LECTURE # 10 - TOPIC 3 (PART-I)

3.2.4.3 Single Side Band - Suppressed Carrier. (SSB-SC).

While discussing DSB-SC it was stated that this modulation scheme has one major advantage that by suppressing the carrier we are able to save about 66.6% of the total Transmitted power. The same power i.e the saved 66.6% of P_T can be reutilized either by using low power Transmitters or by covering larger transmission distances. This shall be possible by using the saved power in increasing the power of Sidebands (LSB & USB). Also it was stated that even though there is power saving but no advantages has been achieved where Bandwidth (BW) is concerned.

Again compare the Frequency Spectrum of DSB-Full Carrier & DSB-SC
Again Draw the Fig 1(b) and Fig 2(b) of pg 93.

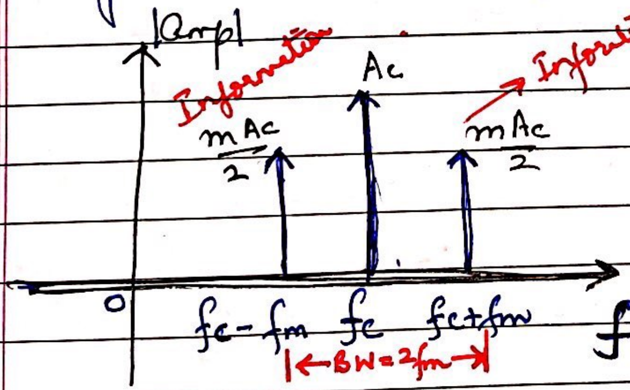

Fig 1(b): DSB - Full carrier Spectrum

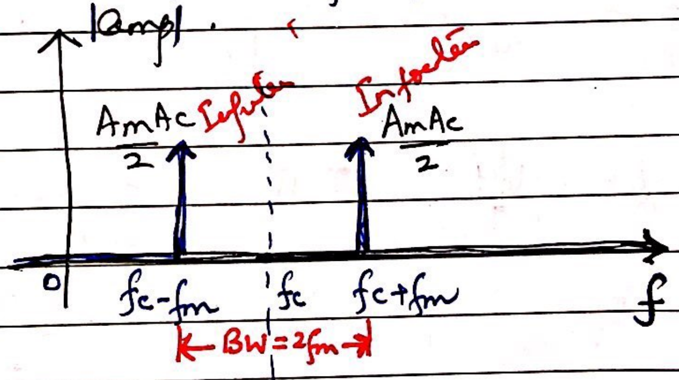

Fig. 2(b): DSB - SC Spectrum

fc → This has no information content. There is no fm component in it so no information in Carrier.

fc+fm → There is Information content present because of of fm frequency component. This implies information in the modulated Signal
fc-fm ↗

DSB- Full carrier spectrum thus has information in two components f_c+f_m & f_c-f_m. Same information is carried by the sidebands. Similarly DSB-SC spectrum also has same information carried by the two side bands.

Q. The question here can be asked that if same information is carried by the side bands then if we suppress one side band then can the recovery of information be possible?

The answer to this is that if just transmission of LSB only at f_c-f_m or USB only at f_c+f_m is sufficient for effective detection and effective recovery of original baseband information signal. Such signals which are obtained by suppressing one of the side bands is called SSB-SC.

Example 1 DSB-SC signal is at transmitter.

$$Tx\ O/p = \overset{USB}{\frac{mA_c}{2}\cos(\omega_c+\omega_m)t} + \overset{LSB}{\frac{mA_c}{2}\cos(\omega_c-\omega_m)t}.$$

Pass above signal through Low pass filter then $\cos(\omega_c+\omega_m)t$ will be suppressed. This will result in LSB-SC type of SSB-SC signal.
[See Fig (8)](a,b).
We can also get a USB-SC type of SSB-SC signal

Example 2. Let the DSB-SC signal be passed through High pass filter so that high freq $\cos(\omega_c+\omega_m)t$ is passed whereas $\cos(\omega_c-\omega_m)$ is attenuated.

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Tx Side:

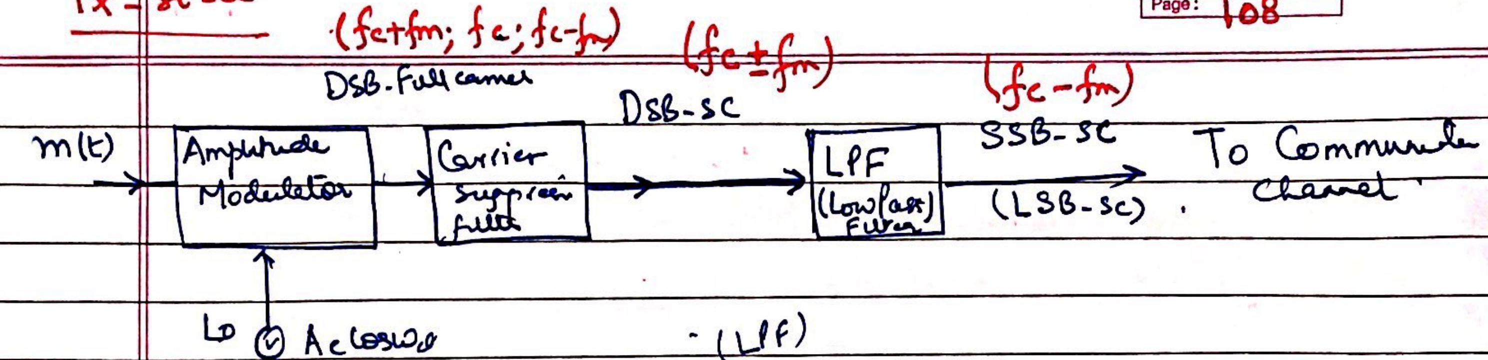


Fig (8.a) :- Low pass Filter used to block or attenuate (fc + fm) component of the DSB-SC signal. Therefore output is LSB-SC and has only component at position (fc-fm).

- **Tx Side:**

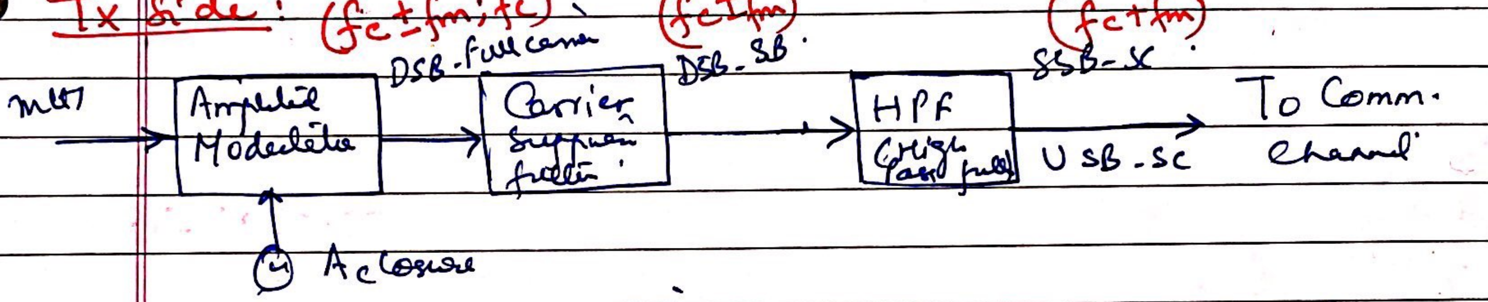


Fig (8.b) : High Pass Filter used to block or attenuate (fc - fm) component of the DSB-SC signal. Therefore output is USB-SC and has only component at position at (fc+fm).

- **Rx Side:** For both SSB-SC (LSB-SC & USB-SC) the detection is carried out by using a Product detector also called the Synchronous product detection. Just as in case of DSB-SC carrier has to be synchronized at Rx both in frequency & phase, Here also carrier has to be synchronized for carrying out information recovery without any loss or distortion of information.

Q. Consider an ideal case where Tx Side generates LSB-SC signal. Show that cos ωct at Rx is required to recover the message.

DSB-SC

Solution

$$\text{Tx O/p} = \frac{mA_c}{2}\left[\cos(\omega_c+\omega_m)t\right] + \frac{mA_c}{2}\left[\cos(\omega_c-\omega_m)t\right].$$

(blocked by LPF)

Using a Low Pass filter, it blocks $\frac{mA_c}{2}\left[\cos(\omega_c+\omega_m)t\right]$ so that

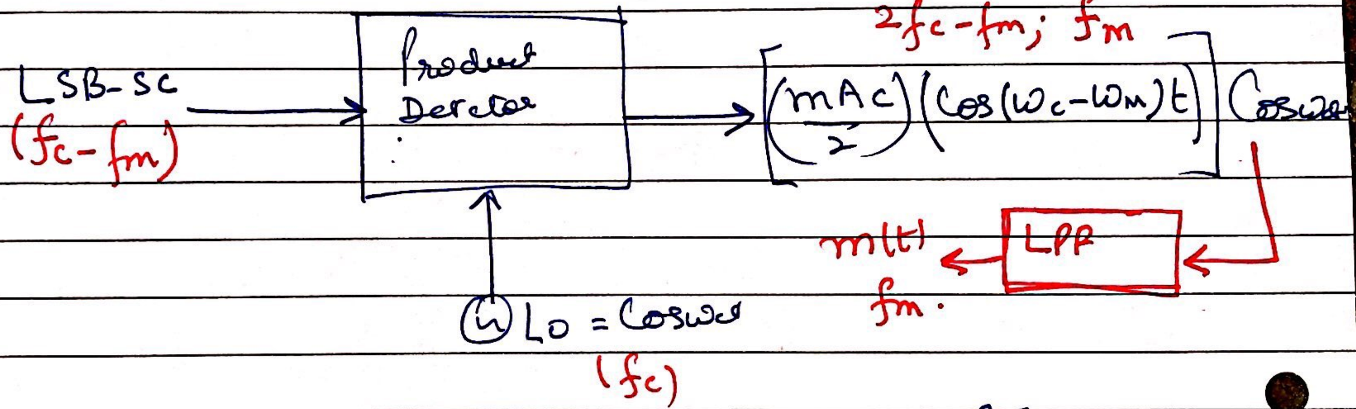
$$\text{SSB-SC Tx O/p} = \frac{mA_c}{2}\left[\cos(\omega_c-\omega_m)t\right].$$

LSB-SC

At Receiver :- This is the point of reverse frequency translation. Here LO carrier $= \cos\omega_c t$.

At the product detector.

Fig: 9



$$\text{Product detector O/p} = \left[\frac{mA_c}{2}\cos(\omega_c-\omega_m)t\right]\left[\cos\omega_c t\right].$$

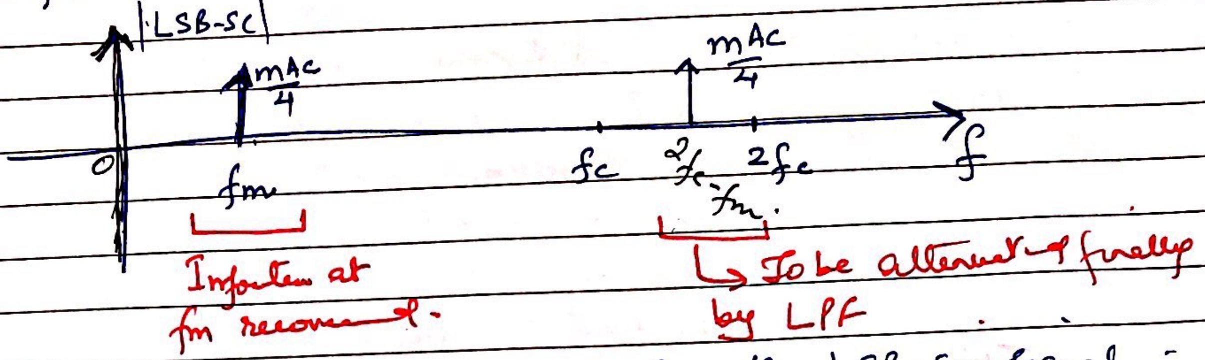
Using $\cos A \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$.

$$\therefore \text{Product detector O/p} = \frac{mA_c}{4}\left[\cos(2\omega_c-\omega_m)t\right] + \frac{mA_c}{4}\left[\cos(\omega_c-\omega_m-\omega_c)t\right]$$

$$\text{Product detector O/p} = \frac{mA_c}{4}\left[\cos(2\omega_c-\omega_m)t\right] + \frac{mA_c}{4}\left[\cos(\omega_m)\right]t.$$

(Here $\cos(-\theta) = \cos\theta$
$\therefore \cos(-\omega_m t) = \cos\omega_m t$)

We can draw the corresponding Spectrum of this equation as below.



We have recovered information from the LSB-SC signal. Finally we can pass the above signal through LPF so that $(2f_c - f_m)$ component which is not required is blocked.

After LPF :- $\frac{mA_c}{4}\left[\cos(2\omega_c-\omega_m)t\right] + \frac{mA_c}{4}\left[\cos(\omega_m)t\right]$.

LPF block it.

$m(t) = \frac{mA_c}{4}\cos(\omega_m t)$ → message signal recovered.

Q. Consider an ideal case where Tx side generates USB-SC signal. Show that $\cos\omega_c t$ at Rx is required to recover the message.

HINT:- Repeat same way as for LSB-SC.
However you'll see that Product detector O/P is
$\left[\left(\frac{mA_c}{2}\right)\cos(\omega_c+\omega_m)t\right]\left[\cos\omega_c t\right]$.

Q So at final output to recover m(t) at fm do we now require LPF or HPF?
Also draw the Spectrum.

Q. Advantage of SSB-SC Scheme over DSB-SC.

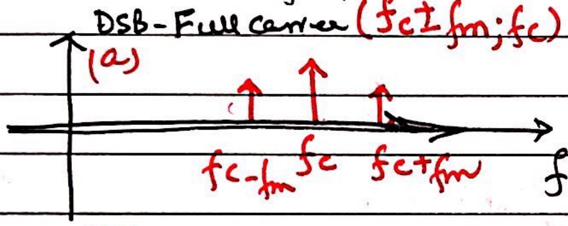
From previous two examples of SSB-SC for both LSB & USB it is now proved that :-

(i) m(t) at fm is detected from DSB-SC;
(ii) m(t) at fm is also detected from LSB-SC, &
(iii) m(t) at fm is also detected from USB-SC

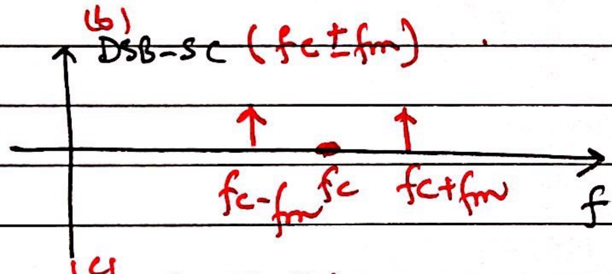
This implies further advantage of BW conservation also in case of SSB-SC and further power Saving. How is this achieved? This can be shown with help of following spectrum illustrations.

Compare the spectrums of DSB-Full carrier, DSB-SC; SSB-SC for both LSB; USB.

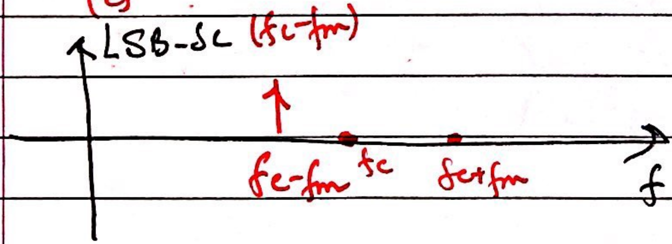
Fig.10 (a, b, c, d)



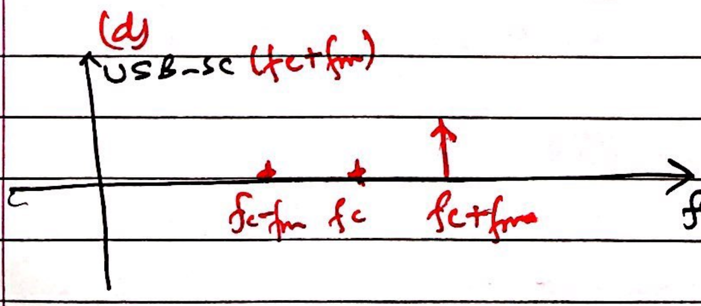
$P_T = P_{carrier} + P_{LSB} + P_{USB}$.
$BW = 2f_m$.



$P_T = P_{LSB} + P_{USB}$.
$BW = 2f_m$
66.6% of P_T saved.



$P_T = P_{LSB}$.
$BW = f_c - f_m$.
(66.6% + 16.7%) of P_T saved
$B.W < 2f_m$.



$P_T = P_{USB}$
$B.W = f_c + f_m$
(66.6% + 16.7%) of P_T saved
$B.W < 2f_m$

Fig 10 on page 111 show the Spectrum all DSB-Full Carrier, DSB-SC, SSB-SC

It is seen that as we move from DSB-Full carrier towards implementing DSB-SC (Fig 10(a), 10(b)). the advantage is only saving 66.6% of Total trasmitted power.

As we move from DSB-SC to SSB-SC (LSB-SC), further 16.7% of power is saved. This means now a total of (66.6% + 16.7%) P_T is now saved.

Another advantage is now B.W covered is less than that of DSB-SC & DSB-full carrier.

Similarly (66.6% + 16.7%) of P_T is saved in SSB-SC (USB-SC) scheme. Here also B.W is lower than DSB-full carrier and DSB-SC carrier.

Thumb rule: 3.10 (i) Power Required for DSB-Full Carrier Trasmission is greater than Power Required by DSB-SC.

(ii) Power Required for DSB-S Trasmission is greater than power required by SSB-SC

(iii) $(B.W)_{\text{DSB-Full carrier}} = (B.W)_{\text{DSB-SC}}$

(iv) $(B.W)_{\text{SSB-SC}} < (B.W)_{\text{DSB-Full carrier \& DSB-SC carrier}}$

Q. How is SSB-SC signals generated?

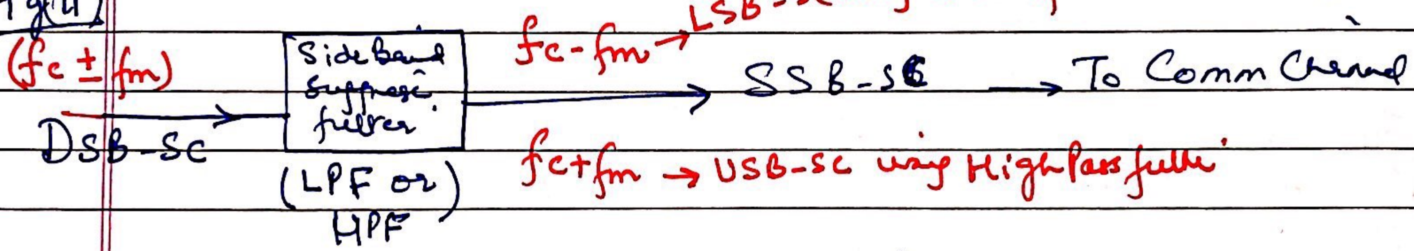
There are three major methods of generation of SSB-SC signals. These are:

(i) The Filter Method.
(ii) Phase Shift Method.
(iii) The Weavers Method.

(i) <u>The Filter Method</u> :-

In this method a DSB-SC signal ($f_c \pm f_m$) is passed through a filter called the sideband suppression filter. As was discussed earlier if LSB-SC has to be generated then the sideband suppression filter is a LPF. And if USB-SC has to be generated then the sideband suppressor filter is an HPF.

<u>Fig(4)</u>



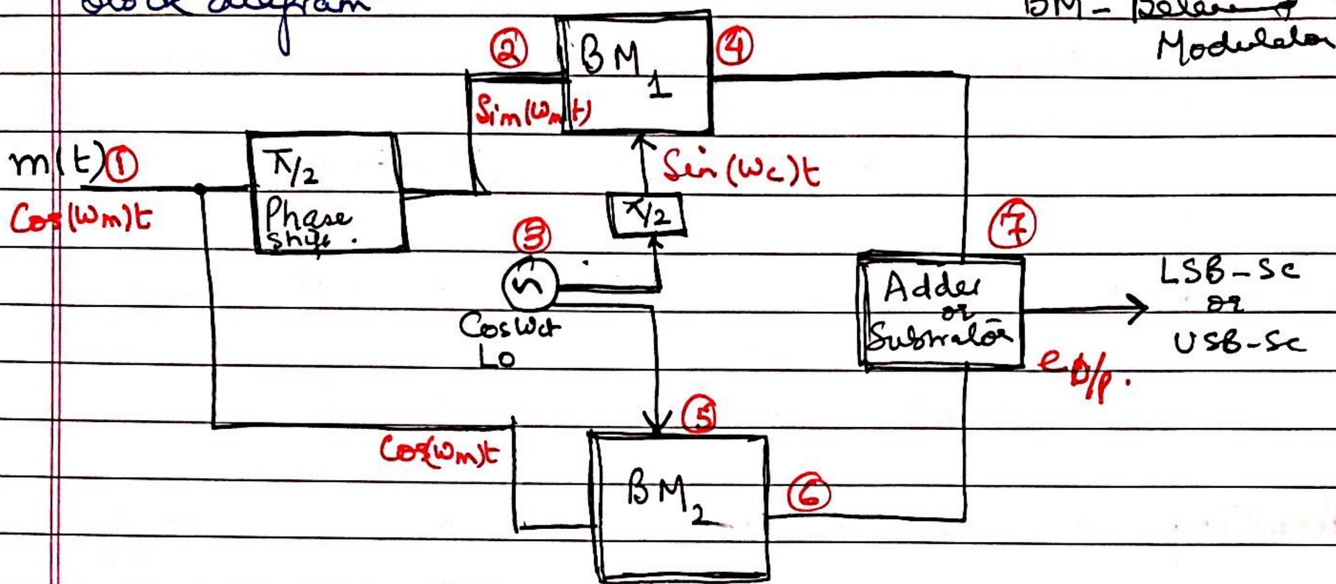
Advantage: This is a very simple method as it requires only a filter for suppression of the unwanted sideband

Disadvantage:- However such filters are very complex to design. These have to attenuate completely the unwanted side band without attenuating the desired sidebands. This means that the filter required have to be highly selective. Since $f_c - f_m$ component is very close to $f_c + f_m$ this is very difficult to design such filters. especially when f_c carrier is very high.

(ii) Phase Shift Method.

This is also called the phase discrimination method. This method can be explained by describing the following block diagram'

BM - Balanced Modulator



Position ① Here the signal assumed is m(t). This is the information signal or the modulating signal.

$$\text{Let } m(t) = \cos(\omega_m)t \quad \dots \text{ (1)}$$

Position ② m(t) is passed through a $\pi/2$ phase shifting network there output is $\pi/2$ phase shifted m(t).

$$\therefore \text{Signal at position ② is} = \cos[(\omega_m t) + \pi/2]$$

$$= \sin(\omega_m)t \quad \text{(2)}$$

This $\sin(\omega_m)t$ will be Input to the upper branch BM_1.

Position ③ This is the Carrier generated by the Local Oscillator (LO) → $\cos(\omega_c)t$ where $f_c \gg f_m$.

$\cos(\omega_c)t$ is also passed through $\pi/2$ phase shifting network providing another input to $(BM)_1$ as $\sin(\omega_c)t$.

$\pi/2$ phase shifting network introduces phase shift of $\pi/2$ to $\cos\omega_c t$ so that

$$\cos(\omega_c)t + \pi/2 = \sin\omega_c t. \quad (3)$$

Position (4):- The balanced Modulator performs the mathematical operation of multiplication of the two inputs.

$$\text{O/p of } BM_1 = \sin(\omega_c)t \cdot \sin(\omega_m)t. \quad (4)$$

Position (5):- This is one of the inputs to BM_2 and it is $\cos\omega_c t$.
Another input is $\cos(\omega_m)t$.

Position (6):- The output of $BM_2 = \cos(\omega_c)t \cdot \cos\omega_m(t)$.

Position (7):- If Adder used then

Adder:-

$$e_{o/p} = \cos(\omega_c)t \cdot \cos(\omega_m)t + \sin(\omega_c)t \sin(\omega_m)t.$$

This is of form $\cos A \cos B + \sin A \sin B$
$= \cos(A - B)$.

$$\therefore \boxed{e_{o/p} = \cos(\omega_c - \omega_m)t.} \rightarrow \text{SSB-SC signal (LSB-SC generated)}$$

Subtractor:- If subtractor used then

$$e_{o/p} = \cos(\omega_c)t \cos(\omega_m)t - \sin(\omega_c)t \sin(\omega_m)t.$$

Again using $\cos A \cos B - \sin A \sin B = \cos(A+B)$.

$$\therefore \boxed{e_{o/p} = \cos(\omega_c + \omega_m)t} \rightarrow \text{SSB-SC Signal (USB-SC generated)}.$$

(36)

Q. Draw the block diagram corresponding to following :- SSB-SC signals to be generated by phase shift method.

LSB-SC (i) $\cos(\omega_c - \omega_m)t$ (Hint: Already Drawn)

USB-SC (ii) $\cos(\omega_c + \omega_m)t$ (Hint: Already Drawn).

LSB-SC (iii) $\sin(\omega_c - \omega_m)t$.

USB-SC. (iv) $\sin(\omega_c + \omega_m)t$.

Q. What are the various benefits and drawbacks of phase shift method.

1) Benefit / Advantage :- As compared to the Filter Method. here there is no requirement of a highly selective sideband suppression filter with sharp cut off characteristics.

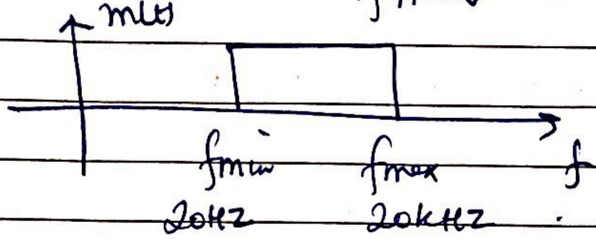
2) It can provide better rejection of unwanted sideband than the filter method.

Drawbacks :-

1) The Phase Shift method requires more elaborate, complex design and expensive setup.

2) It requires two Balanced Modulators one in upper branch (BM_1) & another in lower Branch (BM_2). Both have to be identical with respect to each other to allow complete cancellation of the unwanted sideband.

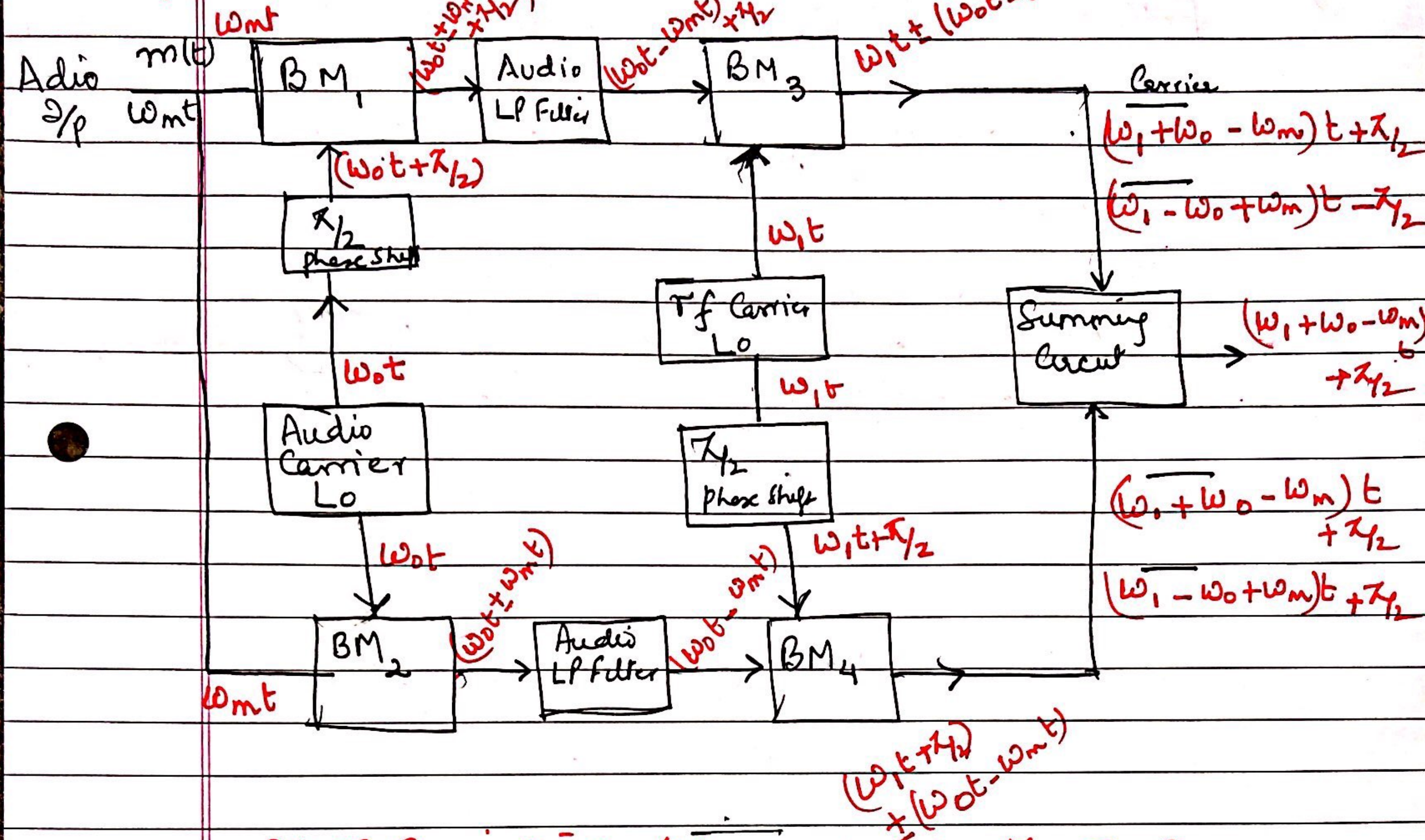
3) This method needs two $\pi/2$ phase shifting network. This is no problem to introduce $\pi/2$ phase shift to the single-tone carrier $\cos(\omega_c)t$.
However single-tone $m(t)$ is not used but a more realistic demand is to have broadband $\pi/2$ phase shifting network to efficiently introduce $\pi/2$ phase shift to each component of multitone $m(t)$.
e.g let $m(t)$ have frequency range from $f_{min} = 20Hz$ to $f_{max} = 20kHz$



Such Broadband $\pi/2$ phase shifting n/ws are very difficult to built. There will be some unwanted error here.

(iii) Third Method:- This is also called the Weaver's method. This method of generation of SSB-SC modulation was invented by D.K. Weaver. It is similar to phase shifting method but one major difference is that the modulating signal is first modulated on a low frequency audio carrier (range kHz). This is called the subcarrier. Then this is modulated onto the high frequency radio frequency (rf) carrier (range MHz). Its major Advantage over previous method is that it does not use $\pi/2$ phase shift on broadband multitone $m(t)$. It uses $\pi/2$ phase shift on carrier frequencies.

We may follow the signals at different positions of the block diagram by just considering the frequency position
e.g. $\cos(\omega_m t) \equiv \omega_m$; $\cos(\omega_0 t) \equiv \omega_0 t$ etc.



O/p of Summing Circuit has four components:—
$(\omega_1 + \omega_0 - \omega_m)t + \pi/2$] From upper
$(\omega_1 - \omega_0 + \omega_m)t - \pi/2$] Branch

$(\omega_1 + \omega_0 - \omega_m)t + \pi/2$] From lower
$(\omega_1 - \omega_0 + \omega_m)t + \pi/2$] branch.

→ Out of these components $(\omega_1 + \omega_0 - \omega_m)t + \pi/2$ is in phase wrt in both branches. This will add up and is the Final O/p.

→ Out of these components $(\omega_1 - \omega_0 + \omega_m)t - \pi/2$ & $(\omega_1 - \omega_0 + \omega_m)t + \pi/2$ are same frequency components but differ in phase by π. Hence they will cancel.

Hence here LSB-SC generated where new carrier is $\omega_1 + \omega_0$.

Q. Follow the Block diagram of the Weaver's Method of SSB-SC generation. Describe the inputs and subsequent o/ps of each blocks in both the arms.

Q. Write the merits & demerits of weaver's method as compared to the phase shift method.