AM Modulation

Types of AM

- DSB-FC
- DSB-SB
- SSB-SC
- VSB
- ISB

DSBFC

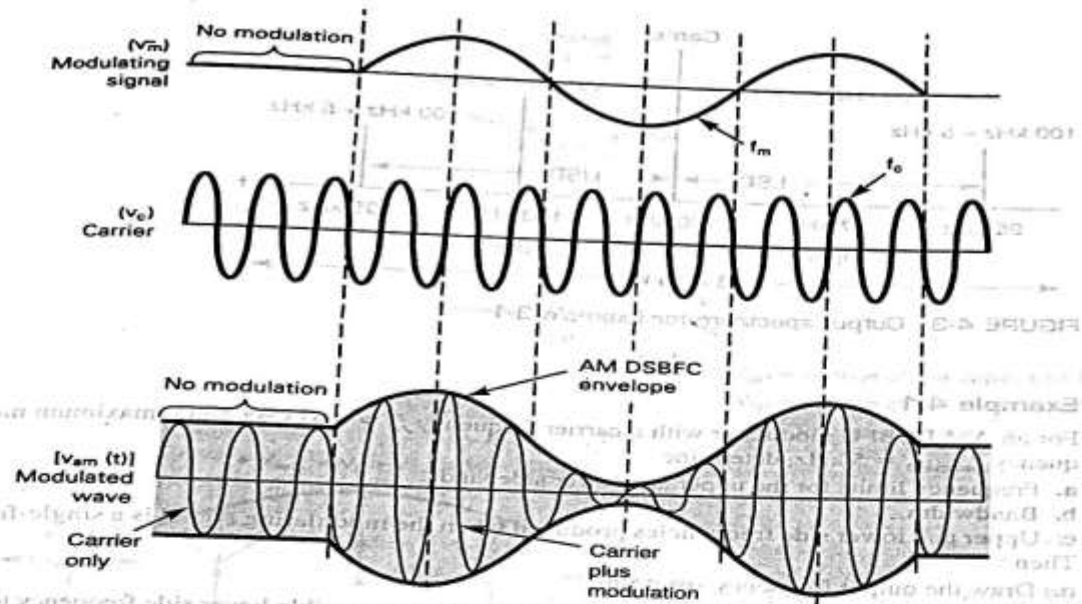


FIGURE 4-1 AM generation

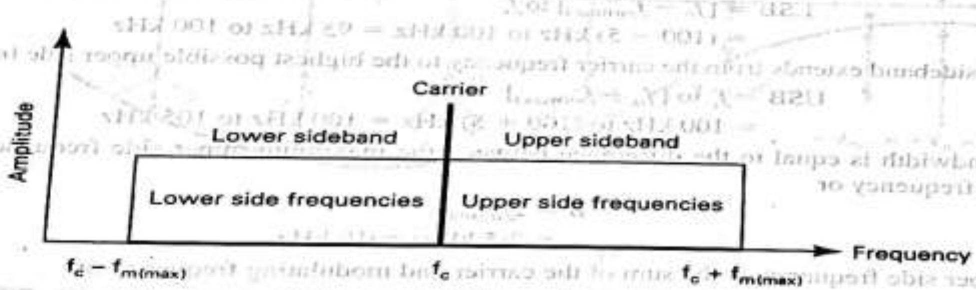
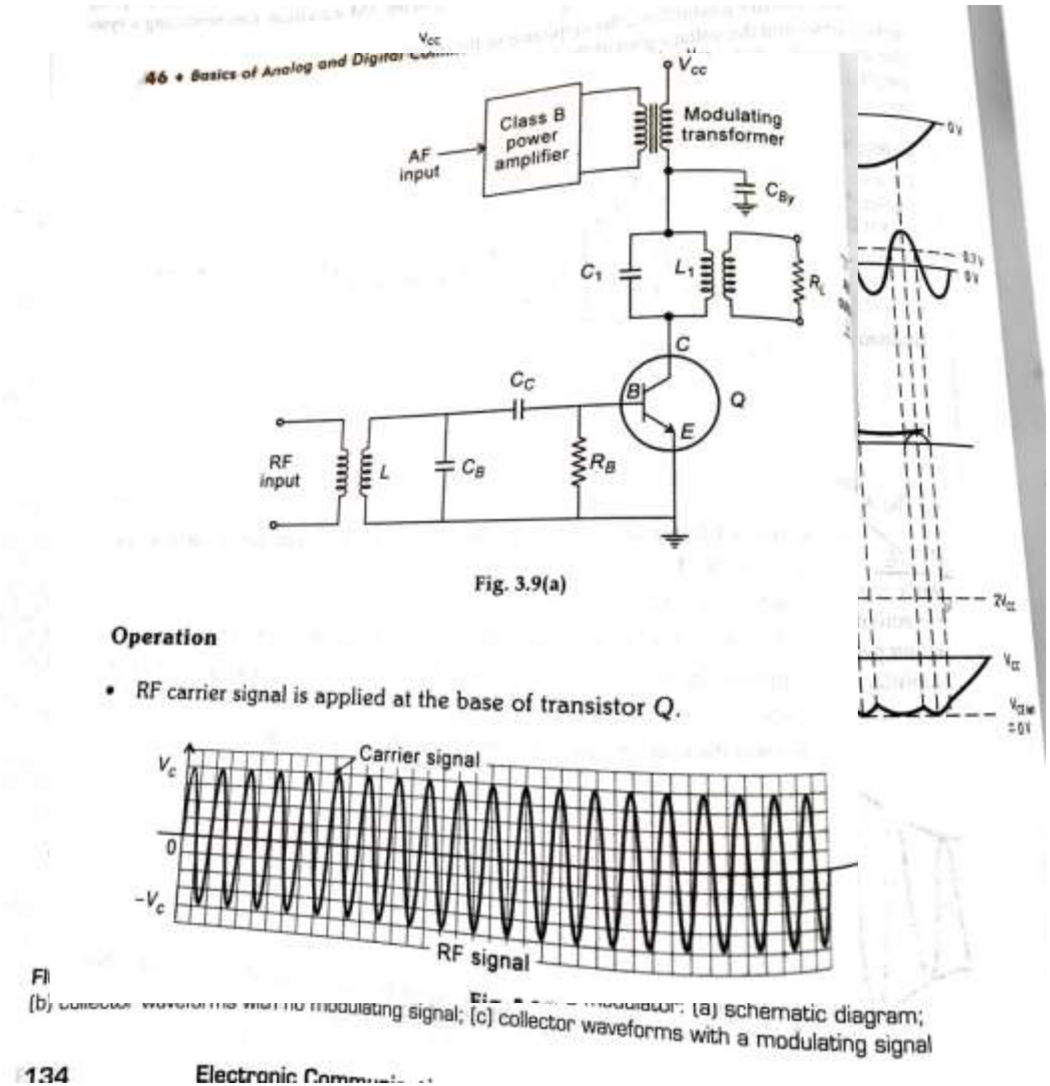


FIGURE 4-2 Frequency spectrum of an AM DSBFC wave

Medium/High Level AM Modulator



Low level Transmitter

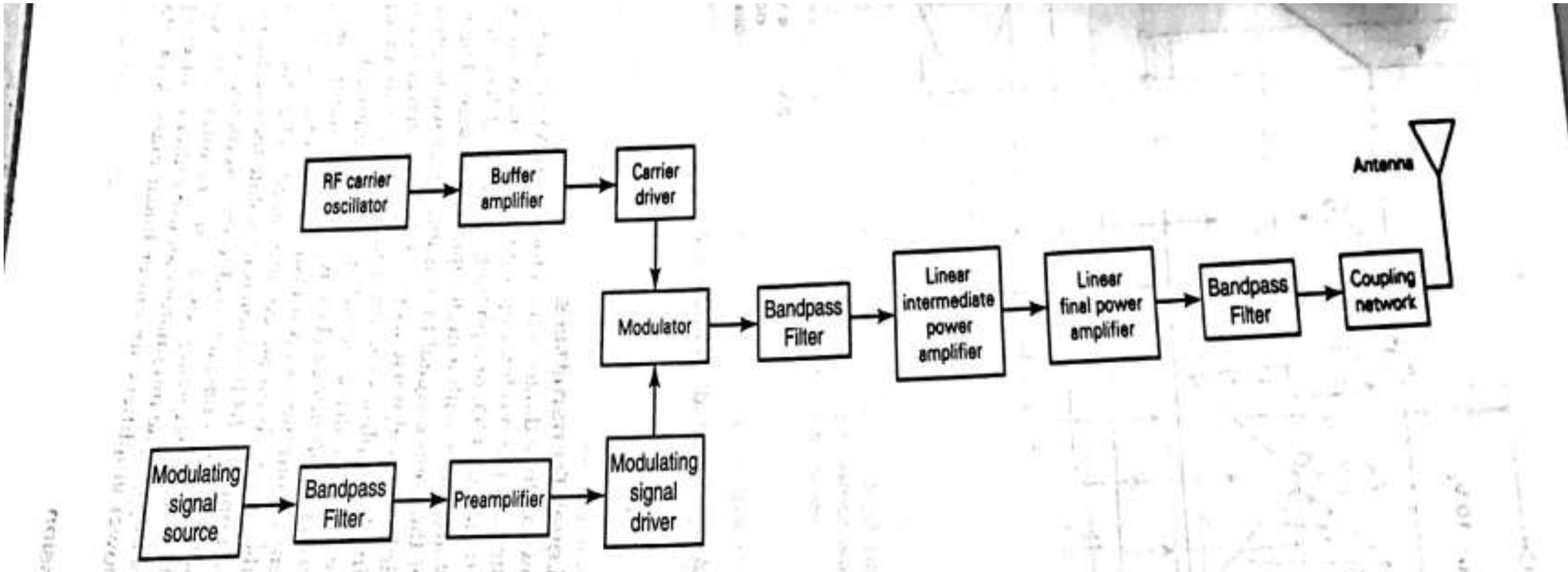


FIGURE 4-22 Block diagram of a low-level AM DSBFC transmitter

High Level Transmitter

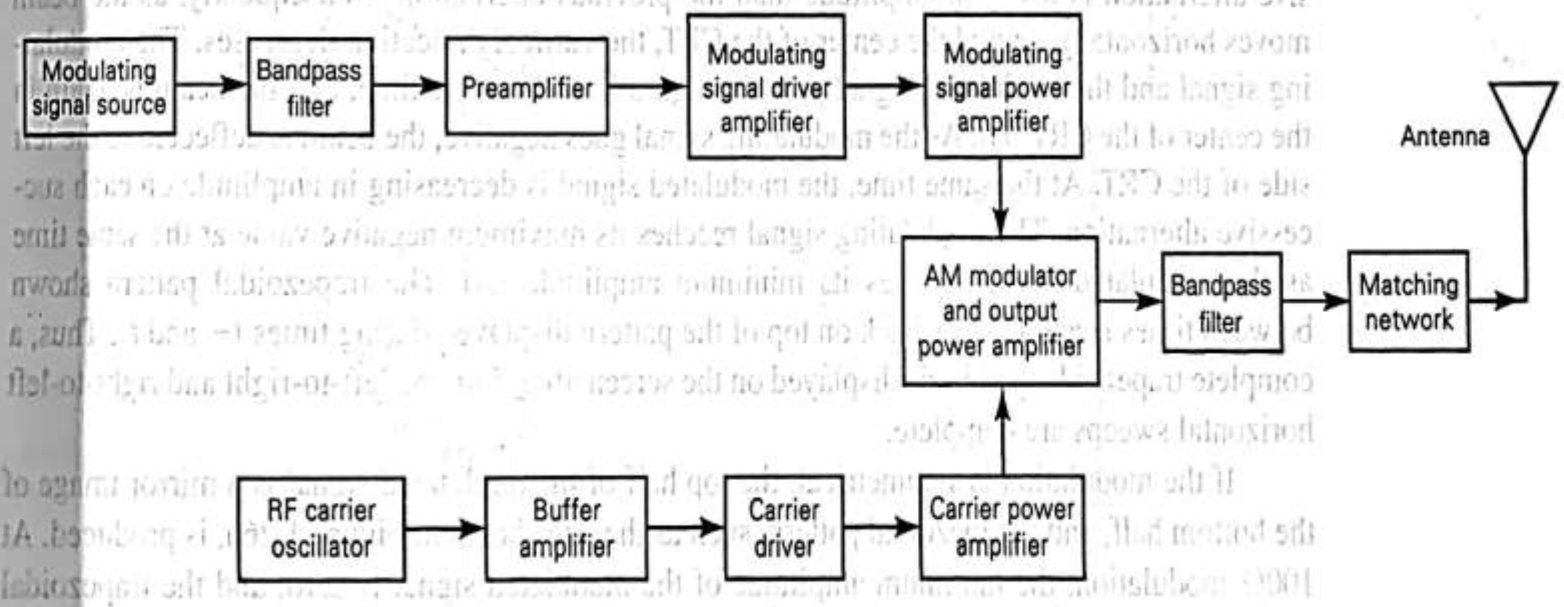


FIGURE 4-23 Block diagram of a high-level AM DSBFC transmitter

Difference

Differentiate Between HLM and LLM

Sr.	High Level Modulation	Low Level Modulation
(1)	Modulation takes place at high power level.	Modulation takes place at low power level.
(2)	High efficiency.	Comparatively low efficiency.
(3)	Signal generated can be directly transmitted after modulation.	Signal generated can not be directly transmitted after modulation.
(4)	Modulating signal is applied at collector/plate.	Modulating signal is applied at grid or emitter.
(5)	No amplifiers are required after modulation.	Amplifiers are required after modulation.
(6)	Distortion in generated output is less.	Distortion in generated output is more.
(7)	Complex system.	Comparatively less complex.
(8)	**Applications** : High power broadcast transmitters.	**Applications** : TV transmitting station, wireless intercoms, short range walkie-talkies.

Table 3.1

Test Setup

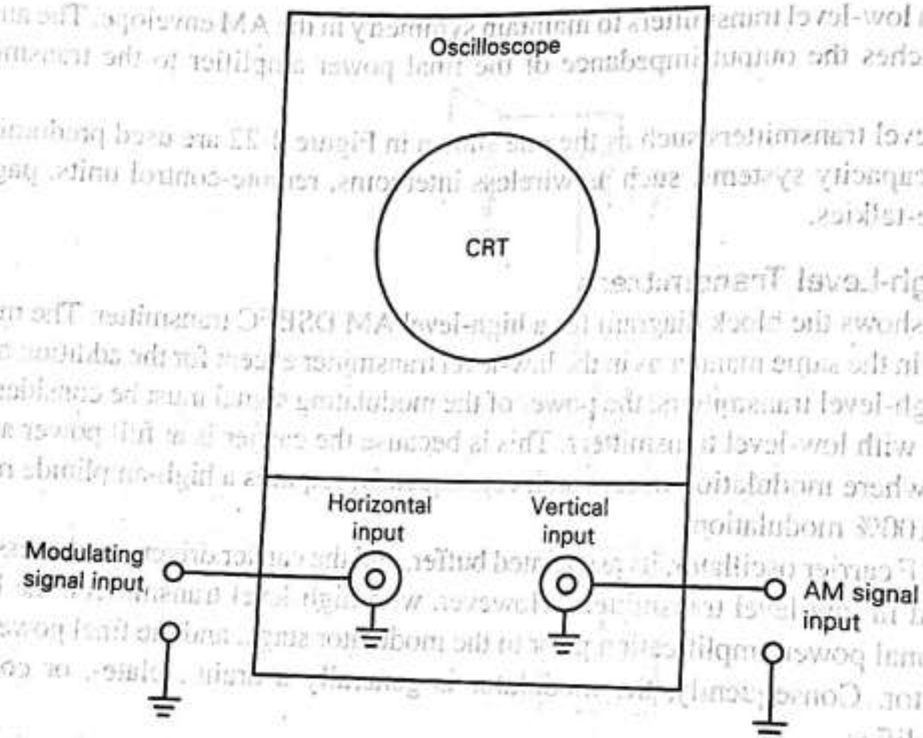


FIGURE 4-24 Test setup for displaying a trapezoidal pattern on an oscilloscope

Example

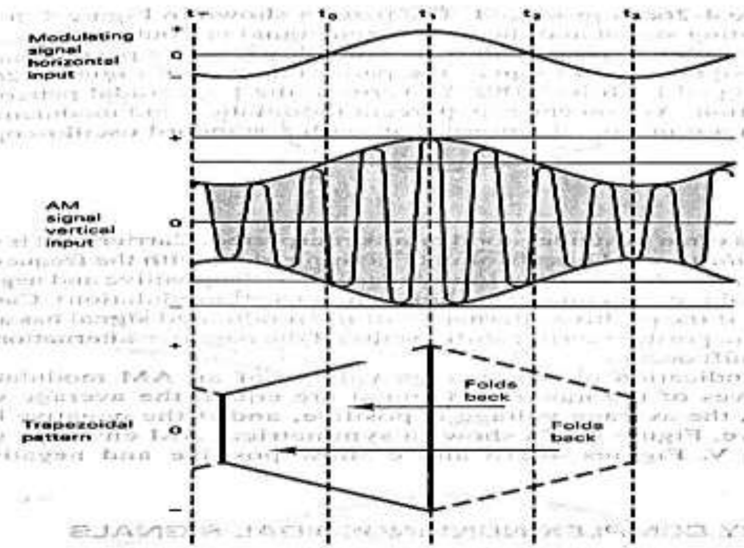


FIGURE 4-25 Producing a trapezoidal pattern

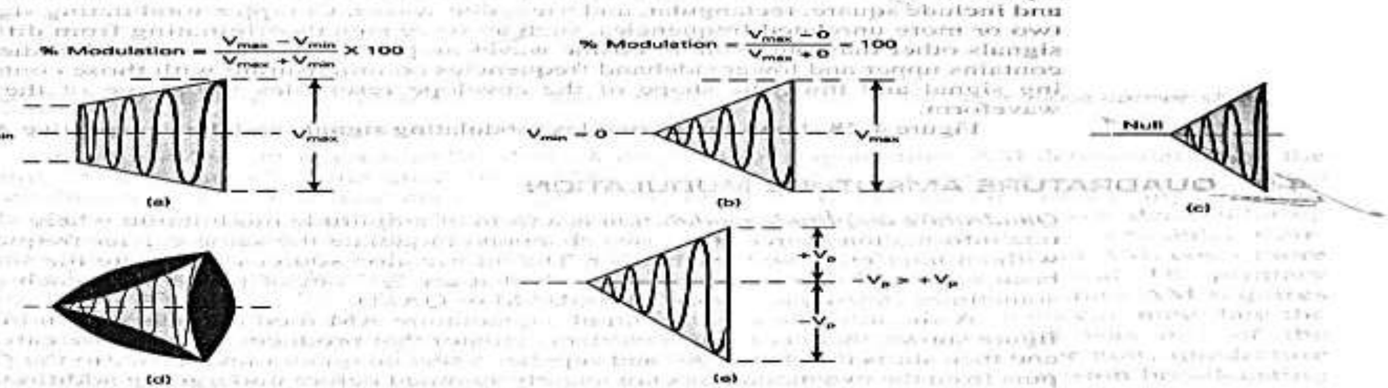
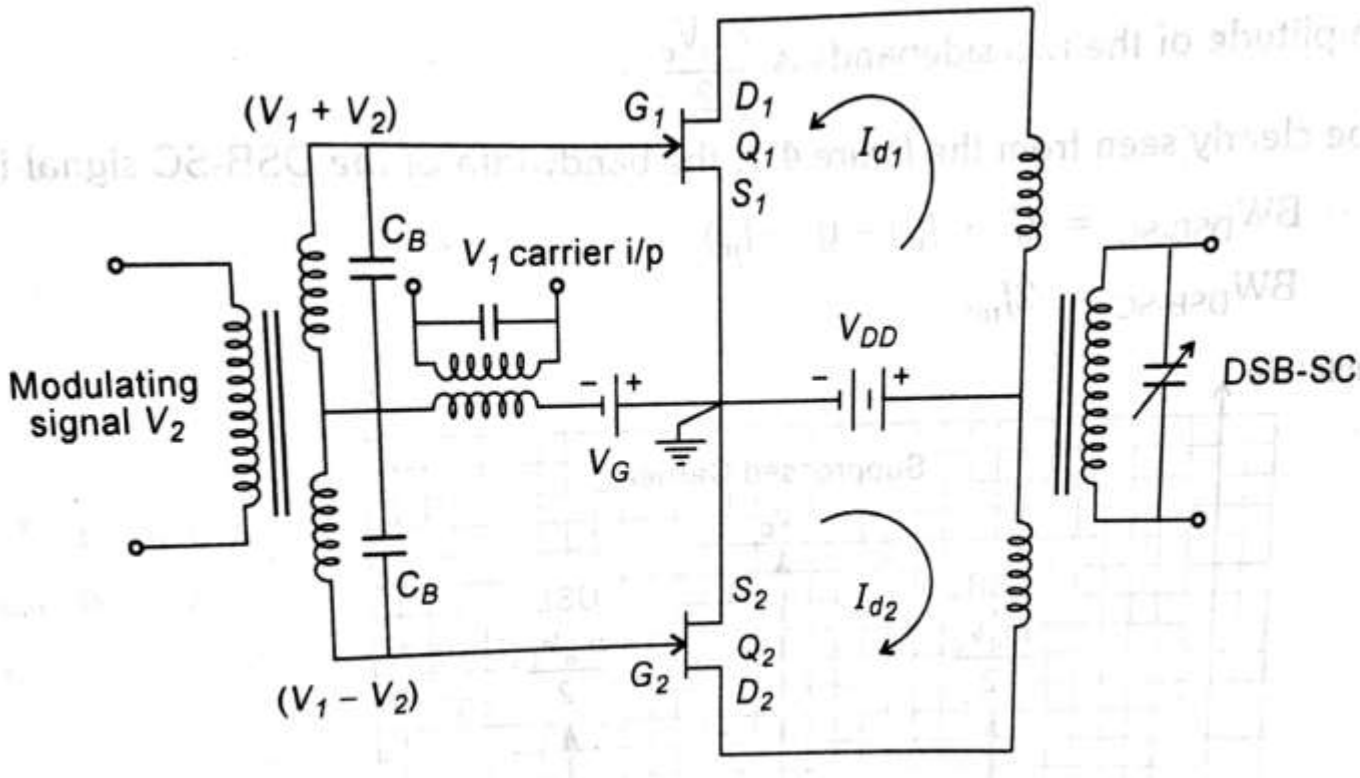


FIGURE 4-26 Trapezoidal patterns: (a) linear 50% AM modulation; (b) 100% AM modulation; (c) more than 100% AM modulation; (d) improper phase relationship; (e) nonsymmetrical AM envelope

DSBSC

- Balance Modulator
- Ring Modulator

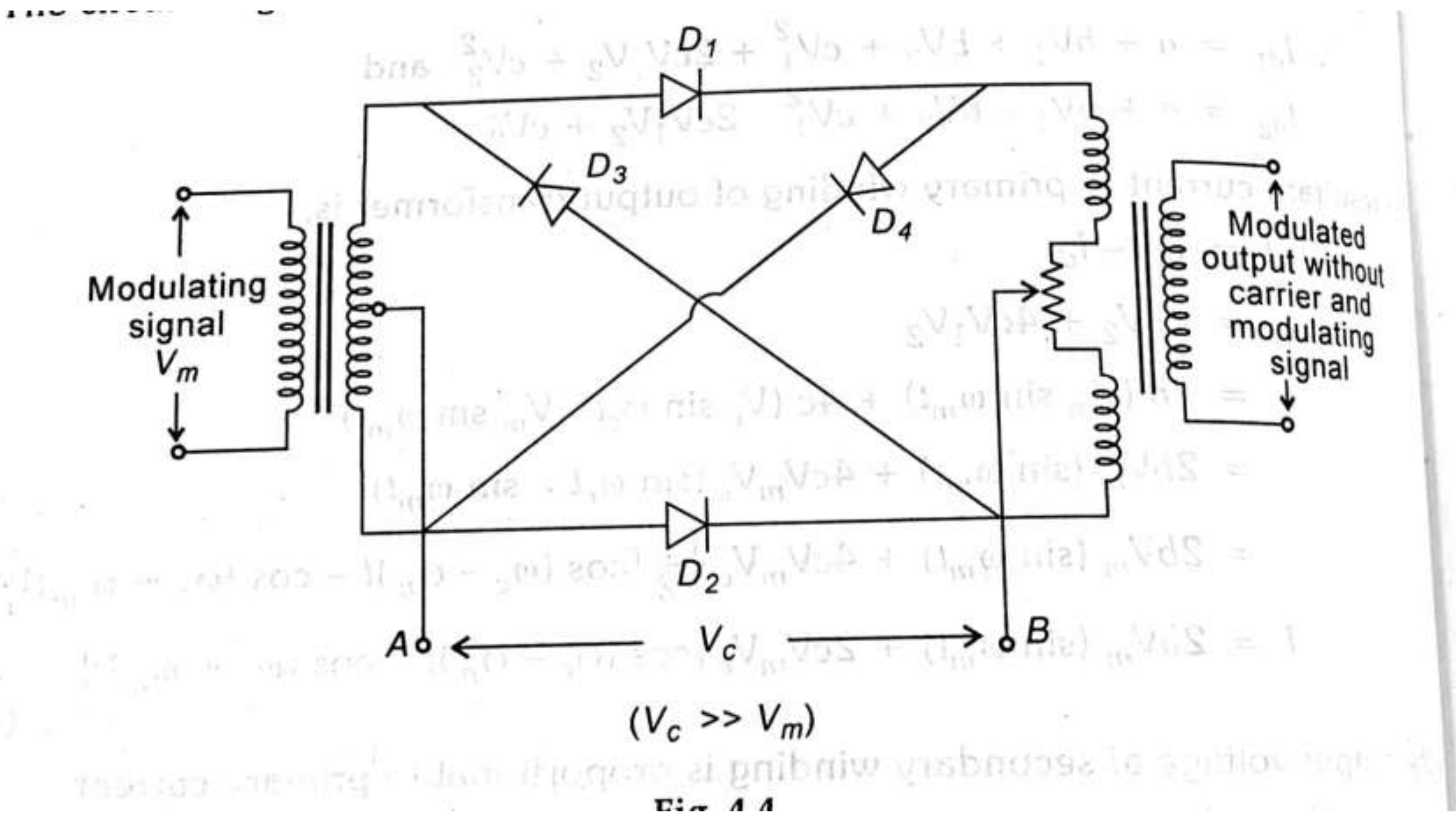
DSBSC using Balance modulator



V_G : Reverse bias voltage used to bring Q point at the centre of load line such that the two JFET's operate in class A mode

Fig. 4.3

DSBSC using Ring Modulator



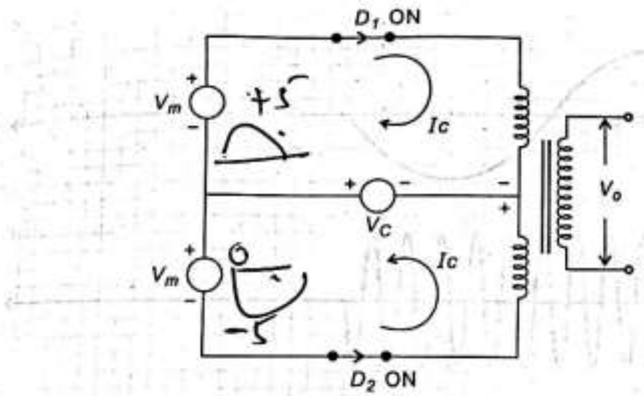


Fig. 4.5

(4) The modulating signal appears at the output with some polarity only during positive half cycle of carrier signal.

- During negative half cycle of carrier signal.

(1) Point B becomes positive with respect to point A.

(2) Hence diodes D_3 and D_4 conduct and acts as short circuit.

(3) Diodes D_1 and D_2 are reverse biased. Hence acts as open circuit.

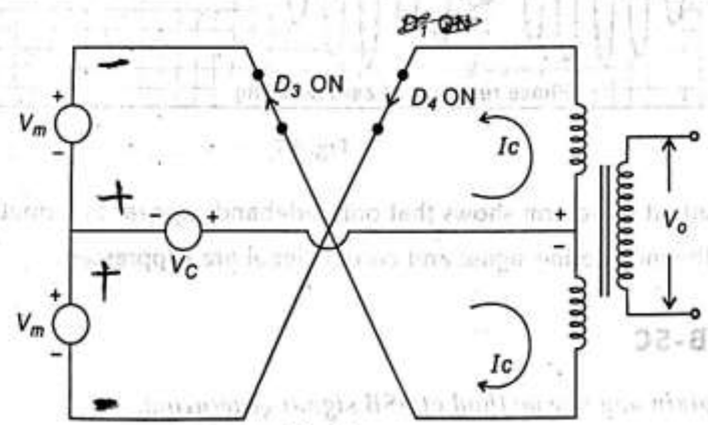
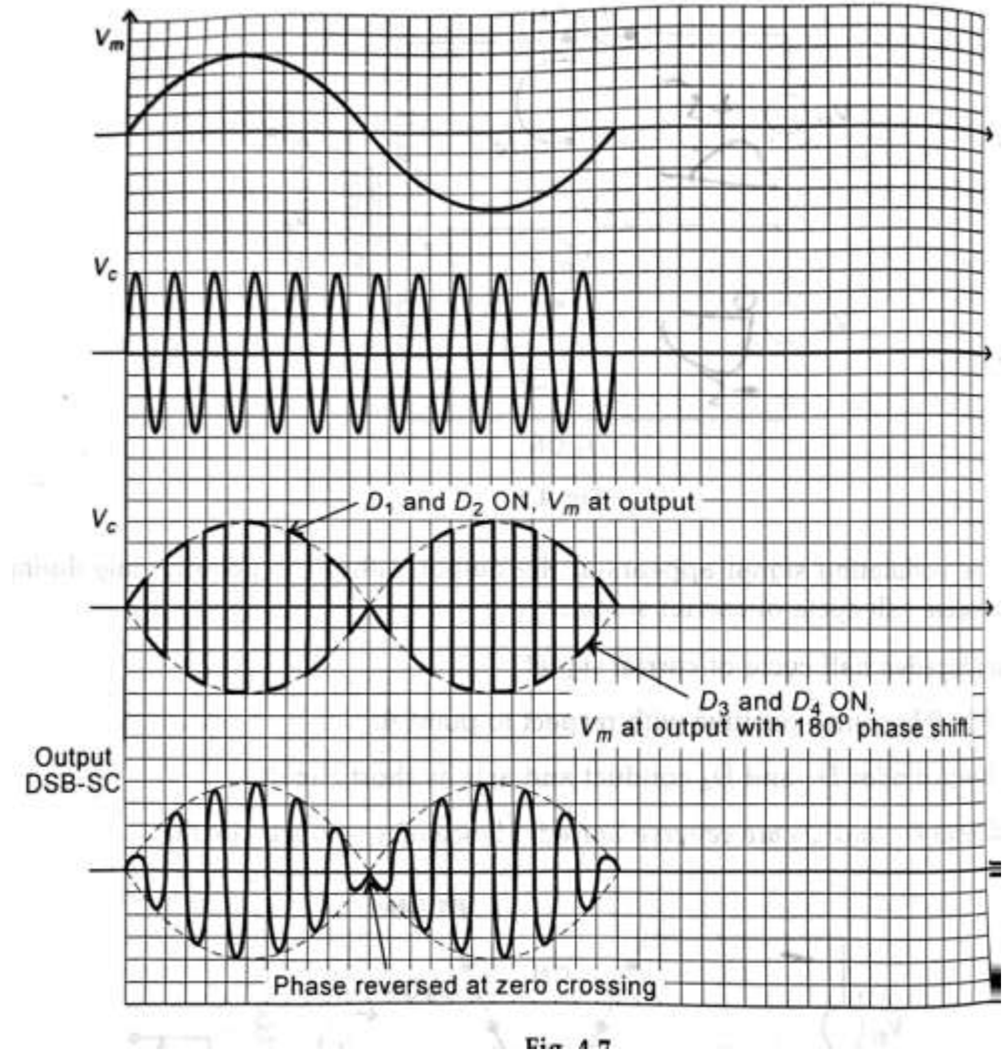


Fig. 4.6

DSBSE Waveforms



Waveforms SSB

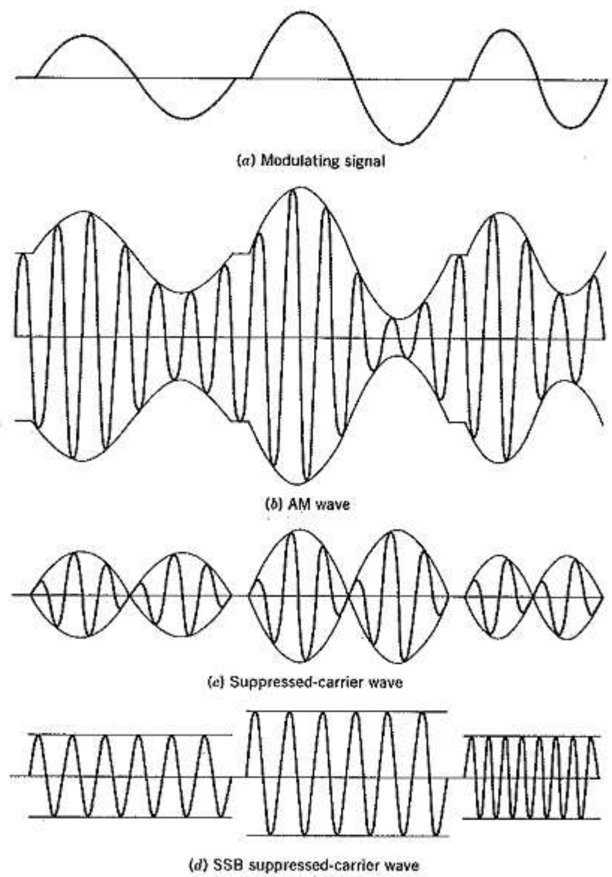
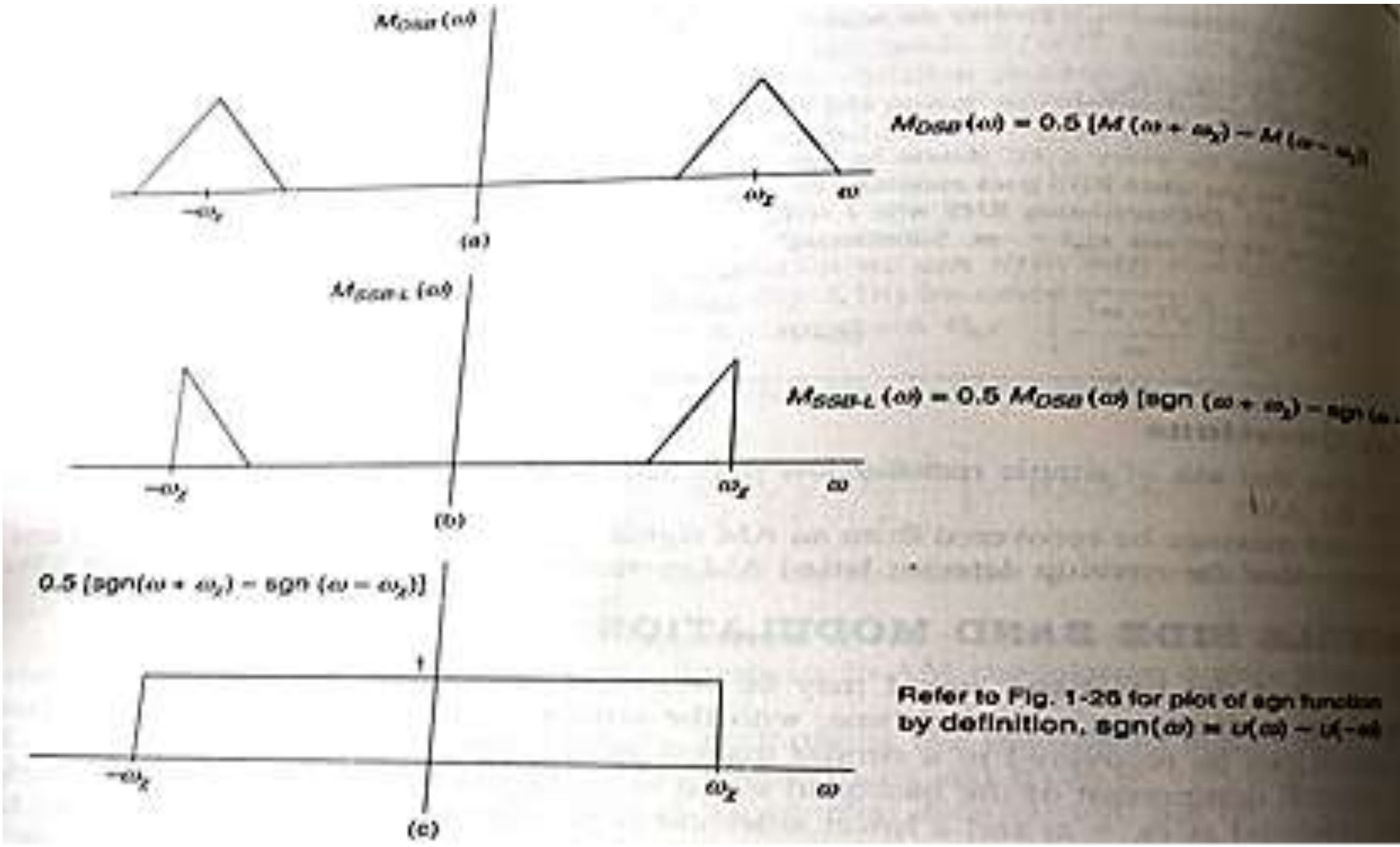


FIGURE 4-1 Waveforms for various types of amplitude modulation. (*a*) Modulating signal; (*b*) AM wave; (*c*) suppressed-carrier wave; (*d*) SSB suppressed-carrier wave.

SSB

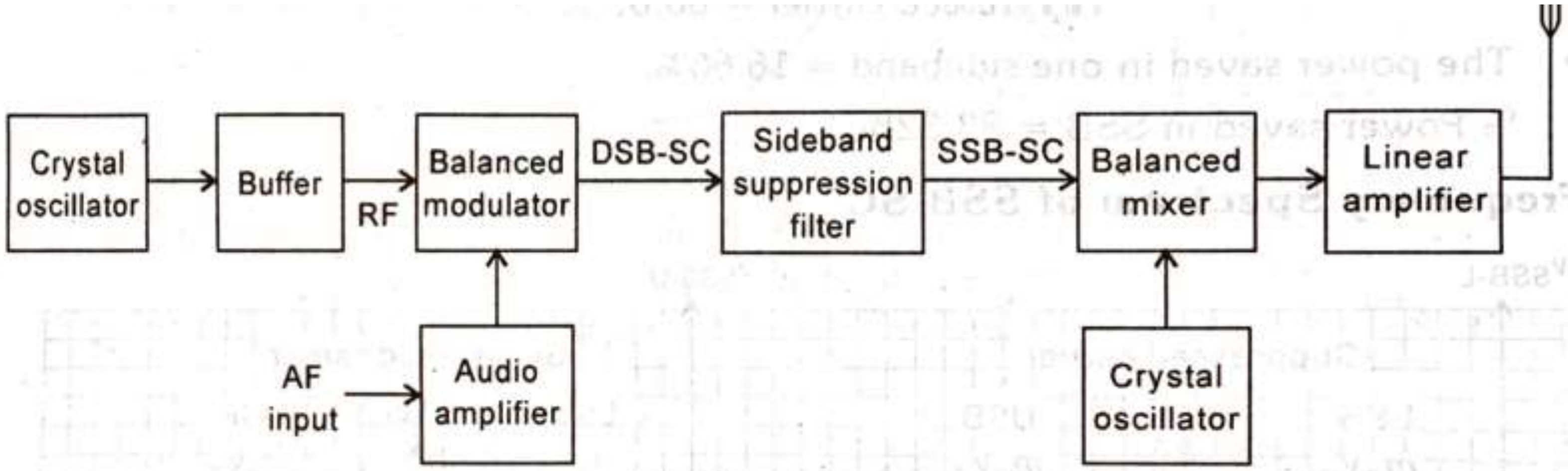


(a)
(b)
0.5 [sgn(ω + ω_x) − sgn (ω − ω_x)]
(c)
M_DSB(ω) = 0.5 [M (ω + ω_x) − M (ω −
M_SSB-L (ω) = 0.5 M_DSB (ω) [sgn (ω + ω_x) − sgn
Refer to Fig. 1-26 for plot of sgn function
by definition, sgn(ω) = u(ω) − u(−ω)

SSB Generation

- Filter Method
- Phase shift Method
- Third Method

Filter Method



Phase shift Method

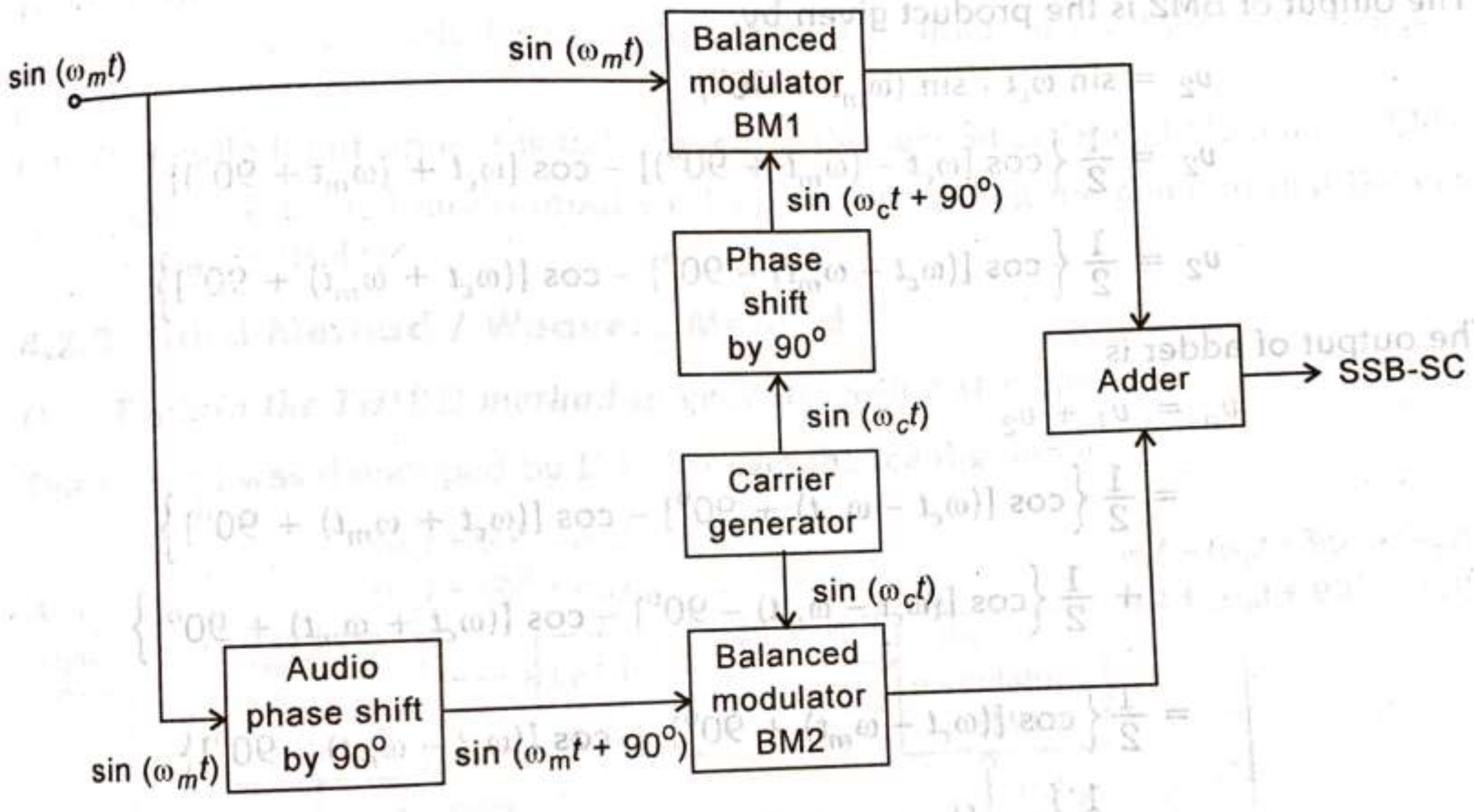
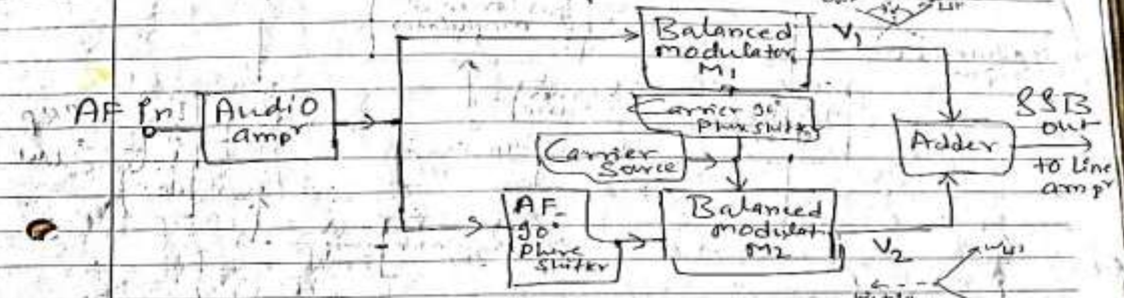


Fig 4.10

2) Phase Shift Method :-

The Phase-Shift method avoids filter and some of the inherent disadvantages and makes use of two balanced modulators and two phase-shift networks.



Let AF = $\sin \omega_m t$ or $\cos \omega_m t$

RF = $\sin \omega_c t$ + $\cos \omega_c t$

(i) Balanced modulator M_1 will receive $\cos \omega_m t$ & $\cos(\omega_c t + 90°)$

(ii) Whereas M_2 takes $\cos(\omega_m t + 90°)$ and $\cos \omega_c t$

O/p of Balanced modulator contain sum & diff frequencies.

the O/p of modulator 1

$$V_1 = \frac{1}{2}\cos[(\omega_c t + 90° + \omega_m t)] + \frac{1}{2}\cos[\omega_c t + 90 - \omega_m t]$$

USB with 90° advance ($= -\sin\theta$)

LSB with 90° delay advance, $\cos(90+\theta) = -\sin\theta$

& O/p of modulator 2

$$V_2 = \frac{1}{2}\cos[\omega_c t + \omega_m t + 90°] + \frac{1}{2}\cos[\omega_c t - \omega_m t - 90°]$$

LSB with 90° delay, $\sin\theta$

$-\cos\theta = -\sin$, $+\sin$, $-\sin\theta$

the O/p of the adder is

$$V_1 + V_2 = \frac{1}{2}\left[\cos[(\omega_c t + \omega_m t + 90°)]\right.$$ $= -\sin\theta$

$$+ \cos[\omega_c t + \omega_m t + 90] + \cos[\omega_c t - \omega_m t + 90°)]$$

$= \cos \omega_c t - \omega_m t - 90$

Adder O/p $= USB$

$\sin\theta = \sin\theta$

The LSBs in the o/p of M_1 & M_2 are $180°$ out of phase w.r.t to each other. Hence they are cancelled out when added so o/p contains only the upper SB.

② Suppression of Upper Side band :-

Input to M_1 = $\cos \omega_m t$ and $\cos \omega_c t$

" " M_2 = $\cos(\omega_m t + 90°)$ & $\cos(\omega_c t + 90°)$

O/p of M_1 = $\cos\omega_c t \cos\omega_m t$

$$= \underbrace{\frac{1}{2}\cos(\omega_c t + \omega_m t)}_{\text{USB with } 0° \text{ Phase shift}} + \underbrace{\frac{1}{2}\cos(\omega_c t - \omega_m t)}_{\text{LSB with } 0° \text{ Phase shift}}$$

O/p of M_2 = $\cos(\omega_c t + 90°)$ & $\cos(\omega_c t + 90°)$

$$= \frac{1}{2}\left[\cos(\omega_c t + 90° + \omega_m t + 90°)\right] + \frac{1}{2}\left[\cos(\omega_c t + 90° - (\omega_m t + 90°))\right]$$

$$= \frac{1}{2}\left[\cos(\omega_c t + \omega_m t + 180°)\right] + \frac{1}{2}\left[\cos(\omega_c t + \cancel{90°} - \omega_m t - \cancel{90°})\right]$$

USB with 180° Phase Shift
LSB with zero Phase shift

∴ Adder O/P = $\cos(\omega_c - \omega_m)t$.

Ad - Generate SSB at any freq.
- easy to switch from one side band to other.
- Can use low audio freq.

DIS - this method need correct 90° Phase shift at all the freq. which is practically not possible.

Advantages

- It is very easy to switch from one sideband to other i.e. between LSB and USB.
- It is useful to generate SSB at any frequency even at low frequencies.

Disadvantages

- If the Phase Shifter provides a phase change other than 90°, then particular frequency will not be removed completely from the unwanted sidebands.
- The audio- phase shifter is more complex device since it has to work over a large frequency range.
- The two Balanced Modulators used also should match to avoid incomplete cancellation of frequencies.

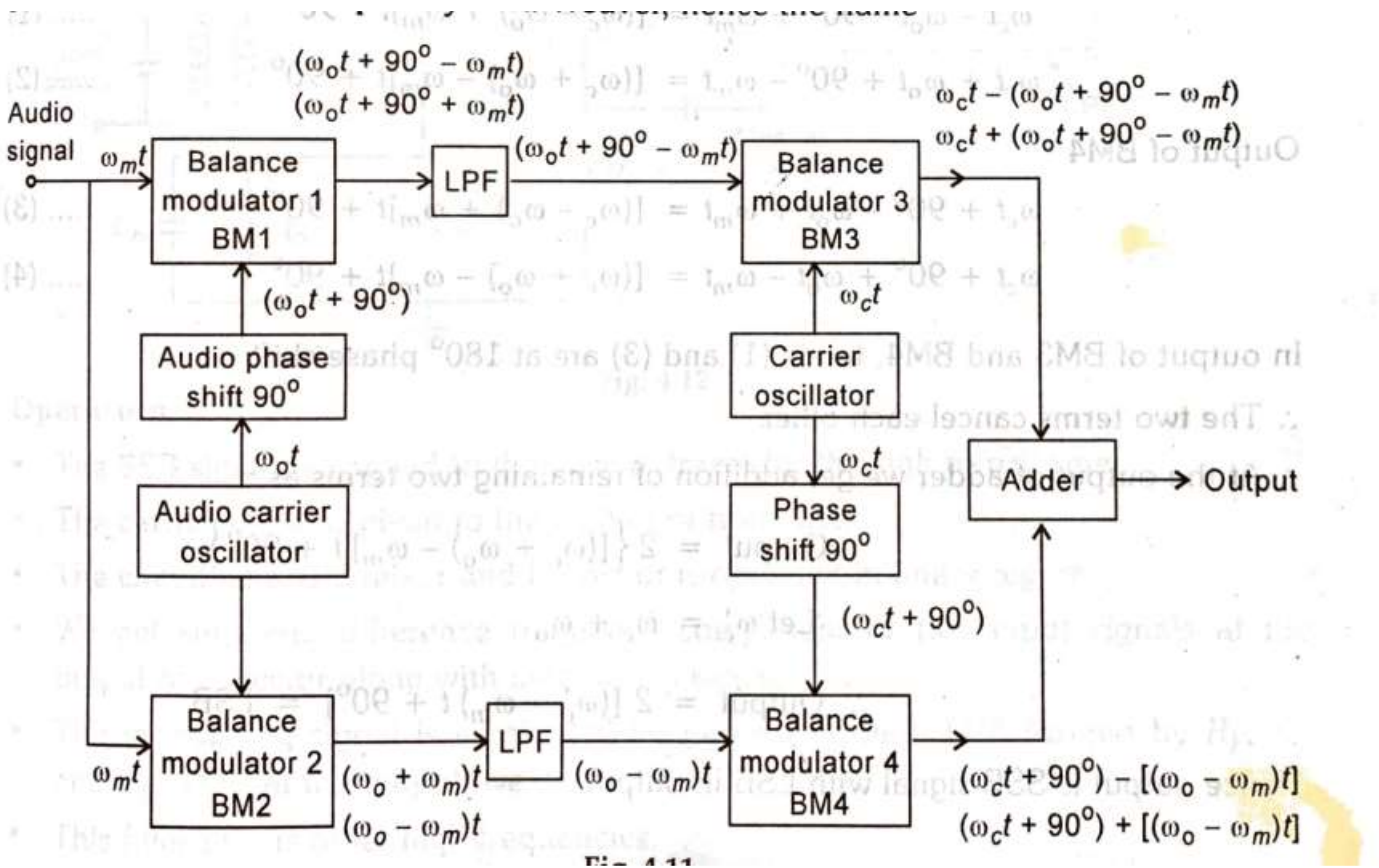
To Obtain Lower Side Band

To obtain Lower Side Band at the adder, we should make following changes in the circuit.

(1) The audio input $\sin \omega_m t$ is to be given to the second Balanced Modulator (BM_2).

(2) The phase shifted audio input $\sin (\omega_m t + 90^o)$ should be given to first Balanced Modulator (BM1).

Third Method



Circuit Description

- The above method is very much similar to phase shift method.
- This method uses four balanced modulators, two carrier generators, two phase shifters and an adder.
- This method has all the advantages of the phase shift method.
- Unlike phase shift method, in this method the modulating signal does not undergo any phase shift.
- An intermediate frequency (ω_o) is generated and applied to BM1 and 90° phase shifted signal ($\omega_o + 90^\circ$) is applied to BM2.
- Modulating signal is applied to both BM1and BM2.
- Now, let us see the mathematical proof

Output of BM1

$$\omega_o t + 90^\circ \pm \omega_m t$$

Output of BM2

$$(\omega_o \pm \omega_m)t$$

Output of BM3

$$\omega_c t - \omega_o t - 90^\circ + \omega_m t = [(\omega_c - \omega_o) + \omega_m]t - 90^\circ \quad \text{..... (1)}$$

$$\omega_c t + \omega_o t + 90^\circ - \omega_m t = [(\omega_c + \omega_o) - \omega_m]t + 90^\circ \quad \text{..... (2)}$$

Output of BM4

$$\omega_c t + 90^\circ - \omega_o t + \omega_m t = [(\omega_c - \omega_o) + \omega_m]t + 90^\circ \quad \text{..... (3)}$$

$$\omega_c t + 90^\circ + \omega_o t - \omega_m t = [(\omega_c + \omega_o) - \omega_m]t + 90^\circ \quad \text{..... (4)}$$

In output of BM3 and BM4, terms (1) and (3) are at 180° phase shift

∴ The two terms cancel each other

∴ At the output of adder we get addition of remaining two terms as :

$$\text{Output} = 2\left\{[(\omega_c + \omega_o) - \omega_m]\,t + 90^\circ\right\}$$

$$\text{Let } \omega_c' = \omega_c + \omega_o$$

$$\therefore \text{Output} = 2\,[(\omega_c' - \omega_m)\,t + 90^\circ] = \text{LSB}$$

Hence output is SSB signal with LSB in output.

Advantages

- It can generate SSB signal at any frequency, even at low frequencies.
- After modulation, amplifiers are not required for up conversion.

Disadvantages

- Difficult to match all balanced modulators.
- Very complex, not practically used.

Difference

Q.2. Compare the three main systems of SSB generation.

Ans.

Sr.	Parameter	Filter Method	Phase Shift Method	Third Method
(1)	Low modulating frequency	Cannot be used	Can be used	Can be used
(2)	SSB generation at high frequency	Not possible	Possible	Possible
(3)	Design	Using Filters	Using phase shifters by 90°	Using phase shifters by 90°
(4)	Complexity	Less	Average	Very complex
(5)	Frequency upconversion	Required	Not required	Not required

SSB Demodulator

4.3 SSB Demodulator

The detectors used for DSB-FC can not be used for detection of SSB signal because the amplitude of SSB signal is constant.

We use following detectors.

4.3.1 Product Detector

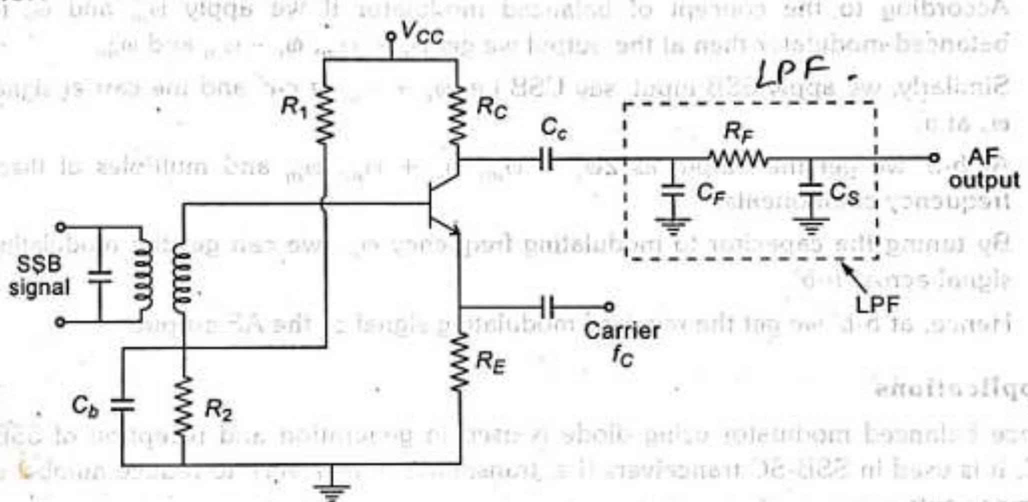


Fig. 4.12

Operatoin

- The SSB signal is applied to the base of transistor through transformer.
- The carrier signal is given to the emitter of transistor.
- The circuit acts as a mixer and transistor is operated in linear region.
- We get sum and difference frequency component of two input signals at the output of collector along with modulating signal.
- The modulating signal is eliminated by passing through LPF formed by R_F, C_F and C_S. Thus at the output, we get modulating signal.
- This filter rejects other high frequencies.

4.3.2 Balanced Demodulator

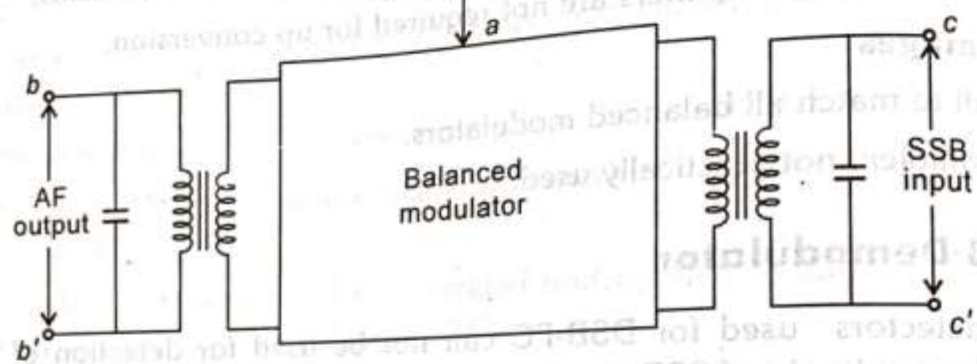


Fig. 4.13

- A balanced modulator which is used to generate DSB-SC can also be used as SSB-SC detector.
- According to the concept of balanced modulator if we apply ω_m and ω_c to balanced modulator then at the output we get $\omega_c + \omega_m$, $\omega_c - \omega_m$ and ω_m.
- Similarly, we apply SSB input, say USB i.e. $\omega_c + \omega_m$ at c-c' and the carrier signal ω_c at *a*.
- At *b-b'* we get the output as $2\omega_c + \omega_m$, $\omega_c + \omega_m$, ω_m and multiples of these frequency components.
- By tuning the capacitor to modulating frequency ω_m, we can get the modulating signal across *b-b'*.
- Hence, at *b-b'* we get the required modulating signal or the AF output.

Applications

Since balanced modulator using diode is used in generation and reception of SSB-SC, it is used in SSB-SC tranceivers (i.e. transmitter + receiver) to reduce number of components.

Pilot Carrier SSB Transmitter

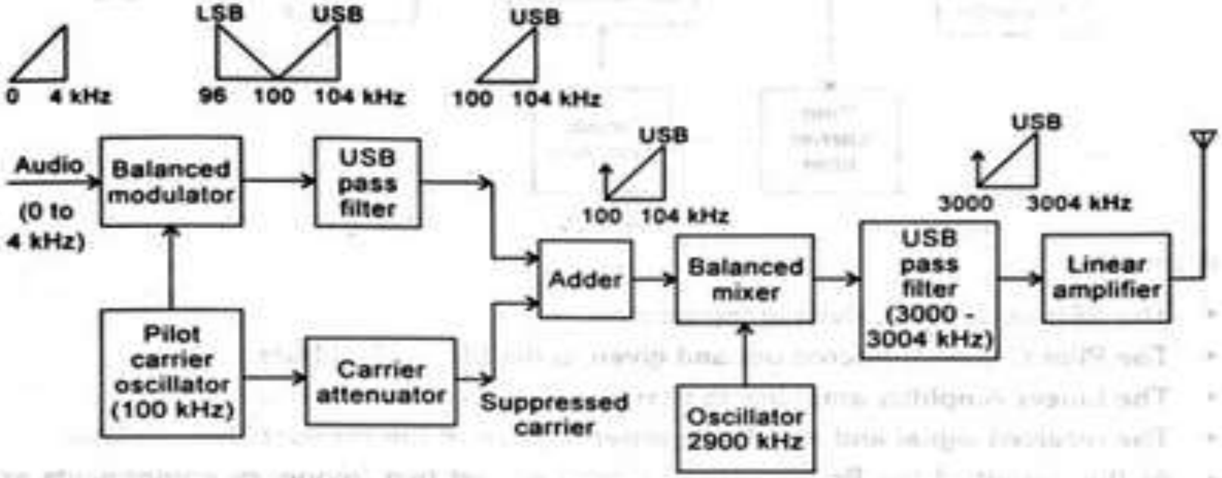


Fig. 4.14

Operation

- As shown in *figure 4.14* transmitter system, the inputs to the balanced modulator are audio signal and carrier signal.
- The balanced modulator produces two side bands where USB = 100 to 104 kHz and LSB = 100 to 96 kHz.
- At the output of USB pass filter, we get only the USB.
- According to Pilot Carrier System, the reduced pilot carrier is inserted and at the output of Adder we get SSB signals along with reduced carrier.
- Balanced mixer along with the 2900 kHz frequency oscillator is used to boost the signal given by the adder.
- The output of balanced mixer consists of sum and difference frequency components.
- The USB pass filter allows to pass only the upper side band frequency components.
- The linear amplifiers are used to increase the power level of the signal before transmission.
- Hence the transmission of SSB signal is with large power and at high frequency.

Pilot Carrier Receiver

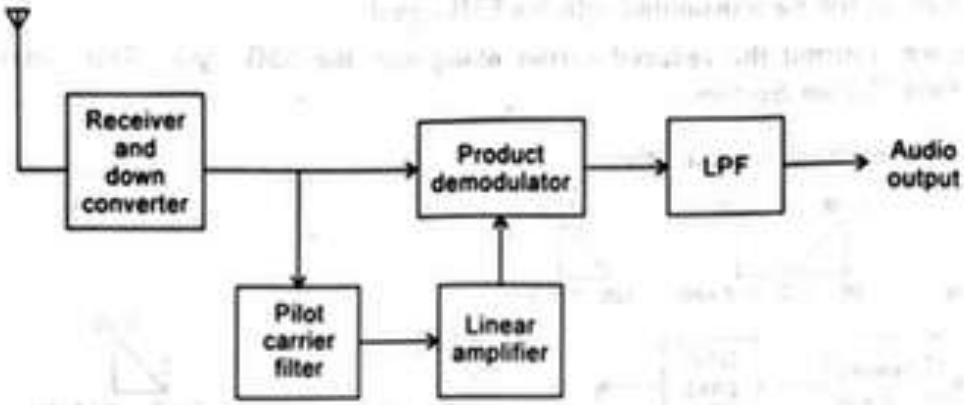


Fig. 4.15

Operation

- The SSB signal is received at the receiver.
- The Pilot Carrier is filtered out and given to the Linear Amplifier.
- The Linear Amplifier amplifies the carrier signal and filters out the noise.
- The received signal and amplified carrier is given to the Product Demodulator.
- At the output of the Product Demodulator we get two frequency components as follows :

$$\left(\frac{mV_c}{2}\sin(\omega_c + \omega_m)t\right) \cdot V_c \sin \omega_c t$$

$$= \frac{mV_c^2}{2}\sin(\omega_c + \omega_m)t \sin \omega_c t$$

$$= \frac{mV_c^2}{4}\left[\cos \omega_m t - \cos(2\omega_c + \omega_m)t\right]$$

- We get (ω_m) and $(2\omega_c + \omega_m)$ frequency components.
- The LPF rejects higher frequency component i.e. $(2\omega_c + \omega_m)$.
- The ω_m component is passed through LPF which is nothing but the audio signal.

Vestigial Side Band (VSB)

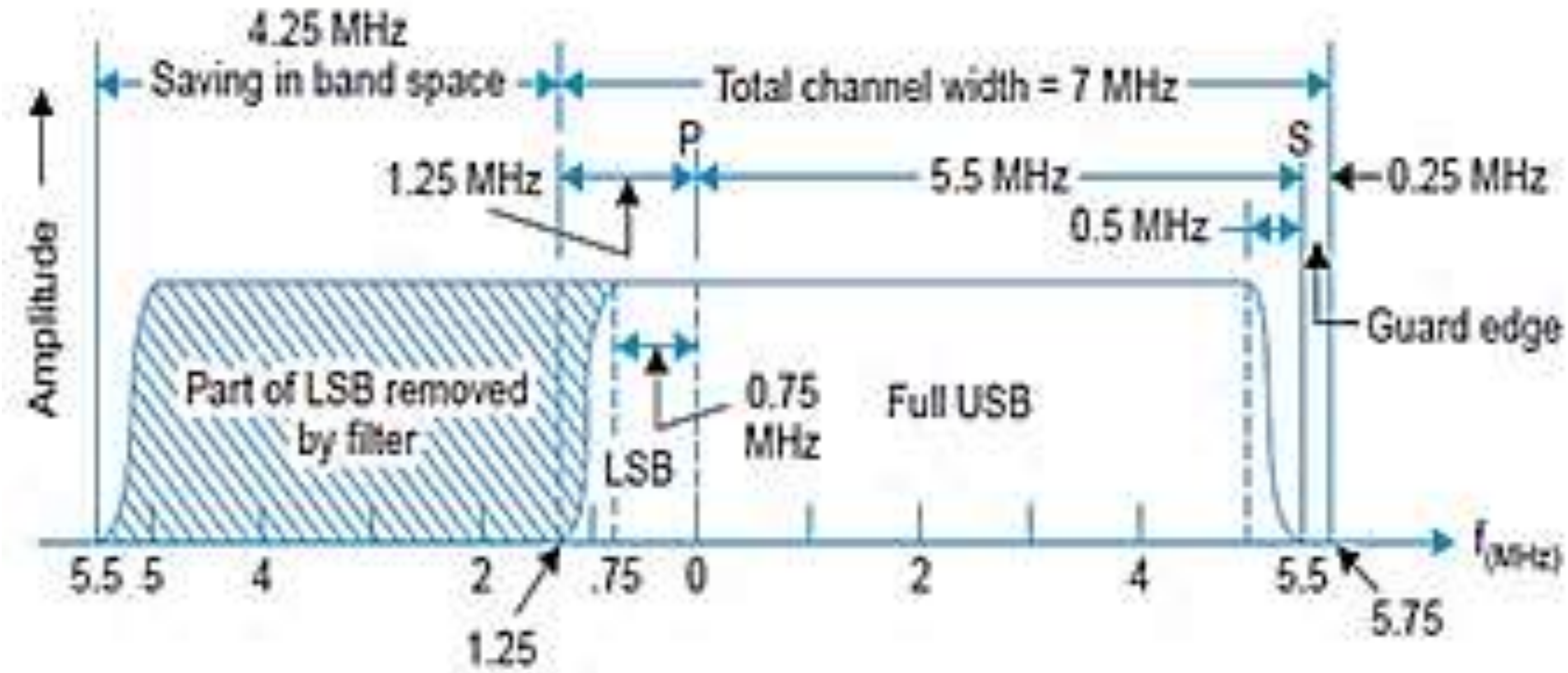


Fig. 4.3 Total channel bandwidth using vestigial' lower sideband.

VSB

So, the bandwidth requirement is less and we can transmit more channels.

This system is widely used to transmit TV signals.

Let us study the system with the help of example of TV transmission.

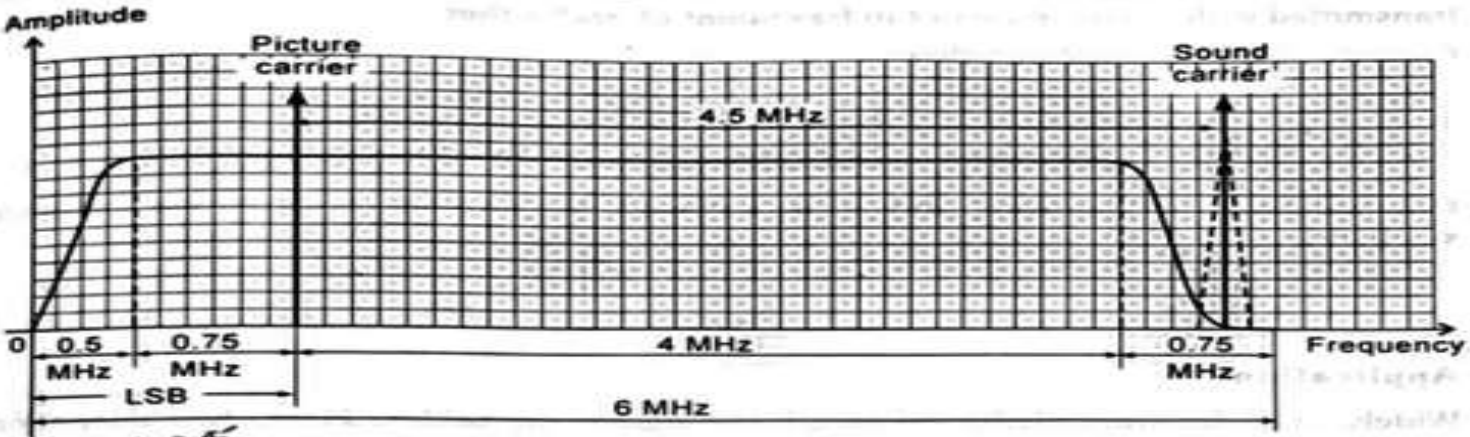


Fig. 4.16

- In TV transmission, the signal consists of video signal and audio signal.
- Video signal is amplitude modulated where as Audio signal is frequency modulated.
- To minimize the required bandwidth we can think of using SSB-SC system.
- But if we try to suppress one sideband (let us say LSB) then the information content in other sideband (the USB) near to carrier will also get attenuated.
- As most of video information lies on lower side of frequency near carrier, the suppression produces phase distortion.
- To avoid this, some part (i.e. vestige) of LSB is also transmitted.
- Therefore in TV transmission we transmit full USB of 4 MHz and only 1.25 MHz of LSB, a total of 5.25 MHz.
- We add extra 0.75 MHz for tapering of frequency response of filter on USB and also to accommodate the sound carrier.
- Therefore the bandwidth requirement reduces from 9 MHz to 6 MHz.

Independent Side Band

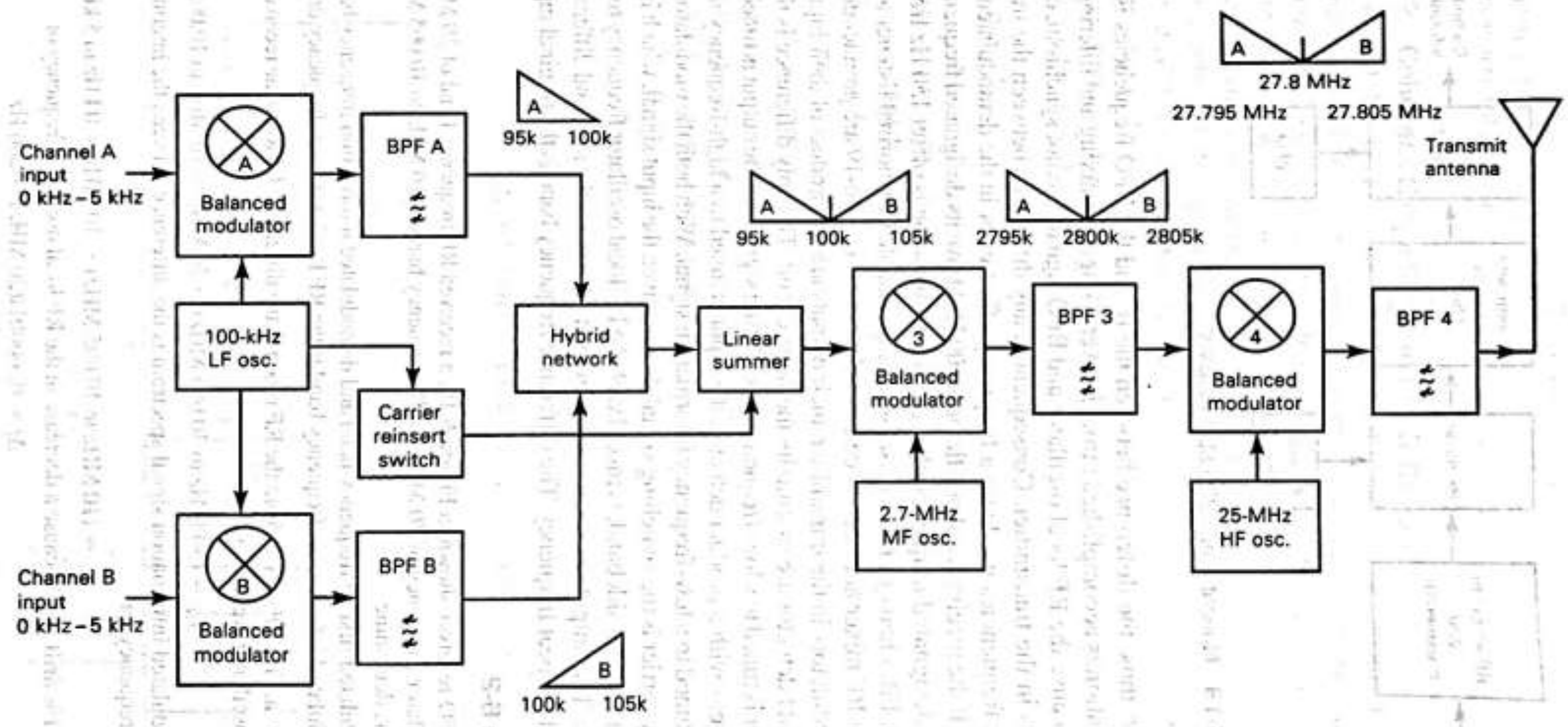


FIGURE 6-18 ISB transmitter: block diagram

Ans.

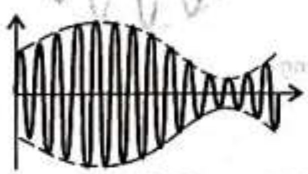
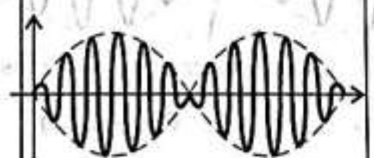
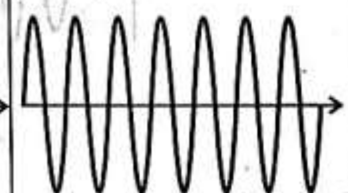
Parameter	DSB-FC	DSB-SC	SSB-SC
Carrier	Full carrier present	Suppressed carrier	Suppressed carrier
Number of sidebands	Two	Two	One
Equation	$v = V_c \sin \omega_c t - \frac{mV_c}{2} \cos (\omega_c + \omega_m)t + \frac{mV_c}{2} \cos (\omega_c - \omega_m)t$	$v = \frac{mV_c}{2} \cos (\omega_c - \omega_m)t - \frac{mV_c}{2} \cos (\omega_c + \omega_m)t$	$v = \frac{mV_c}{2} \cos (\omega_c + \omega_m)t$ OR $v = \frac{mV_c}{2} \cos (\omega_c - \omega_m)t$
Physical appearance			
Power saving	No	67 %	83 %
Non coherent reception	Possible	Not possible	Not possible
Bandwidth	$2f_m$	$2f_m$	f_m

Table 4.2