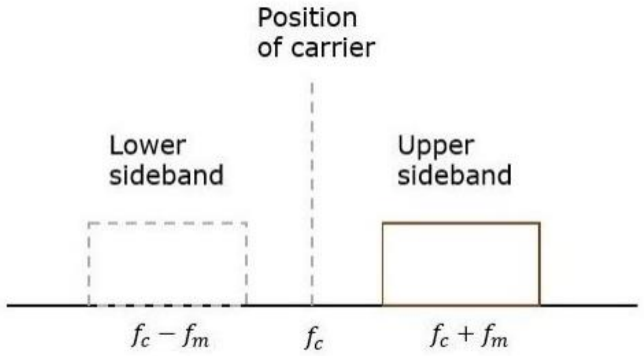


Figure 3: Concept of Single -sideband suppressed-carrier transmission

The process of suppressing one of the sidebands along with the carrier and transmitting a single sideband is called as Single Sideband Suppressed Carrier system or simply SSBSC. It is plotted as shown in the figure 3. As shown in figure.3, the carrier and side band are suppressed and a single side band is allowed for transmission. Hence, the upper sideband is used for transmission.

This SSBSC system, which transmits a single sideband, has high power, as the power allotted for both the carrier and the other sideband is utilized in transmitting this Single Sideband.

Mathematical Expressions:

Mathematically, we can represent the equation of SSBSC wave as

s(t)=AmAc2cos[2π(fc+fm)t] for the upper sideband

s(t)=AmAc2cos[2π(fc−fm)t] for the lower sideband

2.8 Amplitude Demodulators

Demodulators, or detectors, are circuits that accept modulated signals and recover the original modulating information. The demodulator circuit is the key circuit in any radio receiver.

Diode Detectors

The simplest and most widely used amplitude demodulator is the diode detector (see Figure 4).

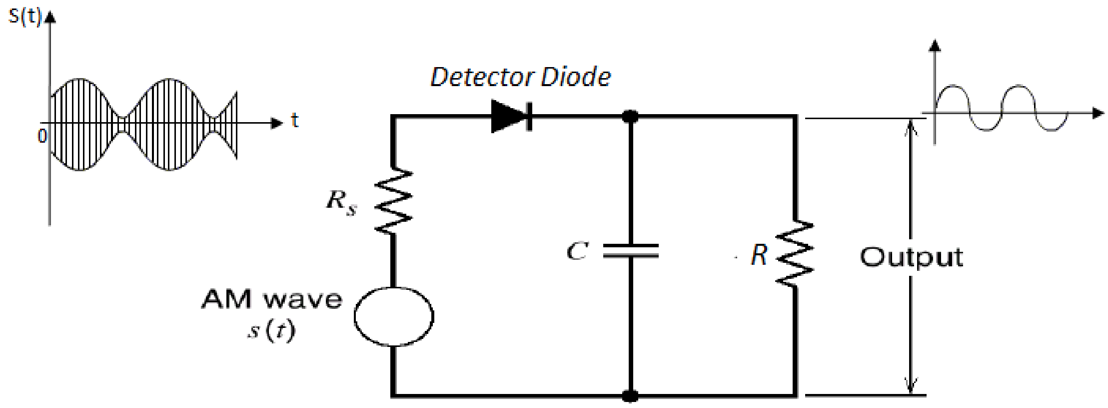


Figure 4: Envelope demodulator consists of a diode and RC filter.

The standard AM wave is applied at the input of the demodulator.

The diode conducts when the positive half-cycles of the AM signals occur. During the positive half-cycles, diode is forward biased and charge the filter capacitor C connected across the load resistance R to almost the peak value of the input voltage.

During the negative half-cycles, the diode is reverse-biased and no current flows through it. As a result, the voltage across R is a series of positive pulses whose amplitude varies with the modulating signal. A capacitor C is connected across resistor R, effectively filtering out the carrier and thus recovering the original modulating signal.

Because the diode detector recovers the envelope of the AM signal, which is the original modulating signal, the circuit is sometimes referred to as an **envelope detector**.

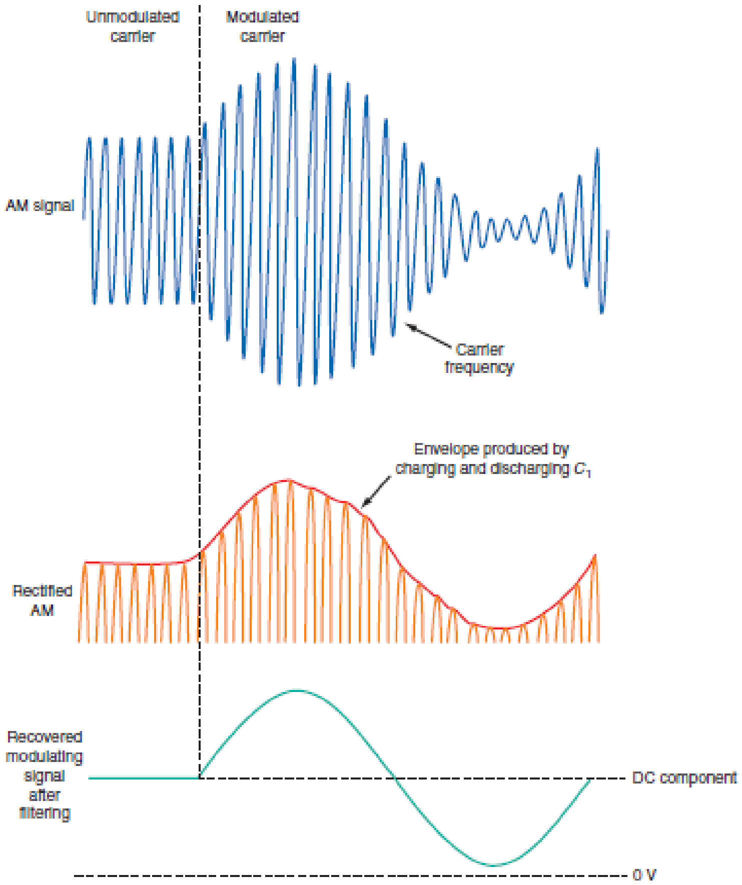
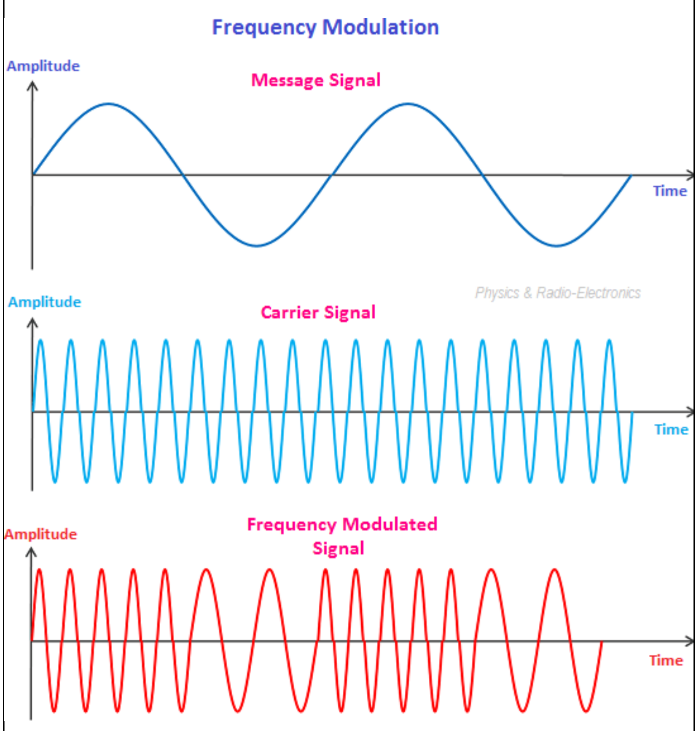


Figure 5: Diode detector waveforms

2.9 Frequency Modulation:



Frequency modulation is a type of modulation where the carrier wave's frequency changes in response to the modulating signal's instantaneous amplitude while maintaining **the phase and amplitude** constant. The objective of changing the carrier wave frequency is to transfer data or information over short distances.

The frequency modulation index is consistently greater than one, requiring a wide bandwidth of 200 kHz, operating in a very high-frequency range of **88 to 108 MHz**, a complex circuit with an endless number of sidebands, and receives a high-quality signal with good sound quality. Angle modulation is a type of carrier frequency modulation commonly employed in telecommunications transmission systems. Frequency and phase modulation complement basic types of angle modulation.

2.9.1 Modulation Index:

Modulation index is defined as the ratio of maximum frequency deviation of the carrier signal to the frequency of the message signal.

$$\text{Modulation Index } (M_i) = \frac{\Delta f}{f_m}$$

Where, Δf = Maximum frequency deviation of the carrier signal,
fm = Frequency of the message signal

2.9.2 Frequency deviation

The amount of change in the carrier frequency produced; by the amplitude of the input modulating signal is called frequency deviation. The carrier frequency swings between f_{max} and f_{min} as the input varies in its amplitude. The difference between f_{max} and fc is known as frequency deviation.

$$f\,d = f_{max} - f_c$$

Similarly, the difference between fc and f_{min} also is known as frequency deviation.

$$f\,d = f_c - f_{min}. \qquad \text{It is denoted by } \Delta f.$$

Therefore, $\Delta f = f_{max} - f_c = f_c - f_{min}$

Therefore, $fd = f_{max} - f_c = f_c - f_{min}$

A standard channel spacing of 100 or 200 kHz is used in the FM broadcasting range between 87.5 and 108 MHz, with a maximum frequency deviation (Δf) of **+/-75 kHz.**

2.9.3 The Bandwidth (BW) of Frequency Modulation Signal

One of the most critical aspects of an FM signal is its bandwidth. The sidebands will extend to infinity on either side; however, their strength will diminish. It can limit the BW of an FM signal without affecting its value considerably.

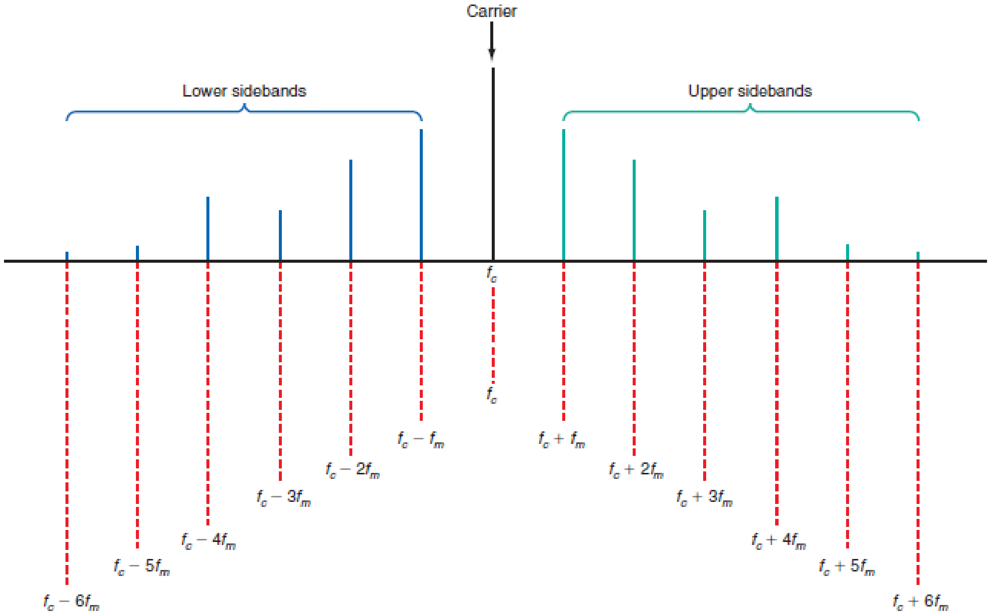


Figure 5: Frequency spectrum of an FM signal

Remember that the bandwidth of a complex signal like FM is measured in Hertz and is defined as the difference between its highest and lowest frequency components (Hz). Bandwidth is only concerned with frequencies. The bandwidth of AM was discovered to be 2fm (i.e. twice of modulating signal frequency), with only two sidebands (USB and LSB).

It is not that easy in FM, and its signal spectrum is highly complex and has many sidebands. The spectrum extends as the modulation index rises. However, we find that the FM wave is effectively limited to a finite number of significant side-frequencies compatible with a specified amount of distortion.

A very useful rule of thumb used by many engineers to determine the bandwidth of an FM signal for radio broadcast and radio communications systems is known as Carson's Rule. This rule states that 98% of the signal power is contained within a bandwidth equal to the deviation frequency, plus the modulation frequency doubled. Carson's Rule can be expressed simply as a formula:

Carson's Rule

- Bandwidth (98% of total power) equals twice the sum of max. frequency deviation (Δf) plus max. modulating frequency (f_m)

$$BW = 2(\Delta f + f_m)$$

- Example:
  - FM broadcast stations have max deviation (Δf) = 75 kHz and max modulating frequency (f_m)= 15 kHz
  - 98% power bandwidth is ≈ 2(75 + 15) ≈ 180 kHz

Advantages and Disadvantages of Frequency Modulation

Advantages	**Disadvantages**
Less interference and noise.	Equipment cost is higher. Has a large bandwidth.
Power Consumption is less as compared to AM.	More complicated receiver and transmitter
Adjacent FM channels are separated by guard bands.	The antennas for FM systems should be kept close for better communication.

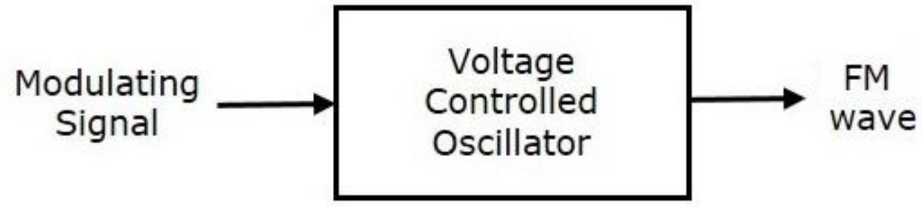
Comparison between AM and FM:

Amplitude Modulation (AM)	**Frequency Modulation (FM)**
Frequency and phase remain the same	Amplitude and phase remain the same
Can be transmitted over a long distance but has poor sound quality.	Better sound quality with higher bandwidth.
The frequency range varies between 535 to 1705 KHz	For FM it is from88 to 108 MHz mainly in the higher spectrum
Signal distortion can occur in AM	Less instances of signal distortion
Consists of two sidebands	An infinite number of sidebands
Circuit design is simple and less expensive.	Circuit design is intricate and more expensive
Easily susceptible to noise	Less susceptible to noise

2.10 Generation of FM using VCO

Oscillators whose frequencies are controlled by an external input voltage are generally referred to as voltage-controlled oscillators (VCOs). By varying the input DC voltage, the output frequency of the signal produced is adjusted. Although some VCOs are used primarily in FM, they are also used in other applications where voltage-to-frequency conversion is required.

This method is called as the Direct Method because we are generating a wide band FM wave directly. In this method, Voltage Controlled Oscillator (VCO) is used to generate WBFM. VCO produces an output signal, whose frequency is proportional to the input signal voltage. This is similar to the definition of FM wave. The block diagram of the generation of WBFM wave is shown in the following figure.



Here, the modulating signal $m(t)$ is applied as an input of Voltage Controlled Oscillator (VCO). VCO produces an output, which is nothing but the FM signal.

$$f_i \propto m(t)$$

Where,

f_i is the instantaneous frequency of FM wave.

2.11 FM demodulator/Detector

The circuits which are used to detect original modulating signal from FM signal are called demodulators or FM detectors or discriminators. FM detectors function in two steps. In the first step FM signal is converted into AM signal by using 1 or 2 tuned circuits, in second step form this AM signal of the original information can be extracted by using linear diode detector. There are different types of FM detectors; some of them are as follows:

1. Slope detector.
2. Balanced slope detector.
3. Foster-Seely discriminator.
4. Ratio detectors.

2.11.1 Slope detector.

The very simplest form of FM demodulation is known as slope detection or demodulation. The slope detector is a method of Frequency demodulation which converts the received FM signal to AM and demodulates with an envelope detector. An FM slope detector consists of a tuned circuit where the center frequency is tuned to a frequency slightly offset from the carrier of the signal. In this way the frequency modulated signal sits on the slope of the response curve, giving rise to the name of FM slope detector.

The simplest frequency demodulator, the *slope detector,* makes use of a tuned circuit and a diode detector to convert frequency variations to voltage variations. The basic circuit is shown in Figure. 6.

The transformer, T, shown in Figure (a), passes the received signal to the diode D1. The secondary winding of the transformer T1 used as the inductor, and a capacitor. C2 is connected in parallel to constitute an LC resonating circuit. Note that at the secondary winding is tuned to a frequency slightly less than the resonating frequency (fr) of the LC resonating circuit. In short, the resonant frequency (fr) is greater than the central frequency of the input signal (fc).

When the signal frequency increases above *f*, the amplitude of the carrier voltage rises and when the signal frequency decreases below *f* the carrier voltage falls.

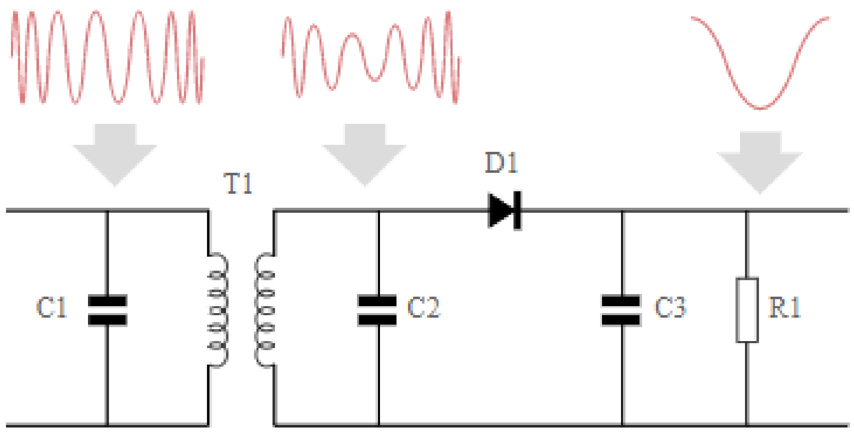


Figure 6 : Slope Detector

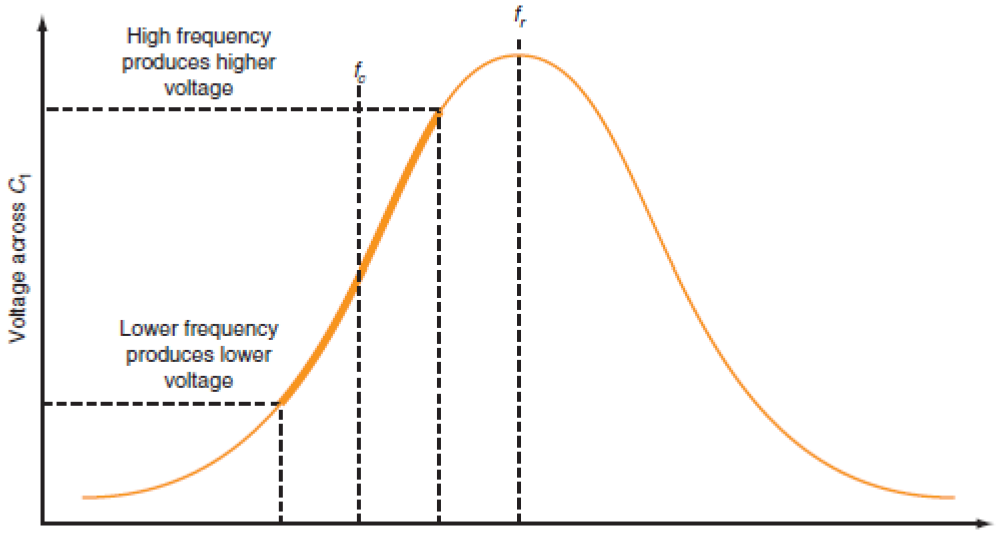


Figure 7: Response curve of tune circuits

To use the circuit to detect or recover FM, the circuit is tuned so that the center (fc) or carrier frequency of the FM signals is approximately centered on the leading edge of the response curve, as shown in Figure.7. As the carrier frequency varies above and below its center frequency, the tuned circuit responds as shown in the figure. If the frequency goes lower than the carrier frequency, the output voltage across C2 decreases. If the frequency goes higher, the output across C2 goes higher. Thus, the ac voltage across C2 is proportional to the frequency of the FM signal.

In short, the frequency variation is converted into the corresponding voltage variation, and the voltage available at the anode of the diode D carries both the amplitude variation and the frequency variation in direct proportion to the modulating signal.

2.12 Super heterodyne Receiver

All modern radio receivers are essentially the superheterodyne receivers. They are the most superior (super) circuits which utilize the principle of 'heterodyning' (mixing or beating) two frequencies.

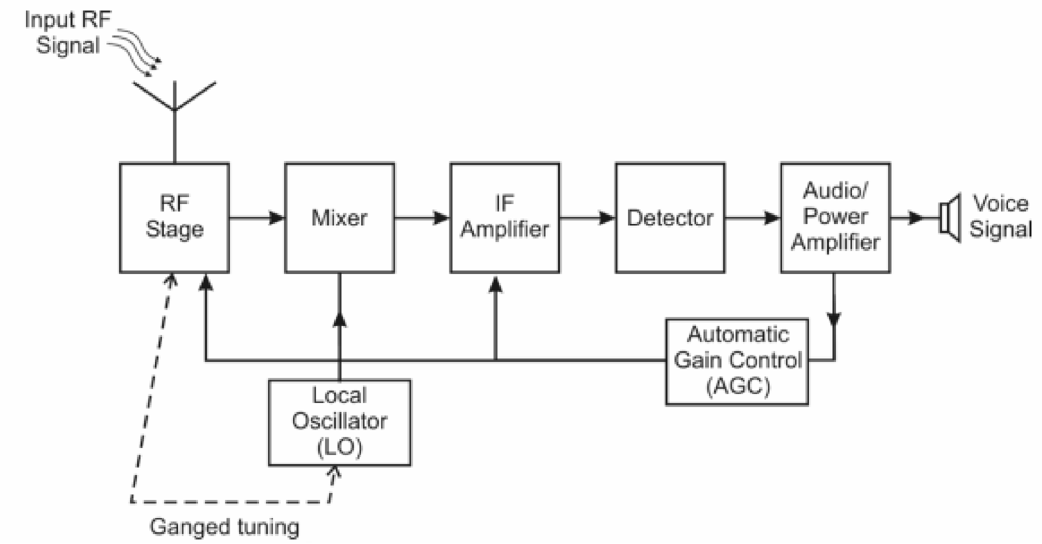


Figure 8: Block diagram of Super heterodyne Receiver

Receiving antenna: The receiving antenna receives the signal which was sent by the transmitter. It sends the received signal for further processing.

RF Stage: The received signal is fed to the RF amplifier stage so as to amplify it, as the signal gets attenuated during long-distance transmission. It is tuned in such a way that it can choose the desired carrier frequency and amplify it. RF amplifiers provide some initial gain and selectivity, they are sometimes referred to as preselectors.

Mixer:

The output of the RF amplifier is applied to the input of the mixer. The mixer also receives an input from a local oscillator or frequency synthesizer. The mixer output is the input signal, the local oscillator signal, and the sum and difference **frequencies of these signals. Usually a tuned circuit at the output of the mixer selects the difference frequency or intermediate frequency** (IF). The sum frequency may also be selected as the IF in some applications. The mixer may be a diode, a balanced modulator, or a transistor**. The typical value of intermediate frequency** (IF) for AM is **455 KHz** whereas FM receiver is **10.7MHz.**

Local Oscillators:

The local oscillator is made tunable so that its frequency can be adjusted over a relatively wide range. As the local-oscillator frequency is changed, the mixer translates a wide range of input frequencies to the fixed IF.

IF Amplifiers:

The output of the mixer is an IF signal containing the same modulation that appeared on the input RF signal. This signal is amplified by one or more IF amplifier stages, and most of the receiver gain is obtained in these stages. Here, the sensitivity and selectivity are uniform and does not show variations

Demodulators

The highly amplified IF signal is finally applied to the demodulator, or detector, which recovers the original modulating information. The demodulator may be a diode detector (for AM), a quadrature detector (for FM) etc.

Automatic Gain Control (ACG)

The output of a demodulator is usually the original modulating signal, the amplitude of which is directly proportional to the amplitude of the received signal. The recovered signal, which is usually ac, is rectified and filtered into a dc voltage by a circuit known as the automatic gain control (AGC) circuit. This dc voltage is fed back to the IF amplifiers, and sometimes the RF amplifier, to control receiver gain. AGC circuits help maintain a constant output voltage level over a wide range of RF input signal levels; they also help the receiver to function over a wide range so that strong signals do not produce performance-degrading distortion.

Principle of Heterodyning (Mixing Principles)

The selected radio frequency (***fs***) and a high frequency (***fo)*** produced by a local oscillator provided in the receiver are fed into a 'mixer' in which both frequencies are heterodyned, as a result of which, lower and higher frequencies are produced. The mixer circuit is so designed that lower frequency (***fo - fs***) are accepted as 'output' and upper frequency (***fo + fs***) are rejected.

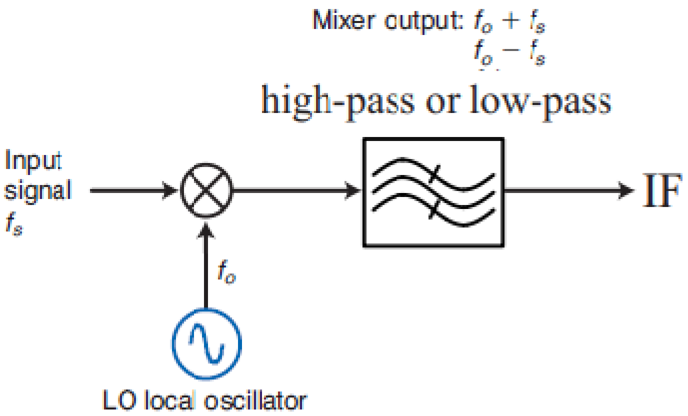


Figure 9: Concept of a mixer

For example, for an FM radio receiver to translate an FM signal at 107.1 MHz to an intermediate frequency of 10.7 MHz for amplification and detection, a local oscillator frequency of 96.4 MHz is used. The mixer output signals are $f_s =$ 107.1 MHz, $f_o = 96.4$ MHz, $f_o + f_s = 96.4 + 107.1 = 203.5$ MHz, and $f_s - f_o =$ $107.1 - 96.4 = 10.7$ MHz. Then a filter selects the 10.7-MHz signal (the IF, or f_{IF}) and rejects the others.

Question Bank

(A) Multiple Choice Questions:

1. To superimpose low frequency signals on the high frequency signal is known as ______.

a) modulation b) demodulation c) both and b d) none of these

2. The method used to recover original signal from modulating signal is known as ______.

a) modulation b) demodulation c) both and b d) none of these

3. Modulation is done at______.

a) transmitter b) receiver c)both receiver and Transmitter d) none of these

4. Demodulation is done at______.

a) transmitter b) receiver c)both receiver and Transmitter d) none of these

5. In AM, when Em>Ec then this condition is known as ______.

a) under modulation b) over modulation c)ideal condition d) none of these

6. In AM, when Em=Ec then this condition is known as ______.

a) under modulation b) over modulation c)ideal condition d) none of these

7. In AM, when Em < Ec then this condition is known as ______.

a) under modulation b) over modulation c)ideal condition d) none of these

8. In AM, in under modulation condition we have ______.

a) ma=1 b) ma < 1 c) ma >1 d) none of these

9. In AM, in ideal modulation condition we have ______.

a) ma=1 b) ma < 1 c) ma >1 d) none of these

10. In AM, in over modulation condition we have ______.

a) ma=1 b) ma < 1 c) ma >1 d) none of these

11. The amplitude of an audio signal is10Vand that of carrier wave is 50V, then percentage of modulation index is _____

a) 0 .2% b) 20% c) 5% d) 50%

12. In super heterodyne receiver, difference in frequency signal is termed as _____signal.

a) IF b) RF c) AF d) none of these

13. The maximum frequency deviation allowed in FM broadcast transmitter is ______.

a) 15 KHz b) 75 KHz c) 100 KHz d) 50 KHz

14. Slope detector consists of ______ tuned circuit

a) Series b) Parallel

c) Perpendicular d) None of these

15. The modulation index of FM = ______

a) Δf/fm b) fm/Δf

c) Δf/fm-1 d) None of these

16. In an AM wave, the majority of the power is in ______

a) Lower sideband b) Upper sideband

c) Carrier d) None of these

17. Slope detector is used for ______ .

a)	Frequency Modulation	b)	Frequency Demodulation
c)	Amplitude Modulation	d)	Amplitude Demodulation

18. In amplitude modulation, ______ of the carrier signal is varied

a)	amplitude	b)	frequency
c)	phase	d)	none of these

(A) Short Answer Questions:

1. What is the need of modulation?
2. Define modulation index and percentage modulation in AM.
3. Explain the working of AM diode detector.
4. Define frequency deviation in FM?
5. What are the advantages of FM.?
6. What is meant by Voltage control oscillator (VCO)?
7. Define modulation index of AM and FM
8. Define modulation index of an AM signal

(B) Short Answer Questions:

1. Define AM. Obtain an expression for AM wave and draw the frequency spectrum for the same.
2. Explain the power distribution of AM Wave.
3. With neat block diagram explain the FM super heterodyne radio receiver.
4. Draw the block diagram of FM super heterodyne radio receiver. Explain working of each block mentioning the typical frequencies at different points.
5. With neat diagram explain the slop detector for FM.

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