UNIT I : AMPLITUDE MODULATION

Communication is the transfer of information from one place (known as the source of information) to another place (known as the destination of information).It is used in Teleconferencing, teleshopping, telebanking, internet, computer networks and mobile etc.

Basic Communication System:

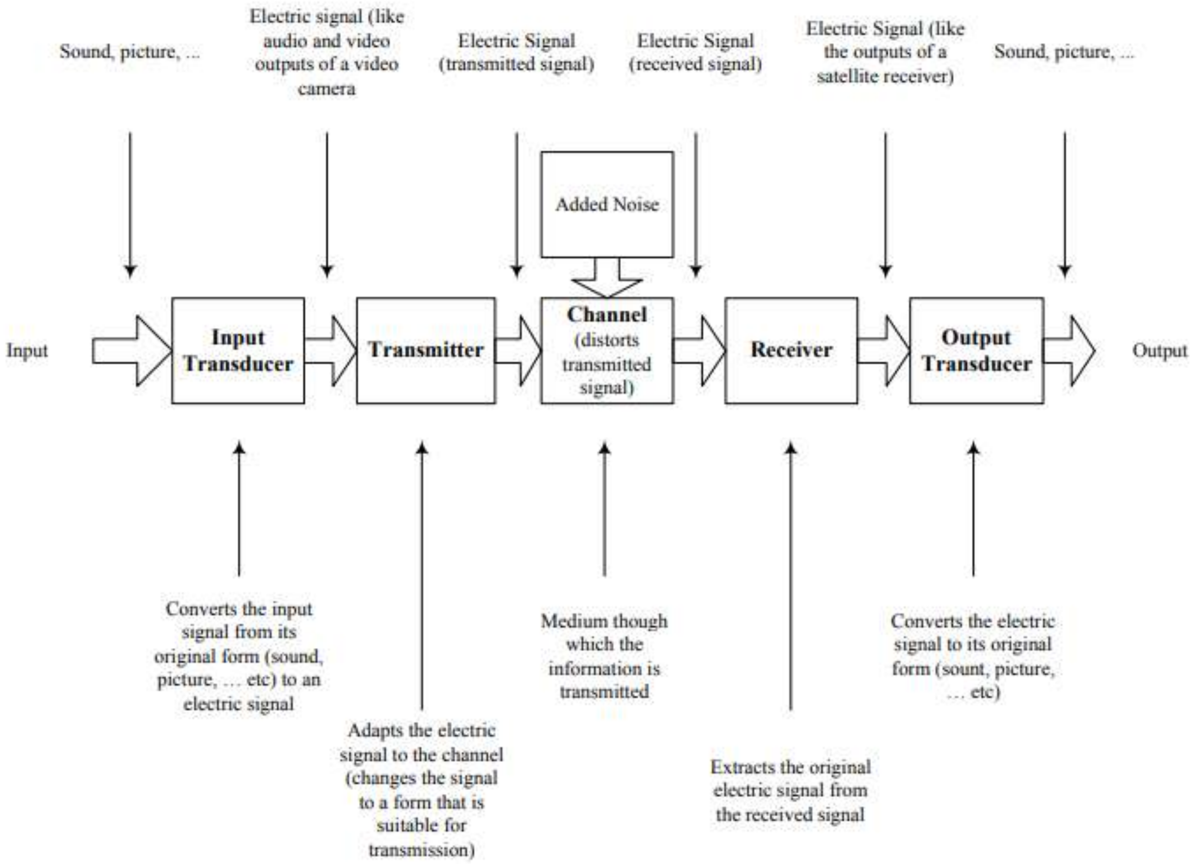


Fig.1 Communication system

Advantages of Digital Communication over Analog Communication:

1. Immunity to Noise
2. Efficient use of communication bandwidth Digital communication provides higher security
3. The ability to detect errors and correct them if necessary.
4. Design and manufacturing of electronics for digital communication systems is much easier and much cheaper than the design and manufacturing of electronics for analog communication systems.

Modulation: Modulation is changing one or more of the characteristics of a carrier signal in accordance with the modulating signal to produce a modulated signal.

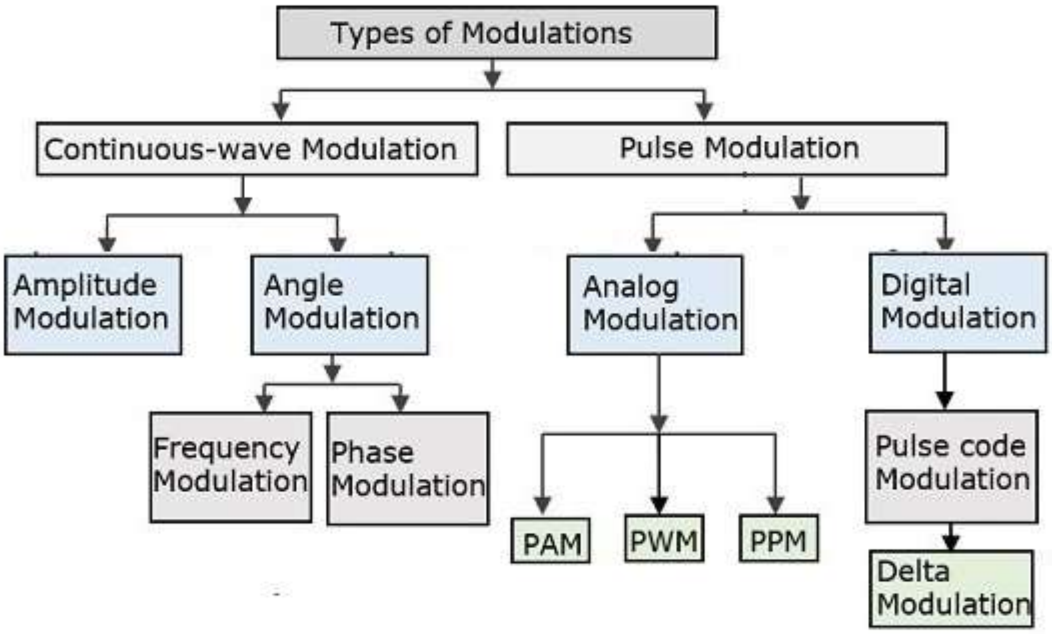


Fig.2 Types of Modulations

Continuous Wave modulation Types:

1. **Amplitude Modulation (AM):**Process of changing the amplitude of the carrier signal in accordance with instantaneous amplitude of the modulating signal.
2. **Frequency Modulation (FM):** Process of changing the frequency of the carrier signal in accordance with instantaneous amplitude of the modulating signal.
3. **Phase Modulation (PM):**Process of changing the phase of the carrier signal in accordance with instantaneous amplitude of the modulating signal.

Need for Modulation:

1. Reduction in the height of antenna
2. Avoids mixing of signals
3. Increases the range of communication
4. Multiplexing is possible
5. Improves quality of reception

MATHEMATICAL REPRESENTATION OF AM:

The method of varying amplitude of a high frequency carrier wave in accordance with theinformation to be transmitted, keeping the frequency and phase of the carrier wave unchanged is called Amplitude Modulation. The information is considered as the modulating signal and it is superimposed on the carrier wave by applying both of them to the modulator. The detailed diagram showing the amplitude modulation process is given.

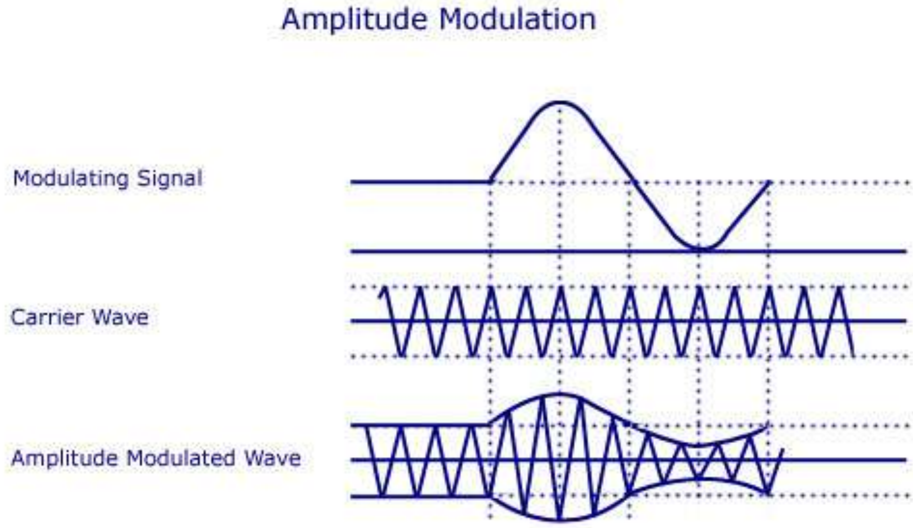


Fig 3. AM modulated wave

From the figure, the amplitude variation of the high frequency carrier is at the sig al frequency and the frequency of the carrier wave is the same as the frequency of the resulting wave.

MATHEMATICAL REPRESENTATION OF AM WAVE: TWO TITLES

Analysis of Amplitude Modulation Carrier Wave:

Let carrier signal be represented as $v_{c(t)} = V_c \text{ Sin } w_c t$ -------------- (1)
Let the message signal be represented as $v_m(t) = Vm \text{ Sin } w_m t$ -----(2)
v_c – Instantaneous value of the carrierV_c – Peak value of the carrier
w_c – Angular velocity of the carrier
v_m – Instantaneous value of the modulating signal
V_m – Maximum value of the modulating signal
w_m – Angular velocity of the modulating signal
f_m – Modulating signal frequency

The amplitude of modulated carrier waveis given by the equation
$A = V_c + v_m = V_c + V_m \text{ Sin } w_m t = V_c \, [1+ (\frac{Vm}{V_c \, Sin \, W_m t})] = V_c \, (1 + m\text{Sin}w_m t)$
m – Modulation Index. The ratio of $\frac{Vm}{Vc}$.
Instantaneous value of amplitude modulated carrier wave is given by the equation

Cm(t) = A Sin w_ct = Vc (1 + m Sin w_mt) Sin wct

= V_c Sin w_ct + mVc (Sin w_mt Sin w_ct)

Cm(t) = V_c Sin wct + [$\frac{mVc}{2\ Cos}$ (wc-wm)t – mVc/2 Cos (wc + wm)t]

The above equation represents the sum of three sine waves. One with amplitude of Vc and a frequency of $w_c/2$, the second one with an amplitude of $mV_c/2$ and frequency of $(w_c – w_m)/2$ and the third one with an amplitude of $mV_c/2$ and a frequency of $(w_c + w_m)/2$.

In practice the angular velocity of the carrier is known to be greater than the angular velocity of the modulating signal ($w_c >> w_m$). Thus, the second and third cosine equations are more close to the carrier frequency. The equation is represented graphically as shown below.

Frequency Spectrum of AM Wave:

Lower side frequency = $\frac{(wc - wm)}{2}$

Upper side frequency =$\frac{(wc + wm)}{2}$

The frequency components present in the AM wave are represented by vertical lines. Thus there will not be any change in the original frequency, but the side band frequencies $(w_c – w_m)/2$ and $(w_c + w_m)/2$ will be changed. The former is called the upper side band (USB)frequency and the later is known as lower side band (LSB) frequency.Since the signal frequency $w_m/2$ is present in the side bands, it is clear that the carrier voltage component does not transmit any information.Two side banded frequencies will be produced when a carrier is amplitude modulated by a singlefrequency. That is, an AM wave has a band width from $(w_c – w_m)/2$ to $(w_c + w_m)/2$, that is, $2w_m/2$ or twice the signal frequency is produced. When a modulating signal has more than one frequency, two side band frequencies are produced by every frequency. Similarly for twofrequencies of the modulating signal 2 LSB‘s and 2 USB‘s frequencies will be produced.

The side band frequencies present above the carrier frequency is known to be the upper side band and all those below the carrier frequency belong to the lower side band. The USB frequencies represent the some of the individual modulating frequencies and the LSB frequenciesrepresent the difference between the modulating frequency and the carrier frequency. The total bandwidth is represented in terms of the higher modulating frequency and is equal to twice this frequency.

Modulation Index (m):

The ratio between the amplitude change of carrier wave to the amplitude of the normal carrier wave is called modulation index. It is represented by the letter _m‘.

It can also be defined as the range in which the amplitude of the carrier wave is varied by the modulating signal. m = $\frac{Vm}{Vc}$.

Percentage modulation, %m = m*100 = $\frac{Vm}{Vc}$* 100

Amplitude Modulated Carrier Wave:

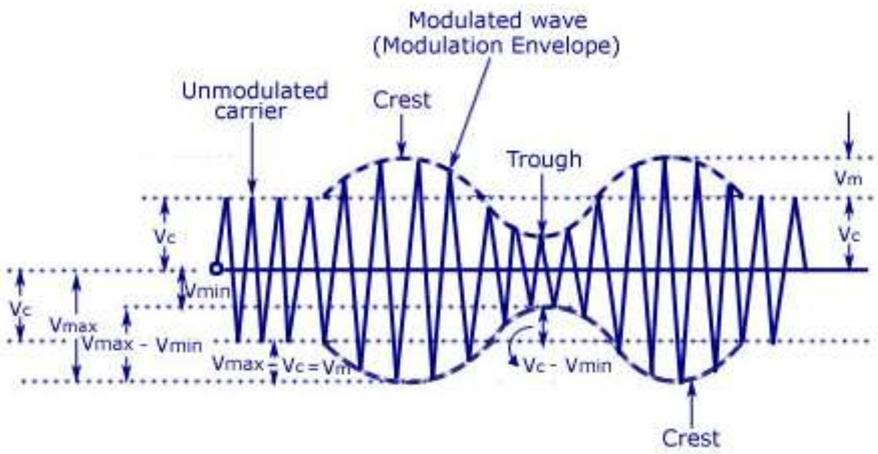


Fig.4 AM modulated wave

$$2\ Vin = Vmax - Vmin$$

$$V_{in} = \frac{(Vmax - Vmin)}{2}$$

$$Vc = Vmax - Vin$$

$$= V_{max} - \frac{(Vmax - Vmin)}{2}$$

$$= \frac{(Vmax + Vmin)}{2}$$

Substituting the values of Vm and Vc in the equation m = Vm/Vc , we get

M = $\frac{Vmax - Vmin}{Vmax + Vmin}$

As told earlier, the value of ‗m' lies between 0 and 0.8. The value of m determines the strength and the quality of the transmitted signal. In an AM wave, the signal is contained in the variations of the carrier amplitude. The audio signal transmitted will be weak if the carrier wave is only modulated to a very small degree. But if the value of m exceeds unity, the transmitter output produces erroneous distortion.

Power Relations in an AM wave:

A modulated wave has more power than had by the carrier wave before modulating. The total power components in amplitude modulation can be written as:

$$Ptotal = Pcarrier + PLSB + PUSB$$

Considering additional resistance like antenna resistance R.

$$P_{carrier} = [(V_c/\sqrt{2})/R]^2 = V^2_C/2R$$

Each side band has a value of m/2 V_c and r.m.s value of $mV_c/2\sqrt{2}$. Hence power in LSB and USBcan be written as

$P_{LSB} = P_{USB} = (mV_c/2\sqrt{2})^2/R = m^2/4*V^2C/2R = m_2/4\ P_{carrier}$
$P_{total} = V^2{}_C/2R + [m^2/4*V^2C/2R] + [m^2/4*V^2C/2R] = V^2{}_C/2R\ (1 + m^2/2) = P_{carrier}\ (1 + m^2/2)$
In some applications, the carrier is simultaneously modulated by several sinusoidal modulatingsignals. In such a case, the total modulation index is given as

$$Mt = \sqrt{(m1^2 + m2^2 + m3^2 + m4^2 + \ldots}$$

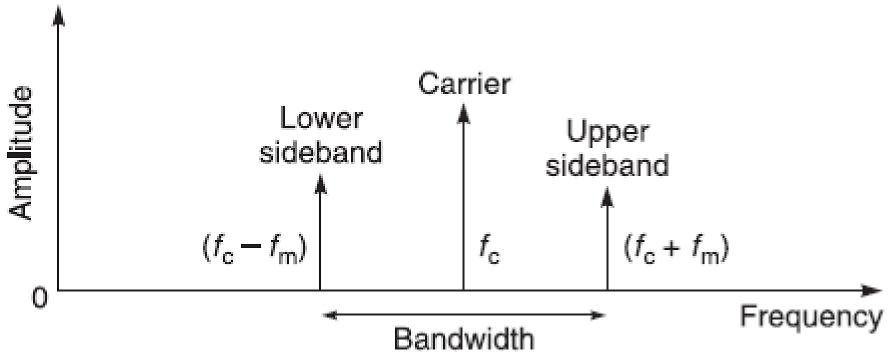
If Ic and It are the r.m.s values of unmodulated current and total modulated current and R is theresistance through which these current flow, then

$\frac{Ptotal}{Pcarrier} = (\frac{It.R}{Ic.R})^2 = (\frac{It}{Ic})^2$

$\frac{Ptotal}{Pcarrier} = (1 + \frac{m2}{2})$

$\frac{It}{Ic} = 1 + \frac{m2}{2}$

Frequency spectrum of AM:



B.W= 2fm

Fig.5 Frequency Spectrum of AM

Limitations of Amplitude Modulation:

2 Low Efficiency- Since the useful power that lies in the small bands is quite small, so the efficiency of AM system is low.
3 Limited Operating Range – The range of operation is small due to low efficiency. Thus, transmission of signals is difficult.
4 Noise in Reception – As the radio receiver finds it difficult to distinguish between the amplitude variations that represent noise and those with the signals, heavy noise is prone to occur in its reception.
4. Poor Audio Quality – To obtain high fidelity reception, all audio frequencies till 15 KiloHertz must be reproduced and this necessitates the bandwidth of 10 KiloHertz to minimise the interference from the adjacent broadcasting stations. Therefore in AM broadcasting stations audio quality is known to be poor.

AM TRANSMITTERS:

Transmitters that transmit AM signals are known as AM transmitters. These transmitters are used in medium wave (MW) and short wave (SW) frequency bands for AM broadcast. The MW band has frequencies between 550 KHz and 1650 KHz, and the SW band has frequencies ranging from 3 MHz to 30 MHz. The two types of AM transmitters that are used based on their transmitting powers are:

1. High Level

2. Low Level

High level transmitters use high level modulation, and low level transmitters use low levelmodulation. The choice between the two modulation schemes depends on the transmitting powerof the AM transmitter. In broadcast transmitters, where the transmitting power may be of the orderof kilowatts, high level modulation is employed. In low power transmitters, where only a fewwatts of transmitting power are required , low level modulation is used.

High-Level and Low-Level Transmitters Below figure's show the block diagram of high-level andlow-level transmitters. The basic difference between the two transmitters is the poweramplification of the carrier and modulating signals

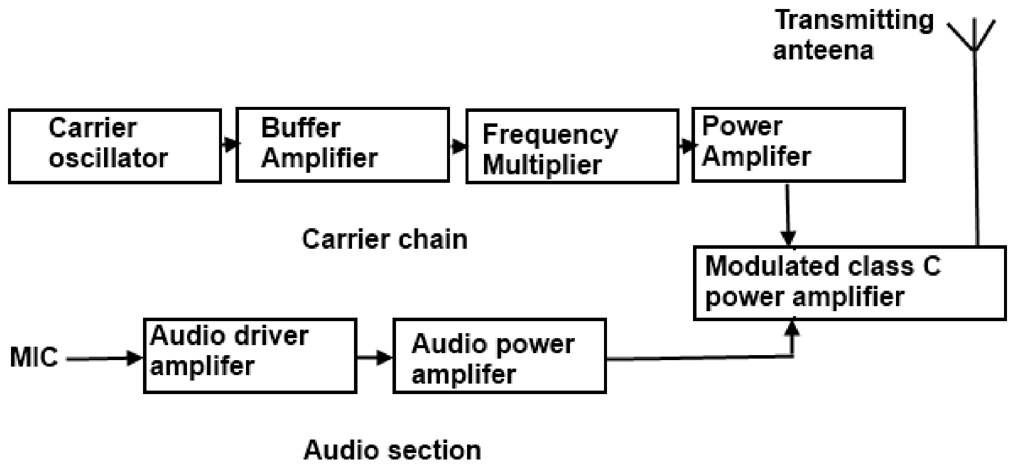


Fig.6 Block diagram of High level AM transmitter

In high-level transmission, the powers of the carrier and modulating signals are amplified before applying them to the modulator stage, as shown in figure (a). In low-level modulation, the powers of the two input signals of the modulator stage are not amplified. The required transmitting power is obtained from the last stage of the transmitter, the class C power amplifier.

The various sections of the figure (a) are:

- Carrier oscillator
- Buffer amplifier
- Frequency multiplier
- Power amplifier
- Audio chain
- Modulated class C power amplifier

1.**Carrier oscillator**

The carrier oscillator generates the carrier signal, which lies in the RF range. The frequency of the carrier is always very high. Because it is very difficult to generate high frequencies with goodfrequency stability, the carrier oscillator generates a sub multiple with the required carrier frequency. This sub multiple frequency is multiplied by the frequency multiplier stage to get therequired carrier frequency. Further, a crystal oscillator can be used in this stage to generate a lowfrequency carrier with the best frequency stability. The frequecy multiplier stage then increasesthe frequency of the carrier to its requirements.

2.**Buffer Amplifier**

The purpose of the buffer amplifier is twofold. It first matches the output impedance of the carrier oscillator with the input impedance of the frequency multiplier, the next stage of the carrier oscillator. It then isolates the carrier oscillator and frequency multiplier. This is required so that the multiplier does not draw a large current from the carrier oscillator. If this occurs, the frequency of the carrier oscillator will not remain stable.

3.**Frequency Multiplier**

The sub-multiple frequency of the carrier signal, generated by the carrier oscillator , is now applied to the frequency multiplier through the buffer amplifier. This stage is also known as harmonic generator. The frequency multiplier generates higher harmonics of carrier oscillator frequency. The frequency multiplier is a tuned circuit that can be tuned to the requisite carrier frequency that is to be transmitted.

4.**Power Amplifier**

The power of the carrier signal is then amplified in the power amplifier stage. This is the basic requirement of a high-level transmitter. A class C power amplifier gives high power current pulses of the carrier signal at its output.

5.**Audio Chain**

The audio signal to be transmitted is obtained from the microphone, as shown in figure (a). The audio driver amplifier amplifies the voltage of this signal. This amplification is necessary to drive the audio power amplifier. Next, a class A or a class B power amplifier amplifies the power of the audio signal.

6.**Modulated Class C Amplifier**

This is the output stage of the transmitter. The modulating audio signal and the carrier signal, afterpower amplification, are applied to this modulating stage. The modulation takes place at thisstage. The class C amplifier also amplifies the power of the AM signal to the reacquiredtransmitting power. This signal is finally passed to the antenna., which radiates the signal intospace of transmission.

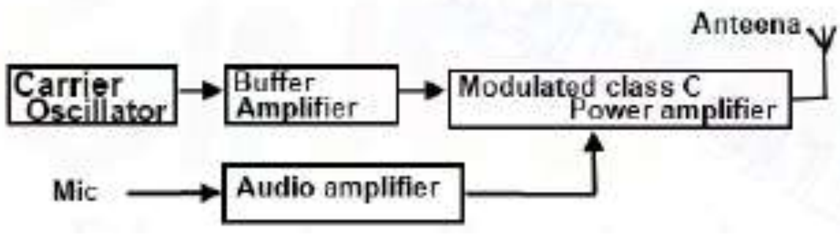


Fig.7 Low level AM transmitter

The low-level AM transmitter shown in above figure is similar to a high-level transmitter, except that the powers of the carrier and audio signals are not amplified. These two signals are directly applied to the modulated class C power amplifier.

Modulation takes place at the stage, and the power of the modulated signal is amplified to the required transmitting power level. The transmitting antenna then transmits the signal.

7. **Coupling of Output Stage and Antenna**

The output stage of the modulated class C power amplifier feeds the signal to the transmitting antenna. To transfer maximum power from the output stage to the antenna it is necessary that the impedance of the two sections match. For this , a matching network is required. The matching between the two should be perfect at all transmitting frequencies. As the matching is required at different frequencies, inductors and capacitors offering different impedance at different frequencies are used in the matching networks.

1. DSBSC MODULATION:

Double-sideband suppressed-carrier transmission (DSB-SC) is transmission in which frequencies produced by amplitude modulation (AM) are symmetrically spaced above and below the carrier frequency and the carrier level is reduced to the lowest practical level, ideally being completely suppressed.

DSB-SC is basically an amplitude modulation wave without the carrier, therefore reducing power waste, giving it a 50% efficiency. This is an increase compared to normal AM transmission (DSB), which has a maximum efficiency of 33.333%, since 2/3 of the power is in the carrier.

Generation of DSB – SC – AM

In DSB – SC, the transmitted wave consists of only upper and lower sidebands.Transmitted power is saved here through the suppression of the carrier wave because it does not contain any useful information, but the channel bandwidth required is thesame as before.

Expression for DSB –SC:

Let the modulating signal,

$$V_m(t) = V_m \sin \omega_m t$$

The carrier signal be,

$$V_c(t) = V_c \sin \omega_c t$$

$$V_m(t)_{DSC-SC} = V_m(\text{t})\, V_c(\text{t})$$

$$V_m(t)_{DSC-SC} = V_m \sin \omega_m t . V_c \sin \omega_c t$$

$$= V_m V_c \sin \omega_m t \sin \omega_c t$$

$$V_m(t)_{DSC-SC} = \frac{V_m V_c}{2} \lfloor \cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t \rfloor$$

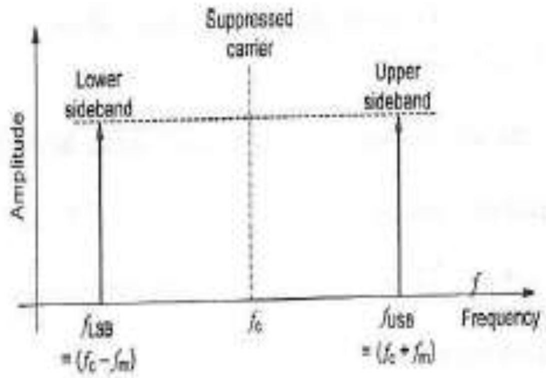


Fig 8. Frequency spectrum of DSBSC

There are two ways of generating **DSB–SC–AM** such as ,

i) Balanced modulator,
ii) Ring modulator.

Balanced Modulator

This is the circuit that is very commonly used for **DSB–SC generation**. In balanced modulator, two non-linear devices are connected in the balanced mode, so as to suppress the carrier wave. It is assumed that the two transistors are identical and the circuit is symmetrical. Since the operation is confined in non-linear region of its transfer characteristics.

Modulating voltage across the two windings of a centre-tap transformer is equal,opposite in phase,

i.e., Vm = V'm

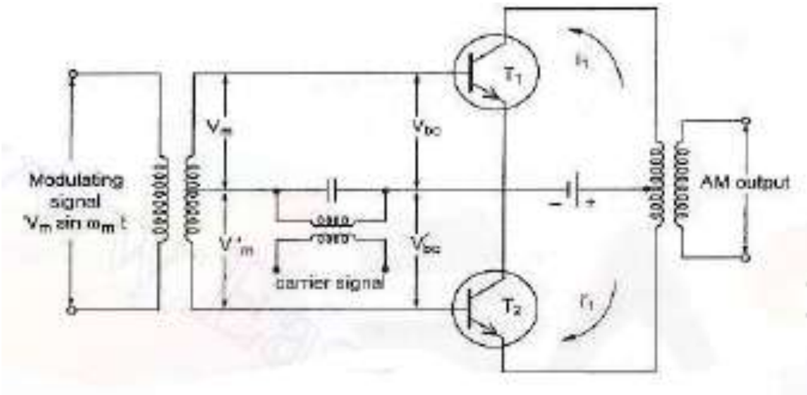


Fig.9 Balanced Modulator

Ring Modulator:

The one of the most popular method of generating a **DSB – SC** wave is ring modulator.
The circuit employs diodes as non-linear devices and the carrier signal is connected between centre taps of the input and output transformers. There is no need for a band pass filter at the output. The four diodes are controlled by a

carrierVc(t) of frequency fc. The carrier signal acts as a switching signal to alternate the polarity of the modulating signals at the carrier frequency. For better understanding of the operation, assume that the modulating input is zero. Only carrier signal is present.

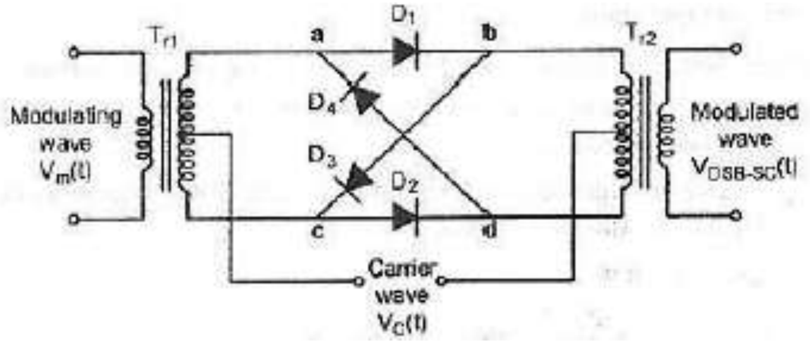


Fig.10 Ring modulator

Positive Half Cycle of Carrier:

Diodes D1 and D2 are form ward biased. AT this time D3 and D4 are reverse biased and act like open circuits. The current divides equally in the upper and lower portions of the primary winding of T12 .

The current in the upper part of the winding produces a magnetic field that is equal and opposite to the magnetic field produced by the current in the lower half of the secondary. Therefore, these magnetic fields cancel each other out and no output is induced in the secondary. Thus the carrier is effectively suppressed.

Negative Half Cycle of Carrier:

When the polarity of the carrier reverses. Diodes D1 and D2 are reverse biased and diodes D3 and D4 conduct. Again the current flows in the secondary winding of Tr1 and the primary winding of Tr2.

The equal and opposite magnetic fields produced in Tr2 cancel each other out and thus result in zero carrier output. The carrier is effectively balanced out.

Principle of Operation:

When both the carrier and the modulating signals are present, during positivehalf cycle of the carrier, diodes D1 and D2 conduct, while diodes D3 and D4 does notconduct.

During negative half cycle of the carrier voltage diodes D3 and D4 conduct and D1 and D2 does not conduct.

Phase Reversal

When polarity of the modulating signal changes, the result is a 180° phase reversal.

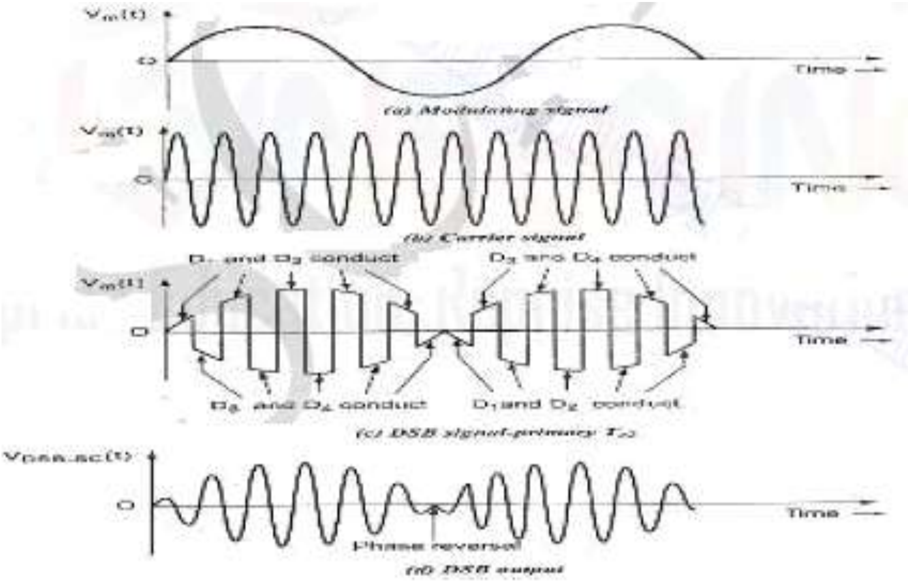


Fig.11 DSB output

At the time, during the positive half cycle of the carrier, diodes D3 and D4 are in forward bias and the negative half cycle of the carrier, diodes D1 and D2 are in reverse bias.

The ring modulator circuit is also known as double balanced modulator because comparing to balanced modulator here two more diodes are used.

Advantages:

1. DSB –SC is more efficient in transmitted power as compared to DSBFC .
2. DSB –SC has better signal to noise ratio as compared to single side band (SSB)transmission.

Disadvantage:

Even though the carrier is suppressed the bandwidth of DSBSC remains sameas DSBFC.

5.**GENERATION OF AM USING A NON LINEAR MODULATOR CIRCUIT:**

Non linear modulator circuits:

A simple diode can be used as a non linear modulator by restricting its Operation to non linear operation of its characteristics.

The undesired frequency terms are filtered out by a band pass filter. The methods for generation of AM waves using non linear property are broadly divided into two types

(a) Square law modulator

(b) Balance modulator

(a)Square law modulators:

Any device operated in non linear region of its output characteristics is capable of producing amplitude modulated waves when the carrier and modulating signals are fed at the input. Thus a transistor, a triode tube,a diode etc. may be used as the square law modulator. A square law modulator circuit consists of the following:

i) A non linear device
ii) A bandpass filter
iii) A carrier source and modulating signal

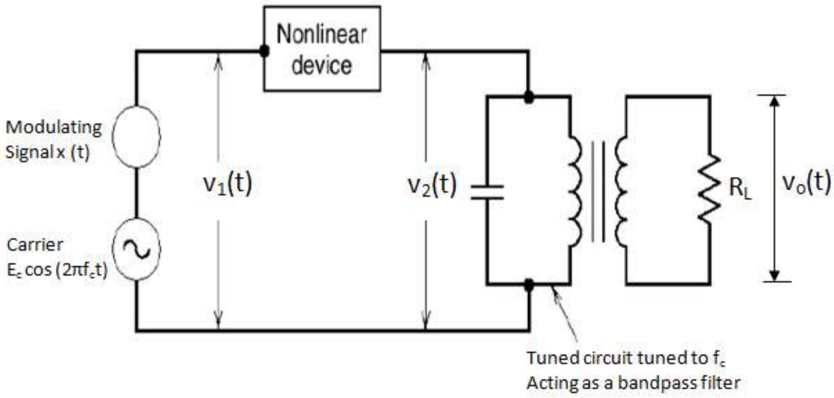


Fig12.Square law modulator.

Consider a non linear device to which a carrier ***c(t)*= *A*cos(2Π*fct*)** and an information signal *m(t)* are fed simultaneously as shown in figure12. The total input to the device at any instant is

$V_{in} = c(t) + m(t)$

$V_{in} = A_c \cos 2\pi f_c t + m(t)$

As the level of the input is smll very small, the output can be considered up to square of the input

$V_\circ = a_\circ + a_1 V_{in} + a_2 V^2{}_{in}$

Taking Fourier transform on both sides we get

$$V_o(f) = \left(a_o + \frac{a_2 A_c}{2}\right)\delta(f) + \frac{a_1 A_c}{2}[\delta(f - f_c) + \delta(f + f_c)] + a_1 M(f) + \frac{a_2 A^2{}_c}{2}[\delta(f - 2f_c) + \delta(f + 2f_c)] + a_2 M(f) + a_2 A_c[M(f - f_c) + M(f + f_c)]$$

Therefore the square law device output Vo consists of the dc component at f=0 The information signal ranging from 0 to W Hz and its second harmonics Signal at fc and 2fc Frequency band centered at fc with a deviation of ± W Hz.

The required AM signal with a carrier frequency fc can be separated using abandpass filter at the output of the square law device. The filter should have a lower cutoff frequency ranging between 2W and (fc - W) and upper cut-off frequency between (fc+W) and 2fc. The output AM signal is free from distortion and attenuation only when(fc-W)2W or
fc<3W

6. DSBSC DEMODULATION – ENVELOPE DETECTOR

The most commonly used AM detector is simple diode detector as the shown in Fig. The AM signal at fixed IF is applied to the transformer primary. The signal at secondary is half wave rectified by diode D. This diode is the detector diode. The resistance R is load resistance to rectifier and C is the filter capacitor. In the positivehalf cycle of AM signal diode conducts and currents flows through R, whereas innegative half cycle, the diode is reverse biased and no current flows. Therefore onlypositive half of the AM wave appears across resistance R as shown in figure. Thecapacitor across capital R provides low impedance at the carrier frequency and muchhigher impedance at the modulating frequency. Therefore capacitor reconstructs theoriginal modulating signal shown in figure and high frequency carrier is removed.

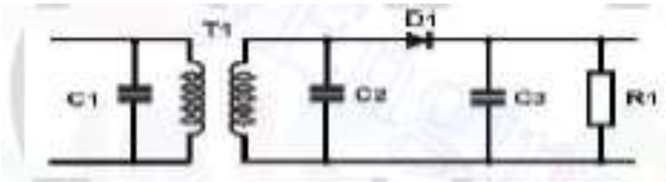


Fig13. Envelope detector

Negative peak clipping in diode detector:
This is the distortion that occurs in the output of diode detector because ofunequal *ac* and *dc* load impedances of the diode. The modulation index is defined as E***m*** /E***c.***

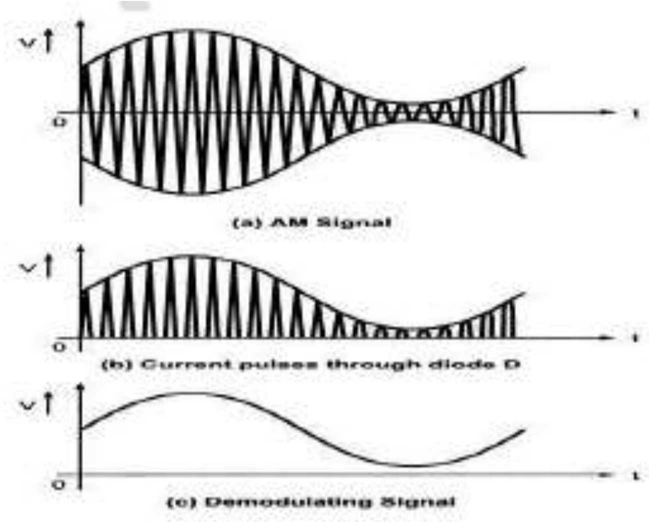


Fig.14 Waveform of negative peak clipping

The audio load resistance of the diode is smaller than the dc resistance. Hence the AF current I_m is larger, in proportion to dc current. This makes the modulation index in the demodulated wave relatively higher than that of modulated wave applied at the detector input. This introduces the distortion due to over modulation in the detector signal for modulation index near 100%. This is illustrated in Fig 14. In the figure observe that the negative peak of the detected signal takes place because of over modulation effect taking place in detector.

Diagonal Clipping in Diode Detector

As the modulating frequency is increased, the diode ac load impedance, Zm does not remain purely resistive. It does have reactive component also. At high modulation depths, the current changes so fast that the time constant of the load does not follow the changes. Hence the current decays slowly as shown in fig. The output voltage follo s the discharge law of RC circuit. This introduces distortion in the detected signaland it is called diagonal peak clipping.

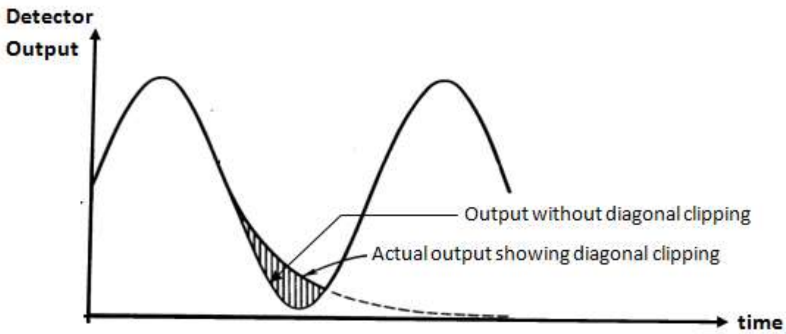


Fig.15 Waveform of Diagonal clipping

7. SSB MODULATION

SSB – SC – AM waves can by generated in three ways.

1. Frequency discrimination (or) Filter method
2. Phase discrimination method.
4. Third method or Weaver's method

Filter Method:

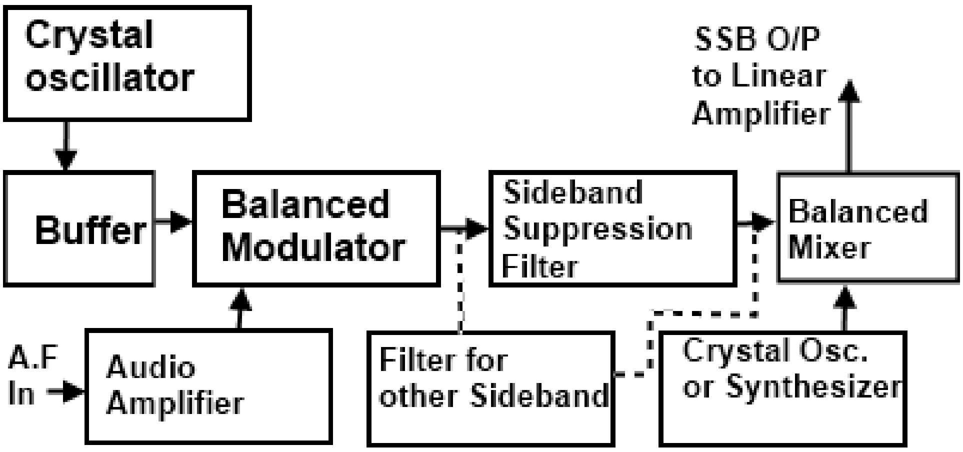


Fig.16 Filter method of SSB Generation

Fig.16 shows the block diagram of filter method to suppress one sideband. As shown in the block diagram, the balanced modulator produces DSB output. This DSB signal contains both the sideband. The filter must have a flat pass band and extremely high attenuation outside the pass band. In order to have this type of response the Q of the tuned circuits must be very high.

The required value of Q factor increases as the difference between modulating frequency and carrier frequency increases. Carrier frequency is usually same as the transmitter frequency increases. Carrier frequency is usually same as the transmitter frequency.

For higher transmitting frequencies required value of Q is so high that there is no practical way of achieving it. In such situation, initial modulation is carried out at a low frequency carrier say 100 kHz by the balanced modulator. Then the filter suppresses one of the sidebands. The frequency of the SSB signal generated at output of filter is very low as compared to the transmitter frequency.

The frequency is boosted up to the transmitter frequency by the balanced mixer and crystal oscillator. This process of frequency booting is also called as up conversion. The SSB signal having frequency equal to the transmitter frequency is then amplified by the linear amplifiers.

Phase Shift Method to Generate SSB

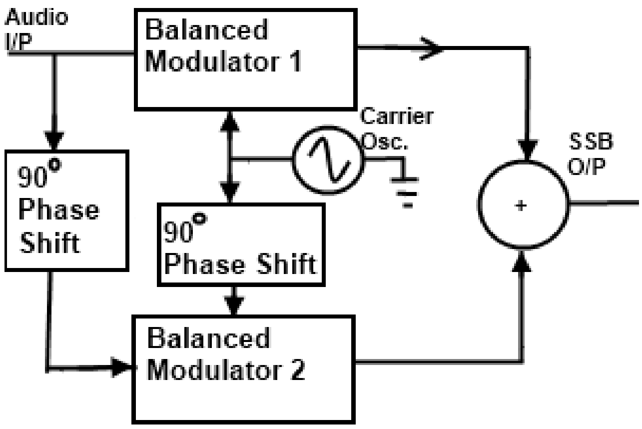


Fig.17 Phase Shift generator

Fig 17 shows the block diagram of phase shift method to generate SSB. The carriersignal is shifted by 90° and applied to the balanced modulator M1. The modulating signal isalso directly applied to the balanced modulator M2. The modulating signal is phase shiftedby 90° and applied to balanced modulator M2.

Both the modulators produce an outputconsisting of only sidebands. The upper balanced modulator (M1) generates uppersideband and lower sideband, but upper sideband is shifted by +90°whereas lowersideband is shifted by -90.The output of balanced modulators are added by the summingamplifier. Since upper sidebands of both the modulators are phase shifted by +900, they are in phase and add to produce double amplitude signal. But lower sideband of the balanced modulator are (+90° ,-90°) 180° out of phase and hence cancel each other. Thus the output of summing amplifier contains only upper sideband SSB signal. The carrier is already suppressed by balanced modulators.

Weaver's Method:

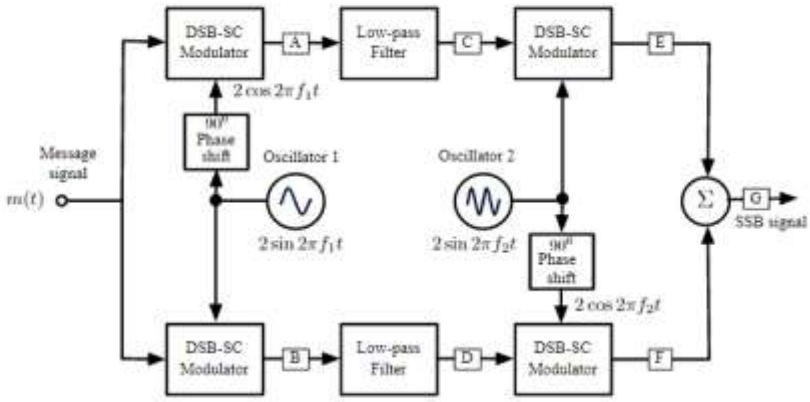


Fig 18. Weaver method

Principle: It uses two carriers: One is audio subcarrier at frequency fo and other is RFcarrier at frequency fc.The input to the modulator is s(t) = cos(2fmt). It is the modulating signal of frequency fm

Frequency spectrum of SSB:

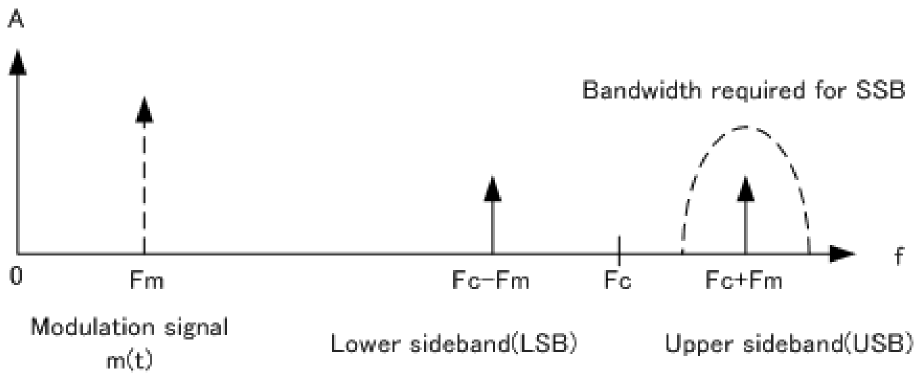


Fig.19 Frequency spectrum of SSB

Above shown is the frequency spectrum of SSB where only one sideband (USB) is retained. Here Bandwidth is fm.

8. SSB DEMODULATION

For demodulation, the same block diagram of a simple DSBSC demodulator can be used. The sideband at the positive and negative frequencies merge (recombine) at zero frequency when the SSB signal is multiplied by the carrier. (Try the exercise of finding the output of the DSBSC demodulator in time– and frequency–domain when its input is a either an USB or a LSB signal).

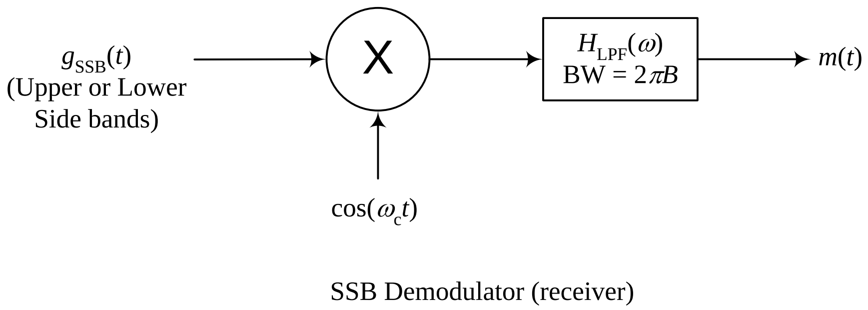


Fig.20 SSB demodulation

If the SSB signal includes a LARGE carrier, it can be demodulated using an envelope detector similar to that used for full AM signals

9. VSB MODULATION AND DEMODULATION

Generation of VSB signals:

A vestigial-sideband system is a compromise between DSB and SSB It inheritsthe advantages of DSB and SSB but avoids the r SSB. It inherits the advantages ofDSB and SSB but avoids their disadvantages.

VSB signals are relatively easy to generate and their bandwdth is VSB signalsare relatively easy to generate and their bandwidth is only slightly (typically 25 percent)greater than that of SSB signals.

In VSB, instead of rejecting one sideband completely as in SSB, a gradual cut-off of one sideband is accepted. All of the one sideband is transmitted and a small amount (vestige) of the other sideband is transmitted The filter is allowed to have a nonzero transition band.

The roll-off characteristic of the filter is such that the partial suppression of the transmitted sideband in the neighborhood of the carrier is exactly compensated for by the partial transmission of the carrier is exactly compensated for by the partial transmission of the corresponding part of the suppressed sideband.

Our goal is to determine the particular H(f) required to produce a modulated signal s(t) with desired spectral characteristics such with desired spectral characteristics, such that the original baseband signal m(t) may be recovered from s(t) by coherent detection.

$$S(f) = U(f)H(f)$$

$$= \frac{A_c}{2}[M(f - f_c) + M(f + f_c)]H(f)$$

$$m(t) \overset{F}{\Longrightarrow} M(f)\ ,\ u(t) \overset{F}{\Longrightarrow} U(f)$$

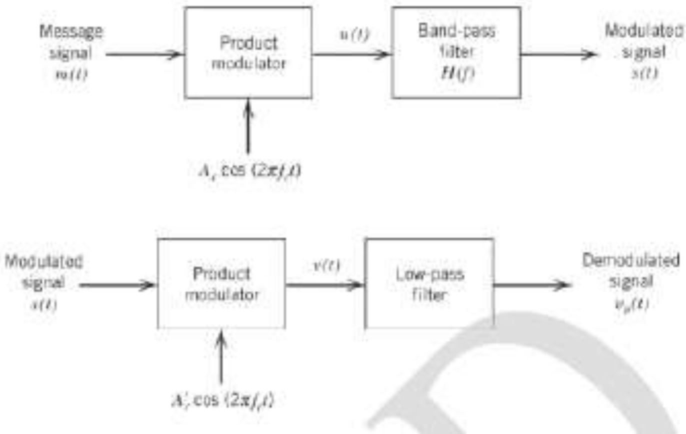


Fig.21Filtering scheme of generation of VSB modulated signal

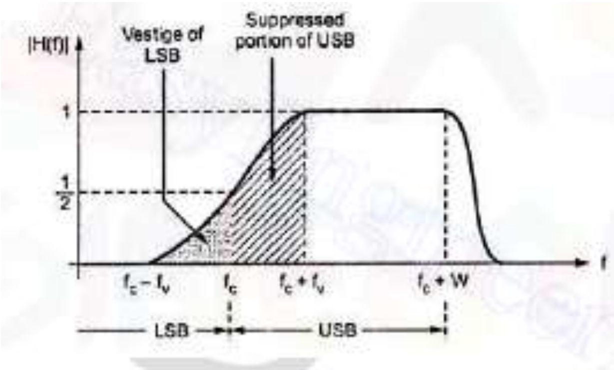


Fig22. Spectrum of VSB SC

Amplitude response of VSB filter

$$V(f) = \frac{A'_c}{2}\left[S(f-f_c)+S(f+f_c)\right]$$

$$V(f) = \frac{A_c A'_c}{4} M(f)\left[H(f-f_c)+H(f+f_c)\right] + \frac{A_c A'_c}{4}\left[M(f-2f_c)H(f-f_c)+M(f+2f_c)H(f+f_c)\right]$$

Low-pass filter

$$V_o(f) = \frac{A_c A'_c}{4} M(f)\left[H(f-f_c)+H(f+f_c)\right]$$

To obtain baseband signal m(t) at coherent detector output, we require Vo(f) to be a scaled version of M(f),Therefore we can write

$$H(f-f_c)+H(f+f_c) = 1, -W \le f \le W$$

Now equation(a) can be written as

$$V_o = \frac{A_c A'_c}{4} m(t)$$

COMPARISON OF AM MODULATION SYSTEMS

Description	AM with the carrier	DSB – SC – AM	SSB – SC -AM	VSB - AM
Bandwidth	2fm	2fm	fm	fm<BW<2fm
Power Saving for Sinusoidal	33.33%	66.66%	83.3%	75%
Power Saving for non - Sinusoidal	33.33%	50%	75%	75%
Generation methods	Easier to generate	Not difficult	More difficult to generate	Difficult.But easier to generate than SSB-SC
Detection methods	Simple & Inexpensive	Difficult	More difficult	Difficult

9.) SUPER HETERODYNE RECEIVER

In a broadcasting system whether it is based on amplitude modulation or frequency modulation, the receivers not only have the task of demodulating the modulated signal, but it is also required to perform some other system functions.

Carrier frequency tuning, the purpose of which is to select the desired signal (i.e.) desired radio or TV station) Filtering, which is required to separate the desire signal from other modulation signals that may be picked up along the way. Amplification, which is intended to compensate for the loss of signal power incurred in the course of transmission.

R.F Section

The incoming amplitude modulated wave is picked up by the receiving antenna and is fed to the RF section. The RF section consists of a pre selector and an RF Amplifier. The pre selector is a band pass filter with an adjustable centre frequency that is tuned to the desired carrier frequency of the incoming signal. The main use of the preselected is to provide sufficient band limiting to prevent undesired ratio in frequency signal or image signal. The effectiveness of suppressing unwanted image signals increases as the number of selective stages in the RF section increases and as the ratio of intermediate to signal frequency increases. R.F amplifiers are used for better selectivity.

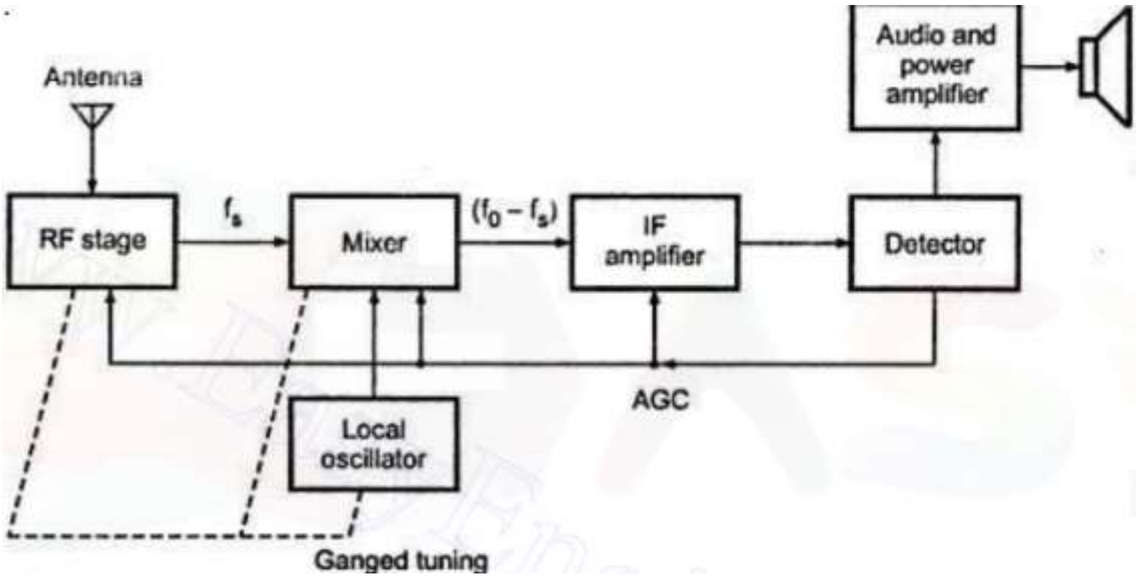


Fig23. Super Heterodyne Receiver

Frequency Changer

The combination of mixer and local oscillator provides a heterodyning functionwhereby the incoming signal is converted to a predetermined fixed intermediatefrequency, usually lower than the incoming carrier frequency. This frequency traslationis achieved without disturbing the relation of the sidebands to the carrier. The result of heterodyning is to produced an intermediate frequency carrier defined by fIF = flo –fRF

Where f_{LO} is the frequency of the local oscillator and fRF is the carrier frequency of the incoming RF signal. Since the output of the frequency his neither the original input frequency not the final baseband frequency, it is called as intermediate frequency. Sometimes the frequency changer circuits are referred to as the first detector, in which case the demodulator i s called as second detector.

IF Section

The IF section consists of one or more stages of turned amplification witha bandwidth corresponding to that required for the particular type of modulation that the receiver intended to handle. The IF section provides most of the amplification purpose of which is to recover the baseband or message signal.

If coherent detection is used, then a coherent signal source must be provided in the receiver.

Audio Amplifiers

The final stage of the super heterodyne receiver consists of one or more audio amplifiers which is used for the power amplification of the recovered message signal.

Image frequency and its rejection ratio

In a super heterodyne receiver, the mixer will develop and intermediate frequency output when the input signal frequency is greater or less than the local oscillator frequency by an amount equal to intermediate frequency

Amplitude Limiter

The basic difference between AM and FM super heterodyne receiver lies in the use of an FM Demodulator such as limiter frequency discriminator. In FM system the message signal is transmitted by the instantaneous value of carrier signal & its amplitude remain constant. Therefore any variation of the carriers amplitude at the receiver input must result from noise or interference.

An amplitude limiter following the IF section is used to remove amplitude variations by clipping the modulated wave is rounded by a band pass filter that suppresses harmonics of the carrier frequency. Thus the filter output is again sinusoidal, with an amplitude that in practically independent of the carrier amplitude of the receiver input.

Performance Parameters of Receivers

The performance of Radio receiver is measured on the basic of its selectivity,sensitivity, fidelity and image frequency rejection selectivity.

Selectivity

The selectivity is the ability of the receiver to select a signal of a desiredfrequency while rejecting all others. The selectivity of the receiver is obtained partiallyby RF amplifier and mainly by IF amplifiers. The selectivity shows the attenuation thatthe receiver offers to signals at frequencies near to the one to which it is tuned. Fig.shows the typical selectivity curve of the receiver. The s l ctivity depends upon tunedLC circuits used in RF and IF stages, fr is the resonating (tuned) frequency and Q isquality factor of these LC Circuits, As shown in Fig. bandwidth should be narrow forbetter selectivity. Hence Q of the coil should be high.

Sensitivity

The ability of the receiver to pick up weak signals and simplify them is call d sensitivity. It is often defined in terms of the voltage that must be applied to the receiv r input terminals to give the standard output power, measured at the output terminals.

As the gain of the receiver is increased, sensitivity is also increased. The sensitivity is expressed in micro volts or decibels. Fig.shows the typical sensitivity curve of a receiver. As shown in the Fig., the sensitivity is decreased (i.e., voltage is increased) at high frequencies.

Fidelity

Fidelity is a measure of the ability of a communication system to produce at the output of the receiver, an exact replica of the original source information. This may also be defined as the degree to which the system accurately reproduces at the output,the **essential c**haracteristics of signals that are impressed upon the input

Signal to noise Ratio

Signal to noise Ratio may be defined as the ratio of signal power to noise power at the receiver output. A good receiver should have high signal to noise ratio (SNR) which indicates negligible noise present at the output.

Image Frequency Rejection

We know that local oscillator frequency is made higher than the signal frequency such that f0 – fs = fi . Here fi is IF. That is f0 = fs + fi. The IF stage passes only fi . If the frequency fi = fs +2fi appears at the input of the mixer, then the mixer will produce different frequency equal to fi . This is equal to IF. The frequency fsi is called image frequency and is defined as the signal frequency plus twice the IF. The image frequency is converted in the IF stage and it is also amplified by IF amplifiers. This is the effect of two stations being received simultaneously. The image frequency rejection is done by tuned circuit in the RF stage. It depends upon the selectivity of the RF stage. The image rejection should be done before the RF stage.

10.) **Hilbert Transform**

If every frequency components of a signal f(t) is shifted by (-π/2) the resultant signal fh (t) is the Hilbert transform of f(t).

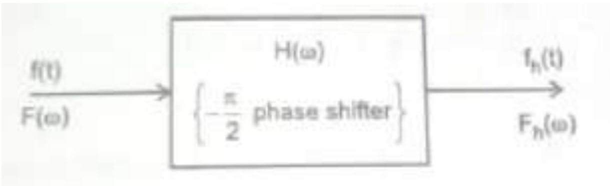


Fig.24 Phase shifting system

A signal f(t) is passed through a phase shift system H(ω) and the output fh (t) shown inabove fig.

The characteristics of the of the system specified as follows:

i) The magnitude frequency components present in f(t) remains unchanged when it ispassed through the system that is H(ω) = 1 and

ii) The phase of the positive frequency components if shifted by -π/2 . Since the phase spectrumθ(ω) has an odd symmetry, the phase of the negative frequency componentsis shifted by π/2. H(ω) and θ(ω) are plotted in Fig by continuous and dotted linesrespectively.

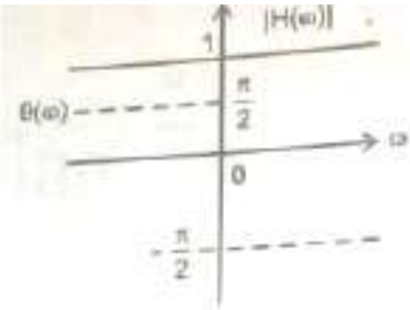


Fig 25.Transfer function of phase shifter

Properties of Hilbert transform

Hilbert transform has the following properties

1. A signal f(t) and its Hilbert transform have the same magnitude spectrum.

2 A signal f(t) and its Hilbert transform sh(t) have the same energy density spectrum.
3 If the Hilbert transform of fh(t) is –f(t), then fh(t) is Hilbert transform of s(t) that is if

$$H[f(t)] = f_H(\text{t})$$

$$H[f_H(\text{t})] = -f(\text{t'})$$

Where H denotes the Hilbert transform.

1. A signal f(t) and its Hilbert transform fh(t) are mutually orthogonal over the time interval (-∞,∞) that is

$$\int_{-\infty}^{\infty} f(t) f_h(t) \boldsymbol{dt} = 0$$

2. A signal f(t) and its Hilbert transform fh(t) have the same auto correlation function. Some useful Hilbert transform.

Application of Hilbert transform pair

1. Generation of SSB signal
2. Design of minimum phase type filters Representation of band pass signals

1. $\cos \omega_c t \xrightarrow{H} \sin \omega_c t$
2. $\sin \omega_c t \xrightarrow{\quad H \quad} \cos \omega_c t$
3. $\sin(\omega_c t + \theta) \xrightarrow{H} \cos(\omega_c t) + \theta - \frac{\pi}{2}$
4. Let *m(t)* be a low pass signal with cutoff frequency W_1 abd *c(t)* a high pass signal with lower cut off frequency $\omega_2 > W_1$. Then

$$m(t)c(t) \xrightarrow{\quad H \quad} m(t)^{n}_{c}(t)$$

Pre envelope:

The pre envelope of a real signal x(t) is the complex function

$$x_+(t) = x(t) + j\,\hat{x}(t).$$

The pre envelope is useful in treating band pass signals and systems. This is due to the result

$$\begin{cases} 2\,X(v), & v > 0 \\ X(0), & v = 0 \\ X+(v)\ 0, & v < 0 \end{cases}$$

Complex envelope:

The complex envelope of a band pass signal x(t) is

$X'(t) = x_+(t)$