JYOTHISHMATHI INSTITUTE OF TECHNOLOGY & SCIENCE

PPT ON FREQUENCY MODULATION

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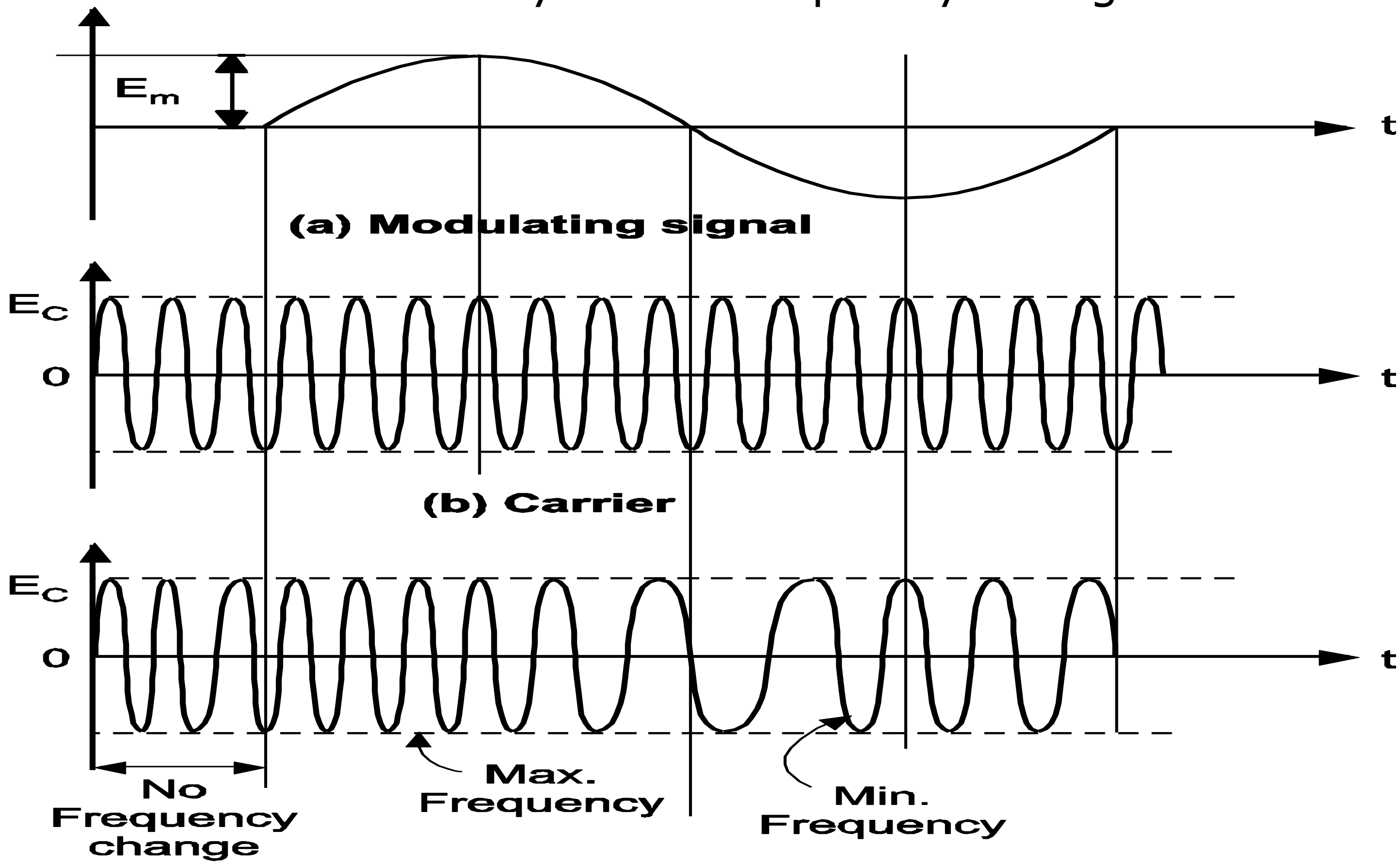
Frequency Modulation

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



(c) FM wave (variation in frequency, amplitude and phase remains constant)

Modulation Index

Definition:

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

$$\text{M.I.} = \frac{\text{Frequency Deviation}}{\text{Modulating Frequency}}$$

$$mf = \frac{\delta}{fm}$$

In FM M.I.>1

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 modulation frequency is called deviation ratio.

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

$$= \frac{\delta max}{fmax}$$

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

Percentage M.I. of FM

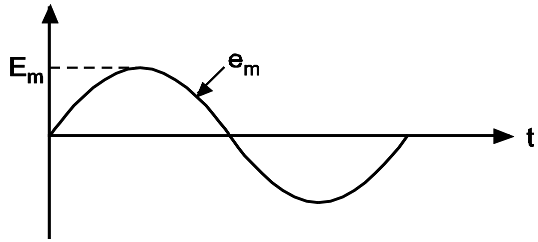
The percentage modulation is defined as the ratio of the actual frequency deviation produced by the modulating signal to the maximum allowable frequency deviation.

$$\% \text{ M.I} = \frac{\text{Actual deviation}}{\text{Maximum allowable deviation}}$$

∴

Mathematical Representation of FM

(i) Modulating Signal:



It may be represented as,

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

Here cos term taken for simplicity

where,

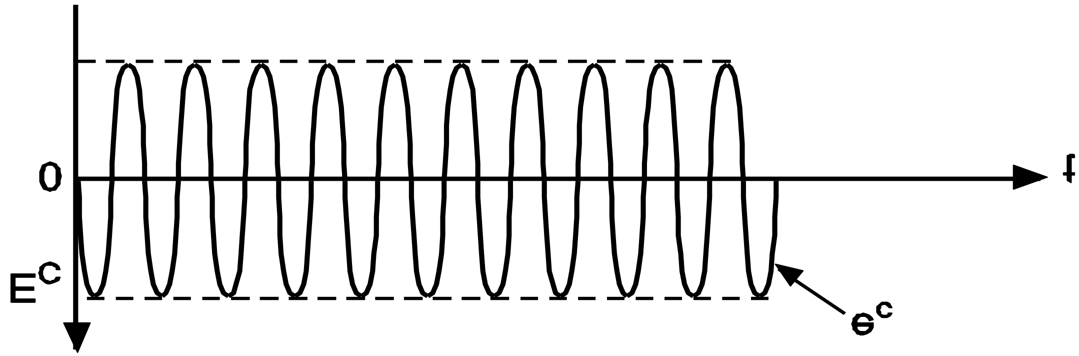
e_m = **Instantaneous amplitude**

ω_m = **Angular velocity**

= $2\pi f_m$

f_m = **Modulating frequency**

(ii) Carrier Signal:



Carrier may be represented as,

$$e_c = E_c \sin (\omega_{ct} + \phi) \qquad \text{-----(2)}$$

where,

e_c	=	**Instantaneous amplitude**
ω_c	=	**Angular velocity**
	=	$2\pi f_c$
f_c	=	**Carrier frequency**
ϕ	=	**Phase angle**

(iii) FM Wave:

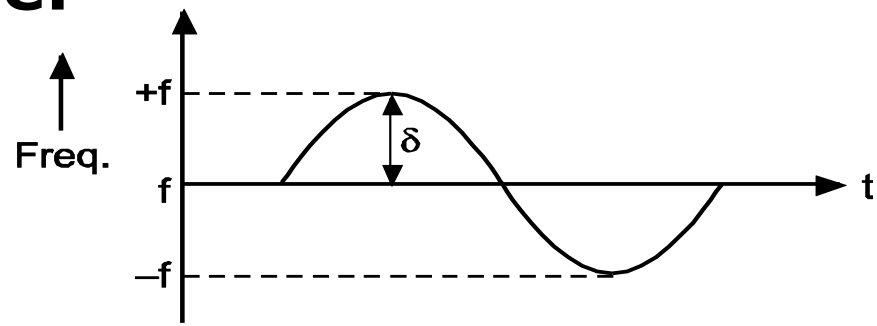


Fig. Frequency Vs. Time in FM

FM is nothing but a deviation of frequency.

From Fig. 2.25, it is seen that instantaneous frequency 'f' of the FM wave is given by,

$$\mathbf{f = f_c (1 + K E_m \cos \omega_m t)} \ldots (3)$$

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 (2.26) becomes,

$$\mathbf{f = f_c (1 \pm K E_m)} \qquad \ldots \mathbf{(4)}$$

$$\therefore \qquad \mathbf{f = f_c \pm K E_m f_c} \qquad \ldots \mathbf{(5)}$$

So that maximum deviation δ will be given by,

$$\boldsymbol{\delta = K E_m f_c} \quad \ldots (6)$$

The instantaneous amplitude of FM signal is given by,

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

$$= A \sin \theta \quad \ldots (7)$$

where,

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

Let us write equation (2.26) 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,

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

$$= \omega_c (1 + K E_m \cos \omega_m t) \, dt$$

$$\theta = \omega_c (1 + K E_m \cos \omega_m t) \, dt$$

$$= \omega_c \left(t + KEm \frac{\sin \omega m t}{\omega m}\right)$$

$$= \omega_c t + KEm\omega_c \frac{\sin \omega m t}{\omega m}$$

$$= \omega_c t + KEmf_c \frac{\sin \omega m t}{\omega m}$$

$$=\omega_c t + \frac{\delta \sin\omega mt}{fm} \qquad [\because \quad \delta = K\, E_m\, f_c]$$

$\therefore$

Substitute value of θ in equation (7)

Thus,

$$e_{FM} = A \sin\left(\omega_c t + \frac{\delta}{fm} \sin\omega mt\right) \text{---(8)}$$

$$e_{FM} = A \sin\left(\omega_c t + mf \sin\omega mt\right) \text{---(9)}$$

This is the equation of FM.

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,

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

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.

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

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

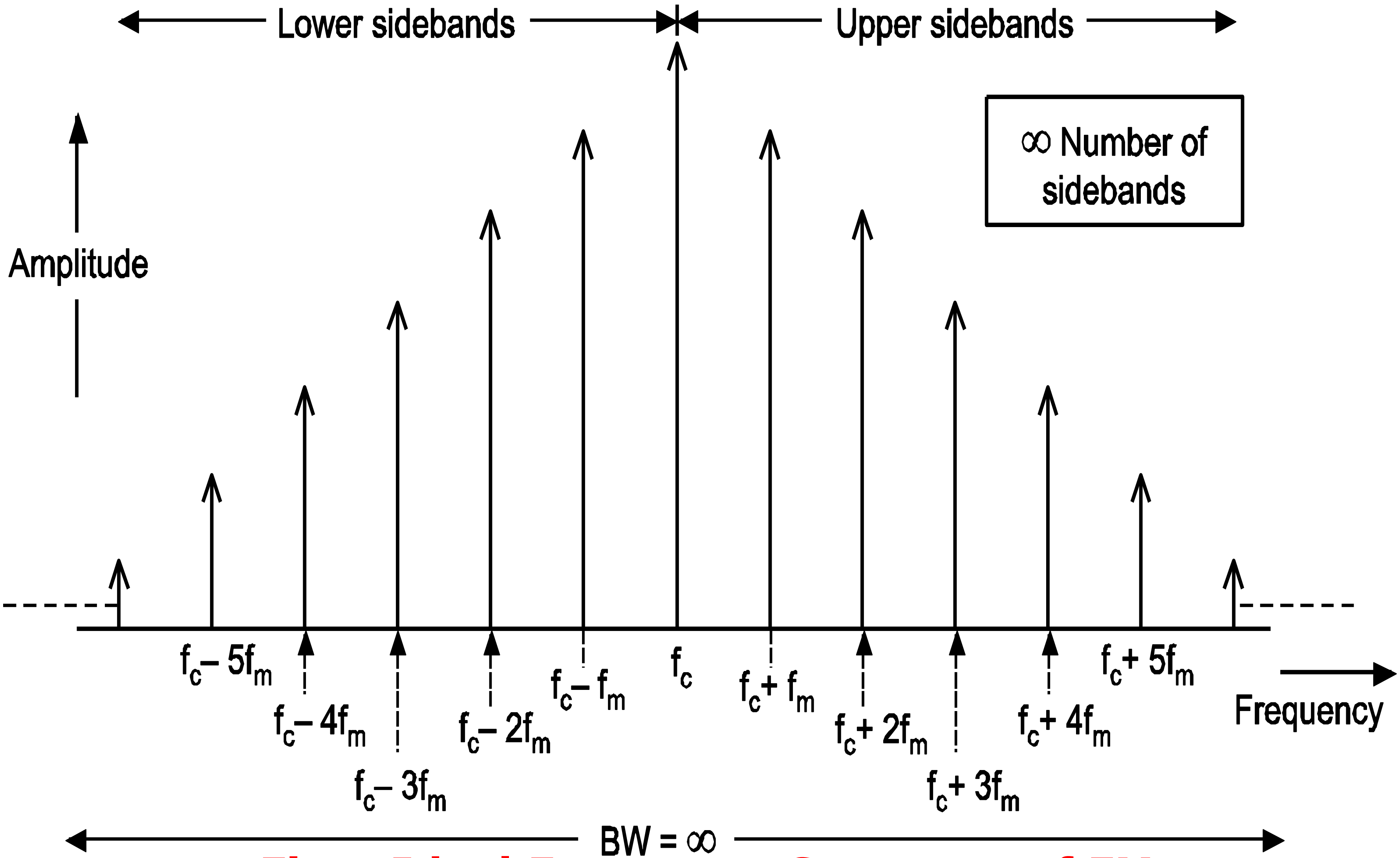


Fig. : Ideal Frequency Spectrum of FM

Bandwidth of FM

From frequency spectrum of FM wave shown in Fig. 2.26, 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=2fmx Number of significant sidebands --(1)

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.

$$BW = 2(\delta + f_{m max}) \qquad \ldots(2)$$

Highest order side band = To be found from table 2.1 after the calculation of modulation Index m where, m = δ / f_m

e.g. If m= 20KHZ/5KHZ

From table, for modulation index 4, highest order side band is 7th.

Therefore, the bandwidth is

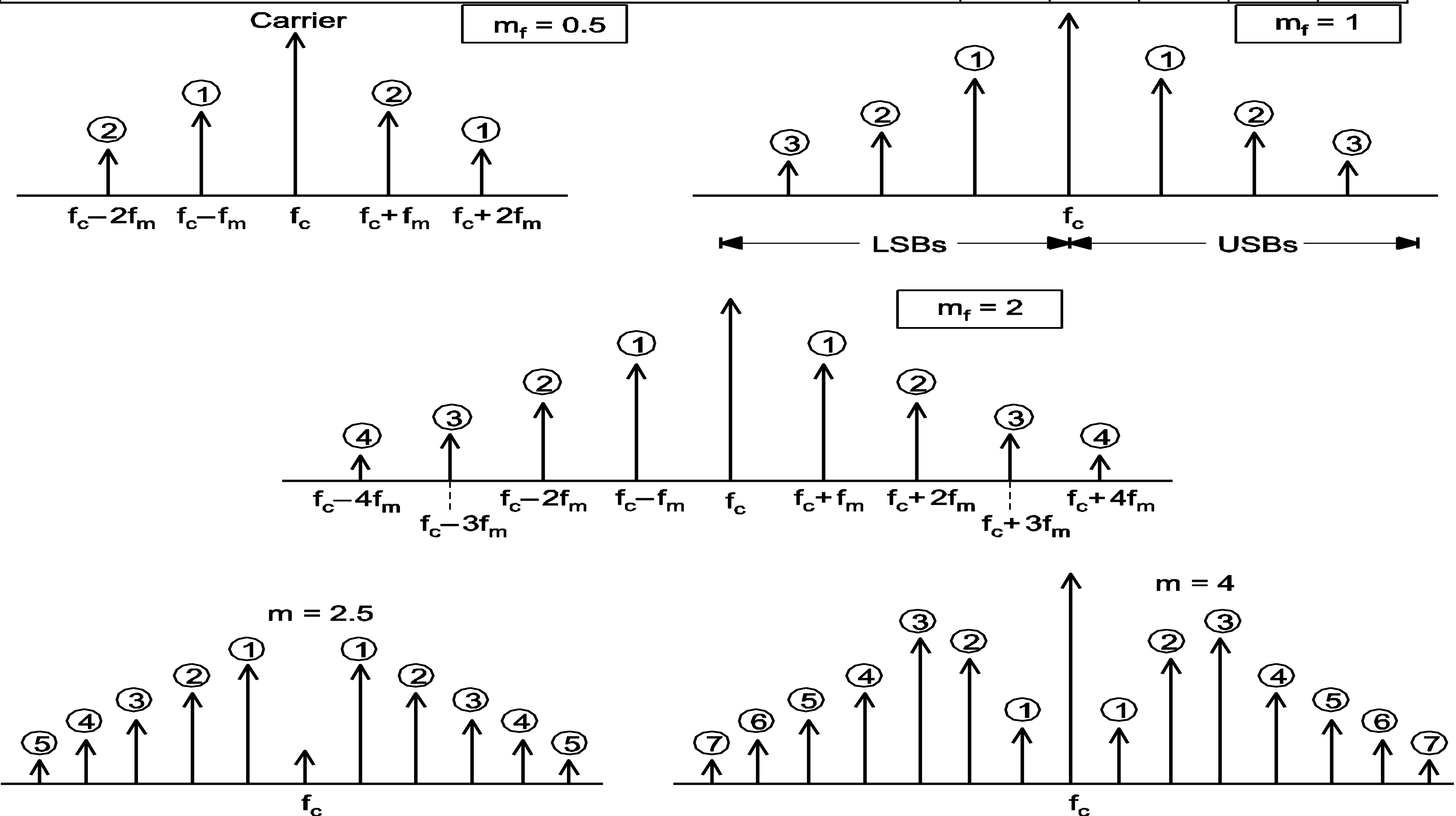
$$B.W. = 2\, f_m \times \text{Highest order side band}$$

$$= 2 \times 5\ \text{kHz} \times 7$$

$$= 70\ \text{kHz}$$

Effect of Modulation Index on Sidebands

Modulation index	0.5	1	2	2.5	4
Number of significant sideband on either side of carrier	2	3	4	5	7



Types of Frequency Modulation

FM (Frequency Modulation)

- Narrowband FM (NBFM) [When modulation index is small]
- Wideband FM (WBFM) [When modulation index is large]

Comparison between Narrowband and Wideband FM

Sr. No.	Parameter	NBFM	WBFM
1.	Modulation index	Less than or slightly greater than 1	Greater than 1
2.	Maximum deviation	5 kHz	75 kHz
3.	Range of modulating frequency	20 Hz to 3 kHz	20 Hz to 15 kHz
4.	Maximum modulation index	Slightly greater than 1	5 to 2500
5.	Bandwidth	Small approximately same as that of AM BW = $2f_m$	Large about 15 times greater than that of NBFM. BW = $2(\delta + fmmax)$
6.	Applications	FM mobile communication like police wireless, ambulance, short range ship to shore communication etc.	Entertainment broadcasting (can be used for high quality music transmission)

Representation of FM

FM can be represented by two ways:

1. Time domain.
2. Frequency domain.

1. FM in Time Domain

Time domain representation means continuous variation of voltage with respect to time as shown in Fig.

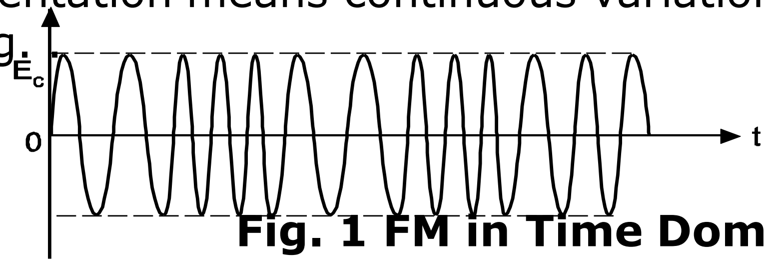


Fig. 1 FM in Time Domain

2. FM in Frequency Domain

- Frequency domain is also known as **frequency spectrum.**
- FM in frequency domain means graph or plot of amplitude versus frequency as shown in Fig. 2.29.

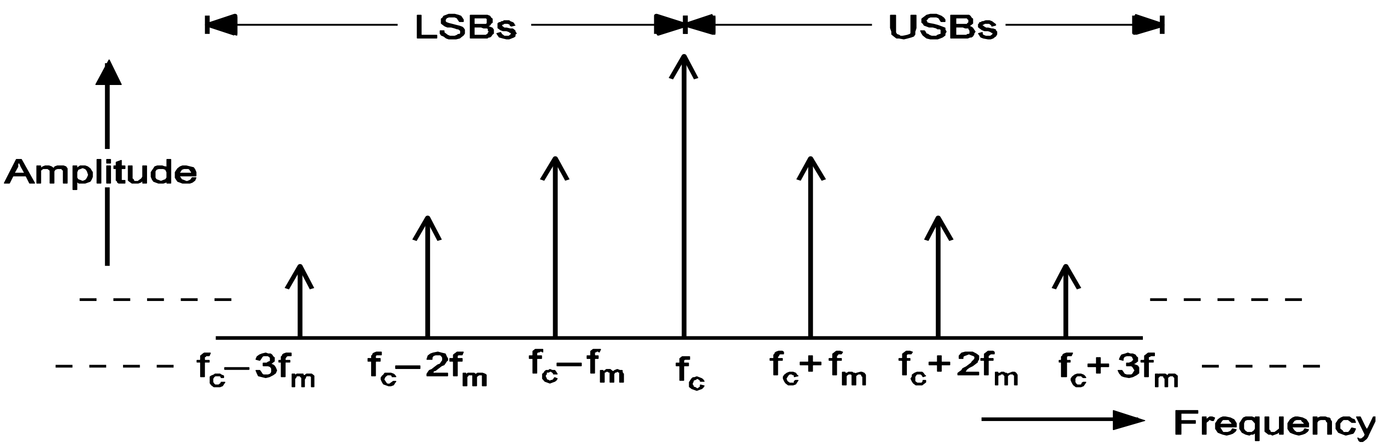


Fig. 2: FM in Frequency Domain

Pre-emphasis and De-emphasis

- Pre and de-emphasis circuits are used only in frequency modulation.
  - Pre-emphasis is used **at transmitter** and de-emphasis **at receiver**.

1. Pre-emphasis

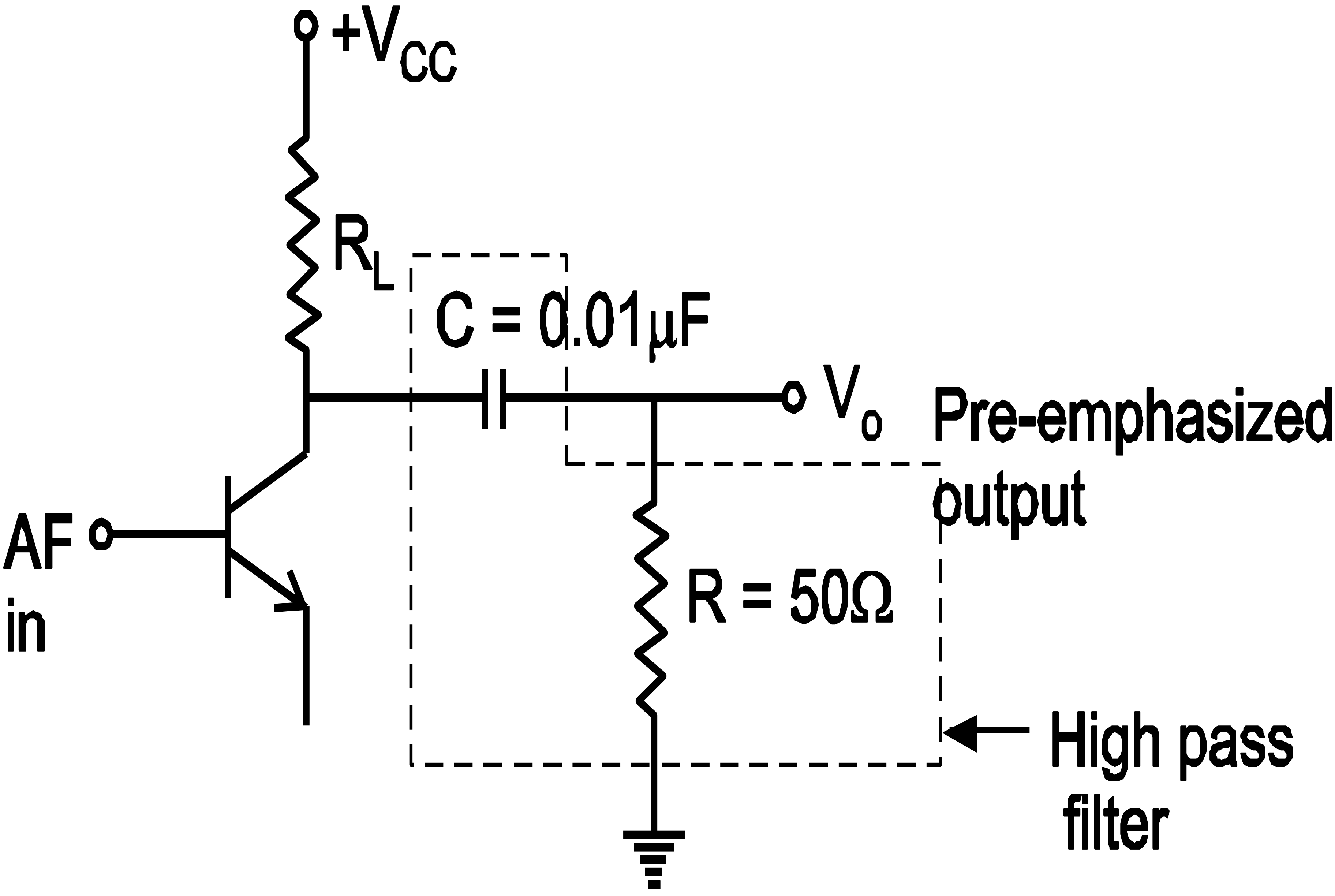
- In FM, the noise has a greater effect on the higher modulating frequencies.
- This effect can be reduced by increasing the value of modulation index (m_f), for higher modulating frequencies.
- This can be done by increasing the deviation ‘δ’ and ‘δ’ can be increased by increasing the amplitude of modulating signal at higher frequencies.

Definition:

The artificial boosting of higher audio modulating frequencies in accordance with prearranged response curve is called pre-emphasis.

- Pre-emphasis circuit is a high pass filter as shown in Fig. 1

Fig. 1: Pre-emphasis Circuit



As shown in Fig. 1, AF is passed through a high-pass filter, before applying to FM modulator.

- As modulating frequency (f_m) increases, capacitive reactance decreases and modulating voltage goes on increasing.

$f_m \propto$ Voltage of modulating signal applied to FM modulat

Boosting is done according to pre-arranged curve as shown in Fig. 2.

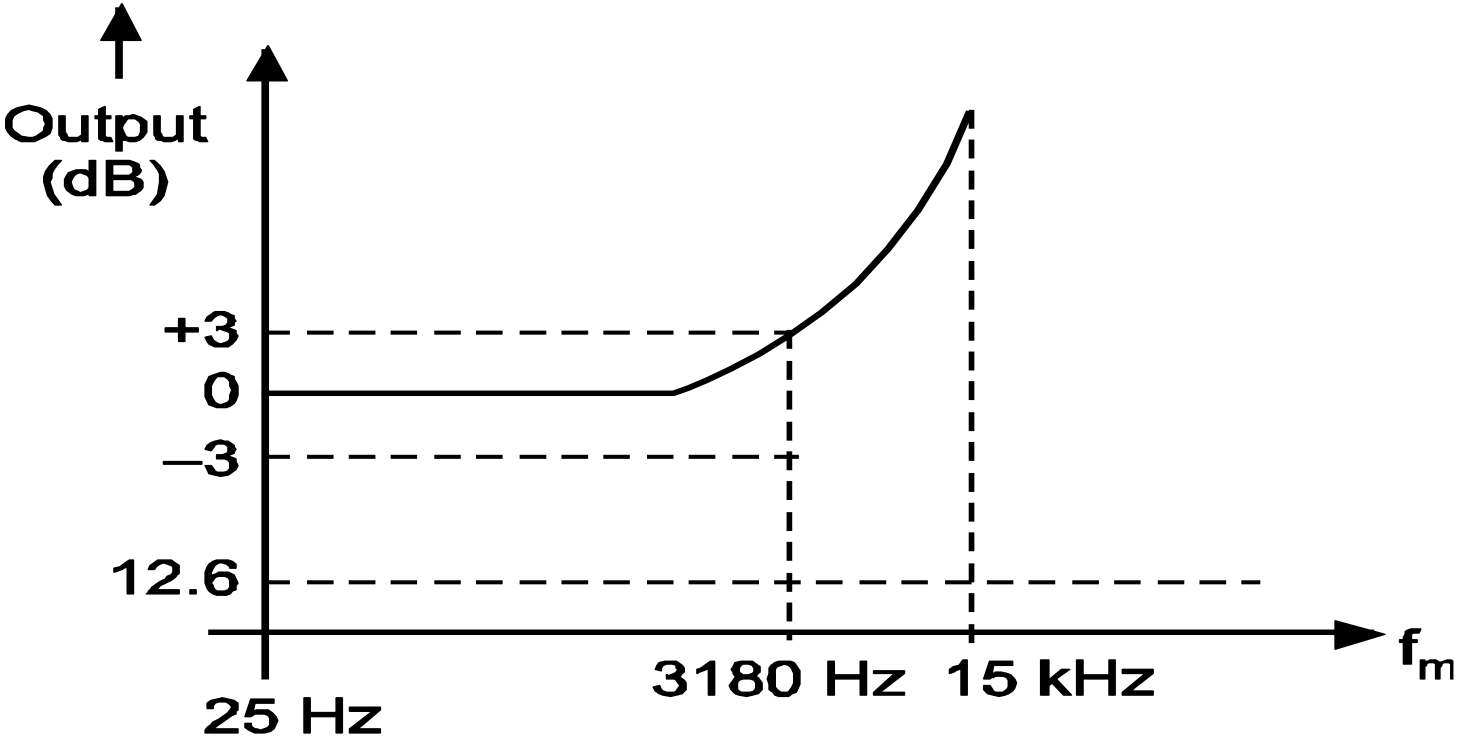


Fig. 2: P re-emphasis Curve

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The time constant of pre-emphasis is at 50 μs in all CCIR standards.

- In systems employing American FM and TV standards, networks having time constant of 75 μsec are used.
- **The pre-emphasis is used at FM transmitter** as shown in Fig. 3.

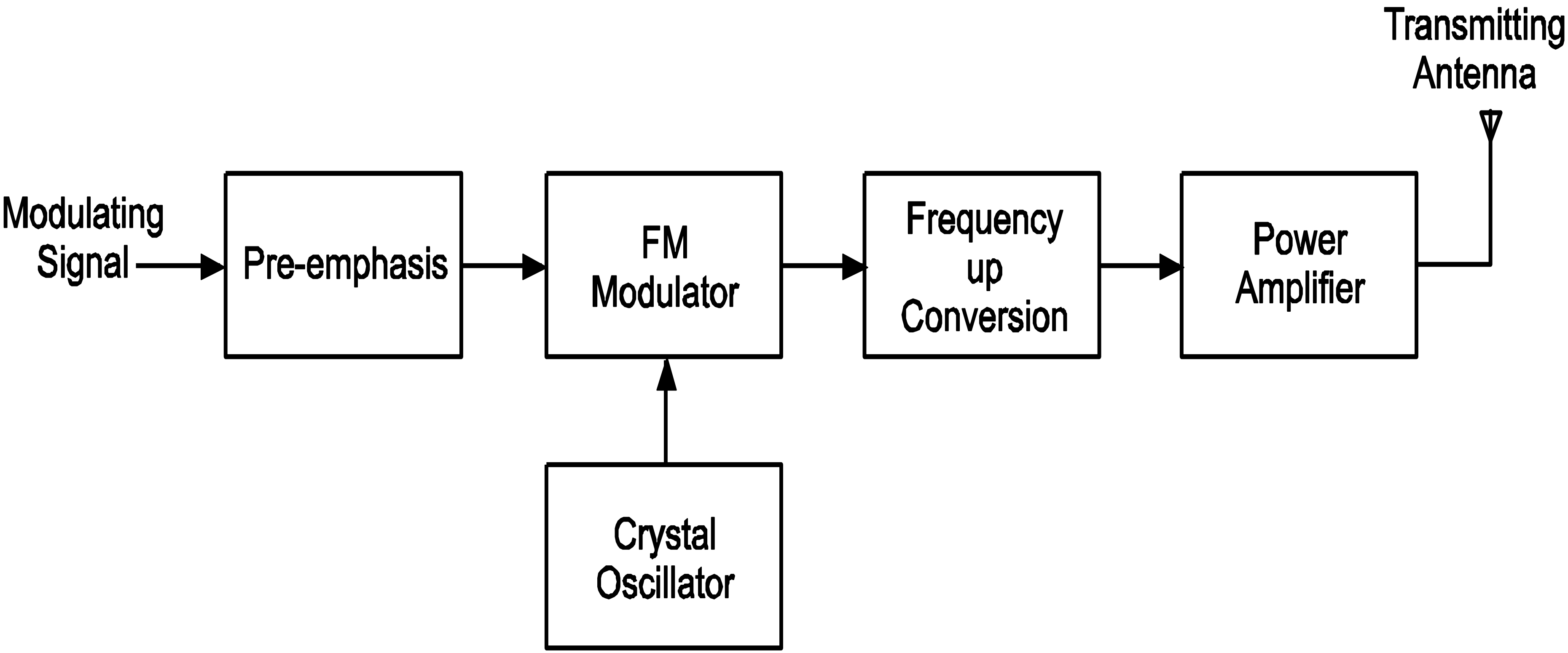


Fig. 3: FM Transmitter with Pre-emphasis

De-emphasis

- De-emphasis circuit is **used at FM receiver**.

Definition:

The artificial boosting of higher modulating frequencies in the process of pre-emphasis is nullified at receiver by process called de-emphasis.

- De-emphasis circuit is a low pass filter shown in Fig. 4.

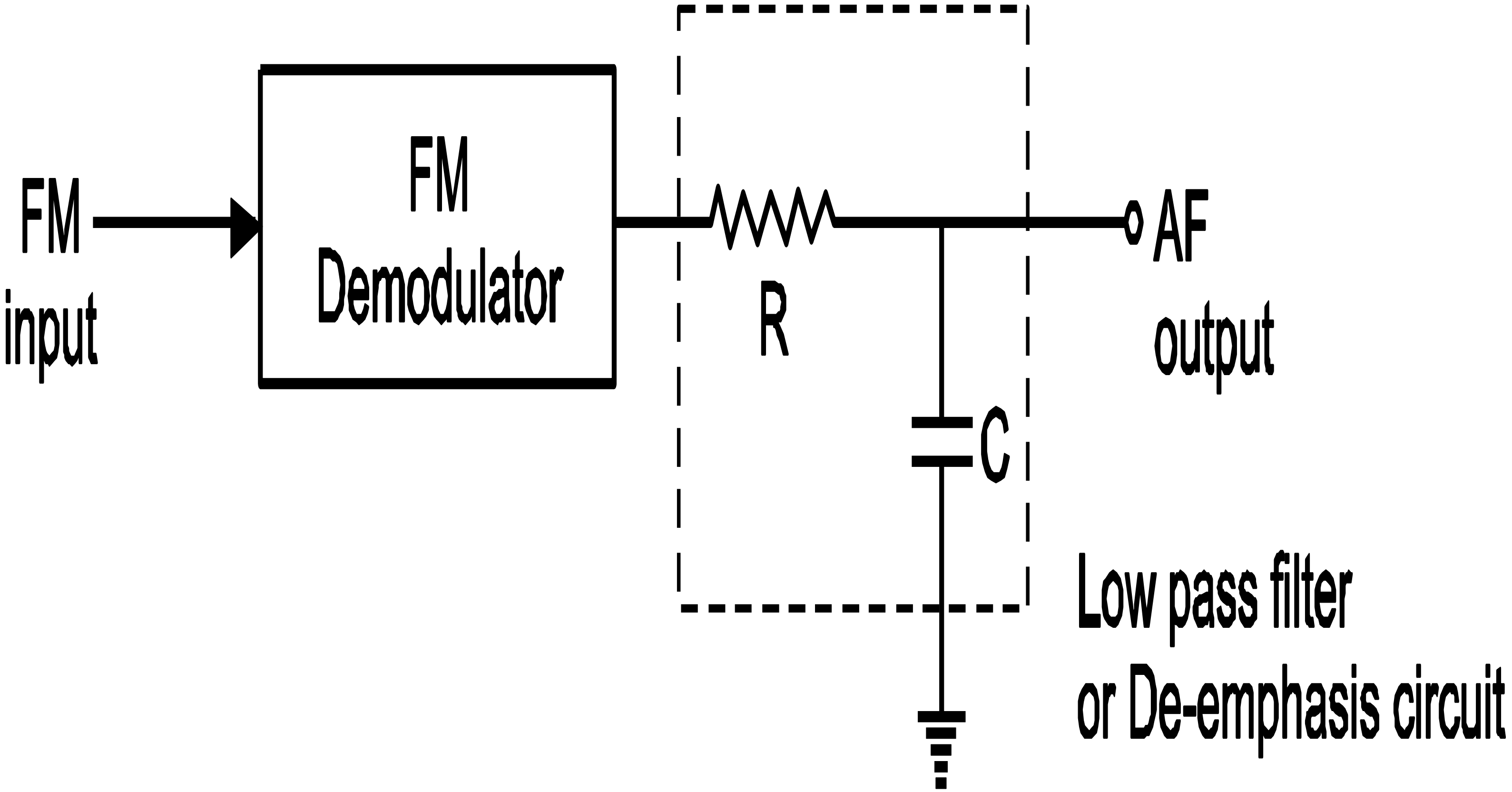
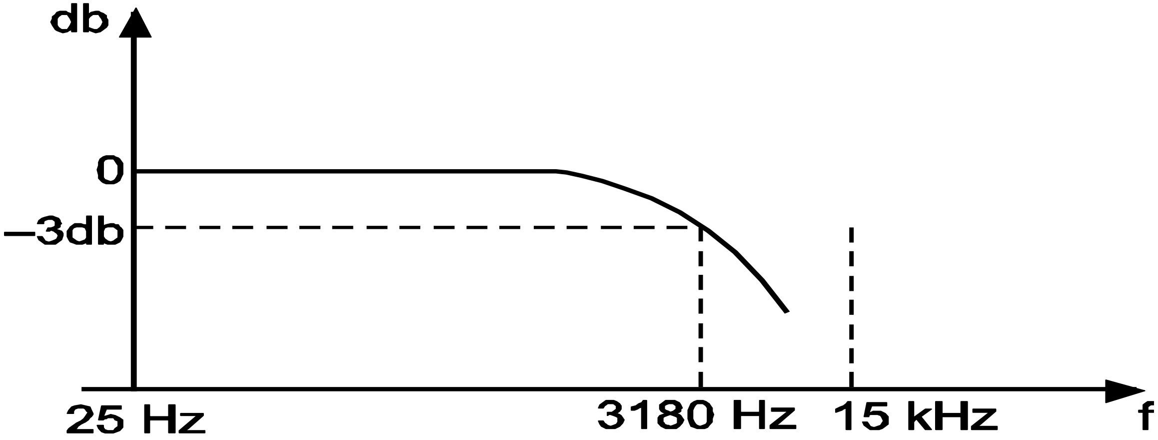


Fig. 4: De-emphasis Circuit

Fig. 5: De-emphasis Curve



As shown in Fig.5, de-modulated FM is applied to the de-emphasis circuit (low pass filter) where with increase in f_m, capacitive reactance X_c decreases. So that output of de-emphasis circuit also reduces •

Fig. 5 shows the de-emphasis curve corresponding to a time constant

50 μs. A 50 μs de-emphasis corresponds to a frequency response curve that is 3 dB down at frequency given by,

$$f = 1/2\pi RC$$

$$= 1/2\pi \times 50 \times 1000$$

$$= 3180 \text{ Hz}$$

The de-emphasis circuit is used after the FM demodulator at the FM receiver shown in Fig. 6.

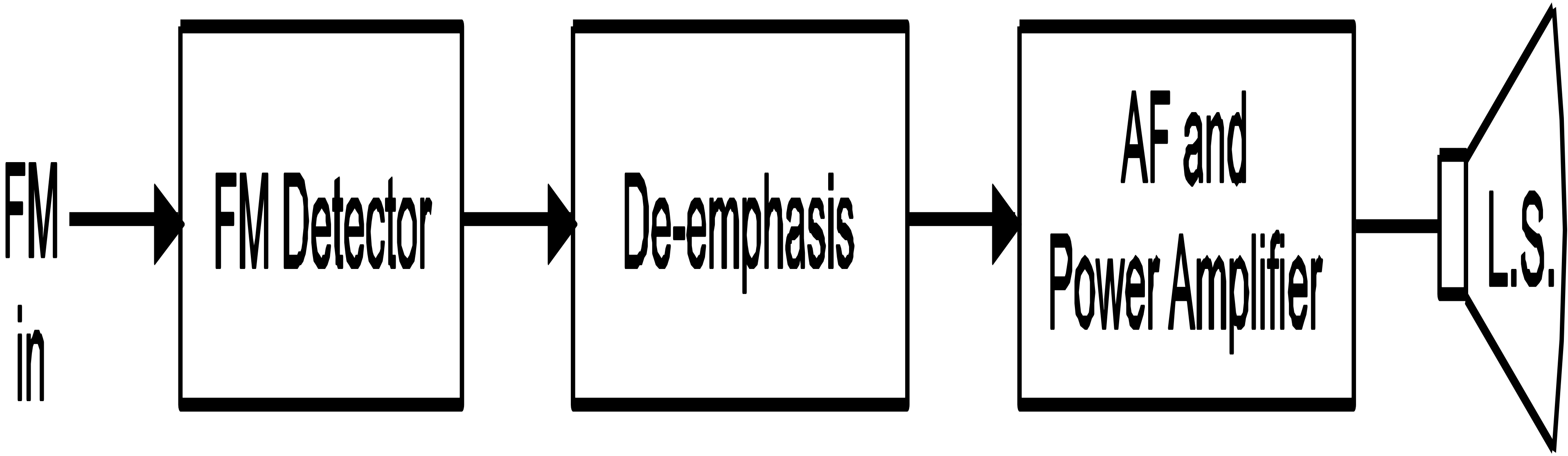
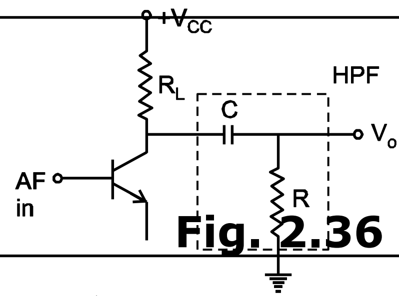
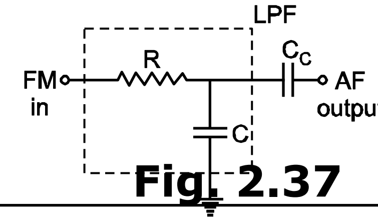
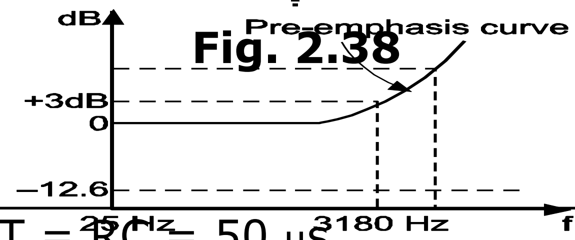
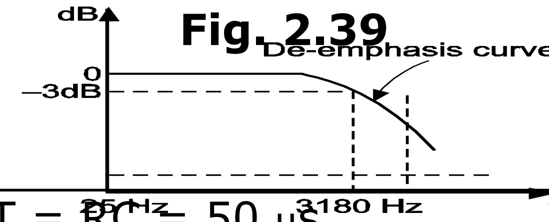


Fig. 6: De-emphasis Circuit in FM Receiver

Comparison between Pre-emphasis and De-emphasis

Parameter	Pre-emphasis	De-emphasis
1. Circuit used	High pass filter.	Low pass filter.
2. Circuit diagram	 Fig. 2.36	 Fig. 2.37
3. Response curve	 Fig. 2.38	 Fig. 2.39
4. Time constant	T = RC = 50 μs	T = RC = 50 μs
5. Definition	Boosting of higher frequencies	Removal of higher frequencies
6. Used at	FM transmitter	FM receiver.

FM Generation

There are two methods for generation of FM wave.

Generation of FM

Direct Method

1. Reactance Modulator
2. Varactor Diode

Indirect Method

1. Armstrong Method

Reactance Method

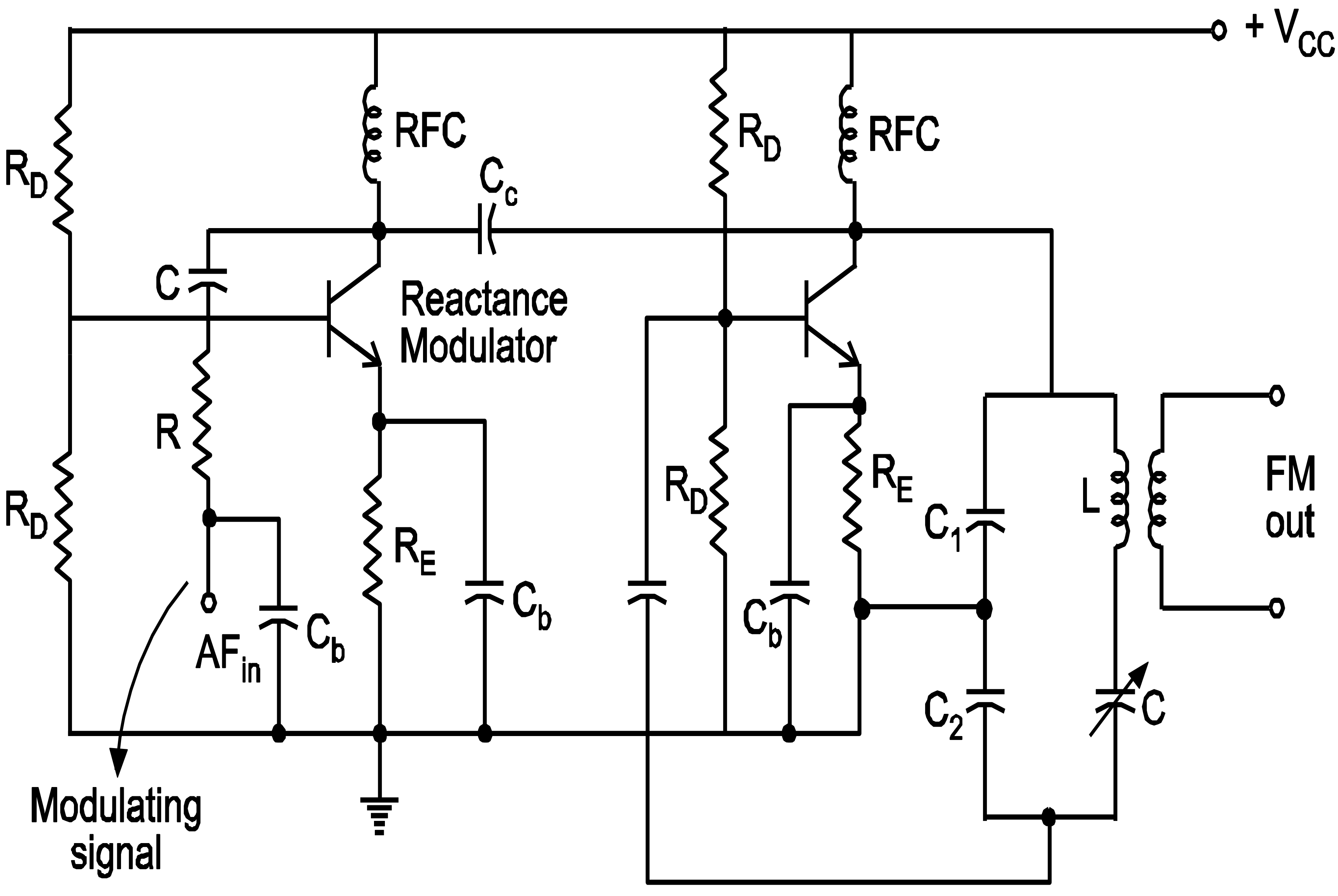


Fig. : Transistorized Reactance Modulator

Varactor Diode Modulator

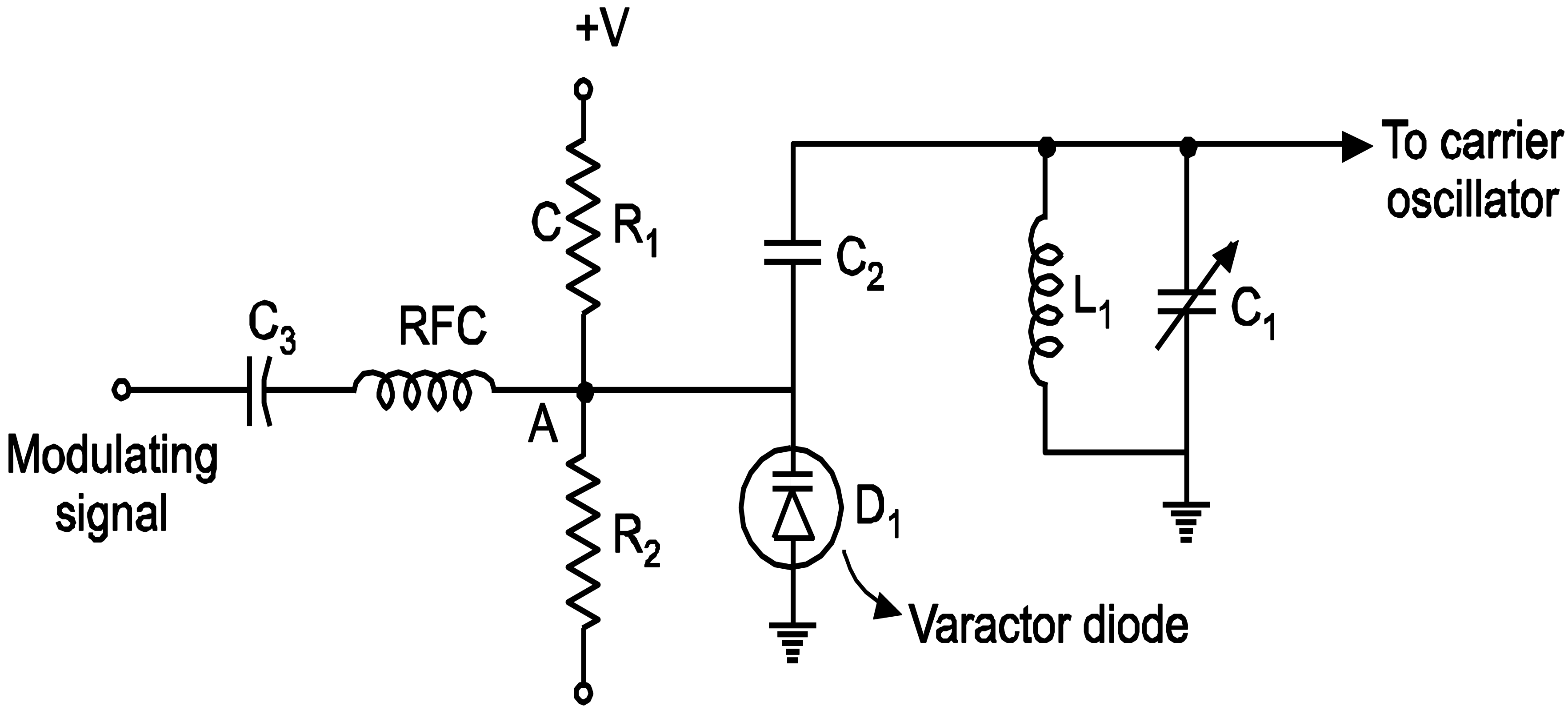


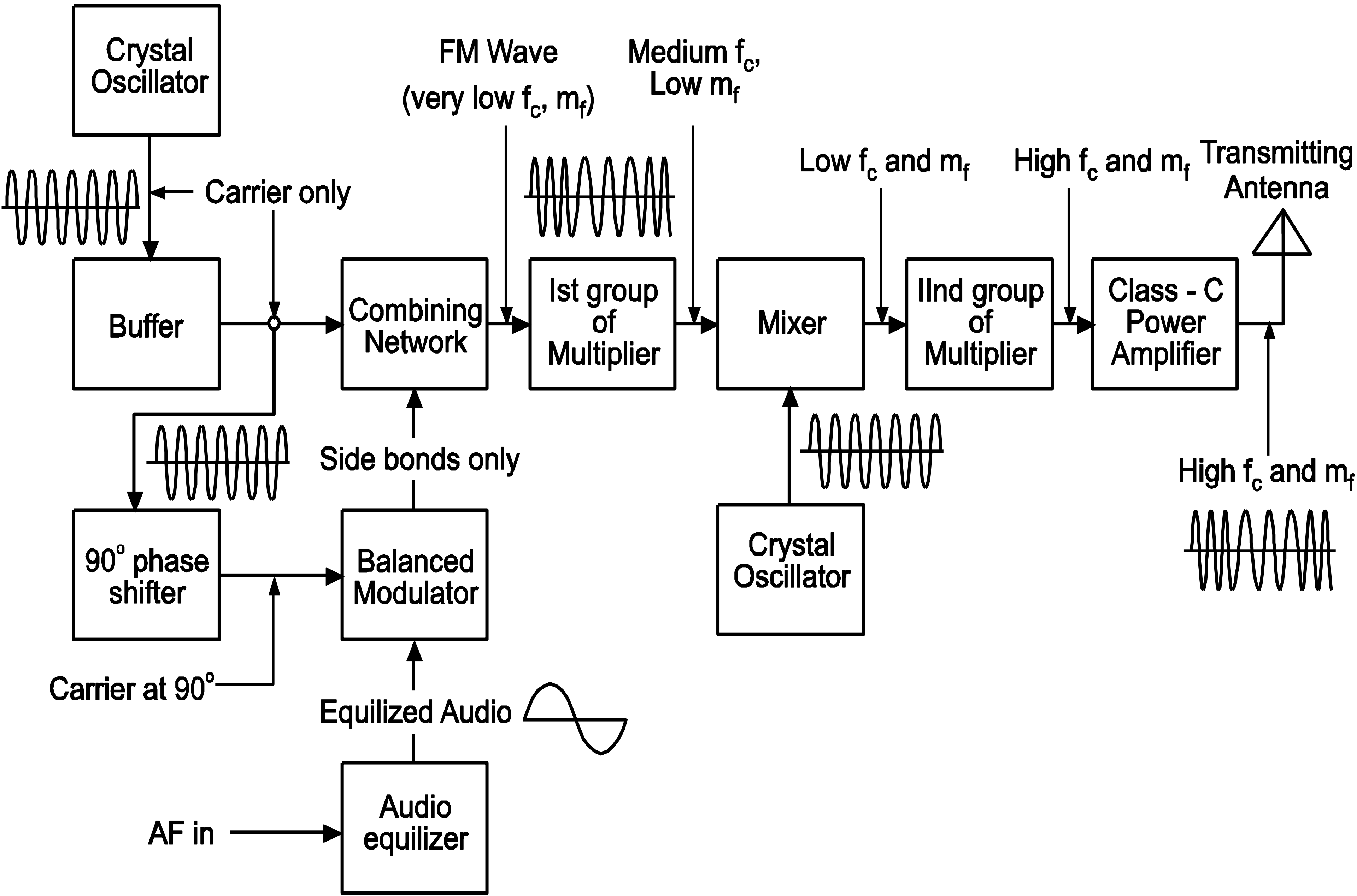
Fig. : Varactor Diode Frequency Modulator

Limitations of Direct Method of FM Generation

1. In this method, it is very difficult to get high order stability in carrier frequency because in this method the basic oscillator is not a stable oscillator, as it is controlled by the modulating signal.

2. Generally in this method we get distorted FM, due to non-linearity of the varactor diode.

FM Transmitter (Armstrong Method)



FM Generation using IC 566

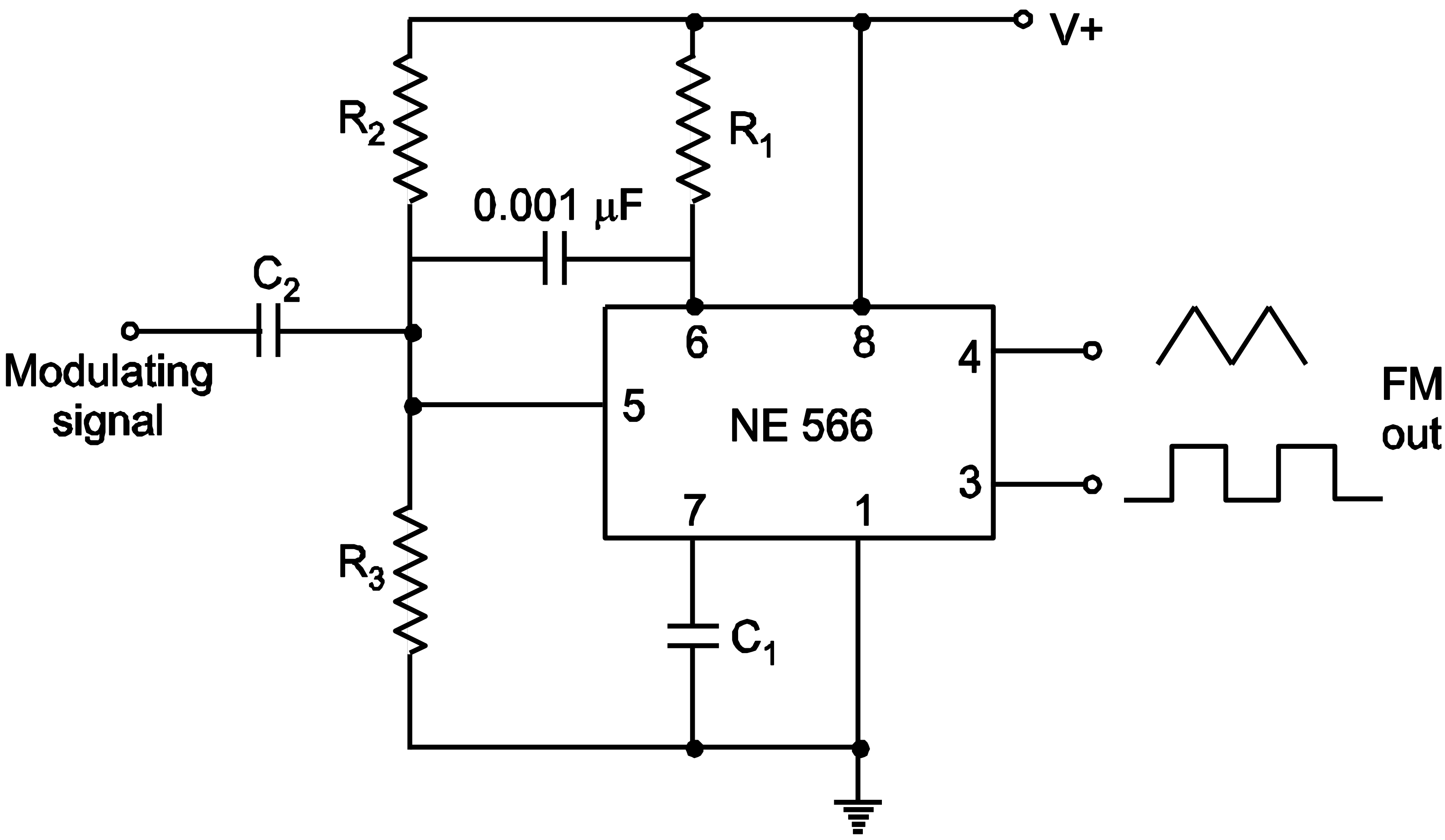


Fig. : Basic Frequency Modulator using NE566 VCO

Advantages / Disadvantages / Applications of FM

Advantages of FM

1. Transmitted power remains constant.
2. FM receivers are immune to noise.
3. Good capture effect.
4. No mixing of signals.

Disadvantages of FM

The greatest disadvantages of FM are:

1. It uses too much spectrum space.
2. The bandwidth is wider.
3. The modulation index can be kept low to minimize the bandwidth used.
4. But reduction in M.I. reduces the noise immunity.
5. Used only at very high frequencies.

Applications of FM

1. FM radio broadcasting.
2. Sound transmission in TV.
3. Police wireless.

THE END