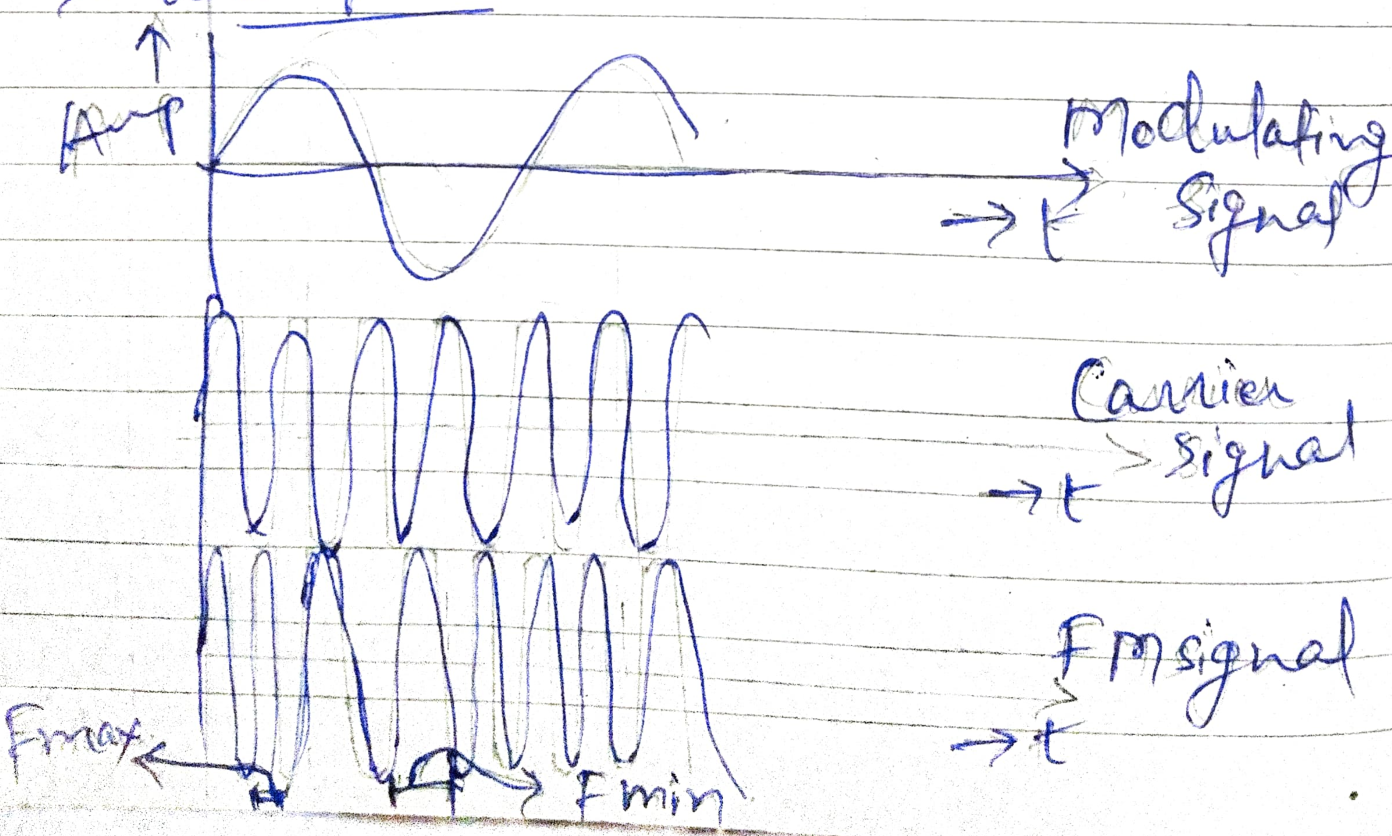
frequency Modulation

Defina^n → Freq. Modula^n is the signal in which amplitude of a modulated a carrier is constant while its freq. is vary in accordance with the instantaneous value of the modulating signal.

As the amplitude of the information signal varies. The carrier freq. ~~been~~ will shift in propotion. As the amplitude of modulating signal ↑se, the carrier freq. ↑ses. If the amplitude of the modulating signal is ↓se, the carrier freq. is also ↓ses.

Waveform



Freq.
Deviation

The amount of change in carrier freq. produce by the modulating signal is known as freq. Deviation.

Max. freq. deviation offered at the max. amplitude of the modulating signal. The freq. of modulating signal determines how many times per second the carrier freq. deviats above & below its normal ~~freq~~ centre freq. This is called as freq. deviation rate.

Modulation Index (mf)

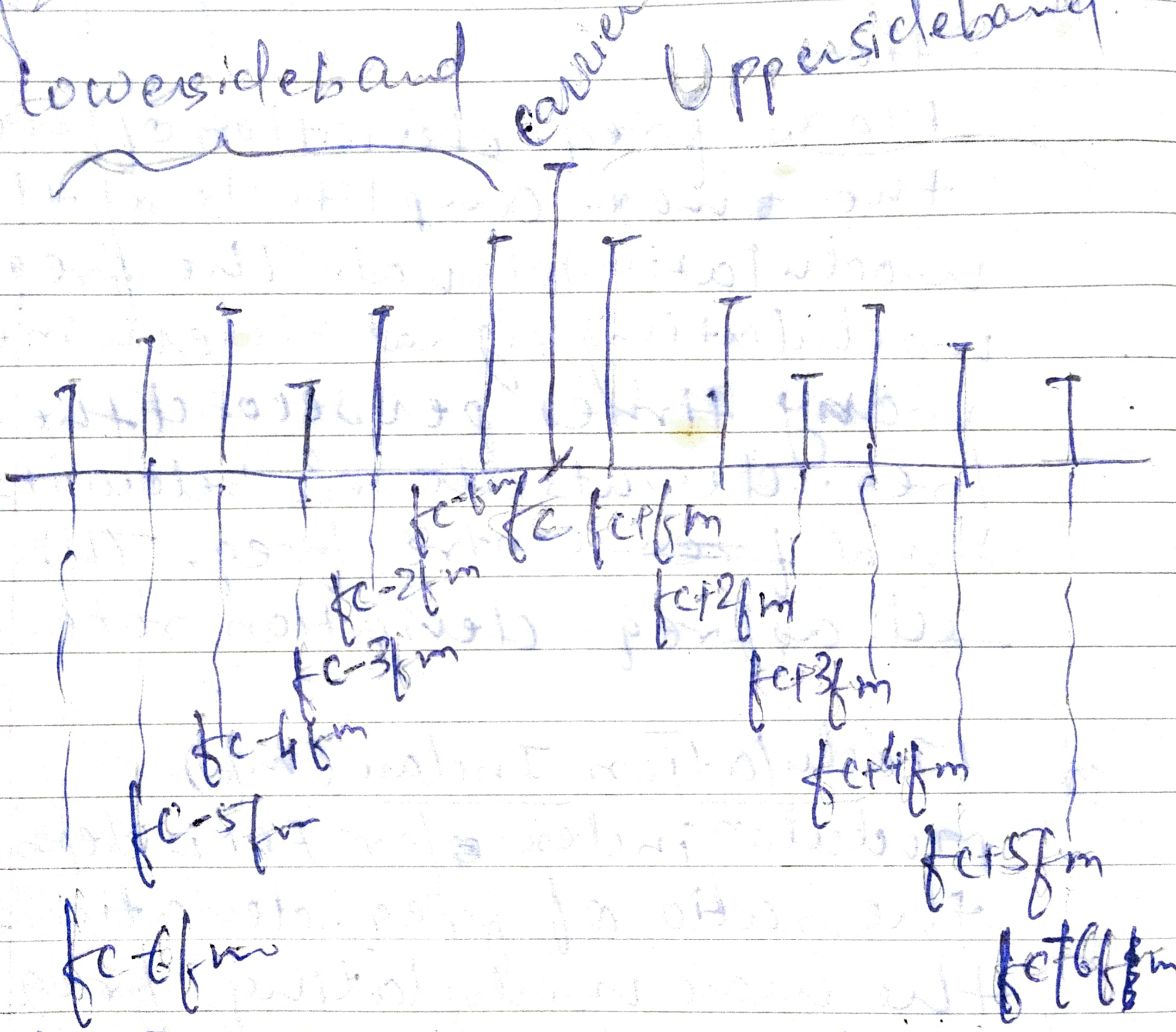
Modulation index for FM is defined as the ratio of freq. deviation in to the max modulating freq.

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

where. δ = freq. deviation.
f_m = max. modulating freq.

* Frequency spectrum of FM signal.

explain



In FM theoratically infinite no. of pairs of upper & lowerside band are generating. Due to this spectrum of FM signal is generally wider than equivalent of AM signal.

Fig. shows an eg. of spectrum of a typical FM signal produced by the modulating carrier with a single freq. sine wave.

Note that the sideband are spaced from the carrier (f_c) and are spaced from one another by a freq. equal to the modulating freq. Fm.

As the amplitude of the modulating signal varies, the freq. deviation will change. The no. of side band pair produced, their amplitude and ~~their~~ spacing depends upon the freq. deviation and modulating freq. fm. FM signal has a constant amplitude. The side band amplitude must vary with freq. deviation and modulating freq. ~~[illegible]~~

~~[illegible] find the amplitude of FM signal.~~

Although the FM process produces an infinite no. of upper & lower sidebands, only those with the largest amplitude are significant in carring informa°. Typically any side band whose amplitude is less than ~~[illegible]~~ 1% of the unmodulated carrier is considered insignificant.

Carson's Rule.

For calculating the ~~otp~~ optimum bandwidth the approximately common rule is used which is known as Carson's Rule.

$$\boxed{\text{Bandwidth} = 2(\delta_{max} + f_{m(max)})}$$

where δ_m = max. freq. deviation.
& $f_{m(max)}$ = max. ~~of~~ Modulating freq.

→ In commercial fm broadcasting maximum allowed deviation is 75 KHz.

(1) 25 MHz carrier is modulated by 400 Hz audio signal if the carrier voltage is 4 V & the maximum deviation is 10 KHz. ~~write~~ find the eqn of the modulated wave for FM.

Solution → eqn of modulated wave,

This final eqn of fm → $V = A\sin(\omega_c t + m_f \cdot \sin\omega_m t)$

find ω_c, ω_m, m_f.

$A = 4V$, $\delta_{max} = 10\,KHz$.

~~$W_m = 2f_m$~~

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

$$= \frac{10\times10^3}{400}$$

$$= 25$$

$$\omega_m = 2\pi f_m$$
$$= 2\pi \times 400$$
$$= 2513.27\ Hz.$$

$$\omega_c = 2\pi f_c$$
$$= 2\pi \times 25\times10^6$$
$$= 157.07\ MHz.$$

$$V = A\sin\left(157.07\times10^6 t + 25\times\sin 2513.27 t\right)$$

(2) The eq^n of fm wave is represented by voltage eq^n $V = 12\sin(6\times10^8 t + 5\sin 1250.t)$

calculat f_c, f_m, m_f, freq. deviation

compair with $V = A\sin(\omega_c t + m_f.\sin\omega_m t)$

$\omega_c = 6\times10^8$ $\qquad$ $\omega_m = 1250$

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

$f_c = \frac{6\times10^8}{2\pi}$ $\qquad$ $f_m = \frac{1250}{2\pi}$

$= 95.49\ MHz.$ $\qquad$ $= 198.94\ Hz$

$$mf = 5$$

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

$$\delta = mf \cdot fm$$
$$= 5 \times 198.94$$
$$\boxed{\delta = 994.75}$$

$$\text{Bandwidth} = 2(994.75 + 198.94)$$

$$= 2.38\ \text{KHz.}$$

★ Pre-Emphasis ckt.

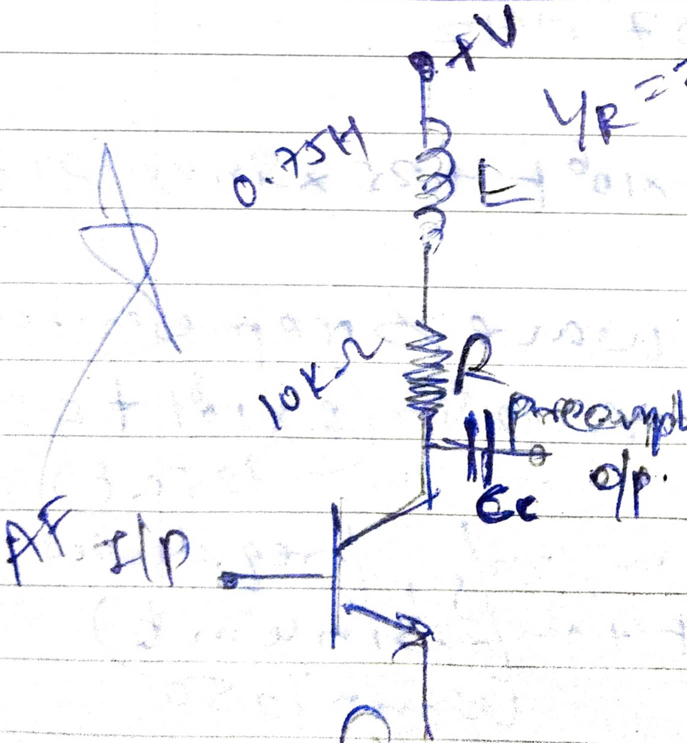


fig (a)

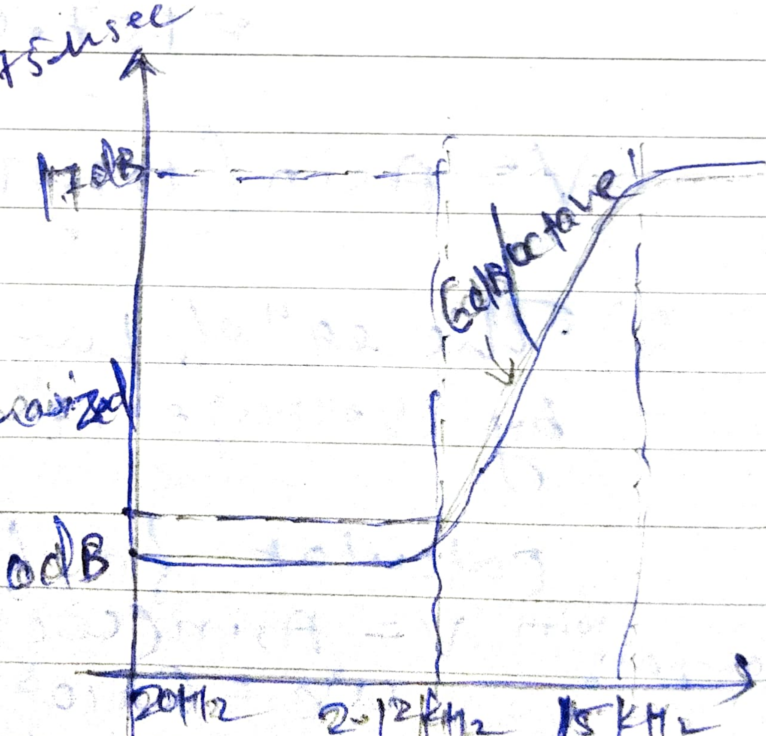


fig (b)

(Higher freq component have less Amplitude compair to low freq component)

Max permitted deviation is 75KHz
Deviation depends upon Amplitude of modulating signal

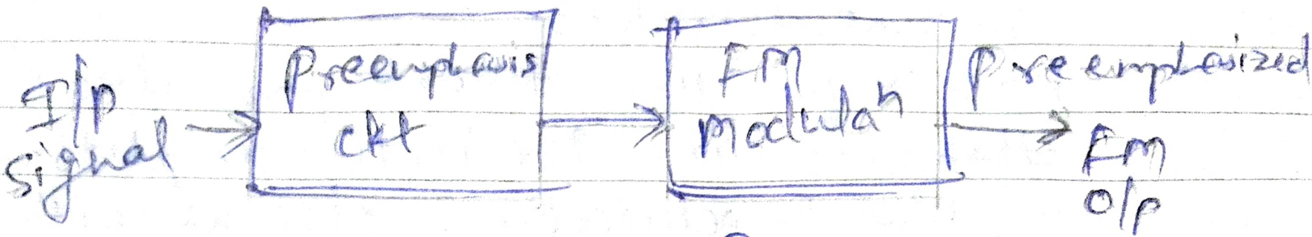


fig (c)

In the modulating voltage high freq. components ~~are~~ have small amplitudes & hence these components produce freq. deviation for less than maximum permitted value of 75KHz. Consequently the signal strength at these high modulating freq. is very low relative to the transistor & ckt noise which are uniformly distributed over the entire spectrum occupied by the channel. To improve the S/N ratio at this high modulating freq. pre-emphasis ckt is used to emphasized the high freq. components prior to modulation.

In pre-emphasis process ~~the~~ a high-pass filter (differentiator). Fig. shows ckt diagram for active pre-emphasis network & the ~~re~~ ~~are~~ corresponding freq. response curve

as shown in fig.
Pre emphasis network provides a ~~the~~ constant ↑se in the amplitude of the modulating signal with an ↑se in the freq. The break freq. is ditermined By RC or $\frac{L}{R}$ time constant of the network. The break freq. occurs at the freq. where $X_C = X_L = R$ ~~ie. capacitive~~ ~~rea~~ Mathematically break freq. is,

$$f_s = \frac{1}{2\pi RC} \quad \text{or} \quad f_s = \frac{1}{2\pi L/R}$$

The network shown in fig. @ of the FM broadcast band which uses 75 μsec time constant, ie. $L/R = 75\mu sec$. Therefore the break freq. approximately equals to $F = 1/2\pi L/R$ which equals to $1/2\pi\, 75\mu sec$ which equals to 2.12 KHz.

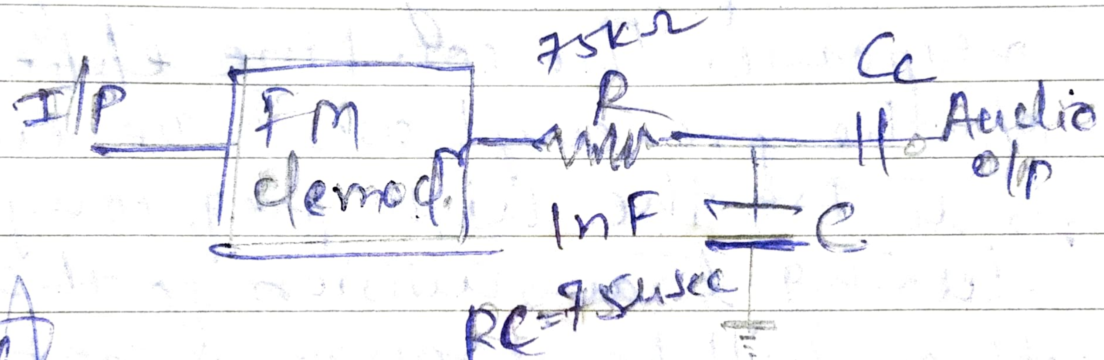
$$\left[F = 1/2\pi L/R = 1/2\pi\, 75\mu sec = 2.12\,KHz\right].$$

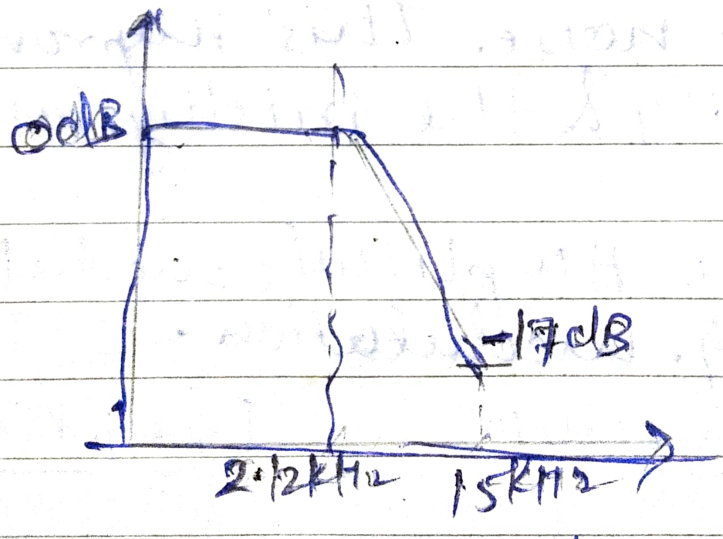
The ~~fm~~ FM transmission of the audio portion of commercial TV broad casting uses a 50 μsec time constant.

Advantages of Pre-emphasis.

(1) It ↑ses the energy content of high freq. signals, so that they are not affected by noise components. This improves the S/N ratio & ↑ses ~~[illegible]~~ fidelity & intelligibility.

De-Emphasis ckt.





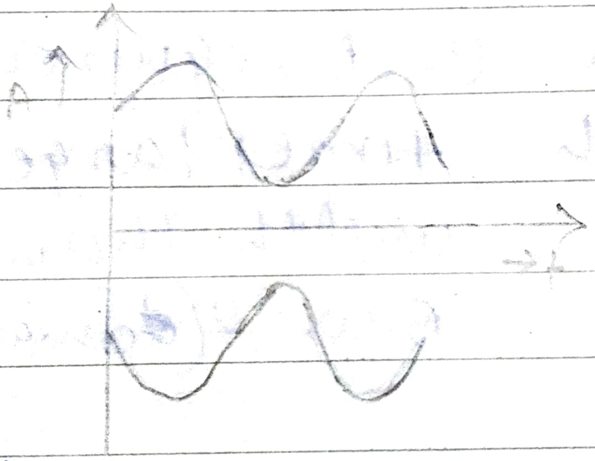
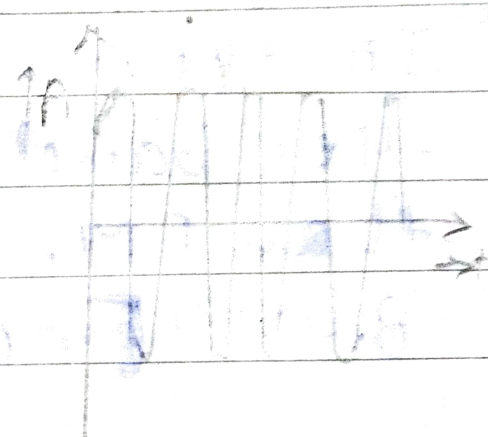
To return the freq. response to its normal level a de-emphasis ckt is used at the receiver. This is a simple low pass filter with a time constant of 75μsec. It features a cut off freq. of 2.12kHz

accuring the signal above this freq. to be attenuated at the rate of 6dB/octave. The response curve is as shown in the fig.
As a result of pre-emphasis at the transmitter is exactly offset by the de-emphasis ckt. in the receiver providing normal freq. response. The combine effect of the pre-emphasis & De-emphasis is to ↑se the high freq. components during transmission so that they will be stronger & not masked by noise. This improves the fedality & the intelligibility.

2) Compair Amplitude modulation & freq. modulation.

Amp. modulaⁿ.	Freq. Modulaⁿ.
(1) In amp. modulaⁿ the amplitude of carrier is changes with instantaneous value of the modulating signal.	(1) In freq. modulaⁿ the freq. of carrier is changes with the instantaneous value of modulating signal

freq. & phase remains constant.	~~Freq.~~ Amp. & phase remains constant.
(2) AM. operate in medium & high freq. band.	(2) FM operate in VHF (very high freq.) & UHF (ultra high freq.) band.
(3) It required smaller band width than FM. B.W. = 2 f_m (max)	(3) It required 7 to 15 times large band width than AM. B.W. = 2(δ_{max} + f_m max)
(4) Modulation index is always less than unity. $m_a = \frac{V_m}{V_c}$.	(4) Modulation index is greater than unity. $m_f = \frac{\delta}{f_m}$
(5) In AM. noise is affected on reception.	(5) In FM noise is eliminated by using limiter ckt in receiver
(6) In AM. only one side band pair is produced.	(6) Infinite side band pair are produced.

(7) Simple ckt is required for transmitting & receiving.	(7) Complex ckt is required for transmitting & receiving
(8) AM covers large area.	(8) FM covers smaller area.
(9) 	(9) 
$V(AM) = V_c \cdot \sin\omega_c t + \frac{m_a \cdot V_c}{2} \cdot \cos(\omega_c - \omega_m)t - \frac{m_a \cdot V_c}{2} \cdot \cos(\omega_c + \omega_m)t$	$V(FM) = A \cdot \sin(\omega_c t + m_f \cdot \sin\omega_m t)$

b) Varactor diode Modulator

* ckt diagram.

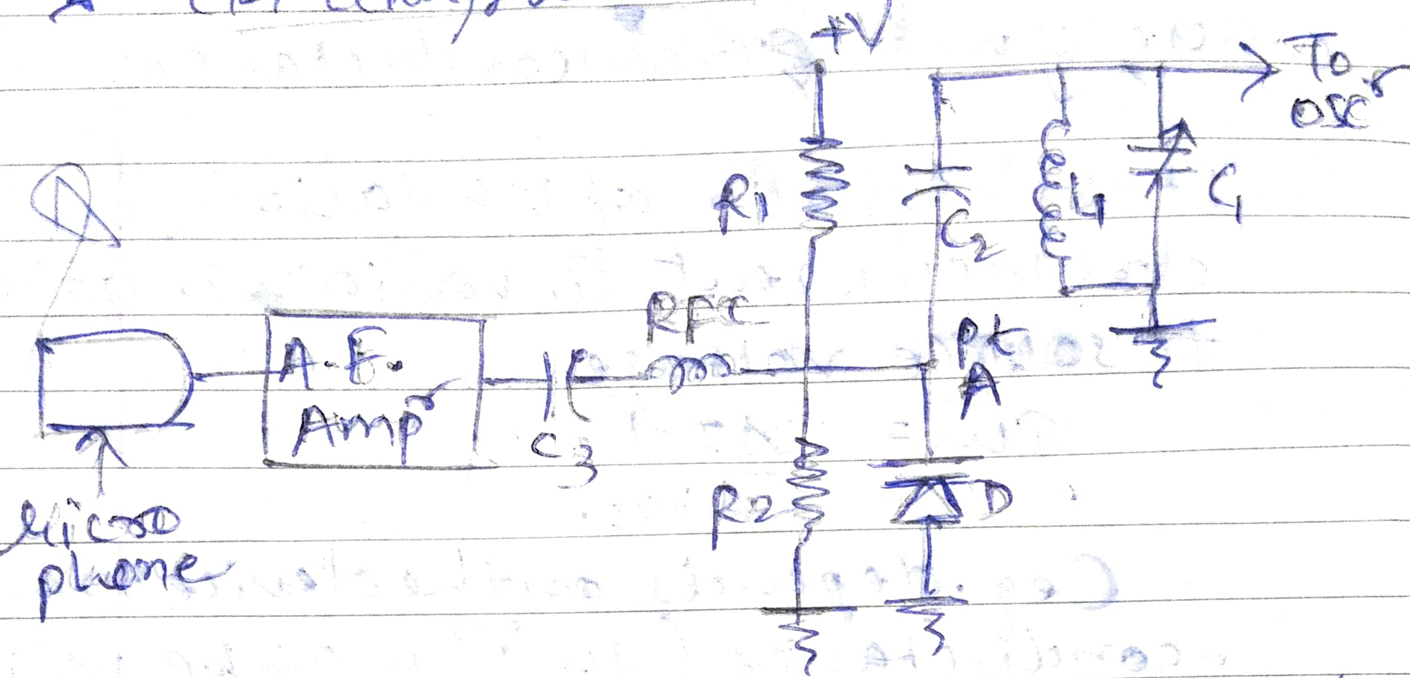


Fig. shows the basic concept of varactor freq. modulator.
The C1 & C1 represent the tuned ckt of the carrier osc^r. Varactor diode 'D' is connected in series with the capacitor C2 across the tuned ckt.
The value of C2 is made very large at the operating freq, so that its reactance is very low, as a result C2 is connected in series with the lower capacitance of 'D'. The effect is that if D is directly connected across the tuned ckt, the total effective ckt capacitance is then a capacitance of D in parallel

with C_1. This fixes centre carrier freq.

The capacitance of 'D' is controlled by two factors.

(i) A fixed DC bias.

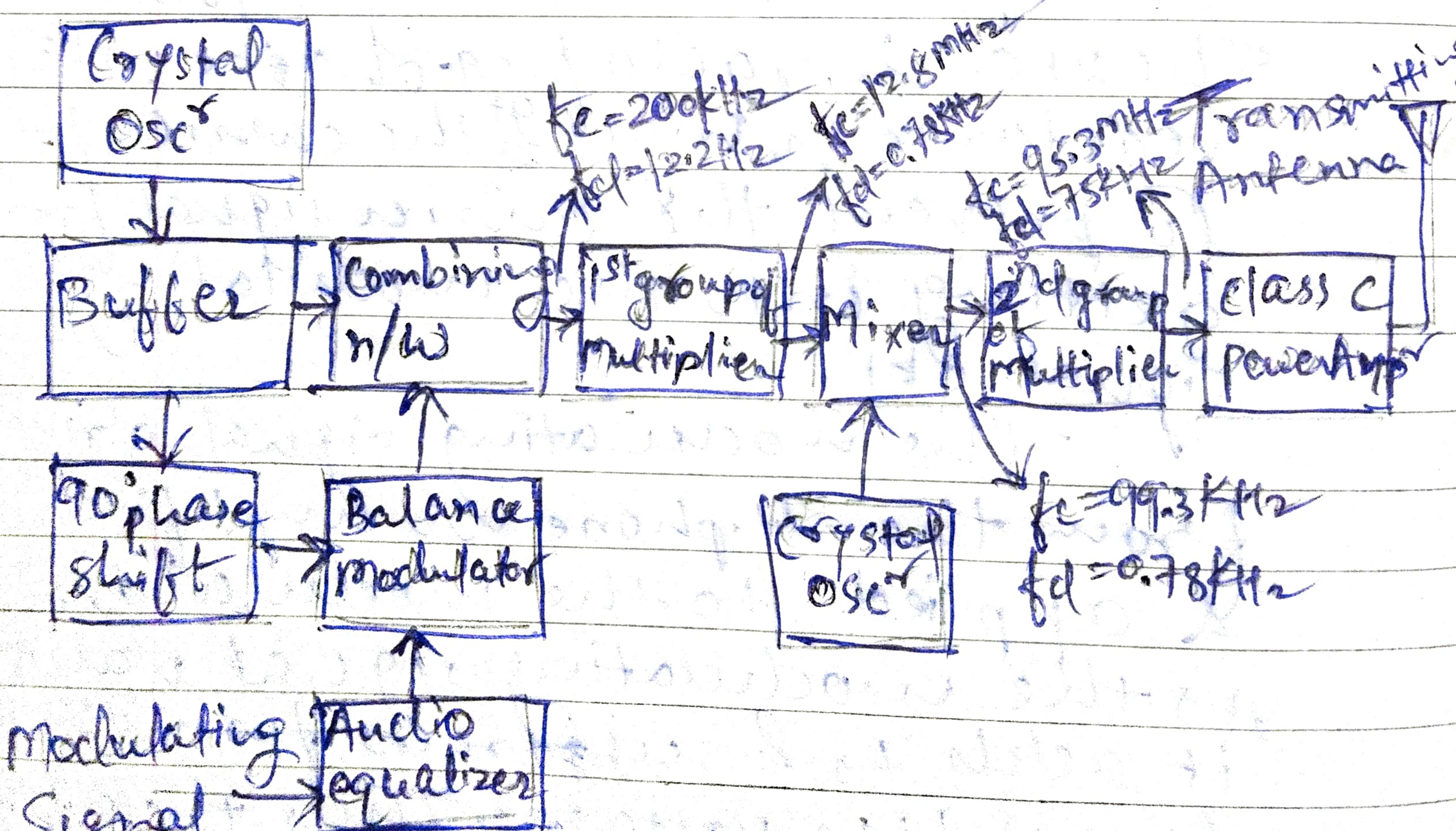
(ii) Modulating signal.

The bias on 'D' is set by voltage divider which is made up of R_1 & R_2. The modulating signal is applied through C_3 & RFC. The C_3 is a blocking capacitor that keeps the DC bias out of the modulating signal ckt. The RFC is radio freq. choke whose reactance is high at the carrier freq. to prevent the carrier signal from getting into the modulating signal ckt.

The modulating signal derives from the M.phone is amplified & applied to the modulator. As the modulating signal varies it adds to & subtracts from the fixed bias voltages. Thus the effective voltage applied to 'D' causes its capacitance to vary. Due to this it produces a deviation of the

carrie freq. as desired.
A +ve going signal at pt. A' adds to the reverse bias, ↓sing the capacitance & ↑sing the carrier freq. A -ve going signal at pt. A subtracts from the bias ↑sing the capacitance & ↓sing the carrier freq.

(2) Indirect Method
or Armstrong method.



at the o/p of combining n/w we get a Deviated signal whose deviation depends upon Amplitude of carrier which is generated by balance modulator

The indirect fm modulating signal directely deviates the phase of the receiver which indirectely changes the freq.

Fig shows the block diagram of wide band armstrong indirect fm transmitter.

(1) Armstrong modulator

With an armstrong transmitter a relatively low freq. subcarrier [fc] is phase shifted by 90° (f-c) and fed to a balance modulator. When it is mixed with the i/p modulating signal, the o/p of the balance modulator is a DSBSC wave & is combined with the original carrier in a combining network to produce a low index phase modulated wave form.

With the armstrong trans-mitter the phase of the carrier is directely modulated in the com-bining network through summation producing indirect freq. modula-tion. The magnitude of the phase deviation is directly proportional

∝ to the amplitude of ~~the~~ the modulating signal, but independent of its freq. ∴ the modulating index remains constant for all modulating signal freq. of a given amplitude.

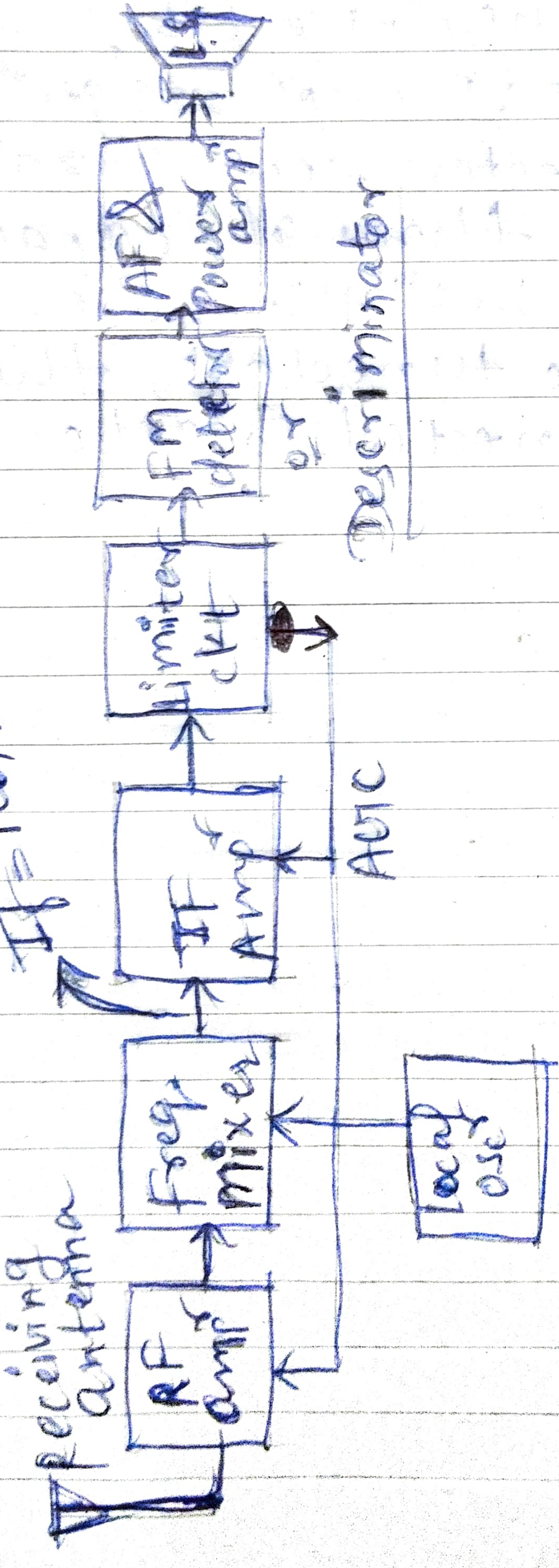
2) Freq. multiplier, freq. changer and power amplifier.
The o/p of combining ampr is a desired freq. modulated voltage Relative amplitude of the modulated voltage and the carrier voltage are so adjusted that the maximum phase deviaⁿ is small. This is necessary in order to avoid excessive result. As a result, freq. deviaⁿ (fd) is small. In the transmitter fd is 12.2 Hz at the o/p of modulator. This ~~is~~ freq. modulated voltage is fed to 6 freq. doubler to get a carrier freq. of 12.8 MHz and fd equals to 0.78 KHz. At this stage the carrier freq. is sufficiently high, but the freq. deviaⁿ is low only about 0.78 KHz. To

ise the freq. deviaⁿ further, the freq. modulated voltage is fed to a mixer which shifts the carrier freq. down to a low value of 99.3 KHz. However freq. deviaⁿ remains unaltered. Subsequently the freq. multiplier raises the carrier freq. to a desired value of 95.3 MHz & freq. deviation to a standard value of 75 KHz.

After power amplifier in a few stages raising the power level to the desired value, the o/p is fed to the transmitting antenna.

FM radio Receiver

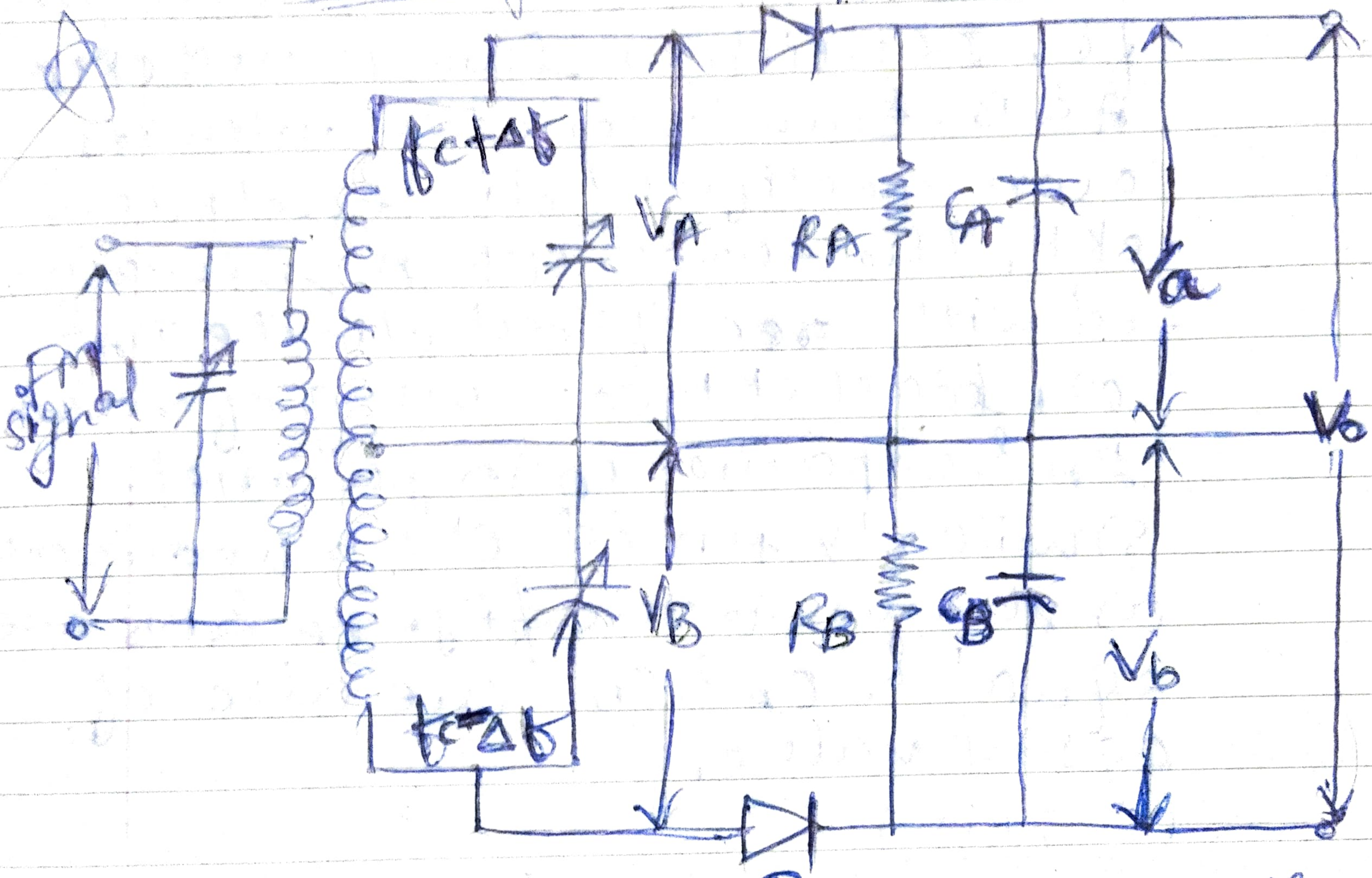
* Superhytrodyne FM radio receiver
* Block dia.



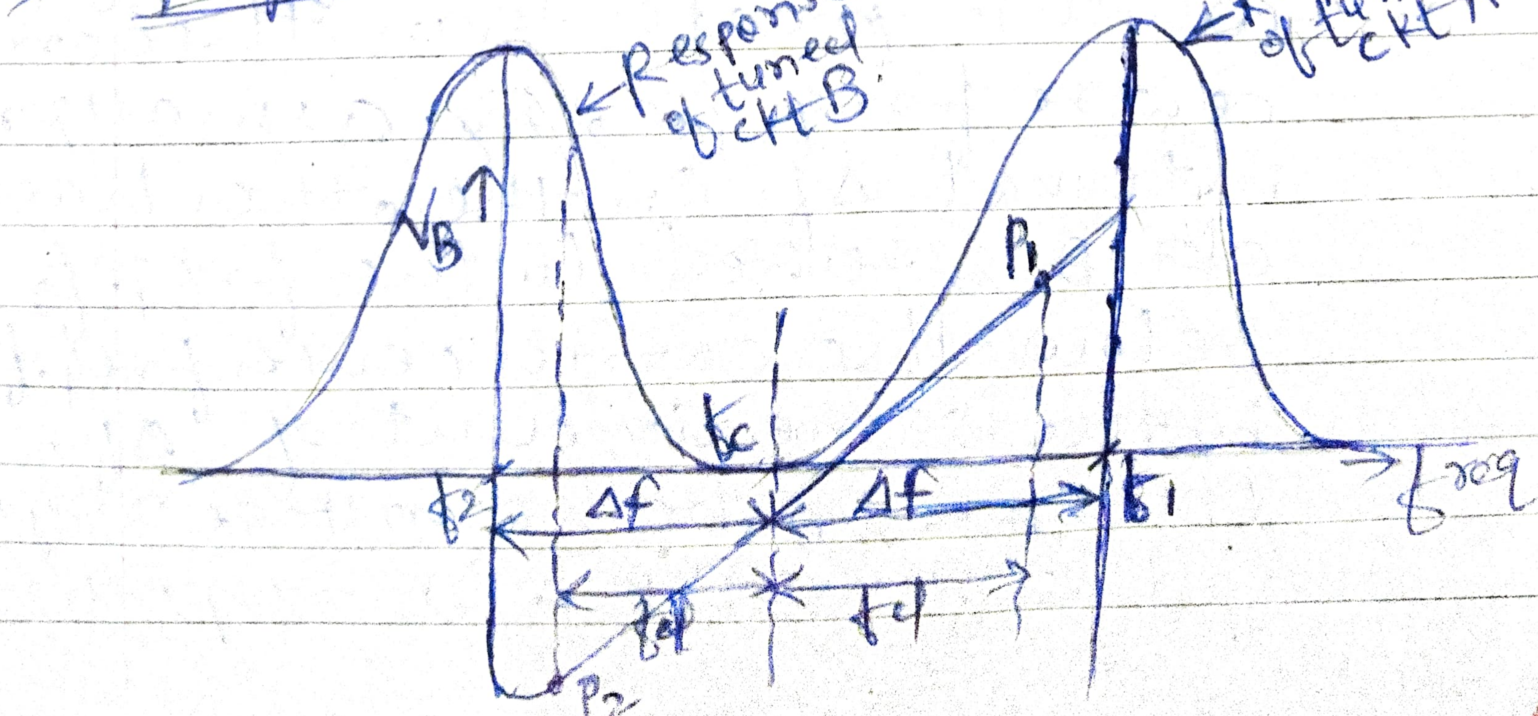
To Remove undesired Amplitude variation we uses limiter ckt

(1) Balance slope detector

ckt diag.



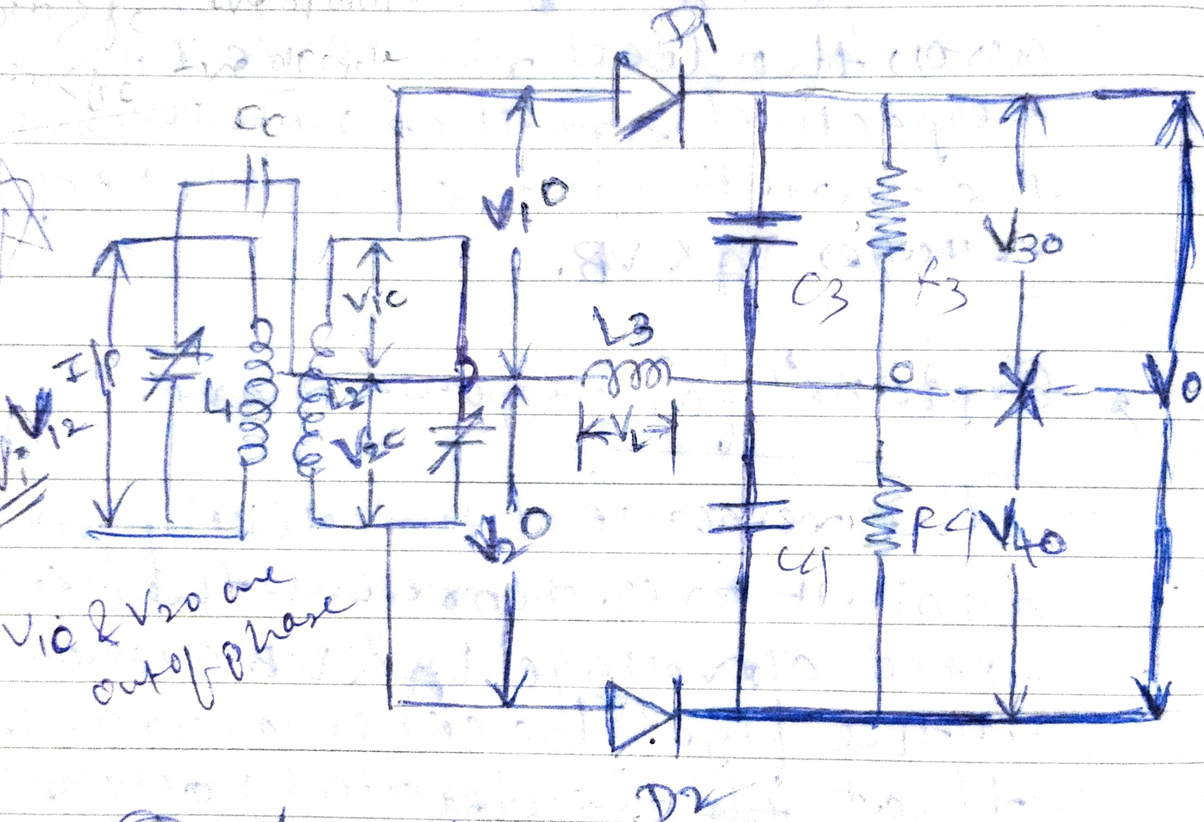
Response.



① linear chara. is limited to small freq. deviation,
② The tuned o/p is not purely band limited hence, LPF of envelop detector introduce distortion

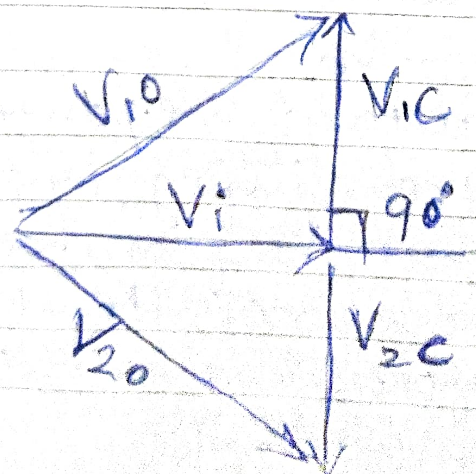
in the range P_1 & P_2 and it cuts the freq. axis at the carrier centre freq. fc.

* Foster phase seelay discriminator.



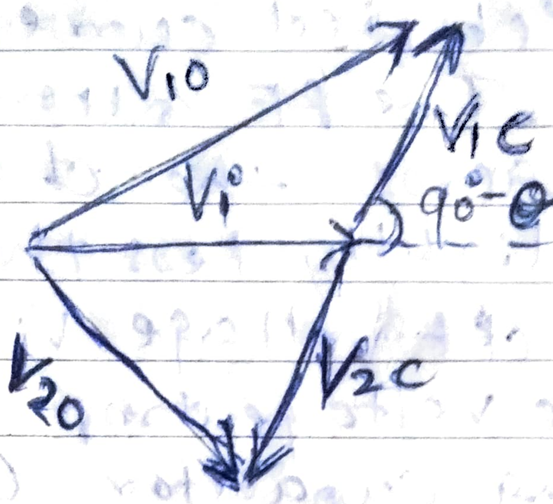
V10 & V20 are out of phase

① fin = fc



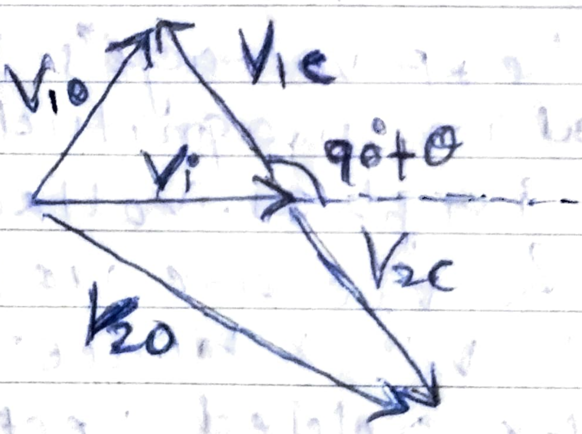
(2)

fin > fc
(fc + Δf)



(3)

fin < fc
(fc − Δf)



Construction & working

It uses a double tuned ckt in which both the primary & the secondary are tunned to the same freq. namely the IF inductively coupled. The centre of the secondary is connected to the ... primary tunned ckt through a coupling capacitor Cc. The RF choke L3 provides the return path for the DC component of the rectified current of diode D_1 & D_2. The RF Voltage V_L developed across the choke L_3 is very slightly less than the primary ckt voltage V_i because of the voltage drop in the coupling capacitor C_c. voltage V_L may be put approximately equal to V_i.

The RF voltage's V_{1c} & V_{2c} are equal in magnitude but opposite in phas. Voltages ~~& these~~ V_{1c} & V_{2c} are not in phase with V_i & hence these have to be added vectorially to V_i to produce voltage V_{10} & V_{20}. This vectorial addin is shown in the fig.

* Explainan of vector dia.

If However the applied freq. differs from the resonant freq. of the tuned ckt, the phase angles of the voltage V_1c & V_2c relative to the voltage V_i

(A) (1) good level of performance & resonance linearity
(2) easy to construct

(D) (1) Not suitable for IC technology
(2) Costly. (3) Amplitude noise

differ from 90°. The voltage applied to each diode is the sum of the primary voltage & corresponding half secondary voltage. It will also shown that the primary & the secondary voltages are,

(1) Exactly 90° out of phase when the i/p freq is fc. [$f_{in} = f_c$]
(2) less than 90° out of phase [$f_{in} > f_c$] when fin is higher than fc.
(3) More than 90° out of phase when fin is below fc. [$f_{in} < f_c$]

The RF voltage V_1O & V_2O are separately rectified in linear diode detector D_1 & D_2 respectively to produce o/p voltages V_3O & V_4O across the resistor R_3 & R_4.

The RF component of the rectified current are by passed through shunt capacitor C_3 & C_4 leaving only the modulating freq. component & DC component to flow through resistor R_3 & R_4.

The output voltages V_3O & V_4O represent the amplitude variaⁿ of RF voltages V_1O & V_2O. It may be seen that for the given arrangement of the diode, the o/p voltages oppose each other. The final o/p V_o is then equal to the arithmatic difference $|V_4O| - |V_3O|$. This resultant rectified o/p voltage V_o will then vary with the instantaneous freq. of the applied signal.

diode.

When $f_{in} = f_c$ the zero voltage results because RF voltages V_1O & V_2O have equal amplitude. At instantaneous freq. greater than the resonant freq. the rectified o/p voltage V_o of discriminator is +ve because RF voltage V_1O. has larger amplitude than the RF voltage V_2O. At an i/p freq.

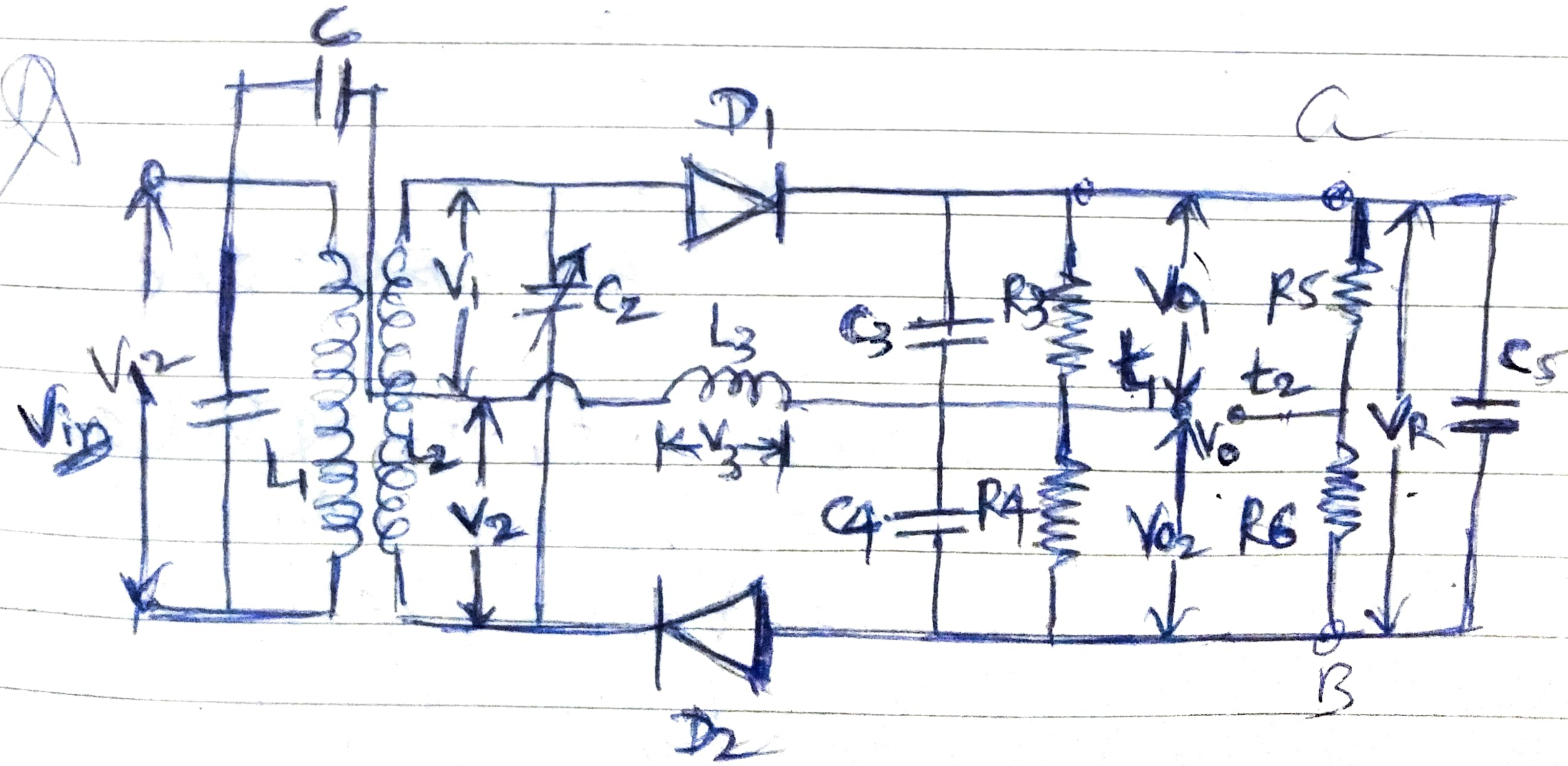
less than the resonant freq., the rectified o/p voltage V_o is -ve because RF voltage $V_1 0$ has smaller amplitude than the RF voltage $V_2 0$.

The performance of forster seelay discriminator is linear over freq. range ±200 KHz.

Disadvantage

(1) It does not provide any amplitude limiting ~~ckt~~ provision.

(4) Ratio Detector ckt



Construction

Ratio detector is an improvement over the foster seelay discriminator & is widly use. It does not respond through amplitude variation a limiter is not required. The ckt is similar to the ckt of foster seelay discri-minator except the following.

(1) The polarity of diode D_2 has beeen reversed.

(2) The o/p voltage is taken from the centre taped of a resistor R that shunts the load imped-ance of two diodes. The o/p voltage varies with the i/p signal freq. exactely in the same way as it does in the foster seelay discriminator, but its magnitude is reduced to half.

$$R_5 = R_6$$

$$V_0 = V \cdot t_1 \cdot t_2$$

$$= |V_t \cdot V_1| - |V_t - V_2|$$

$$= |V_{o2}| - \left|\frac{V_R}{2}\right|$$

$$V_R = |V_{o1}| + |V_{o2}|$$

$$V_o = V_{o2} - \left[|V_{o1}| + |V_{o2}|\right]$$

$$\therefore \boxed{V_o = \frac{V_{o2} - V_{o1}}{2}}$$

(iv) (1) good performance & resonance linearity
(2) Better immunity against amplitude noise
(3) wider BW.

<u>Amplitude limiting by ratio detector</u>

If the i/p voltage V_i is constant & has been so for some time, C_5 is been able to charge up to the potential existing betn {a, b}.
∴ This is the DC voltage if V_i is constant there will be no current either flowing to charge the capacitor or flowing out to discharge it. In other words the i/p impedance of C_5 is infinite.

As soon as the i/p voltage tries to rise, extra diode current flows, but this excess current flows in to the capacitor C_5, charging it. The voltage across V_{t_1}, t_2 remains constant because it is not possible for the voltage across capacitor to change instantaneously. Here the load impedance ↓ses.

If the i/p voltage falls, the diode current will fall, but the load voltage will not, at first because of the presence of the capacitor.

The effect is that of an ↑sed diode load impedance. The diode current has fallen but the load voltage has remain constant

* Adv.

It does not respond to amplitude variations.

Disadv

o/p Efficiency is just ~~half~~ half of foster seeley detector

Not suitable for IC technology.

High cost.