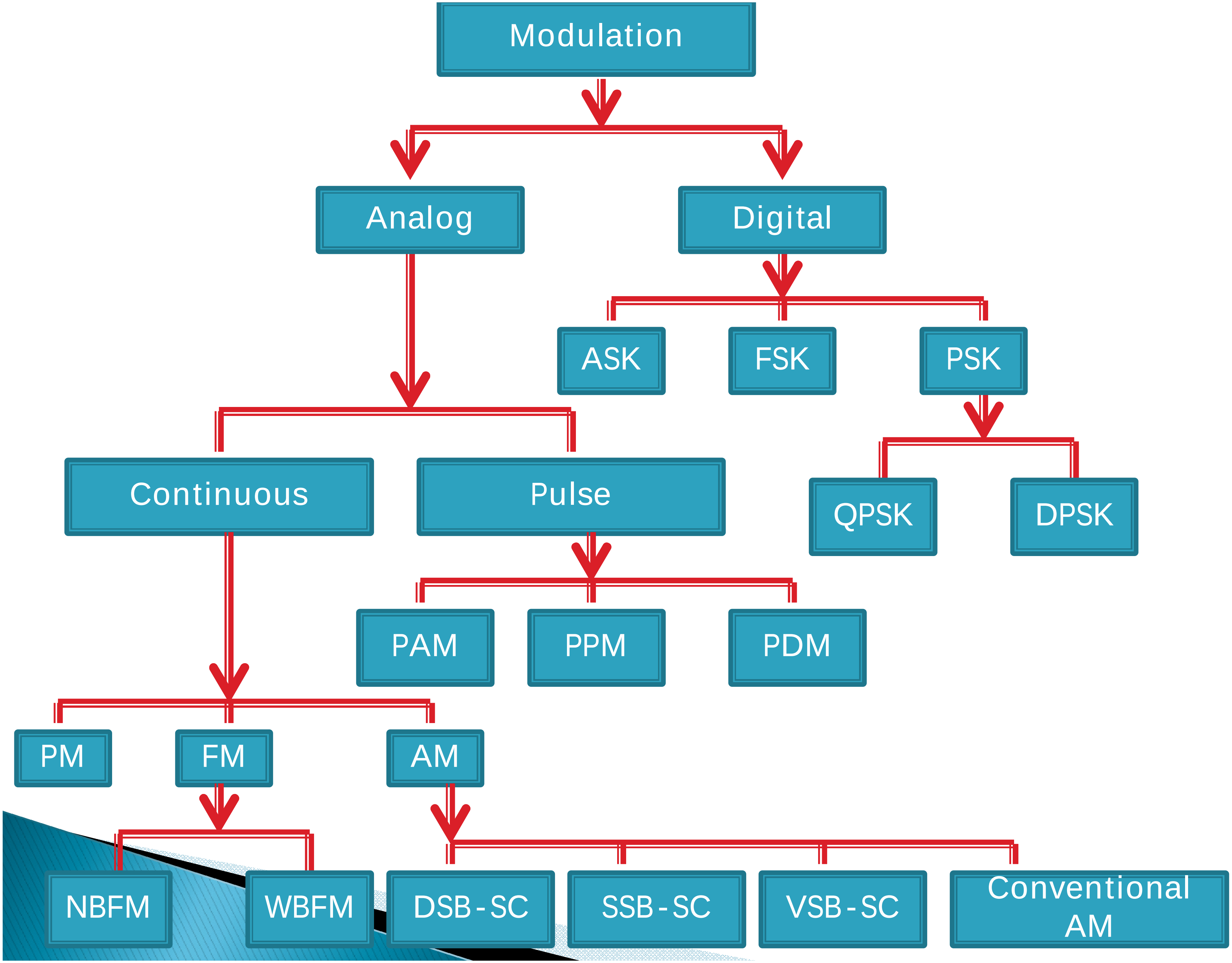
Digital and Analog Communication (EE-217-F)

Section B:
Data Transmission System:

- Physical connections: modulation, amplitude-, frequency-, phase-modulation;
- Data encoding: binary encoding (NRZ), Manchester encoding, differential Manchester encoding.
- Transmission Media: Twisted pair-, co-axial-, fiber optic-cables, wireless media
- Transmission impairments: attenuation, limited band width of the channels, delay distortion, noise, data rate of the channels (Nyquist theorem, Shannon limit).
- Physical layer interfaces: RS232, X.21

Modulation

- Process of modifying some characteristic of a wave (the carrier signal) so that it varies with the instantaneous value of another wave (the modulating wave) in order to transmit a message.
- The modified characteristic may be frequency, phase, and/or amplitude.
- In the modulation process , the frequency of carrier signal must be high than base band signal and modulation process must be chosen in such a way so that transmission of signal occur effectively with minimum distortion.



Modulation
Analog
Digital
ASK
FSK
PSK
QPSK
DPSK
Continuous
Pulse
PAM
PPM
PDM
PM
FM
AM
NBFM
WBFM
DSB-SC
SSB-SC
VSB-SC
Conventional AM

Need of Modulation

- Multiplexing
- Practicability of antenna
- Ease of radiation

Multiplexing

- In this we are transmitting more than 1 signal on the same channel

1. Time division
2. Frequency division

TDM is used in digital modulation , while FDM uses in analog modulation communication.

Multiplexing reduces the cost of installation and maintenance due to reduction of number of channel.

If we are Transmitting more than one signal through a channel, then it overlapped due to identical baseband spectrum.

Practicability of antenna

- For transmitting a signal in free space we require antenna.
- With the help of modulation height of antenna can be decreased.

$$H = \frac{\lambda}{2} = \frac{c}{2f} \qquad f = \frac{C}{\lambda} \qquad f \propto \frac{1}{\lambda}$$

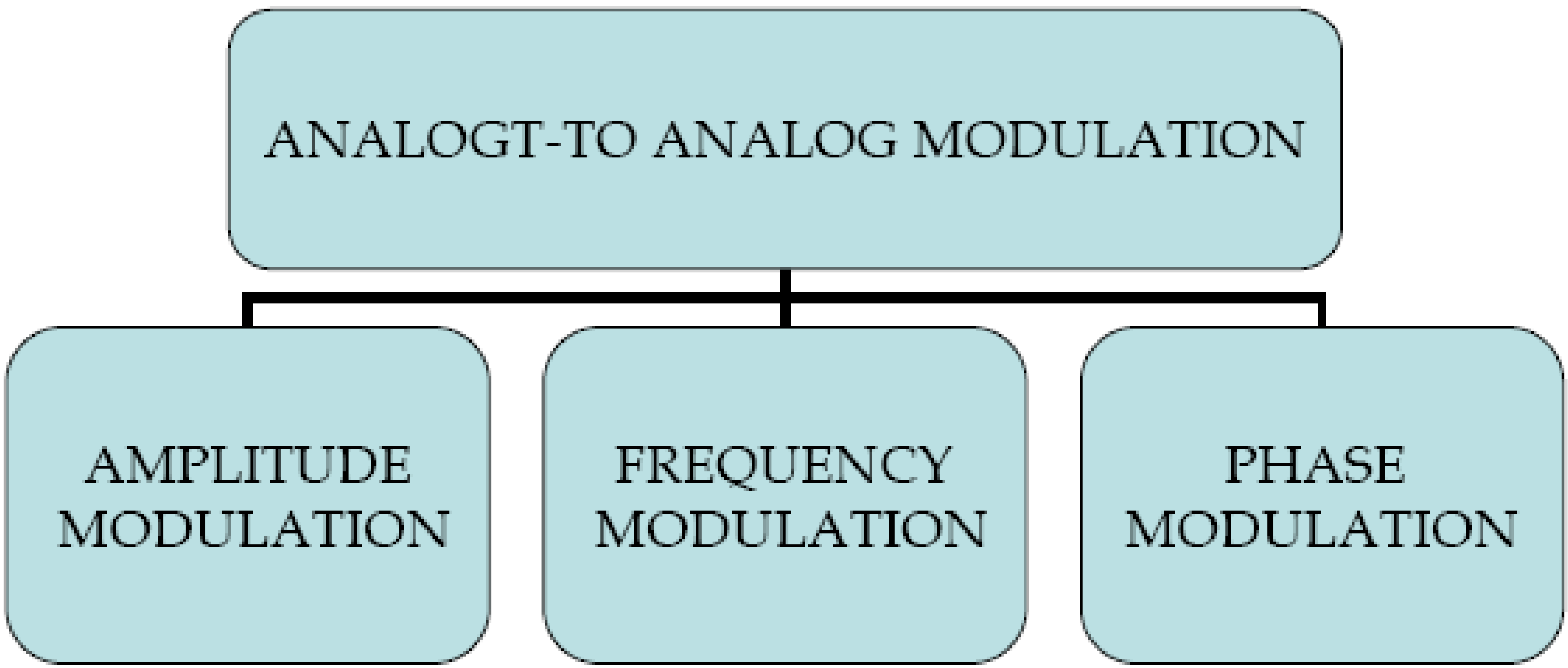
$$At\ 20\ k\ Hz\ , \qquad H = 7.5\ m$$

- So if we modulate signal with a signal of high frequency then automatically height of antenna reduced.

Ease of radiation

- As we modulate the signal by higher frequency carrier signal , the bandwidth is increased and due to that design of amplifier , antenna is become very easier.

- In the process of modulation one at least of the three basic parameters of the carrier (amplitude, frequency or phase) is changed according to the user modulating signal.



Amplitude Modulation

- Process in which amplitude of carrier wave is varied accordance with message signal keeping frequency , phase constant.

Let modulating (message signal) and carrier is represented by m(t), c(t) .

$$m(t) = V_m \sin \omega_m t$$
$$c(t) = V_c \sin \omega_c t$$
$$V_{Am}(t) = \ V_c\ \sin \omega_c t + V_m\ \sin \omega_m t\ \sin \omega_c t$$

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

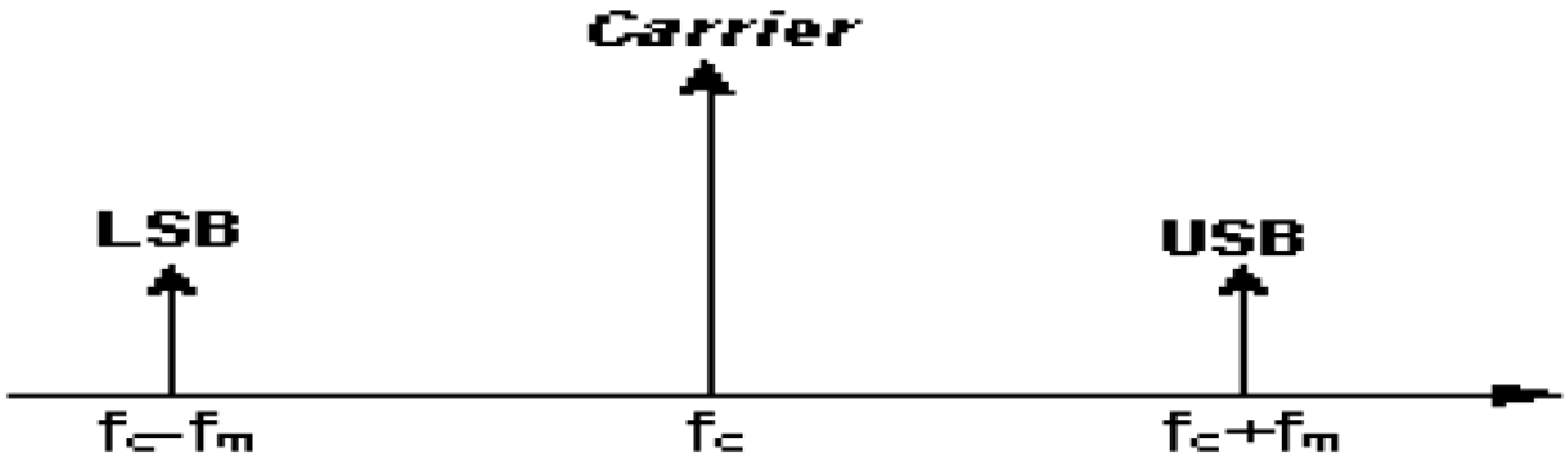
$$V_{Am}(t) = \ V_c\ \left[\sin \omega_c t + \frac{V_m}{2\ V_c} \langle \cos(\omega_c - \omega_m)\, t + \cos(\omega_c + \omega_m)\, t \rangle\right]$$

$$V_{Am}(t) = \ V_c\ \left[\sin \omega_c t + \frac{m}{2} \langle \cos(\omega_c - \omega_m)\, t + \cos(\omega_c + \omega_m)\, t \rangle\right]$$

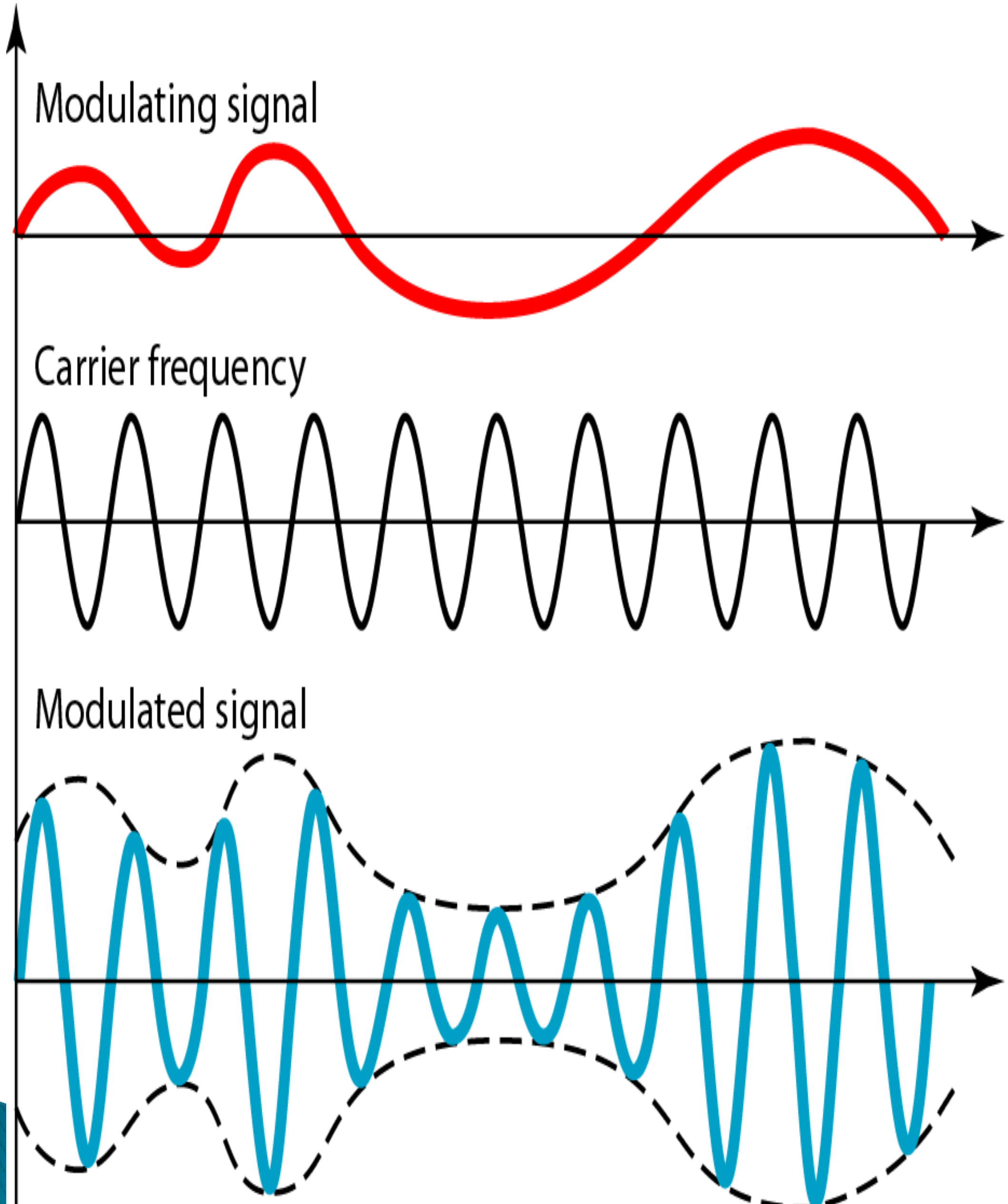
$V_c \sin \omega_c t$= Original carrier
$V_c m/2[\cos(\omega_c - \omega_m)t]$= Lower side band component
$V_c m/2[\cos(\omega_c - \omega_m)t]$= Upper side band component

$$V_{Am}(t) = \ c(t) + \ USB + LSB$$

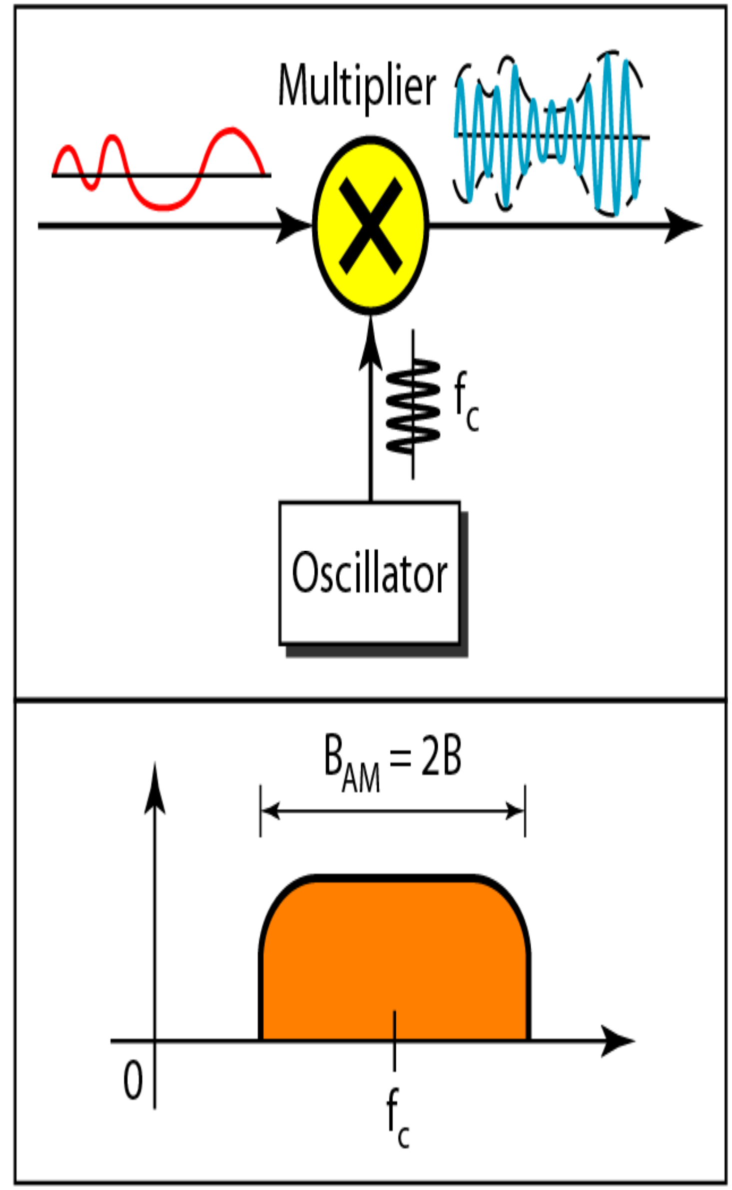
- Amplitude modulated wave v_c contains three terms.
- The first one represents the unmodulated carrier and two additional terms which are a consequence of modulation.
- These two terms are the **Lower side band (LSB) with frequency ($f_c - f_m$), and the Upper side band (USB) with frequency ($f_c + f_m$).**
- So the band width required by AM is twice the frequency of the modulating signal.



- The carrier itself does not fluctuate in amplitude. Instead, the modulating data appears in the form of signal components at frequencies slightly higher and lower than that of the ***carrier.***
- ***These components are called side bands.***
- ***The lower side band(LSB) appears at frequencies below the carrier frequency; the upper side band (USB) appears at frequencies above the carrier frequency.***



Modulating signal
Carrier frequency
Modulated signal



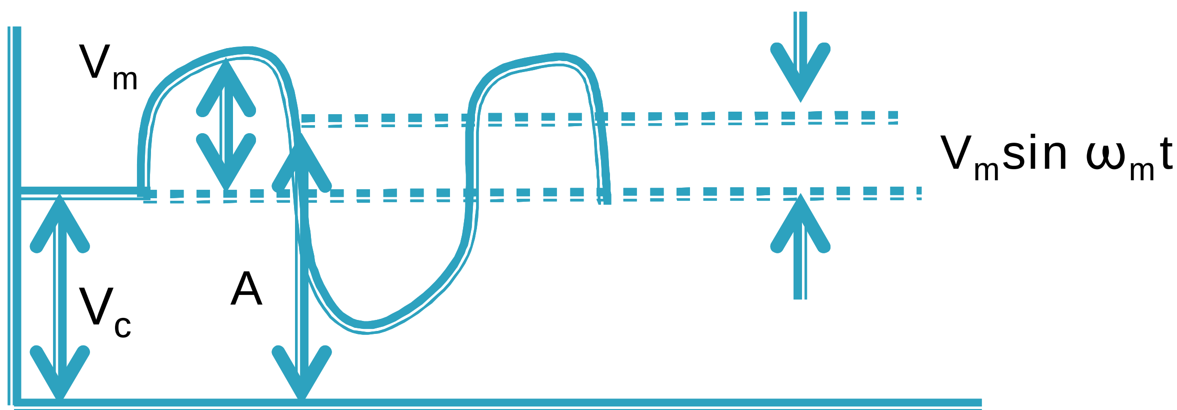
Multiplier
f_c
Oscillator
$B_{AM} = 2B$
0
f_c

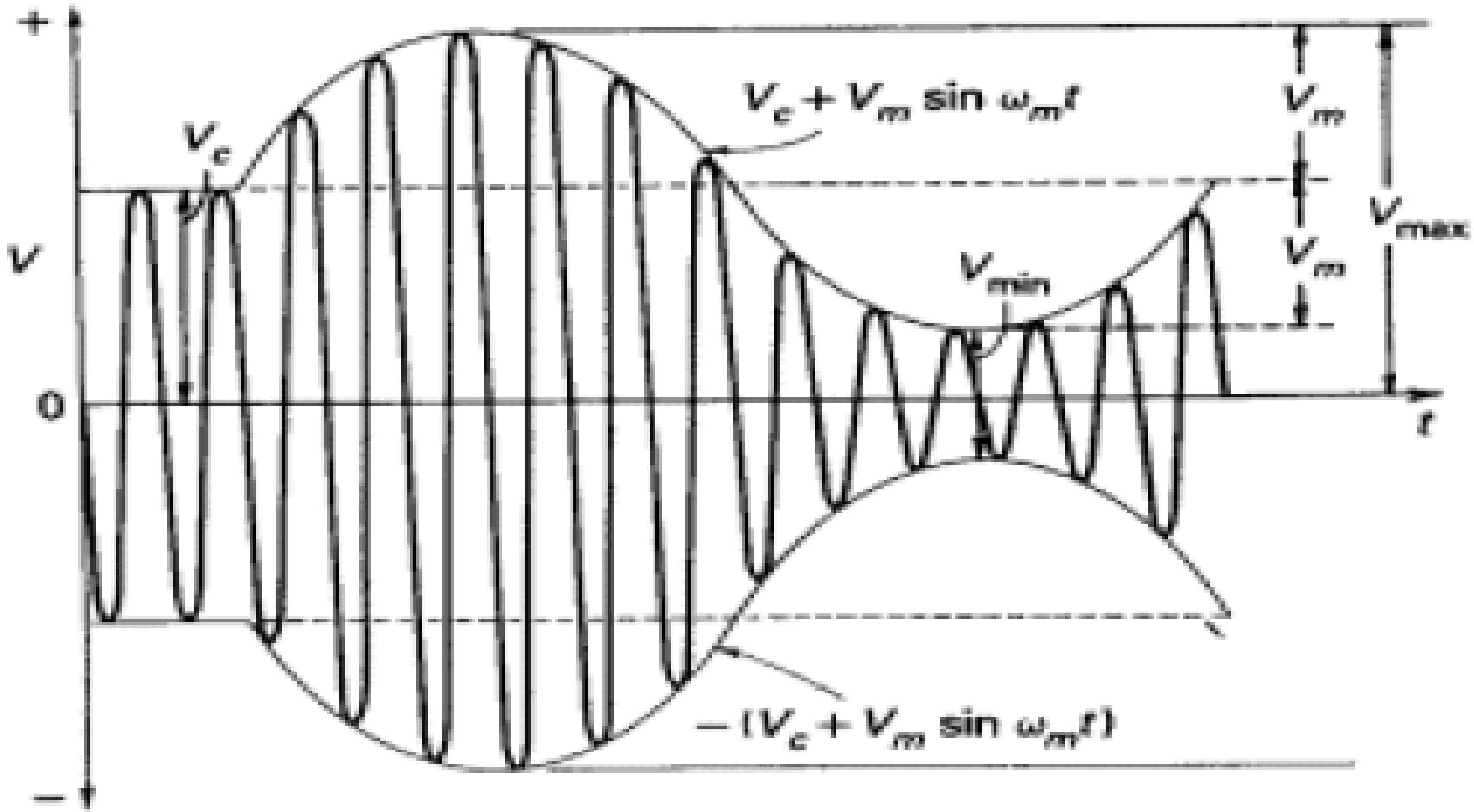
Modulation Index

- Degree of modulation is defined by

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

- M must be in the range of 0<m<1
- If m>1, over modulation occur





+
−
V
0
t
V_c
$V_c + V_m \sin \omega_m t$
V_m
V_m
V_{max}
V_{min}
$-(V_c + V_m \sin \omega_m t)$

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

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

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

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

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

ANGLE MODULATION

- $g(t) = A \sin(\omega_c t + \Theta)$
  - Which consist A, Angle $\Theta_i = (\omega_c t + \Theta)$

- Frequency Modulation
- Phase Modulation

Frequency modulation

- Form of angle modulation in which instantaneous frequency f(t) is varied in accordance with message signal m(t).

$$m(t) = A_m cos 2\pi f_m t$$

$$Instantaneous\ Frequency = \frac{1}{2\pi}\frac{d\theta}{dt}$$

- $f_i = f_c + k_f m(t)$
  - f_i = instantaneous frequency ; f_c = Carrier frequency; k_f = frequency sensitivity of the modulator
- $2\pi f_i = 2\pi f_c + 2\pi k_f m(t)$
- Integrate with respect to time

$$\theta_i(t) = 2\pi f_c t + 2\pi k_f \int_0^t m(t)dt$$

- If FM the modulating signal is s(t)

$$s(t)_{FM} = A_c \cos\theta_i(t)$$

$$s(t)_{FM} = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(t)dt\right]$$

$$s(t)_{FM} = A_c \cos\left[2\pi f_c t + 2\pi k_f A_m \int_0^t \cos 2\pi f_m t \, dt\right]$$

$$s(t)_{FM} = A_c \cos\left[2\pi f_c t + \frac{2\pi k_f A_m}{2\pi f_m} \sin 2\pi f_m t\right]$$

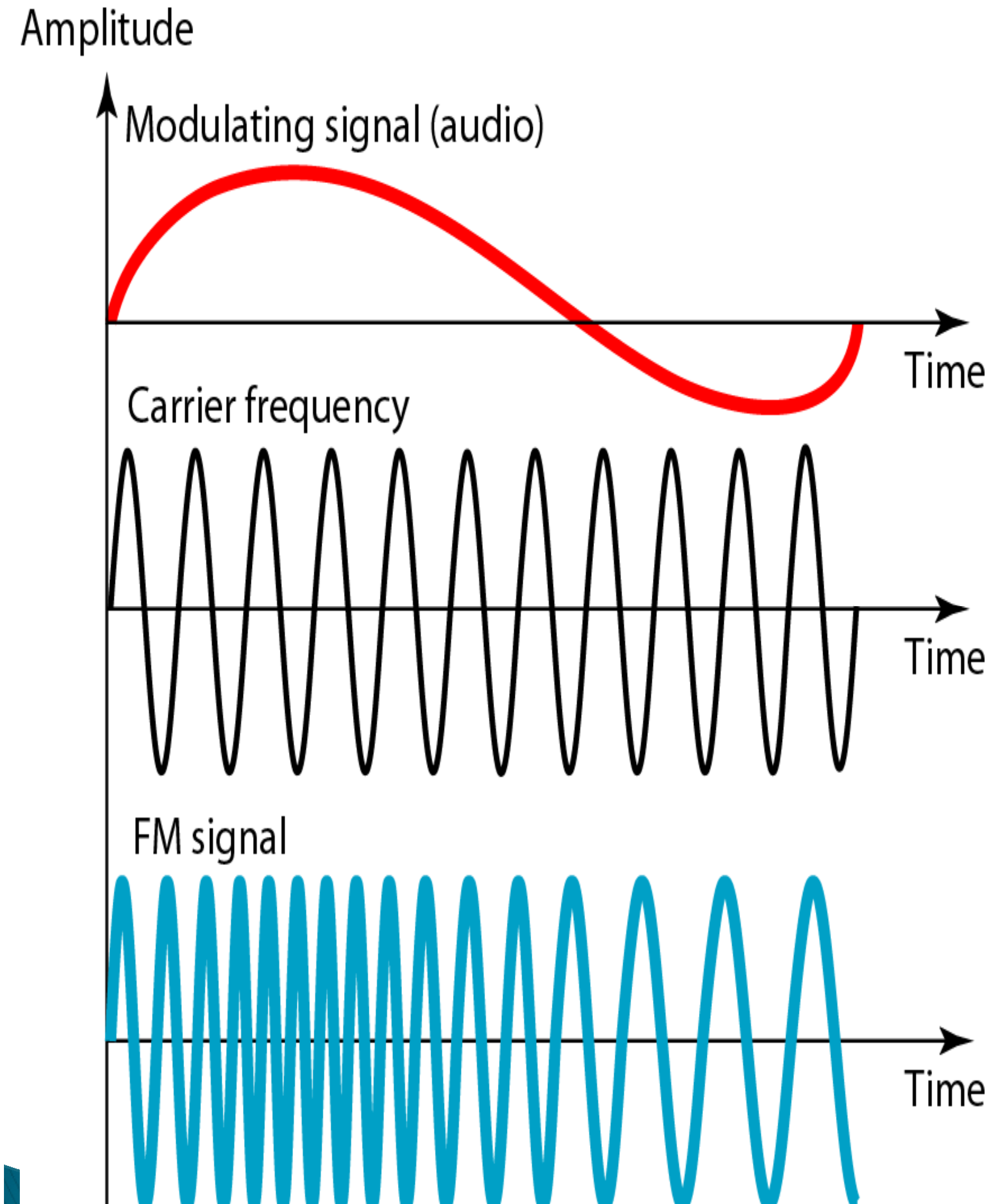
$$s(t)_{FM} = A_c \cos\left[2\pi f_c t + \frac{k_f A_m}{f_m} \sin 2\pi f_m t\right]$$

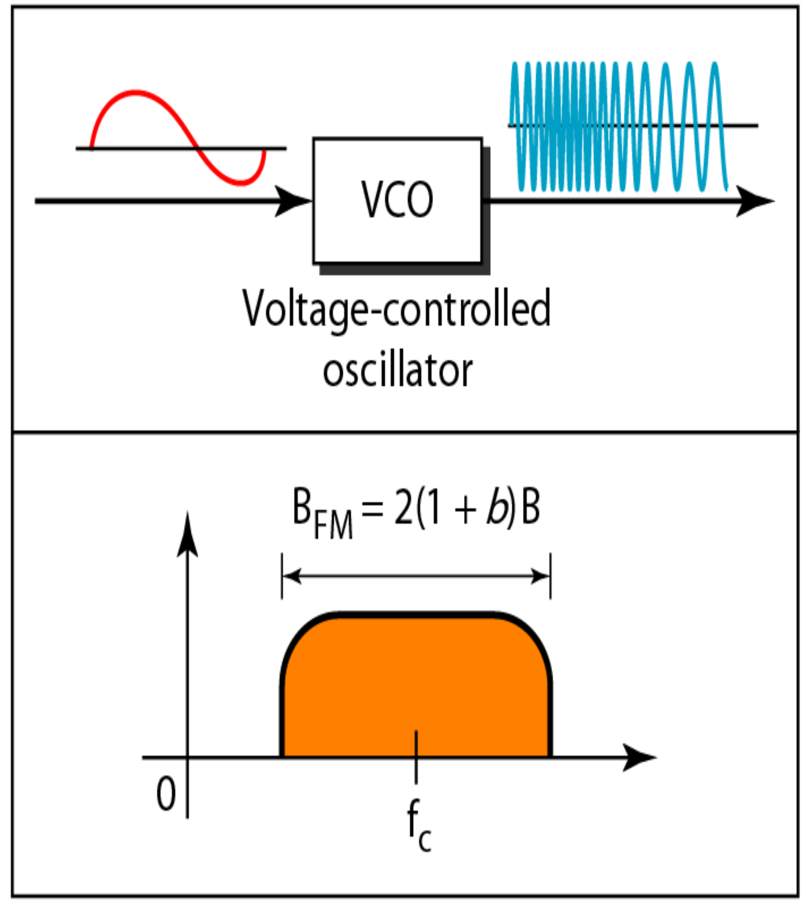
$$s(t)_{FM} = A_c \cos\left[2\pi f_c t + \frac{\Delta f}{f_m} \sin 2\pi f_m t\right]$$

$$\Delta f = k_f A_m = frequency\ deviation$$

$$s(t)_{FM} = A_c \cos[2\pi f_c t + \beta \sin 2\pi f_m t]$$

$$\beta = \frac{\Delta f}{f_m} = modulation\ index\ of\ FM$$


Amplitude
Modulating signal (audio)
Time
Carrier frequency
Time
FM signal
Time


VCO
Voltage-controlled
oscillator
$B_{FM} = 2(1 + b)B$
0
f_c

- On the basis of modulation index , FM is divided in two parts
  - Narrowband FM ($\beta < 1$)
  - Wideband FM ($\beta > 1$)

Phase modulation

- Form of angle modulation in which Θ_i instantaneous angle varied linearly with the amplitude of message signal

$$\theta_i(t) = 2\pi f_c t + k_p\, m(t)$$

$$k_p = phase\ sensitivity$$ =

$$m(t) = A_m cos 2\pi f_m t$$

$$\theta_i(t) = 2\pi f_c t + k_p A_m cos 2\pi f_m t$$

If Phase modulated wave

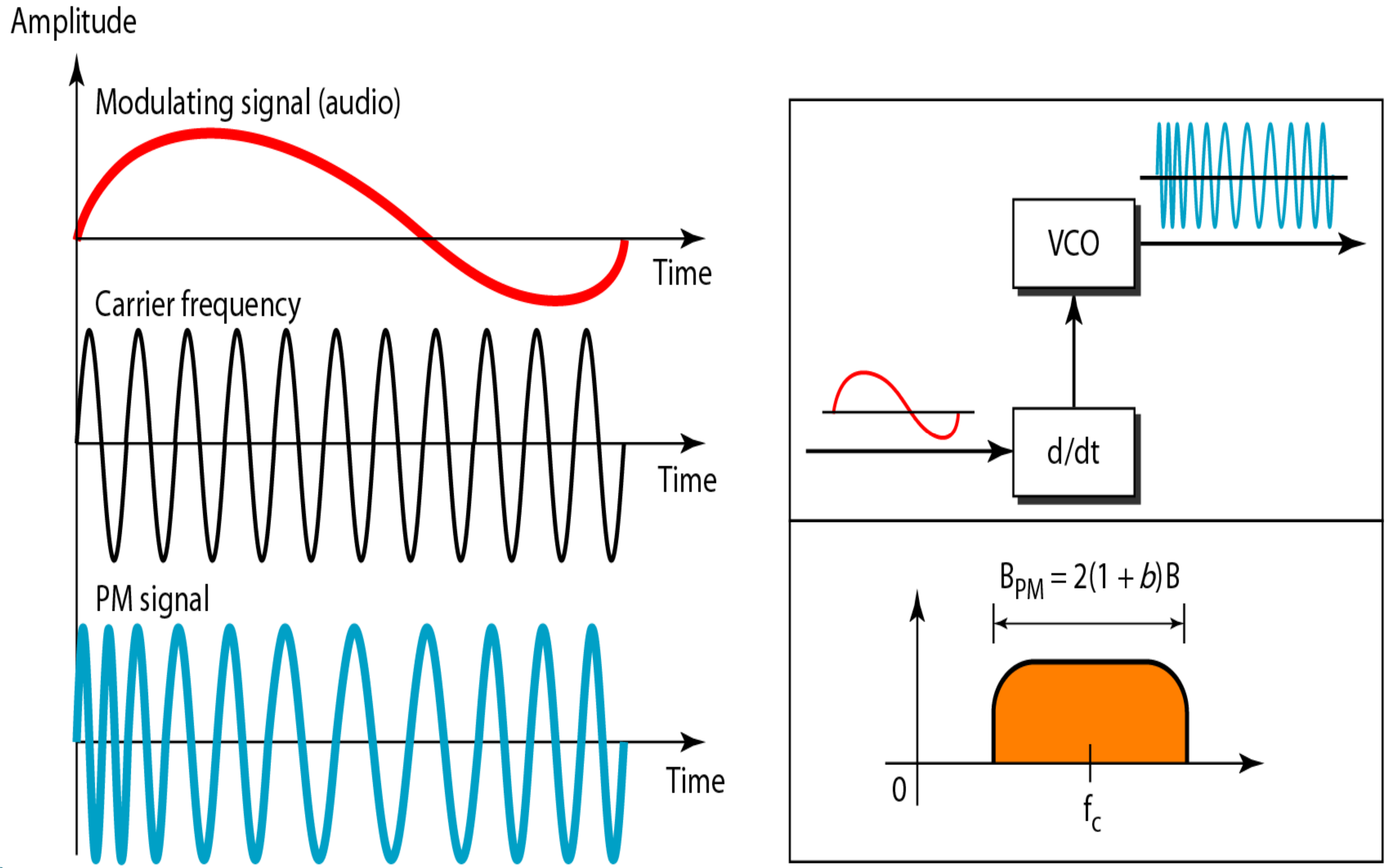
$$s(t)_{PM} = A_c \cos \theta_i(t)$$

$$s(t)_{PM} = A_c \cos\left[2\pi f_c t + k_p A_m cos 2\pi f_m t\right]$$

$$s(t)_{PM} = A_c \cos[2\pi f_c t + \Delta\varphi cos 2\pi f_m t]$$

$$\Delta\varphi = k_p A_m = phase\ deviation = modulation\ index$$

$$\Delta f = \frac{k_p m(t)}{2\pi} = frequency\ deviation$$



Amplitude
Modulating signal (audio)
Time
Carrier frequency
Time
PM signal
Time
VCO
d/dt
$B_{PM} = 2(1 + b)B$
0
f_c

Comparison of AM and FM

AM	FM
❑Transmission and reception is cheap and simpler.	❑Transmitter and receiver both are complex and costly.
❑The amplitude of AM signal depends upon the modulation index.	❑The amplitude of FM signal is constant and independent with modulation index.
❑Bandwidth in AM is less. It cannot be higher that $2f_m$	❑Bandwidth is very high. , generally it is 6 to 15 times.
❑AM is more susceptible to noise, interference in environment and S/N ratio is also low.	❑S/N ratio is very high, so noise is easily removed.
❑Area of coverage is very high.AM is divided in two part medium wave(MW) and short wave (SW).	❑Area of coverage is less.
❑For longer distance like for international broadcasting SW is used.	❑FM is divided in two part narrowband FM and wideband FM.
❑It is generally used for commercial purpose.	❑It cannot used for international broadcasting .For such purpose , required power is very high.
	❑It is used for both commercial and non commercial.

Table 2.1.3 shows the comparison between FM and AM.

Sr. No.	Amplitude Modulation	Frequency Modulation
1.	Amplitude of the carrier is varied according to amplitude of modulating signal.	Frequency of the carrier is varied according to amplitude of the modulating signal.
2.	AM has poor fidelity due to narrow bandwidth.	Since the bandwidth is large, fidelity is better.
3.	Most of the power is in carrier hence less efficient.	All the transmitted power is useful.
4.	Noise interference is more.	Noise interference is minimum.
5.	Adjacent channel interference is present.	Adjacent channel interference is avoided due to wide bandwidth.
6.	AM broadcast operates in MF and HF range.	FM broadcast operates in VHF and UHF range.
7.	In AM only carrier and two sidebands are present.	Infinite number of sidebands are present.
8.	The transmission equipment is simple.	The transmission equipment is complex.
9.	Transmitted power varies according to modulation index.	Transmitted power remains constant irrespective of modulation index.
10.	Depth of modulation have limitation. It can not be increased above 1.	Depth of modulation have no limitation. It can be increased by increasing frequency deviation.

Table 2.1.4 shows the comparison between FM and PM.

Sr. No.	Frequency Modulation	Phase Modulation
1.	The maximum frequency deviation depends upon amplitude of modulating voltage and modulating frequency.	The maximum phase deviation depends only upon the amplitude of modulating voltage.
2.	Frequency of the carrier is modulated by modulating signal.	Phase of the carrier is modulated by modulating signal.
3.	Modulation index is increased as modulation frequency is reduced and vice versa.	Modulation index remains same if modulating frequency is changed.

Comparison of modulated system

ITEM	AM	FM/PM
➢Linear or non linear ➢Depth of modulation ➢	➢Linear ➢Can not be greater than 1	➢Non-linear ➢Can be high