UNIT - 2

ANALOG COMMUNICATION

Modulation process - Classification of modulation, Need for Modulation - Radio Frequency spectrum - Amplitude modulation Generation & demodulation - Super heterodyne receiver - FM and PM - Frequency spectrum.

Why modulation?

(i). long distance communication:

The purpose of modulation is to convert the message signal into suitable form that matches to the transmission medium. This is necessary because the message signal is a low frequency signal that cannot be transmitted effectively over the transmission channel directly. These channels are best suited for high frequency signal transmission for long distance.

(ii) Interference:

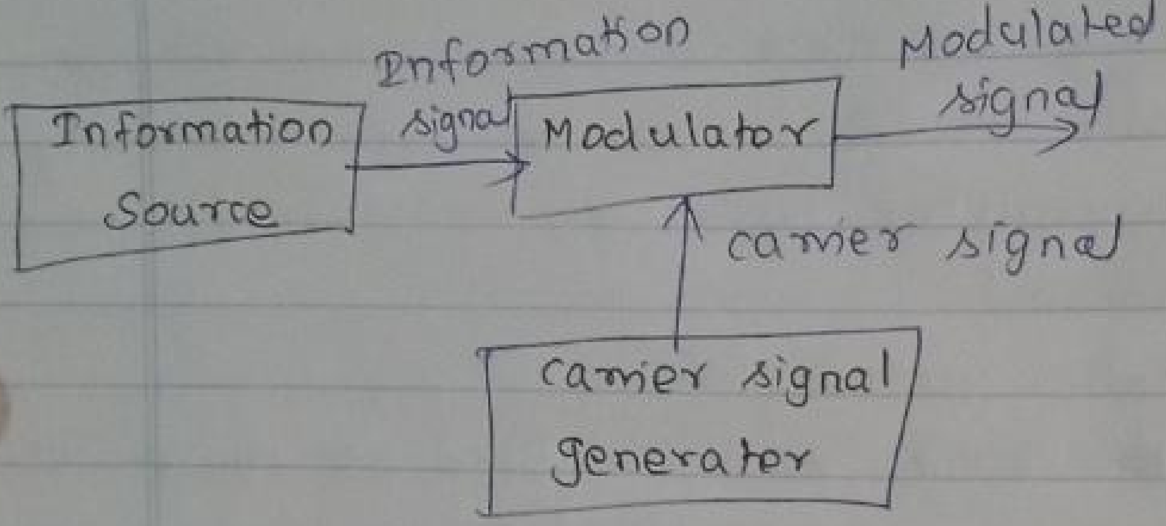
In radio communication, signals from various sources are transmitted through a common media, that is, open space. This cause interference among various signals, and no useful message is received or recovered by the receiver.

The problem of interference is solved by translating the message signal to different radio frequency spectra, which is called "frequency translation" in communication. These main problems can be overcomed by the transmitter by using a process known as "modulation".

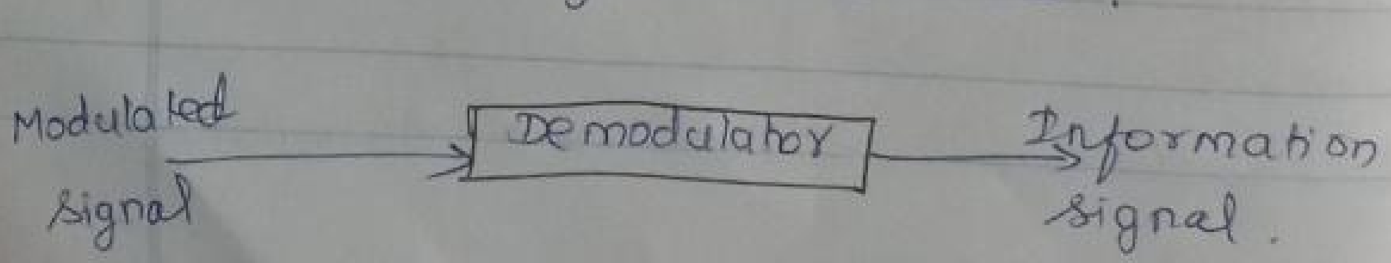
Modulation process:-

Modulation may be defined as the process by which some parameters (amplitude, frequency and phase) of a high Frequency signal termed as "carrier signal" is varied in accordance with the instantaneous amplified value of the "information signal" which is a low frequency signal to achieve long distance communication.

Signals containing information to be transmitted are referred to as modulating signals or information signals or baseband signals. The term baseband designates the band of frequencies representing the signal supplied by the source of information. The carrier signal is the high frequency signal which carries the message signal from transmitter to receiver.



The signal resulting from the process of modulation is called "modulated signal". At the receiver side, this modulated signal is received and the carrier is removed and discarded and the low frequency information signal is retained.

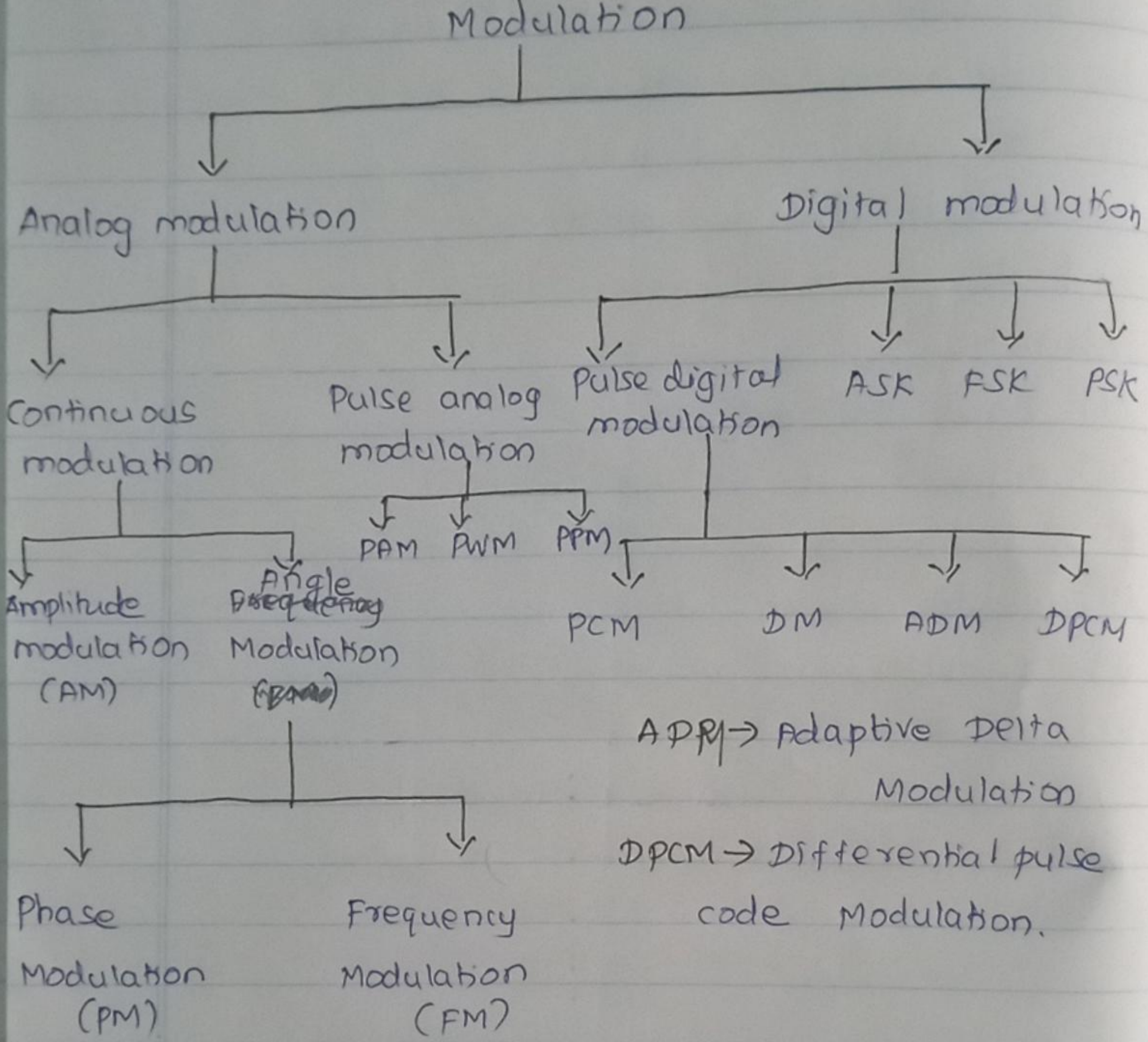


The process of extracting a modulating signal from the modulated signal is called "demodulation or detection" and the device used for this is called as demodulator or detector.

Need for modulation or Advantages of Modulation:

(i) Ease of radiation.
(ii) Adjustment of bandwidth
(iii) Reduction in height of antenna
(iv) Avoids mixing of signals
v) Increases the range of communication.
vi) Multiplexing.
vii) Efficient transmission and
viii) Improved quality of reception.

Classifications or types of modulation:



ADM → Adaptive Delta Modulation

DPCM → Differential pulse code Modulation.

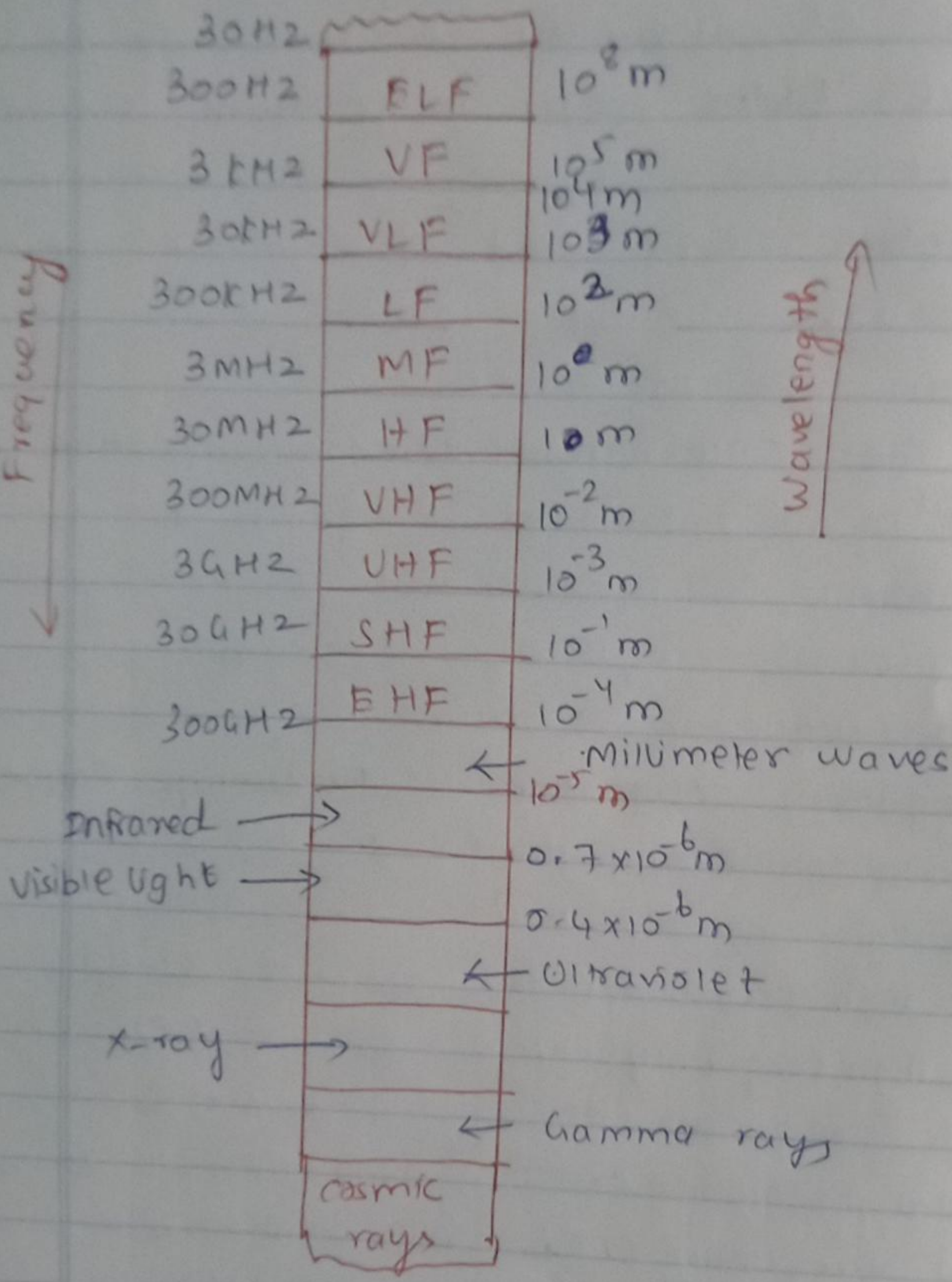
Radio Frequency spectrum:

Communication systems are categorized in terms of frequency of the carrier. The total usable "Radio frequency spectrum" is divided into narrower frequency bands, which are descriptive names and several of these bands are further broken down into various types of services.

The "International Telecommunication Union (ITU)" is an International agency in control of allocating frequencies and services within the overall frequency spectrum.

Radio frequency Spectrum:

Frequency Designation	Frequency Range
Extremely High Frequency (EHF)	30 - 300 GHZ
Super High Frequency (SHF)	3 - 30 GHZ
Ultra High Frequency (UHF)	300 MHZ - 3 GHZ
Very High Frequency (VHF)	30 - 300 MHZ
High Frequency (HF)	3 - 30 MHZ
Medium Frequency (MF)	300 KHZ - 3 MHZ
Low Frequency (LF)	30 - 300 KHZ
Very Low Frequency (VLF)	3 - 30 KHZ
Voice Frequency (VF)	300 - 3000 HZ
Extremely Low frequency	30 - 300 HZ



30Hz
300Hz
3kHz
30kHz
300kHz
3MHz
30MHz
300MHz
3GHz
30GHz
300GHz
ELF
VF
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
10^8 m
10^5 m
10^4 m
10^3 m
10^2 m
10^0 m
10 m
10^{-2} m
10^{-3} m
10^{-1} m
10^{-4} m
Millimeter waves
10^{-5} m
Infrared
0.7×10^{-6} m
visible light
0.4×10^{-6} m
Ultraviolet
x-ray
Gamma rays
cosmic rays
Frequency
Wavelength

Amplitude Modulation:

In AM, the amplitude of a carrier signal is varied according to variations in the amplitude of modulating signal. AM is simply called as double side band full carrier (DSB-FC), because it contains carrier as well as side bands.

Mathematical or time domain specification of Amplitude modulation:

Modulating signal $v_m(t) = V_m \cdot \cos \omega_m t$ —— ①

carrier signal $v_c(t) = V_c \cdot \cos \omega_c \cdot t$ —— ②

where,

V_c = Amplitude of carrier signal is changed after modulation, which is amplitude of an AM wave and is expressed as,

$$V_{AM} = V_c + V_m(t) \quad \text{——} ③$$

sub ① in ③,

$$V_{AM} = V_c + V_m \cos \omega_m t$$

$$= V_c \left[1 + \frac{V_m}{C} \cdot \cos \omega_m \cdot t \right]$$

$$V_{AM} = V_c \left(1 + m_a \cdot \cos \omega_m \cdot t \right)$$

Modulation Index of AM $= m_a = \dfrac{V_m}{V_c}$

Hence, AM wave can be expressed as,

$V_{AM} = V_C(1 + m_a . \cos \omega_m . t)$ —— (4)

$V_{AM}(t) = V_{AM} . \cos \omega_c t$ —— (5).

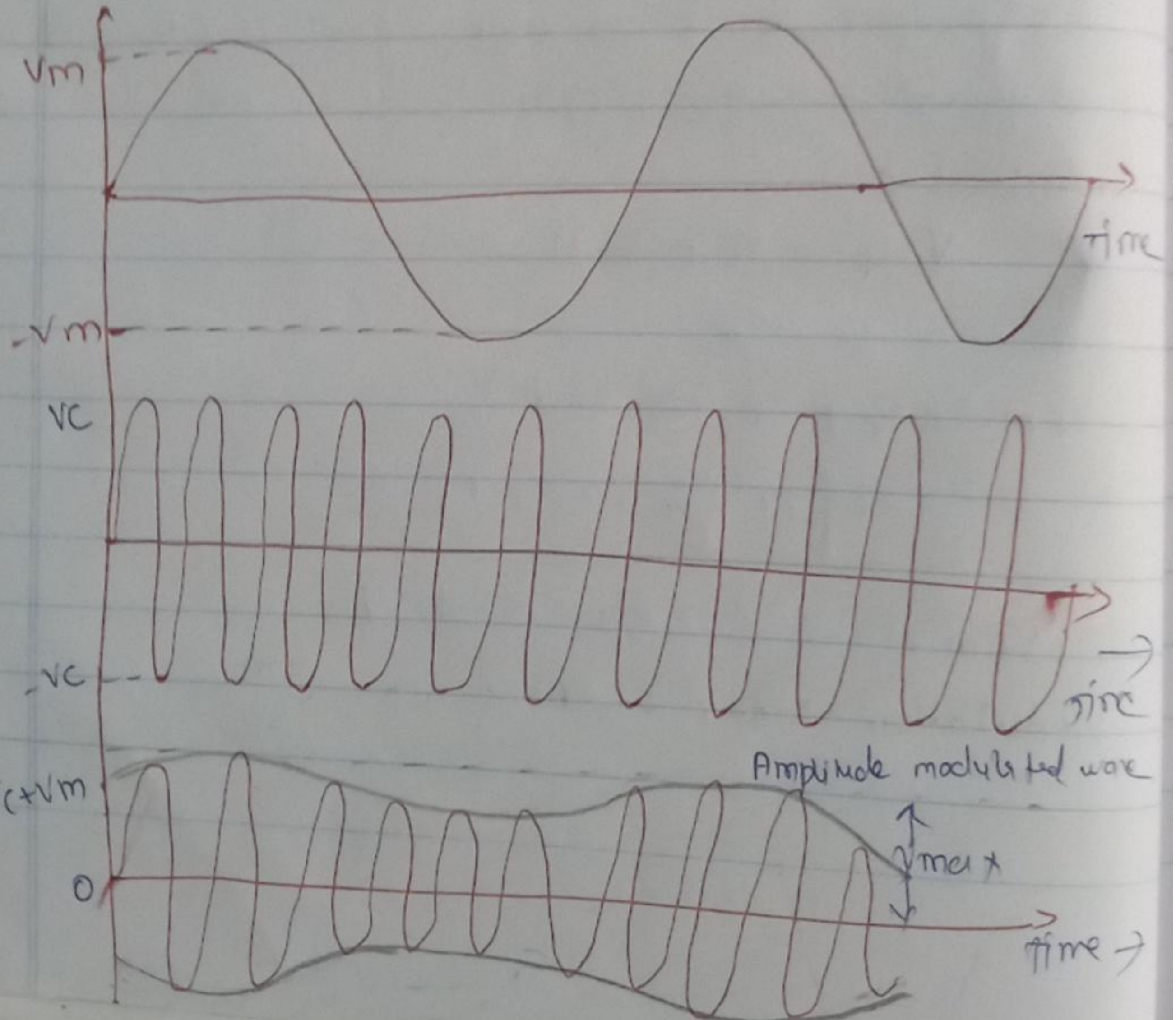
Sub eqn (4) for the amplitude of an AM signal in eqn (5), we get,

$V_{AM}(t) = V_C(1 + m_a . \cos \omega_m . t) \cos \omega_c t$ —— (6)

In terms of frequency, ie. $\omega = 2\pi f$, the AM wave from eqn (6),

$V_{AM}(t) = V_C(1 + m_a \cos 2\pi f_m . t) . \cos(2\pi f_c . t)$ —— (7)

Eqn (6) & (7) are called as the time domain representation of an AM signal.



AM Frequency Spectrum and Bandwidth

Frequency spectrum of an AM wave:

$V_{AM}(t) = V_C(1 + m_a \cdot \cos\omega_m t) \cdot \cos\omega_c t$

$= V_c \cos\omega_c t + m_a V_c \cdot \cos\omega_m t \cos\omega_c t$ —— (1)

we know that,

$$\cos\omega_m t \cos\omega_c t = \frac{\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t}{2} \quad \text{—— (2)}$$

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

Sub (2) in (1),

$$V_{AM}(t) = V_c \cdot \cos\omega_c \cdot t + \frac{m_a \cdot V_C}{2}\left[\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t\right]$$

$$V_{AM}(t) = \underbrace{V_c \cdot \cos\omega_c \cdot t}_{\text{Carrier}} + \underbrace{\frac{m_a V_C}{2} \cdot \cos[\omega_c - \omega_m]t}_{\text{Lower side band}} + \underbrace{\frac{m_a \cdot V_C}{2}\cos(\omega_c + \omega_m)t}_{\text{Upper sideband}}$$

Sidebands:

Whenever a Carrier Signal is modulated by an information signal, new signals at different frequencies are generated as part of the non-linear modulation process. These new frequencies are called as "side frequencies" or "sidebands".

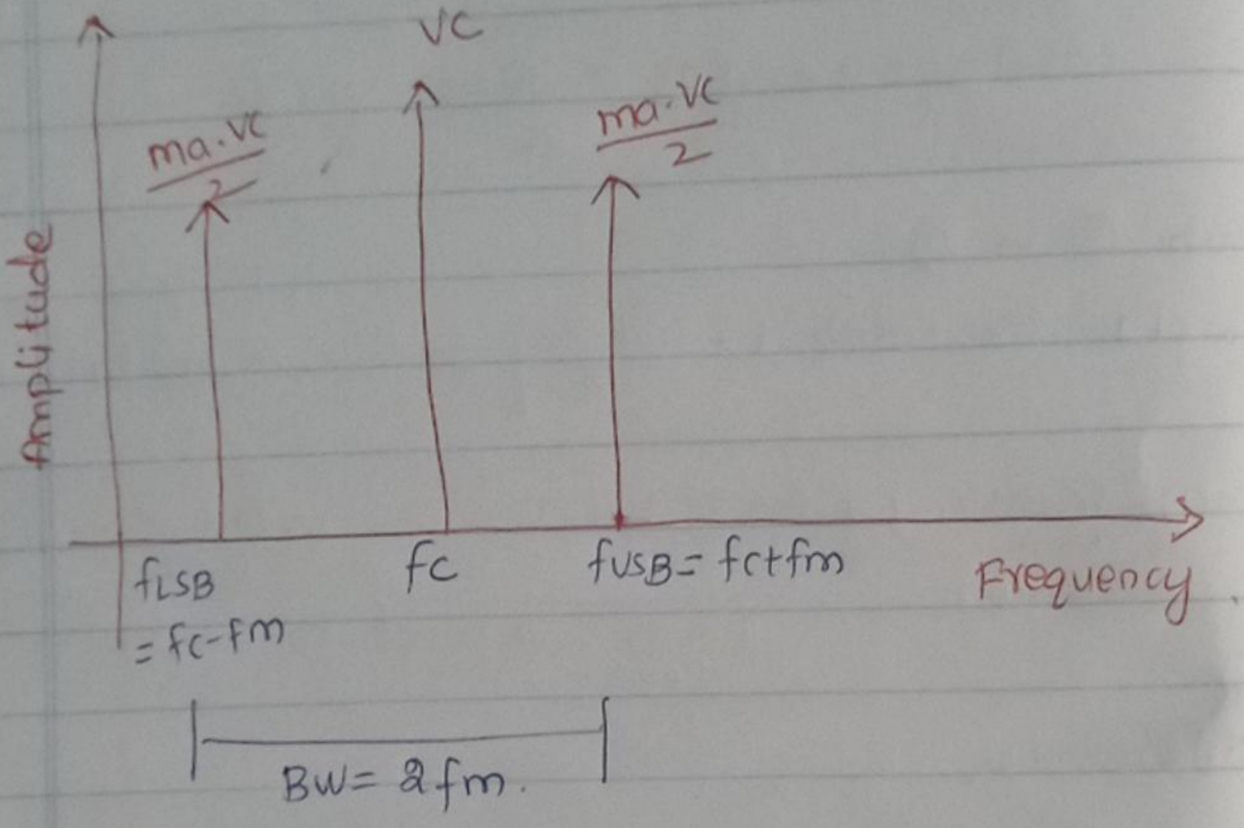
The Sidebands occur in the frequency

spectrum directly above and below the carrier frequency fc,

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

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

Frequency Domain Representation



Bandwidth of AM:

The Bandwidth of the AM signal is given by the subtraction of the highest and the lowest frequency component in the AM frequency spectrum.

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

$$= (f_c + f_m) - (f_c - f_m)$$

$$B = 2f_m$$

where,

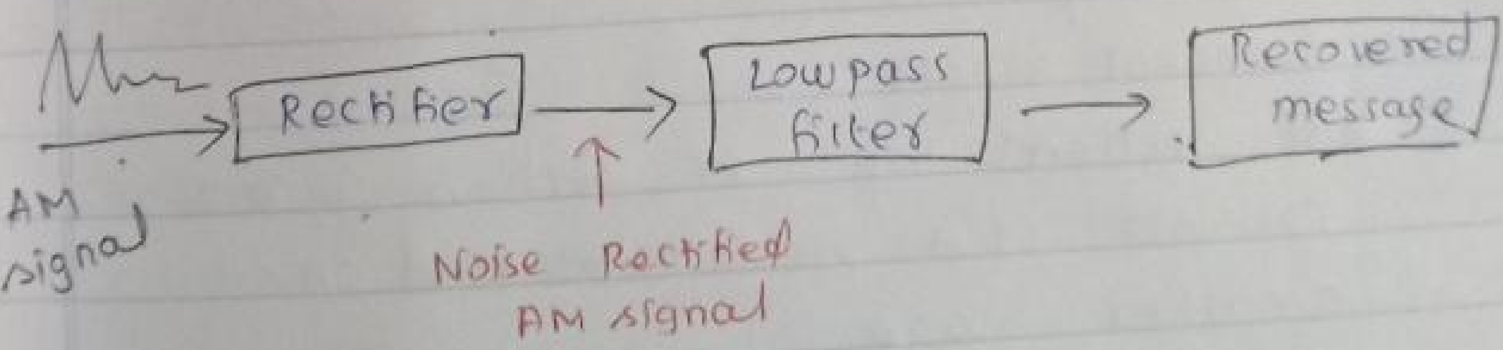
$B \rightarrow$ Bandwidth of AM in Hertz, and

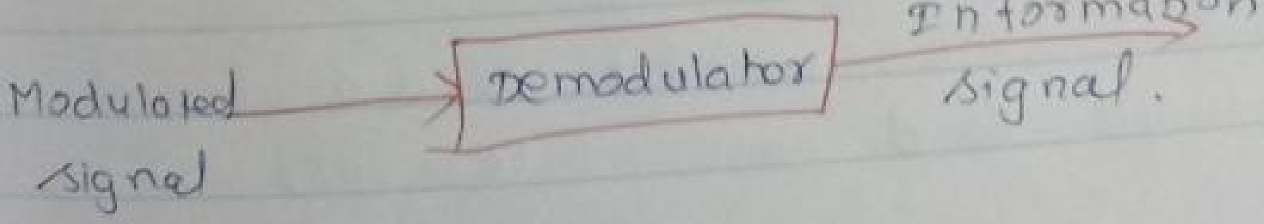
$f_m \rightarrow$ Maximum modulating signal frequency in HZ.

Thus, the bandwidth of AM signal is twice the maximum frequency of modulating signal.

Demodulation:—

The process of extracting a modulating signal from the modulated signal is called demodulation or detection and the device used for this is called as demodulator or detector.





AM superheterodyne receiver:

A higher radio frequencies the performance of TRF becomes poor. The performance of the receiver is improved by a technique known as "heterodyning".

"The process of mixing two signals having different frequencies to produce a signal with new frequency is called as heterodyning".

The problems in the TRF receiver are solved in this receiver by converting every selected RF signal to a fixed lower frequency signal, which is called as the "Intermediate Frequency" (IF).

General Blocks:

(i) RF section: The RF section generally consists of a pre selector and an amplifier stage.

(ii) Pre selector:

The preselector is a broad tuned Band pass filter (BPF) with an adjustable centre frequency that is tuned to be desired carrier frequency of the incoming signal and rejects the unwanted radio frequency called "image frequency".

ii) RF amplifier:

A receiver can have one or more RF amplifiers depending on the desired sensitivity and its output is a desired signal at frequency "fs".

Mixer/converter section:

The combination of mixer and local oscillator provides a heterodyning function, whereby the incoming signals (RF) is converted to a predetermined fixed "Intermediate frequency" (IF) signal, usually lower than the incoming carrier frequency.

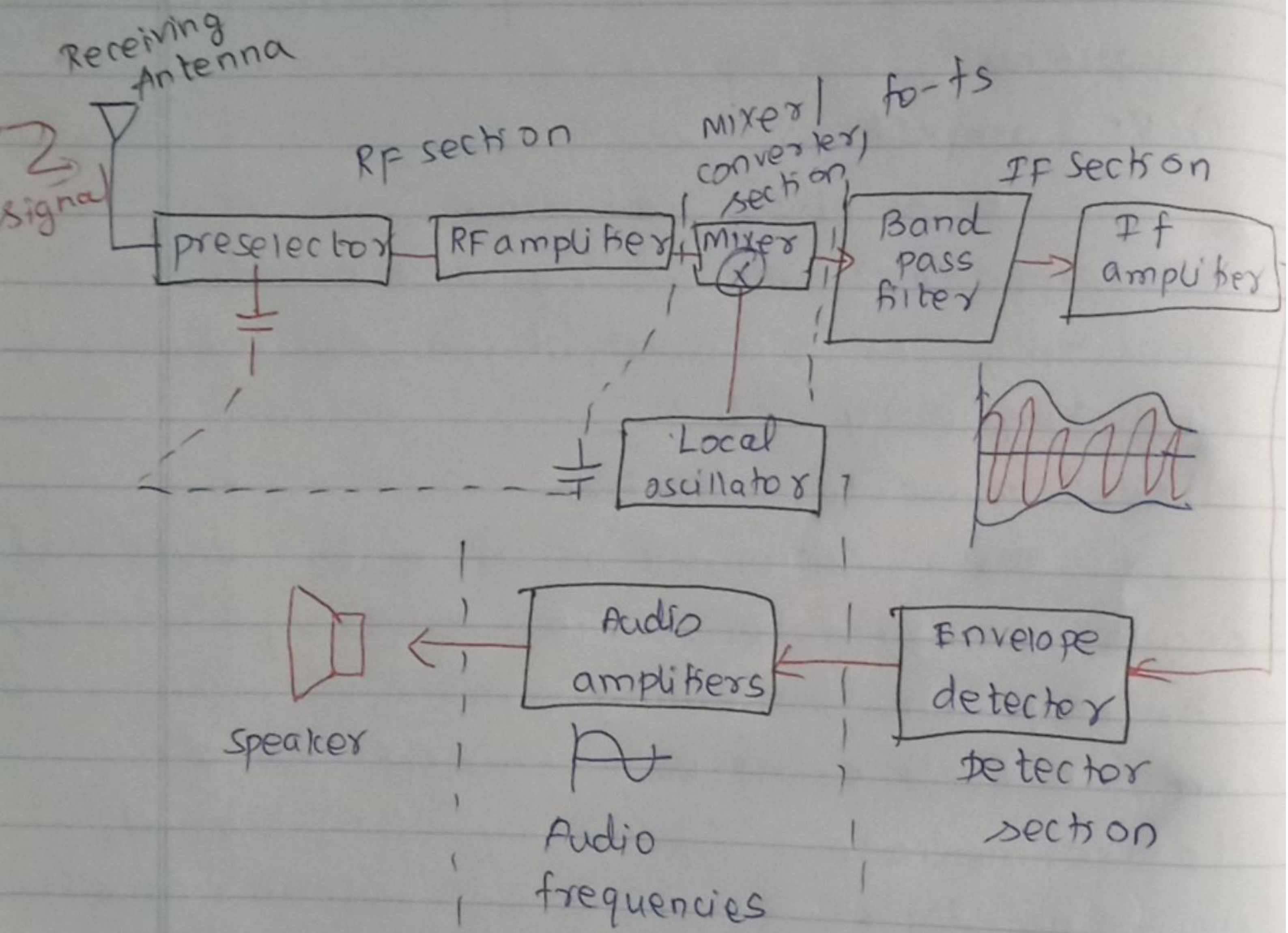
i) Local oscillator frequency (fo):

The mixer receives signals from the RF amplifier at frequency (fs) and from the local oscillator at frequency (fo) such that $f_o > f_s$

$$f_o = f_s + f_i$$

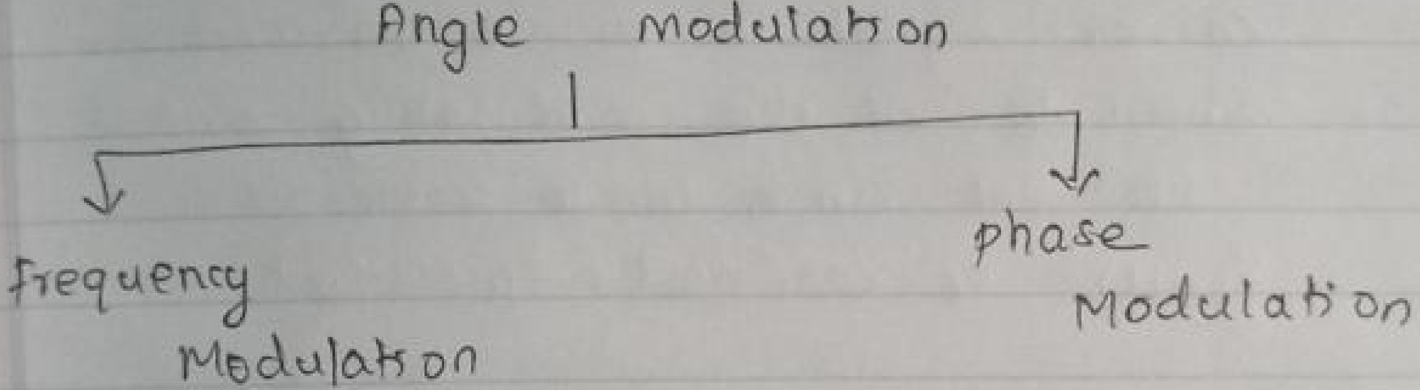
$f_s \rightarrow$ signal frequency

$f_i \rightarrow$ Intermediate Frequency.



Angle Modulation

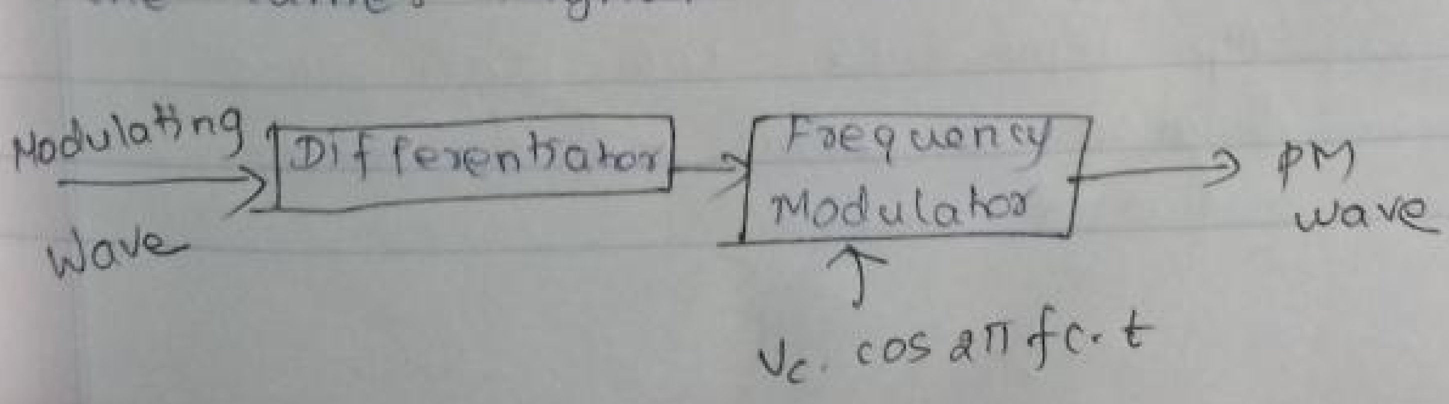
Angle modulation has several advantages over the amplitude modulation such as "noise reduction", "Improved system fidelity" and "more efficient" use of power.



Phase Modulation:

Phase modulation is defined as the process by which "changing the phase of the carrier signal" in accordance with instantaneous amplitude of the message signal.

Here amplitude and frequency of the carrier signal remains constant.



The modulating wave is first differentiated and then applied to the frequency modulator to produce PM wave

Representation of PM wave:

The PM wave is obtained by varying the phase angle ϕ of a carrier signal in proportion with the amplitude of the modulating signal. The PM wave can be expressed as

$$V_{PM}(t) = V_c \cdot \cos(\omega_c \cdot t + \phi_p \cdot \cos\omega_m t) \quad (1)$$

Here, $\phi_p \rightarrow$ Maximum phase change corresponding the maximum amplitude of the modulating signal.

$$V_{PM}(t) = V_c \cdot \cos(\omega_c \cdot t + m_p \cdot \cos\omega_m \cdot t)$$

where,

$m_p = \phi_p =$ Modulation index of PM.

m_p represents the peak phase deviation in radians for a phase modulated carrier.

Modulation Index (Mp) of PM:

In PM, the modulation index is proportional to the amplitude of the modulating signal, independent of its frequency and is expressed as,

$$mp = kp \, vm.$$

where,

kp = Deviation sensitivity (radians per volt)

vm = peak modulating signal amplitude (volts)

Deviation sensitivity (kp):

A deviation sensitivity represents the input output transfer function of the modulators, which gives the relationship between what output parameter changes with respect to specified changes in the input signal.

Therefore, according to equation ③, the equation ② be rewritten interms of modulation index as,

$$Vpm(t) = V_c \cdot \cos(w_c \cdot t + kp \cdot Vm \cdot \cos w_m \cdot t) \quad \text{—— (4)}$$

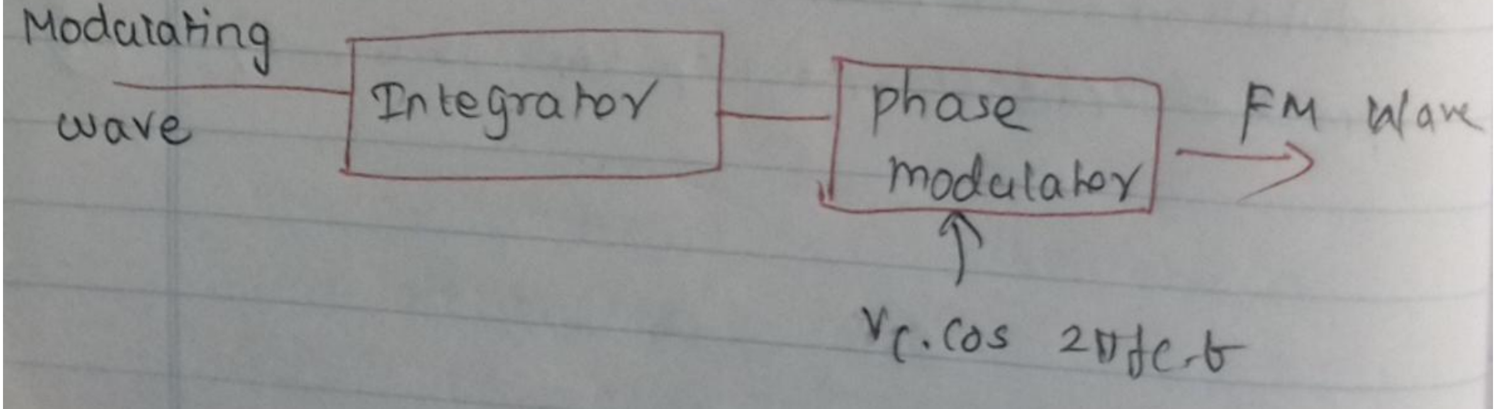
Frequency Modulation (FM):

Frequency modulation can be defined as the process by which the frequency of the carrier wave is varied in accordance with the instaneous amplitude of the modulating signal.

Here the amplitude and phase of the carrier signal remains constant after modulation process.

In PM, phase angle varies linearly with modulating signal whereas in FM phase angle varies linearly with the integral of modulating signal.

First the modulating signal is integrated and then applied to the phase modulator to produce FM wave.



Representation of FM:

For the single tone FM, the modulating signal $v_m(t)$ be a sinusoidal signal.

$$V_m(t) = V_m \cdot \cos \omega_m \cdot t \quad \text{---} (1)$$

Frequency modulation takes place, when the angular velocity of the carrier wave varies in proportion to the instantaneous amplitude of the modulating signal. The instantaneous angular velocity ω_i is given by,

$$\omega_i = \omega_c + k_f \cdot V_m(t) \quad \text{---} (2)$$

Here, k_f is "deviation sensitivity" of FM,

sub eqn (1) in (2),

$$\Rightarrow \omega_c + k_f \cdot v_m \cdot \cos \omega_m \cdot t \quad \text{---} (3)$$

$\Rightarrow$ maximum frequency deviation Δf is given by,

$$\Delta f = \frac{k_f \cdot V_m}{2\pi} \quad (or) \quad \Delta\omega = k_f \cdot V_m.$$

Maximum frequency deviation Δf can be written in more practical form as,

$$\Delta f = k_f \cdot V_m \ (Hz)$$

Integration of equ ③ gives the instantaneous phase angle of the frequency modulated wave,

$$\phi_i = \int w_i \, dt$$

$$= \int (w_c + k_f . V_m . \cos w_m t) \, dt$$

$$= \int (w_c + \Delta w . \cos w_m . t) \, dt$$

$\because \Delta w = 2\pi \Delta f$

$\because w_m = 2\pi f_m$

$$= w_c . t + \frac{\Delta w}{w_m} . \sin w_m . t$$

$$\phi_i = w_c . t + \frac{\Delta f}{f_m} . \sin w_m . t \quad \text{— ④}$$

The FM wave can be expressed as,

$$V_{FM}(t) = V_c . \cos \phi_i \quad \text{— ⑤}$$

Then, sub equ ④ in equ ⑤

$$= V_c . \cos (w_c . t + \frac{\Delta f}{f_m} . \sin w_m . t) \quad \text{— ⑥}$$

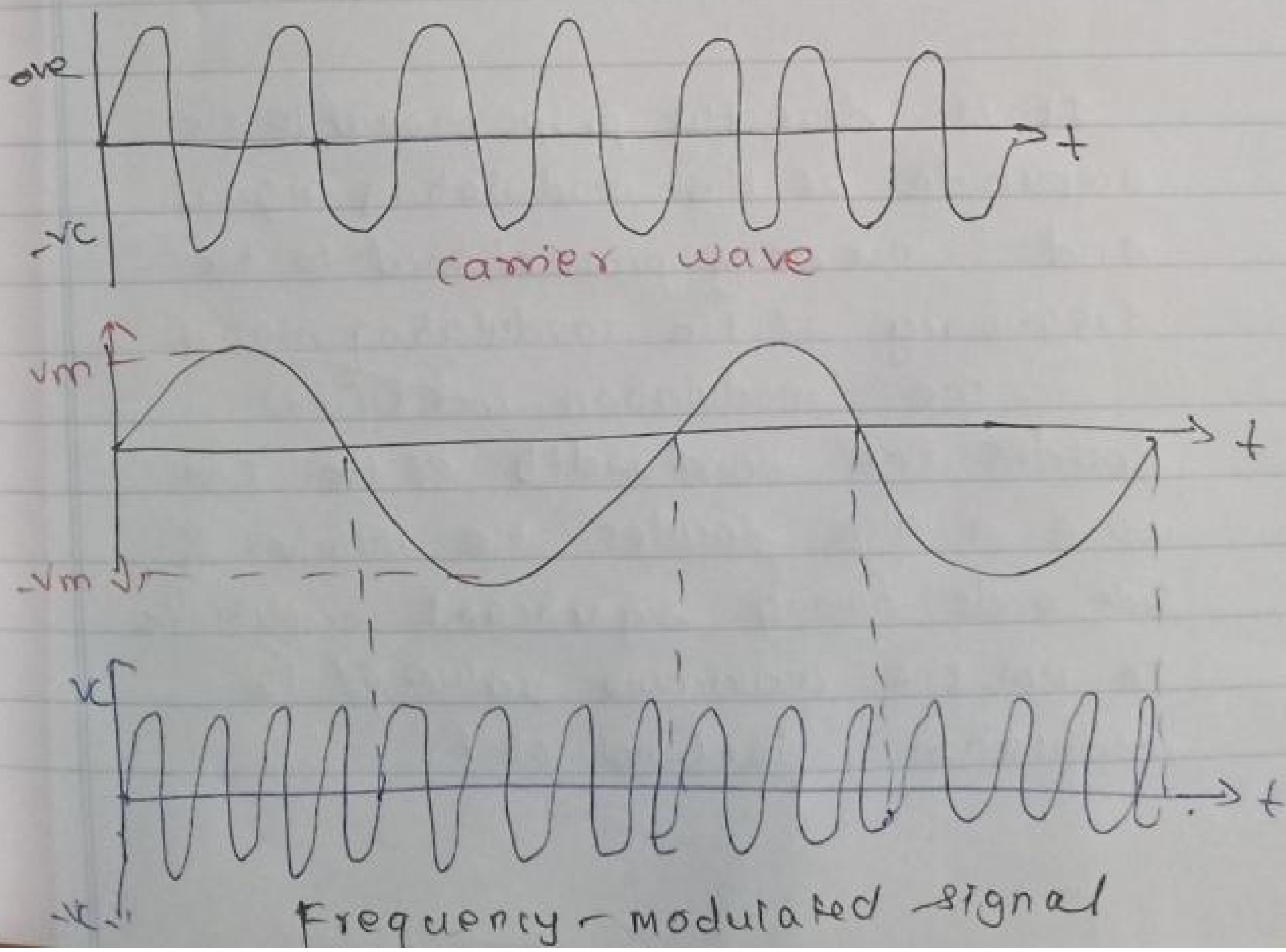
The ratio $\frac{\Delta f}{f_m}$ is termed as the "modulation index" of the frequency modulated wave and is denoted by m_f.

$$mf = \frac{\Delta f \,(Hz)}{fm \,(Hz)} \quad \text{——— (7)}$$

After substituting this modulation index in equ (5), then the equation for FM wave is expressed as,

$$V_{FM}(t) = V_C \cdot \cos(\omega_C \cdot t + mf \cdot \sin \omega m \cdot t).$$

FM wave forms:



Frequency-modulated signal

Modulation Index of FM:

Modulation index of FM is defined as the "ratio of frequency duration to modulating frequency.

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

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

$$m_f = \frac{k_f \cdot V_m}{f_m}$$

It is directly proportional to the amplitude of the modulating signal and inversely proportional to the frequency of the modulating signal.

The modulation index (m_f) decides the bandwidth of the FM wave & also decides the number of sidebands having significant amplitudes. In AM, the maximum value of the modulation index (m_a) is 1.

But for FM the modulation index can be greater then 1.

Percentage Modulation of FM:

The ratio of the actual frequency deviation produced by the modulating signal to the maximum allowable frequency deviation in percentage form.

$$\text{Percentage Modulation} = \frac{\text{Actual Freq. deviation}}{\text{Maximum allowable freq. deviation}} \times 100$$

$$\%\ \text{Modulation} = \frac{\delta f\ (\text{actual})}{\delta f\ (\text{max})} \times 100$$