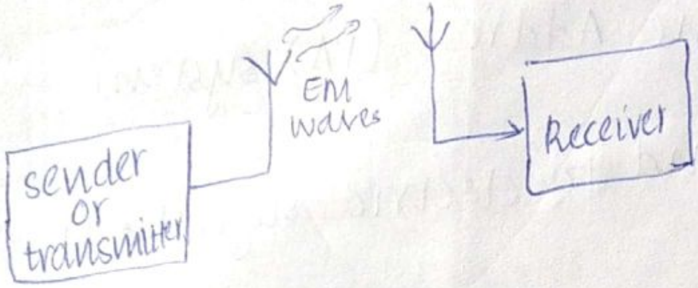
Electronic communication



Modulation

changing amplitude, frequency, phase of carrier wave

- Base band signal will be enclosed in carrier
messages (20 Hz - 3 kHz) are usually in low freq.

Need for modulation

(i) $E = h\nu$
when ν is ↓, E ↓
modulat^n is done to high freq.

(ii) Radiation is efficient only at high freq.

(iii) radiation can only be done with antennae
If no modulation, then l will be ↑
low freq. is modulated with high freq.
Thus freq., amplitude, phase of carrier wave is changed to that of modulating wave

freq. change → frequency modulation

amplitude change → amplitude modulation

so if f ↑, $\lambda = \frac{c}{f}$ so λ will be less

$\lambda/4$: quarter wave antennas

antennae height should be less

(iv) all freq. we use lie in same band. so frequency gets mixed
when different freq. is used for modulation, they will
never mix so lie in diff. freq.
so receiver can tune in station they wish

$v_c = V_c \sin(\omega_c t + \phi)$

V_c : peak value (amplitude)

ϕ_c : phase

v_c : Voltage of carrier

Analog modulation/continuous wave modulation

2 types

(i) Amplitude modulation (AM)

(ii) Angle modulation

(a) Frequency modulation (FM)

(b) Phase modulation (PM)

Digital modulation

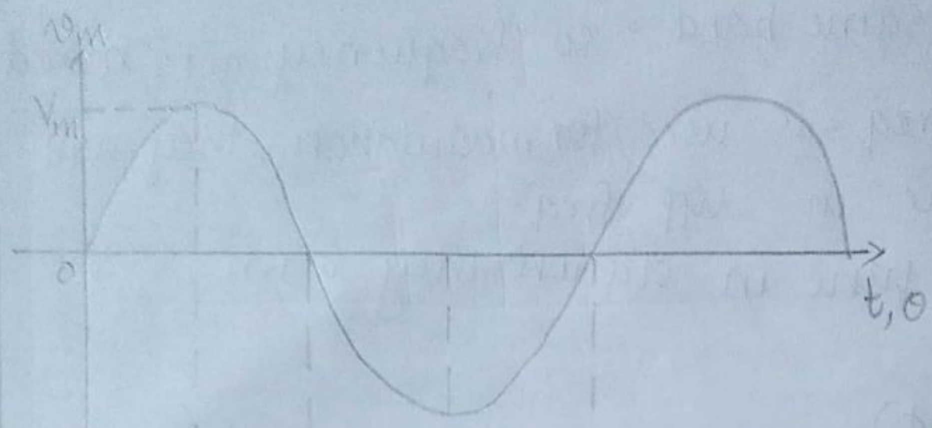
(i) ASK : amplitude shift keying

(ii) FSK : Frequency shift keying

(iii) PSK : phase shift keying

Amplitude modulation

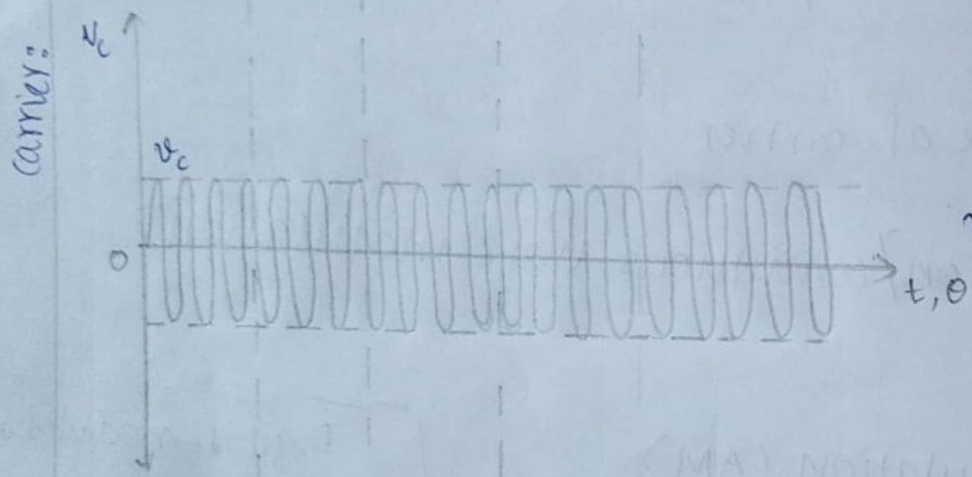
- In process of amplitude modulation, instantaneous amplitude of high frequency carrier wave is varied in proportion to the instantaneous amplitude of the message voltage value, keeping frequency and phase of carrier wave a constant.



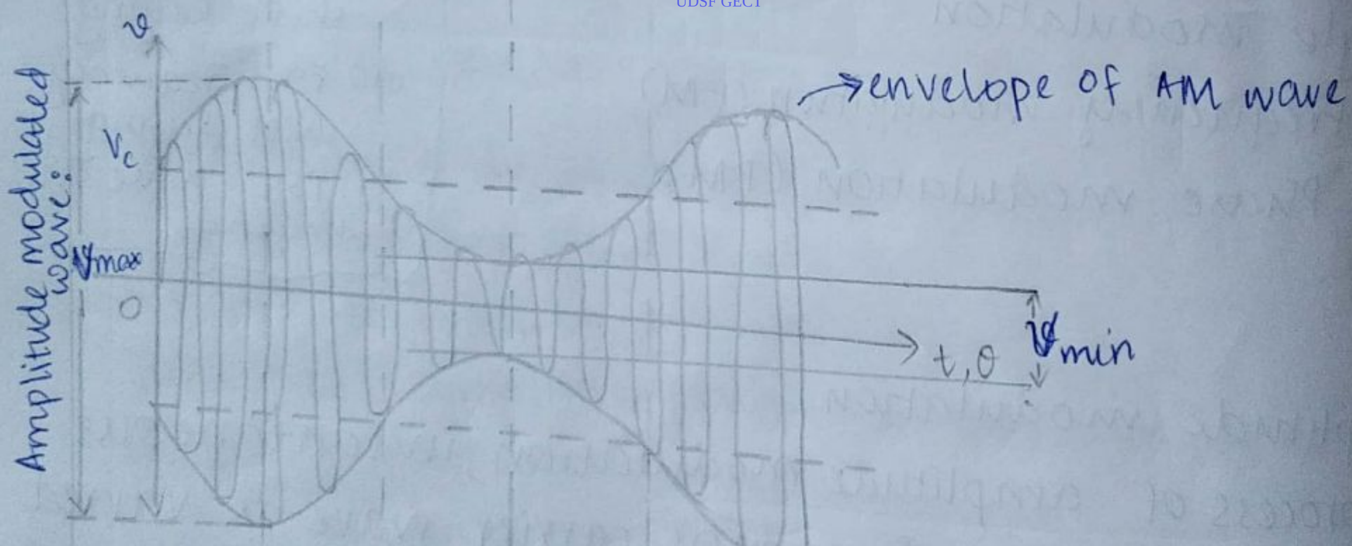
v_m: message or modulating voltage

$$\omega_m = 2\pi f_m$$

$$v_m = V_m \sin \omega_m t \quad \text{—(I)}$$



$$v_c = V_c \sin \omega_c t \quad \text{—(II)}$$



- Only instrument which display electrical waveform is CRO
- AM index: also called depth of A.M.

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

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \qquad 0 \leq m \leq 1$$

- when message wave voltage is 0, $m = 0$
- when $m = 1$, $V_m = V_c$
- when $m > 1$, no signal is received by receiver

This is called over modulation distortion

happens when message amplitude overlaps carrier amplitude.

$$v_m = V_m \sin \omega_m t \quad —(1)$$

$$v_c = V_c \sin \omega_c t \quad —(2)$$

AM wave is,

$$v = A \sin \omega_c t$$

where $A = V_c + v_m$

$$A = V_c + V_m \sin \omega_m t$$

$$v = (V_c + V_m \sin \omega_m t) \sin \omega_c t$$

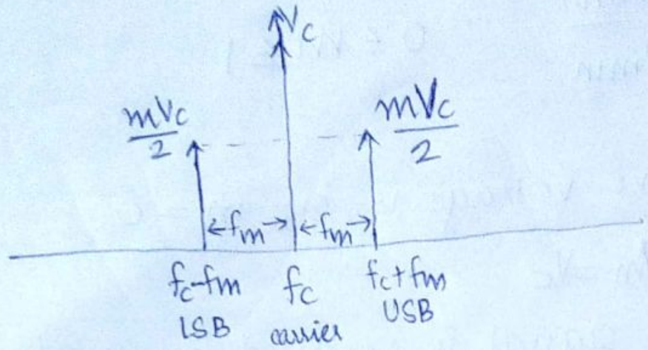
$$v = \underbrace{V_c \sin \omega_c t}_{\text{full carrier}} + V_m \sin \omega_m t \sin \omega_c t$$

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

$$v = V_c \sin \omega_c t + \frac{V_m}{2} \cos(\omega_c - \omega_m)t - \frac{V_m}{2} \cos(\omega_c + \omega_m)t$$

$$m = \frac{V_m}{V_c} \qquad \therefore V_m = mV_c$$

$$v = \underbrace{V_c \sin \omega_c t}_{\text{Full carrier}} + \underbrace{\frac{mV_c}{2} \cos(\omega_c - \omega_m)t}_{\text{LSB}} - \underbrace{\frac{mV_c}{2} \cos(\omega_c + \omega_m)t}_{\text{USB}}$$

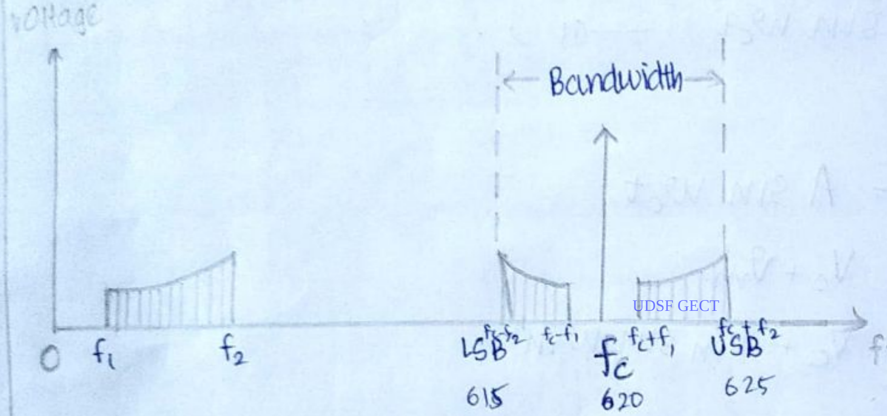


LSB : lower side band

USB : upper side band

Bandwidth of AM = $2 \times f_m$

Frequency spectrum of AM when modulated by a base band of f_1 to f_2



audio : 20Hz – 20 kHz

Speech : 20 Hz – 3 kHz

AM radio : 20 Hz to 5 kHz
f_1 f_2

FM radio : 20 Hz to 15 kHz

DSB - FC

Bandwidth = $2 \times f_2$ = $2 \times$ highest modulating frequency

- For different voltages $v_1, v_2, v_3 \ldots v_n$,
modulation index will be $m_1, m_2, m_3 \ldots m_n$

Then, $$m_{effective} = \sqrt{m_1^2 + m_2^2 + m_3^2 \ldots + m_n^2}$$

Power in A.M.

$$v = V \sin \omega t$$

$$P = \frac{\left(\frac{V}{\sqrt{2}}\right)^2}{R}$$

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$$v = V_c \sin \omega_c t + \frac{mV_c}{2}\cos(\omega_c - \omega_m)t - \frac{mV_c}{2}\cos(\omega_c + \omega_m)t$$

carrier LSB USB

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

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

$$P_{LSB} = \frac{\left(\frac{mV_c}{2\sqrt{2}}\right)^2}{R} = \frac{m^2V_c^2}{8R}$$

$$P_{USB} = \frac{\left(\frac{mV_c}{2\sqrt{2}}\right)^2}{R} = \frac{m^2V_c^2}{8R}$$

∴ Total power,

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

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

$$\boxed{P_t = \frac{V_c^2}{2R}\left[1 + \frac{m^2}{2}\right]}$$

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

* calculate total power transmitted from an ordinary AM radio transmitter whose carrier frequency is 800kHz at 100W power and modulated to a depth of
(i) 0%. (ii) 10%. (iii) 50%. (iv) 100%.

→ $f_c = 800\ kHz$

$P_c = 100\ W$

(i) $P_{t_1} = P_c\left(1+\frac{m^2}{2}\right)$ given $m=0$

$P_{t_1} = 100\ (1+0)$

$P_{t_1} = 100\ W$

(ii) $P_{t_2} = P_c\left(1+\frac{m^2}{2}\right)$ $m = \frac{10}{100}$

$= 100 \times \left(1+\frac{1}{200}\right)$

$= \cancel{100} \times \frac{201}{2\cancel{00}} = 100.5\ W$

UDSF GECT

(iii) $P_{t_3} = P_c\left(1+\frac{m^2}{2}\right)$ $m = \frac{50}{100} = \frac{1}{2}$

$= 100\left(1+\frac{1}{8}\right)$

$= 100 \times \frac{9}{8} = 112.5\ W$

(iv) $P_{t_4} = P_c\left(1+\frac{m^2}{2}\right)$ $m = \frac{100}{100} = 1$

$= 100\left(1+\frac{1}{2}\right)$

$= \overset{50}{\cancel{100}} \times \frac{3}{\cancel{2}} = 150\ W$

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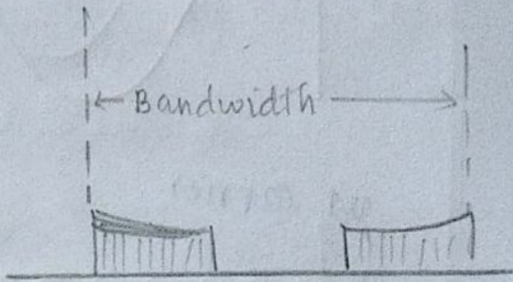
Balanced modulation

- carrier wave will be zero
- therefore, only LSB and USB will be there

DSB - SC



- Here same signal is send twice.
- So a filter is used.
- Filter will select either LSB or USB.
- This is called Single side band (SSB).
- SSB has only one band.
- when bandwidth is less, we can save power and we can include more channels.

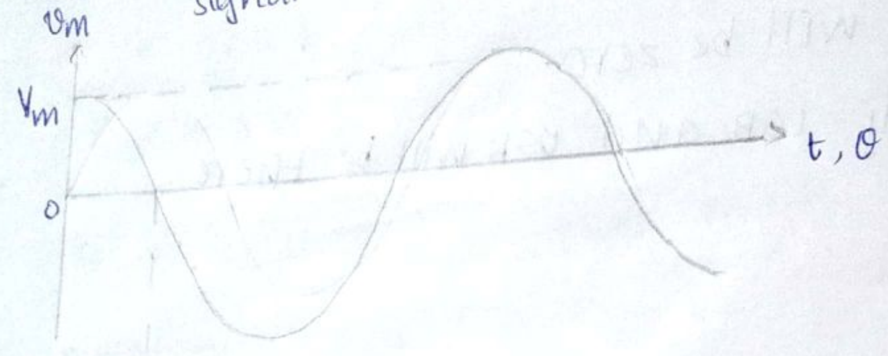
Disadvantages of SSB
- High cost
- some information may be cut

HAM : Hobby amateurs

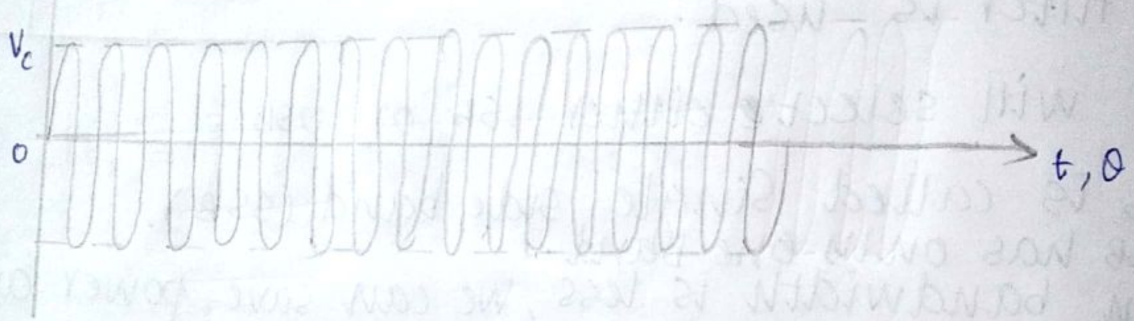
→ In T.V., U.S.B + a part of L.S.B (vestige) is used for signal. This is called vestigial side band

Frequency modulation (FM)
- In the process of frequency modulation, the instantaneous frequency of a high frequency carrier is varied in proportion to the instantaneous amplitude of the message/modulating voltage, keeping the amplitude and phase of the carrier a constant.

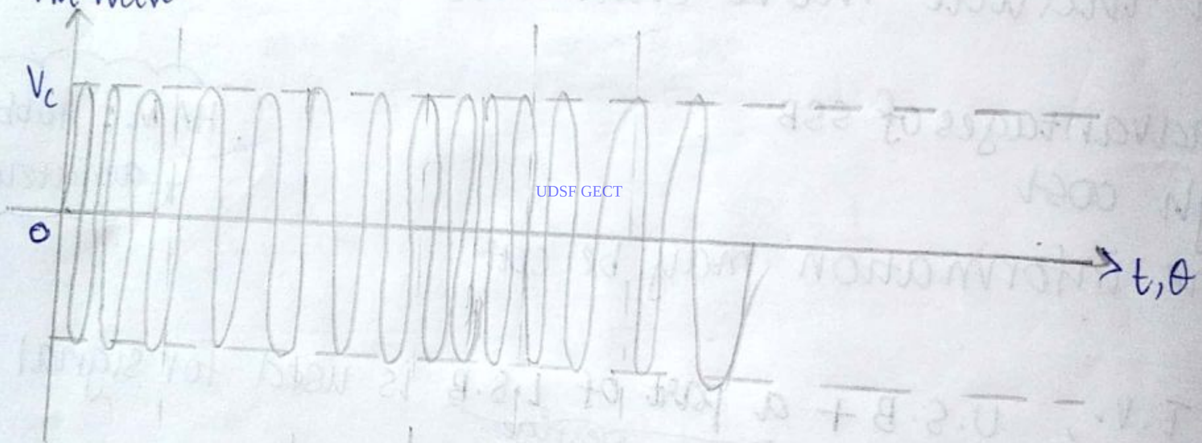
message or modulating signal



v_c carrier



FM wave



- message signal is $v_m = V_m \cos \omega_m t$ —(i)
- carrier signal is $v_c = V_c \cos \omega_c t$ —(ii)

$f = f_c + k v_m f_c$; frequency deviation

- FM wave is $v = V_c \sin \theta$ —(iii)

$$\theta = \int \omega \, dt$$

$$\omega = \omega_c + k\omega_c V_m \cos \omega_m t$$

$$\theta = \int [\omega_c + k\omega_c V_m \cos \omega_m t] \cdot dt$$

Maximum Frequency deviation,

$$\delta = k V_m f_c$$

$$\theta = \omega_c t + \frac{k\omega_c V_m \sin \omega_m t}{\omega_m}$$

$$\theta = \omega_c t + \frac{(k f_c V_m)}{f_m} \sin \omega_m t$$

$$\boxed{\theta = \omega_c t + \frac{\delta}{f_m} \sin \omega_m t} \quad \text{—(A)} \qquad m_f = \frac{\delta}{f_m}$$

$$\boxed{\frac{\delta}{f_m} = \text{modulation index of FM wave}}$$

$$\text{FM index} = \frac{\text{Max. freq. deviation}}{\text{modulating frequency}}$$

UDSF GECT

compare m of AM and FM

AM	FM
• $m = \frac{V_m}{V_c}$	• $m_f = \frac{\delta}{f_m} = \frac{k f_c V_m}{f_m}$
• $0 \leq m \leq 1$	• $m_f > 0$
	• If $m_f < 1$, it is called narrow band F.M. → used for point to point communication
	• If $m_f > 1$, wide band F.M. → used for music, radio broadcasting

$\therefore$ (A) $\Rightarrow$

$$\theta = \omega_c t + m_f \sin \omega_m t$$

FM wave is,

$$v = V_c \sin(\omega_c t + m_f \sin \omega_m t)$$

Bessel function : sine of sine wave

* A wave is defined as $v = 10 \sin(10^8 t + 8 \sin 300t)$ Estimate amplitude, frequency of carrier, m_f, max. freq. deviation and modulating frequency

~~$V_c = 10$~~ ~~$\omega_c = 10^8$~~

→

$$v = 10 \sin(10^8 t + 8 \sin 300t) \text{ V}$$

$$v = V_c \sin(\omega t + m_f \sin \omega_m t)$$

$V_c = 10$ V

$\omega_c = 10^8$ $\Rightarrow f_c = \dfrac{10^8}{2\pi} = 1.59 \times 10^7$ Hz $= \underline{15.9 \text{ MHz}}$

$m_f = 8$

~~$\frac{\delta}{f_m} = m_f$~~ $\omega_m = 300$

~~$\delta = m_f \times f$~~ $f_m = \dfrac{300}{2\pi} = \underline{47.7 \text{ Hz}}$

$$\frac{\delta}{f_m} = m_f$$

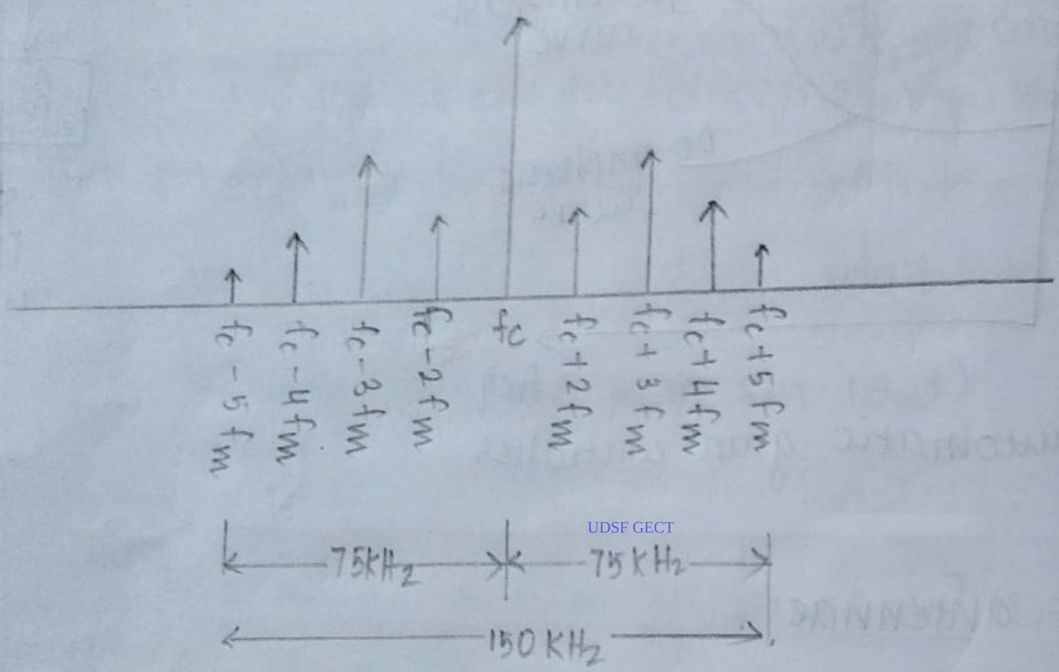
$$\delta = 47.7 \text{ Hz} \times 8 = 381.6 \text{ Hz}$$

- $v = V_c \sin(\omega_c t + m_f \sin \omega_m t)$

Bessel function,

$$= I_0 \sin \omega_c t \pm I_1 \sin(\omega_c \pm \omega_m)t$$
$$\pm I_2 \sin(\omega_c \pm 2\omega_m)t$$
$$\pm I_3 \sin(\omega_c \pm 3\omega_m)t$$

$I_0, I \dots \Rightarrow$ Jacobians. varies for all m_f, f_m



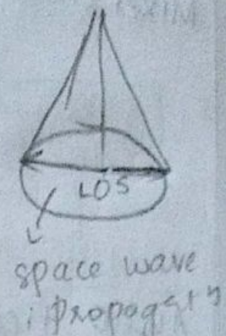
Comparison of FM and AM

- FM $\Rightarrow$ highly quality because FM is highly noise immune (amplitude is constant $\Rightarrow$ noise is clipped)
  - $\Rightarrow$ carrier wave is of high frequency range, thus, noise do not get in it
  - $\Rightarrow$ all power is useful $\rightarrow$ signals can be taken out
  - $\Rightarrow$ Frequency re-usage $\rightarrow$ FM Freq. range 30 MHz – 300 MHz

Frequency do not go out of LOS (line of sight), thus frequencies won't interfere

∴ same frequencies can be FM (reused) without interference

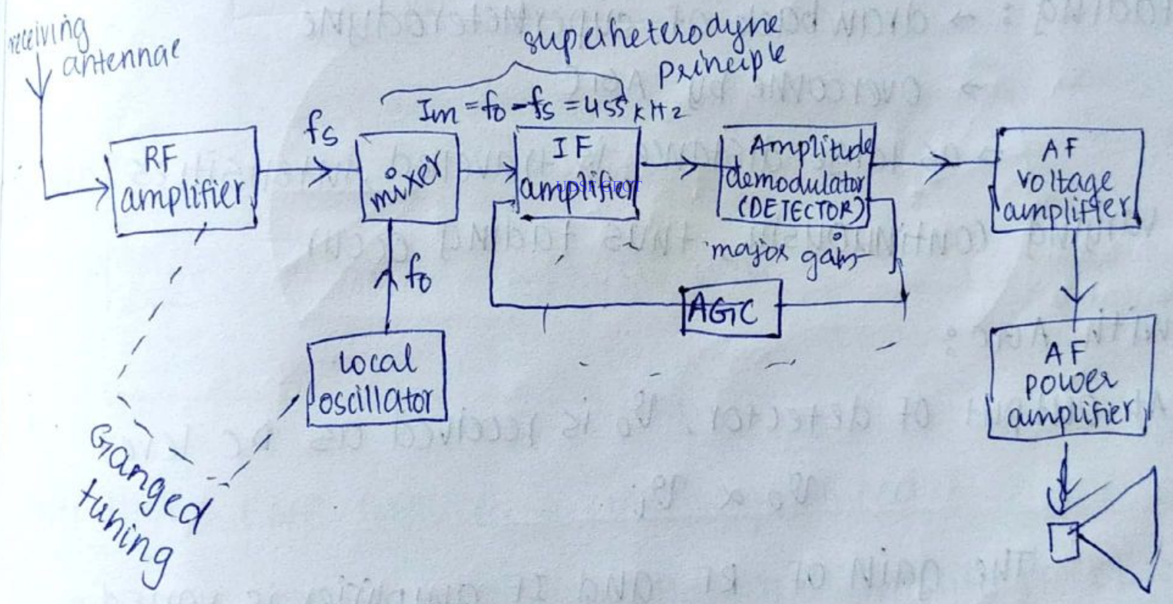
FM: Fidelity ↑ → quality high



limitation :
→ high bandwidth
∴ amplifying circuits are complicated
∴ stations ↓

→ space wave propogation : Range of distance from antenna to station

Super heterodyne AM radio receiver
(mix)



• Receiving antennae : based on principle of faraday's law of EMI

• AM → medium wave 620 - 1650 KHz
short wave 1650 kHz - 3 MHz } Band
10 kHz : bandwidth

FM → 88 MHz - 108 MHz ; band
150 kHz : bandwidth

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- Mixer (local oscillator): IM : $f_o' - f_s$ ⇒ intermediate Frequency

$f_o - f_s$ is constant

AM → $f_o - f_s = 455$ kHz

FM → $f_o - f_s = 10.7$ MHz

- Audio Frequency voltage amplifier → gain in this stage changes (voltage)

$v_o = A v_i$ ⇒ if fluctuates, then output also varies

∴ as $v_i \uparrow$, A should be decreased ⇒ v_o become steady

This reducing A is called Automatic gain control [AGC]

- Fading: → drawback of superheterodyne

→ overcome by AGC

→ as large distance is travelled, intensities are varying continuously, thus fading occur

- With AGC:

At output of detector, v_o is received as DC level

$v_o \propto v_i$

∴ The gain of RF and IF amplifier is varied

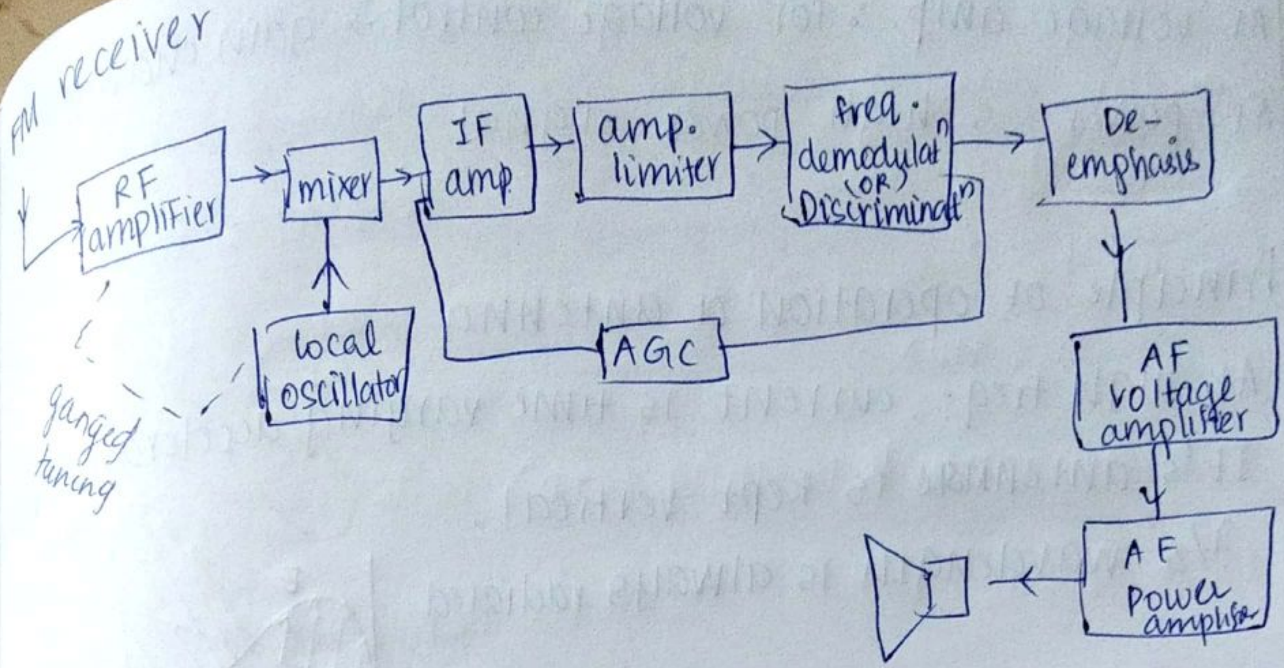
→ as $v_i \uparrow$, A is $\downarrow$

→ automatic gain control

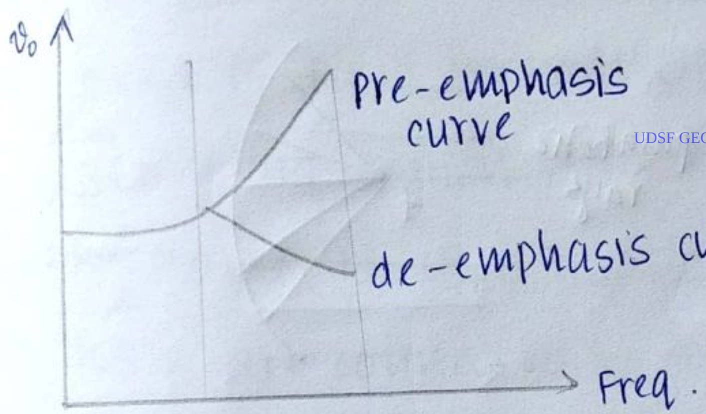
- AGC produce control signal that control gain of IF amplifier (also RF amplifier)

Thus controlling v_o of detector/discriminator

FM receiver



De-emphasis ⇒ smaller gain at receiver
⇒ actual signal can be taken



- Antennae : EMF induced → current produced
- RF amp. : Selects freq. (150 KHz) and amplify if other Frequency gets it, it is tuned
- Mixer : sender frequencies are mixed with a local freq. s $f_0 - f_s = 1M = 10.7 MHz$
- Amplitude limiter : extra noises are taken out with high amplitude
- Discriminator : audio freq. are seperated, gain is made strong

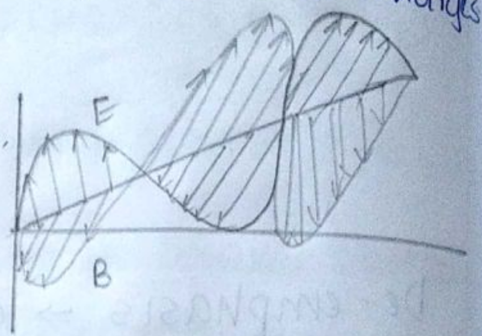
- AF voltage amp. : For voltage control → gain changes
- AF power : high power signal

Principle of operation of antenna

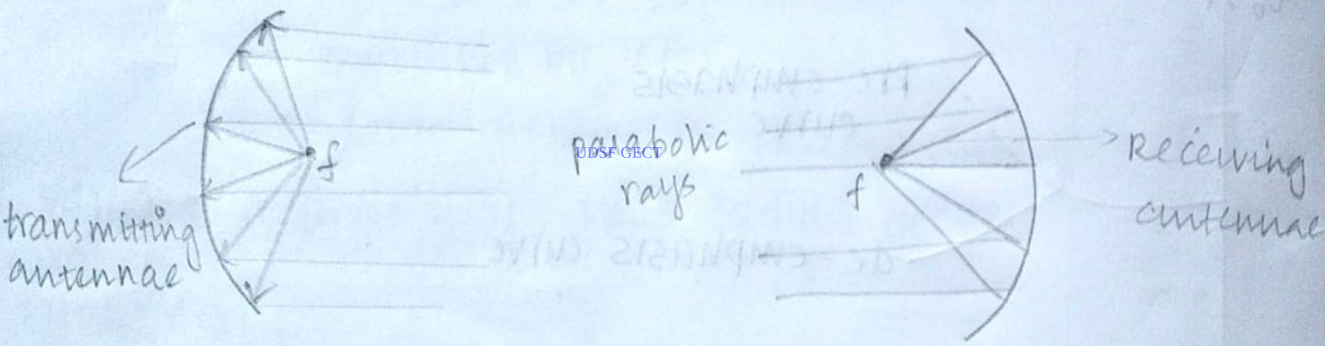
- At high freq., current is time varying accelerated charges

It's antennae is kept vertical.

$\lambda/4$ wavelength is always radiated.



Parabolic reflector (Dish)



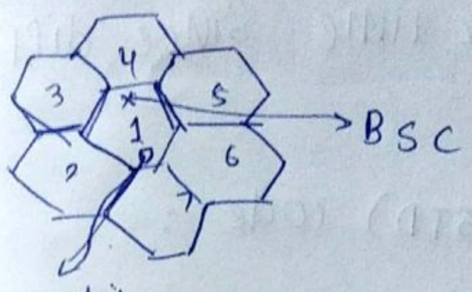
Applications

- microwave tower
- telephone
- television
- DTH (direct to home)
- Wireless LAN and WAN
- radio telescope (weather forecast)
- RADAR
- To navigate

GSM and mobile communication

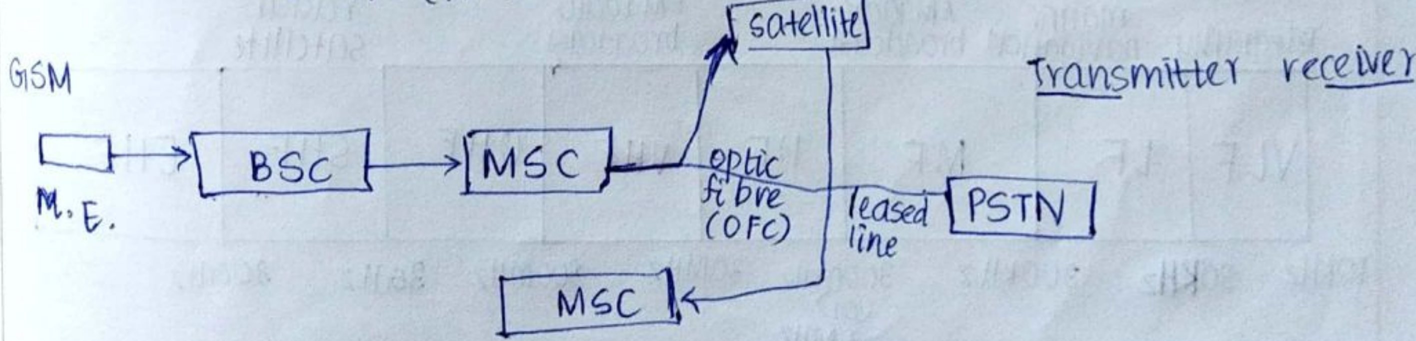
GSM : Global system for mobile communication

- there is a base station controller (BSC) at each centre



MSC : mobile switching centre

- SIM : subscriber identify module : it is unique for each mobile
- code from ME → BSC → threshold limit
- Freq. band is fixed for each service provider
- VLR : visiting location register
  HLR : Home location register
- All BCS's are connected to an MSC
- Authentic centre (AC)



- carrier frequency is alloted by BSC.
- PN code : Pseudo random Noise
- CDMA : code deficient multiple access

Here, many signals can be passed in same medium without any interference

→ ~~Eg~~: Time division multiple access (TDMA)

→ Frequency " " " (FDMA) ; many freq can be passed at same time. Since diff. freq, they do not mix

- Subscriber ~~Trunk~~ Dialling (STD) code :
- PSTN : Public switched telephone network

Advantages

- only communication when persons are in motion
- SMS, MMS, videos, pictures can be shared
- Teleconference, videoconference ..

Drawbacks

- emit radiations which is hazardous

Range of Frequencies

Telegraphy	marine navigation	AM radio broadcast		FM radio broadcast		microwave radar satellite	
VLF	LF	MF	HF	VHF	UHF	SHF	EHF
10KHz	30KHz	300KHz	3000KHz (or) 3MHz	30MHz	300MHz	3GHz	30GHz

VLF : very low frequency

• – Morse code

LF : low frequency

MF : medium frequency

HF : high frequency (for long distance communicat^n)

- above 1 MHz : sky wave propogation
- VHF : very high Frequency
- FM radio broadcast : 88 MHz – 108 MHz
- UHF : ultra high frequency
- SHF : super high frequency
- EHF : extra high frequency
- Bands and ranges
  - L band → 1 GHz – 2 GHz (satellite, mobile, radar, microwave)
  - S band → 2 to 4 GHz
  - C band → 4 to 8 GHz
  - X band → 8 to 12 GHz
  - K_u band → 12 to 18 GHz
  - K band → 18 to 27 GHz
  - K_a band → 27 to 40 GHz

Ku : under k

Ka : above K

Block diagram of an electronic Instrumentation system

- Transducer : convert energy of one form to electrical energy