1.1 ANALOG COMMUNICATION

Communication is the process of conveying or transferring of information from one point to another point. Information can be image, text or any other data. Communication between any two points or places requires a medium in between them. This medium can be wired or wireless medium. The information that needs to be transmitted may not be in a form that is suitable for all medium. It needs to be processed. This processingof raw information to convert it into a form that is suitable for a medium is called asmodulation.

TYPES OF COMMUNICATION

Communication can be of two types- Analog & Digital

In Analog communication the transmit information is continuous in nature, whereas in digital communicationit is discrete in nature.

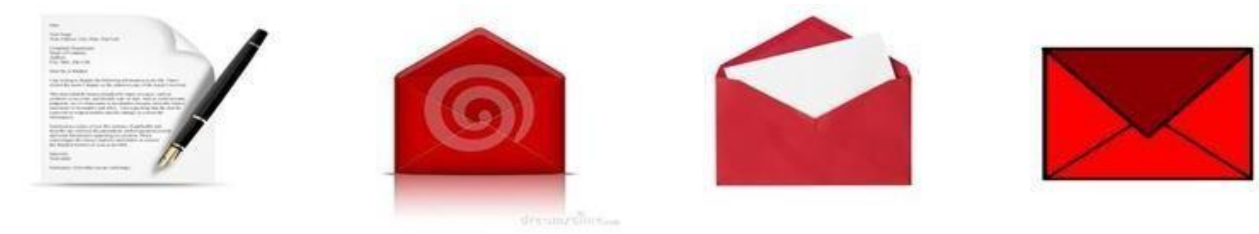
Figure 1.1.1 Basic block diagram for communication System

In Figure 1.1.1 shows that the Information from the source should be modulated before transmission to enable proper transmission of information from transmitter to receiver. The process of modifying or changing any characteristics of any signal is called modulation. Any signal has three characteristic they are

1. Amplitude
2. Frequency
3. Phase

MODULATION:

The process of changing any one of the characteristics of carrier signal with respect to information signal isknown as modulation.



Information (or) message   Carrier   Information + Carrier   =   modulated signal

Figure 1.1.2 Block diagram for communication System

TYPES OF MODULATION

Modulation is classified into two types they are, Analog modulation and Digital modulation. Inanalog modulation both information and carrier signal are analog in nature, whereas in digital information signalis digital but carrier signal is analog.

Modulation

Analog modulation — AM, FM, PM

Digital modulation — ASK, FSK, PSK, QAM

AM (Amplitude modulation):

It is the process of changing the amplitude of high frequency carrier signal in accordance withlow frequency information signal. Here frequency and phase angle of carrier remains unchanged.

FM (Frequency modulation):

It is the process of changing the frequency of carrier signal accordance with amplitude ofinformation signal.

PM (Phase modulation):

It is the process of changing the phase of carrier signal accordance with amplitude of information signal.

NEED FOR MODULATION

- Reduce height of antenna
- Transmit signal over a long distance
- Avoid noise and interference
- Multiplexing
- Improve the signal to noise ratio

1.2 AMPLITUDE MODULATION

It is the process of changing the amplitude of a relatively high frequency carrier signal in proportion with the instantaneous value of the modulating signal. AM is used for commercial broadcasting of audio and video signals.

Applications of AM: 1. Two-way mobile radio, Audio and video broadcast

AM VOLTAGE DISTRIBUTION

The modulating signal is represented as, $e_m(t) = E_m \sin\omega_m t$

The carrier signal is represented as, $e_c(t) = E_c \sin\omega_c t$

According to the definition, the amplitude of the carrier signal is changed after modulation.

$$E_{AM} = E_c + e_m(t) = E_c + E_m \sin\omega_m t \text{ ----- } (1)$$

$$= E_c [1 + (E_m/E_c) \sin\omega_m t] \text{ ------------ } (2)$$

$$E_{AM} = E_c(1 + m_a \sin \omega_m t) \text{ -------------- } (3)$$

Depth of Modulation/Modulation Index:

Coefficient of modulation and percent modulation:

If is defined as the ratio of maximum amplitude of the message signal to the maximum amplitude of thecarrier signal.

$$m_a = \frac{E_m}{E_c}$$

Percent modulation is indicated as M

$$M = \frac{E_m}{E_c} \times 100 \quad \text{or} \quad M = m_a \times 100$$

Relationship between m, E_m & E_c

From the figure.
$E_m = ½ (E_{max} - E_{min})$ $E_C = ½ (E_{ma} + E_{min})$

$$M = \frac{\frac{1}{2}(E_{max} - E_{min})}{\frac{1}{2}(E_{max} + E_{min})} \times 100 = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \times 100$$

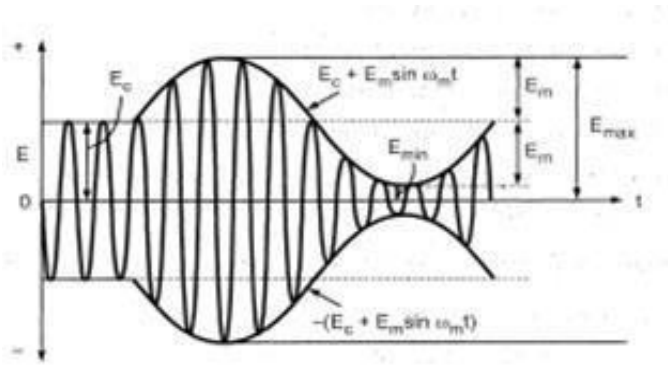


Figure : 1.2.1 Modulation Waveform

Where $m_a = E_m/E_c$ Where m_a is the modulation index (or) depth of modulation. The value E_m must beless than value of E_c to avoid distortion in the modulated signal. Hence maximum value of m_a will be equal to 1. When m_a is expressed in percentage it is called percentage modulation.

But the instantaneous amplitude of modulated signal,

(i). --e at any time$e_{AM}(t) = E_{AM}$ $\sin\omega_c t$ ---(4)

Substitute equation (3) in (4)

$e_{AM}(t) = E_c (1 + m_a \sin\omega_m t)\sin\omega_c t$

$= E_c \sin\omega_c t + m_a E_c \sin\omega_m t$

$\sin\omega_c t$(1) (2)

<u>**Frequency spectrum and Bandwidth of AM Waveform**</u>

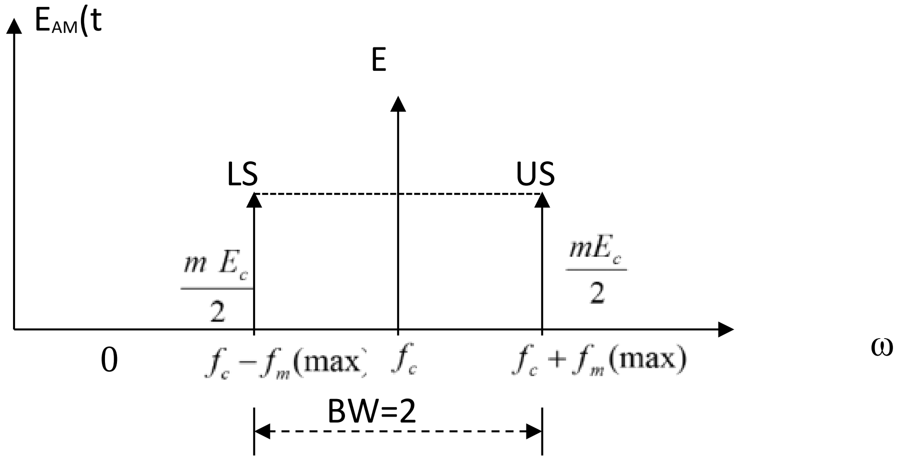


Figure 1.2.2 Frequency spectrum and Bandwidth of AM Waveform

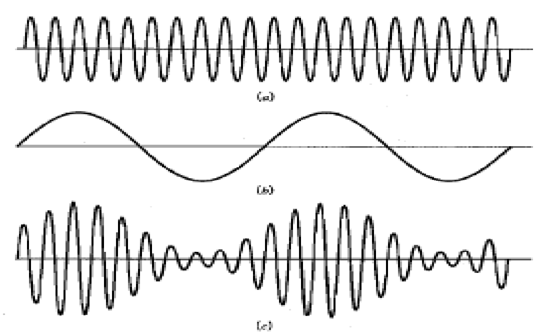
- The figure shows the frequency spectrum of Am.
- It extends from fc -fm (max) to fc + fm (max).
- The band of frequencies b/w fc and fc - fm (max) is called lower side band [LSB] and any frequencywithin this band is called lower side frequency [LSF].
- The band of frequencies b/w fc and fc + fm (max) is called upper side band [USB] and any frequencywithin this and is called upper side frequency [USF]

Bandwidth of AM.

The Bandwidth of Am wave is equal to the difference b/w the highest upper side frequency andlowest lower side frequency.

- B = fc + fm (max) – [fc - fm (max)]
- = fc + fm (max) - fc + fm (max)BW = 2fm (max)

AM Waveform



a) Message signal

b) Carrier signal

c) Amplitude modulated signal.

Figure 1.2.3 AM Waveform

The shape of modulated waveform is known as **AM envelope.**

Phasor representation of AM

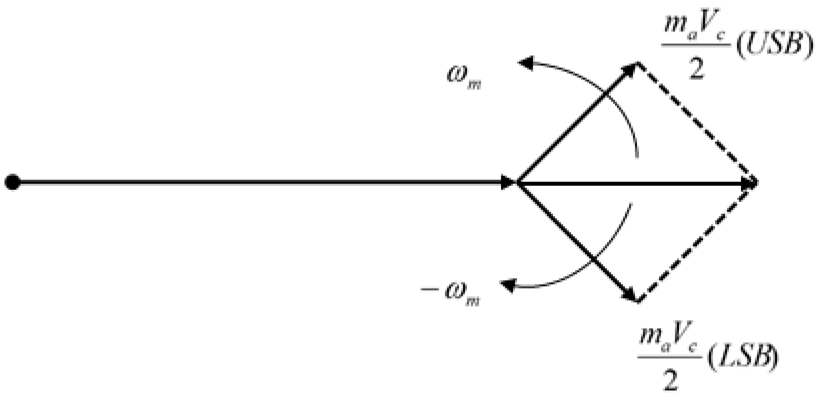


Figure 1.2.4 Phasor representation of AM

Based on the modulation index modulation can be either,

(i). Critical Modulation

(ii). Over Modulation

(iii). Under Modulation

- When Em = Ec modulation goes to 100% this situation is known as critical modulation.
- Em < Ecleads to under modulation.
- Em > Ec leads to over modulation.

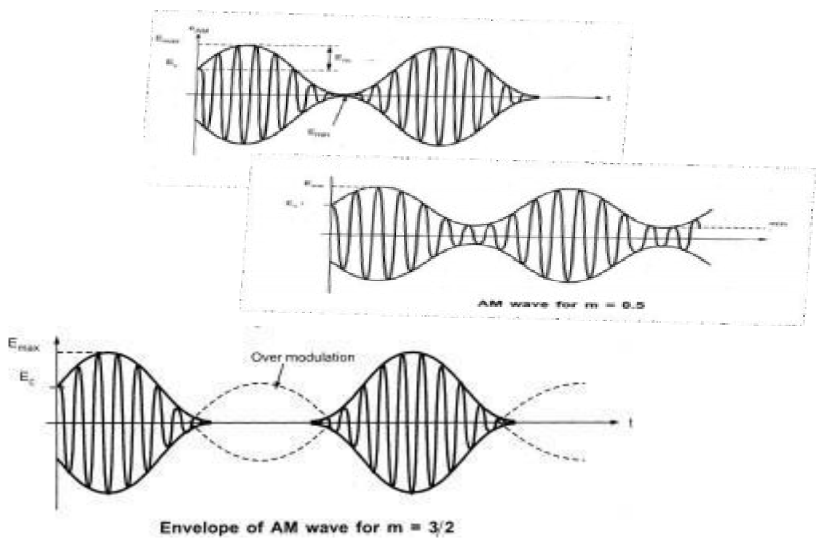


Figure : 1.2.5 Types of Modulation

AM POWER DISTRIBUTION

- The modulated wave contains three terms such as carrier wave, LSB, USB.
- The modulated wave contains more power than the unmodulated carrier.Total Power in modulated wave will be,

$$P_t = P_C + P_{USB} + P_{LSB}$$

i.e. total power P_t of AM wave is the sum of carrier power and side band power.

P_C - Carrier power, P_{USB} - Upper Side Band power, P_{LSB} - Lower Side Band power

Advantages, Disadvantages and Applications of AM (DSBFC)

Advantages

1. Simple and inexpensive receivers. Easy to detect with simple equipment even if the signal is not verystrong
2. Narrow bandwidth than FM
3. Wider coverage
4. Well-established, mature art used for broadcasting almost exclusively

Disadvantages

1. Received signal affected by electrical storms and other radio frequency interference
2. Receivers able to reproduce frequencies up to 5 MHz or less
3. Inefficient use of transmitter power

Applications

1. Low quality form of modulation that is used for commercial broadcast of both audio and video signals.
2. Two way mobile radio communications such as citizen band (CB) radio.
3. Aircraft communication in the VHF frequency range.

1.3 GENERATION OF AM-DSBFC (AM MODULATORS)

The generation method of AM waves are broadly divided in to two types

- Linear modulator(or)large signal modulator(or)high level modulation
- Non Linear modulator(or)small signal modulator(or)low level modulation

LINEAR MODULATOR:

In this type of modulators the devices are operated in linear region of its transfer characteristics. **Linearmodulators are also divided in to two types,**

- Transistor modulator
- Switching modulator.

NON LINEAR MODULATORS:

These modulators are operated in nonlinear region.These are used in low level modulation.

The types of non linear modulators are,

1. Square law modulator,
2. Product modulator,
3. Balanced modulator.

LOW LEVEL AM MODULATOR

- Class A amplifier can perform amplitude modulation.
- Amplifier must have 2 inputs one for the carrier signal & second for modulating signal.
- With no modulating signal present, the circuit operates as a linear class A amplifier, and the output is simply the carrier amplified by the quiescent voltage gain .
- The carrier is applied the base and the modulating signal to the emitter. Hence it is also called as **EmitterModulation**.
- The modulating signal varies the gain of the amplifier at a sinusoidal rate equal to the frequency of themodulating signal.
- The depth of modulation achieved is proportional to the amplitude of the modulating signal.

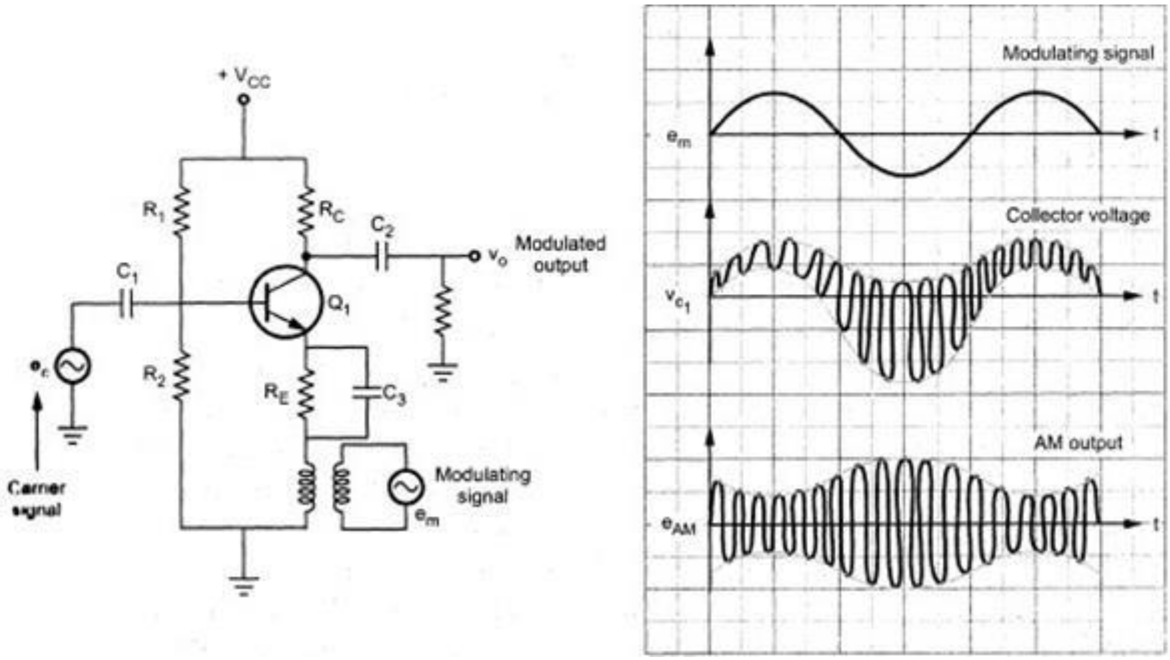


Figure: 1.3.1 (a) Circuit diagram for AM modulator (b) Waveforms

- The voltage gain for an emitter modulator is expressed as, $A_v = A_q (1 + m \sin 2\pi f_m t)$

  Av □ Amplifier voltage gain with modulation.

  Aq □ Amplifier quiescent (without modulation) voltage gain. sin 2□fmt varies from + 1 to -1

Hence, Av = Aq (1 □ m)

Av max = 2Aq, when m = +0

Av min = 0, when m = -1

The modulating signal drives the circuit into both saturation and cutoff, thus producing the nonlinearamplification necessary for modulation to occur. The collector waveform includes the carrier and the upper and lower side frequencies as well as a component at the modulating signal frequency from the waveform,thus producing a symmetrical AM envelop at *Vout*.

Advantages of Low level modulation:

1. Less modulating signal power is required to obtain high percentage modulation.
2. Modulating circuit is designed for low power.

Disadvantage of Low level modulation

Amplifiers following modulator stage must be linear. At high operating powers linear amplifiers are veryinefficient.

HIGH POWER AM MODULATOR / MEDIUM POWER AM MODULATOR

- The class C amplifier is used. It operates nonlinear and is capable of nonlinear mixing (modulation).
- This is known as collector modulator because modulating signal is applied to the collector.
- When the amplitude of the carrier exceeds the barrier potential (0.7V) Q1 turns on collector currentflows.

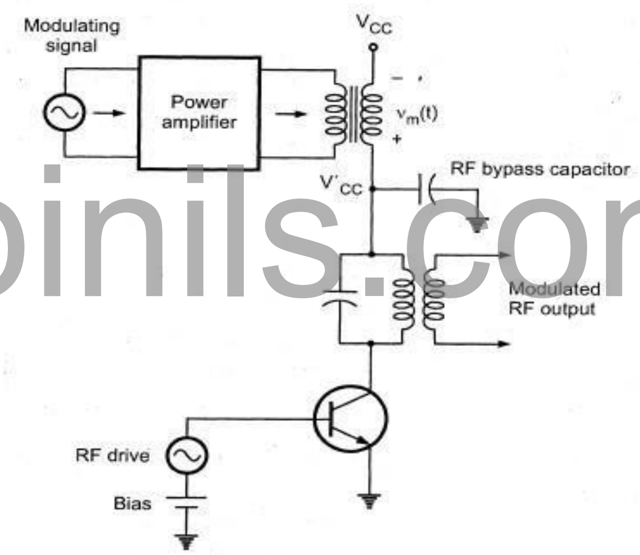


Figure : 1.3.2 High Power AM Modulator

- When carrier voltage drops below 0.7V Q1 turns off and collector current cases.
- The corresponding current and voltage waveforms are shown.
- When the modulating signal is applied it adds up with the Ecc and gets submitted from Eccproducing an Am o/p.

Advantages of high level modulators:

- There is no constraint of linear operation on amplifiers preceding modulator stage.
- Power efficiency is good

Disadvantages of high level modulators:

- High modulating power is required.
- Final modulating signal amplifier has to supply all the sideband power.

AM TRANSMITTERS

Low Level AM Transmitter

- The block diagram of a typical AM transmitter is shown in which carrier source is a crystal oscillator. The crystal oscillator is stabilized in order to maintain the carrier frequency deviation within a prescribed limit.
- The crystal oscillator is followed by a tuned buffer amplifier (class B) and drive amplifier.

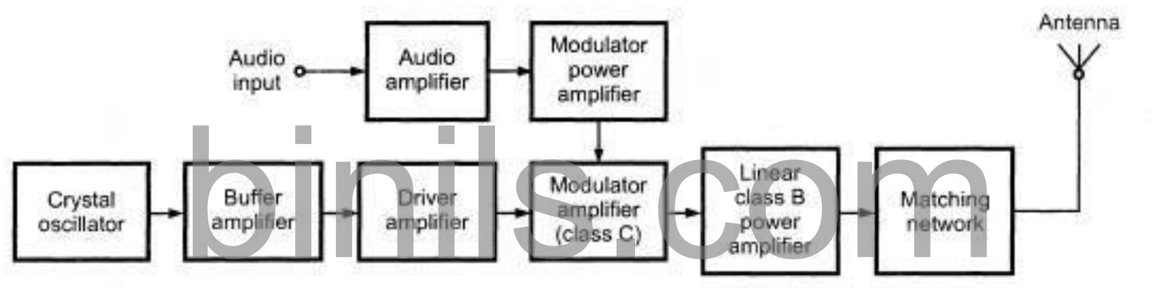


Figure : 1.3.3 Low Level AM Transmitter

Low level AM Transmitter

- The modulator circuit used is generally a class C power amplifier that is a collector modulator.
- The audio signal is amplified by a chain of low level audio amplifiers and a power amplifier. This amplifier is controlling the power being delivered to the final RF amplifier. Class B push pull amplifier is usually used for this purpose.
- The amplified modulating signal is applied to the modulator along with the carrier. AM wave is got atthe output of the modulator.
- This AM signal is then amplified using a chain of linear amplifiers to raise its power level. Class B amplifiers are used for this purpose. The linear power amplifier is used to avoid the distortion in the AMwave.
- The amplitude modulated signal is then transmitted using transmitting

antenna. The matching network matches the output impedance of the final amplifier to the transmission line and antenna.

Application of Low Level AM Transmitter: It is used in low capacity system such as wireless intercoms,Remote control units, pagers, shot range talkie.

High Level AM Transmitter

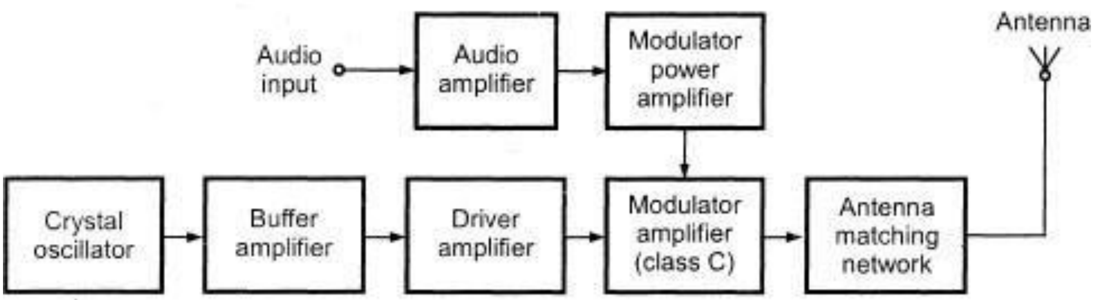


Figure 1.3.4 High level AM Transmitter

- Here modulating signal power should be higher than the low level.
- The amplification takes place prior to modulation.

Application of High Level Transmitter: Used for long distance communications.

SQUARE LAW MODULATOR

- The non linear portion of V-I characteristics of diode is used as a element for non-linear modulators.
- This is suited at low voltage levels because of the fact that current-voltage characteristics of a diode ishighly in the low voltage region as shown in figure.

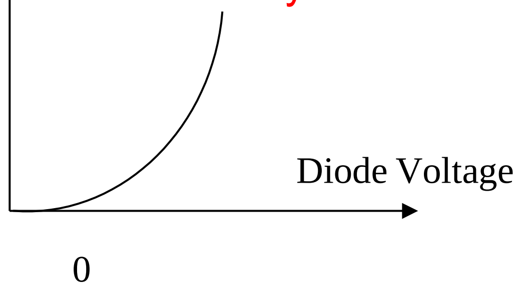


Figure :1.3.5 Square Law Modulator

- A square law modulator has three features shown in figure.
- Summer - To sum carrier and modulating signal
- A non linear element

Band pass filter for extracting desired modulating products.

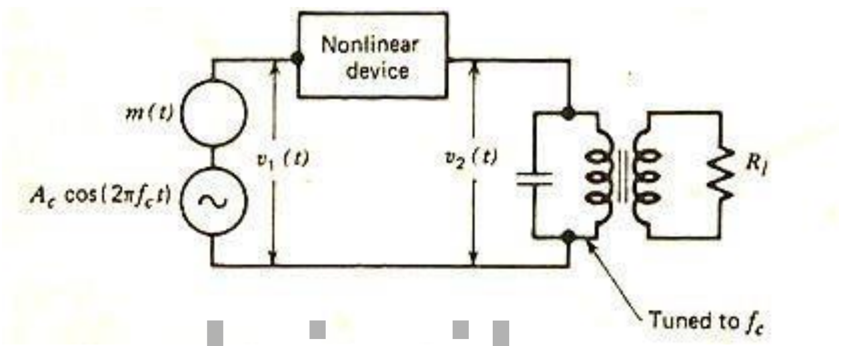


Figure :1.3.6 Square Law Modulator using BPF

Principle of operation:

- From the figure the non linear device diode is used to produce low level amplitude modulation.
- Here the carrier and modulating signals are applied across the diode.
- A dc battery Ecc is connected across the diode to get a fixed operating point on the V-I characteristicsof the diode.
- This amplitude modulation that is low level can be explained by considering the fact when twodifferent frequencies are passed through the non linear device.
- So when we apply carrier and modulating frequencies different frequency terms appear at the output ofdiode.
- These different frequency terms are applied across the tuned circuit which is tuned to carrier frequencyand has a narrow bandwidth just to pass two sidebands along with the carrier and reject other frequencies.

BALANCE MODULATOR METHOD

It is assumed that the two transistors are identical and the circuit is symmetrical. The operation is confinedin the nonlinear region of the active devices employed in this circuit. The carrier voltage across the upper and lower part of the secondary windings of the center tap transformers are equal in magnitude and oppositein phase.

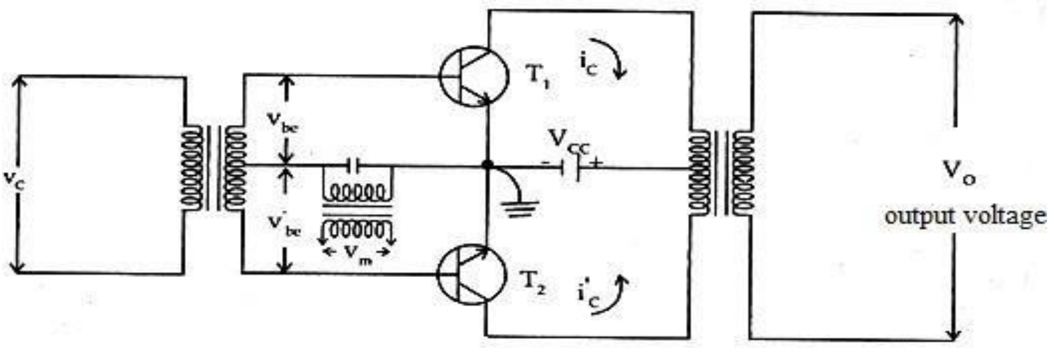


Figure : 1.3.6 Balanced Modulator

DEMODULATION/DETECTION OF AM-DSBFC (AM DEMODULATORS)

- Demodulation or detection is nothing but the process of extracting a modulating or information signalfrom modulated signal. Otherwise in other words, demodulation or detection is the process by which the message is recovered from the modulated signal at receiver.
- The devices used for demodulation or detection are called as demodulators or detector
- For amplitude modulation, the detectors or demodulators are categorized are
- **Square law detectors or nonlinear detectors**
- **Linear detectors**
- The low level modulated signals are using non linear detectors to recover the original message signal

SQUARE LAW DETECTOR

- The square law detector circuit is used for detecting low level modulated signal.
- Here the diode is used in V – I characteristics of the device i.e. non linear characteristics of the diode.
- The square law detector is similar to the square law modulator. The only difference lies in the filtercircuit.
- In square law modulator we are using band pass filters, in square law detector; a low pass filter is used.The operation is limited to the non-linear region of the diode characteristics, so the lower half portion of the modulated waveform is compressed.
- This produces the envelope distortion, so the average value of the diode – current is no longer constantand varies with time. The average diode current consists of steady DC component and time varying modulation frequency. Due to nonlinear region the lower half of its current wave form is compressed. This may cause envelope distortion due to this diode current will not be constant, and varies with time.

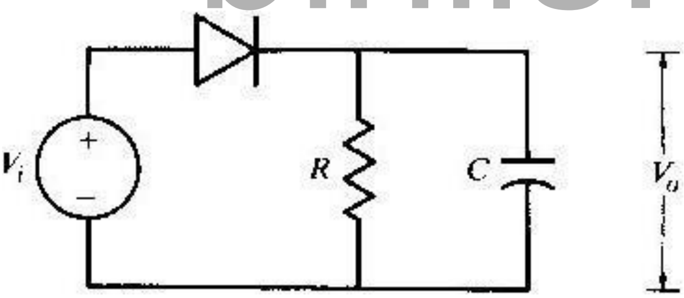
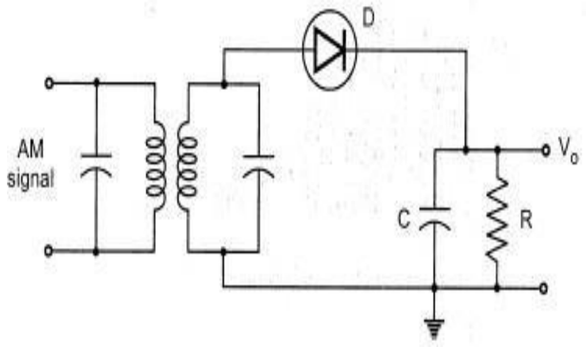


Figure : 1.3.7 Square Law Detector

ENVELOPE DETECTOR

- A detector circuit whose output follows the envelope of the modulated signal which is used toreproduce the modulating or message signal is called as "Envelope Detector".
- This is most popular commercial receiver circuits since it is very simple and not expensive, and also it gives satisfactory performance. An envelope detector of the series type is shown in Figure which consists of a diode and a resistor capacitor filter a

time constant network.



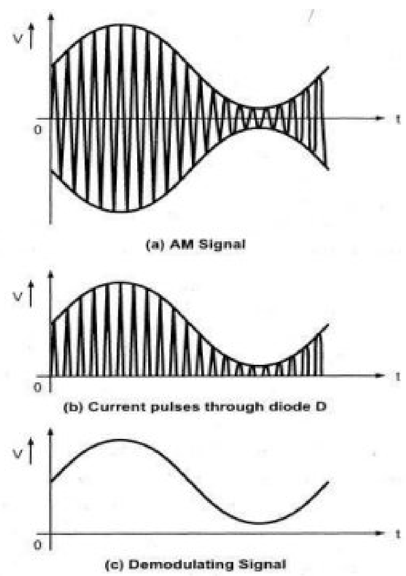


Figure : 1.3.8 Envelope Detector

<u>Principle Of Operation:</u>

- Modulated signal is applied to the series combination of diode and the load impedance consisting of aresistor R and C.
- Operation takes place over the linear region of VI characteristics of Diode.
- For positive cycle of carrier signal the diode D conducts thereby the capacitor charges to the peakvoltage with the time constant **τ =R C o**f the carrier signal through the resistor R.
- As the input falls below the peak value, the diode reaches cut-ff. The diode acts as open switch andhence the capacitor gets discharge path through R.
- During negative half cycle the diode is reverse biased and the carrier voltage is disconnected from theRC circuit. So the capacitor discharges continuously until next positive cycle appears.
- From the peak of one positive cycle to the next the capacitor discharges slowly and this process continues.Thus the voltage across 'C' is same as the envelope of the modulated carrier but spikes areintroduced. So the output voltage across capacitor is a spiky modulating or base band signal. So the envelope is detected at the output of capacitor. Thus from the average value the original signal is recovered by extracting the envelope.
- The spikes can be reduced to a negligible amount by keeping the time

constant RC large so that thecapacitor C discharges negligible amount.

CHOICE OF TIME CONSTANT RC

- Large (or) small value of time constant makes problem. So time constant is important consideration.
- **If time constant RC is quite low: Discharge curve during non conductive period is almostvertical, so fluctuations may occur in output voltage. This results in Diagonal clipping**
- **If RC is very large: Discharge curve is almost horizontal, so several peaks will be missed in therectified output voltage. This results in negative peak clipping.**

Distortion in diode detector:

There are two clippings i.e. distortions available

- **Negative peak clipping**
- **Diagonal clipping.**

Diagonal clipping:

It results when time constant of detector is not selected properly. If the modulating voltage is faster than the rate of voltage fall across RC combination resulting in distorted output. Thistype of distortion is called diagonal clipping which results in distorted output.

Negative peak clipping:

The 2nd source of distortion in linear diode detector is the curvatures of the diode characteristics. So as a result the efficiency varies. It will be reduced by selecting load resistance value large. So when RC is large then ma will be low and signal becomes clipped at the negative peaks. The negative peak clipping provides ac and dc load impedances unequal.

DOUBLE SIDEBAND SUPPRESSED CARRIER (DSBSC) MODULATION

In AM with carrier scheme, there is wastage in both transmitted power and bandwidth. In order to save the power in amplitude modulation the carrier is suppressed because it does not contain any useful information.This scheme is called as the double side band suppressed carrier amplitude Modulation

(DSB-SC). It contains LSB and USB terms, resulting in a transmission bandwidth that is twice the bandwidth of the message signal.

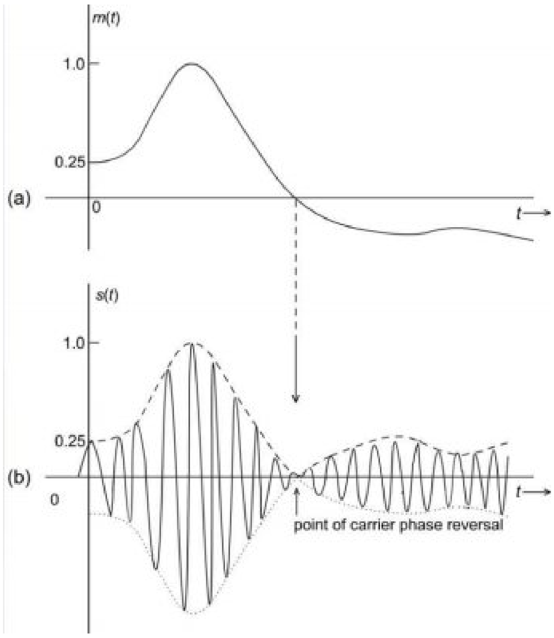


Figure :1.3.9 (a)Base band Signal (b) DSB SC

Frequency spectrum of DSB-SC AM

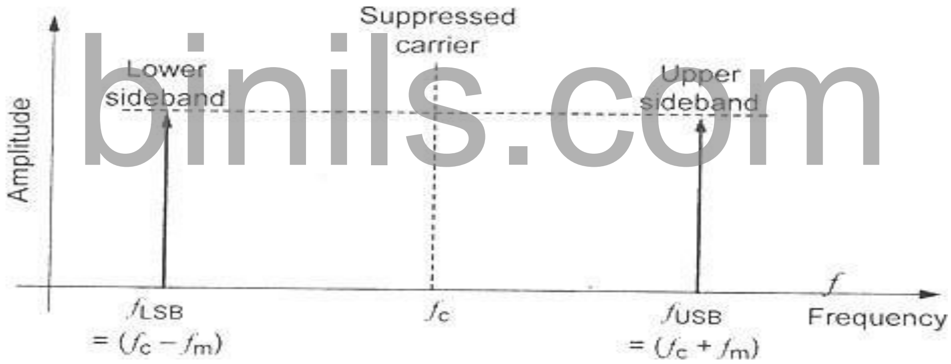


Figure : 1.3.9 Frequency spectrum of DSB-SC AM

It shows that carrier term ωc is suppressed. It contains only two sideband terms having frequency (ωc - ωm)and (ωc + ωm). Hence this scheme is called as DSB-SC AM.

Phasor representation of DSB-SC AM:

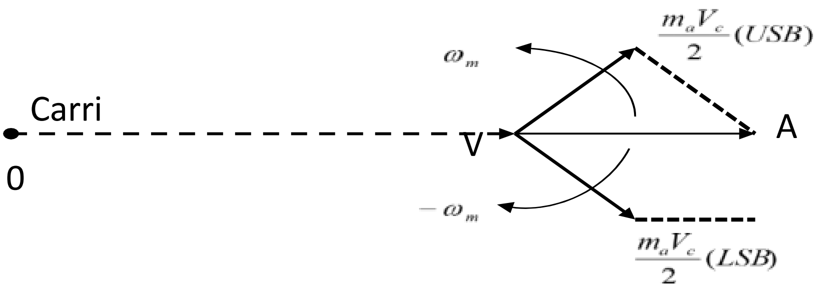


Figure : 1.3.10 Phasor representation of DSB-SC AM

1.4 GENERATION OF AM-DSBSC

1. Balanced Modulator Method
2. Ring Modulator Method

BALANCE MODULATOR METHOD

- The same circuit can be used to generate AM with carrier. The main difference between AM with carrier generation and DSB-SC –AM is the feeding points of the carrier and modulating signals are interchanged.
- The transistor is operated in a balanced mode thus heavy filtering is not required to remove theunwanted harmonics.
- It is assumed that the two transistors are identical and the circuit is symmetrical. The operation is confined in the nonlinear region of the active devices employed in this circuit. The carrier voltages across the upper and lower part of the secondary windings of the center tap transformers are equal inmagnitude and opposite in phase.

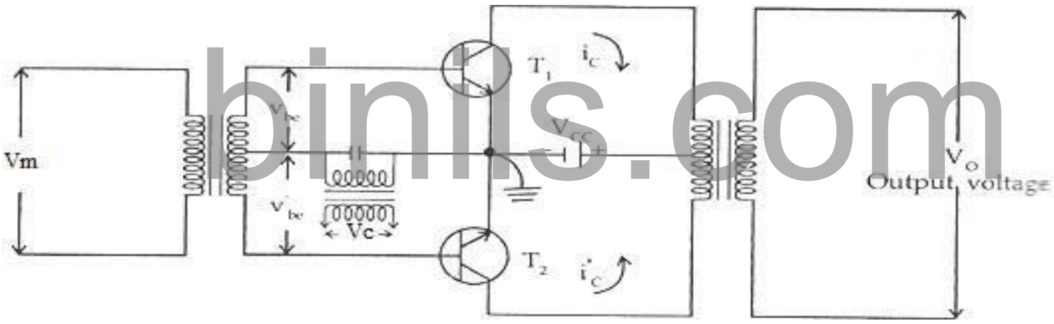


Figure 1.4.1 Balanced Modulator

RING MODULATOR METHOD

- The balanced Ring modulator circuit is widely used in carrier telephony suppresses both unwantedmodulating and carrier signal in its output.
- Ring modulator is a type of product modulator which is used to generate DSB-SC Signal.
- The band pass filter is not used at the output hence the harmonic frequencies are automaticallycontrolled.
- In a ring modulator circuit four diode are connected in the form of ring in which all the four diodesare connected in the same manner and are controlled by a square wave carrier signal ec (t).

- The carrier signal acts as a switching signal to alternate the polarity of the modulating signal at thecarrier frequency.
- When no modulating signal is present diode D1 and D2 or D3 and D4 will conduct depending uponpolarity of the carrier.

POSITIVE HALF CYCLE OF CARRIER:

- Diodes D1 and D3 are forward biased. At this time D2 and D4 are reverse biased and act like opencircuits. The current divides equally in the upper and lower portion of the primary winding T2.
- The current in the upper part of the winding produces a magnetic field that is equal and opposite to themagnetic field produced by the current in the lower half of the secondary.
- Therefore the magnetic fields cancel each other out and no output is induced in the secondary. Thusthe carrier is effectively suppressed.

NEGATIVE HALF CYCLE OF CARRIER:

- When the polarity of the carrier reverses. Diodes D1 and D2 are reverse biased and the diodes D3 and D4 will conduct. Again the current flows in the secondary winding of T1 and the primary winding ofT2.
- The equal and opposite magnetic fields produced in T2 cancel each other and thus result in zero carrieroutput. The carrier is effectively balanced out.

PRINCIPLE OF OPERATION

- When both the carrier and the modulating signals are present, during positive half cycle of the carrierdiodes D1 and D2 conduct, while diodes D3 and D4 does not conduct.
- During negative half cycle of the carrier voltage diodes D3 and D4 conduct and D1 and D2 does notconduct.
- When polarity of the modulating signal changes the result is a 180 phase reversal. At the timeD3 and D4 are in forward bias.

<u>DEMODULATION/DETECTION OF AM-DSBSC</u>

- SYNCHRONOUS OR COHERENT DETECTOR
- COSTAS PLL DETECTOR

<u>SYNCHRONOUS OR COHERENT DETECTOR</u>

- The coherent detector uses exact carrier synchronization for retrieving the message signal frommodulated signal. These types of detectors are mainly used for detecting DSB&SSB signals.

- It consists of a product modulator with a low pass filter.
- For detecting signal local oscillator at the receiver end is required. The frequency and phase of the locally generated carrier and transmitter carrier must be synchronized that is exactly coherent.
- All types of linear modulation can be detected by using synchronous detector. It consists of a productmodulator with LPF.

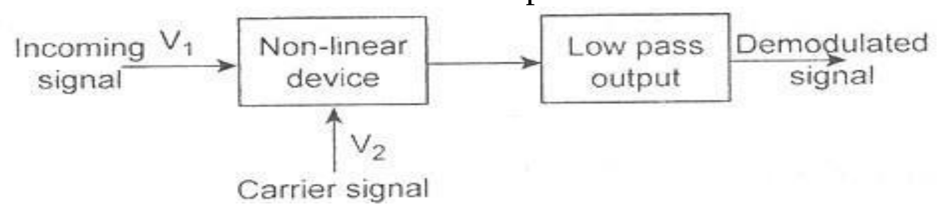


Figure 1.4.2 Coherent Detector

- The incoming signal is first multiplied with locally generated carrier and then passed through low passfilter. The filter bandwidth is same as the message bandwidth ωm
- Tthe local oscillator should be exactly synchronized with carrier signal in both phase and velocity.

COSTAS PLL DETECTOR

- Costas receiver is one of the method for obtaining a practical synchronous receiver suitable for demodulating DSB-SC waves. It consists of two coherent detectors supplied with the same input signal.
- One detector is supplied with the DSB-SC AM and locally generated carrier which is in phase with thetransmitted carrier. This detector is known as **“In-phase coherent detector or I channel”.**
- The other detector is supplied with the DSB-SC AM and locally generated carrier which is quadrature phase with the transmitted carrier. This detector is known as **“Quadrature coherent detector or Q channel”.**
- These two detectors are coupled together to form a negative feedback system designed in such a way as to maintain the local oscillator synchronous with the carrier wave.

<u>Operation of the circuit</u>:

- In this case I channel output contains the desired demodulated signal where as Q channel output is zerodue to the quadrature null effect of Q channel.
- Suppose there is some phase shift φ radians between local oscillator carrier and the transmitting carrierthen I channel output will remain essentially unchanged. But Q channel output contains some signal which is proportional to sin φ
- This Q channel output will have same polarity as the I channel output

for one direction of local oscillatorwhereas the polarity will be opposite to the I channel for the other direction of phase shift.

- Thus the I and Q channel outputs are combined in phase discriminator
- The phase discriminator provides a d.c. control signal which may be used to correct local oscillator phase error.
- The local oscillator is a voltage controlled oscillator. Its frequency can be adjusted by an error control d.c signal.
- The costas receiver ceases phase control when there is no modulation and that phase lock has to be re- established with reappearance of modulation.

1.5 SINGLE SIDEBAND SUPPRESSED CARRIER

In AM with carrier both the transmitting power and bandwidth is wasted. Hence the DSB-SC AMscheme has been introduced in which power is saved by suppressing the carrier component but the bandwidth remains same.

- Increase in the saving of power is possible by eliminating one sideband in addition to the carrier component because the USB and LSB are uniquely related by symmetry about the carrier frequency. Soeither one sideband is enough for transmitting as well as recovering the useful message. The block diagram of SSB-SC AM is shown in figure.
- As for as transmission information is concerned only one side band is necessary. So if the carrier and one of the two sidebands are suppressed at the transmitter, no information is lost.
- This type of modulation is called as single side band suppressed carrier-AM and the SSB system reducesthe band width by half.

Frequency Spectrum Of SSB-SC-AM:

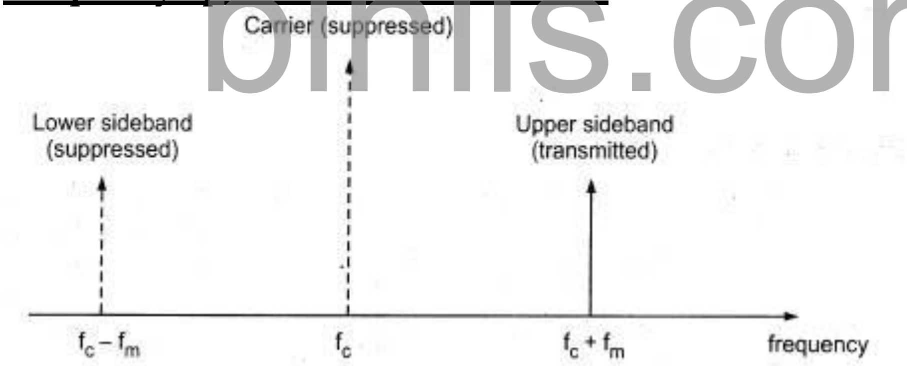


Figure 1.5.1 Frequency Spectrum Of SSB-SC-AM

- The Frequency spectrum shows that only one side band signal is present, the carrier and the other sideband signal are suppressed. Thus the bandwidth required reduces from 2 ωm to ωm i.e., bandwidth requirement is reduced to half compared to AM & DSB-SC signals.

Phasor representation of SSB-SC-AM:

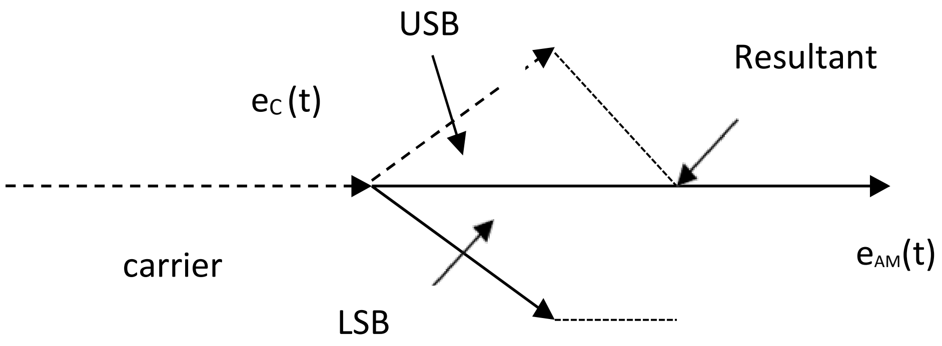


Figure 1.5.2 Phasor representation of SSB-SC-AM

Applications of SSB

1. Used to save applications where such a power saving is warranted, i.e., in mobile system, in which weight and power consumption must naturally be kept low.
2. Single sideband modulation is at a premium. Point-to-Point communication, land, air, maritime mobile communication, TV, Telemetry, Military and Radio navigation are the greatest use of SSB in one formor another.

SSB Advantages

- ***Power conservation**:* Much less total transmitted power required to produce the same quality signal.
- ***Bandwidth conservation**:* Half of the bandwidth of conventional AM bandwidth.
- ***Selective Fading**:* Not present in SSBSC.
- ***Noise Reduction:*** Since SSB uses half the bandwidth, the thermal noise power is reduced to half.Hence immunity to selective fading is improved.

SSB Disadvantages

- ***Complex Receivers**:* Required carrier recovery and synchronization circuit adds cost, complexity andsize.
- ***Tuning Difficulties**:* Complex and Expensive Tuning Circuits.

GENERATION OF SSB

1. Filter Method
2. Phase Shift Method
3. Modified Phase Shift Method or Weaver Method

FILTER METHOD

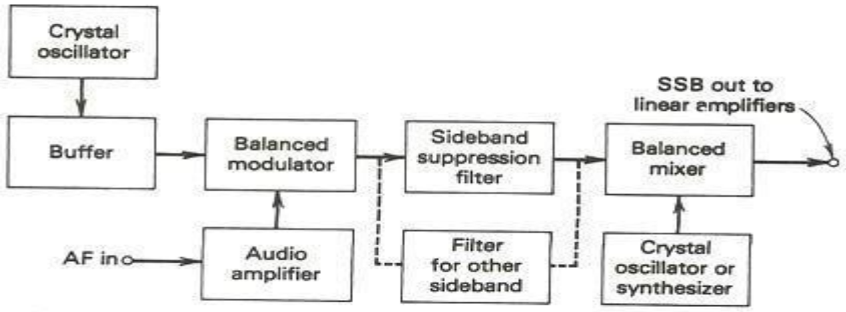


Figure 1.5.3 Filter Method

In this method of SSB generation, after the BM, the unwanted sideband is removed (actually heavilyattenuated) by a filter and hence this name. The filter may be LC, ceramic or mechanical depending upon the carrier frequency and other requirements. Such a filter must have a flat bandpass and extremely high attenuation outside the passband.

In radio communication system, the frequency range used for voice is 300 Hz to about 2800 Hz in mostcases. If it is required to suppress the lower sideband and if the transmitting frequency is f_C , then the lowestfrequency that this filter must pass without attenuation is f_C+300 Hz whereas the highest frequency that must be fully attenuated is f_C-300 Hz. So we need a filter whose transition band is very low. This situation becomes worse if lower modulating frequencies are employed, such as the 50 Hz minimum in AM broadcasting. In order to obtain a filter response curve with skirts as steep the 'Q' of the tuned circuits mustbe very high.

The initial modulation takes place in the balanced modulator at a low frequency (such as 100 kHz) because of the difficulty of making adequate filters at higher frequencies. The filter is a BPF with a sharp cutoff frequency at either side of the bandpass to obtain satisfactory adjacent sideband rejection. The filtered signal is up-converted in a mixer to the final transmitter frequency and then amplified before beingcoupled to the antenna. The integrated ceramic filters are used as sideband filters. The drawback of filter method is that it requires sharp filtering, which requires filters with high Q. Primary modulation cannot bedone at the transmitting frequency which is another drawback of the filter method.

PHASE SHIFT METHOD

- This method avoids the prime disadvantage of filtering method. That is requirement of a sidebandfilter with a narrow transition band and it cannot be used for very low and very high frequencies.
- This method does not have any sideband filters and the primary modulation can be done at the transmitting frequency. The unwanted sideband can be removed by generating the components ofsideband out of phase.
- If the undesired sideband is LSB then the two LSB are generated such that they are 180 out of phasewith each other. So that USB add with each other and LSB cancel each other. When two undesired sideband components are added they cancel each other with only the presence of desired signal.
- Two balanced modulators and two phase shifters are used. One of the modulator BBM1 receives the carrier voltage shifted by 90^0 and the modulating voltage, where as another balanced modulator BBM2 receives the modulating voltage shifted by 90^0 and the carrier voltage.
- The carrier signal is cancelled out by both the balanced modulator and then unwanted sidebands cancel at the output of the summing amplifiers and hence produces SSB signal.

MODIFIED PHASE SHIFT METHOD (OR) WEAVER'S METHOD

- The modified phase shift method overcomes the limitation of phase shift method. That is AF phaseshift network is required to operate over a large range of audio frequencies but also retains the advantage like its ability to generate SSB at any frequency and use of low audio frequency.
- This method provides both RF and AF oscillator phase shift and also used in low frequency and so itcan be used for both audio and radio frequencies.
- Modulators 1 and 2 both have the unshifted modulating signal as inputs. BM1 takes low frequencysubcarrier with a 90 phase shift from the AF oscillator. BM2 receives the subcarrier signal directly from the oscillator.
- This method tries to aEoid the phase shift of audio frequencies and combine the audio frequencycarrier with AF which lies in the middle of audio frequency.
- The low pass filter at the output of BM1 and BM2 with cut off frequency ensures the input to thebalance modulator BM3 and

BM4. The output of BM3 and BM4 gives the desired sideband suppression.

DEMODULATION/DETECTION OF AM-SSBSC

SYNCHRONOUS OR COHERENT DETECTOR

- The coherent detector uses exact carrier synchronization for retrieving the message signal frommodulated signal. These types of detectors are mainly used for detecting DSB&SSB signals.
- It consists of a product modulator with a low pass filter.
- For detecting signal local oscillator at the receiver end is required. The frequency and phase of the locally generated carrier and transmitter carrier must be synchronized that is exactly coherent.
- All types of linear modulation can be detected by using synchronous detector. It consists of a productmodulator with LPF.

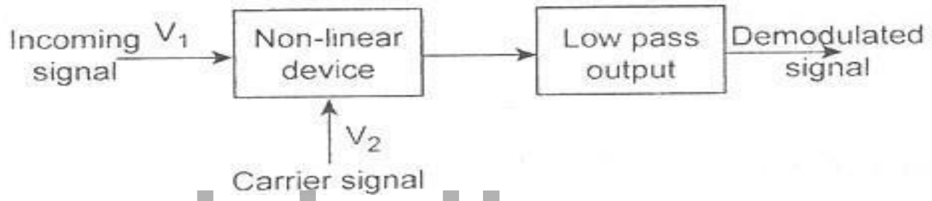


Figure 1.5.4 Coherent Detector

- The incoming signal is first multiplied with locally generated carrier and then passed through low passfilter. The filter bandwidth is same as the message bandwidth ωm
- Tthe local oscillator should be exactly synchronized with carrier signal in both phase and velocity.

VESTIGIAL SIDE BAND MODULATION

Definition : One of the sideband is partially suppressed and vestige (portion) of the other sideband is transmitted, This vestige (portion) compensates the suppression of the sideband. It is called vestigial sideband transmission.

Generation and demodulation of VSB:

A VSB signal is obtained as shown figure below by suppressing one of the sidebands of a DSBSC usinga VSB filter.

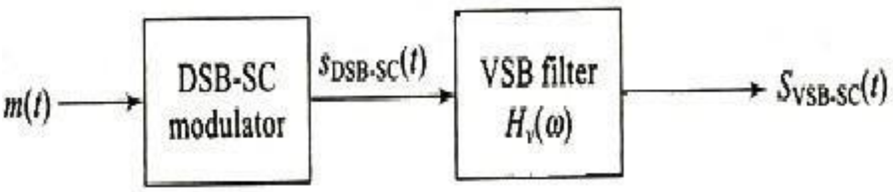


Figure 1.5.5 Vestigial Side Band Modulation

VSB filter is a BPF having an asymmetric frequency response in the transition band, positioned in such a way that the carrier frequency corresponds to the middle of the transition band. From the figure,

$$S_{DSB-SC}\ (t) = A_c m(t) cos(\omega_c t)$$

The transfer function of the VSB filter is $H_v(\omega)$.

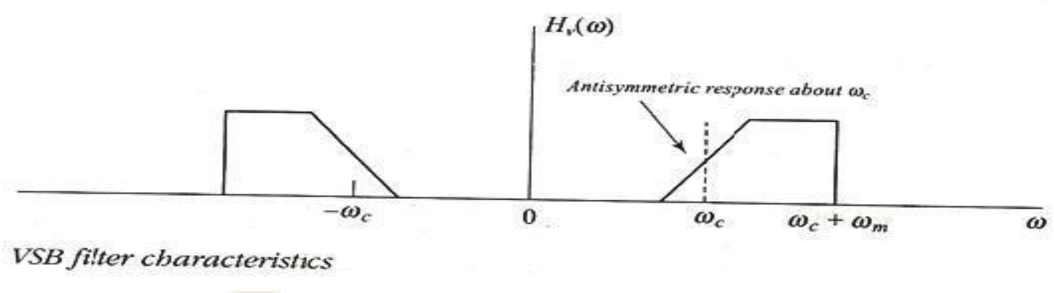


Figure 1.5.6 Transfer Function of the VSB Filter

The coherent detector is a sort of universal detector of AM signals in the sense that DSBSC, conventional AM and SSBSC can all be detected successfully by using it. It would be natural to expect that coherent detectionto work for the VSB-SC signal too.

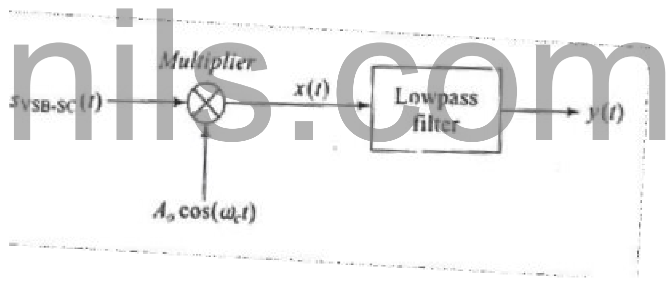


Figure 1.5.7 Coherent Detector

Magnitude Response of VSB Filter

Fig. shows the magnitude response of VSB filter.

- Here observe that fc to fc+W is USB. It's portion from fc to fc +fv is suppressed partially. *fc* to fc - W is LSB. It's portion from fc -fv to fc istransmitted as vestige.
- Observe that H(fc)=1/2. And the frequency response fc-fv ≤ H(f)≤ fc+fv exhibits odd symmetry. The sum of any two frequency components in the range is

fc-fv≤ f ≤fc+fv

equal to unity. i.e H(f-fc) + H(f+fc) = 1

Phase response is linear

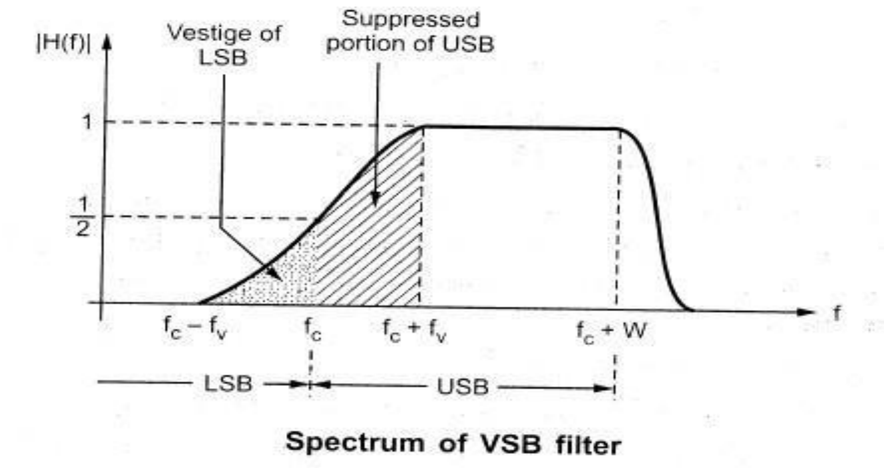


Figure 1.5.8 Spectrum of VSB Filter

Advantages:

1. Low frequencies, near *fc* are, transmitted without any attenuation.
2. Bandwidth is reduced compared to DSB.

Applications:

VSB is mainly used for TV transmission, since low frequencies near *fc* represent significant picture details.They are unaffected due toVSB.

1.5 INTRODUCTION

Angle Modulation

Definition

We know that amplitude, frequency or phase of the carrier can be varied by the modulating signal. Amplitude is varied 'in AM. *When frequency or phase of* the carrier is varied by the modulating signal, then it is called angle modulation, There are two types of angle modulation.

1. **Frequency Modulation :**

When frequency of the carrier varies as per amplitude variations of modulating signal, then it is called Frequency Modulation (FM). Amplitude of the modulated carrier remains constant.

2. **Phase Modulation :**

When phase of the carrier varies as per amplitude variations of modulating signal, then it is called PhaseModulation (PM). Amplitude of the modulated carrier remains constant,

Frequency Modulation:

The frequency of the high frequency carrier signal is carried in accordance with the modulating signal.

$V_m = E_m \sin 2\pi f_m t$

$V_c = E_c \sin 2\pi f_c t$

$V_{fm} = E_c \sin (2\pi f_c t + m_f \sin 2\pi f_m t)$

$V_{fm} = E_c \sin (w_c t + m_f \sin w_m t)$

$M_f \rightarrow$ modulating index of fm

Relationship/Difference between FM and PM:

- The basic difference between FM and PM lies in which property of the carrier isdirectly varied by modulating signal. Note that when frequency of the carrier varies,phase of the carrier also varies and viceversa.
- But if frequency is varied directly, thenit .is called FM.,
- And if phase is varied. directly, then it is called PM.

The instantaneous phase deviation is denoted by θ *(t)*. It is the instantaneous change in phase of the carrier with respect to reference phase. The instantaneous phase of the carrier is precise phase of the carrier at a given instant. It is mathematically expressed as,

Instantaneous phase =

$$\omega_c t + \theta(t) \qquad ....(1)$$

Here θ(t) is the instantaneous phase deviation and ωc is the carrier frequency. Now the instantaneous frequencydeviation is defined as

$$= \frac{d}{dt}\theta(t) = \theta'(t) \; Hz \qquad ....(2)$$

Definition for instantaneous frequency deviation: It is the instantaneous change in carrier frequency. It isequal to the rate at which instantaneous phase deviation takes place.

Definition of instantaneous frequency:It is the frequency of the carrier t a given instant of time. It is given as

$$\text{Instantaneous frequency} = \omega_i(t) = \frac{d}{dt}[\omega_c t + \theta(t)]$$

$$= \omega_c + \theta'(t) \;\; \text{rad/sec}$$

...................(3)

Instantaneous phase deivation θ(t) is proportional to modulating signal voltage

$$\theta(t) = k\, e_m(t) \text{ rad} \qquad \text{-....................(4)}$$

Where K is the deviation sensitivity of phase

Similarly the instatneous frequency deviation is proportional to modulating Signal voltage.

$$\theta'(t) = k_1\, e_m(t) \text{ rad/sec} \qquad \text{........................(5)}$$

Where k1 is the deviation sensitivity of frequency.From equation (2), We have

$$\theta(t) = \int \theta'(t)\, dt$$
$$= \int k_1\, e_m(t)\, dt \text{.....................(6)}$$

Let the modulating signal be given as

$$e_m(t) = E_m \cos\omega_m t$$

Using the equation in equation (6)

$$\theta(t) = k_1 \int E_m \cos\omega_m t\, dt$$
$$= k_1 \frac{E_m}{\omega_m} \sin\omega_m t \qquad \text{.......................(7)}$$

The angle modulated wave is mathematically expressed as

$$e(t) = E_c \sin[\omega_c t + \theta(t)] \qquad \text{.......................(8)}$$

Using the value of θ(t) in the above equation from equation (7)

FM equation : $$e(t) = E_c \sin\left[\omega_c t + \frac{k_1 E_m}{\omega_m} \sin \omega_m t\right] \qquad \text{…..(9)}$$

Similarly using the value of θ(t) from equation (5) in equation (8) we get

$$\text{PM equation}: \quad e(t) = E_c \sin\left[\omega_c t + kE_m \cos\omega_m t\right] \qquad \text{..........(10)}$$

FM and PM waveforms:

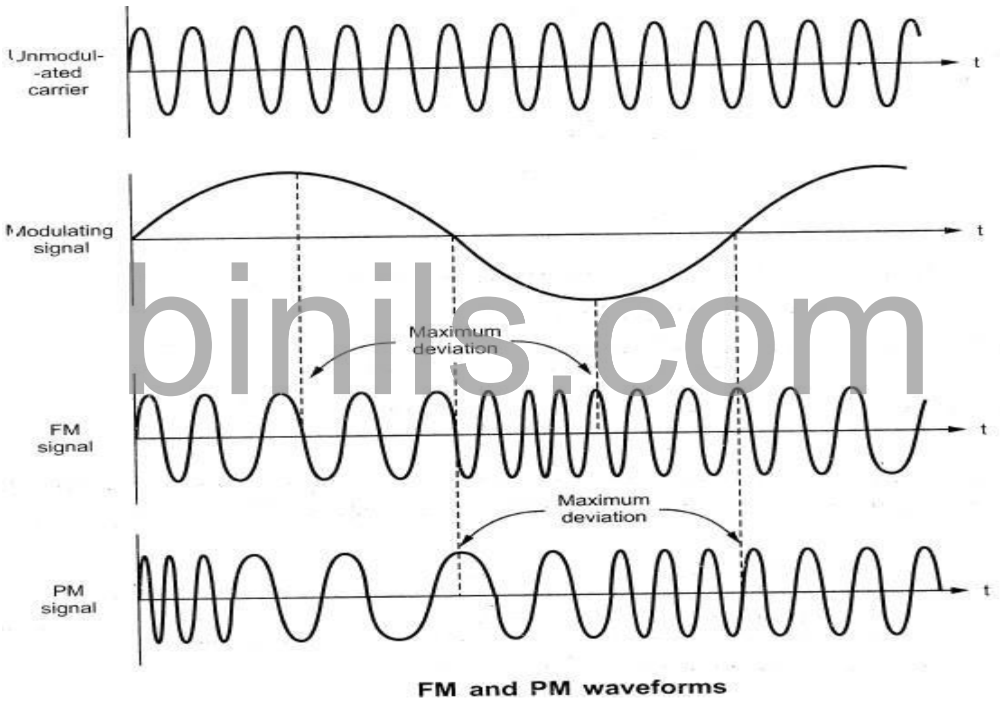


Figure 1.5.1 FM and PM Waveforms

From the above waveform we can note the following

- For FM signal maximum frequency" deviation takes Place when Modulating signal is at positive .and negative peaks.
- For PM signal the maximum frequency. deviation takes place near zero crossings of the modulatingsignal.

- Both FM anid PM waveforms are identical except the phase shift.

M=KEm

For FM It is the ratio of maximum frequency deviation (□) to the modulating frequency (fm).

$$mf = \frac{\text{Maximum frequency deviation}}{\text{Modulating frequency}} = \frac{□}{fm}$$

- The maximum frequency deviation is the shift from centre frequency fc when the amplitude of messageis maximum.

□ f = K1 Em

(Hz)

K1 = Deviation

sensitivity.

Definition of Modulation index of PM and FM

The modulation index of PM is given as

The Bandwidth of FM:

- By Carson's rule the Bandwidth needed by fm is given as,
- B□ = 2 (□ + fmmax)

□ □ Maximum frequency Deviation

fmmax is Maximum modulating frequency.

Deviation Ratio :

The modulation index corresponding to maximum modulating frequency is called deviation ratio.

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

Frequency Spectrum of angle modulated wave :

- FM and PM analysis is quite complicated. It is derived with the help of

Bessel function.Efm = Ec sin (wct + mf cos wmt)

Using Bessel function this can be expanded as,

Efm = A {Jomf sin wct + J1mf [sin (wc + wm)t – sin (wc - wm)t]

+ J2mf [sin (wc + 2wm)t – sin (wc - 2wm)t] + J3mf [sin (wc + 3wm)t

– sin (wc - 3wm)t] + J4mf [sin (wc + 4wm)t – sin (wc - 4wm)t] …..}

J0, J1, J2, J3 …. Are Bessel functions. The value of this depends on modulation index mf.

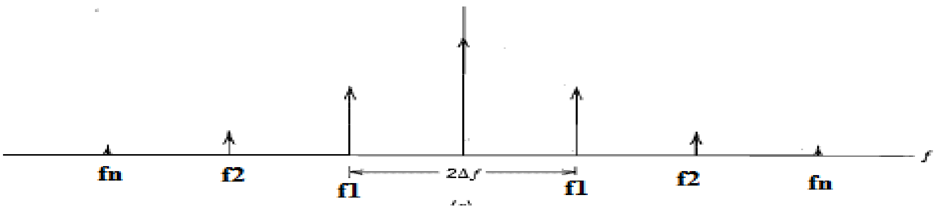


Figure 1.5.2 Frequency Spectrum of angle modulated wave

From the figure the Bandwidth of FM is given by

B = fc + nfm – fc + nfm

BW = 2nfm

Classification of FM:

1. Narrowband FM
2. Wide band FM

Narrow band FM:

When the modulation index is less than I, it is called narrowband FM. The FM Equation given by eq. 9can also be expressed as,

$$e(t) = E_c \cos\left[\omega_c t + \frac{k_1 E_m}{\omega_m} \sin \omega_m t\right]$$

…………………(1)

$$\frac{k_1 E_m}{\omega_m} = m,$$

$$e(t) = E_c \cos\left[2\pi f_c t + m \sin 2\pi f_m t\right]$$

Expanding the equation

$$e(t) = E_c \cos(2\pi f_c t) \cos[m \sin(2\pi f_m t)] - E_c \sin(2\pi f_c t) \sin[m \sin(2\pi f_m t)]$$

.........(2)

For narrowband FM, the modulation index, m is very small therefore following approximations can beconsidered.

$$\cos[m \sin(2\pi f_m t)] \approx 1$$

$$\sin[m \sin(2\pi f_m t)] \approx m \sin(2\pi f_m t)$$

Using this in equation (2)

$$e(t) = E_c \cos(2\pi f_c t) - m E_c \sin(2\pi f_c t) \sin(2\pi f_m t)$$

Expanding

$$e(t) = E_c \cos(2\pi f_c t) + \frac{1}{2} m E_c \left\{\cos 2\pi(f_c + f_m)t - \cos 2\pi(f_c - f_m)t\right\}$$

This equation gives the spectrum of narrowband FM. Observe that there is carrier frequency fc, upper sideband(fc + *fm)* and lower sideband (fc - *fm).*

Wide band FM

If the modulation index is higher than 10 it is called as wide band FM

$$\begin{aligned} e(t) &= E_c \cos[2\pi f_c t + m \sin 2\pi f_m t] \\ &= \mathrm{Re}\left[E_c\ e^{j(2\pi f_c t + m \sin 2\pi f_m t)}\right] \\ &= \mathrm{Re}\left[E_c e^{j2\pi f_c t} \cdot e^{jm \sin 2\pi f_m t}\right] \end{aligned}$$

then the above equation becomes

Let $x(t) = E_c e^{jm \sin 2\pi f_m t}$,

$$e(t) = \text{Re}\left[x(t)\, e^{j2\pi f_c t}\right] \qquad \text{.........(1)}$$

Here $x(t) = E_c e^{j\, m \sin 2\pi f_m t}$ is periodic with fundamental frequency of f_m. It can be expressed with the help of Fourier series as,

$$x(t) = \sum_{n=-\infty}^{\infty} C_n\, e^{j2\pi n f_m t} \qquad \text{........(2)}$$

where

$$C_n = f_m \int_{-\frac{1}{2} f_m}^{\frac{1}{2} f_m} x(t)\, e^{-j\, 2\pi n f_m t}\, dt$$

$$= f_m \int_{-\frac{1}{2} f_m}^{\frac{1}{2} f_m} E_c\, e^{j m \sin 2\pi f_m t}\, e^{-j 2\pi n f_m t}\, dt$$

$$= f_m E_c \int_{-\frac{1}{2} f_m}^{\frac{1}{2} f_m} e^{j(m \sin 2\pi f_m t - 2\pi n f_m t)}\, dt$$

put $y = 2\pi f_m t$ hence the limits will change from $-\pi$ to π

$$\therefore \quad C_n = \frac{E_c}{2\pi} \int_{-\pi}^{\pi} e^{j(m \sin y - ny)}\, dy$$

The above integral is known as the nth order Bessel function of the first kind. It is given as

$$J_n(m) = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{j(m \sin y - ny)}\, dy$$

$$C_n = J_n(m) E_c$$

Using the value of Cn in equation (2)

$$x(t) = \sum_{n=-\infty}^{\infty} J_n(m) E_c\, e^{j2\pi n f_m t}$$

Using the value x(t) in equation (1)

$$
\begin{aligned}
e(t) &= \text{Re}\left[\sum_{n=-\infty}^{\infty} J_n(m) E_c \; e^{j2\pi n f_m t} \, . e^{j2\pi f_c t}\right] \\
&= E_c \sum_{n=-\infty}^{\infty} \text{Re}\left[J_n(m) e^{j2\pi(f_c + n f_m)t}\right] \\
&= E_c \sum_{n=-\infty}^{\infty} J_n(m) \cos\left[2\pi(f_c + n f_m)t\right] \qquad \ldots\ldots\ldots(3)
\end{aligned}
$$

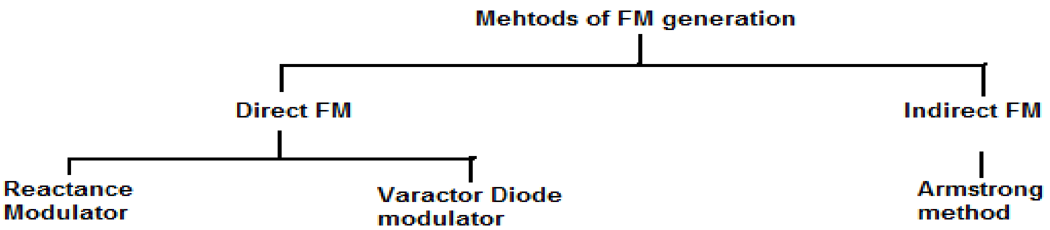
The Fourier transform of the above equation becomes

$$
E(f) = \frac{E_c}{2} \sum_{n=-\infty}^{\infty} J_n(m) \{\delta(f - f_c - n f_m) + \delta(f + f_c + n f_m)\}
$$

This equation shows that there are infinite number of components locatedfc±fm, fc±2fm,fc ±3fm…………….

FM Modulators: There are 2 types of FM modulators.

1. Direct Method
2. Indirect Method



Direct FM Modulators : In this type the frequency of the carrier is varied directly by the modulating signal.

Indirect FM Modulators: In this type FM is obtained by phase modulation of the carrier.

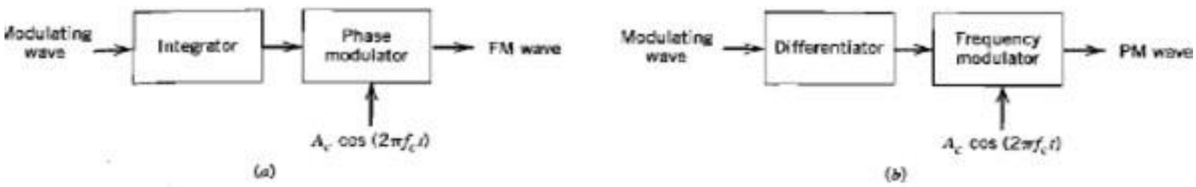
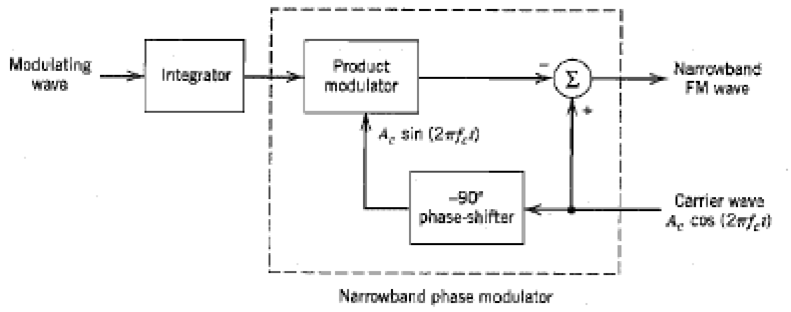


Figure 1.5.3 Illustration of the relationship between FM and PM (a) generation of FM using PM (b) generation of PM from FM

Generation of Narrow band FM:



Block diagram of a method for generating a narrowband FM signal.

Figure 1.5.4 Generation of Narrow band FM

Direct FM reactance modulator:

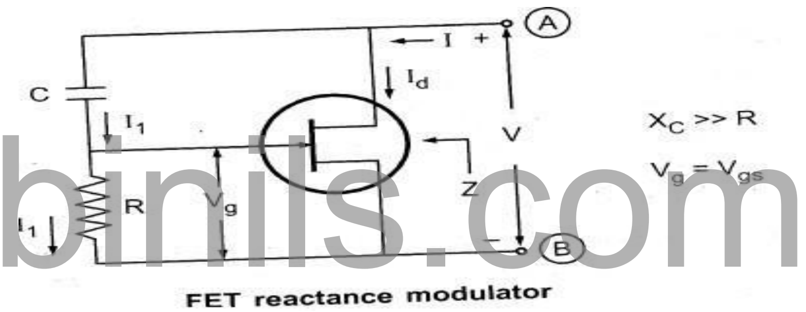


Figure 1.5.5 Direct FM reactance modulator

- It behaves as reactance across terminal A-B.
- The terminal A-B of the circuit may be connected across the tuned circuit of the oscillator to get fm o/p.
- The varying voltage (modulating voltage) V, across the terminals A-B changes the reactance of FET.
- This charge in reactance can be inductive or capacitive.
- Neglecting the gate current, let the current through C & R be I1.
- At the carrier freq. the reactance of C is much larger than
- The impedance of FET is capacitive.
- By carrying the modulating voltage across FET, the operating paint gm can be varied and hence Ceq.
- This change in the capacitance will change the frequency of the oscillator.

Frequency Modulation using Varactor diode.

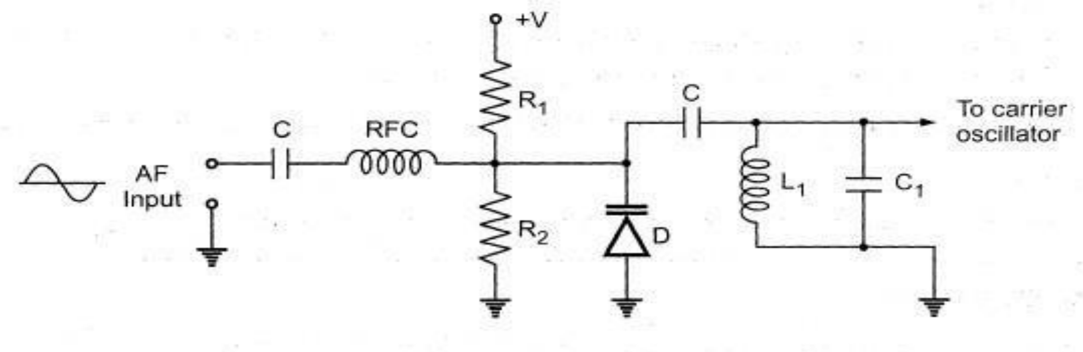


Figure 1.5.6 Varactor diode for FM generation

- We know that the junction capacitance of the varactor diode changes as the reverse bias across it isvaried.
- L1 & C1 forms the tank circuit of the carrier oscillator.
- The capacitance of the varactor diode depends on the fixed bias set by R1 & R2 & AF modulating signal.
- Either R1 or R2 is made variable.
- The radio frequency choke [RFC] has high reactance at the carrier frequency to prevent carrier signalfrom getting into the modulating signal.
- At +ve going modulating signal adds to the reverse bias applied to the varactor diode D, which decreases its capacitance & increases the carrier frequency.
- A –ve going modulating signal subtracts from the bias, increasing the capacitance, which decreases thecarrier frequency.

Direct FM Transmitters :

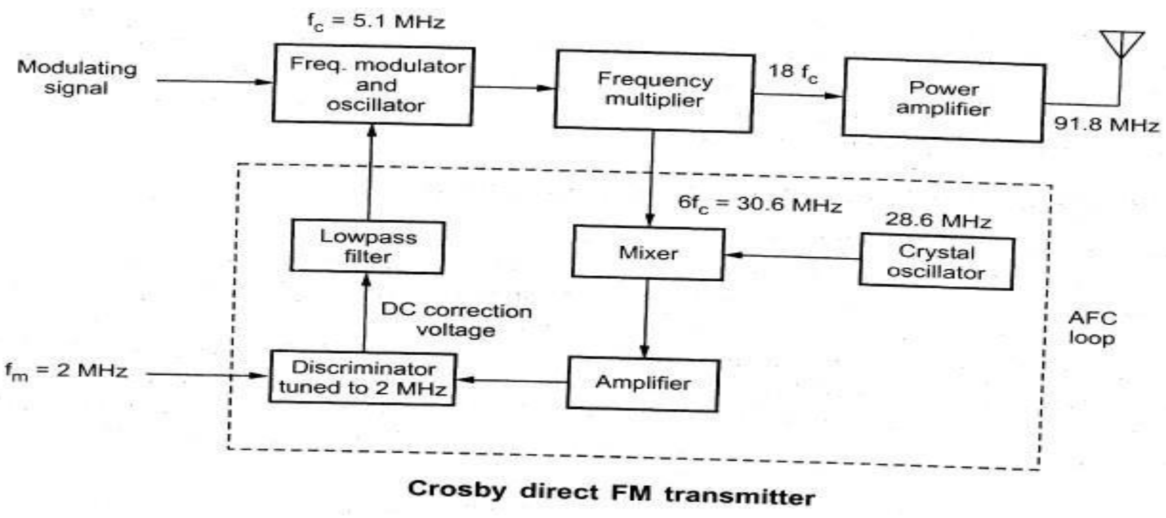


Figure 1.5.7 Direct Fm Transmitters

- Fig. shows the FM Crosby transmitter with an AFC loop. (Automatic frequency correction loop).
- The Frequency modulator can be either a reactance modulator or voltage controlled oscillator.
- The carrier freq is 5.1MHz. which multiplies by 18 in three steps to produce a final frequency of 91.8MHz.
- When the frequency modulated carrier is multiplied, its frequency & phase deviations are alsomultiplied.
- The rate at which the carrier is deviated is unaffected by the multiplication process. Hence themodulation index is multiplied.
- When an angle modulated carrier is heterodyned with another freq in a non linear mixer, the carrier can either be up converted or down converted.

AFC loop :

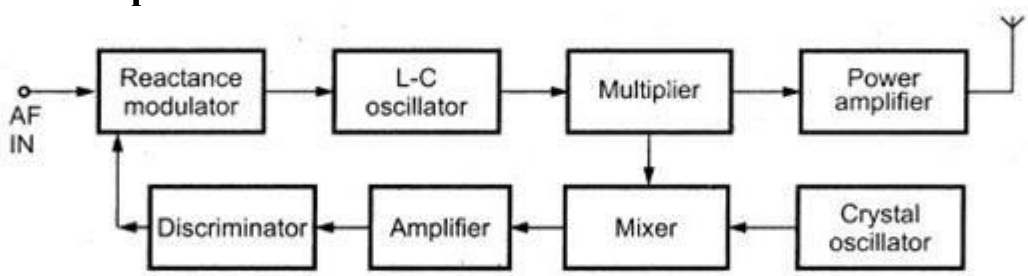


Figure 1.5.8 Typical AFC circuit

- The purpose of the AFC loop is the achieve near crystal stability of the transmit carrier freq. withoutusing a crystal in the carrier oscillator.
- The cassier frequency is mixed with a local oscillator freq and then down converted in freq. & the fedto a frequency discriminator.
- Frequency discriminator is a device whose o/p voltage is proportional to difference b/w i/p freq and itsresonant freq.
- Discriminator responds to low freq changes in the carrier center freq because of master oscillator freqdrift.
- When the discriminator responds to frequency deviation, the feedback loop would cancel the deviationand this remove the modulation.
- The dc correction voltage is added to the modulating signal to automatically adjust the master oscillator’s centre frequency to compensate for low freq drift.

PLL Direct FM transmitter:

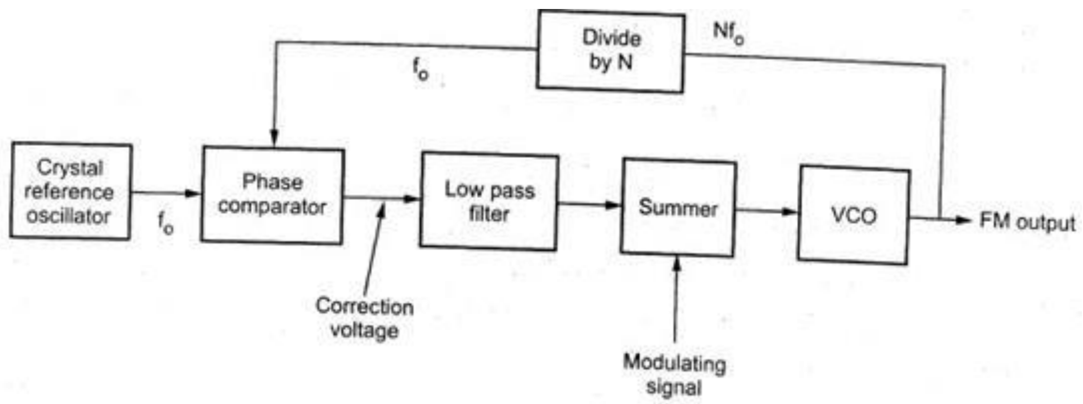


Figure 1.5.9 Block diagram of PLL direct FM transmitter

- Fig shows a wide band FM transmitter.
- The VCO o/p freq is divided by N & fed bark to the PLL phase comparator, where it is compared to astable reference freq.
- The phase comparator generator a correction voltage that is

proportional to the difference b/w the 2frequencies.

- The correction voltage is added to the modulating signal & applied to the VCO i/p.
- The correction voltage adjusts the VCO centre freq to its proper value.
- The LPF prevents the changes in the VCO o/p frequency due to the modulating signal from beingconverted to a voltage & fed back to VCO.
- The LPF also prevents the loop from locking onto a side frequency.

Indirect Fm transmitter

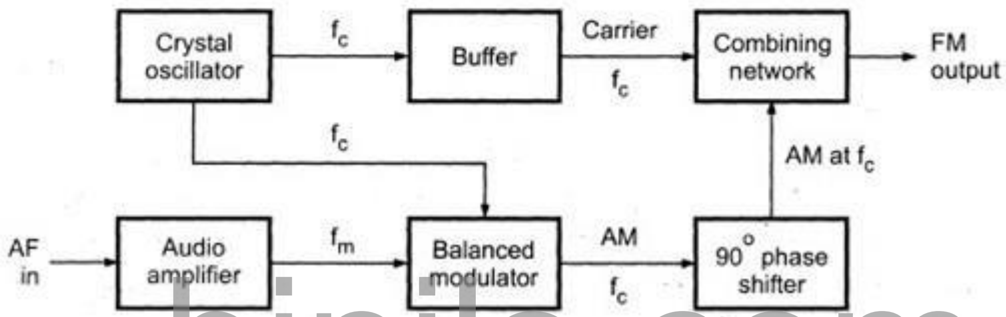


Figure 1.5.9 Block diagram of Armstrong to generate FM

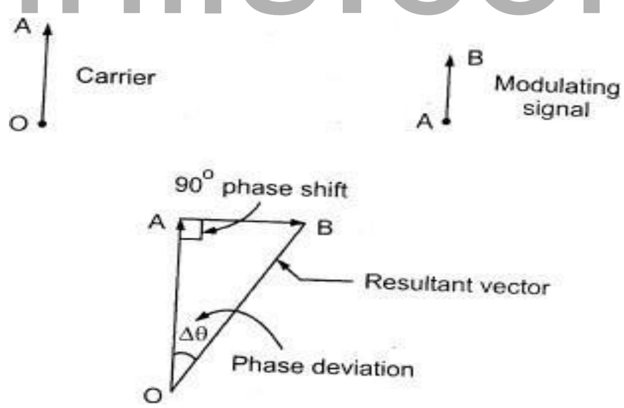


Figure 1.5.10 Modulating Signal

- Here the modulating signal directly deviates the phase of the carrier, which indirectly changes thefrequency.
- The carrier source is a crystal oscillator hence stability can be achieved without a AFC.
- A carrier is phase shifted to 90^0 & fed to the Balanced modulator. Where it is mixed with the i/pmodulating signal.

- The o/p of balanced modulator is DSBSC.
- The o/p of Balanced modulator is combined with original carrier in the combining N/W. to produce a low index, phase modulated wavefrom.
- Fig (b) shows phasor of original carrier, modulating signal and the resultant Vector.
- Fig (b) shows the phasors for the side freq. components of the suppressed carrier wave. As suppressedcarrier is out of phase with Vc, the upper & Lower side bands combine to produce Vm – 90^o with Vc.
- The phase modulated signal is obtained by vector addition of carrier and modulating signal.
- Modulating signal vector adds to the carrier OA with 90^0 phase Shift.
- The resultant phase modulated vector is OB with phase shift ❒.
- This works only if both have the same frequency. The means carrier & modulating signal should havesame frequency. Under this condition phase modulation produces FM o/p.

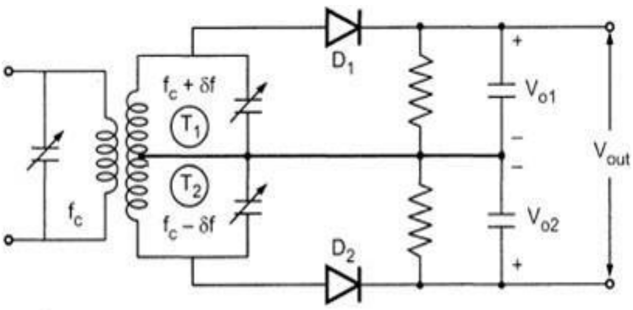
FM demodulator must satisfy the following requirements

- It must convert the frequency variations into amplitude variations
- This conversion must be linear and efficient.
- The demodulator circuits must be insensitive to amplitude changes.
- It should not be too critical in its adjustment and operation.

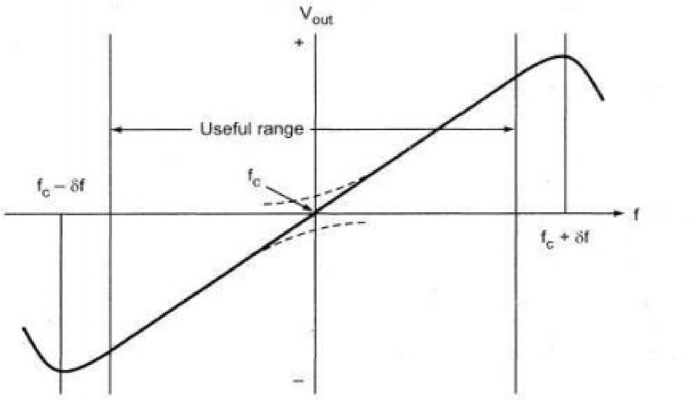
Types of FM demodulator:

- Round Travis Detector or Balanced discriminator.
- Foster – Seley Discriminator or Phase discriminator.
- Ratio Detector.

Slope Detector / Round Travis Detector :



Balanced slope detector



Characteristic of balanced slope detector, or 'S'-curve

Figure 1.5.11 Slope Detector / Round Travis Detector

- Consists of 2 identical circuit connected back to back.
- FM signal is applied to the tuned LC circuit.
- Two tuned LC circuits are connected in series.
- The inductance of the secondary tuned LC circuit is coupled with the inductance of the primary LCcircuit this forms a tuned transformer.
- Upper tuned circuit is T1 & lower tuned circuit is T2.
- I/P side LC is tuned to be

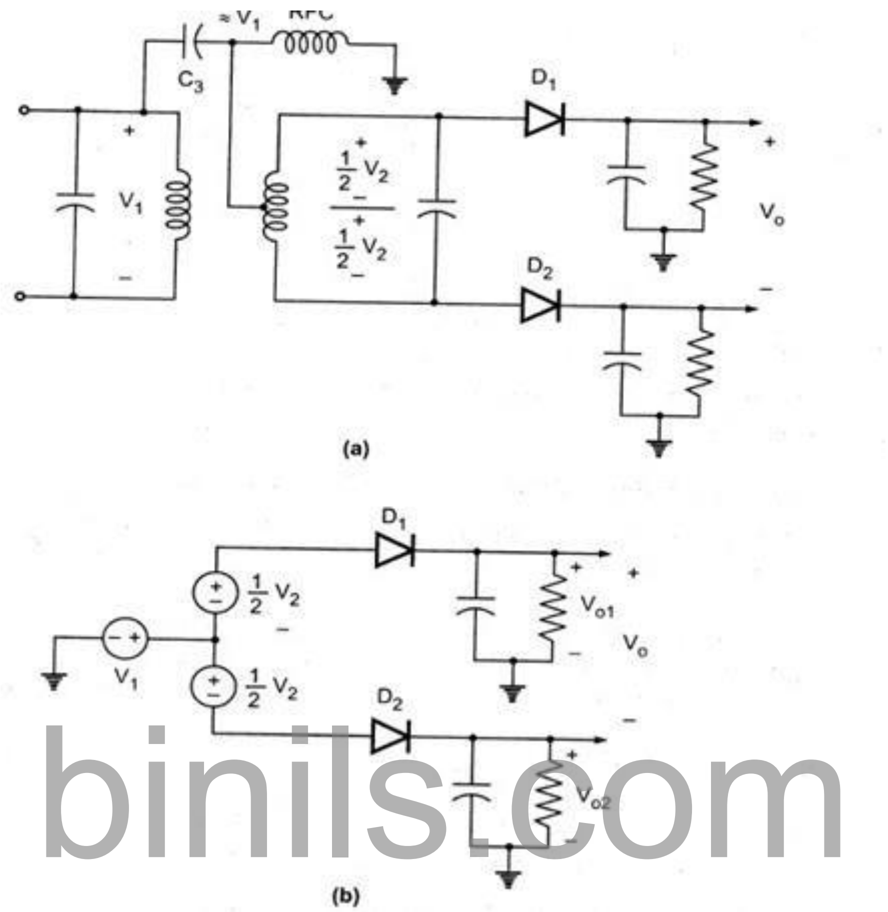
T1 is tuned to fc + □f - max freq fm. T2 is tuned to fc - □f - max freq fm.

- Secondary of T1 & T2 are connected to diodes D1 & D2 with RC loads.
- The total o/p is equal to difference b/w Vo1 & Vo2.
- When i/p freq is fc, both T1 & T2 produce the same voltage hence o/p = 0
- When i/p freq is fc + □f, the upper circuit T1 produces maximum voltage since it is tuned to this freq. Hence this produces maximum votalge.

V01 is high compared to V02.
Vout = V01 - V02 is positive for fc + □f.

- When i/p freq is fc - □f. T2 produces maximum signal since it is tuned to it. But T1 produces minimumvoltage. Hence o/p Volt = V01 – V02 is negative. Thus we get a modulating signal.

Foster - Seeley Discriminator :



1.5.12 Figure (a) Basic Foster-Seeley Discriminator (b) Voltage Generator Equivalent Circuit

- The primary voltage is coupled through C3 & RFC to the centre tap on the secondary.
- The capacitor C3 passes all the frequencies of Fm. The voltage V1 is generated across RFC.
- RFC offers high impedance to frequencies of Fm.

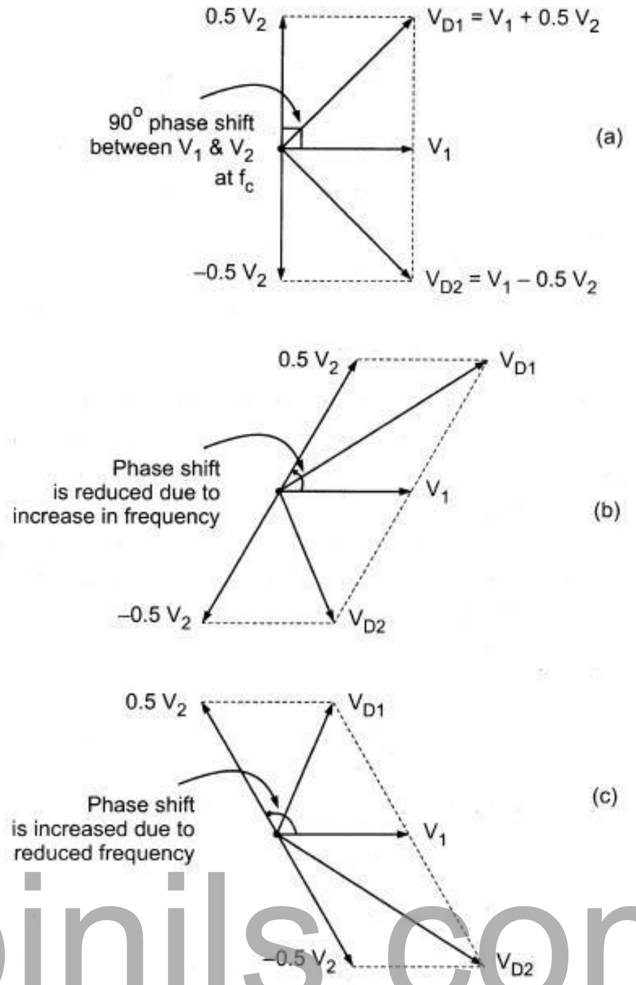


Figure 1.5.13

(a) At center frequency, phase shift between V_1 and V_2 is 90°. Hence $|V_{D1}| = |V_{D2}|$

(b) For the frequencies above center frequency, the phase shift between V_1 and V_2 is reduced. Hence $|V_{D1}| > |V_{D2}|$

(c) For frequencies below center frequency, the phase shift between V_1 and V_2 is increased. This makes $|V_{D1}| < |V_{D2}|$

- The voltage $V1$ thus appears across centre tap of secondary and ground also.
- The voltage of secondary is $V2$ & equally divided across upper half & lower half of the secondary.
- In the figure the voltage across diode D1 is $VDI = V1 + 0.5\ V2$ and that across D2 is $VD2 = V1 + 0.5\ V2$

  .
- The o/p of upper rectifier is $V01$ and lower rectifier is $V02$.
- The net o/p $V0 = V01 – V02$ $V0 = |VD1| - |VD2|$
- At carrier frequency $VD1$ x $VD2$ are equal hence the net o/p of the

discriminator will be zero.

- When the i/p frequency increases above fc the phase shift b/w V1 & V2 reduces | VD1 | > | VD2 | henceV01 = | VD1 | - | VD2 | will be +ve.
- When the i/p frequency reduces below fc then | VD1 | > | VD2 | hence V01 = | VD1 | - | VD2 | will be –ve.

Ratio detector :

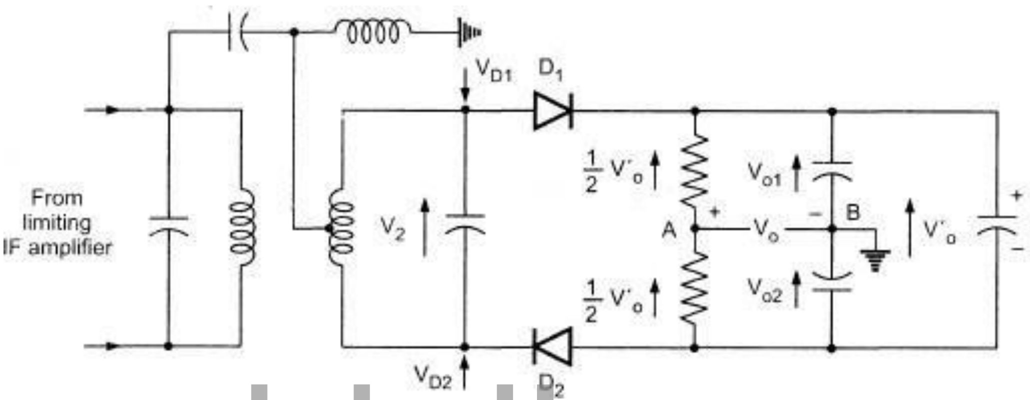


Figure 1.5.14 Ratio detector

Ratio detector can be obtained by sight modifications in the foster-Seeley discriminator. Fig shows the circuit diagram of ratio detector. As shown in the diagram the diode D2 is reversed, and output is taken from different points. In the above circuit the regular conversion from frequency to phase shift and phase shift to amplitude takes place as in faster–Seeley discriminator. The polarity of voltage in the lower capacitor is reversed. Hence the voltages V01 and V02 across two capacitors add. (Note that these voltages subtract in faster- seely circuit). And we know that when V01 increases, V02 decreases and vice-versa as we have seen in faster- Seeley circuit. Since, V0' is sum of V01 and V02, it remains constant. From the circuit of Fig we can write two equations for the output voltage V0 (Note that V0 is the net output voltage and taken across points A and B). The First equation will be,

V0 = ½ V'0 – V02 and

V0 = - ½ V'0 – V01

adding the above two equations,

$2\ V0 = V01 - V02$

$V0 = \frac{1}{2}(V01 - V02)$

Since V01 ❐ | VD1| and | V02 | above equation will be,

$V0 = \frac{1}{2}(|VD1| - |VD2|)$

- Here VD1 & VD2 are obtained as discussed earlier in foster seeley circuit.
- From the equation we know that the output of ratio detector is half compared to that of Foster-Seeleycircuit
- As frequency increases above fc' | VD1 | > | VD2| hence o/p is +ve.
- III rly as frequency decreases below fc = | VD2 | > | VD1|, hence o/p is –ve.

Advantages :

- Reduced fluctuations in the o/p voltage compared to foster seeley circuit

PLL Demodulator circuit

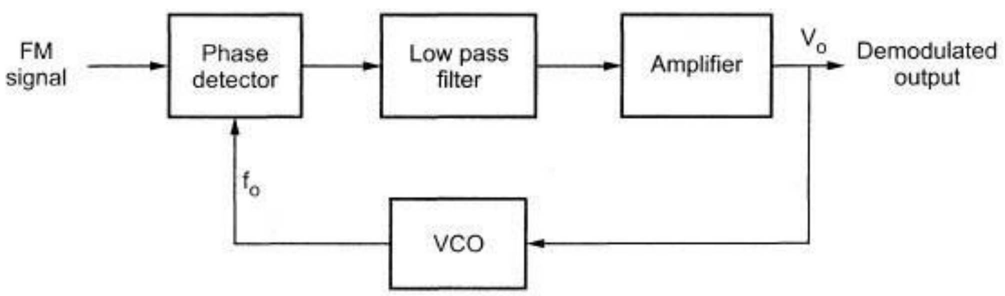


Figure 1.5.15 PLL Demodulator circuit

- Fig. shows the block diagram of PLL FM demodulator.
- The output frequency of VCO is equal to the frequency of unmodulated carrier.
- The phase detector generates the voltage which is proportional to

difference between the FM signal andVCO output.

- This voltage is filtered and amplified. It is the required modulating voltage.
- Here frequency correction is not required in VCO since it is already done at transmitter