DEPARTMENT
OF
ELECTRONICS & COMMUNICATION ENGINEERING

Communication Theory
[19EC4DCOT]

(Theory Notes)

Autonomous Course

Prepared by

Sapna P J

Module – 1 Contents
Amplitude modulation: Elements of communication system, AM modulation techniques: DSBFC Time and frequency domain description, modulation index, Spectral analysis, Generation of AM using square law modulator, Detection of AM using Envelope Detector. DSBSC Time and frequency domain description, Generation of DSBSC using Balanced Modulator, Coherent detection of DSBSC, SSBSC with frequency domain description, VSB with frequency domain description, Frequency translation, FDM

Dayananda Sagar College of Engineering
Shavige Malleshwara Hills, Kumaraswamy Layout,
Banashankari, Bangalore-560078, Karnataka
Tel : +91 80 26662226 26661104 Extn : 2731 Fax : +90 80 2666 0789
Web - http://www.dayanandasagar.edu Email : hod-ece@dayanandasagar.edu

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UNIT 1

INTRODUCTION:

Modulation is a fundamental used in communication systems. It is defined as a process by which some characteristic of a signal called carrier is varied in accordance with instantaneous value of another signal called modulating signal. Information signal is called modulating signal or baseband signal. The carrier frequency is much greater than the modulating frequencies. The signal resulting from the process of modulation is called modulated signal.

There are three types of modulations

1] Amplitude Modulation

2] Frequency Modulation

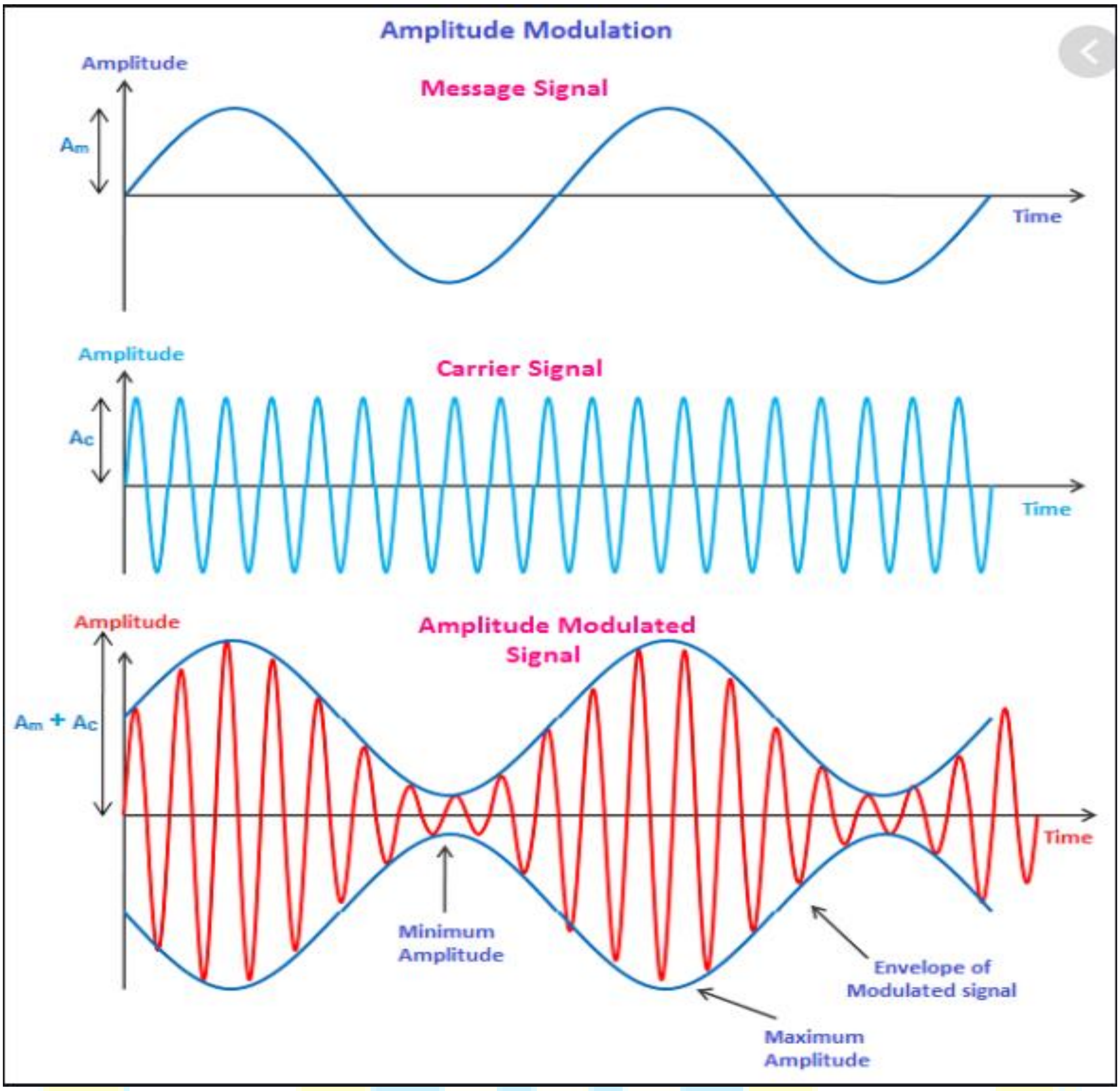
3] Phase Modulation

NEED FOR MODULATION

1. Increases the range of communication
2. Reduces the height of the Antenna
3. Avoids mixing of the signals
4. Allows multiplexing of the signals
5. Improves quality of reception

AMPLITUDE MODULATION:

Amplitude Modulation is defined as the process in which amplitude of the carrier wave is varied in accordance with the instantaneous amplitude of the modulating signal. Frequency and phase of the carrier is kept constant.

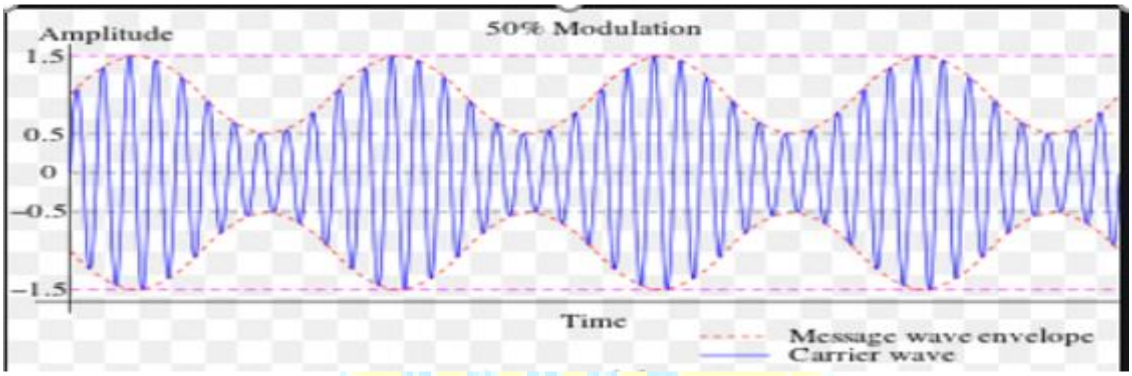


The degree of modulation is reflected by the modulation index. Modulation index is the ratio of max value of the modulating signal to the max value of the carrier

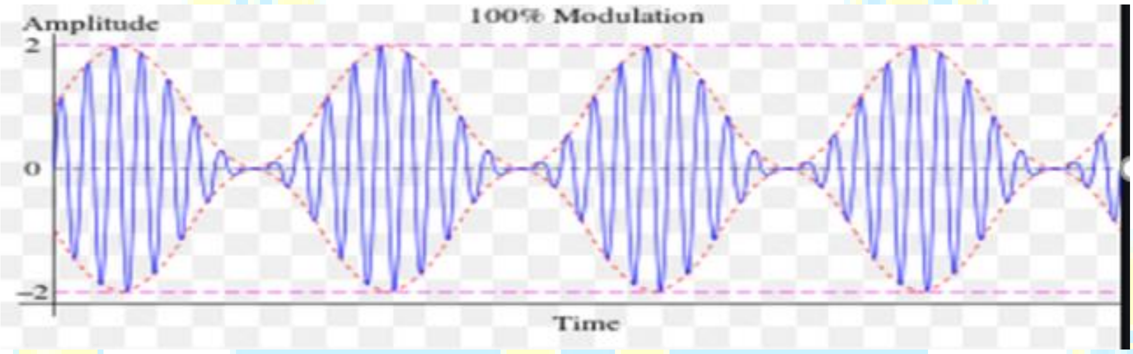
$$m = \frac{Am}{Ac}$$

This value lies between 0 and 1 and is often expressed as a percentage and is called percentage modulation

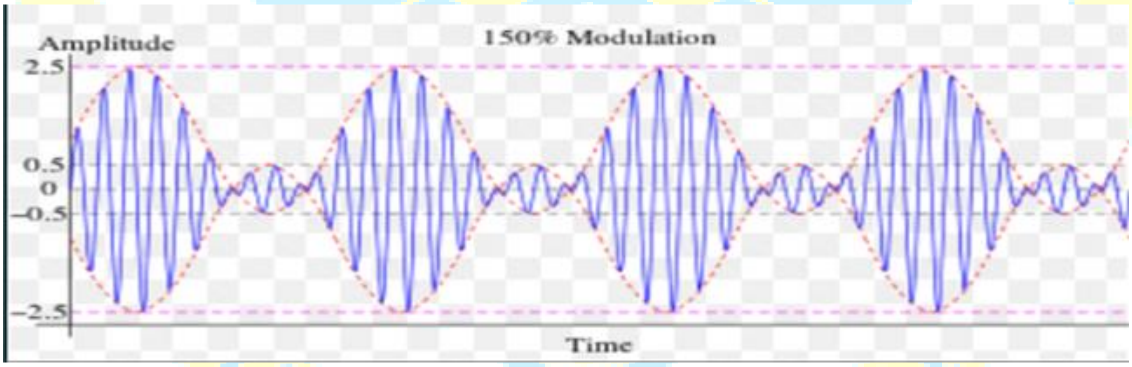
For m<1, Ac >Am , let Ac = 1v and Am = 0.5v



For m =1, Ac =Am , let Ac = 1v and Am = 1v



For m >1, Ac < Am , let Ac = 1v and Am = 1.5v



TIME DOMAIN DESCRIPTION:

Let A_m = Amplitude of modulating signal

f_m = modulating frequency

A_c = Amplitude of carrier signal

f_c = carrier frequency

The modulating signal is given by m(t)

The carrier signal is given by c(t)

$$c(t) = A_c \ \text{Cos}\ 2\pi f_c t \quad \text{---------1}$$

Let A be the Amplitude of the modulated signal and is given by

$$A = A_c + m(t) \quad \text{-----------2}$$

The instantaneous value of AM wave is given by

$$S(t) = A\ \text{Cos}\ 2\pi f_c t \quad \text{------3}$$

Sub Eqn 2 in Eqn3 we get

$$S(t) = A_c\ [1 + Ka\ m(t)]\ \text{Cos}\ 2\pi f_c t$$

Where Ka is a constant called the amplitude sensitivity.

Simplifying the above equation

$$S(t) = A_c\ \text{Cos}\ 2\pi f_c t + A_c Ka\ m(t)\ \text{Cos}\ 2\pi f_c t \quad \text{-------- (I)}$$

FREQUENCY DOMAIN DESCRIPTION:

Taking Fourier transform of eqn (I)

$$S(f) = A_c\ [\partial\ (f\text{-}fc) + \partial\ (f\text{+}fc)] + A_c\ Ka/2\ [\ M(f - fc) + M(f + fc)]$$

Spectrum S(f) of AM wave is as shown in Fig below

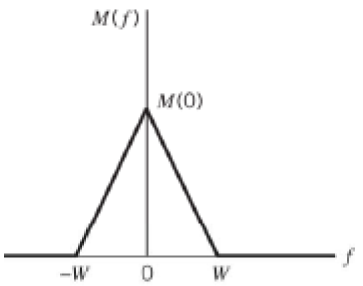


Fig: spectrum of the message signal

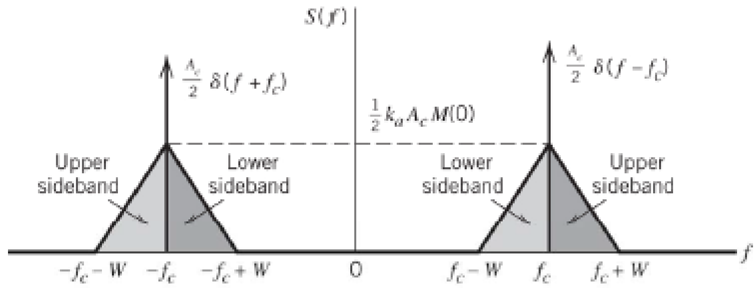


Fig: Spectrum of AM

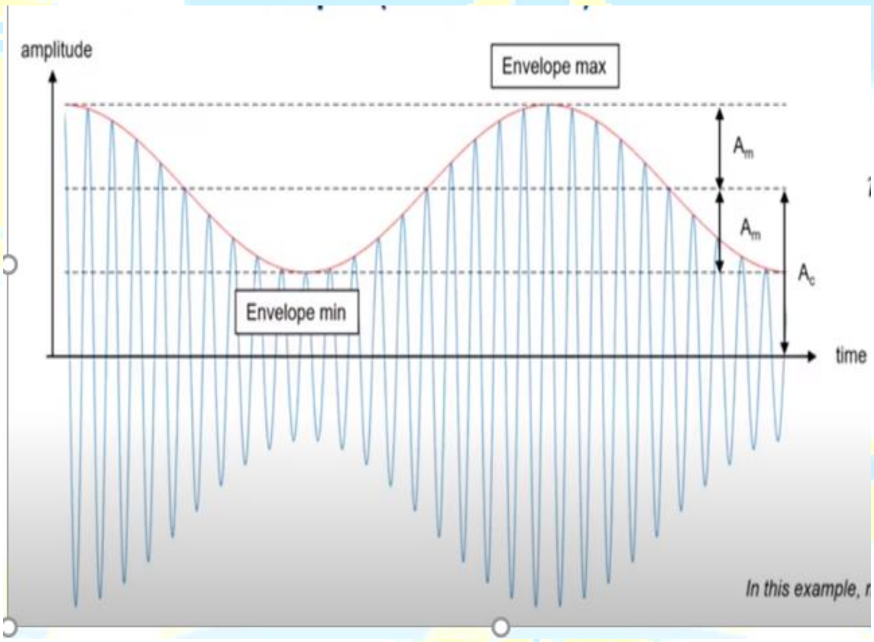
We can observe that

1. The message spectrum centered at f=0 and extending from –W to W gets translated to fc
2. On either sides of ±fc, bands known as the upper and lower sidebands are present. Frequencies fc < |f | < fc + W constitutes upper side band (USB) and frequencies fc – W < |f | < fc constitutes lower sideband(LSB).
3. The width of the spectrum S(f) for positive frequencies defines transmission bandwidth B for AM wave and is given by 2W or 2fm

EXPRESSION OF MODULATION INDEX IN TERMS OF AMAX AND AMIN

w.k.t $m = \frac{Am}{Ac}$

From fig $Am = \frac{Amax - Amin}{2}$



$Ac = Amax - Am$

$Ac = Amax - \frac{Amax - Amin}{2}$

$Ac = \frac{Amax + Amin}{2}$

$m = \frac{Amax - Amin}{Amax + Amin}$

POWER RELATIONS IN AM WAVE

Total power is sum of carrier power and power in two side bands

$$P_T = P_c + P_{USB} + P_{LSB}$$

w.k.t $S(t) = Ac\cos(2\pi f_c t)] + \frac{Ac\, m}{2}[\cos 2\pi(f_c - f_m)t + \cos 2\pi(f_c + f_m)t$

$$= \frac{A^2{}_{Carrier}}{R} + \frac{A^2{}_{USB}}{R} + \frac{A^2{}_{LSB}}{R}$$

$$= \frac{A_c^2}{2R} + \frac{m2A_c^2}{8R} + \frac{m2A_c^2}{8R}$$

$$P_T = \frac{A_c^2}{2R}[1 + \frac{m^2}{2}]$$

$$P_T = [1 + \frac{m^2}{2}]P_c$$

EFFICIENCY OF TRANSMISSION

It is the ratio of the power carried by the side bands to the total power

$$\eta = \frac{PSB}{PT}$$

$$= \frac{\frac{m2A_c^2}{8R} + \frac{m2A_c^2}{8R}}{\frac{A_c^2}{2R}[1 + \frac{m^2}{2}]}$$

$$= \frac{m2}{2+m2}$$

When m=0, η =0%

m= 0.5, η =11.1%

m= 1, η =33.3%

CURRENT CALCULATION FOR AM

I_T = total current (modulated)

I_C = unmodulated carrier current

$$\frac{PT}{PC} = \frac{R\,II^2}{R\,Ic^2} = [1 + \frac{m^2}{2}]$$

$$II^2 = [\ 1+ \frac{m^2}{2}]\ \ IC^2$$

$$II = \sqrt{[\ 1+ \frac{m^2}{2}]}\ IC$$

MODULATION BY SEVERAL SINE WAVES

Several sine waves are simultaneously used to modulate a carrier then m1, m2,m3 are the modulation indices of these waves

Total power is now given by

$$P_T = P_c + P_{USB1} + P_{LSB1} + P_{USB2} + P_{LSB2} + \ldots\ldots$$

$$= \frac{A_c^2}{2R} + \frac{m1^2A_c^2}{8R} + \frac{m1^2A_c^2}{8R} + \frac{m2^2A_c^2}{8R} + \frac{m2^2A_c^2}{8R} + \ldots\ldots$$

$$P_T \ = \frac{A_c^2}{2R}[\ 1+ \frac{m1^2}{2} + \frac{m2^2}{2} + \text{---}]$$

$$P_T \ = [\ 1+ \frac{mt^2}{2}]\ P_c$$ where $mt^2 = m1^2 + m2^2 + \text{----}$

SINGLE TONE MODULATION:

Time domain description:

Consider a wave that consists a single tone or frequency component that is

$m(t) = A_m \ \ Cos\ 2\pi f_m t$ ---------1

w.k.t

$S(t) = A_c\ [1 + Ka\ m(t)]\ Cos\ 2\pi f_c t$ ------2

Sub 1 in 2

$S(t) = A_c\ [1 + Ka\ A_m \ Cos\ 2\pi f_m t\ ]\ Cos\ 2\pi f_c t$-----3

Eqn 3 becomes

$S(t) = A_c\ [1 + m \ Cos\ 2\pi f_m t\ ]\ Cos\ 2\pi f_c t$

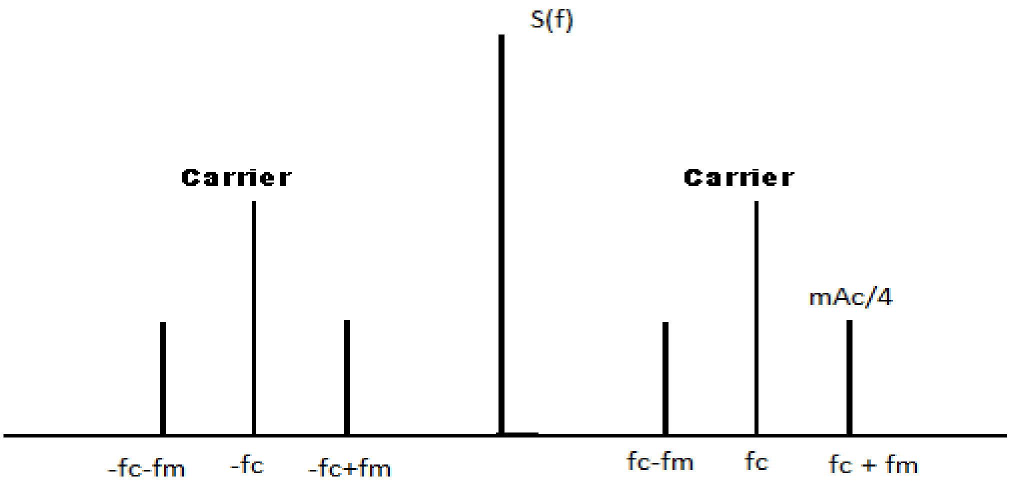
$S(t) = A_c\ Cos\ 2\pi f_c t \ + m\ A_c/2\ [\ Cos\ 2\pi\ (fc - \ fm)t + \ Cos\ 2\pi\ (fc + fm)t$

FREQUENCY DOMAIN DESCRIPTION:

The fourier transform of the above eqn is

$$S(f) = A_c/2\ [\partial\ (f\text{-}fc) + \partial\ (f\text{+}fc)] + m\ A_c/4\ [\partial\ (f\text{-}fc\ \text{+}fm) + \partial\ (f\text{+}fc\text{-}fm)]$$
$$+\ mA_c/4\ [\partial\ (f\text{-}fc\ \text{-}fm) + \partial\ (f\text{+}fc\text{+}fm)]$$

From the above eqn it is clear that modulated wave contains 3 terms. The 1st term represents the unmodulated carrier. The 2nd term is the lower sideband and the 3rd term is the upper sideband. Frequency spectrum is given by



Problems

1. A 220w unmodulated carrier is modulated to a depth of 65%. Calculate the total power in the modulated wave.

Given P_c = 220w

m = 0.65

$$\frac{PT}{PC} = [\ 1+\frac{m^2}{2}]$$

$$PT\ = 266.5w$$

2. An audio frequency signal 5 sin2π(1000)t is used to amplitude modulate a carrier of 100 sin2π(10^6)t . Assume modulation index as 0.4. Find the
i) side band frequencies ii) Amplitude of each side band
iii) bandwidth required iv) Total power delivered to the load of 100Ω

Given w.k.t $m(t)= Am \cos(2\pi f_m t)$ and $c(t) = Ac \cos(2\pi f_c t)$

$= 5 \sin 2\pi(1000)t$ $= 100 \sin 2\pi(10^6)t$

Am = 5; fm =1000Hz ; m=0.4; Ac = 100; fc= 10^6 Hz ; R= 100Ω

i) LSB = fc-fm = 999KHz ; USB = fc+fm = 1.001MHz

ii) Amplitude of each side band = $\frac{Ac\, m}{2}$ = 20V

iii) B.W= 2fm =2000Hz

iv) $P_T = \frac{A_c^2}{2R}[1+\frac{m^2}{2}] = 54w$

GENERATION OF AM:

AM can be generated by using square law modulator and the switching modulator. Both of which require the use of a nonlinear element for their implementation. These two devices are well suited for low power modulation purposes

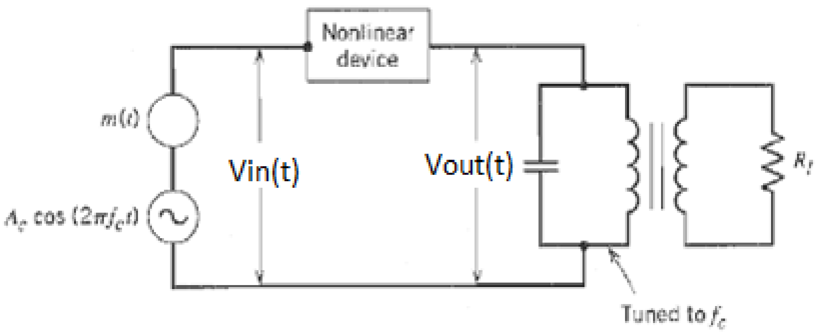
SQUARE-LAW MODULATOR :

A square law modulator consists of non-linear element and a band pass filter. The non-linear element used may be a diode or a transistor.

When a non-linear element such as a diode is suitably biased and operated in a restricted portion of the characteristic curve, we find that the transfer chs. Of the diode load resistor combination can be represented as square law i.e

$$V_{out}(t) = a_1 V_{in}(t) + a_2 Vin^2(t) \text{ -----1}$$

Where a_1 and a_2 are constants



Input voltage of the carrier wave plus modulating wave

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

Sub 2 in 1

$V_2(t) = a_1 A_c [1 + 2 a_2 / a_1 m(t)] \cos 2\pi f_c t + a_1 m(t) + a_2 m^2(t) + a_2 A_c^2 \cos^2 2\pi f_c t$

Specifications of the BPF

Mid band frequency =fc

B.W =2W

Frequency specifications

fc-W > 2W & 2fc> fc+W

fc>3W & fc>W

therefore fc>3W

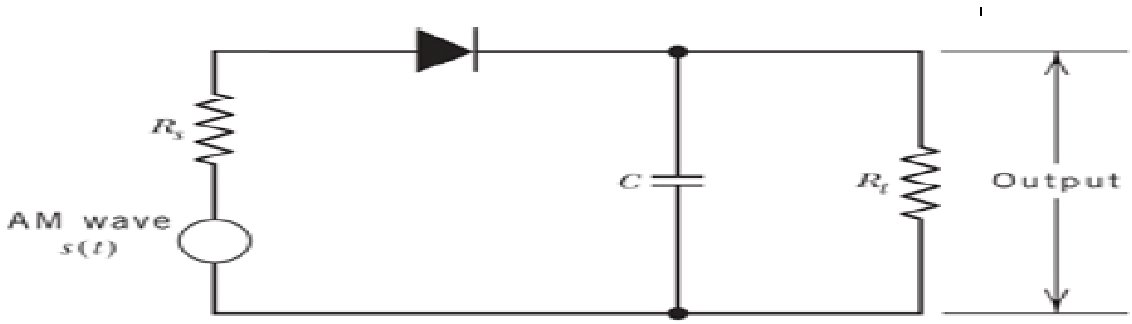
DETECTION OF AM WAVES:

Demodulation or detection is the process by which the message is recovered from the modulated wave at the receiver. This is a downward frequency translation widely used Amplitude demodulators are square law demodulators and envelope detectors.

ENVELOPE DETECTOR:

An envelope detector is a simple and highly effective device that is well suited for the demodulation of narrow band AM wave for which the percentage modulation is less than

100%.in an envelope detector the output of the detector follows the envelope of the modulated signal. Envelope detector consists of a diode and a resistor capacitor filter.



On the positive half cycle of the input signal the diode is forward biased and the capacitor C charges up rapidly to the peak of the input signal.

When the input signal falls below this value, the diode becomes reverse biased and the capacitor discharges through the load resistor R_L. The discharge process continuous until the next positive half cycle. When the input signal becomes greater than the voltage across the capacitor the diode conducts again and the process is repeated.

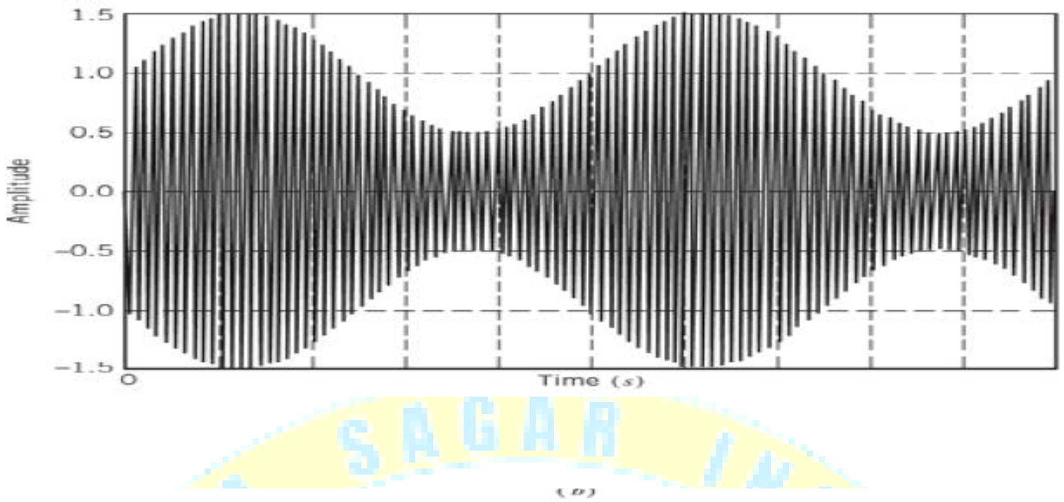
The charging time constant R_sC must be short compared with the carrier time period i.e

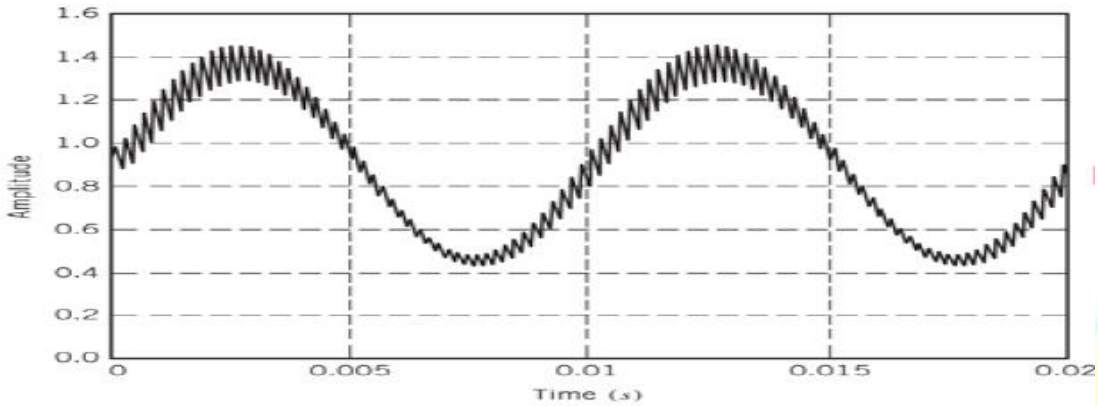
$$R_sC \ll \frac{1}{fc}$$

So that the capacitor charges rapidly and thereby follows the applied voltage when the diode is conducting. On the other hand the discharging time constant R_LC must be long enough to ensure that the capacitor discharges slowly through the resistor R_L between positive peaks of the carrier wave, but not so long that the capacitor voltage will not discharge at the maximum rate of change of the modulating wave

$$\frac{1}{fc} \ll R_L \ll \frac{1}{W}$$

Where W is the message bandwidth.





LIMITATIONS AND MODIFICATIONS OF AM

AM is the oldest method of performing modulation

Am is cheap to build and simple

AM is used in Radio broadcasting

Limitations:

1. AM is wasteful of Power
2. AM is wasteful of Bandwidth

To overcome these limitations three modified forms of AM are used

1.Double Side Band suppressed carrier [DSBSC]

2.Vestigial Side Band suppressed carrier [VSBSC]

3. Single Side Band suppressed carrier [SSBSC]

DOUBLE SIDEBAND SUPPRESSED CARRIER MODULATION (DSB-SC)

In the standard form of amplitude modulation the carrier wave is completely independent of the message signal which means that the transmission of the carrier wave represents a waste of power i.e for 100% modulation about 67% of the total power is required for transmitting the carrier which does not contain any information. To overcome this short coming, the carrier is suppressed before transmission which reduces the overall power required. This type of modulation is known as double side band suppressed carrier modulation

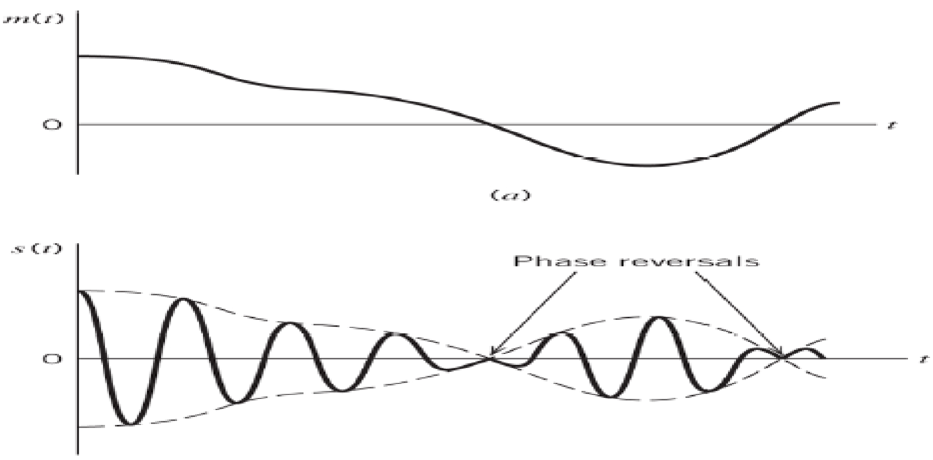
TIME DOMAIN DESCRIPTION:

DSB-SC modulation consists of product of message signal m(t) and the carrier C(t)

$$S(t) = C(t)\, m(t)$$

$$= A_c \cos 2\pi f_c t \quad m(t) \quad \text{----1}$$

This modulated wave undergoes a phase reversal whenever the message signal m(t) crosses zero. Unlike amplitude modulation the envelope of a DSBSC modulated wave is different from the message signal.



FREQUENCY DOMAIN DESCRIPTION:

The suppression of the carrier from the modulated wave is well understood by examining the frequency spectrum. Taking Fourier transform of both sides of S(t)

$$S(t) = A_c \cos 2\pi f_c t \quad m(t)$$

$$S(f) = \frac{Ac}{2} [\ M(f-fc) + M(f+fc)] \quad ---2$$

When the message signal m(t) is limited to the interval $-W \le f \le W$ as in fig a. the modulation process simply translates the base band spectrum by $\pm$ fc. The transmission bandwidth is 2W same as that of standard AM

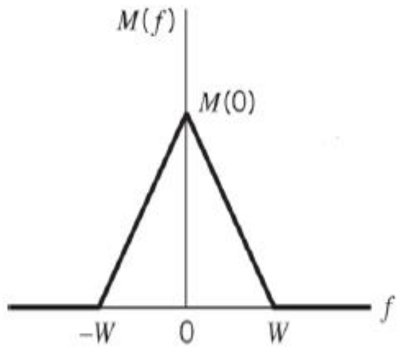
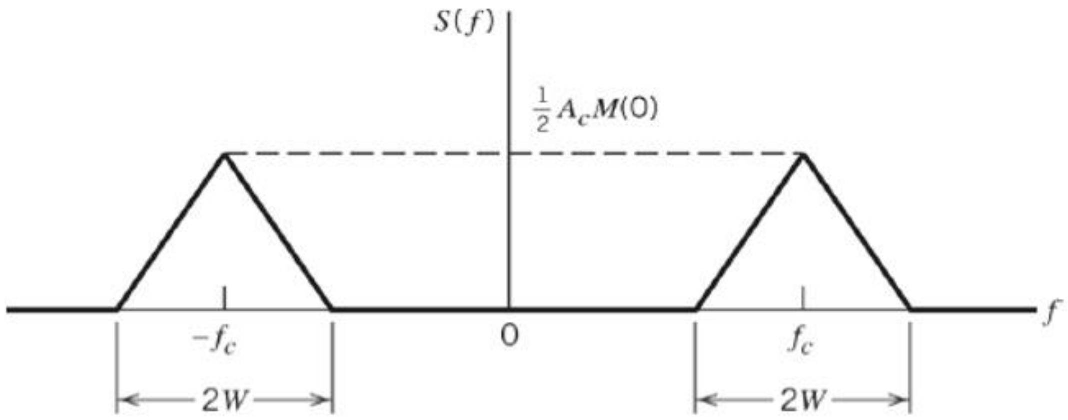


Fig a: message spectrum

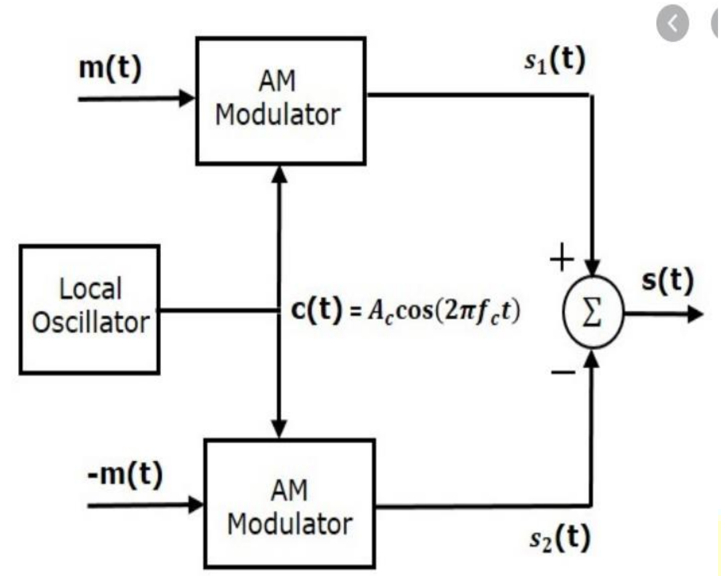


GENERATION OF DSBSC WAVES:

A DSB-SC signal is the product of the base band signal and the carrier wave. A single electronic device or component cannot generate this signal. A system for achieving this is called a product modulator. Two types of product modulators are balanced modulator and the ring modulator.

BALANCED MODULATOR:

It consists of two AM modulators arranged in Balanced configuration to suppress the carrier.



Let us assume that the two modulators are identical. One input to each modulator is from an oscillator which generates sinusoidal carrier . Other imput signal is the modulating wave.base band signal is applied to one of the modulators has a sign reversal. The output of two AM modulators can be expressed as

$S_1(t) = A_c\,[1 + Ka\, m(t)]\, \mathrm{Cos}\, 2\pi f_c t$ -----1

$S_2(t) = A_c\,[1 - Ka\, m(t)]\, \mathrm{Cos}\, 2\pi f_c t$ ------2

$S(t) = S_1(t) - S_2(t)$

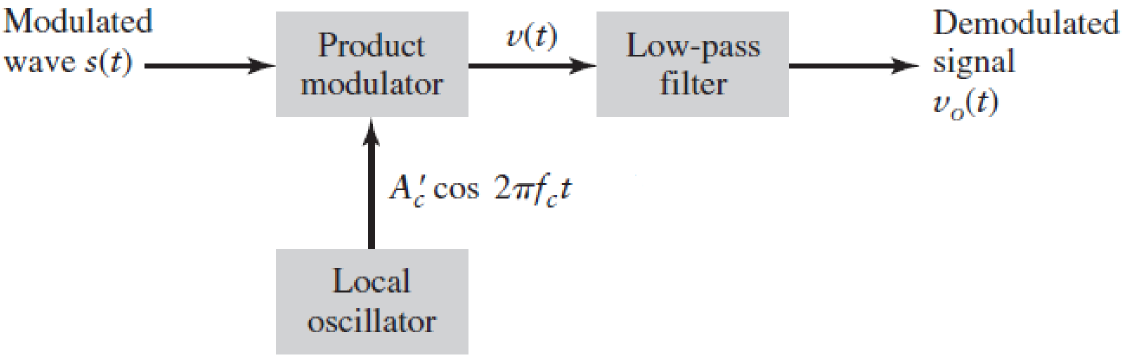
$= 2\, A_c\, Ka\, m(t) \cos 2\pi f_c t$

Therefore except for scaling factor 2Ka the balanced modulator output signal to the product of the modulating wave and the carrier, which is nothing but the DSB-SC signal.

DEMODULATION OR DETECTION OF DSB_SC SIGNALS:

Synchronous detection or coherent detection:

The message signal m(t) is recovered from a DSB-SC wave s(t) by first multiplying s(t) with a locally generated sinusoidal wave and then low-pass filtering the product as in the figure below



It is assumed that the local oscillator output is exactly coherent or synchronized in both frequency and phase , with the carrier wave c(t) used in the product modulator to generate s(t). This method of demodulation is known as coherent detection

$V(t) = S(t) Ac' \cos 2\pi f_c t$

$= Ac \cos 2\pi f_c t \;\; Ac' \cos 2\pi f_c t$

$$Vo(t) = \frac{AcAc'}{2}\, m(t)$$

The desired signal centered about f=0 is obtained by passing volt through an ideal LPF of band width greater than WHz but less than $2f_c$-WHz.

Two Possible errors:

1] **Frequency error :-**

Let the output of the local oscillator be $\cos 2\pi f_1 t$ where $f_1 = f_c \pm \Delta f$. where Δf is the error in frequency.

$$V(t) = S(t) \cos 2\pi f_1 t$$

$$= A_c \cos 2\pi f_c t \; m(t) \cos 2\pi f_1 t$$

$$= \frac{A_c}{2} m(t) [\cos 2\pi(f_c - f_1) t + \cos 2\pi(f_c + f_1) t]$$

So we can see that there is no desired modulating signal . for small vaues of Δf the base band spectrum will overlap . However for speech signals Δf=10Hz is tolerable.

2) Phase Error:

For recovery of modulating signal m(t) the local oscillator output should be exactly of the same frequency but arbitrary phase difference ϕ is measured with respect to the carrier wave c(t) Thus if the local oscillator output is $\cos(2\pi f_c + \phi)$. The output of product modulator is given by

$$V(t) = S(t) \cos(2\pi f_c t + \phi)$$

$$= A_c \cos 2\pi f_c t \; m(t) \cos(2\pi f_c t + \phi)$$

$$= \frac{A_c m(t)}{2} \cos(4\pi f_c t + \phi) + \frac{A_c m(t)}{2} \cos(\phi) \text{ ---A}$$

The first term in equation (A) represents a DSB-SC modulated signal with carrier frequency $2f_c$ whereas the 2^{nd} term is proportional to the message signal m(t).

The first term of equation (A) is removed by LPF provided cut off frequency of this filter is greater than W but less than $2f_c - W$. This is satisfied by choosing $f_c - W$.

Therefore filter output is given by

$$V_O(t) = \frac{Acm(t)}{2}\cos(\phi)$$

The demodulated signal $V_o(t)$ is therefore proportional to m(t) when the phase error ϕ is a constant . The amplitude of this demodulated is max when $\phi = 0$ and is minimum(zero) when $\phi = \pm \pi/2$. The zero demodulated sugnal , which occurs for $\phi = \pm \pi/2$ represents the quadrature null effect of the coherent detector.

Thus phase error ϕ in the local oscillator causes the detector output to be attenuated by a factor equal to cos ϕ. As long as the phase error ϕ is constant the detector output provides an undistorted version of the original base band signal m(t). However phase error ϕ varies randomly due to random variations in the communication channel. Therefore provision must be made in the system to maintain the local oscillator in the receiver in perfect synchronism in both frequency and phase with the carrier wave used to generate the DSB-SC signal in the transmitter.

SINGLE TONE MODULATION

$$m(t) = A_m \ \text{Cos}\ 2\pi f_m t$$

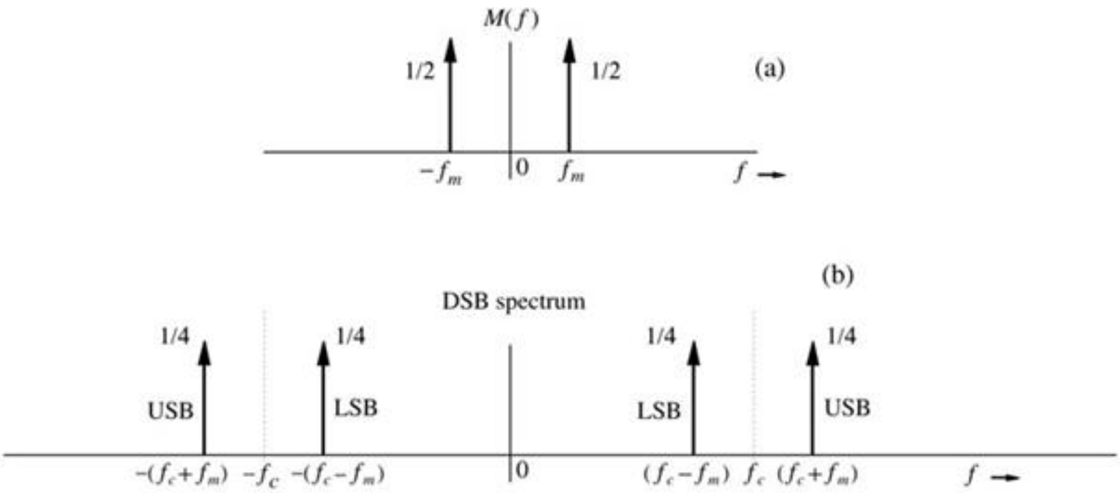
$$S(t) = Ac\ \text{Cos}\ 2\pi f_c t \quad A_m\ \text{Cos}\ 2\pi f_m t$$

$$= \frac{Ac\ Am}{2}\text{Cos}\,[2\pi(f_c+f_m)\,t\ ] + \frac{Ac\ Am}{2}\ \text{Cos}\,[2\pi(fc-fm)\,t\ ]$$

Taking Fourier transform

$$S(f) = \frac{Ac\ Am}{4}[\partial(f-fc-fm) + \partial(f+fc=fm) + \partial(f-fc+fm) + \partial(f+fc-fm)]$$

Thus the spectrum is



DETECTION :

Assuming perfect synchronism between local oscillator and the carrier wave

$$V(t) = S(t)\ \mathrm{Cos}\ 2\pi f_c t$$

$$= (Ac\ \mathrm{Cos}\ 2\pi f_c t \quad A_m\ \mathrm{Cos}\ 2\pi f_m t)\ \mathrm{Cos}\ 2\pi f_c t$$

$$= \frac{Ac\ Am}{4}[\mathrm{Cos}\ [2\pi(2f_c+f_m)\ t\ ] + \frac{Ac\ Am}{2}\ \mathrm{Cos}\ 2\pi f_m t + \frac{Ac\ Am}{4}[\mathrm{Cos}\ [2\pi(2f_c-f_m)\ t\ ]$$

2^{nd} term is the desired modulating signal. 1^{st} and 3^{rd} are unwanted terms which are removed using a LPF . Therefore the coherent detector output reproduces original modulating wave.

SINGLE SIDE BAND –SUPPRESSED CARRIER [SSB-SC] MODULATION

We know that conventional AM and DSBSC wave bandwidth is $2f_m$. In both these systems one half of the transmission bandwidth is occupied by the upper side band (USB) and the other half is occupied the lower side band (LSB) . But the information contained in the USB is exactly identical to that carried by the LSB. Therefore we can transmit only one side band LSB or USB without loss of information. It is possible to suppress the carrier and one side band completely by the modulation technique known as single side band modulation

FREQUENCY DOMAIN DESCRIPTION:

The precise frequency domain description of a single side band modulated wave depends on which side band is transmitted. Consider a message signal m (t) with a spectrum Mf) limited to the band $-W \le f \le W$ as in figure

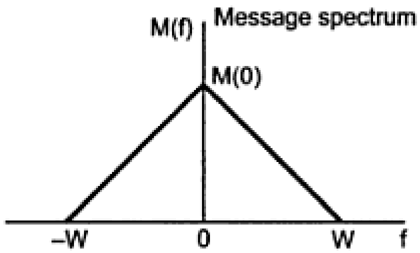


Fig a

The spectrum of DSB-SC modulated wave is obtained by multiplying m(t) by the carrier wave $V_c\cos2\pi f_c t$ is as in figure (b)

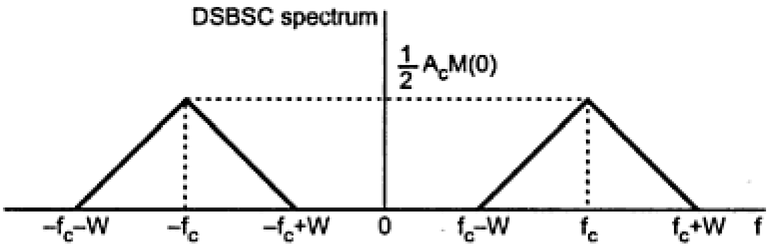


Fig b

The upper side band is represented by the frequencies above f_c and those below $-f_c$. When only USB in transmitted the resulting SSB modulated wave has the spectrum shown in figure (c)

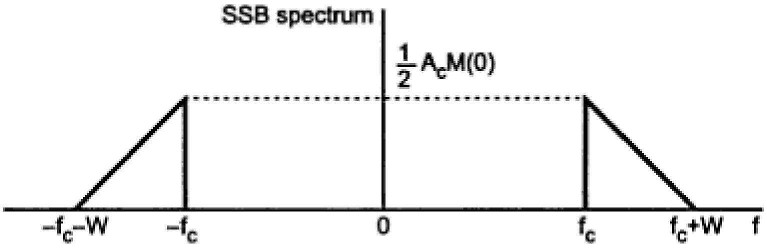


Fig c

Likewise , the lower side band is represented by frequencies below f_c and those above $-f_c$ and when only the LSB is transmitted , the spectrum is as shown in figure (d)

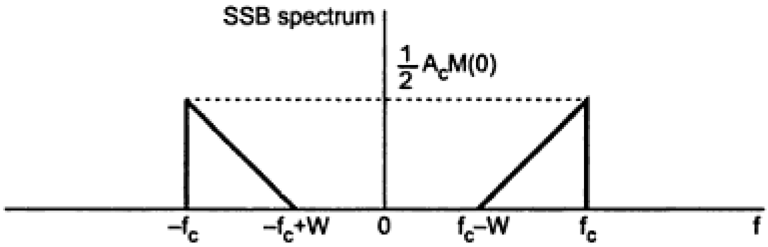


Fig d.

Benefit of SSB: - reduced bandwidth

Elimination of high power carrier wave

Disadvantage: - cost and complexity of its implementation

VESTIGIAL SIDE BAND MODULATION[VSB-SC]

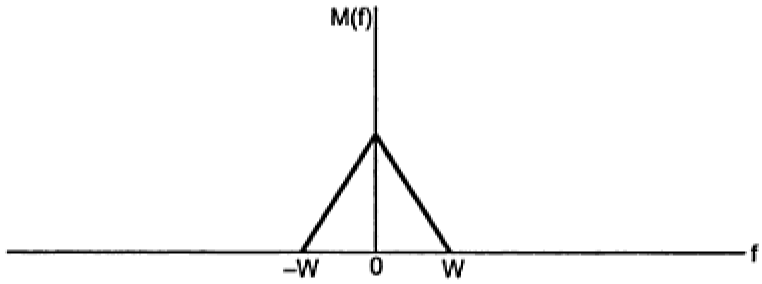
Single side band modulation is well suited for the transmission of voice because of the energy gap that exists in the spectrum of voice signals. Between zero and a few hundred hertz. When the message signal contains significant components at extremely low frequencies, the upper and lower side bands meet at the carrier frequency. This means that the use of SSB modulation is inappropriate for the transmission of such signals owing to the difficulty of isolating one side band. Therefore another scheme known as Vestigial Side Band Modulation is used. Here one sideband is passed almost completely whereas just a trace or vestige of the other sideband is retained.

FREQUENCY DOMAIN DESCRIPTION:

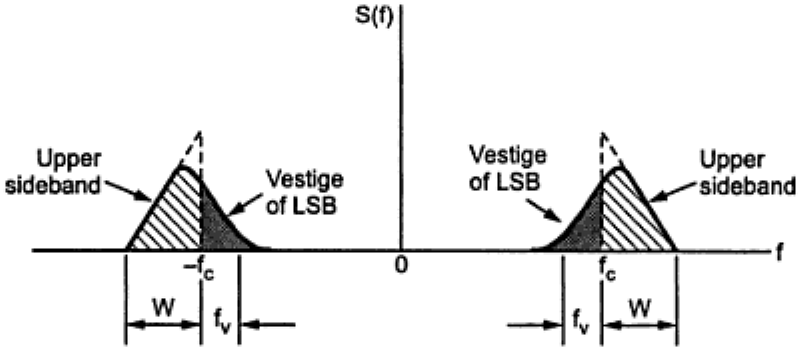
Fig shows the spectrum of the VSB modulated wave S (t) in relation to that of message signal assuming that the lower sideband is modified into the vestigial sideband. The transmitted vestige of the LSB compensates for the amount removed from the USB. The transmission bandwidth required by the VSB modulated wave is therefore given by

$B = W + fv$

Where W is the message bandwidth and fv is the width of the vestigial side band



(a) Spectrum of message signal



(b) Spectrum of VSB modulated wave

The VSB modulation has become standard for the transmission of television and similar signals where good phase characteristics and transmission of low frequency components are important

COMPARISON OF AMPLITUDE MODULATION TECHNIQUES

Standard AM:

1. Side bands are transmitted in full along with carrier
2. Demodulation is accomplished by using an envelope detector or square law detector
3. Require more power to transmit

DSB-SC:

1. Carrier is suppressed
2. More complex circuitry
3. Requires less power to transmit
4. Transmitters are less expensive than standard AM

SSB:

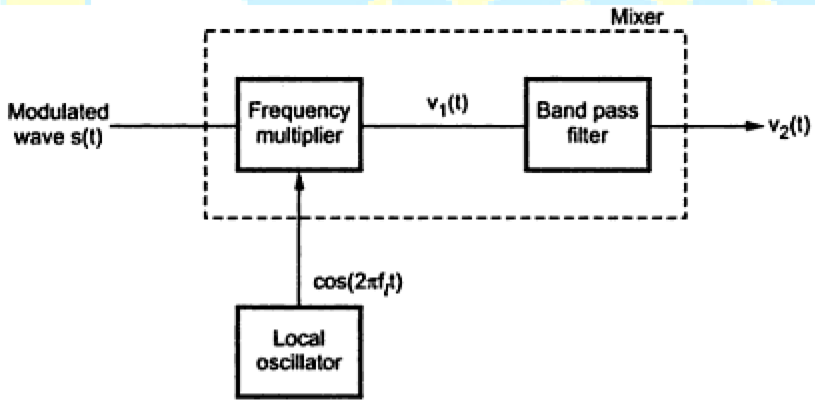
1. Requires minimum transmitter power
2. Requires minimum transmission bandwidth

VSB

1. Requires a transmission bandwidth that is intermediate between that required for SSB or DSB-SC

FREQUENCY TRANSLATION:

In communication systems, it is often necessary to translate the modulated wave upward or downward in frequency so that it occupies a new frequency band. This frequency translation is accomplished by multiplication of the signal by a locally generated sine wave, and subsequent filtering



Consider the DSB-SC wave

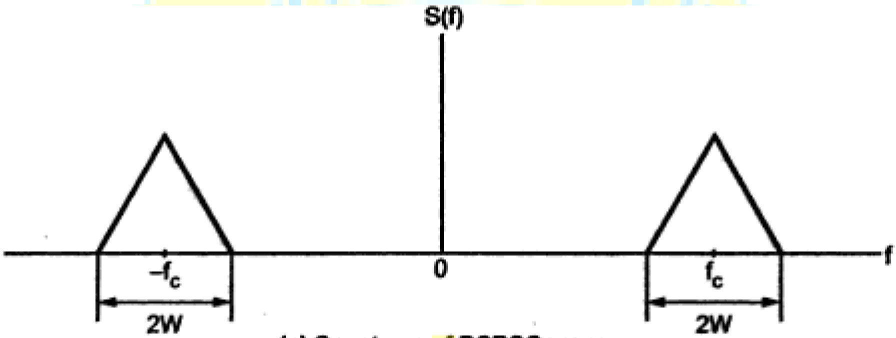
$$S(t) = m(t) \text{ Cos } 2\pi fct \text{ -------1}$$

Suppose that it is required to translate this modulated wave downward in frequency, so that its carrier frequency is changed from fc to a new value fo, where fo < fc. To do this, we must first multiply the incoming modulated wave S(t) by a sinusoidal wave of frequency f_1 supplied by a local oscillator to obtain

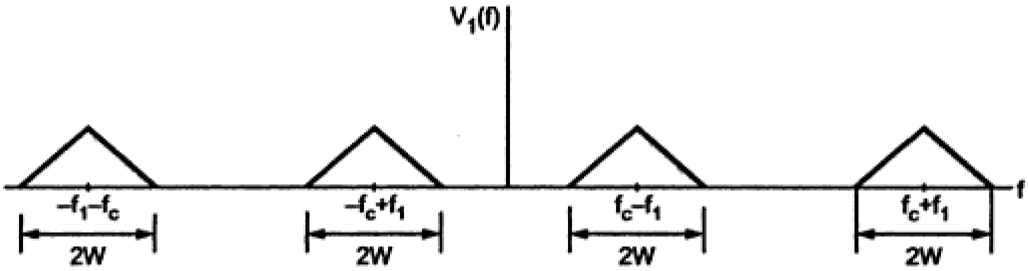
$$V_1(t) = S(t)\,\mathrm{Cos}\,2\pi f_1 t$$

$$= m(t)\,\mathrm{Cos}\,2\pi fct\,\mathrm{Cos}\,2\pi f_1 t$$

$$= \frac{m(t)}{2}[\mathrm{Cos}\,2\pi\,(fc - f_1)t + \mathrm{Cos}\,2\pi\,(fc + f_1)t]$$



(a) Spectrum of DSBSC wave



(b) Spectrum of signal obtained by multiplying DSBSC wave with a local carrier

The multiplier output $V_1(t)$ consists of two DSB waves one with carrier frequency of fc-f_1 and other with a carrier frequency of fc+f_1. The spectrum of $V_1(t)$ is as in fig b

Let the frequency f_1 of the local oscillator be chosen so that

fc-f_1 = fo

Then from b we see that the modulated wave with the desired carrier frequency fo may be extracted by passing the multiplier output $V_1(t)$ through a band pass filter of mid-band frequency fo and bandwidth 2W provided

fc+f_1-W > fc+f_1+W

or

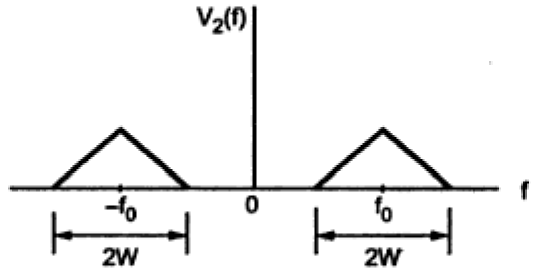
$f_1 > W$

The filter output is therefore

$$V2(t) = \frac{1}{2} m(t) \text{ Cos } 2\pi (fc- f_1)t$$

$$= \frac{1}{2} m(t) \text{ Cos } 2\pi fot$$

This output is desired modulated wave, translated downward in frequency as shown in fig.



(c) Spectrum of DSBSC wave translated downward in frequency

A device that carries out the frequency translation of a modulated wave is called a mixer. The operation itself is called mixing and heterodyning. For the implementation of a mixer we use a multiplier and bandpass filter as shown in block diagram.

FREQUENCY DIVISION MULTIPLEXING [FDM]

Multiplexing is a technique whereby a number of independent signals can be combined into a composite signal suitable for transmission over a common channel. To transmit a number of signals over the same channel the signals must be kept apart so that they do not interfere with each other and thus they can be separated at the receiving end. This is accomplished by separating the signals either in frequency or in time. The technique of separating the signals in frequency is referred to as frequency division multiplexing.

The block diagram of an FDM system is as shown. The incoming message signals are assumed to be of the low pass type. Following each signal input ,LPF is used, which is designed to remove high frequency components that do not contribute significantly to signal representation but are capable of distributing other message signals that share the common channel. The filtered signals are applied to the modulators that shift the frequency ranges of the signals so as to occupy mutually exclusive frequency intervals. The necessary carrier frequencies needed to perform these frequency translations are obtained from a carrier supply. For the modulation mostly SSB is used. The band pass filters following the modulators are used to restrict the band of each modulated wave to its prescribed range. The resulting band pass filter outputs are next combined in parallel to form the input to the common channel.