Principles of Communication (BEC-28)

Unit-2

Angle Modulation

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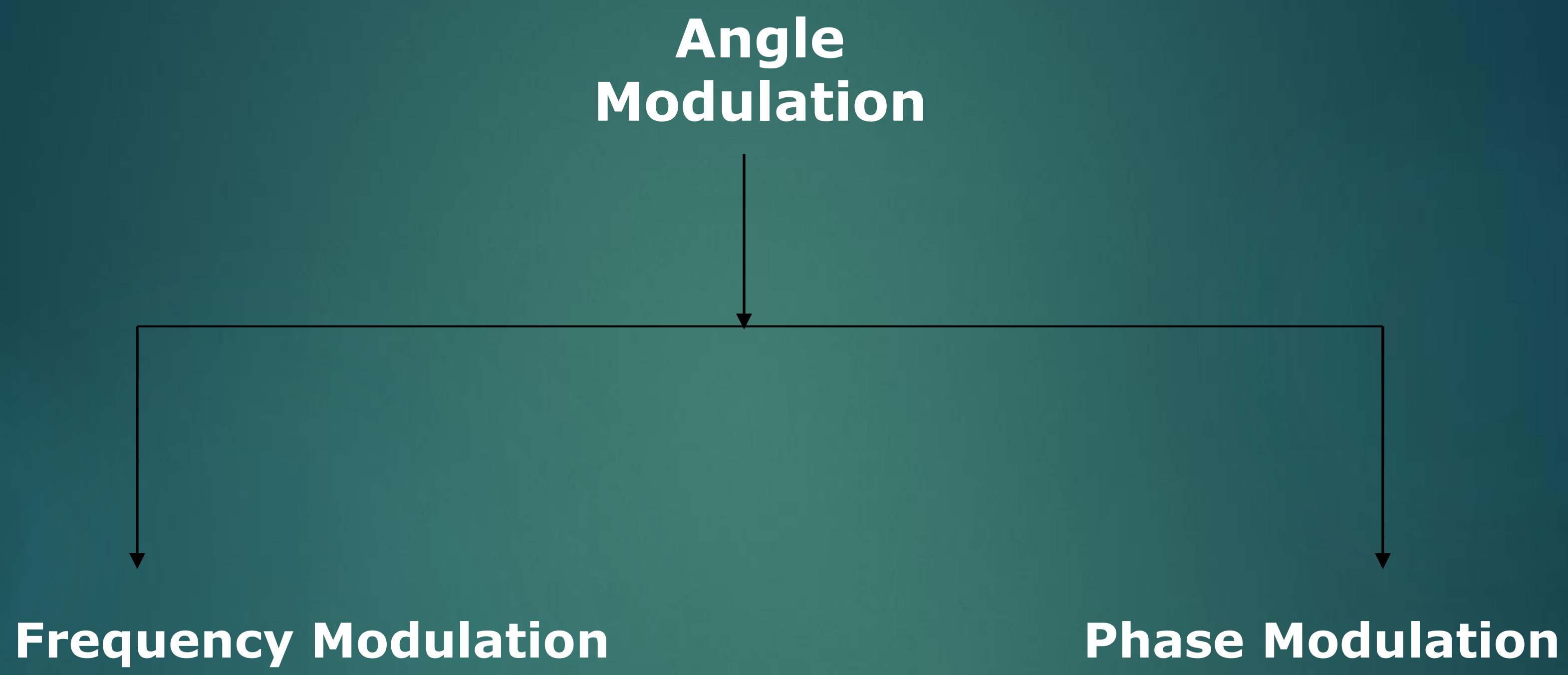
Content of Unit-2

Introduction to Angle Modulation: Frequency modulation, Narrowband and Wideband FM, Generation of FM waves, Indirect FM and direct FM, FM modulators and demodulators, Phase locked loop, Angle Modulation by Arbitrary Message Signal, Phase Modulation, Pre-emphasis and De-emphasis, Linear and Nonlinear Modulation, Comparison between Angle Modulation and Amplitude Modulation, Radio Receivers.

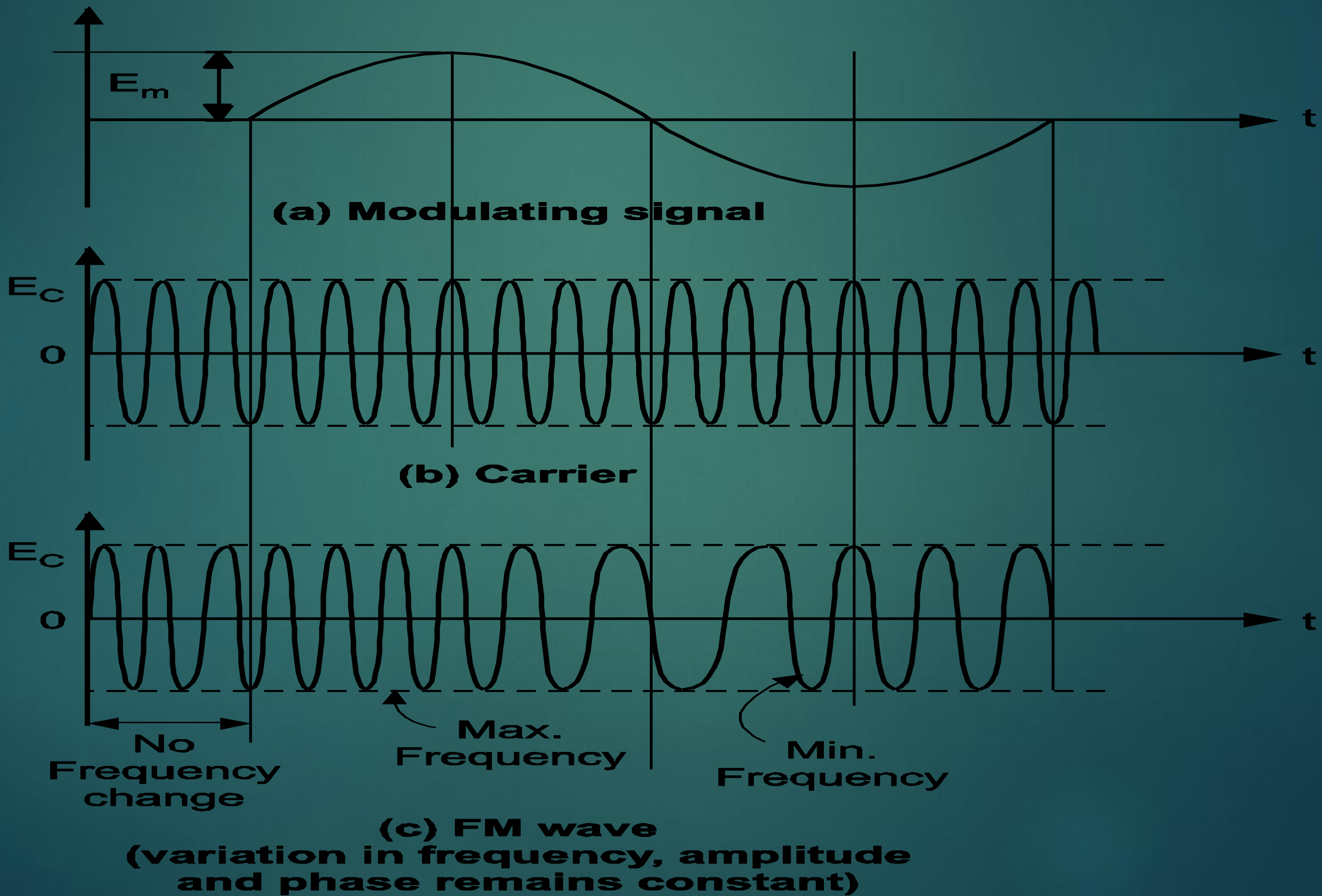
Angle Modulation



Frequency Modulation

Definition of FM: Frequency modulation is a technique of modulation in which the frequency of carrier is varied in accordance with the amplitude of modulating signal.

- In FM, amplitude and phase remains constant.
- Thus, the information is conveyed via. frequency changes.



Modulation Index : Modulation Index is defined as the ratio of frequency deviation (δ) to the modulating frequency (f_m).

$$\text{Modulation Index (M.I.)} = \frac{\text{Frequency Deviation}}{\text{Modulating Frequency}}$$

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

In FM M.I.<1 NBFM

M.I.>1 WBFM

Modulation Index of FM decides –

(i) Bandwidth of the FM wave.

(ii) Number of sidebands in FM wave.

Deviation Ratio: The modulation index corresponding to maximum deviation and maximum modulating frequency is called deviation ratio.

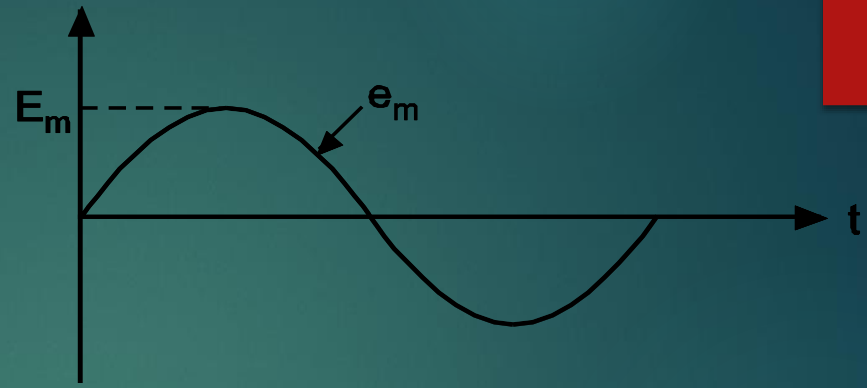
$$\text{Deviation Ratio} = \frac{\text{Maximum Deviation}}{\text{Maximum modulating Frequency}}$$

$$= \frac{\delta_{max}}{f_{max}}$$

In FM broadcasting the maximum value of deviation is limited to **75 kHz.** The maximum modulating frequency is also limited to **15 kHz.**

Mathematical Representation of FM

(i) Modulating Signal:



It may be represented as,

$$e_m = E_m \cos \omega_m t \qquad \ldots(1)$$

Here cos term taken for simplicity

where,

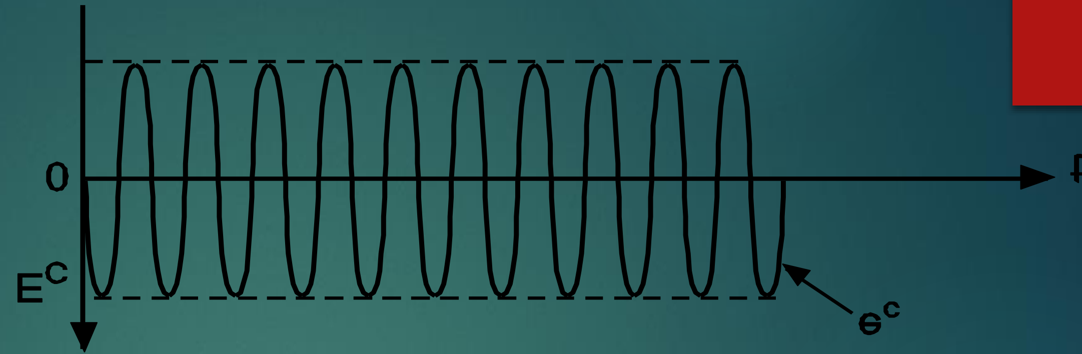
e_m = Instantaneous amplitude

ω_m = Angular velocity

= $2\pi f_m$

f_m = Modulating frequency

(ii) Carrier Signal:



Carrier may be represented as,

$e_c = E_c \sin(\omega_{ct} + \phi)$ ....(2)

where,

e_c = Instantaneous amplitude

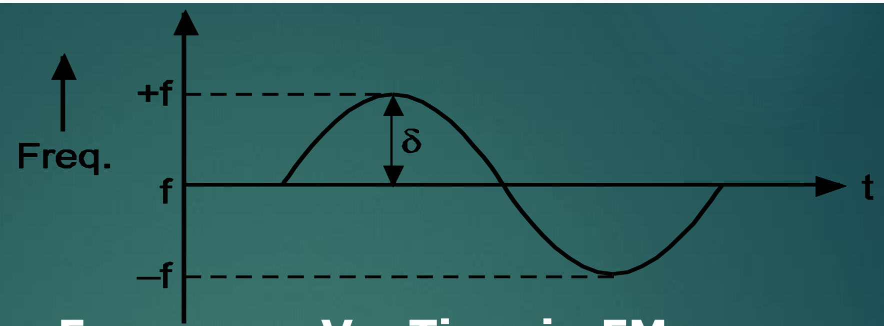
ω_c = Angular velocity

= $2\pi f_c$

f_c = Carrier frequency

ϕ = Phase angle

(iii) FM Wave:



Frequency Vs. Time in FM

- FM is nothing but a deviation of frequency. The instantaneous frequency 'f' of the FM wave is given by,

$$f = f_c\,(1 + K\,E_m \cos \omega_m t) \qquad \dots (3)$$

where,

f_c = Unmodulated carrier frequency

K = Proportionality constant

$E_m \cos \omega_m t$ = Instantaneous modulating signal

(Cosine term preferred for simplicity otherwise we can use sine term also)

- The maximum deviation for this particular signal will occur, when $\cos \omega_m t = \pm 1$ i.e. maximum.

∴ Equation (3) becomes,

$$f = f_c\,(1 \pm K\,E_m) \qquad \dots (4)$$

$$\therefore \quad f = f_c \pm K\,E_m f_c \qquad \dots (5)$$

Cont...

So that maximum deviation δ will be given by,

$$\delta = K E_m f_c \qquad \dots (6)$$

The instantaneous amplitude of FM signal is given by,

$$e_{FM} = A \sin [f(\omega_c, \omega_m)]$$

$$e_{FM} = A \sin \theta \qquad \dots (7)$$

where, $f(\omega_c, \omega_m)$=Some function of carrier and modulating frequencies

Let us write equation (3) in terms of ω as,

$$\boldsymbol{\omega = \omega_c (1 + K E_m \cos \omega_m t)}$$

To find θ, ω must be integrated with respect to time.

Thus,

$$\theta = \int \omega \, dt = \int \omega_c (1 + K E_m \cos \omega_m t)\, dt = \omega_c \left(t + K E_m \frac{\sin \omega_m t}{\omega_m}\right)$$

$$\theta = \omega_c t + K E_m \omega_c \frac{\sin \omega_m t}{\omega_m} = \omega_c t + K E_m f_c \frac{\sin \omega_m t}{\omega_m} = \omega_c t + \frac{\delta \sin \omega_m t}{\omega_m} \quad [\because \delta = K E_m f_c]$$

Substitute value of θ in equation (7)

Thus, $e_{FM} = A \sin \left(\omega_c t + \frac{\delta}{f_m} \sin \omega_m t\right)$ ---(8)

$$\boldsymbol{e_{FM} = A \sin (\omega_c t + m_f \sin \omega_m t)} \qquad ---(9)$$

Frequency Spectrum of FM

Frequency spectrum is a graph of amplitude versus frequency. The frequency spectrum of FM wave tells us about number of sideband present in the FM wave and their amplitudes.

The expression for FM wave is not simple. It is complex because it is sine of sine function.

Only solution is to use **'Bessels Function'.**

Equation (2.32) may be expanded as,

$$
\begin{aligned}
e_{FM} = \; & \{A\, J_0\,(m_f) \sin \omega_c t \\
& + J_1\,(m_f)\,[\sin\,(\omega_c + \omega_m)\, t - \sin\,(\omega_c - \omega_m)\, t] \\
& + J_1\,(m_f)\,[\sin\,(\omega_c + 2\omega_m)\, t + \sin\,(\omega_c - 2\omega_m)\, t] \\
& + J_3\,(m_f)\,[\sin\,(\omega_c + 3\omega_m)\, t - \sin\,(\omega_c - 3\omega_m)\, t] \\
& + J_4\,(m_f)\,[\sin\,(\omega_c + 4\omega_m)\, t + \sin\,(\omega_c - 4\omega_m)\, t] \\
& + \ldots\ldots\} \qquad \ldots (2.33)
\end{aligned}
$$

From this equation it is seen that the FM wave consists of:

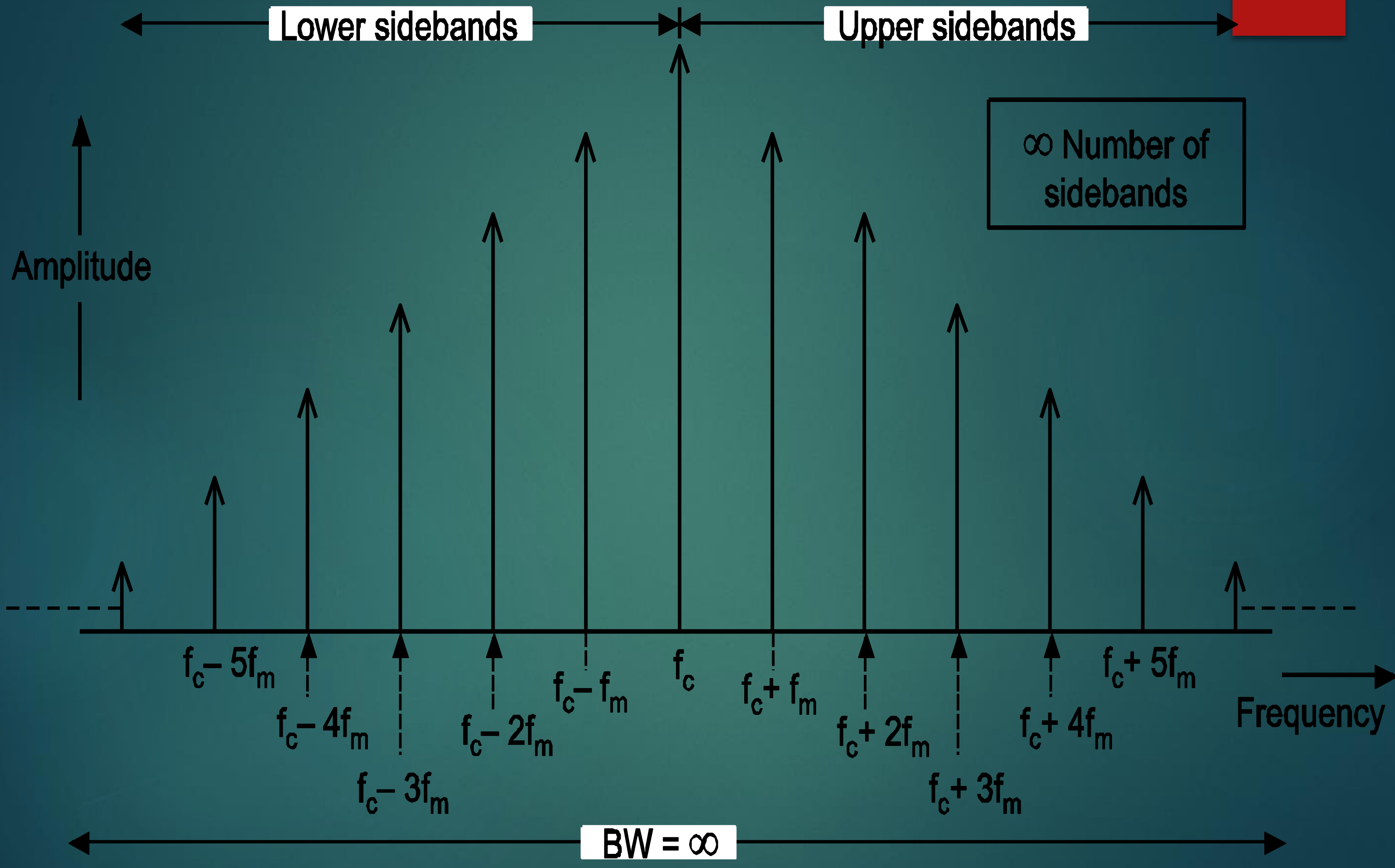
(i) Carrier (First term in equation).

(ii) Infinite number of sidebands (All terms except first term are sidebands).

The amplitudes of carrier and sidebands depend on 'J' coefficient.

$\omega_c = 2\pi f_c, \qquad \omega_m = 2\pi f_m$

So in place of ω_c and ω_m, we can use f_c and f_m.



Ideal Frequency Spectrum of FM

Bandwidth of FM

From frequency spectrum of FM wave shown in Fig. we can say that the bandwidth of FM wave is infinite.

But practically, it is calculated based on how many sidebands have significant amplitudes.

(i) The Simple Method to calculate the bandwidth is –

$BW = 2f_m \times$ Number of significant sidebands

With increase in modulation index, the number of significant sidebands increases. So that bandwidth also increases.

(ii)The second method to calculate bandwidth is by **Carson's rule.**

Carson's rule states that, the bandwidth of FM wave is twice the sum of deviation and highest modulating frequency.

$$BW = 2(\delta + f_m max) \qquad ...(2)$$


Thank You