# Indirect method

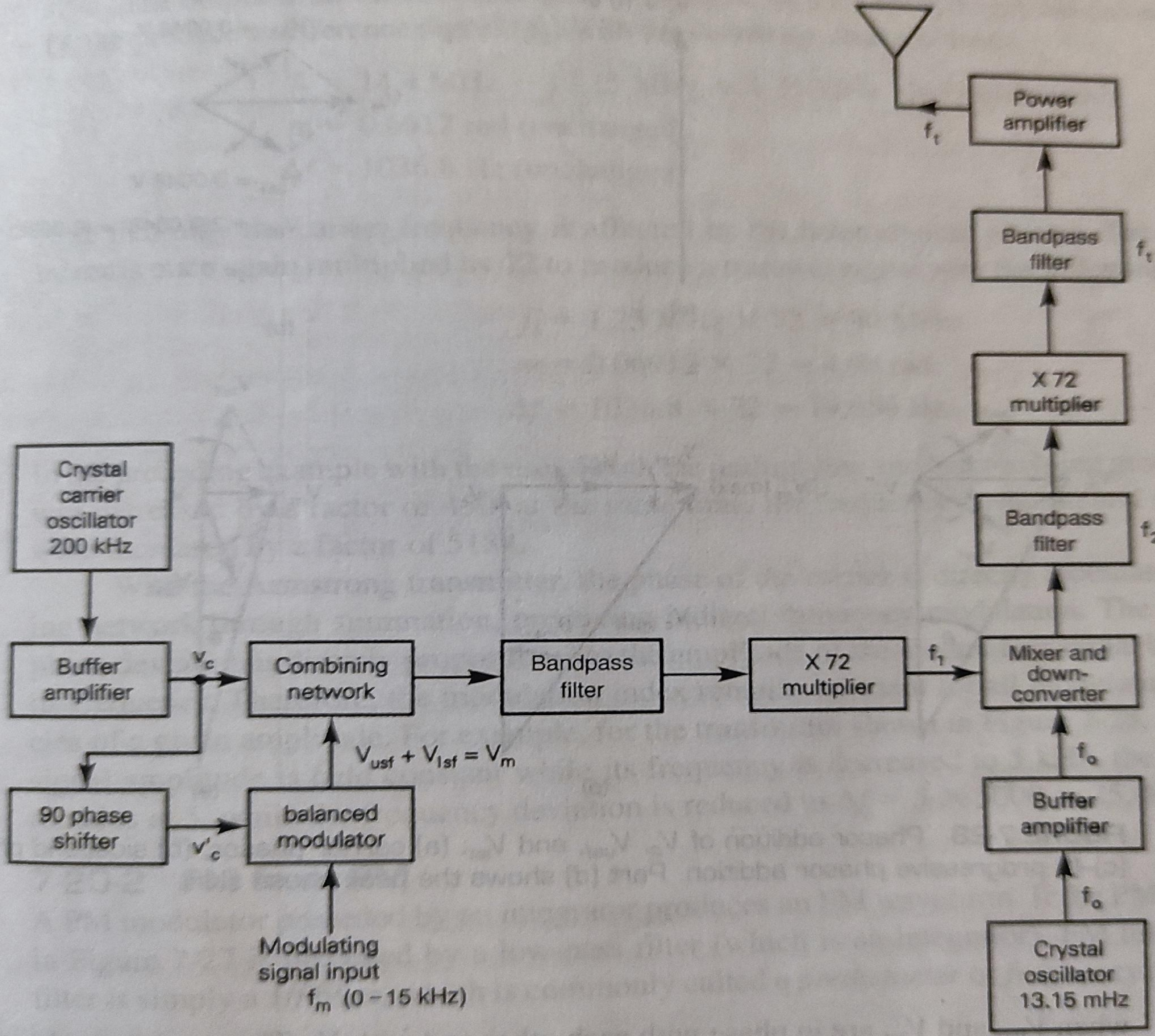
- This method of FM generation is also known as Armstrong method of FM generation.

- In this method the FM is obtained through phase modulation.

- In this method crystal oscillator is used for frequency stability.

# 4.9.2 : Indirect FM Transmitter

- Indirect FM transmitters produce an output waveform in which the phase deviation is directly proportional to the modulating signal.
- Consequently, the carrier oscillator is not directly deviated. As a result, the stability of the oscillators can be achieved without using an AFC circuit.
- Block diagram for wideband *Armstrong indirect FM transmitter* :
  - low frequency sub-carrier $f_c$ is phase shifted 90° and fed to a balanced modulator. It is mixed with the modulating signal $f_m$.
  - the output from the balanced modulator is DSBSC wave that is combined with the original carrier in a combining network to produce a low-index, phase-modulated waveform.


Crystal carrier oscillator 200 kHz
Buffer amplifier
$V_c$
Combining network
Bandpass filter
X 72 multiplier
$f_1$
Mixer and down-converter
90 phase shifter
$V'_c$
balanced modulator
$V_{usf} + V_{lsf} = V_m$
Modulating signal input $f_m$ (0 – 15 kHz)
Crystal oscillator 13.15 mHz
$f_o$
Buffer amplifier
$f_o$
Bandpass filter
$f_2$
X 72 multiplier
Bandpass filter
$f_t$
Power amplifier
$f_t$

## 4.9.2 : Indirect FM Transmitter

- Proof : $m(t) = V_c \cos\left[\omega_c t + m\cos(\omega_m t)\right]$

By using trigonometric function : cos (A+B) =cos A cos B – sin A sin B

$$m(t) = V_c\left[\cos(\omega_c t)\cos(m\cos(\omega_m t)) - \sin(\omega_c t)\sin(m\cos(\omega_m t))\right]$$

For a small modulation index,

$$\cos(m\cos(\omega_c t)) \approx \cos(0) \approx 1$$

$$\sin(m\cos(\omega_m t)) \approx m\cos(\omega_m t)$$

Thus,

$$m(t) = V_c\cos(\omega_c t) - V_c m\sin(\omega_c t)\cos(\omega_m t)$$

where $V_c cos(\omega_c t)$ = original carrier

$V_c sin(\omega_c t)$ = phase-shifted carrier

$cos(\omega_m t)$ = modulating signal

## 4.9.2 : Indirect FM Transmitter

- Ex :

  Consider a 200 kHz carrier being phase-modulated with a 15 kHz modulating signal producing modulation index of 0.00096.

  - the frequency deviation at the output of the combining network :

$$\Delta f = mf_m = 0.00096 \text{ x } 15000 = 14.4 \text{ Hz}$$

  - in order to achieve the required 75 kHz deviation for the FM broadcast at the antenna, the frequency must be multiplied by approximately 5208. However, this would produce a transmission carrier at the antenna of

$$f_t = 5208 \text{ x } 200 \text{ kHz} = 1041.6 \text{ MHz}$$

  This value is beyond the limits for the commercial FM broadcast band (30 ~ 300MHz).

## 4.9.2 : Indirect FM Transmitter

- Ex : (continue)
  - Let the output waveform of the network is multiplied by 72, producing the following signal,

$$f_1 = 72 \text{ x } 200 \text{ kHz} = 14.4 \text{ MHz}$$
$$m = 72 \text{ x } 0.00096 = 0.06912 \text{ rad}$$
$$\Delta f = 72 \text{ x } 14.4 \text{ Hz} = 1036.8 \text{ Hz}$$

  - this signal is then mixed with a 13.15 MHz crystal-controlled frequency $f_0$ to produce a difference signal $f_2$ with the following characteristics :

$$f_2 = 14.4 - 13.15 = 1.25 \text{ MHz (down-converted)}$$
$$m = 0.06912 \text{ rad (unchanged)}$$
$$\Delta f = 1036.8 \text{ Hz (unchanged)}$$

  - the output of the mixer is once again multiplied by 72 to produce the transmit signal with the following characteristics :

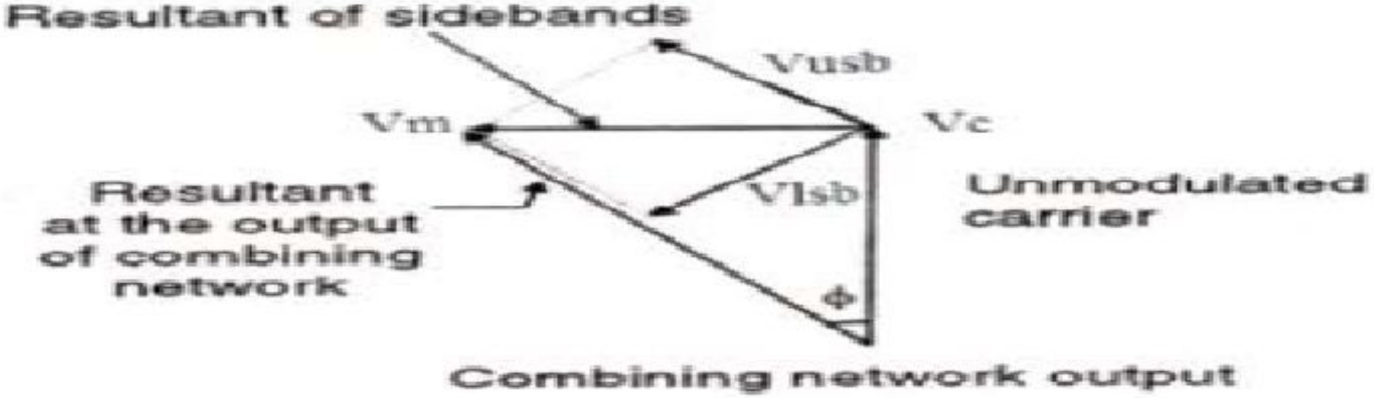
$$f_t = 72 \text{ x } 1.25 \text{ MHz} = 90 \text{ MHz}$$
$$m = 72 \text{ x } 0.06912 \text{ rad} = 4.98 \text{ rad}$$
$$\Delta f = 72 \text{ x } 1036.8 \text{ Hz} = 74.65 \text{ kHz}$$

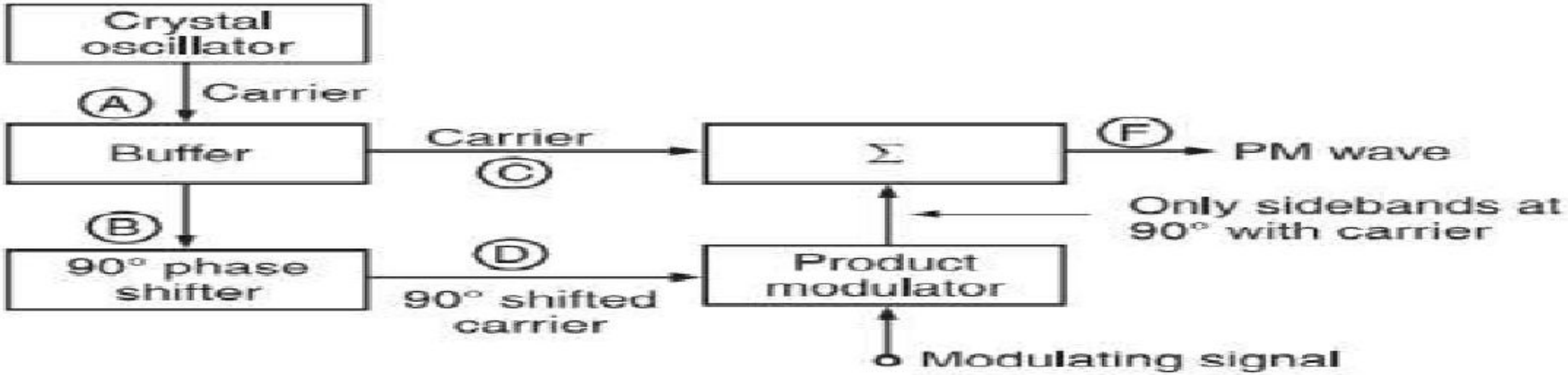
## 4.9.2 : Indirect FM Transmitter

- with Armstrong transmitter, the phase of the carrier is directly modulated in the combining network producing indirect frequency modulation.
- the magnitude of peak phase deviation (i.e. the modulation index) is directly proportional to the amplitude of the modulating signal but independent of its frequency ($m = KV_m$).
- the modulation index remains constant for all modulating signal frequencies of given amplitude.


Vc
Unmodulated carrier
Vc'
90° shifted carrier
Vusb
Vm
Vc
Suppressed carrier
Vlsb
Resultant of sidebands

(a) (b) (c)


Resultant of sidebands
Vusb
Vm
Vc
Resultant at the output of combining network
Vlsb
Unmodulated carrier
ϕ
Combining network output


Crystal oscillator
A
Carrier
Buffer
Carrier
C
Σ
F
PM wave
B
90° phase shifter
D
90° shifted carrier
Product modulator
Only sidebands at 90° with carrier
Modulating signal

# 4.15 Noise and Angle Modulation

- when a constant density of thermal noise is added to an angle-modulated signal, unwanted deviation of carrier frequency is expected.
- magnitude of the unwanted deviation depends on the relative amplitude of the noise with respect to the carrier amplitude.
- Consider a noise signal with amplitude $V_n$ and frequency $f_n$ :
  - for PM, the unwanted peak phase deviation due to this interfering noise signal is given by

$$\Delta\theta_{peak} \approx \frac{V_n}{V_c} rad \tag{6.13}$$

  - for FM, when Vc > Vn, the unwanted instantaneous phase deviation is approximately,

$$\theta(t) = \frac{V_n}{V_c}\sin(\omega_n t + \theta_n) rad \tag{6.14}$$

taking derivative,

$$\Delta\omega(t) = \frac{V_n}{V_c}\omega_n \cos(\omega_n t + \theta_n) rad\ /\ s \tag{6.15}$$

# 4.15 Noise and Angle Modulation

therefore, the unwanted peak frequency deviation is

$$\Delta\omega_{peak} = \frac{V_n}{V_c}\omega_n rad\ /\ s \qquad \Delta f_{peak} = \frac{V_n}{V_c} f_n Hz \tag{6.16}$$

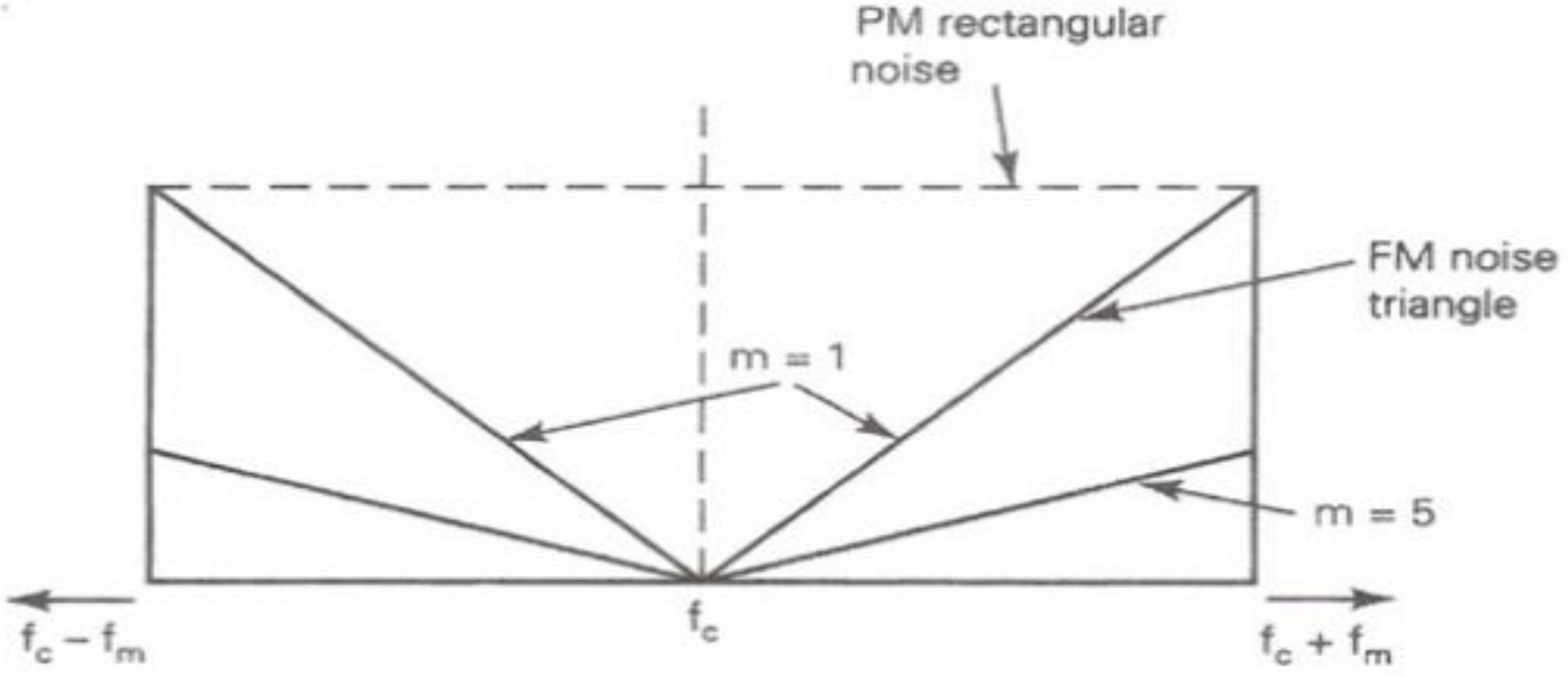
- when the above unwanted carrier deviation is demodulated, it becomes noise.
  - the frequency of the demodulated noise signal is equal to the difference between the carrier frequency and the interfering signal frequency $(f_c - f_n)$.
  - the signal-to-noise ratio at the demodulator output due to the unwanted frequency deviation from an interfering signal defined as

$$\frac{S}{N} = \frac{\Delta f_{signal}}{\Delta f_{noise}} \tag{6.17}$$

  - the spectral shape of the demodulated noise depends on whether an FM or PM demodulator is used :
    - → noise voltage at the PM demodulator output is constant with frequency.
    - → noise voltage at the FM demodulator output increases linearly with frequency.

# FM Noise triangle

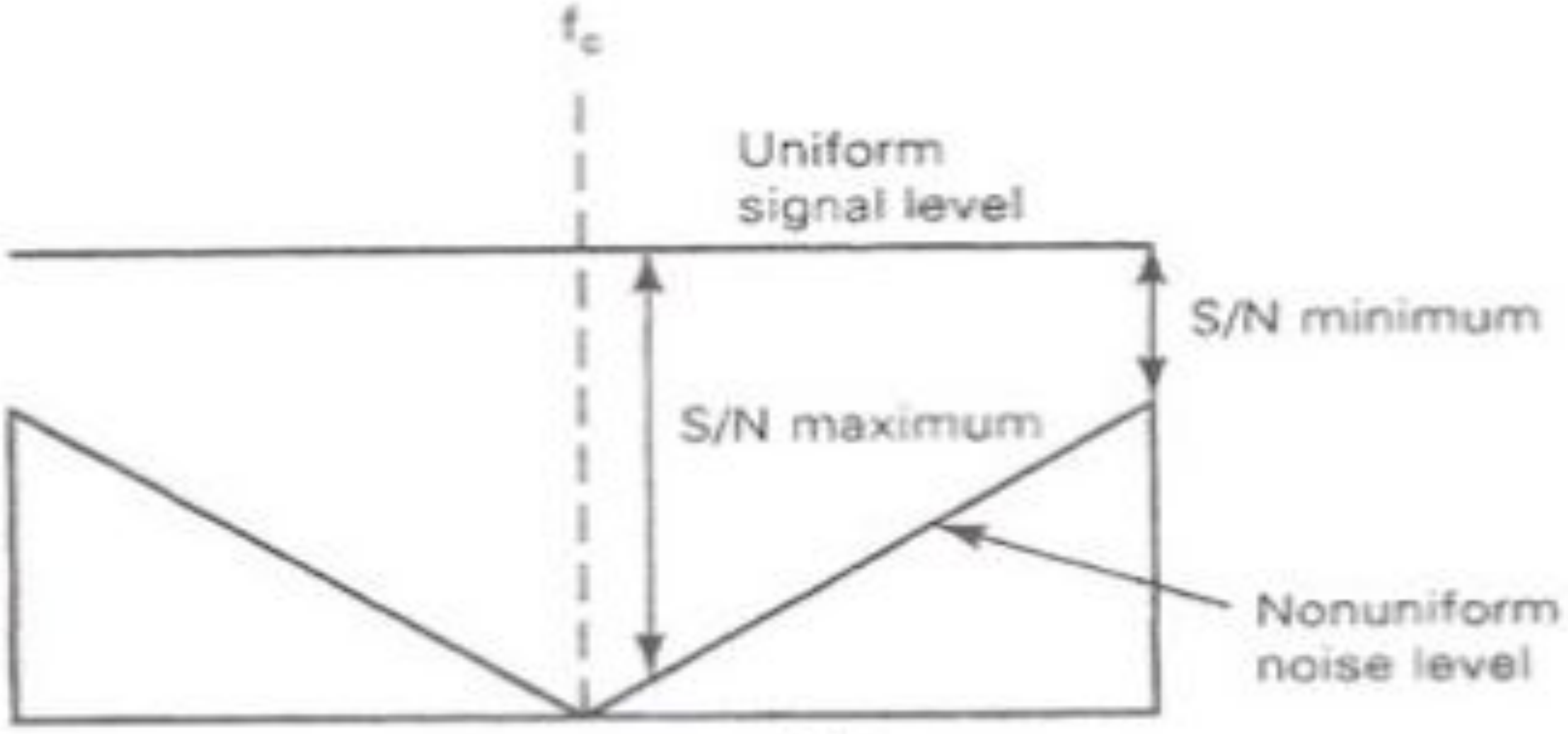
## 4.15 Noise and Angle Modulation




FM noise triangle

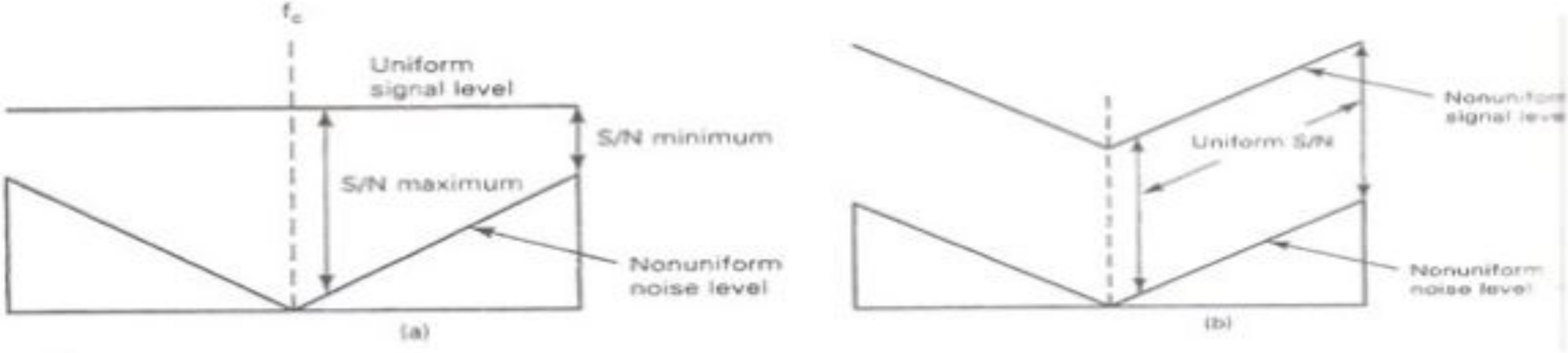
# 4.16 Preemphasis & Deemphasis

- based on the previous figure, noise is distributed non-uniformly in FM.
- noise at the higher modulating signal frequency is greater than noise at lower frequencies.
- for that, for information signal with uniform signal level, a non-uniform signal-to-noise ratio is produced as follow :




(a)

# 4.16 Pre-emphasis & De-emphasis




- S/Nratio is lower at the high frequency ends of the triangle (figure a).
- to compensate for this, the high frequency modulating signal is **<u>emphasized</u>** or boosted in amplitude prior to performing modulation (figure b).
- at the receiver, to compensate this boot, the high frequency signal is **<u>de-emphasized</u>** or attenuated after the demodulation is performed.

- <u>pre-emphasis network</u> allows the high frequency modulating signal to modulate the carrier at a higher level while the <u>de-emphasis network</u> restores the original amplitude-versus-frequency characteristics to the information signal.
  - pre-emphasis network is a high pass filter (i.e. a differentiator).
  - de-emphasis network is a low pass filter (i.e. integrator).

# 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

# 1.Pre-emphasis

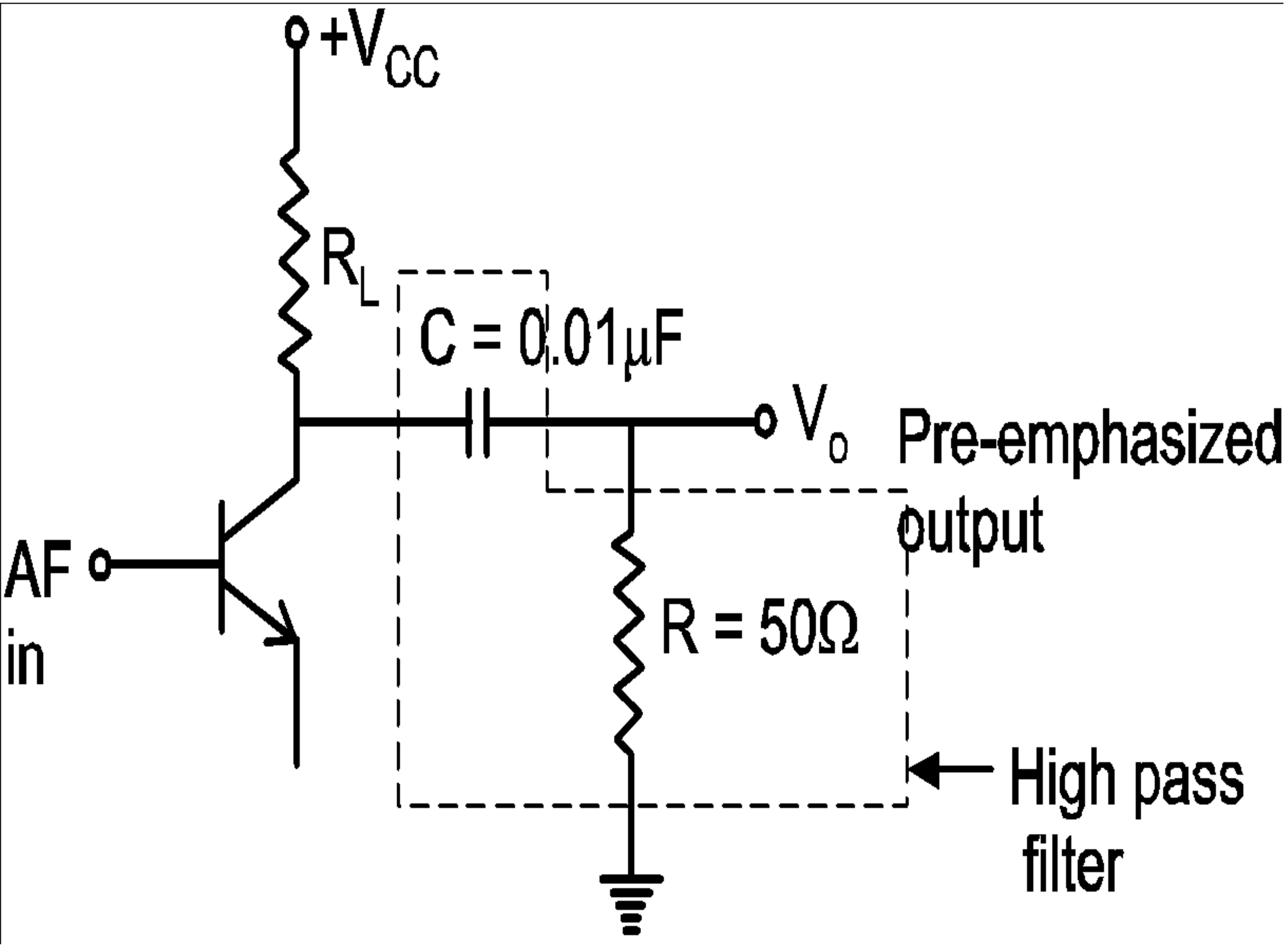



**Fig. 1: Pre-emphasis Circuit**

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 modulator.

# 1.Pre-emphasis

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

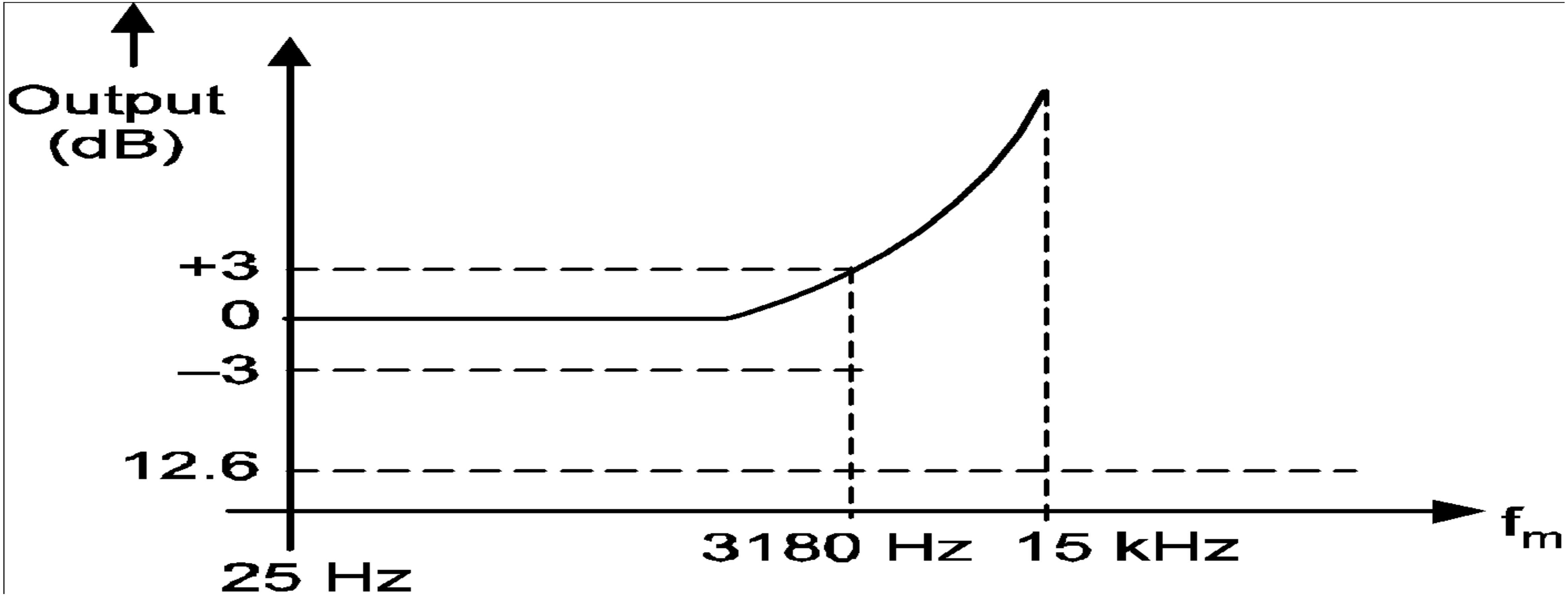



Fig. 2: Pre-emphasis Curve

# Pre-emphasis in FM Transmitter

•The time constant of pre-emphasis is at 50 μs in all CCIR(Consultative Committee for International Standards).
•In systems employing American FM and TV standards, networks having time constant of 75μsec are used. •**The pre-emphasis is used at FM transmitter** as shown in Fig. 3.

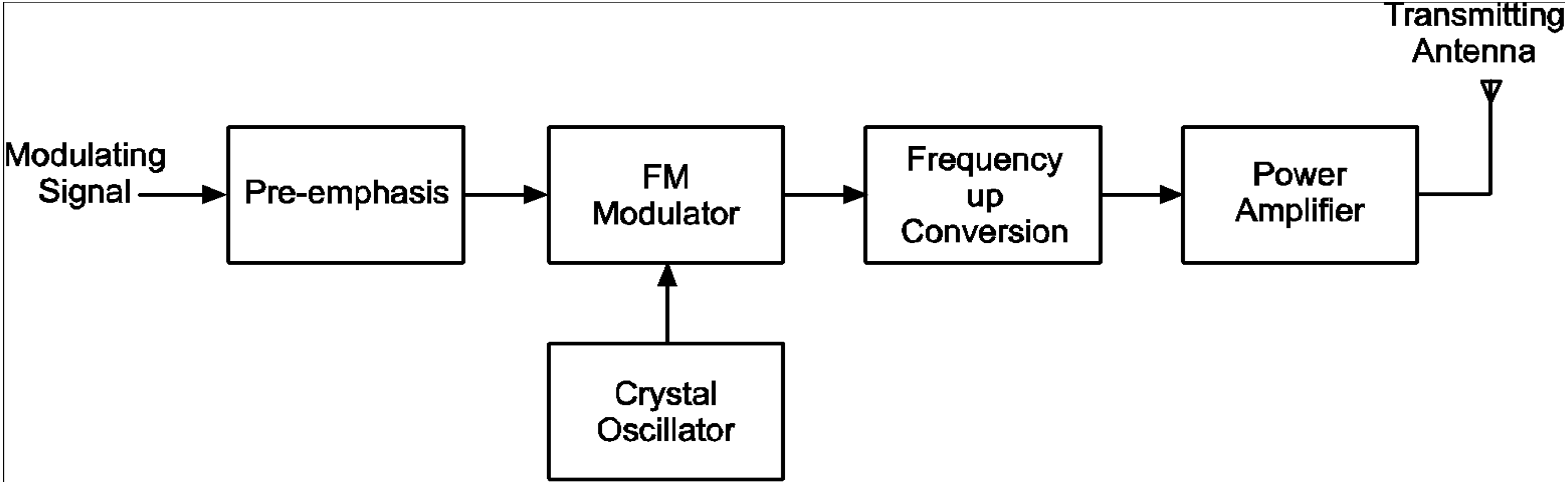



Fig. 3: FM Transmitter with Pre-emphasis

# 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.

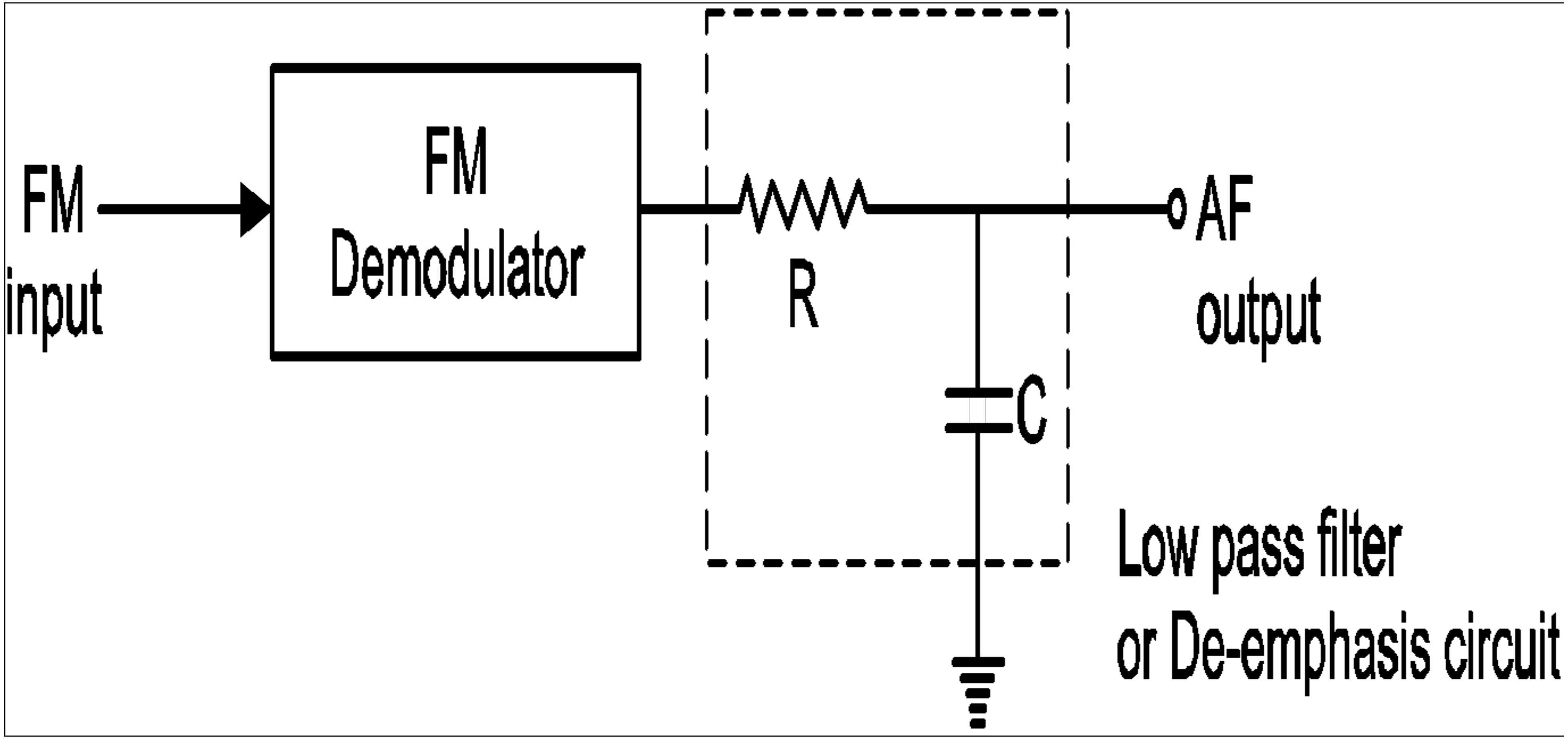



Fig. 4: De-emphasis Circuit

## De-emphasis

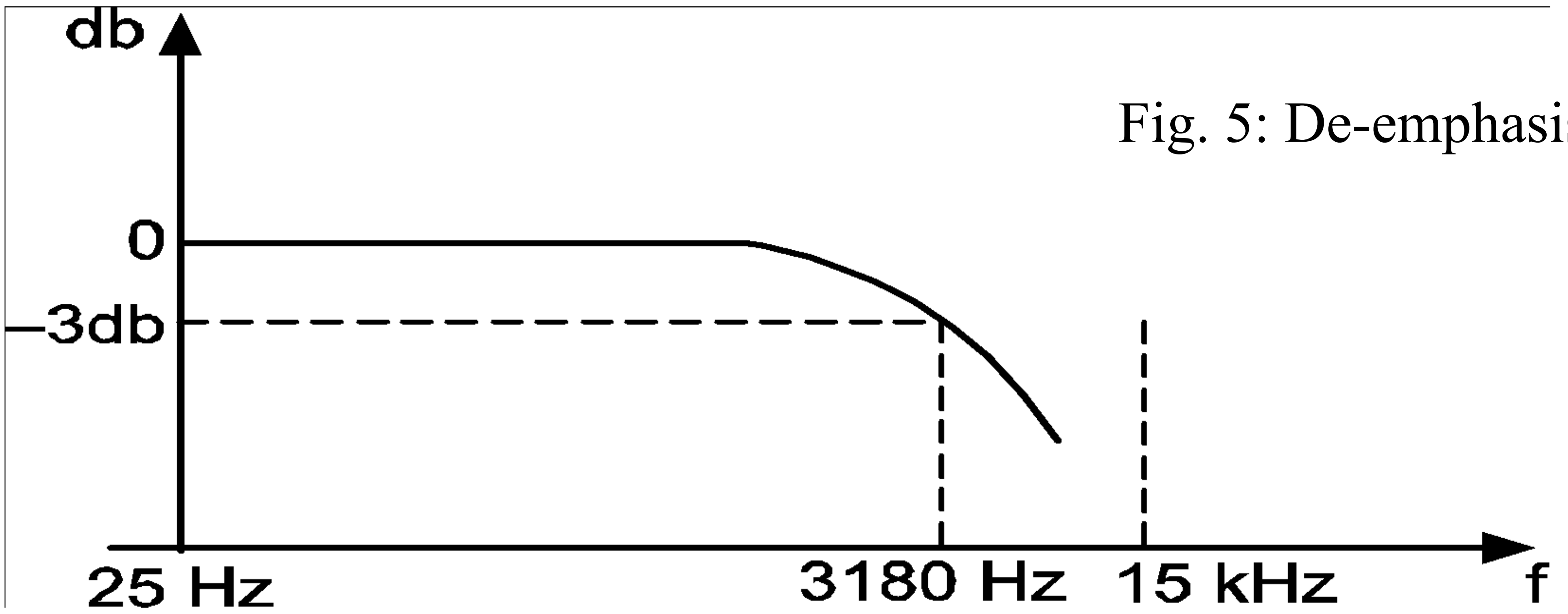



Fig. 5: De-emphasis Curve

- ✔ 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, $f = 1/2\pi RC$

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

$$= 3180 \text{ Hz}$$

## 4.16 Pre-emphasis & De-emphasis

- the break frequency (the frequency where pre-emphasis & de-emphasis begins) is determined by the RC or L/R time constant of the network.

$$f_b = \frac{1}{2\pi RC} = \frac{1}{2\pi L / R} \qquad (6.18)$$

- from the preceding explanation, it can be seen that the output amplitude from a pre-emphasis network increases with frequency for frequencies above the break frequency $f_b$.
  - from equation 4.15, if changes in $f_m$ produce corresponding changes in $V_m$, the modulation index $m$ remains constant.

    - this is the characteristic of phase modulation (modulation index is independent of frequency : $m = \Delta\theta = KV_m$).

    - i.e. for frequencies below 2.12 kHz produce FM, and frequencies above 2.12 kHz produce PM.

$$m = \frac{K_1 V_m}{\omega_m} = \frac{K_1 V_m}{f_m} (unitless) \qquad (4.15)$$

# De-emphasis in FM Transmitter

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

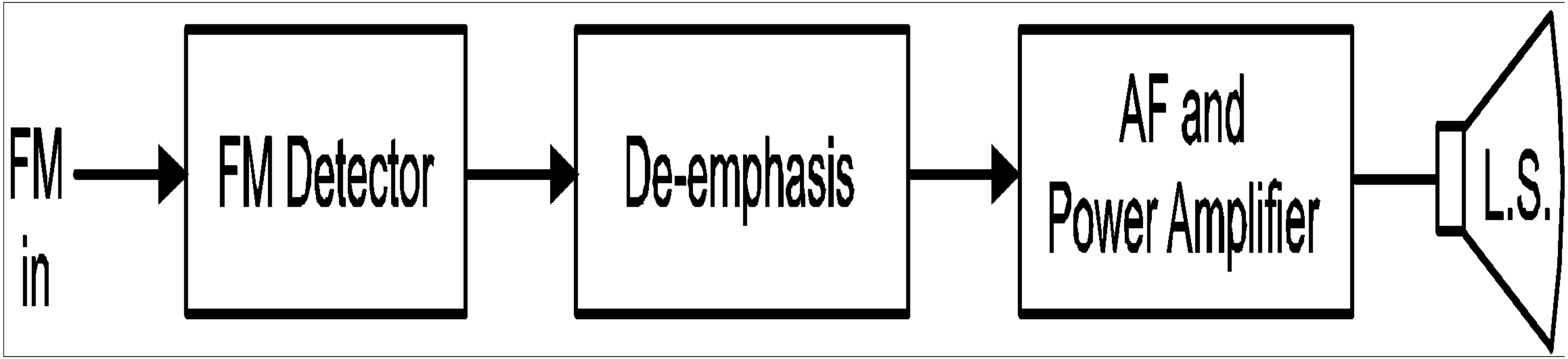
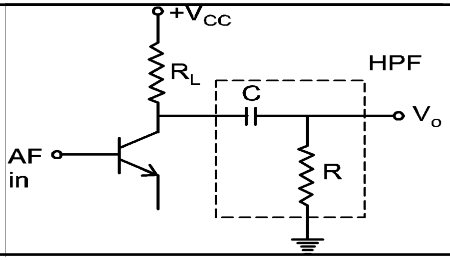
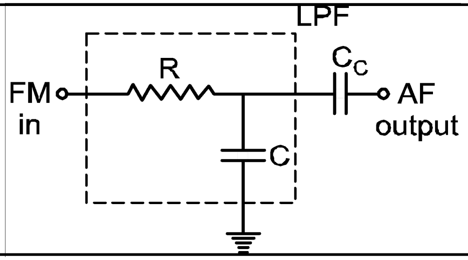
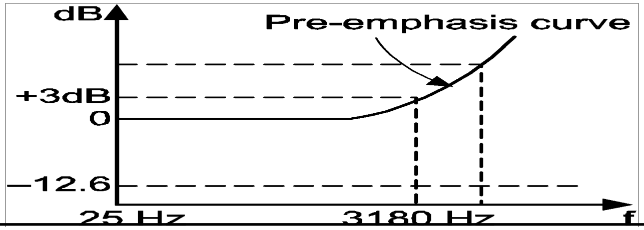
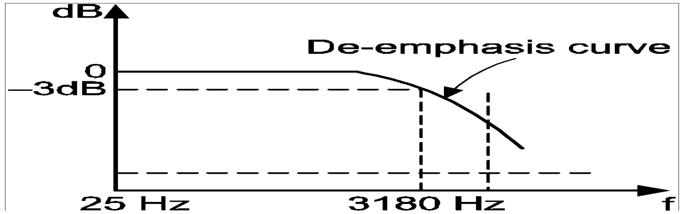
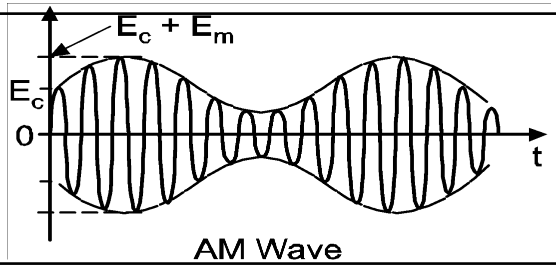
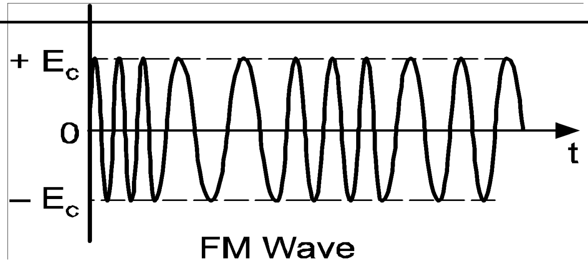



Fig. 6: De-emphasis Circuit in FM Receiver

# Comparison between Pre-emphasis and De-emphasis

| Parameter | Pre-emphasis | De-emphasis |
|---|---|---|
| 1. Circuit used | High pass filter. | Low pass filter. |
| 2. Circuit diagram |  |  |
| 3. Response curve |  |  |
| 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. |

# Comparison between AM and FM

| Parameter | AM | FM |
|---|---|---|
| 1. Definition | Amplitude of carrier is varied in accordance with amplitude of modulating signal keeping frequency and phase constant. | Frequency of carrier is varied in accordance with the amplitude of modulating signal keeping amplitude and phase constant. |
| 2. Constant parameters | Frequency and phase. | Amplitude and phase. |
| 3. Modulated signal |   |   |
| 4. Modulation Index | m=Em/Ec | m = δ/ fm |
| 5. Number of sidebands | Only two | Infinite and depends on $m_f$. |
| 6. Bandwidth | $BW = 2f_m$ | $BW = 2 (\delta + f_{m\,(max)})$ |
| 7. Application | MW, SW band broadcasting, video transmission in TV. | Broadcasting FM, audio transmission in TV. |

# 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

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.

# 4.14 : Angle Modulation vs Amplitude Modulation

- Advantages of Angle Modulation

  - Noise immunity – most noise results in unwanted amplitude variations in the modulated wave (i.e. AM noise). FM and PM receivers include limiters that remove most of the Am noise from the received signal before the final demodulation process occurs – a process that cannot be used with AM receivers because the information is also contained in amplitude variations, and removing the noise would also remove the information.

  - Noise performance and S/N improvement – with the use of limiters, FM and PM actually reduce the noise level and improve the S/N ratio during the demodulation process.

  - Capture effect - with FM and PM, a phenomenon of capture effect allows a receiver to differentiate between two signals received with the same frequency by capturing the stronger signal and eliminate the weaker one. With AM, both signals will be demodulated and produce audio signals.

# 4.14 : Angle Modulation vs Amplitude Modulation

- <u>Advantages of Angle Modulation</u>

  - <u>Power Utilization and efficiency</u>

    - with AM transmission, (especially DSBFC), - most of the transmitted power is contained in the carrier while the information is contained in the much lower power sidebands.

    - with AM, the carrier power remains constant with modulation, and the sideband power simply adds to the carrier power.

    - with angle modulation, the total power remains constant regardless if modulation is present.

    - with angle modulation, power is taken from the carrier with modulation and redistributed in the sidebands – puts most of its power in the information.

# 4.14 : Angle Modulation vs Amplitude Modulation

- Disadvantages of Angle Modulation

  - Bandwidth

    - high quality angle modulation produces many side frequencies, thus necessitating a much wider bandwidth than is necessary for AM transmission.

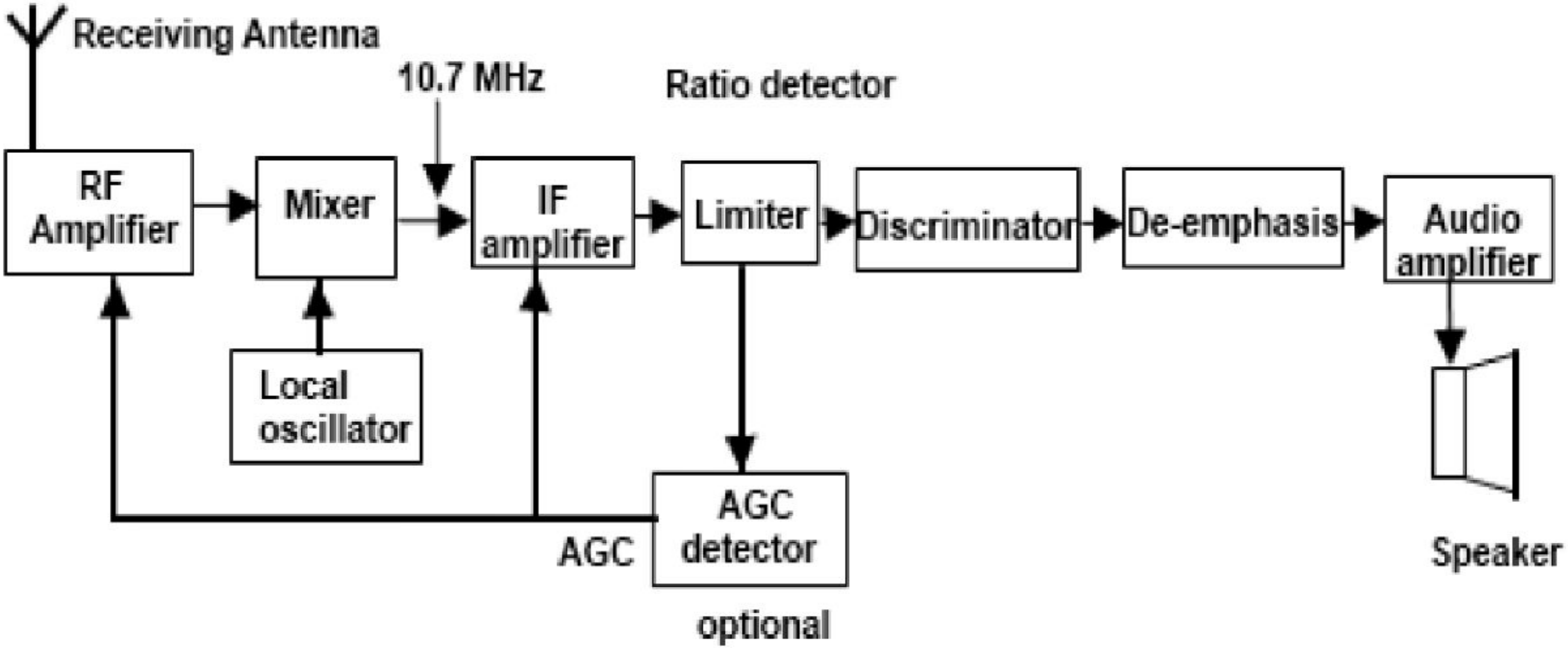
  - Circuit complexity and cost

    - PM and FM modulators, demodulators, transmitters, and receivers are more complex to design and build than their AM counterparts.

    - At one time, more complex means more expensive.

    - However with the advent of inexpensive, large-scale integration ICs, the cost is comparable to their AM counterparts.

# FM Receiver



Receiving Antenna
10.7 MHz
Ratio detector
RF Amplifier
Mixer
IF amplifier
Limiter
Discriminator
De-emphasis
Audio amplifier
Local oscillator
AGC
AGC detector
optional
Speaker

- *Limiter* is used to remove amplitude variations caused by noise (which is one of AM's drawback).
- *frequency discriminator* extracts the information from the modulated wave.
- *de-emphasis network* contributes to the improvement in signal-to-noise ratio.
- the first IF is a relatively high frequency (often 10.7 MHz) for good image frequency rejection.
- the second IF is a relatively low frequency (often 455 kHz) that allows the IF amplifiers to have high gain.

## 4.11 : FM Demodulator

- FM demodulator is a frequency-dependent circuits designed to produce an output voltage that is proportional to the instantaneous frequency at its input.
- the overall transfer function for the FM demodulator is nonlinear but when operating over its linear range,

$$K_d = \frac{V}{f} \tag{28}$$

- the output from the FM demodulator is

$$v_{out}(t) = K_d \Delta f \tag{29}$$

where $v_{out}(t)$ = demodulated output signal (volts)

$K_d$ = demodulator transfer function (volts per hertz)

$\Delta f$ = difference between input frequency and the centre frequency of demodulator (hertz)

# Types of FM Demodulators

**FM Demodulation**

**Direct**

- Slope Detector
- Balanced Slope Detector
- Foster-Seeley Phase Discriminator
- Ratio Detector

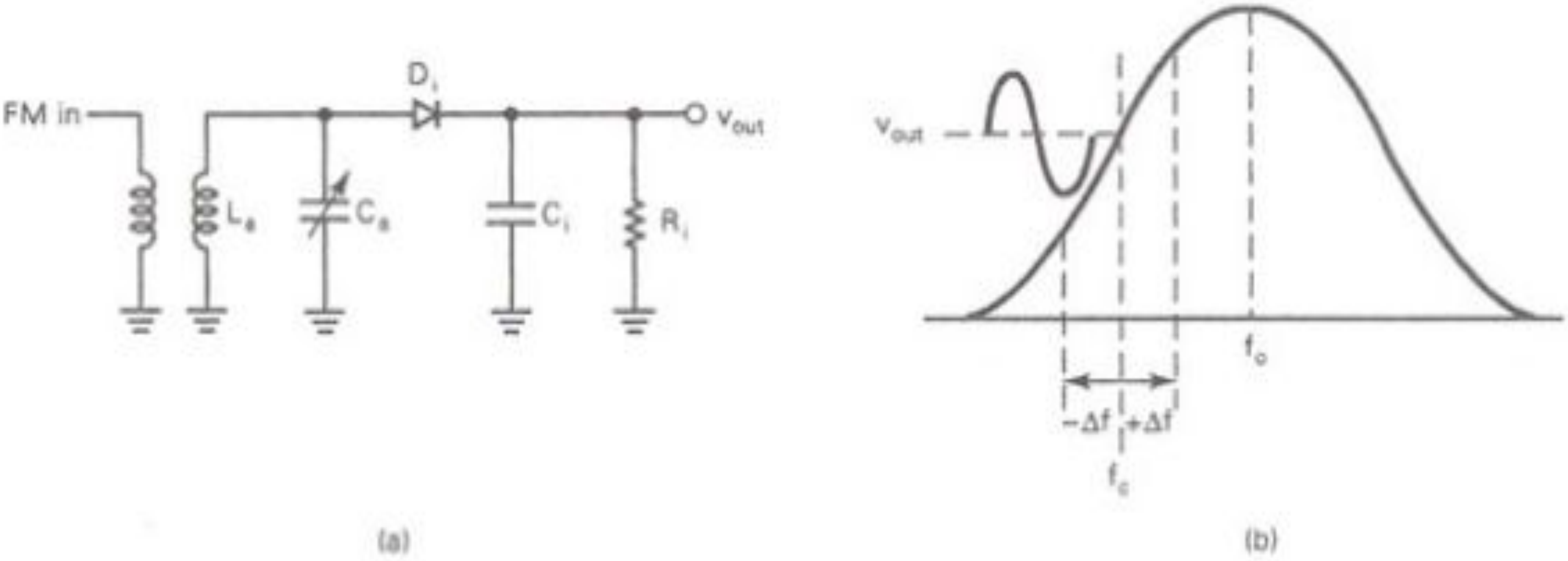
**Indirect**

Phase Lock Loop(PLL)

# 4.11.1 : Tuned-circuit Frequency Discriminator

- convert FM to AM and then demodulate the AM envelope with the conventional peak detector.

## 1) Slope Detector



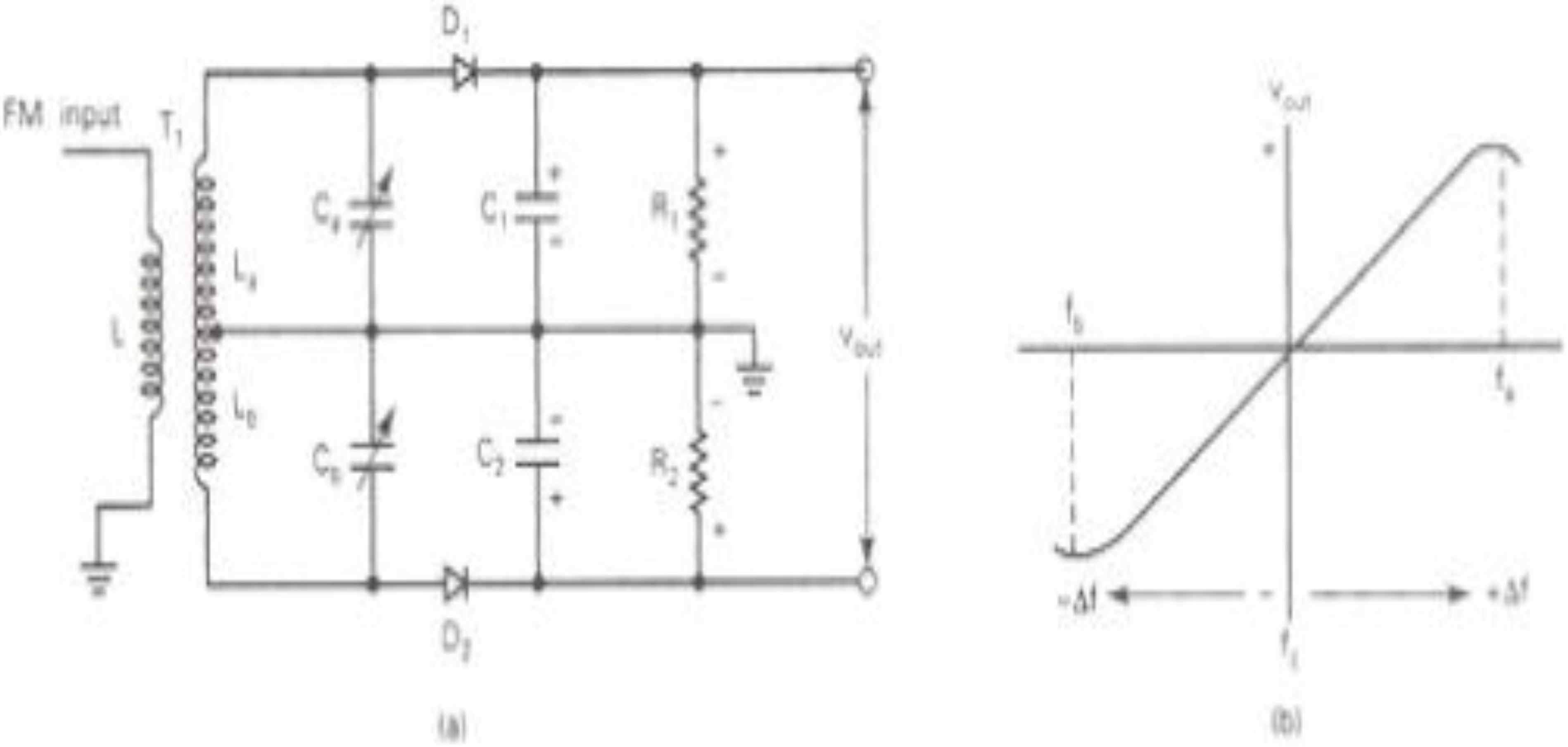

Slope detector: (a) schematic diagram; (b) voltage-versus-frequency curve

- the tuned circuit ($L_a$ and $C_a$) produces an output voltage that is proportional to the input frequency.
- the maximum output voltage occurs at the resonant frequency $f_0$ and its output decreases proportionally as the input frequency deviates above or below $f_0$.
- the circuit is designed so that the IF centre frequency $f_c$ falls in the centre of the most linear portion of the voltage-versus-frequency (figure (b)).
  - when IF deviates below $f_c$, the output voltage decreases
  - when IF deviates below $f_c$, the output voltage increases
- the tuned-circuit therefore, converts frequency variations to amplitude variations.
- $D_i$, $C_i$ & $R_i$ make up a simple peak detector to demodulate the AM signals.

- Di, Ci and Ri make up a single peak detector that converts the amplitude variations to the output voltage that varies at a rate equal to that of input frequency changes and whose amplitude is proportional to the magnitude of the frequency changes.

# 4.11.1 : Tuned-circuit Frequency Discriminator

## 2) Balanced Slope Detector




Balanced slope detector: (a) schematic diagram; (b) voltage-versus-frequency response curve

- Balanced slope detector is simply two single-ended slope detector connected in parallel and fed 180° out of phase.
- Phase inversion accomplished by centre tapping secondary windings of $T_1$.
- Tuned circuits ($L_a$, $C_a$ & $L_b$, $C_b$) perform an FM-to-AM conversion.
- Balanced peak detectors ($D_1$, $C_1$, $R_1$ & $D_2$, $C_2$, $R_2$) remove the information from the AM envelope.
- $L_a$ & $C_a$ is tuned to frequency $f_a$ that is above the IF centre frequency $f_c$.
- $L_b$ & $C_b$ is tuned to frequency $f_b$ that is below the IF centre frequency $f_c$.

- Operation

Balanced slope detector: (a) schematic diagram; (b) voltage-versus-frequency response curve

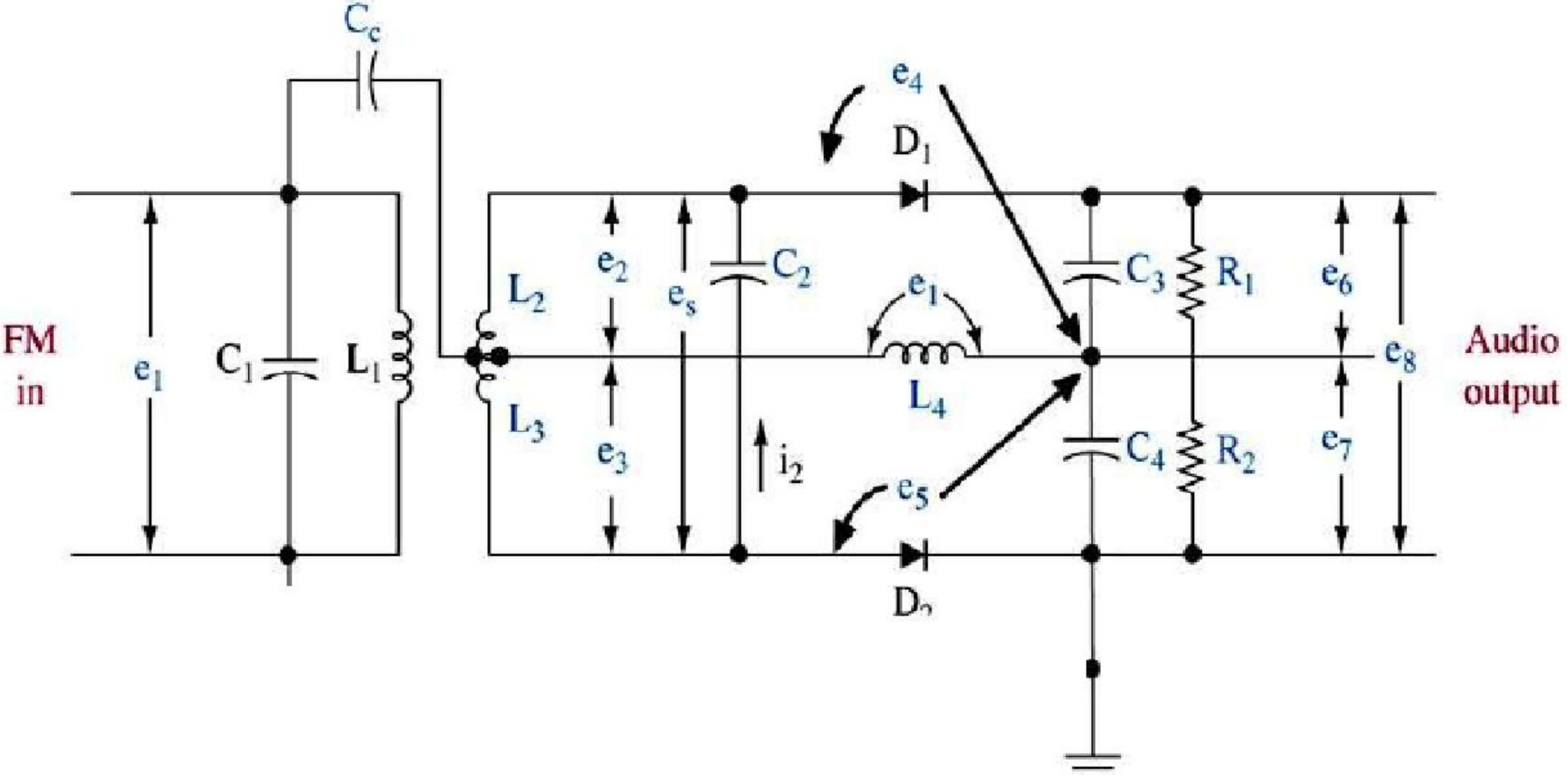
  - the IF centre frequency $f_c$ falls exactly halfway between the resonant frequency of the two tuned circuits.
  - at $f_c$, the output voltage from the tuned circuits are equal in amplitude but opposite in polarity. I.e. the rectified voltage across $R_1$ & $R_2$, when added, produce an output voltage $V_{out} = 0$.
  - when IF deviates above the resonance, the top tuned circuit produces higher output voltage than the lower tuned circuit, and $V_{out}$ goes positive.
  - when IF deviates below the resonance, the output voltage from lower tuned circuit is larger than the voltage from top tuned circuit, and $V_{out}$ goes negative.

## 4.11.1 : Tuned-circuit Frequency Discriminator

- Comparison Slope Detector vs Balanced Slope Detector

| Slope Detector | Balanced Slope Detector |
|---|---|
| ▪ simpler circuit<br>▪ poor linearity, difficult to tune<br>▪ need to use separate limiter stage to compensate amplitude variation | ▪ more complex circuit<br>▪ better linearity and tuning<br>▪ does not need limiter stage |

# FOSTER-SEELEY DISCRIMINATOR



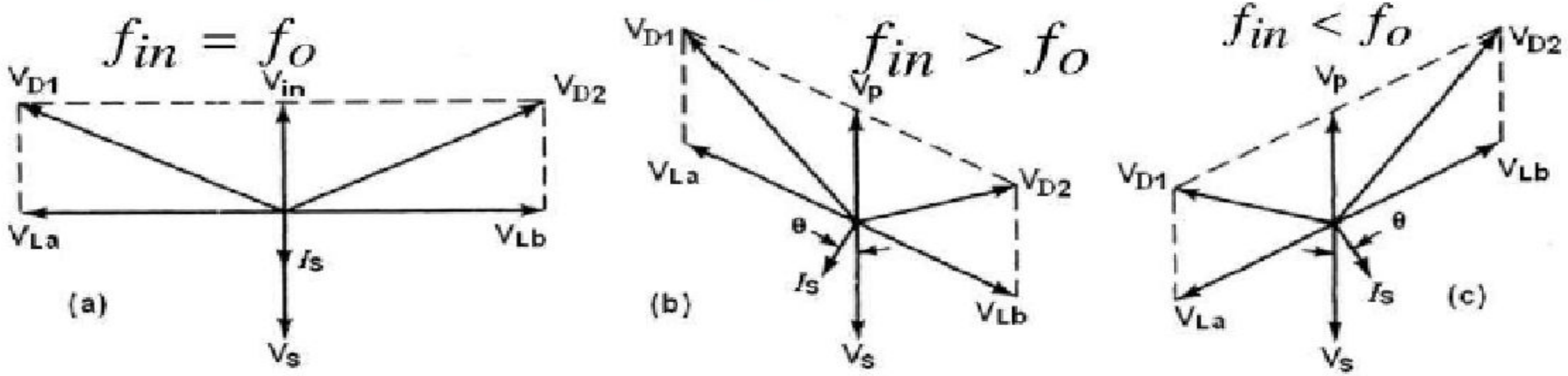
# Foster Seeley Discriminator

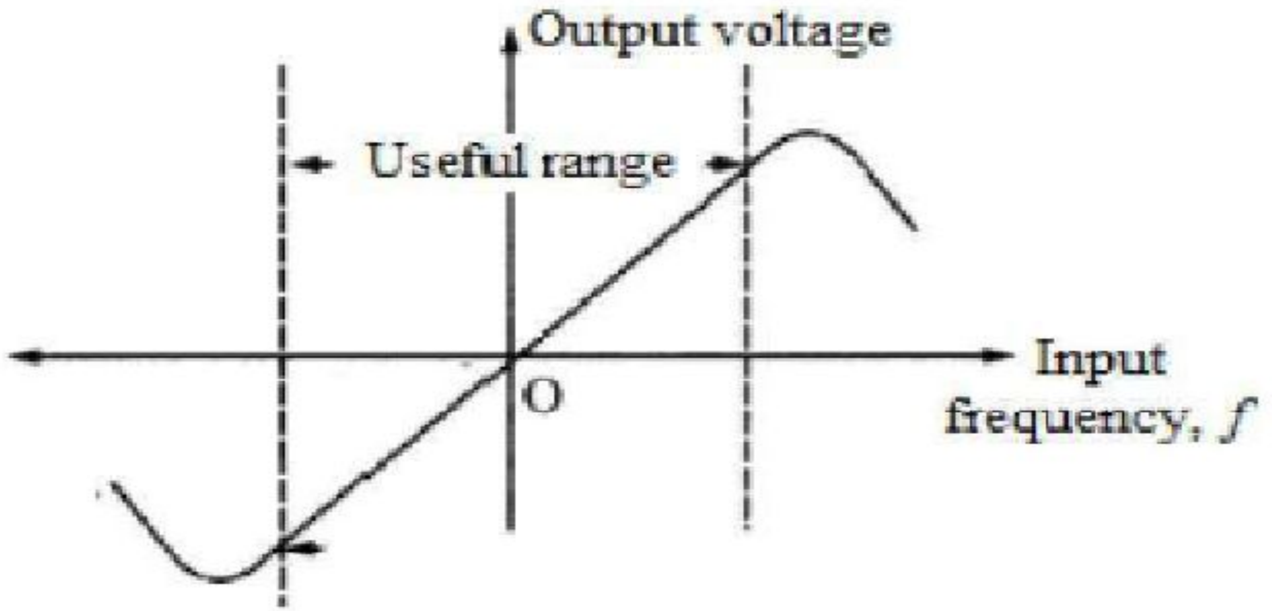
-  sometimes called as Phase shift Discriminator is a tuned circuit frequency discriminator whose operation is very similar to that of the balanced slope detector.
-  The capacitance values for Cc, C1 and C2 are chosen such that they are short circuits for IF center frequency.
-  Therefore the right side of L2 is at ground potential and the IF signal (Vin) is fed directly (in phase) across L3(VL3)
-  The incoming IF is inverted 180 degree by transformer T1 and divided equally between La and Lb.
-  At the resonant frequency of the secondary tank circuit (the IF center frequency), the secondary current (Is) is in phase with the total secondary voltage (Vs) and 180 degree out of phase with VL3.
-  Also because of loose coupling the primary of T1 acts as an inductor and the primary current Ip is 90 degree out of phase with Vin. And because magnetic induction depends on primary current, the voltage induced in the secondary is 90 degree out of phase with Vin (VL3)
-  Therefore Vla and Vlb are 180 degree out of phase with each other and in quadrature or 90 degree out of phase with Vl3.
-  The voltage across the top diode (VD1) is vector sum of VL3 and VLa. And the voltage across the bottom diode VD2 is the vector sum of VL3 and Vlb.The corresponding vector diagrams are shown in figure a).

# Foster Seeley Discriminator

- The figure shows that the voltages across D1 and D2 are equal. Therefore at resonance I1 and I2 are equal and C1 and C2 charge to equal magnitude voltages except with opposite polarities. Consequently Vout = Vc1-Vc2 = 0 V.
- When the **IF goes above resonance (XL > Xc)** the secondary tank circuit impedance becomes inductive and the secondary **current lags the secondary voltage** by some angle ϴ, which is proportional to the magnitude of the frequency deviation. Corresponding diagram is shown in fig b) (vector Diagram b) The figure shows the vector sum of the voltage across D1 is greater than the vector sum of the vector sum of voltages across D2.
- Consequently **C1 charges while c2 discharges** and Vout goes positive.
- When **IF goes below resonance (XL< Xc),** the secondary **current leads the secondary voltage** by some angel ϴ, which is again proportional to the magnitude of the change in frequency. The corresponding phasors are shown in figure c). It can be seen that the vector sum of the voltage across D1 is now less than the sum of the voltage across D2.
- Consequently **C1 discharges while C2 charges** and Vout goes negative.
- A Foster Seeley Discriminator is tuned by injecting a frequency equal to the IF center frequency,

# Foster-Seeley Discriminator



# Foster-Seeley...

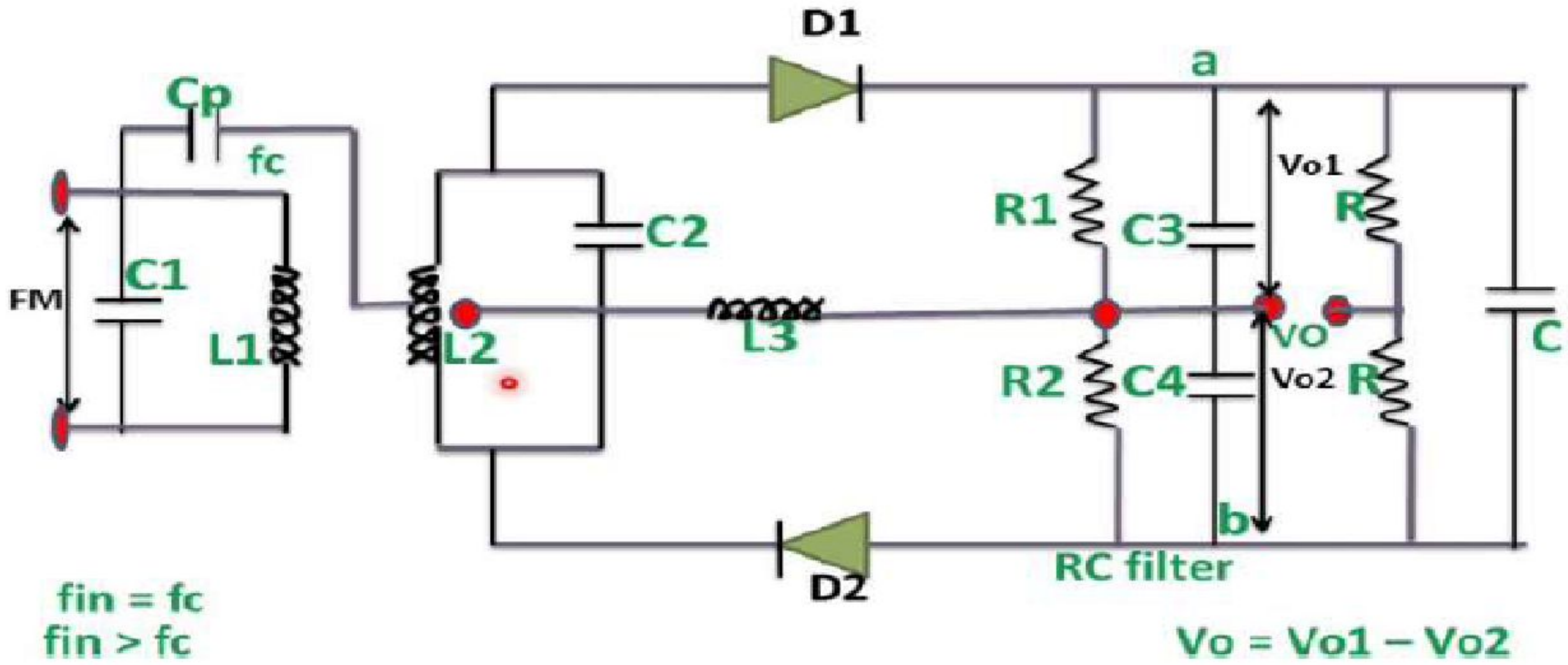
***Advantages*:**

- Tuning procedure is simpler than balanced slope detector, because it contains only two tuned circuits and both are tuned to the same frequency .
- Better linearity, because the operation of the circuit is dependent more on the primary to secondary phase relationship which is very much linear.

***Limitations*:**

It does not provide amplitude limiting. So in the presence of noise or any other spurious amplitude variations, the demodulator output respond to them and produce errors.

# Ratio detector



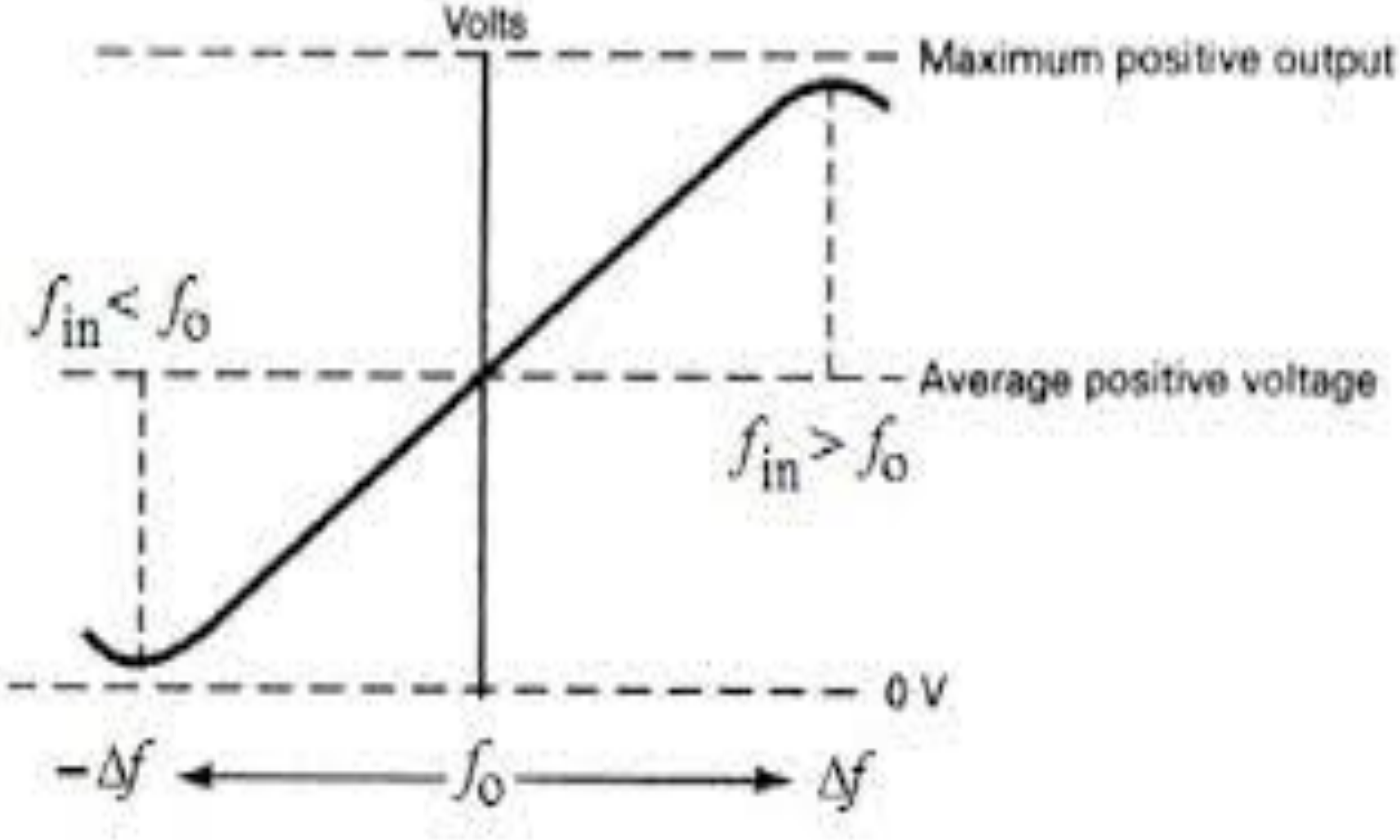
# Ratio Detector

- The Ratio detector has one major advantage over the slope detector and Foster Seely discriminator. A Ratio detector is relatively **immune to amplitude variations** in its input signal.
- As with Foster Seely discriminator, a ratio detector has a single tuned circuit in the transformer secondary.
- Therefore the operation of a ratio detector is similar to that of Foster Seeley discriminator.
- Voltage vectors for D1 and D2 are identical to those of the foster Seely discriminator circuit shown.
- However with the ratio detector, one diode is reserved (D2) and current (Id) can flow around the outermost loop of the circuit.
- Therefore after several cycles of the input signal, shunt capacitor Cs, charges to approximately the peal voltage across the secondary winding of T1.

# Ratio Detector

- The reactance of Cs is low, and Rs simply provides a dc path for diode current.
- So Time constant of Rs and Cs is sufficiently long so that rapid changes in amplitude of input signal due to thermal noise or other interfacing signals are shorted to ground and have no effect on the average voltage across Cs.
- Consequently C1 and C2 charge and discharge proportional to frequency changes in the input signal and are relatively immune to amplitude variations.
- Also the output voltage from a ratio detector is taken with respect to ground and for diode polarities as shown in diagram, the average output is positive.
- At resonance, the output voltage is divided equally between C1 and C2 and redistributed as the input frequency is deviated above and below resonance.
- Therefore changes in Vout are due to the changing ratio of the voltage across C1 and C2 while the total voltage is clamped by Cs.

# Ratio Detector




- It can be seen that at resonance, Vout is not equal to )v but rather to one half of the voltage across the secondary windings of T1.
- Because the ratio detector is relatively immune to amplitude variations, it is often selected over a discriminator.
- However the discriminator produces a more linear output voltage versus frequency response curve.

# Ratio Detector

Similar to the Foster-Seeley discriminator .

(i) The direction of diode is reversed.

(ii) A large capacitance $C_s$ is included in the circuit.

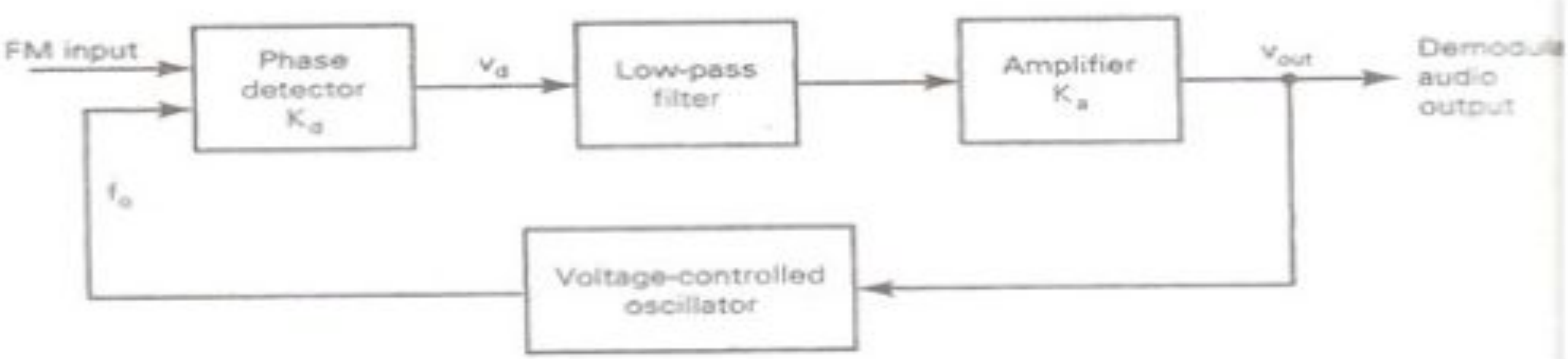
(iii) The output is taken different locations.

**Advantages:**

- Easy to align.
- Good linearity due to linear phase relationship between primary and secondary.
- Amplitude limiting is provided inherently. Hence additional limiter is not required.

## 4.11.2 : PLL FM Demodulator

- A PLL frequency demodulator requires no tuned circuits and automatically compensates for changes in the carrier frequency that is caused by the instability in the transmitter's oscillator.

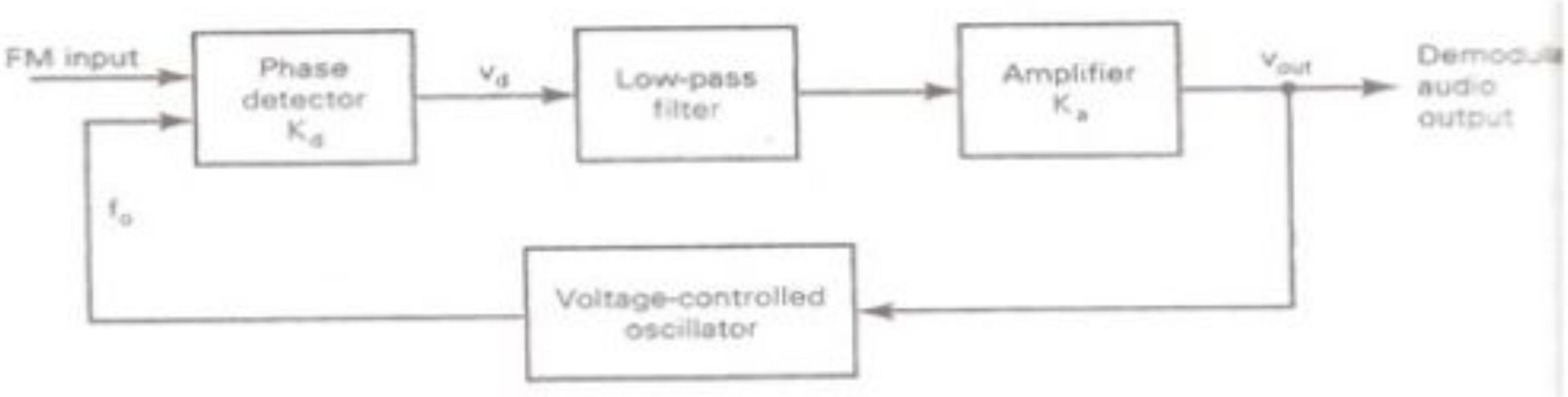



  - after the frequency lock had occurred, the VCO tracks frequency changes in the input signal by maintaining the phase error at the input of the phase comparator.
  - if the input is deviated FM signal and the VCO natural frequency is equal to the centre IF frequency, the correction voltage produced at the phase comparator is proportional to the frequency deviation.

$$V_d \propto \Delta f$$

I.e. correction voltage produced is proportional to the modulating/information signal.

# 4.11.2 : PLL FM Demodulator




- if the amplitude is sufficiently limited before reaching the PLL and the loop is properly compensated, the PLL loop gain $K_v$ is constant.

  Therefore the demodulated signal can be taken directly from the output and is mathematically expressed as

$$V_{out} = \Delta f K_d K_a \tag{30}$$

where $\Delta f$ = frequency deviation, $K_d$ = phase comparator gain,

$K_a$ = amplifier gain

# Performance Comparison of FM Demodulators

| S.No. | Parameter of Comparison | Balanced Slope detector | Foster-Seeley (Phase) discriminator | Ratio Detector |
|---|---|---|---|---|
| (i) | Alignment/tuning | Critical as three circuits are to be tuned at different frequencies | Not Critical | Not Critical |
| (ii) | Output characteristics depends on | Primary and secondary frequency relationship | Primary and secondary phase relation. | Primary and secondary phase relation. |
| (iii) | Linearity of output characteristics | Poor | Very good | Good |
| (iv ) | Amplitude limiting | Not providing inherently | Not Provided inherently | Provided by the ratio detector. |
| (v) | Amplifications | Not used in practice | FM radio, satellite station receiver etc. | TV receiver sound section , narrow band FM receivers. |