BASIC ELECTRONICS

Common to 1st Year

ARUNKUMAR G **M.Tech**

Lecturer in E&CE Dept.,

S.T.J.I.T., Ranebennur.

For suggestions and feedback:

Cell: 9731311770, 8553655825, 8095382275

e-mail: arunkumar.stjit@gmail.com

ARUNKUMAR G M.Tech
Lecturer in E&CE Department
S.T.J.I.T., Ranebennur

COMMUNICATION SYSTEMS

❖ Communication :-

Communication is the process of transferring information meaningfully (voice, text, picture etc) from one point to another. In electronics, communication refers to the sending, receiving information.

Types of communication

The various types of communication's are

1) Radio telephony and telegraphy
2) Radio broadcasting
3) Point to point mobile communication
4) Computer communication
5) Radar
6) Radio telemetry and Radio aids to navigation

Radio Communication

Radio communication is the process of sending information in the form of electronic signal from one place and receiving it in another place without using any connecting wires between the transmitter and receiver it is also called wireless communication.

Ex! TV broadcasting and Radio broadcasting.

❖ Communication :-

Communication is the process of transferring information meaningfully (voice, text, picture etc) from one point to another. In electronics, communication refers to the sending, receiving information.

Types of Communication

The various types of communication's are

1) Radio telephony and telegraphy
2) Radio broadcasting
3) Point to point mobile communication
4) Computer communication
5) Radar
6) Radio telemetry and Radio aids to navigation

Radio Communication

Radio communication is the process of sending information in the form of electronic signal from one place and receiving it in another place without using any connecting wires between the transmitter and receiver it is also called wireless communication.

Ex: TV broadcasting and Radio broadcasting.

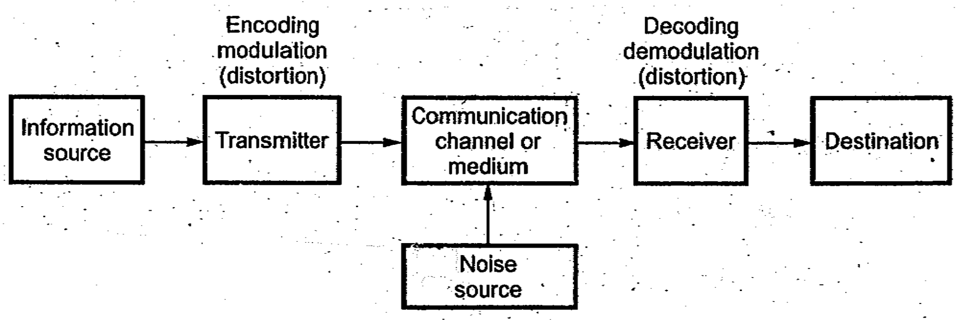
❖ **Why is modulation necessary? With the help of a block schematic explain important features of a communication system?**

Jan-04, 7M

The (baseband) message signal are incompatible for direct transmission over the medium (channel) and therefore we have to used modulation techniques for the transmission of msg signal.

For next part refer Next question

1. **With a block diagram, explain the important features of a communication system.** **Jan-04, 6M**
2. **Draw the block diagram of a communication system and explain the function of each stage.** **June-03, 8M**



Communication system

Fig shows the block diagram of communication system

<u>Information Source</u> :-

Information source gives the message to be transmitted.

Ex : Text, voice, video etc.

<u>Transmitter</u> :- The message is converted into electrical form and then transmitted. Before transmitting electrical signal is modulated. So that it becomes

ARUNKUMAR G M.Tech, *Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.*

easy to transmit for longer distance.

Channel :- channel is the medium through which the electrical signal is transmitted from one place to another.

There are two types of channels.

1) Wired channel or line communication.

Ex: Co-axial cable, OFC, pair of conducting wire.

2) Wireless channel or Radio channels

Ex: Free space.

Noise Source :- Noise is an unwanted signal that gets added to the message signal during transmission over the channel.

Noise signal is random in nature. Its effect is greatest when message signal is weak.
Noise may be natural or Man made.

Receiver :- The original message signal is extracted from the modulated signal at the receiver. Most of the receiver are of superheterodyne type receiver.

The O/p of receiver can be fed to loud speaker or radar display or video display & TV picture tube etc.

Line communication :-

Line communication uses a pair of wires to carry the information signal from the transmitter to the receiver. It is called as wired communication

Ex: Telephony and line telegraphy.

ARUNKUMAR G M.Tech, Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.

Radio Communication :

Radio communication does not use connecting wires between transmitter and receiver for sending information signal. It is also called as wireless communication.

Ex: TV broadcasting and Radio broadcasting.

Frequency bandwidth :

The frequency Bandwidth as the range of signal frequencies that can be transmitted over a , common channel without any distortion.

Ex: frequency bandwidth of a telephone line is 3.4 KHz.

Modulation :-

Modulation is the process of changing some characteristics (amp. phase or frequency) of a carrier wave in accordance with the instantneous value of modulating signal.

Types of Modulation

There are three diffrent types of modulation

1) Amplitude modulation
2) Frequency modulation
3) Phase modulation

ARUNKUMAR G M.Tech, *Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.*

and then it is difficult to seporate these signals at the receiver end.

3) Increases the range of communication:-

* Low frequency signals have poor radiation and they get highly attenuated. Therefore baseband signals cannot be transmitted directly over long distances.
* Modulation increases the frequency of the signal and thus they can be transmitted over long distances.

4). Allows multiplexing of signals:-

* Modulation allows the multiplexing to be used. Multiplexing means transmission of two or more signals simultaneously over the same communication channel.

Ex: 1) Number of TV channels operating simultaneously
2) Number of radio stations broadcasting the signals in MW & SW and Simultneously.

5) Allows adjustments in the bandwidth:-

Bandwidth of a modulated signal may be made smaller or larger.

6) Improves quality of reception

Modulation techniques Like frequency modulation, pulse code modulation reduces the effect of noise improves quality of reception.

❖ **Define Amplitude modulation? Explain the advantages of modulation.**

Amplitude modulation

Amplitude modulation is defined as the modulation in which the amplitude of the carrier wave is varied in accordance with the instantaneous amplitude of the modulating signal, keeping its (carrier) frequency and phase constant.

The advantages of modulation are

1) Reduce the height of antenna :-

Height of antenna is a function of wavelength 'λ'. The minimum height of antenna is given by $\lambda/4$.

i.e height of antenna $= \frac{\lambda}{4} = \frac{c}{4f}$

$\because \boxed{c = \lambda . f \quad \lambda = \frac{c}{f}}$

where, $\lambda = \frac{c}{f}$

$c = 3\times10^8$, velocity of light

f = Transmitting frequency

Ex: i) $f = 15\,kHz$

height of antenna $= \frac{\lambda}{4} = \frac{c}{4f} = \frac{3\times10^8}{4\times15\times10^3} = 5000$ meters

ii) $f = 1\,MHz$

height of antenna $= \frac{\lambda}{4} = \frac{c}{4f} = \frac{3\times10^8}{4\times1\times10^6} = 7$ meters

From above two examples it is clear that as the transmitting frequency is increased, height of the antenna is decreased.

2) Avoids mixing of signals

All audio (message) signals ranges from 20Hz to 20kHz. The transmission of message signals from various sources causes the mixing of signals

❖ **Explain the need for modulation in communication systems.** **June-05,4M**

❖ **Explain the need for modulation.** **Jan-06,4M | Jan-09,4M | June-08,4M**

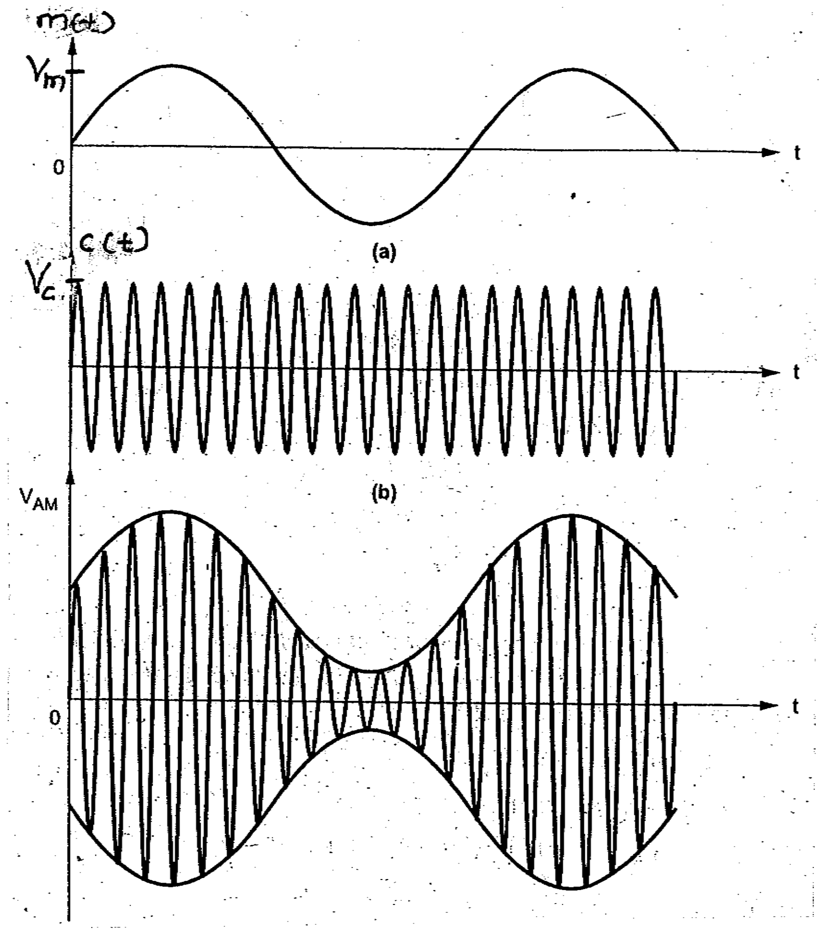
The message (baseband) signals are incompatiable for direct transmission over the medium (channel) and therefore we have to use modulation techniques for the transmission of message signals.

The advantages of modulations are

1) Reduce the height of the antenna
2) Avoids mixing of signals
3) Increase the range of communication.
4) Allows multiplexing of signals
5) Allows adjustments in the BW.
6) Improves quality of reception.

---

1. **Explain with waveforms the principle of amplitude modulation. Write the expression for AM wave.** **Jan-03,5M | Jan-10,6M**
2. **Define AM and derive the necessary expression for AM.** **Jan-05, 8M**
3. **Derive an expression for the instantaneous value of an AM signal in terms of carrier and sideband frequencies.** **Jan-05, 8M**
4. **Explain amplitude modulation. Derive an expression for the instantaneous value of an AM signal in terms of carrier and sideband frequencies.** **June-06, 8M**



Amplitude modulation is defined as the modulation in which the amplitude of the carrier wave is varied in accordance with the Instantaneous amplitude of the modulating signal keeping its (carrier) frequency and phase constant.

The Instantaneous Value of modulating signal is

$$\boxed{m(t) = V_m \sin \omega_m t} \longrightarrow (1)$$

Where $V_m \rightarrow$ Max amplitude of modulating signal
$\omega_m \rightarrow 2\pi f_m$ = Angular frequency and
$f_m \rightarrow$ frequency of modulating Signal

The Instantaneous Value of carrier signal is

$$c(t) = V_c \sin \omega_c t \longrightarrow (2)$$

The amplitude of the AM signal is given by

$$V(t) = V_c + m(t) \quad \text{--- (3)}$$

Subsititute eqⁿ (1) in eqⁿ (3), we get

$$V(t) = V_c + V_m \sin \omega_m t \quad \text{--- (4)}$$

* The instantaneous voltage of AM wave is

$$V_{AM} = V(t) \sin \omega_c t \quad \text{--- (5)}$$

Subsititute eqⁿ (4) in eqⁿ (5) we get

$$V_{AM} = [V_c + V_m \sin \omega_m t] \sin \omega_c t$$

$$V_{AM} = V_c \left[1 + \frac{V_m}{V_c} \sin \omega_m t\right] \sin \omega_c t$$

W.K.T $\mu = m = \dfrac{V_m}{V_c}$

$$V_{AM} = V_c [1 + m \sin \omega_m t] \sin \omega_c t$$

$$V_{AM} = V_c \sin \omega_c t + m V_c \sin \omega_c t \cdot \sin \omega_m t$$

By using trignometric relation

$$\sin A \cdot \sin B = \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]$$

$$V_{AM} = \underbrace{V_c \sin \omega_c t}_{\text{carrier}} + \underbrace{\frac{mV_c}{2} \cos(\omega_c - \omega_m)t}_{\text{Lower Sideband}} - \underbrace{\frac{mV_c}{2} \cos(\omega_c + \omega_m)t}_{\text{upper sideband.}}$$

Frequency spectrum :-

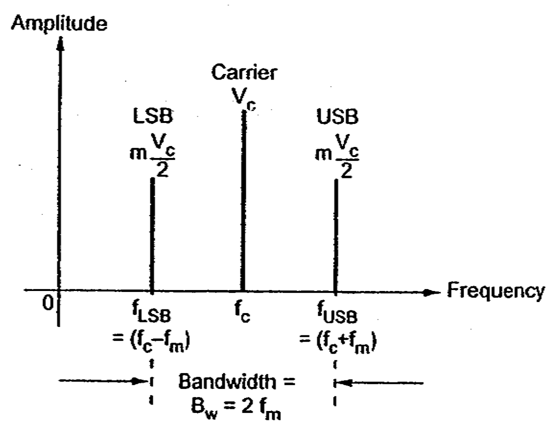


Fig. 12.6 Frequency spectrum of AM wave

BW of AM wave

$$BW = f_{USB} - f_{LSB}$$

$$= f_c + f_m - [f_c - f_m]$$

$$= \cancel{f_c} + f_m - \cancel{f_c} + f_m$$

$$\boxed{BW = 2f_m}$$

The BW of an AM wave is twice the frequency of the modulating signal.

Modulation Index

* Modulation index is defined as the ratio of the amplitude of the modulating voltage to the amplitude of the carrier wave and is given by

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

* Modulation Index is expressed in percentage and is called percentage modulation.

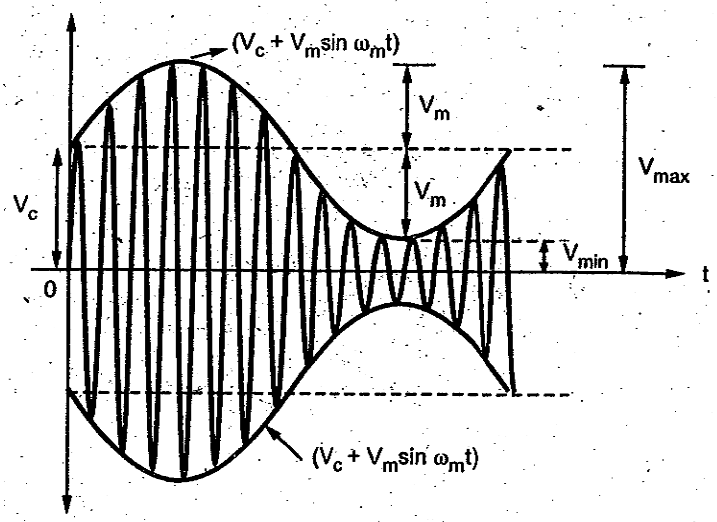
$$\% \ m = \frac{V_m}{V_c} \times 100\%$$

NOTE :

1) If $V_m > V_c$, then distortion is introduced into the system.
2) For proper amplitude modulation, $A_m < A_c$.
3) Modulation Index lies between '0' and '1'.

ARUNKUMAR G M.Tech, Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.

❖ **Calculate modulation index using AM wave.** **June-07, 5M**



WKT $m = \dfrac{V_m}{V_c}$ —— (1)

From fig $V_m = \dfrac{V_{max} - V_{min}}{2}$ — (2)

$V_c = V_{max} - V_m$ —— (3)

substitute eqn (2) in eqn (3) we get

$$V_c = V_{max} - \left[\frac{V_{max} - V_{min}}{2}\right]$$

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

$$V_c = \frac{V_{max} + V_{min}}{2} \quad \text{— (4)}$$

substitute eqn (2) and (4) in eqn (1), we get

$$m = \frac{V_{max} - V_{min}/\cancel{2}}{V_{max} + V_{min}/\cancel{2}}$$

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

❖ Obtain the expression for total transmitted power of AM wave.

W.K.T AM wave is given by

$$V_{AM} = V_c \sin 2\pi f_c t + \frac{mV_c}{2}\cos(\omega_c - \omega_m)t - \frac{mV_c}{2}\cos(\omega_c+\omega_m)t \quad \text{—(1)}$$

The AM wave has three components

i) Unmodulated carrier ii) LSB iii) USB

∴ The total power of AM wave is the sum of the carrier power 'P_c' and Power in the two sidebands (ie P_{USB} & P_{LSB})

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

$$P_T = \frac{V_c^2}{R} + \frac{V_{LSB}^2}{R} + \frac{V_{USB}^2}{R}$$

* The average carrier power

$$P_c = \frac{\left(\frac{V_c}{\sqrt{2}}\right)^2}{R} = \frac{V_c^2}{2R}$$

* The average Sideband power is

$$P_{USB} = P_{LSB} = \left(\frac{mV_c}{2\sqrt{2}}\right)^2 / R$$

$$= \frac{\frac{m^2V_c^2}{4\times 2}}{R}$$

$$P_{USB} = P_{LSB} = \frac{m^2V_c^2}{8R}$$

W.K.T $P = \frac{V^2}{R}$

W.K.T $V_{rms} = \frac{V_m}{\sqrt{2}}$

Ily $V_{crms} = \frac{V_c}{\sqrt{2}}$

$$P = \frac{V_{crms}^2}{R} = \frac{[V_c/\sqrt{2}]^2}{R}$$

$$P = \frac{V_c^2}{2R}$$

The average total power

$$P_T = P_C + P_{USB} + P_{LSB}$$

$$= \frac{V_C^2}{2R} + \frac{m^2 V_C^2}{8R} + \frac{m^2 V_C^2}{8R}$$

$$= \frac{V_C^2}{2R}\left[1 + \frac{m^2}{4} + \frac{m^2}{4}\right]$$

$$\boxed{P_T = P_C\left[1 + \frac{m^2}{2}\right]}$$

$$P_{USB} = P_{LSB} = \frac{\left(\frac{mV_C}{2\sqrt{2}}\right)^2}{R}$$

$$= \frac{\frac{m^2 V_C^2}{4 \times 2}}{R}$$

$$P_{USB} = P_{LSB} = \frac{m^2 V_C^2}{8R}$$

$$\left[\because \frac{m^2}{4} + \frac{m^2}{4} = \frac{2m^2}{4} = \frac{m^2}{2}\right]$$

NOTE :

For 100% modulation $m = 1$, we have

$$P_T = P_C\left[1 + m^2/2\right]$$

$$= P_C\left[1 + 1^2/2\right]$$

$$P_T = 1.5\, P_C$$

$$P_C = \frac{1}{1.5} P_T$$

$$\boxed{P_C = 0.666\, P_T}$$

In AM wave. the 66.66% of the transmitted power is used by the carrier signal and remaining 33.33% of the power is used by the sidebands(P_{USB} and P_{LSB})

$\therefore$ Power in sidebands is given by

$$\boxed{P_{SB} = P_T - P_C}$$

ARUNKUMAR G M.Tech, Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.

Transmission efficiency of an AM wave :-

Transmission efficiency is defined as the ratio of the power carried by the sidebands to the total transmitted power is called transmission efficiency 'η' is given by

$$\eta = \frac{P_{SB}}{P_T} = \frac{P_{USB} + P_{LSB}}{P_T}$$

W.K.T $\quad P_T = P_c\left(1 + \frac{m^2}{2}\right)$ and

$$P_{USB} = P_{LSB} = \frac{m^2 V_c^2}{8R}$$

$$\eta = \frac{\frac{m^2 V_c^2}{8R} + \frac{m^2 V_c^2}{8R}}{P_c\left[1 + \frac{m^2}{2}\right]} = \frac{\frac{m^2 V_c^2}{4R}}{P_c\left[\frac{2+m^2}{2}\right]}$$

$$= \frac{\frac{m^2}{2}\left[\frac{V_c^2}{2R}\right]}{P_c\left[\frac{2+m^2}{2}\right]} = \frac{m^2/2\ P_c}{P_c\left[\frac{2+m^2}{2}\right]}$$

$$= \frac{m^2/2}{\frac{2+m^2}{2}}$$

$$\eta = \frac{m^2}{m^2+2}$$

The percentage Transmission efficiency is

$$\boxed{\%\,\eta = \left(\frac{m^2}{m^2+2}\right) \times 100\%}$$

Ex : When $m = 1$. Calculate $\% \eta$?

W.K.T $$\% \eta = \frac{m^2}{m^2 + 2} \times 100\%$$

$$= \frac{1^2}{1^2 + 2} \times 100\%$$

Hence the maximum transmission efficiency of the AM wave is 33.33%.

Modulation Index interms of P_T and P_c :-

W.K.T $$P_T = P_c\left[1 + \frac{m^2}{2}\right]$$

$$\frac{P_T}{P_c} = 1 + \frac{m^2}{2}$$

$$\frac{m^2}{2} = \frac{P_T}{P_c} - 1$$

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

$$\therefore \quad m = \sqrt{2\left(\frac{P_T}{P_c} - 1\right)}$$

FORMULAE

1) Total modulation Index $m_t = \sqrt{m_1^2 + m_2^2 + \dots + m_n^2}$

2) $$P_t = P_c\left[1 + \frac{m_t^2}{2}\right]$$

3) $BW = 2f_m$

4) $f_{USB} = f_c + f_m$

5) $f_{LSB} = f_c - f_m$

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

7) $$P_c = \frac{V_c^2}{2R}$$

8) $P_{SB} = P_T - P_c$

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

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

11) Power in Sidebands $$P_{USB} = P_{LSB} = \frac{m^2 V_c^2}{8R} = \frac{V_c^2}{2R}\left[\frac{m^2}{4}\right] = P_c\left[\frac{m^2}{4}\right]$$

12) Magnitude of the Sideband component or Amplitude of Sideband $= \frac{mV_c}{2}$

13) Magnitude of Carrier ~~or~~ amplitude $= V_c$

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

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

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

Problems

1. A 500W, 1MHz carrier is amplitude modulated with a sinusoidal signal of 1kHz. The depth of modulation is 60%. Calculate the bandwidth power in the sidebands and the total power transmitted.

July-07 5M
Jan-03 5M
July-06 4M

Sol^n: Given $P_c = 500W$, $f_c = 1MHz$, $f_m = 1kHz$, $\%m = 60\%$, $m = 0.6$

1) $BW = 2f_m = 2 \times 1kHz = 2kHz$

2) Power in sidebands $P_{USB} = P_{LSB} = \frac{m^2 P_c}{4}$

$$= \frac{(0.6)^2}{4} \times 500 = 45 \text{ Watts}$$

$$P_{SB} = P_{USB} + P_{LSB} = 45W + 45W = 90W$$

3) $P_T = P_c\left[1 + \frac{m^2}{2}\right] = 500\left[1 + \frac{0.6^2}{2}\right] = 590 \text{ Watts}$

2. Draw the waveform of an AM Signal with V_{max} = 80V and V_{min} = 20V. Assume $f_c = 10 f_m$. Obtain i) Modulation index ii) Magnitude of the carrier wave and magnitude of the sideband components

July-03, 6M

Given: $f_c = 10 f_m$, $V_{max} = 80V$, $V_{min} = 20V$

1) Modulation Index $m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$

$$= \frac{80-20}{80+20} = \frac{60}{100} \qquad m = 0.6$$

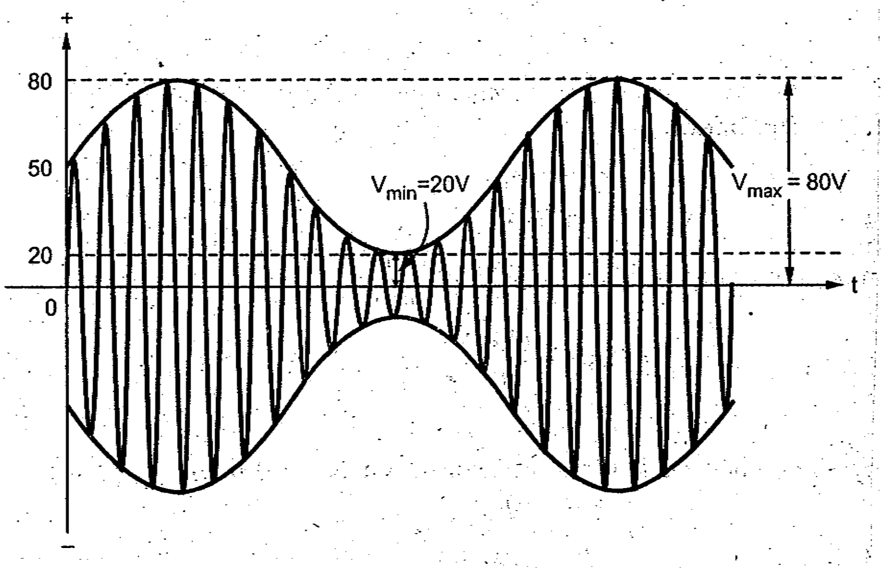
ARUNKUMAR G M.Tech, *Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.*

2) Magnitude of carrier wave

$$V_c = \frac{V_{max} + V_{min}}{2} = \frac{80+20}{2} = 50V$$

3) Magnitude of Sideband component

$$= \frac{mV_c}{2} = \frac{0.6 \times 50}{2} = 15$$



3) A Carrier of 1MHz with 400 watt of its power is amplitude modulated with a sinusoidal signal of 2500 Hz. The depth of modulation is 75%. Calculate the sideband frequencies, the bandwidth the power in the sidebands and the total power in the modulated wave

$\boxed{\text{Jan -04, 6M}}$

Given : $f_c = 1MHz$, $P_c = 400W$, $f_m = 2500Hz$

$m = 0.75$

ARUNKUMAR G M.Tech, *Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.*

Calculate f_{USB}, f_{LSB}, BW, P_T, P_{SB}, P_{LSB} & P_{USB}

i) $f_{USB} = f_c + f_m = 1\,MHz + 2500\,Hz = 1002.5\,Hz$

ii) $f_{LSB} = f_c - f_m = 1\,MHz - 2500\,Hz = 997.5\,KHz$

iii) $BW = 2f_m = 2 \times 2500\,Hz = 5\,KHz$

iv) $P_T = P_c\left[1 + \frac{m^2}{2}\right] = 400\left(1 + \frac{(0.75)^2}{2}\right) = 512.5\,Watt$

v) $P_{SB} = P_T - P_c = 512.5W - 400W = 112.5W$

vi) Power in each sideband

$$P_{USB} = P_{LSB} = P_c\left(\frac{m^2}{4}\right) = \overset{100}{\cancel{400}}\left(\frac{0.75}{\cancel{4}}\right) = 56.25W$$

---

4) A carrier of 2MHz with 1KW of its power is amplitude modulated with a sinusoidal signal of 2KHz. The depth of modulation is 60%. Calculate sidebands frequencies the B.W, the power in the sidebands and the total power in the modulated wave.

Jan-04 6M

Given : $f_c = 2\,MHz$, $m = 0.6$, $f_m = 2\,KHz$

$P_c = 1\,KW$

Calculate : f_{USB}, f_{LSB}, BW, P_T, P_{USB}, P_{LSB}, P_{SB}

Solution :

(1) $P_{USB} = f_c + f_m = 2\times10^6 + 2\times10^3 = 2.002\times10^6\,Hz$

(2) $f_{LSB} = f_c - f_m = 2\times10^6 - 2\times10^3 = 1998\,KHz$

ARUNKUMAR G M.Tech, Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.

3) $BW = 2f_m = 2 \times 2KHz = 4KHz.$

4) $P_T = P_c\left[1+\frac{m^2}{2}\right] = 1\times10^3\left[1+\frac{(0.6)^2}{2}\right] = 1.8KW$

5) $P_{USB} = P_{LSB} = P_c\left[\frac{m^2}{4}\right] = 1\times10^3\left(\frac{0.6^2}{4}\right) = 90W$

6) $P_{SB} = P_T - P_c = 1.8KW - 1KW = 0.8KW$

---

5) A sinusoidal carrier voltage of frequency 1.2MHz is amplitude modulated by a sinusoidal voltage of frequency 20KHZ resulting in maximum and minimum modulated carrier amplitude of 110V and 90V respectively. Calculate

i) Frequency of lower and upper side bands

ii) Unmodulated carrier amplitude

iii) Modulation Index

iv) Amplitude of each side band.

Jan-06, 8M

Given: $f_c = 1.2MHz$, $f_m = 20KHz$, $V_{cmax} = 110V$, $V_{cmin} = 90V$

Sol^n: 1) i) $f_{LSB} = f_c - f_m = 1.2MHz - 20KHz = 1180KHz$

ii) $f_{USB} = f_c + f_m = 1.2MHz + 20KHz = 1220KHz$

2) $$V_c = \frac{V_{cmax} + V_{cmin}}{2} = \frac{110+90}{2} = 100V$$

3) $$m = \frac{V_{cmax} - V_{cmin}}{V_{cmax} + V_{cmin}} = \frac{110-90}{110+90} = 0.1$$

4) Amplitude of each sideband $= \frac{mV_c}{2} = \frac{0.1 \times 100}{2}$

$= 5V$

6) For an AM, amplitude of modulating signal is 0.5V and carrier amplitude is 1V. Find modulation Index.

$\boxed{\text{Jan - 07, 5M}}$

Given: $V_m = 0.5V$, $V_c = 1V$

$$m = \frac{V_m}{V_c} = \frac{0.5}{1} = 0.5$$

$$\% \, m = \frac{V_m}{V_c} \times 100\% = \frac{0.5}{1} \times 100\% = 50\%$$

7) A carrier of 750W, 1MHz is amplitude modulated by sinusoidal signal of 2KHz to a depth of 50%. Calculate bandwidth, power in sideband and total power transmitted.

$\boxed{\text{Jan - 08, 6M}}$

Given: $P_c = 750W$, $f_c = 1MHz$, $f_m = 2KHz$, $m = 0.5$

Sol^n: i) $BW = 2f_m = 2 \times 2KHz = 4KHz$

ii) Power in sidebands $P_{USB} = P_{LSB} = P_c\left(\frac{m^2}{4}\right)$

$$= 750\left(\frac{(0.5)^2}{4}\right) = 46.875\,W$$

$$P_{SB} = P_{USB} + P_{LSB} = 46.875\,W + 46.875\,W = 93.75\,W$$

iii) $$P_T = P_c\left(1 + \frac{m^2}{2}\right) = 750\left(1 + \frac{(0.5)^2}{2}\right) = 843.75\,W.$$

8) A 500W, 100KHZ carrier is modulated to a depth of 60% by modulating signal frequency of 1KHZ. Calculate the total power transmitted. what are the sideband components of the AM wave.

$\boxed{\text{Jan-10, 5M}}$

Given: $P_c = 500W$, $f_c = 100KHz$, $f_m = 1KHz$. $m = 0.6$

Soln: i) $$P_T = P_c\left(1 + \frac{m^2}{2}\right) = 500\left(1 + \frac{(0.6)^2}{2}\right) = 590W$$

ii) Sideband components of the AM wave

* $$P_{USB} = P_{LSB} = P_c\left(\frac{m^2}{4}\right) = 500\left(\frac{0.6^2}{4}\right) = 45W$$
* $$P_{SB} = P_{USB} + P_{LSB} = 45W + 45W = 90W$$
* $$f_{USB} = f_c + f_m = 100KHz + 1KHz = 101KHz$$
* $$f_{LSB} = f_c - f_m = 100KHz - 1KHz = 99KHz$$

❖ **With suitable waveform's, explain the principle of frequency modulation. What are its advantages over amplitude modulation?**

June-04, 8M

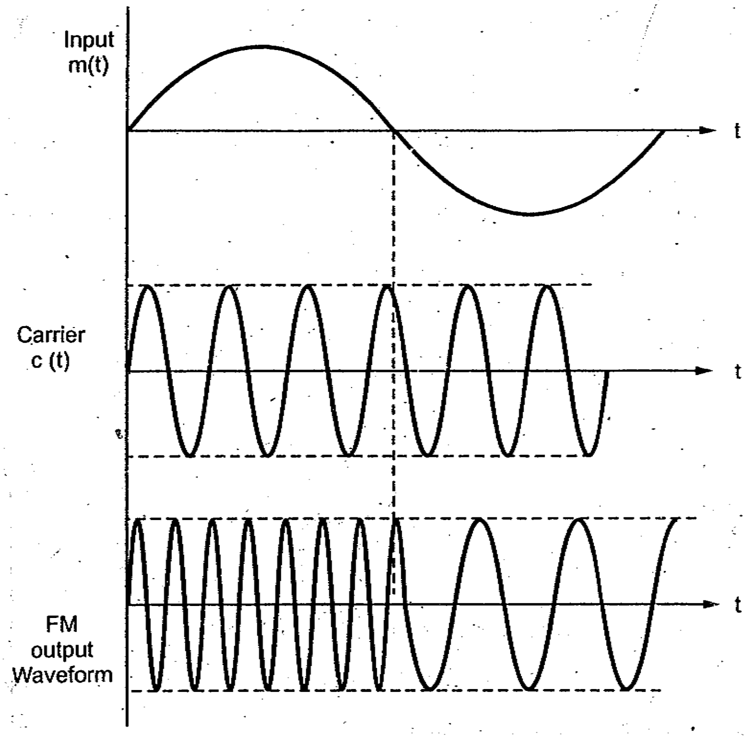


fig (1)

Frequency modulation is defined as the modulation in which the frequency of the carrier is varied in accordance with the instantaneous amplitude of the modulating signal keeping its (carrier) amplitude and phase constant.

FM has the following advantages over AM

1) In FM all the transmitted power is useful, whereas in AM 66.66% of the transmitted power is used by the carrier and remaining 33.33% of the power is used by the sidebands which convey information. so efficiency of AM is less compared to FM.

2) FM receivers use amplitude limiter circuits to eliminate the amplitude variations caused by noise. Due to this, FM reception is more immune to noise

than AM reception.

3) For commercial FM transmitting stations a guard band of frequencies is allocated this reduces adjacent channel interference, as compared to AM.

4) Since FM operates in VHF and UHF range, the propogation is line of sight propogation by space wave.

5) In FM, amplitude of carrier is constant. Hence transmitted power is constant and independent of modulation Index.

6) In FM greater transmitter efficiency can be realised using class-C amplifiers as amplitude of FM wave is constant.

7) Better quality, higher S.NR.

1. Explain the principle of frequency modulation. Draw the frequency spectrum of FM wave. **June-05, 6M**

2. Derive the formulae for the instantaneous value of an FM voltage and define the modulation index. **June-03, 6M**

Refer fig (1) previous page

* The FM wave in time domain is given by

$$\boxed{s(t) = A \sin[\theta(t)]} \quad -(1).$$

* The modulating signal is defined by

$$\boxed{m(t) = V_m \cos(2\pi f_m t)} \quad \text{—(2)}$$

* The instantaneous frequency of the FM Signal is given by

$$f_i(t) = f_c + K_f\, m(t) \quad \text{—(3)}$$

Subsititute eqⁿ(2) in eqⁿ(3) we get

$$f_i(t) = f_c + K_f V_m \cos(2\pi f_m t)$$

$$f_i(t) = f_c + \Delta f \cos(2\pi f_m t) \quad \text{—(4)}$$

Where $\Delta f = K_f A_m$ and it is called frequency deviation.

* WKT the angular velocity $\omega_i(t)$ is the rate of change of $\theta(t)$

$$\omega_i(t) = \frac{d}{dt}\theta(t)$$

$$2\pi f_i(t) = \frac{d}{dt}\theta(t) \quad \text{—(5)}$$

Integrating eqⁿ(5) w.r.t 't'

$$\int_0^t \frac{d}{\cancel{dt}}\theta(t)\,\cancel{dt} = \int_0^t 2\pi f_i(t)\,.dt$$

$$\theta(t) = \int_0^t 2\pi f_i(t)\,dt \quad \text{—(6)}$$

Subsititute eqⁿ(4) in eqⁿ(6) we get

$$\theta(t) = \int_0^t 2\pi\left[f_c + \Delta f \cos(2\pi f_m t)\right]dt$$

$$= \int_0^t 2\pi f_c\,dt + \int_0^t 2\pi\,\Delta f \cos(2\pi f_m t)\,dt$$

$$= 2\pi f_c t + \cancel{2\pi}\,\Delta f\,\frac{\sin(2\pi f_m t)}{\cancel{2\pi} f_m}$$

$$\because \int_0^t \cos at = \frac{\sin at}{a}$$

$$= 2\pi f_c t + \frac{\Delta f}{f_m} \cdot \sin(2\pi f_m t)$$

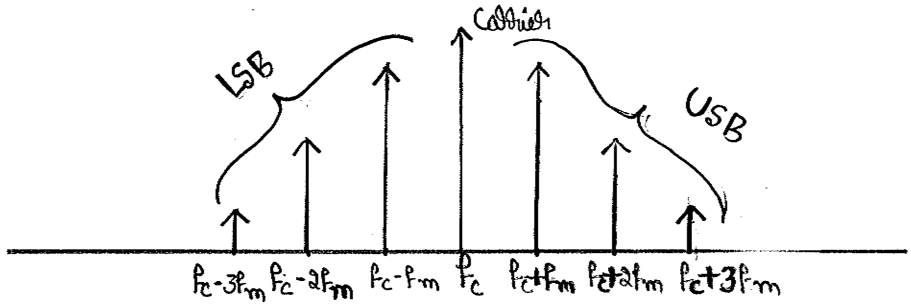
$$\theta(t) = 2\pi f_c t + m_f \sin(2\pi f_m t) \quad \text{—— (7)}$$

Where

$$m_f = \frac{\Delta f}{f_m}$$

Subsititute eq^n (7) in eq^n (1) we get

$$\boxed{S(t) = A \sin[2\pi f_c t + m_f \sin(2\pi f_m t)]}$$



Modulation Index (m_f or β) :-

Modulation Index is defined as the ratio of frequency deviation 'Δ_f' to the modulating frequency 'f_m'.

$$m_f = \frac{\text{Frequency deviation}}{\text{Modulating frequency}}$$

$$\boxed{m_f = \frac{\Delta_f}{f_m}}$$

Note :

$$\boxed{\begin{array}{l} \Delta_f = \delta \\ m_f = \beta \end{array}}$$

Note : In FM, the modulation Index m_f is greater than 1.

Bandwidth of FM :-

Theoretically FM requires infinite bandwidth

* By carson's rule, BW of FM wave is

$$\boxed{BW = 2f_m(1+m_f)} \quad (1)$$

NOTE :-

* The FM wave can also expressed interms of frequency deviation 'Δ_f'

W.K.T $m_f = \dfrac{\Delta_f}{f_m}$

$\Delta_f = m_f \cdot f_m$

From equation (1)

$$BW = 2f_m(1+m_f)$$
$$= 2f_m + 2m_f f_m$$
$$= 2f_m + 2\Delta_f$$
$$= 2\Delta_f\left[1 + \frac{f_m}{\Delta_f}\right]$$

$$\boxed{B.W = 2\Delta_f\left[1 + 1/m_f\right]}$$

$\because m_f = \dfrac{\Delta_f}{f_m}$

$\dfrac{1}{m_f} = \dfrac{f_m}{\Delta_f}$.

❖ **What are the advantages and disadvantages of frequency modulation? Explain.** **June-05, 6M June-04, 8M**

Advantages of FM :

1) In FM all transmitted power is useful, whereas in AM 66.66% of the transmitted power is used by the carrier

and remaining 33.33% of the power is used by the sidebands which convey information. So efficiency of AM is less compared to FM.

2) FM receivers use amplitude Limiter circuits to eliminate the amplitude variations caused by noise. Due to this, FM reception is more immune to noise than AM reception.

3) For commercial FM transmitting stations a guard band of frequencies is allocated this reduces adjcant channel interferance, as compared to AM.

4) Since FM operates in VHF and UHF range, the propogation is Line of sight propagation by space wave.

5) In FM. amplitude of carrier is constant. Hence transmitted power is constant and independent of modulation Index.

6) In FM greater transmitter efficiency can be realised using Class-C amplifiers as amplitude of FM wave is constant.

7) Better quality, higher SNR.

❖ **Disadvantages :-**

1) FM wave requires much larger transmission BW than AM wave. [BW- Band Width]

2) FM transmitter and Receiver are complex compared to AM.

3) In FM, the area of reception is small as it is limited to line of sight.

❖ **Compare the performance of AM and FM communication systems.**

Jan-05, 6M

Sl.No.	FM	AM
1.	The equation of FM wave is $S(t)_{FM} = A.\sin[\omega_c t + m_f \sin\omega_m t]$	The equation of AM wave is $S(t)_{AM} = A[1 + m.\sin\omega_m t]\sin\omega_c t$
2.	The modulation Index can have any value ie either < 1 or > 1.	The modulation Index is always always in between 0 and 1.
3.	All the transmitted power is useful.	Carrier power and one sideband power are useless.
4.	$BW = 2f_m[1 + m_f]$	$BW = 2f_m$
5.	Modulation Index $m_f = \frac{\Delta f}{f_m}$	Modulation Index $m = \frac{A_m}{A_c}$
6.	The main advantage of FM over AM is the noise immunity.	The AM system is more susceptible to noise and more affected by noise than FM.
7.	The BW required to transmit FM signal is much larger than the BW of AM.	The BW required to transmit AM signal is much less than that of FM.
8.	FM transmission and reception	AM equipments are less complex

ARUNKUMAR G M.Tech, *Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.*

Sl.No	FM	AM
	equipments are more complex.	less expensive.
9.	FM transmission is expensive than AM transmission.	AM transmission is cheaper than FM transmission
10.	Used short distance communication.	Used for long distance communication.

ARUNKUMAR G M.Tech, *Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.*

FM- FORMULAE

1. Modulation Index : m_f or $\beta = \frac{\Delta_f}{f_m}$

2. power dissipation : $P = \frac{A_c^2}{2R}$

3. Frequency deviation : $\Delta_f = m_f \times f_m$

$$\Delta_f = K_f V_m$$
$$K_f = \frac{\Delta_f}{V_m}$$

4. Bandwidth : $BW = 2(\Delta_f + f_m)$

or $BW = 2f_m[1 + m_f]$

5. Highest frequency reached
$f_{imax} = f_c + \Delta_f$

6. Lowest frequency reached $f_{imin} = f_c - \Delta_f$

7. Carrier Swing $= f_{imax} - f_{imin}$

* $f_c = f_{imax} - \Delta_f$
* $f_c = f_{imin} + \Delta_f$

$$= f_c + \Delta_f - [f_c - \Delta_f]$$
$$= \cancel{f_c} + \Delta_f - \cancel{f_c} + \Delta_f$$

Carrier Swing $= 2\Delta_f$.

* $$\Delta_f = \frac{\text{Carrier swing}}{2}$$

Problems

1. $V = 10 \sin[2\pi \times 10^8 t + 5 \sin(2\pi \times 15 \times 10^3 t)$.

find i) The carrier frequency ii) Modulation Index iii) Frequency deviation iv) Modulating frequency what power will this FM wave dissipate in a $10\,\Omega$ resistance.

Solution: WKT $A_c = 10V$

$$S(t)_{FM} = A \sin[2\pi f_c t + m_f \sin(2\pi f_m t)] \quad -(1)$$

Given

$$V = 10 \sin[2\pi \times 10^8 t + 5 \sin(2\pi \times 15 \times 10^3 t)] \quad -(2)$$

Comparing eq^n (1) and (2) we get

i) $f_c = 10^8\,Hz = 100MHz$

ii) $m_f = 5$

iii) $f_m = 15 \times 10^3\,Hz = 15KHz$

iv) $\Delta f = m_f \times f_m = 5 \times 15\,KHz = 75\,KHz$

* The power dissipated in a $10\,\Omega$ will be

$$P = \frac{A_c^2}{2R} = \frac{10^2}{2 \times 10} = \frac{100}{20} = 5W.$$

---

2) A 25MHz carrier is frequency modulated by a 400Hz audio sine wave. The carrier voltage is 4V and the max. deviation is 10KHz. write the equation for this FM wave.

Given: $f_c = 25MHz$, $A_c = 4V$, $\Delta f = 10KHz$, $f_m = 400\,Hz$

Sol^n: * $m_f = \frac{\Delta f}{f_m} = \frac{10 \times 10^3}{400} = 2.5$

WKT $S(t)_{FM} = A_c \sin[2\pi f_c t + m_f \sin(2\pi f_m t)]$

$S(t)_{FM} = 4 \sin[2\pi \times 25 \times 10^6 t + 2.5 \sin(2\pi \times 400 t)]$

---

3) In an FM System $K_f = 1 KHz/V$ and a sinusoidal modulating voltage of amplitude 15V and frequency 3KHz is applied. Find the maximum frequency deviation and modulation Index.

Given: $K_f = 1 KHz/V$, $V_m = 15V$, $f_m = 3KHz$

* $\Delta_f = K_f V_m = 1 \times 15 KHz$

* $m_f = \frac{\Delta f}{f_m} = \frac{15}{3} = 5$

---

4) In a FM system the audio frequency (AF) is 500Hz, the AF voltage is 2.5V and the deviation is 5KHZ. If the AF voltage is now increased to 7.5V, what is the new deviation? If the AF voltage is raised to 10V while AF is dropped to 250Hz, what is the deviation? Find the modulation Index in each case.

Given: i) $V_m = 2.5V$, $f_m = 500Hz$, $\Delta_f = 5KHz$

ii) $V_m = 7.5V$, $\Delta_f = ?$ $f_m = 500Hz$

iii) $V_m = 10V$, $f_m = 250Hz$, $\Delta_f = ?$

Solution: WKT $\Delta_f = K_f V_m$

$K_f = V_m/\Delta_f = \frac{5KHz}{2.5} = 2KHz/V$

ARUNKUMAR G M.Tech, Lecturer in E&CE Dept. S.T.J.I.T., Ranebennur.

when $V_m = 7.5V$, $\Delta_f = K_f . V_m = 2KHz/V \times 7.5V$
$= 15 KHz$

when $V_m = 10V$,
$\Delta_f = K_f V_m = 2KHz \times 10 = 20KHz$

Modulation Index

i) $m_{f1} = \frac{\Delta_{f1}}{f_{m1}} = \frac{5\times10^3}{500} = 10.$

ii) $m_{f2} = \frac{\Delta_{f2}}{f_{m2}} = \frac{15\times10^3}{500} = 30$

iii) $m_{f3} = \frac{\Delta_{f3}}{f_{m3}} = \frac{20\times10^3}{250} = 80$

---

5) If an FM wave is represented by the equation $s(t)_{FM} = 50 \sin(5\times10^8 t - 10 \cos 1000t)$, Calculate

i) Carrier and modulating frequencies

ii) Modulation Index and Maximum deviation

iii) Power dissipated by the wave in resistance to 75Ω.

Solution:

W.K.T

$$s(t)_{FM} = A \sin[W_c t + m_f \sin W_m t] \quad -(1)$$

Given

$$s(t)_{FM} = 50 \sin[5\times10^8 t - 10 \cos 1000t] \quad -(2)$$

Comparing eq^n (1) & (2) we get

$A = 50V$, $R = 75\Omega$

$W_c = 5\times10^8$, $\omega_m = 1000$, $m_f = 10$

i) WKT

$$W_c = 2\pi f_c$$

$$f_c = \frac{\omega_c}{2\pi} = \frac{5\times10^8}{2\pi} = 79.57\ MHz.$$

$$\omega_m = 2\pi f_m$$

$$f_m = \frac{\omega_m}{2\pi} = \frac{1000}{2\pi} = 159.15 Hz.$$

ii) $m_f = 10$

$$\Delta f = m_f f_m = 10 \times 159.15\ Hz = 1591.55$$

iii) $$P = \frac{A^2}{2R} = \frac{(50)^2}{2\times75} = 16.67\ W.$$

---

6) A 93.2 MHz carrier is frequency modulated by a 5KHz Sine wave. The resultant FM Signal has a frequency deviation of 40KHz.

a) Find the carrier Swing of the FM signal.

b) What are the highest and lowest frequencies attained by the frequency modulated Signal.

c) Calculate the modulation Index for the wave.

Given: $f_c = 93.2\ MHz$, $f_m = 5KHz$. $\Delta f = 40KHz$

Solution: a) Carrier swing $= 2\Delta f = 2\times 40KHz$
$= 80kHz.$

b) $f_{imax} = f_c + \Delta f = 93.2MHz + 40KHz$
$= 93.24\ MHz.$

$f_{imin} = f_c - \Delta f = 93.2MHz - 40KHz$

$f_{imin} = 93.16\ MHz$

c) $$m_f = \frac{\Delta f}{f_m} = \frac{40KHz}{5KHz} = 8.$$

7) When a 50.4 MHz carrier is frequency modulated by a sinusoidal AF modulating signal. The highest frequency reached is 50.405 MHz. Calculate.

a) The frequency deviation produced.

b) Carrier swing of the wave.

c) Lowest frequency reached.

Given:

$f_c = 50.4\,MHz$. $f_{imax} = 50.405\,MHz$

a) WKT $f_{imax} = f_c + \Delta f$

$\Delta f = f_{imax} - f_c$

$= 50.405\,MHz - 50.4\,MHz$

$\Delta f = 5\,kHz$.

b) Carrier Swing $= 2 \times \Delta f = 2 \times 5\,kHz = 10\,kHz$.

c) $f_{imin} = f_c - \Delta f = 50.4\,MHz - 5\,kHz$

$= 50.395\,MHz$.

---

8) Calculate the carrier swing, Carrier frequency, frequency deviation and modulation Index for a FM signal which reaches a maximum frequency of 99.047 MHz and a minimum frequency of 99.023 MHz. The frequency of the modulating signal is 7 kHz.

Given: $f_{imax} = 99.047\,MHz$, $f_{imin} = 99.023\,MHz$

$f_m = 7\,kHz$

Solution: i) Carrier swing $= f_{imax} - f_{imin}$

$= 99.047\,MHz - 99.023\,MHz$

$= 24\,kHz$

ii) Carrier swing $= 2\Delta f$

$$\Delta f = \frac{\text{Carrier swing}}{2} = \frac{24\,KHZ}{2} = 12\,KHz.$$

iii) $f_{i_{max}} = f_c + \Delta f$

$$f_c = f_{i_{max}} - \Delta f = 99.047\,MHz - 12\,KHz$$
$$= 99.035\,KHZ$$

iv) $$m = \frac{\Delta f}{f_m} = \frac{12\,KHz}{7\,KHz} = 1.714.$$

Radio Receivers :-

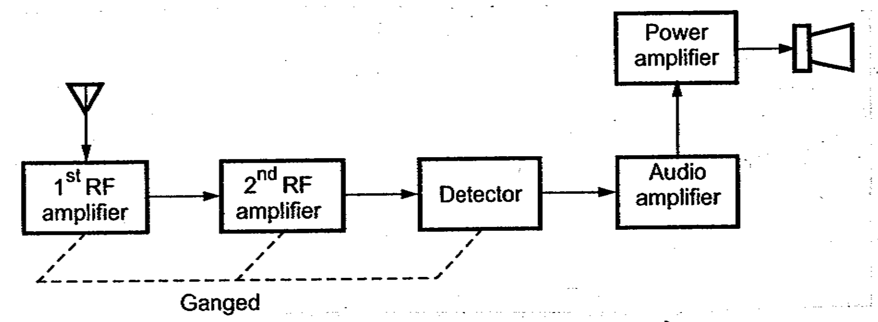
A radio receiver is a device that picks up the desired signal from numerous signals propagating at that time through the atmosphere, amplifies the desired signal to the required level to recover the original signal

There are two types of radio receivers.

1> Tuned Radio frequency receivers.

2> Super heterodyne receiver.

Tuned Radio frequency receiver :-



Block diagram of TRF receiver

* It consists of two or three stages of RF amplifier. detector, audio amplifier and power amplifier.

* The receiving antenna reduces the radio waves from different broadcasting stations.

* The RF amplifier stages placed between the antenna and detector to increase the strength of the received signal before it is applied to the detector.

* The RF amplifier tunes the desired radio waves. which employs tuned parallel circuit. The selected radio wave

is amplified by the RF amplifier.

* Therefore, they (RF amplifiers) provide amplification for sidebands band of frequencies and rejects all other frequencies.

* The amplified signal is fed to the detector circceit. This circuit extracts the audio signal from the radio wave.

* The recoverd audio signal is further amplified by the audio amplifier followed by power amplifier which provides sufficient gain to drive the loudspeaker.

Limitations or drawbacks

* 1) In tuned radio receivers, tuned circuits are used The capacitors in the tuned circuits are more variable. These capacitors are 'ganged' between the stages so that they all can be changed simulteanously when the tuning knob is rotated.

To have perfect tuning the capacitors value between the stages must be exactly same but this is not possible. so there is a considerable variations of 'Q'. This changes the sensitivity and selectivity of radio receivers.

2) There is a too much interfernce of adjacent stations.

Heterodyning

The process of mixing of two frequencies f_1 and f_2 to produce beat frequencies of $f_1 \pm f_2$ i.e $f_1 + f_2$ and $f_1 - f_2$ is called heterodyning.

* A superheterodyne receiver is so called because it use the process of heterodyning.

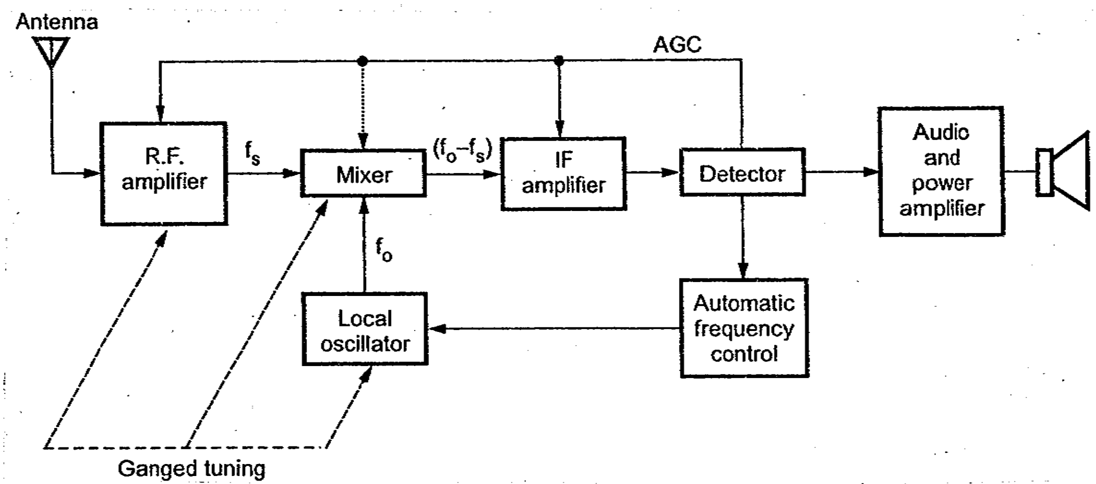
Superheterodyne Receiver.

* Draw the block diagram of a superheterodyne receiver and explain the function of each stage with necessary waveforms.

July-05, 10M | Jan-03, 10M.

* Draw the block diagram of super heterodyne AM receiver and explain the function of each block.

Jan-08, 10M | July-09, 8M | Jan-09, 8M | July-08, 10M



* The incoming radio frequency (or selected frequency) is converted to a fixed lower frequency called 'Intermediate frequency'. This is achieved by a special electronic circuit. called Mixer Circuit.

* In mixer circuit the incoming signals are mixed with the local oscillator frequency signal in which a way that a constant frequency difference is maintained between the local oscillator and the incoming signals.

The block diagram shows a superheterodyne receiver is as shown in fig.

RF amplifier stage :-

The RF amplifier stage uses a tuned parallel circuit L_1C_1 with a variable capacitor C_1. The radio waves from various broadcasting stations are intercepted by the receiving antenna are coupled to this stage.

This stage selects the desired radio wave and raises the strength of the wave to the desired level.

Local oscillator :-

The local oscillator generates a voltage of frequency f_o. this frequency may be either above or below the RF signal frequency.

In practice, it is above RF Signal frequency

Mixer :-

The amplified o/p of RF amplifier is fed to the mixer stage where it is combined with the o/p of a local oscillator. The two frequencies heterodyne or beat together and produce an Intermediate frequency (IF).

i.e Difference frequency is $\boxed{f_i = f_o - f_s}$

* The IF of 455KHz is chosen for the reason that the amplifier works with almost sensitivity & stability.

* The process of using two signals at slightly different frequency to produce a new frequency is called beating or heterodyning.

IF amplifier :-

The o/p of the mixer is always 455 KHz and is fed to fixed tuned IF amplifiers.

The 455 KHz signal is amplified by the IF amplifier and fed to detector.

Detector :-

The detector circuit consists of a diode half wave rectifier and RC filter.

Here the audio signal is extracted from the IF o/p.

* The diode detector is used because of its low distortion and excellent audio facility.

Audio and power amplifier :-

The audio signal from the detector is amplified by one or more stages of audio amplifiers till a suitable level is reached to drive the speaker.

* The speaker converts the audio signal into sound waves corresponding to the original sound at the transmitter.

AGC and AFC Circuit :-

AGC is used to maintain a constant o/p voltage levels over a wide range of RF i/p signal levels.

AFC :-

Circuit generates AFC signal which is used to adjust and stabilize the frequency of the local oscillator.

Advantages

1) High RF amplification
2) Improved selectivity
3) Lower cost
4) Less interferance of adjacent stations.