Sri SAI RAM ENGINEERING COLLEGE
INSTITUTE OF TECHNOLOGY
West Tambaram, Chennai - 44

SAIRAM DIGITAL RESOURCES

YEAR II | SEM III

EC8394

ANALOG AND DIGITAL COMMUNICATION

UNIT NO 1 ANALOG MODULATION

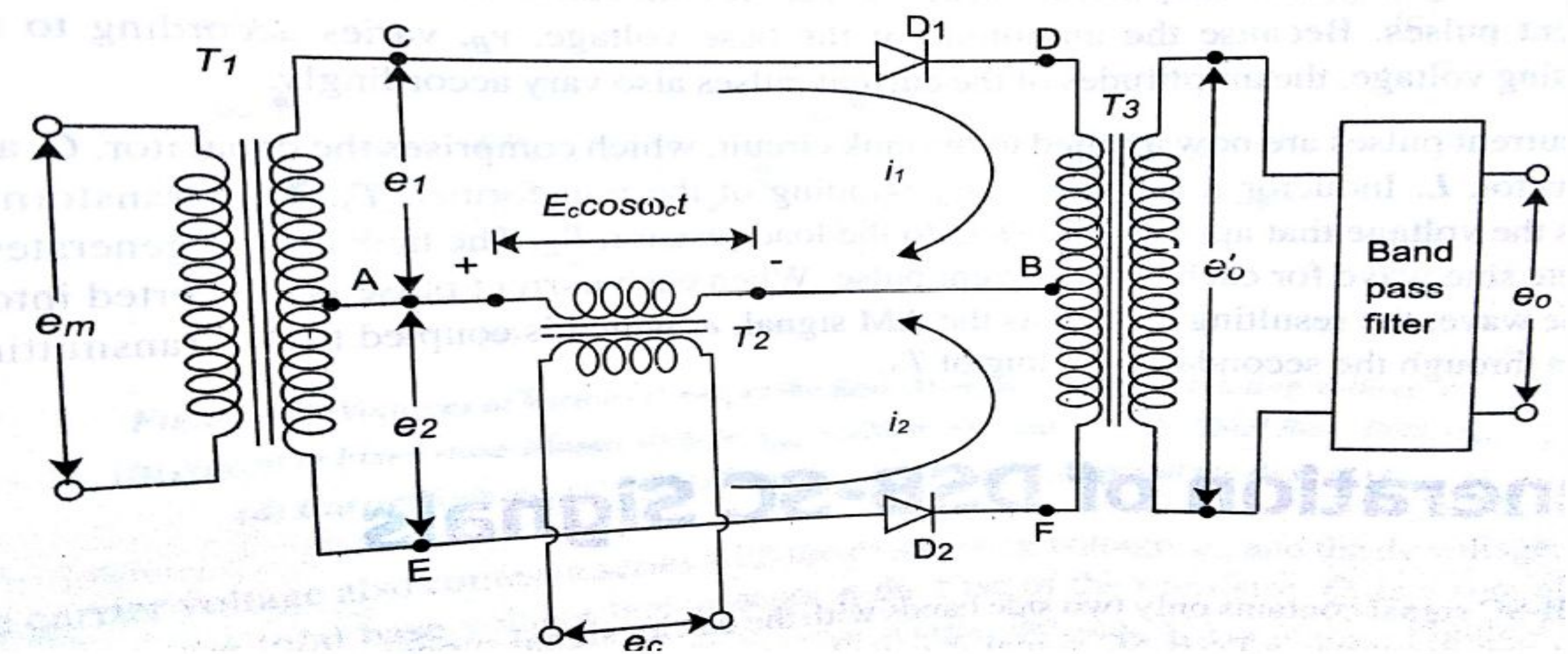
SINGLE SIDE BAND

ELECTRONICS & COMMUNICATION ENGINEERING

Single side band

- **What are the limitations of DSB-SC ?**
- **What is SSB signal?**
- If we consider the fact that two sidebands carry same information, DSB signal is redundant
- That is in DSB the basic information is transmitted twice once in each sideband
- Therefore there is absolutely no reason to transmit both sidebands in order to convey the information
- One sideband may be suppressed
- The resulting signal is a single sideband commonly referred to as single sideband suppressed carrier signal

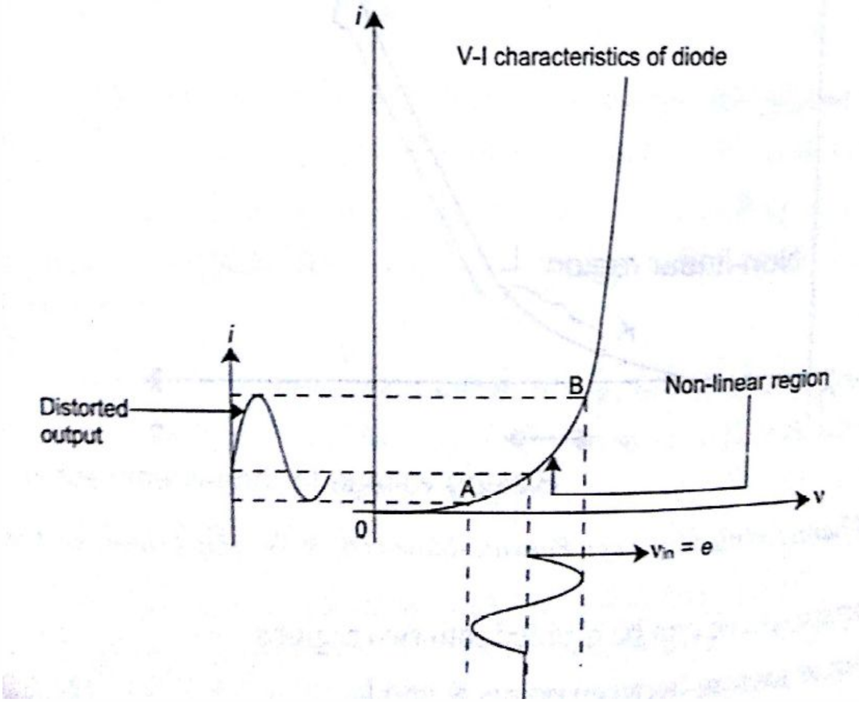
Balanced modulator- SSB



Eqn in balanced modulator

- As a rule if the voltage e is applied to a non linear device the resulting current is expressed as

$$i = ae + be^2 + ce^3 + de^4 + \ldots$$



$$a > b > c > d > e \ldots$$

$$i = ae + be^2$$

Eqn in balanced modulator

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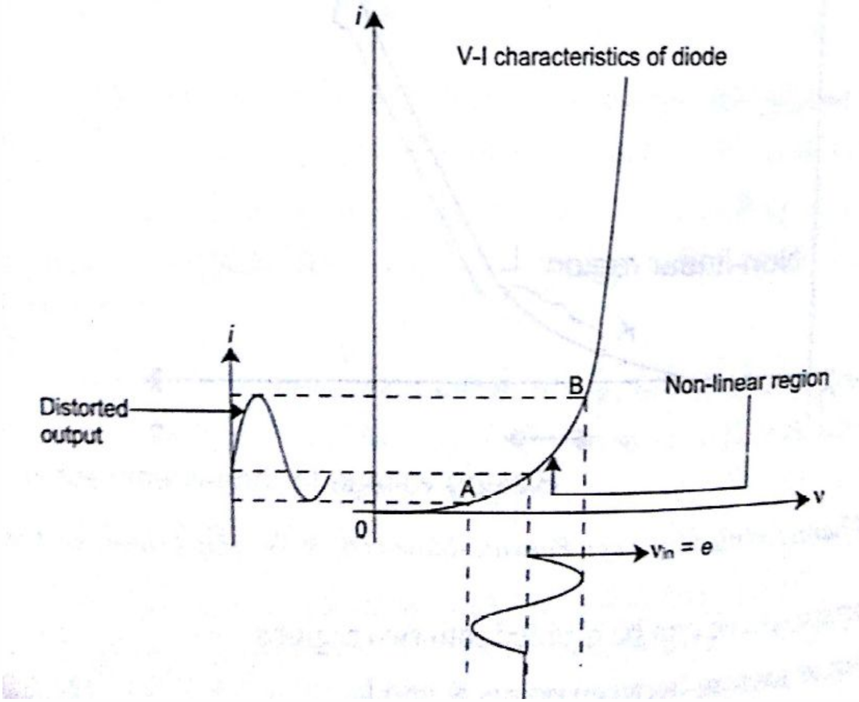


$$a > b > c > d > e \dots$$

$$i = ae + be^2$$

Eqn in balanced modulator

- **VOLTAGE DEVELOPED ACROSS SECONDARY WINDING OF T_3**

$$v_{upper} = i_1 R$$

$$v_{lower} = -i_2 R$$

$$e'_0 = v_{upper} + v_{lower}$$

$$e'_0 = i_1 R - i_2 R$$

$$e'_0 = (i_1 - i_2)R$$

$$e'_0 = R\{[a\,(E_c \cos \omega_c t + e_m) + b\,(E_c \cos \omega_c t + e_m)^2] - [a\,(E_c \cos \omega_c t - e_m) + b\,(E_c \cos \omega_c t - e_m)^2]\}$$

$$e'_0 = R\{[a\,(E_c \cos \omega_c t + e_m) + b\,(E_c^2 \cos^2 \omega_c t + 2E_c\, e_m \cos \omega_c t + e_m^2)] - [a\,(E_c \cos \omega_c t - e_m) + b\,(E_c^2 \cos^2 \omega_c t - 2E_c\, e_m \cos \omega_c t + e_m^2)]\}$$

Eqn in balanced modulator

$$e'_0 = R\{[a E_c \cos \omega_c t + a e_m + b E_c^2 \cos^2 \omega_c t + 2bE_c e_m \cos \omega_c t + be_m^2] - [aE_c \cos \omega_c t - a e_m + b E_c^2 \cos^2 \omega_c t - 2bE_c e_m \cos \omega_c t + be_m^2]\}$$

$$e'_0 = R\{aE_c \cos \omega_c t + ae_m + b E_c^2 \cos^2 \omega_c t + 2bE_c e_m \cos \omega_c t + be_m^2 - a E_c \cos \omega_c t - a e_m - b E_c^2 \cos^2 \omega_c t + 2bE_c e_m \cos \omega_c t - be_m^2\}$$

$$e'_0 = R(2ae_m + 4bE_c e_m \cos \omega_c t)$$

Eqn in balanced modulator

- Consider the modulating voltage as

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

- Substituting e_m in e_0 we get

$$e_0 = 2R\,(ae_m + 2bE_m \cos \omega_m t\; E_c \cos \omega_c t)$$

$$e_0 = 2R\,(a\,e_m + 2bE_cE_m \cos \omega_c t \cos \omega_m t)$$

- Eqn can be expanded using the trignometric identity as

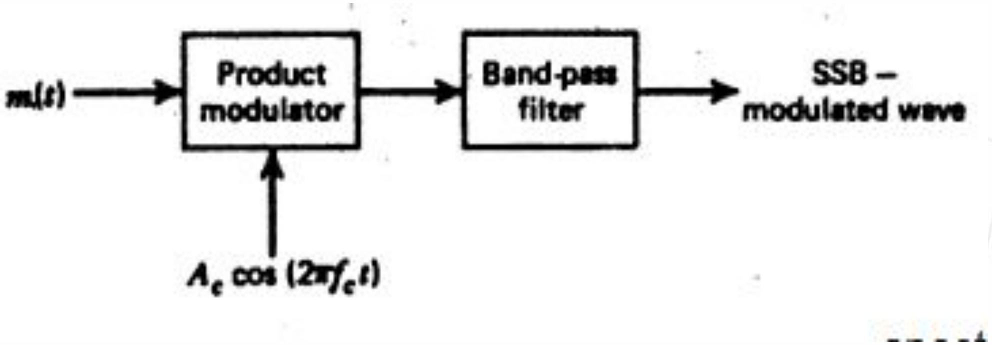
$$e_0' = 2R\left\{ae_m + \frac{2bE_cE_m}{2}\left[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t\right]\right\}$$

$$e_0 = 2RbE_cE_m\,[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$$

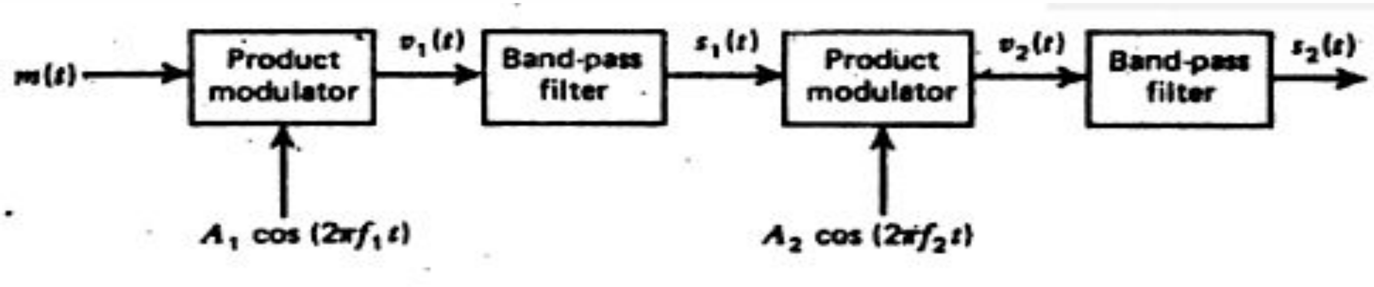
$$e_0 = \underbrace{k\cos(\omega_c + \omega_m)t}_{\text{USB}} + \underbrace{k\cos(\omega_c - \omega_m)t}_{\text{LSB}}$$

Generation of SSB waves

- FREQUENCY DISCRIMINATION METHOD/FILTER METHOD
- **Block Diagram of the Frequency Discrimination Method for Generating SSB Waves**

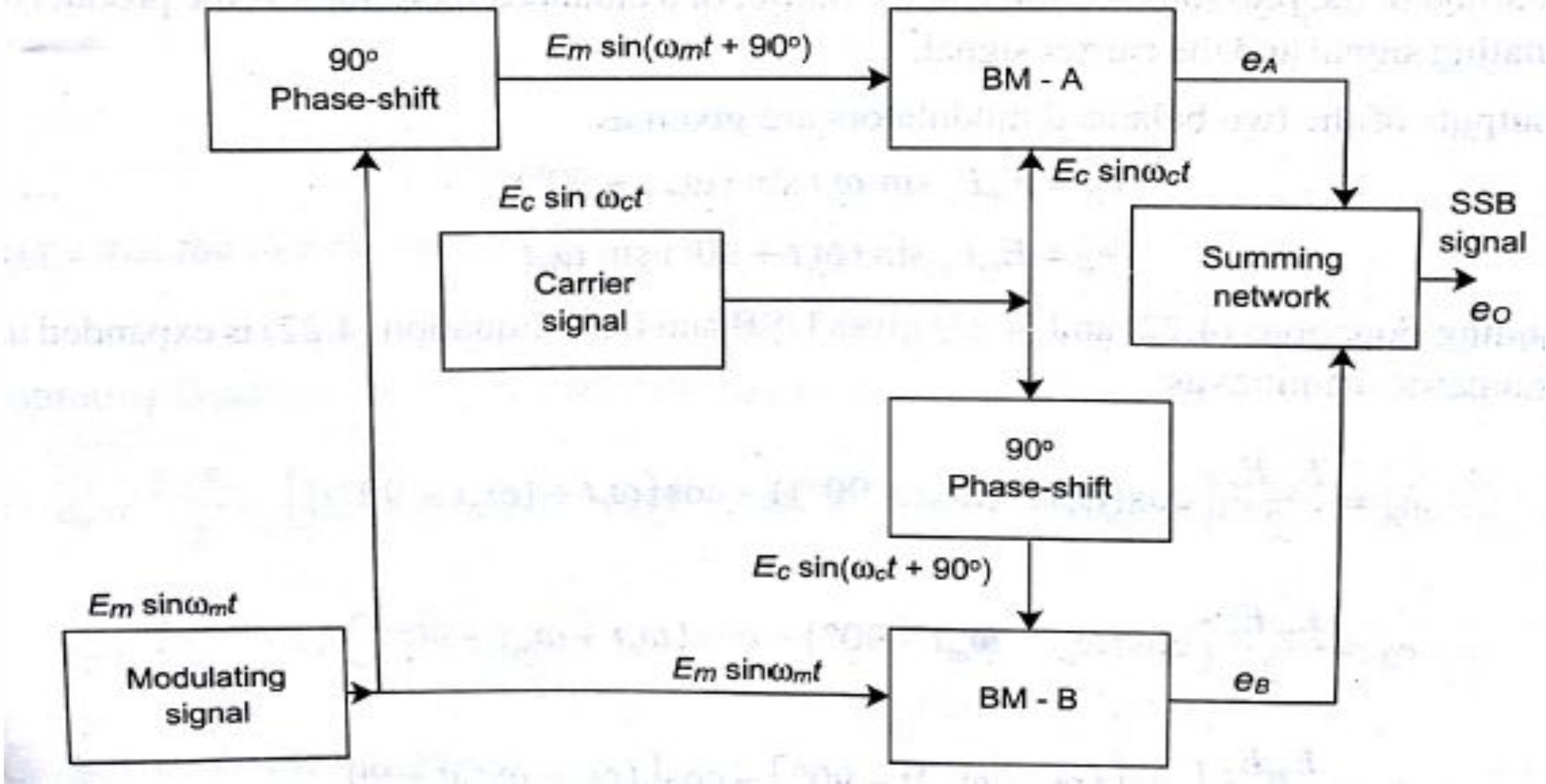


- **Block diagram of a two stage SSB modulator**



Phasing method

PHASE DESCRIMINATION METHOD/HARTLEY MODULATOR



Mathematical analysis of phasing method

- eA= DSB-SC output of balanced modulator A
- eB= DSB-SC output of balanced modulator B

$$e_0 = e_A \pm e_B$$

- Consider the modulating and the carrier signal

$$e_m = E_m \sin \omega_m t$$

$$e_c = E_c \sin \omega_c t$$

- Inputs of balanced modulator A: $E_m \sin(\omega_m t + 90°)$ and $E_c \sin \omega_c t$
- Inputs of balanced modulator B: $E_m \sin \omega_m t$ and $E_c \sin(\omega_c t + 90°)$

The outputs of the two balanced modulators are given as:

$$e_A = E_m E_c \sin \omega_c t \sin(\omega_m t + 90°)$$

$$e_B = E_m E_c \sin(\omega_c t + 90°) \sin \omega_m t$$

Cont….

- Expanding eqn gives USB and LSB

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

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

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

$$e_A = \frac{E_m E_c}{2}\left[\sin(\omega_c - \omega_m)t + \sin(\omega_c + \omega_m)t\right]$$

- Expanding the second eqn we get

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

Cont….

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

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

$$e_B = \frac{E_m E_c}{2}\left[-\sin(\omega_c - \omega_m)t + \sin(\omega_c + \omega_m)t\right]$$

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

$$\cos(\theta - 90°) = \sin\theta$$

$$\cos(\theta + 90°) = -\sin\theta$$

Cont….

- Assume that the two outputs Ea and Eb are added together

$$e_0 = e_A + e_B$$

$$e_0 = \frac{E_m E_c}{2}\left[\sin(\omega_c - \omega_m)t + \sin(\omega_c + \omega_m)t - \sin(\omega_c - \omega_m)t + \sin(\omega_c + \omega_m)t\right]$$

$$e_0 = \frac{E_m E_c}{2} 2\sin(\omega_c + \omega_m)t$$

$$e_0 = E_m E_c \sin(\omega_c + \omega_m)t$$

- If the output of the modulator is subtracted in the summing network the signal is

$$e_0 = e_A - e_B \rightarrow e_0 = \frac{E_m E_c}{2}\left[\sin(\omega_c - \omega_m)t + \sin(\omega_c + \omega_m)t + \sin(\omega_c - \omega_m)t - \sin(\omega_c + \omega_m)t\right]$$

$$e_0 = \frac{E_m E_c}{2} 2\sin(\omega_c - \omega_m)t$$

$$e_0 = E_m E_c \sin(\omega_c - \omega_m)t$$

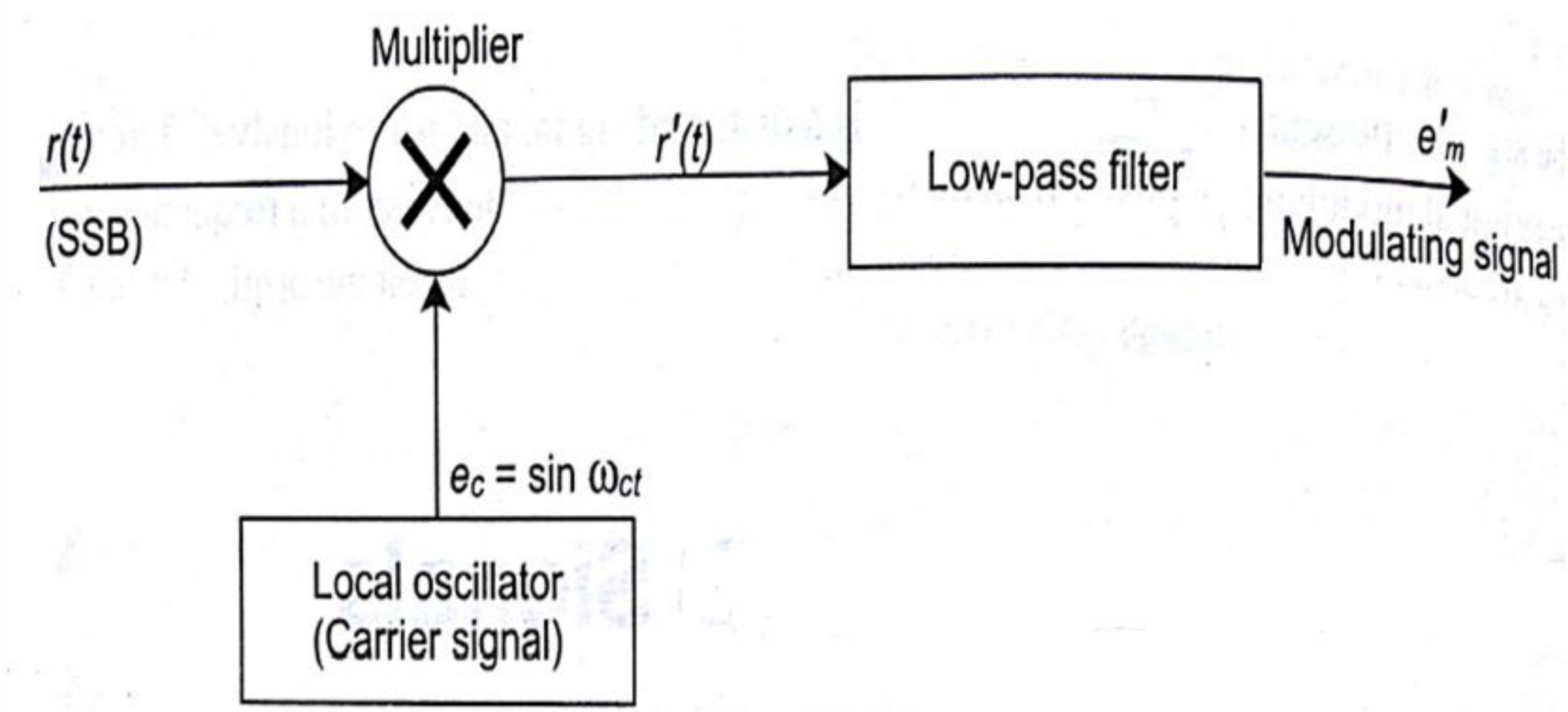
Demodulation of SSB signal

- The eqn of SSB signal is given as

$$e_{SSB\text{-}L} = \frac{m_a E_c}{2} \cos(\omega_c - \omega_m)t$$

$$e_{SSB\text{-}U} = \frac{m_a E_c}{2} \cos(\omega_c + \omega_m)t$$

Coherent detector



- Consider the SSB signal multiply it with the carrier signal to obtain r'(t)

$$r'(t) = \left[\frac{m_a E_c}{2}\cos(\omega_c - \omega_m)t\right]\sin\omega_c t$$

$$r'(t) = \frac{m_a E_c}{2}\left[\sin\omega_c t\cos(\omega_c - \omega_m)t\right]$$

$$r'(t) = \frac{m_a E_c}{2}\left[\frac{1}{2}\sin(\omega_c + \omega_c - \omega_m)t + \frac{1}{2}\sin(\omega_c - \omega_c + \omega_m)t\right]$$

$$r'(t) = \frac{m_a E_c}{4}\left[\sin(2\omega_c - \omega_m)t + \sin\omega_m t\right]$$

$$r'(t) = \underbrace{\frac{m_a E_c}{4}\sin\omega_m t}_{\text{Modulating signal}} + \underbrace{\frac{m_a E_c}{4}\sin(2\omega_c - \omega_m)t}_{\text{Unwanted higher-frequency component}}$$

Advantages of SSB:

Power conservation

Bandwidth conservation

Selective Fading

Noise Reduction

Disadvantage:

Complex Receivers

Need for carrier recovery

Tuning difficulties

Comparison between SSB suppression methods

Sr. No.	Parameter	Filter Method	Phase shift method	Third method
1.	Method used	Filter is used to remove unwanted sideband.	Phase-shifting techniques is used to remove unwanted sideband.	Similar to phase-shift method, but carrier signal is phase shifted by 90°.
2.	90° phase shift	Not required	Requires complex phase shift network	Phase shift network is simple RC circuit
3.	Possible frequency range of SSB	Not possible to generate SSB at any frequency.	Possible to generate SSB at any frequency.	Possible to generate SSB at any frequency.
4.	Need for up-conversion	Required	Not required	Not required
5.	Complexity	Less	Medium	High
6.	Design aspects	Q of tuned circuit, Filter type, it size, weight and upper frequency limit.	Design of 90° phase shifter for entire modulating frequency range. Symmetry of balanced modulators.	Symmetry of balanced modulators.
7.	Bulkyness	Yes	No	No
8.	Switching ability	Not possible with existing circuit. Extra filter and switching network is necessary	Easily possible	Easily possible. But extra crystal is required