DSB-SC, SSB and VSB

Contents

- Theory
- Implementation
  - Transmitter
  - Detector
    - Synchronous
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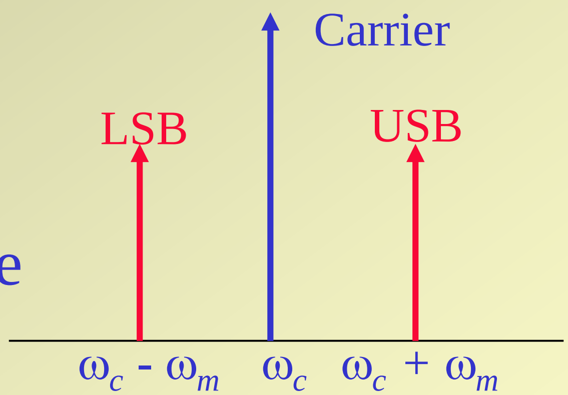
- Power analysis
- Summary

Double Side Band Suppressed Carrier

From AM spectrum:

- Carries signal ω_c carries no information ω_m.
- Carries signal consumes a lot of power more than 50%



Single frequency

Question: *Why transmit carrier at all?*

Ans:

Question: *Can one suppress the carrier?*

Ans.: *Yes, just transmit two side bands (i.e* ***DSB-SC****)*

But what is the penalty?

System complexity at the receiver

DSB-SC - *Theory*

General expression: $c(t) = [k_1 m(t) + C] \cos(\omega_c t + \phi_c)$

Let $k_1 = 1$, $C = 0$ and $\phi_c = 0$, the modulated carrier signal, therefore:

$$\boxed{c(t) = m(t) \cos\omega_c t}$$

Information signal $m(t) = E_m \cos \omega_m t$

Thus

$$c(t) = E_m \cos\omega_m t \cos\omega_c t$$

$$= \frac{ME_c}{2}\cos(\omega_c + \omega_m)t + \frac{ME_c}{2}\cos(\omega_c - \omega_m)t$$

upper side band

lower side band

DSB-SC - *Waveforms*

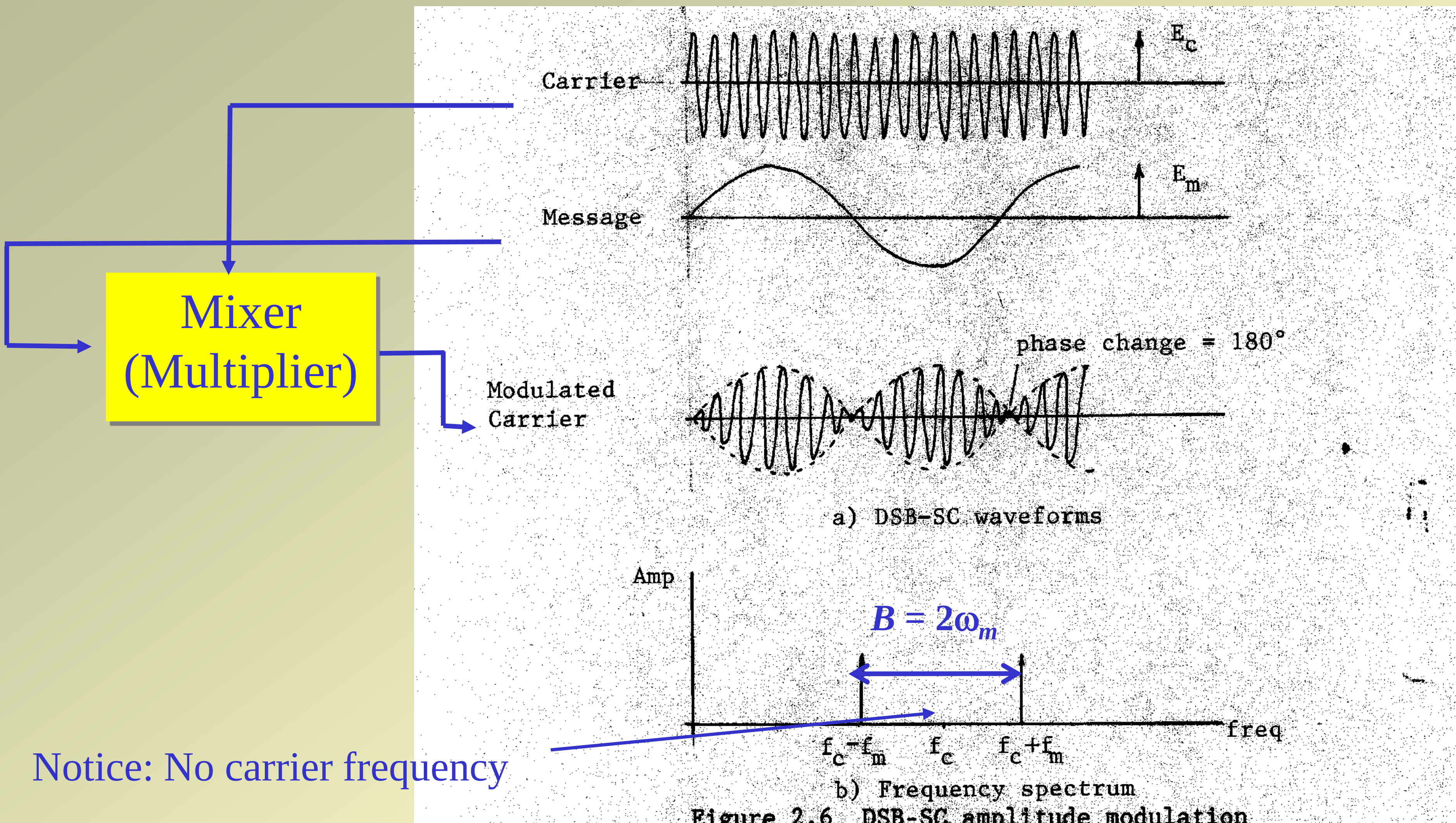
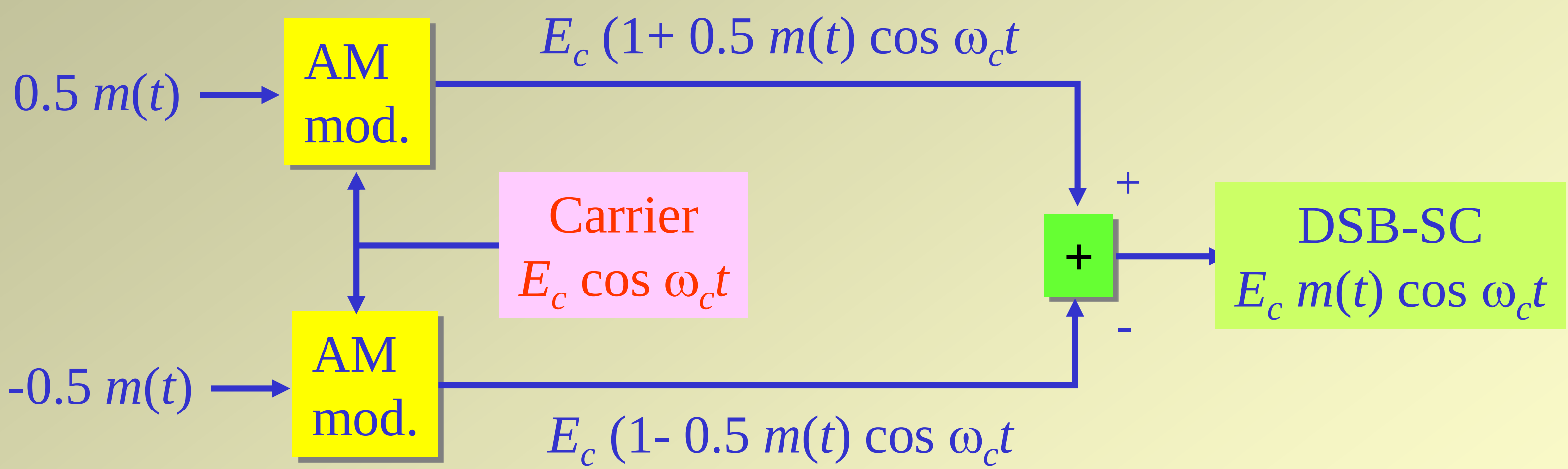


Figure 2.6 DSB-SC amplitude modulation

Notice: No carrier frequency

DSB-SC - *Implementation*

- **Balanced modulator**



- **Ring modulator**

- **Square-law modulator**

DSB-SC - *Implementation*

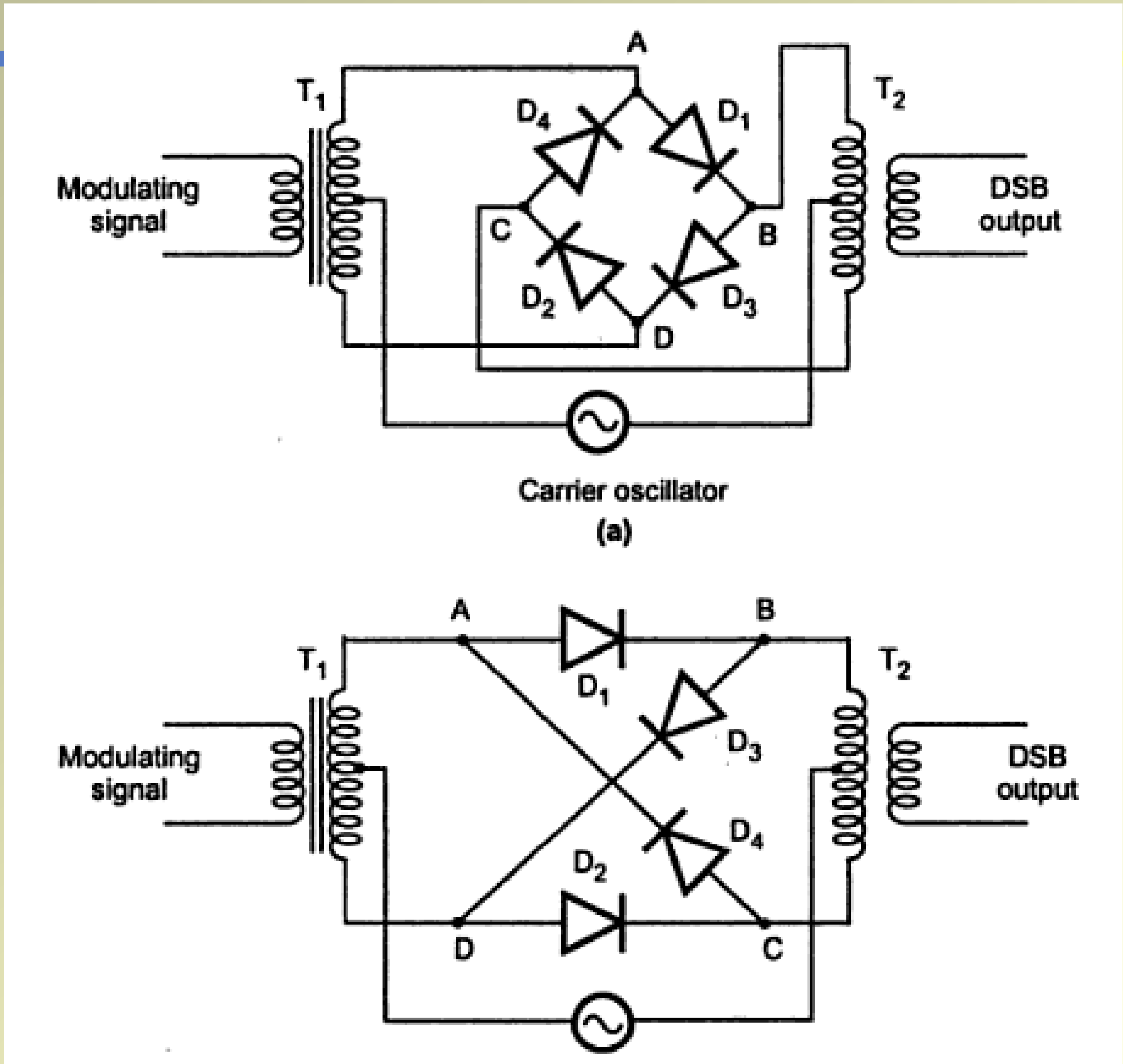
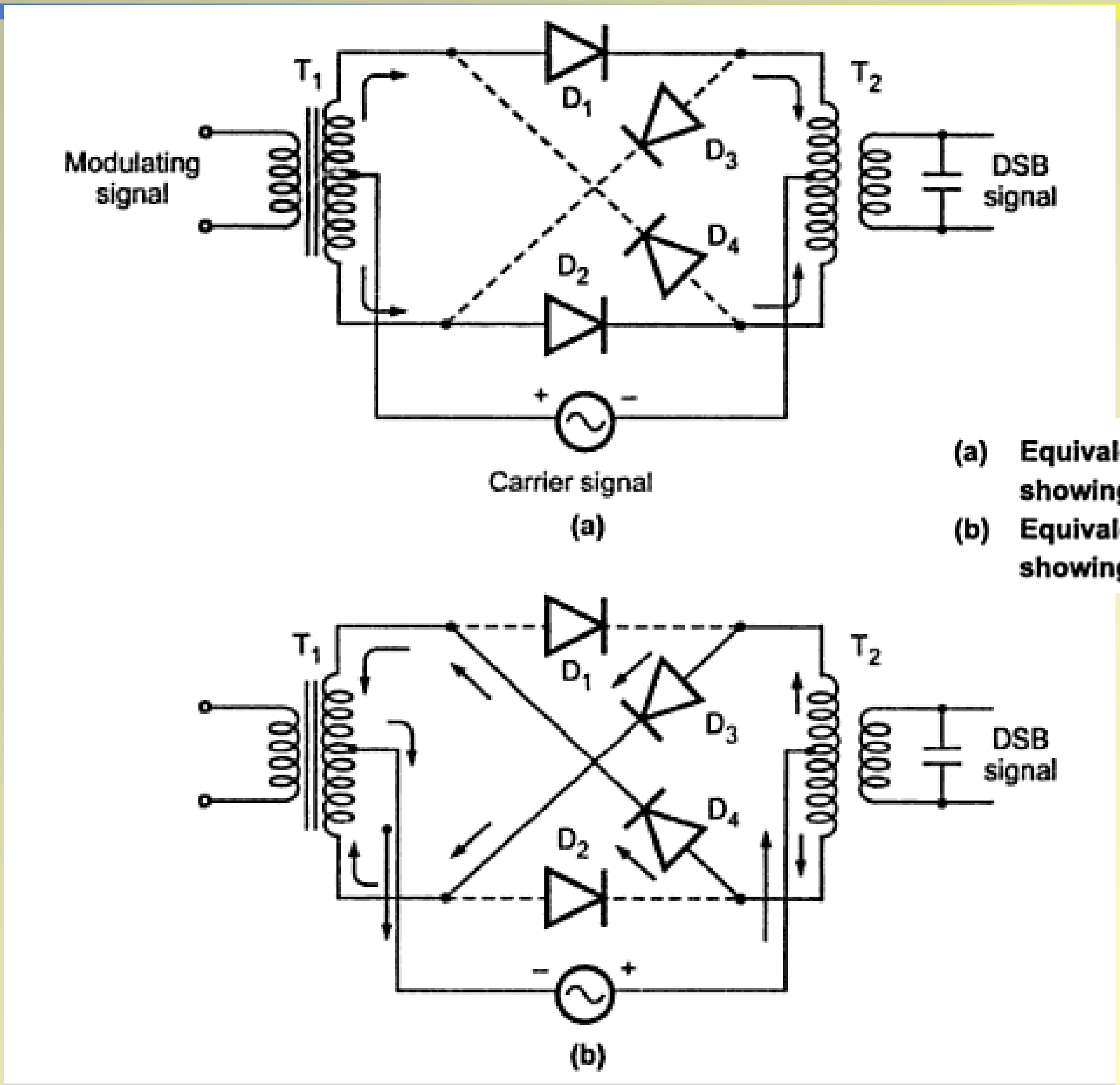


Fig: Balanced Ring Modulator

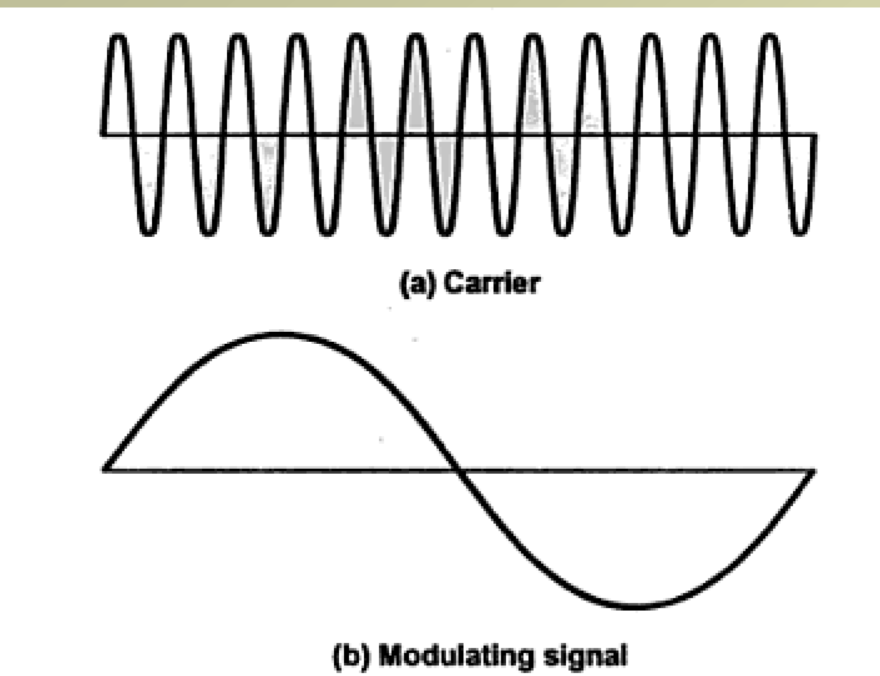
DSB-SC - *Implementation*



(a) Equivalent circuit of balanced modulator showing positive half cycle of carrier

(b) Equivalent circuit of balanced modulator showing negative half cycle of carrier

DSB-SC - *Implementation*



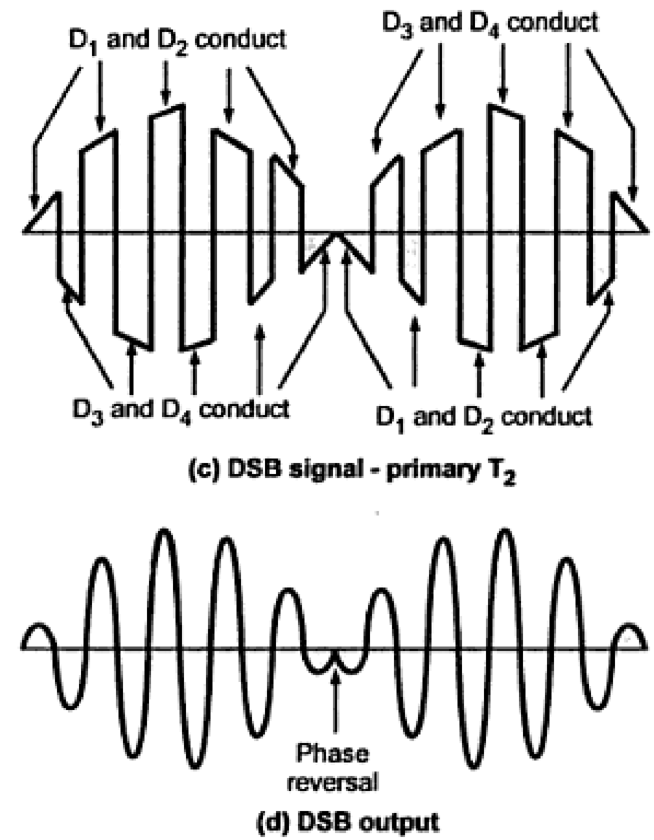


Fig. 1.5.6 (a) A carrier signal (b) Sinusoidal modulating signal (c) DSB signal at primary of T_2 (d) DSB output at secondary of T_2

DSB-SC - *Implementation*

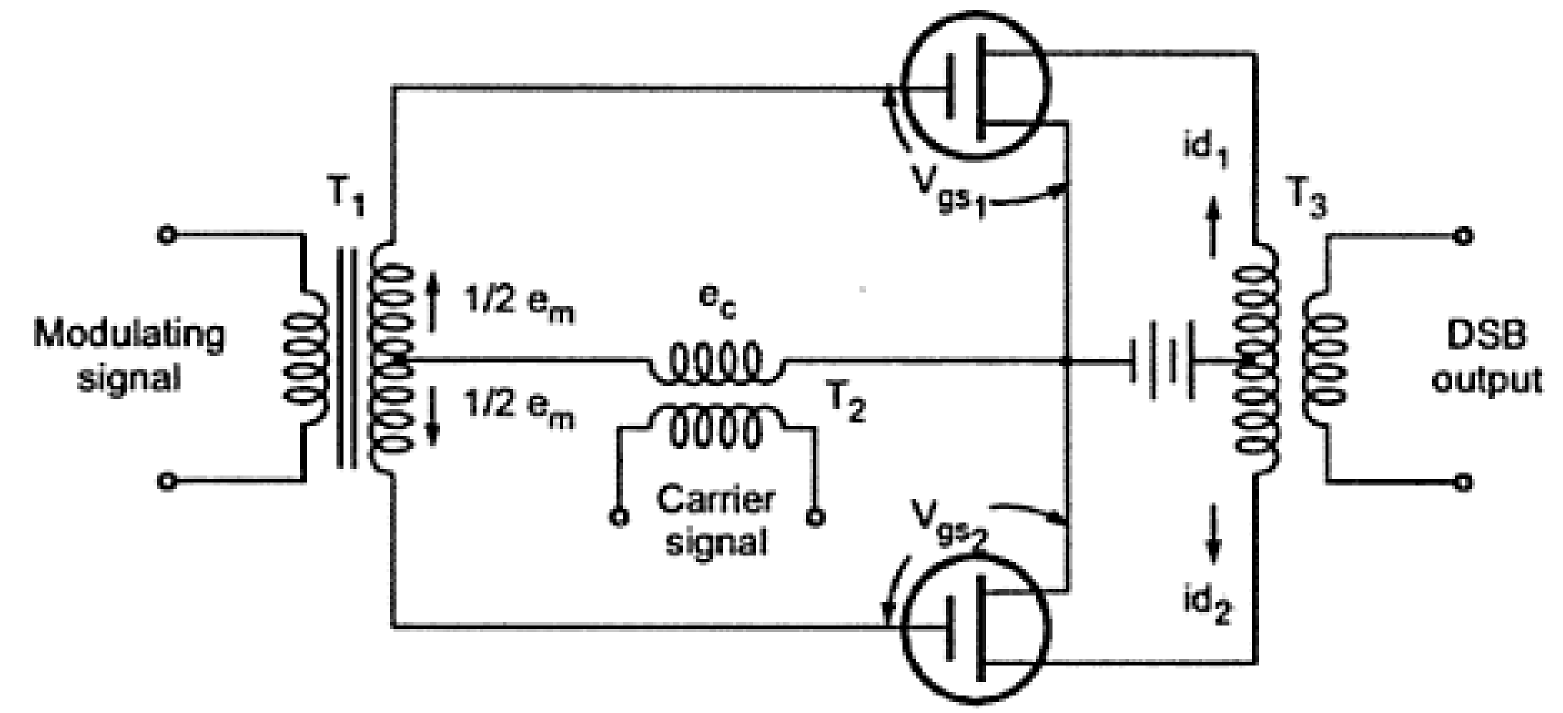
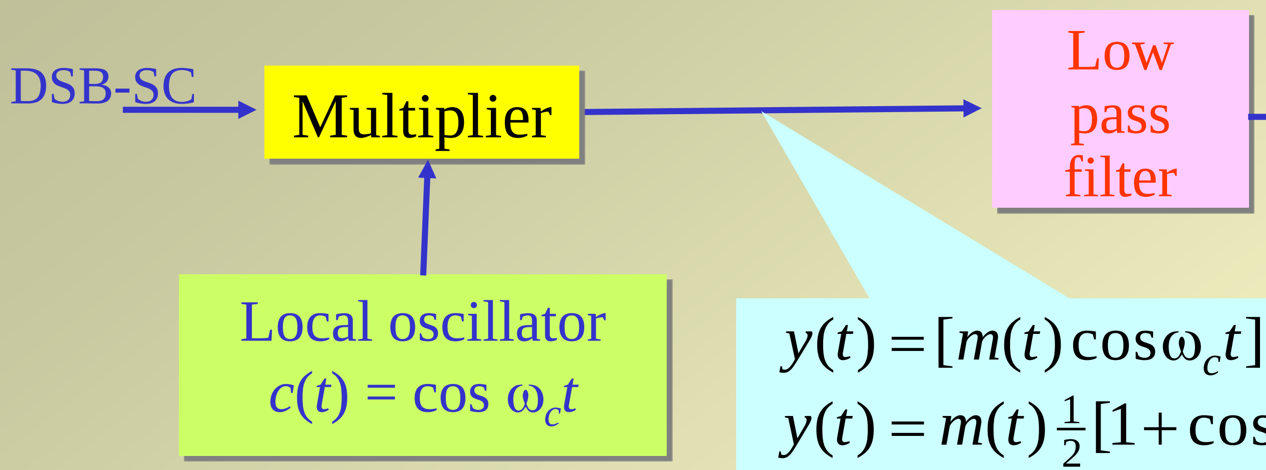


Fig. 1.5.7 Balanced modulator using FETs

DSB-SC - *Detection*

- **Synchronous detection**

$$v(t) = \tfrac{1}{2} m(t)$$



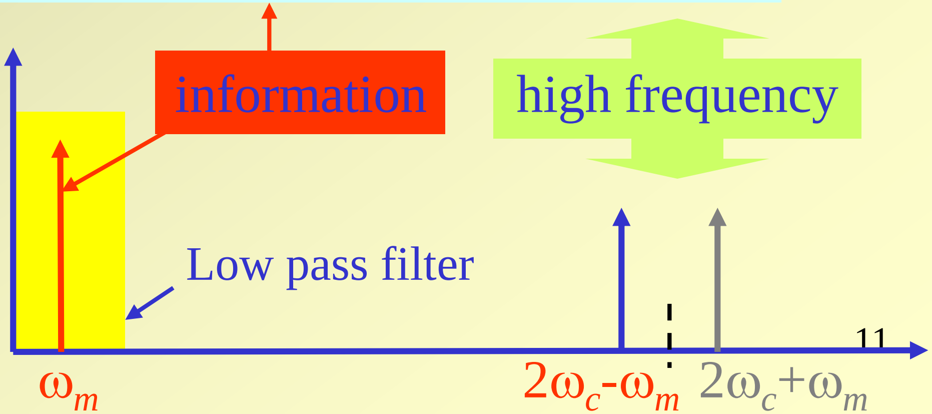
$$y(t) = [m(t)\cos\omega_c t] * \cos\omega_c t$$

$$y(t) = m(t)\tfrac{1}{2}[1+\cos 2\omega_c t]$$

$$= \tfrac{1}{2} m(t) + \tfrac{1}{2} m(t)\cos 2\omega_c t$$

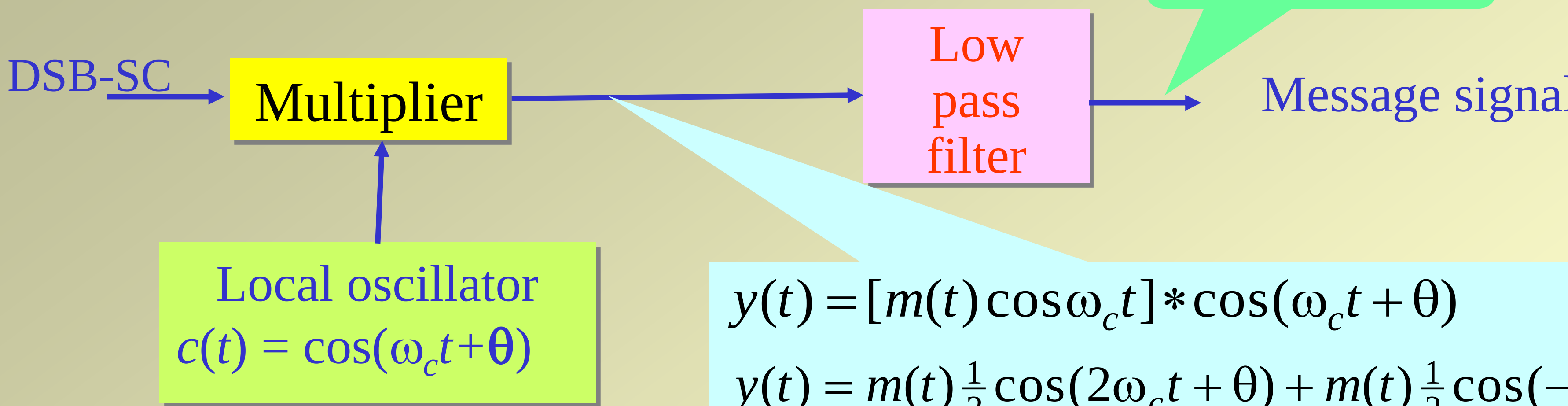
Condition:

- Local oscillator has the same **frequency** and **phase** as that of the carrier signal at the transmitter.



DSB-SC - *Synchronous Detection*

- **Case 1 - Phase error**

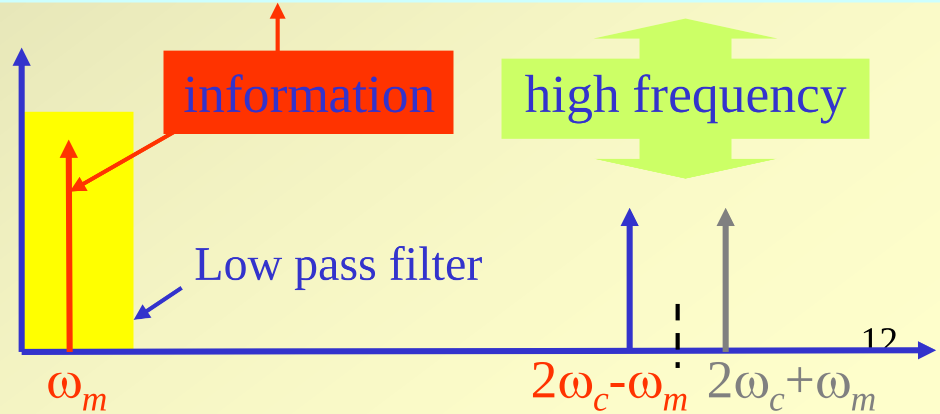


$$v(t) = \tfrac{1}{2} m(t) \cos\theta$$

$$y(t) = [m(t)\cos\omega_c t] * \cos(\omega_c t + \theta)$$

$$y(t) = m(t)\tfrac{1}{2}\cos(2\omega_c t + \theta) + m(t)\tfrac{1}{2}\cos(-\theta)$$

$$= m(t)\tfrac{1}{2}\cos\theta + m(t)\tfrac{1}{2}\cos(2\omega_c t + \theta)$$



Condition:

- Local oscillator has the same **frequency** but *different* **phase** compared to carrier signal at the transmitter.

Demodulation of DSB-SC AM Signals

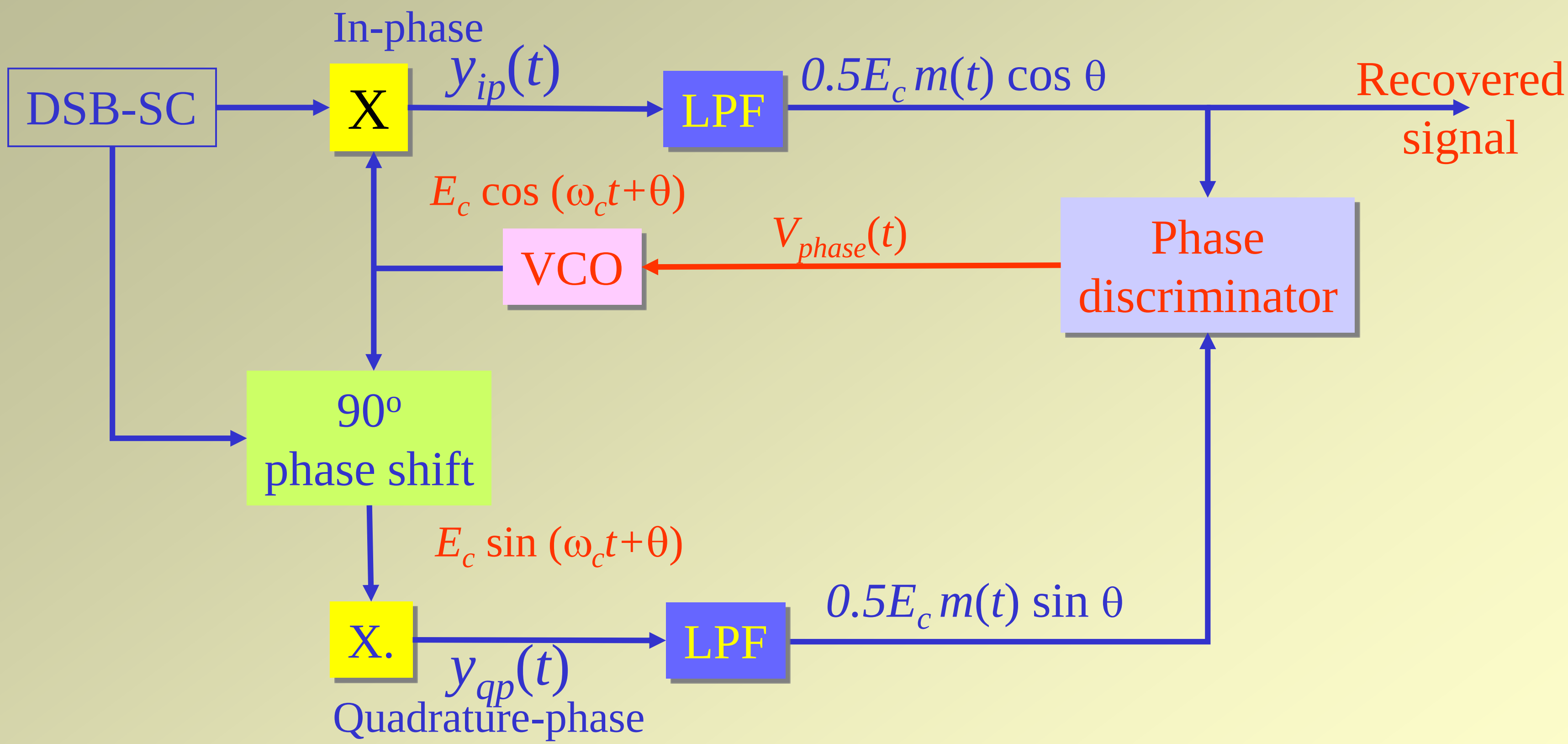
- Consequently, the output of the ideal lowpass filter

$$y_l(t) = \frac{1}{2} A_c m(t) \cos(\phi)$$

- Note that *m(t)* is multiplied by $cos(\phi)$
  - So the power in the demodulated signal is decreased by a factor of $\cos^2\phi$
  - Thus, the desired signal is scaled in amplitude by a factor that depends on the phase ϕ of the locally generated sinusoid

1. When $\phi \neq 0$, the amplitude of the desired signal is reduced by the factor $\cos(\phi)$
2. If $\phi = 45°$, the amplitude of the signal is reduced by $\sqrt{2}$ and the power is reduced by a factor of two
3. If $\phi = 90°$, the desired signal component vanishes

Phase Synchronisation - *Costa Loop*

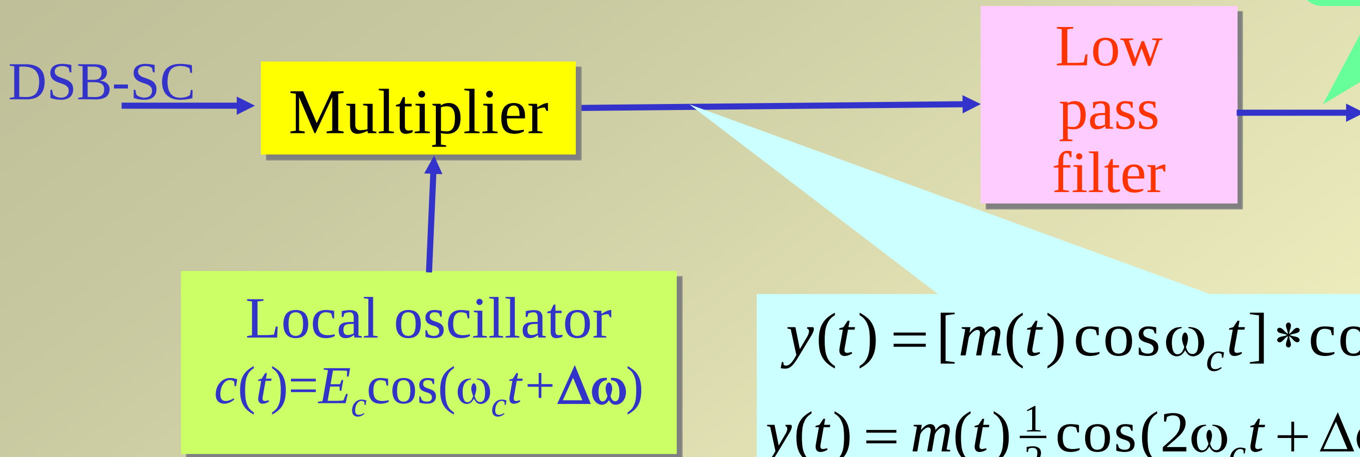


- When there is no phase error. The quadrature component is zero
- When $\theta \neq 0$, $y_{ip}(t)$ decreases, while $y_{qp}(t)$ increases
- The out put of the phase discriminator is proportional to θ

DSB-SC - *Synchronous Detection*

- **Case 1 - Frequency error**

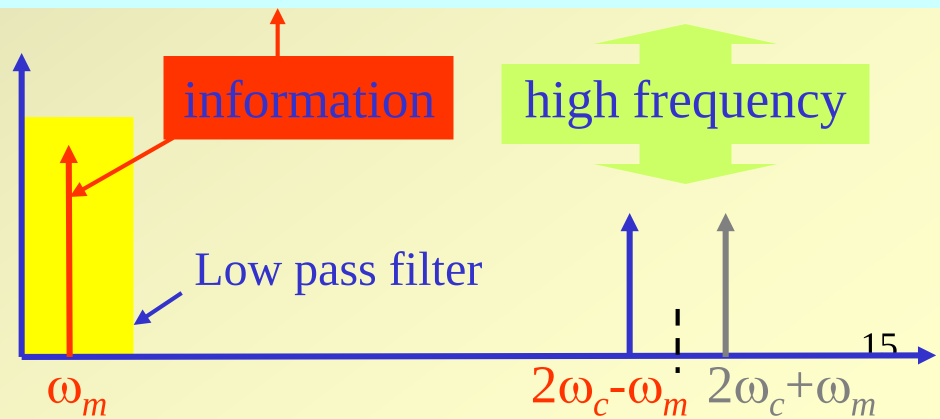
$$v(t) = \tfrac{1}{2} m(t) \cos\Delta\omega$$



$$y(t) = [m(t)\cos\omega_c t] * \cos(\omega_c t + \Delta\omega)$$

$$y(t) = m(t)\tfrac{1}{2}\cos(2\omega_c t + \Delta\omega) + m(t)\tfrac{1}{2}\cos(-\Delta\omega)$$

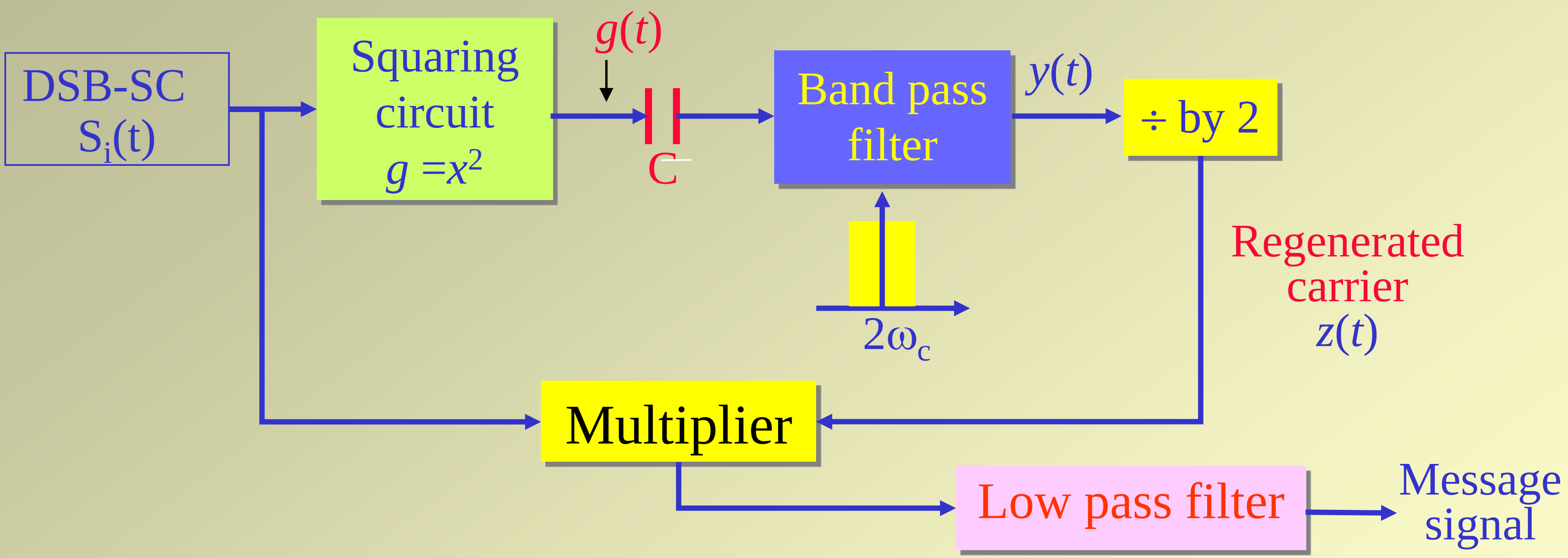
$$= m(t)\tfrac{1}{2}\cos\Delta\omega + m(t)\tfrac{1}{2}\cos(2\omega_c t + \Delta\omega)$$



Condition:

•Local oscillator has the same **phase** but *different* **frequency** compared to carrier signal at the transmitter.

DSB-SC - *Square Detection*



$$g(t) = S_i^2(t) = B^2 \cos^2 \omega_m t \cos^2 \omega_c t$$
$$= B^2 (½ + ½ \cos 2\, \omega_m t)(½ + ½ \cos 2\, \omega_c t)$$
$$= B^2/4\, [1 + ½ \cos 2(\omega_c + \omega_m)t + ½ \cos 2(\omega_c - \omega_m)t + \cos 2\omega_m t + \underline{\mathbf{\cos 2}}\, \omega_c t\,]$$

$y(t) = B^2/4 \cos 2w_c t$

$z(t) = B^2/4 \cos w_c t$

DSB-SC - *Power*

- The total power (or average power):

$$P_{T-DSB-SC} = \frac{2}{R}\left[\frac{kA_c/\sqrt{2}}{2}\right]^2 = \frac{(kA_c)^2}{4R}$$

- The maximum and peak envelop power

$$P_{P-DSB-SC} = \frac{(kA_c)^2}{R}$$

DSB-SC - *Summary*

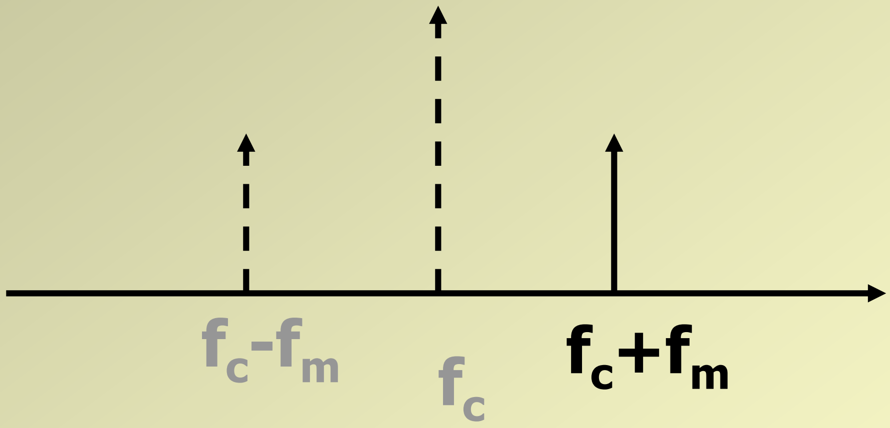
- **Advantages:**
  – Lower power consumption

- **Disadvantage:**
  - Complex detection

- **Applications:**
  - Analogue TV systems: to transmit colour information
  - For transmitting *stereo* information in FM sound broadcast at VHF

Single Side band Suppress Carrier (SSB-SC)

Frequency spectrum:



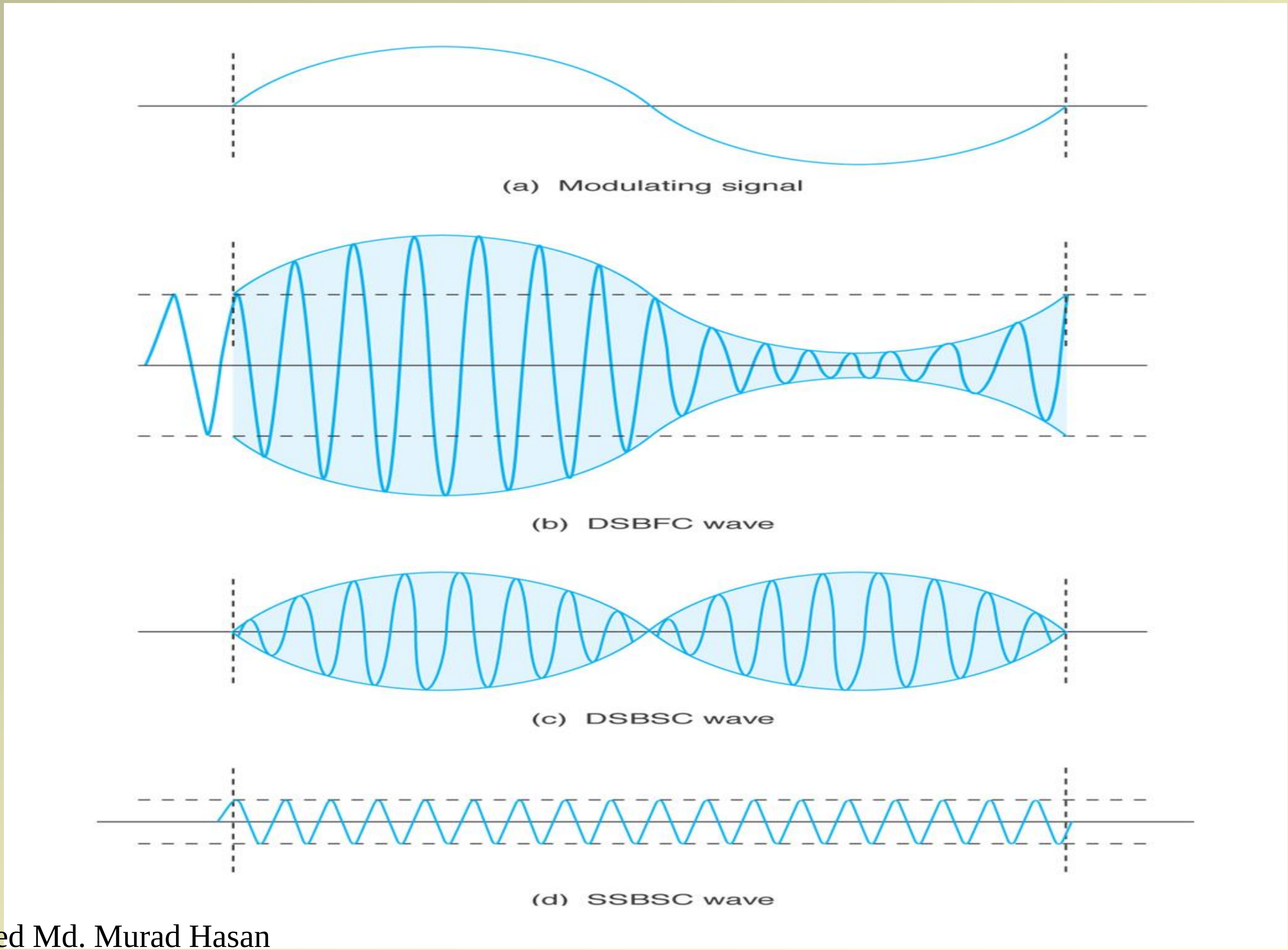
Bandwidth=$f_{m(max)}$

Total Power=+P_{usb}

Cont'd…

- A form of amplitude modulation in which the carrier is totally suppressed and one of the sidebands removed.
- Therefore, SSBSC requires half as much bandwidth as conventional DSB AM and considerably less transmitted power

Comparison of time domain representation of three common AM transmission systems:



Example 1

For an AM DSCFC wave with a peak unmodulated carrier voltage V_c = 10 Vp,frequency of 100kHz, a load resistor of R_L = 10 Ω, frequency of modulating signal of 10kHz and m = 1, determine the following

i) Powers of the carrier and the upper and lower sidebands.

ii) Total power of the modulated wave.

iii) Bandwidth of the transmitted wave.

iv) Draw the power and frequency spectrum.

Example 1..cont'd

- For the same given values, determine questions (ii)-(iv) for a AM DSB-SC, AM SSB-FC and AM SSB-SC systems. Determine also the percentage of power saved in each of the system design.

Example 1..cont'd

- Solution for DSBFC;

i)

$$\boxed{\begin{aligned} P_c &= \frac{(V_c/\sqrt{2})^2}{R} = \frac{V_c^{\,2}}{2R} = \frac{(10)^2}{2*10} = 5W \\ P_{usb} &= P_{lsb} = \frac{k^2 P_c}{4} = 1.25W \end{aligned}}$$

ii)

$$P_t = P_c + \frac{k^2}{4}P_c + \frac{k^2}{4}P_c$$

$$= 5 + \frac{1^2}{4}(5) + \frac{1^2}{4}(5) = 7.5W$$

iii) Bandwidth=2xf_{mmax}=2(10kHz)=20kHz

Example 1..cont'd

- Solution:For DSB-SC

ii) $$P_t = \frac{k^2}{4}P_c + \frac{k^2}{4}P_c$$

$$= \frac{1^2}{4}(5) + \frac{1^2}{4}(5) = 2.5W$$

$$Power_{saved} = 7.5W - 2.5W$$

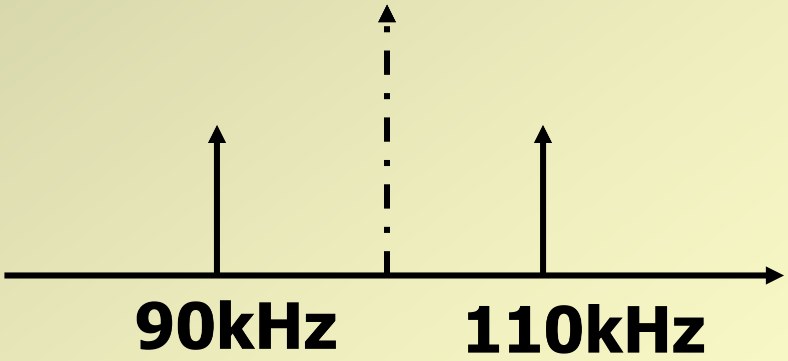
$$= 5W$$

$$\%Power_{saved} = \frac{5W}{7.5W} x100\%$$

$$= 66.67\%$$

iii) Bandwidth=2xf_{mmax}=2(10kz)=20kHz

iv)



Example 1..cont'd

- Solution:For SSB-FC

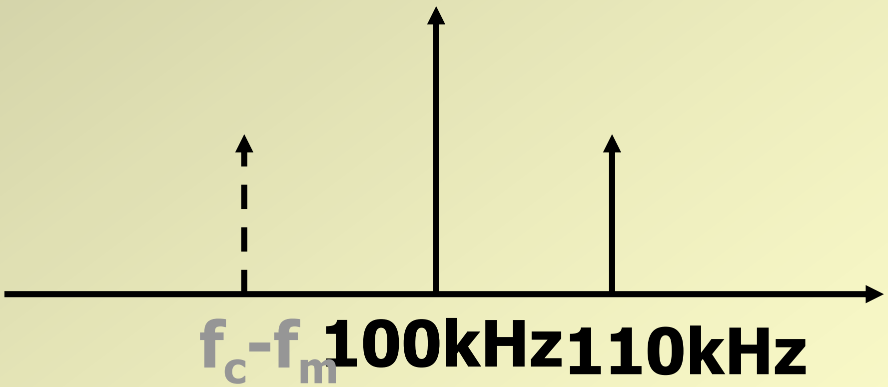
ii)
$$P_t = P_c + \frac{k^2}{4} P_c$$

$$= 5 + \frac{1^2}{4}(5) = 6.25W$$

$$Power_{saved} = 7.5W - 6.25W$$
$$= 1.25W$$
$$\%Power_{saved} = \frac{1.25W}{7.5W} x100\%$$
$$= 16.67\%$$

iii) Bandwidth=f_{mmax}=10kHz

iv)



Example 1..cont'd

- Solution:For SSB-sC

ii)

$$P_t = \frac{k^2}{4} P_c$$

$$= \frac{1^2}{4}(5) = 1.25W$$

$$Power_{saved} = 7.5W - 1.25W$$

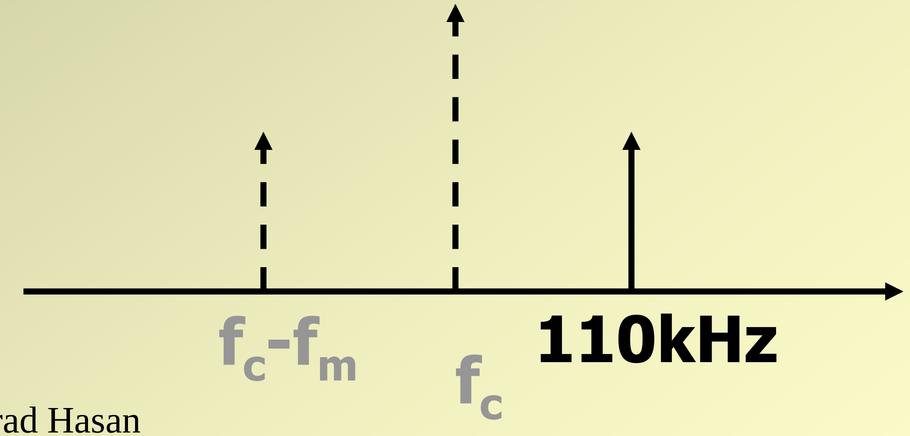
$$= 6.25W$$

$$\%Power_{saved} = \frac{6.25W}{7.5W} x100\%$$

$$= 83.33\%$$

iii) Bandwidth=f_{mmax}=10kHz

iv)

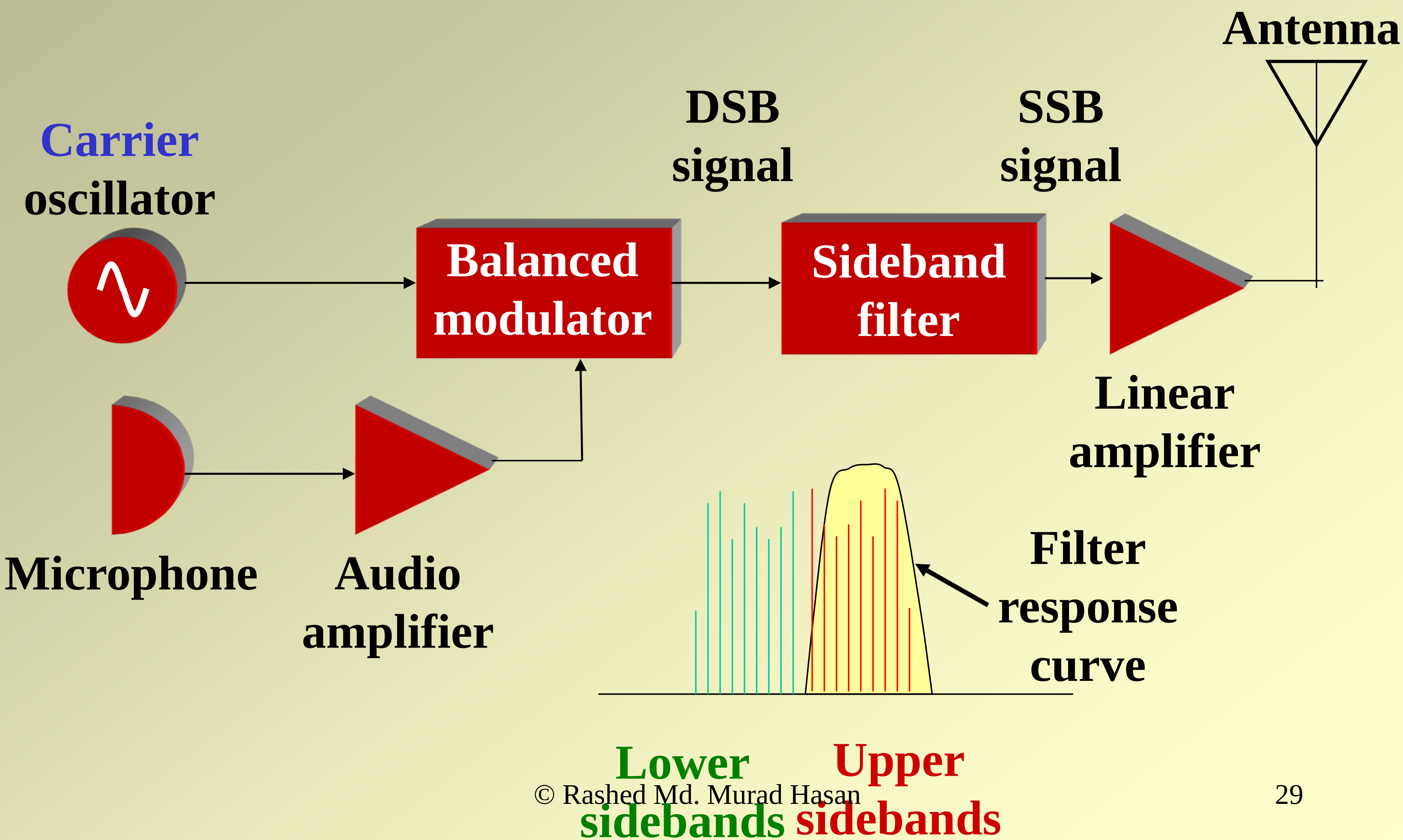


Methods of Generating SSB

i) Filtering method

- A filter removes the undesired sideband producing SSB.
- Balanced modulators is used to suppress the unwanted carrier and filters to suppress the unwanted sidebands
- Quartz crystal filters are the most widely used sideband filters since they are very selective and inexpensive.

Block diagram of filtering method

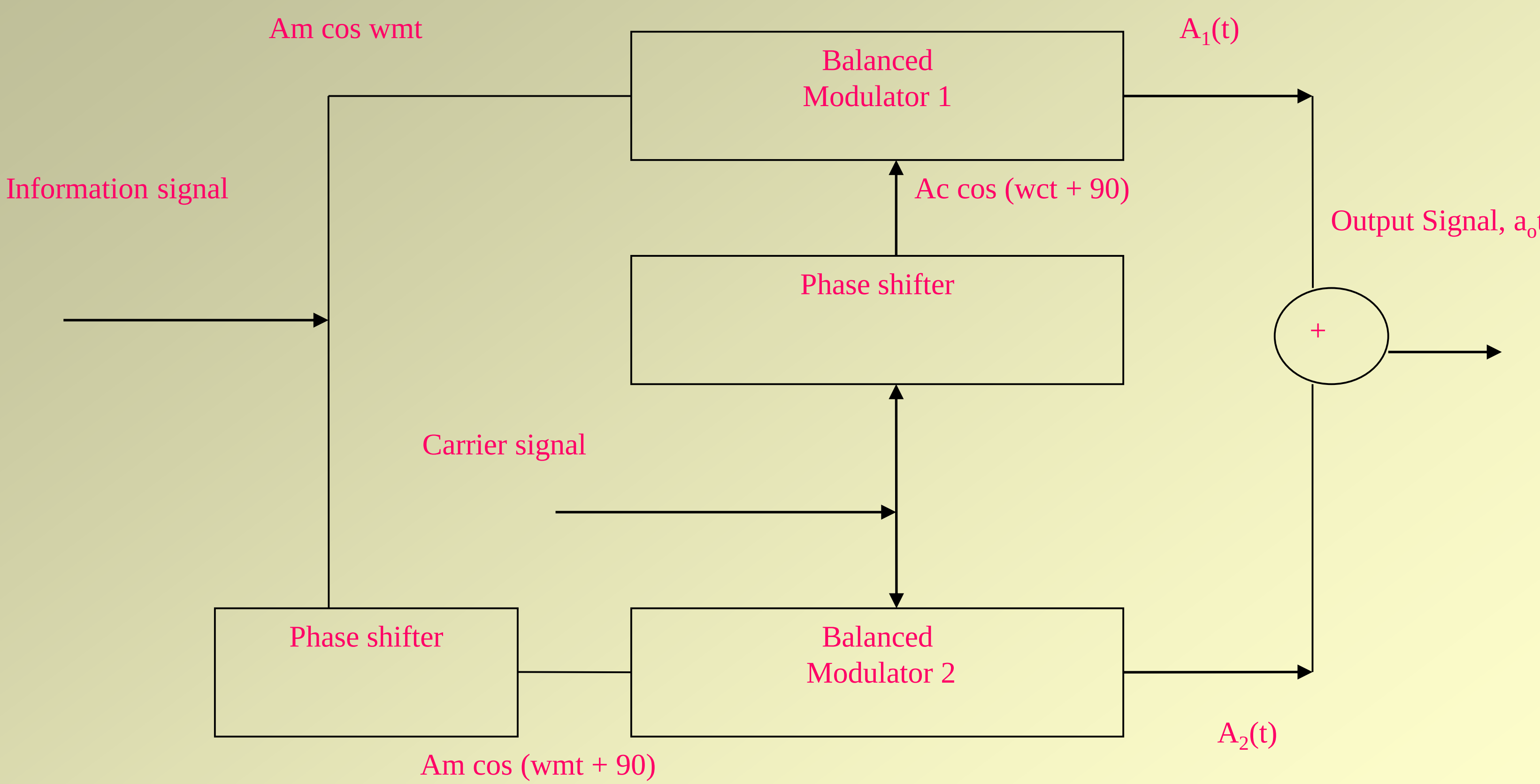


Cont'd…

ii) Phasing method using two balance modulator

- Another way to produce SSB uses a phase shift method to eliminate one sideband.
- Two balanced modulators driven by carriers and modulating signals 90º out of phase produce DSB.
- Adding the two DSB signals together results in one sideband being cancelled out.

Block diagram of phasing method



Mathematical analysis of phasing method

$$a_0(t) = a_1(t) + a_2(t) ------> (1)$$

$$a_1(t) = A_c \cos(w_c t + 90^0) * A_m \cos w_m t$$

$$= \frac{1}{2}\left\{A_c A_m \cos(w_c t + 90^0 - w_m t) + A_c A_m \cos(w_c t + 90^0 + w_m t)\right\} --> (2)$$

$$a_2(t) = A_c \cos(w_c t) * A_m \cos(w_m t + 90^0)$$

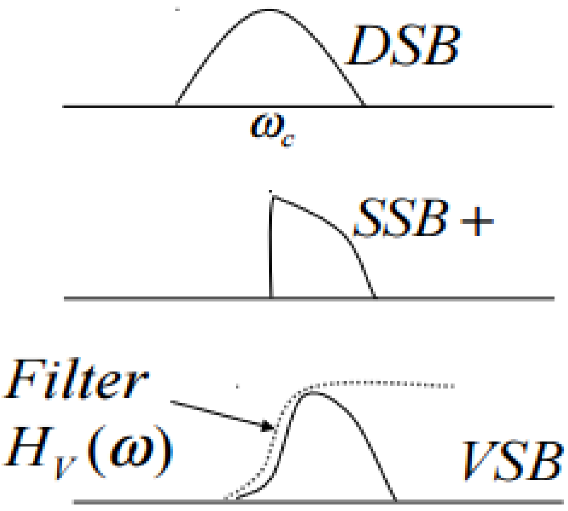
$$= \frac{1}{2}\left\{A_c A_m \cos(w_c t - 90^0 - w_m t) + A_c A_m \cos(w_c t + 90^0 + w_m t)\right\} --> (3)$$

$$a_0(t) = (2) + (3)$$

$$= \left\{A_c A_m \cos(w_c t + 90^0 + w_m t)\right\}$$

Vestigial-Sideband Modulation (VSB)

- DSB modulation is wasteful of bandwidth.
- SSB is difficult to generate when modulating signal bandwidth is wide or has low frequency components.
- VSB is a compromise :
  - Partial suppression of one sideband reduces bandwidth
  - Filtering requirements are not as severe as SSB
  - Can demodulate via synchronous detection or envelope detection if "large carrier" transmitted



Vestigial-Sideband Modulation (VSB)

- Transmitted signal

$$\Phi_{VSB}(\omega)=[\frac{1}{2}F(\omega-\omega_c)+\frac{1}{2}F(\omega+\omega_c)]H_V(\omega)$$

- We must design the "roll off" of $H_V(\omega)$ such that simple synchronous detection results in perfect signal recovery.
- To design $H_V(\omega)$, need to consider demodulation.

$$e_0(t)=[\varphi_{VSB}(t)\cos\omega_c t]_{LPF}$$

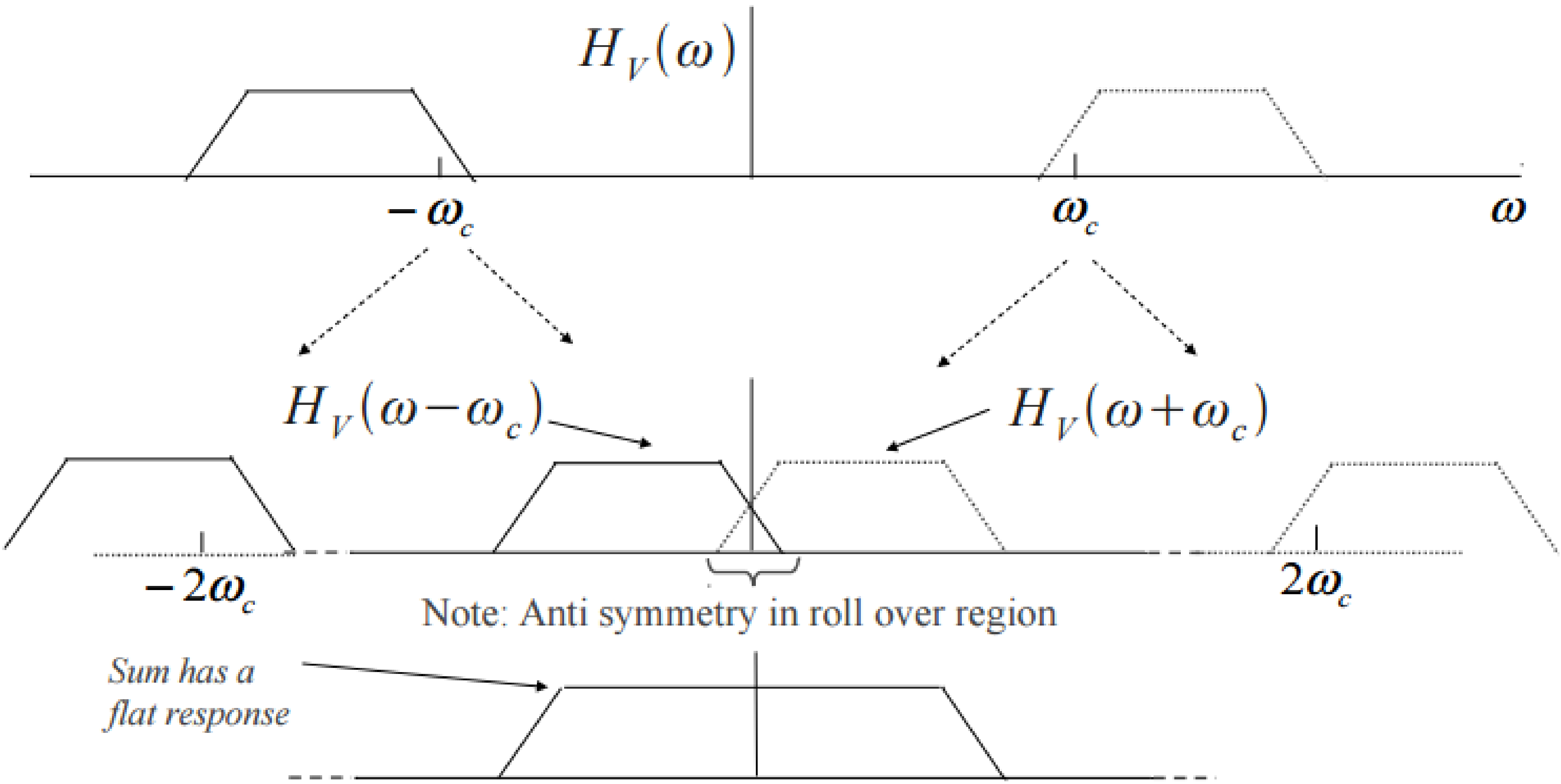
$$e_0(\omega)=[\frac{1}{2}\Phi_{VSB}(\omega+\omega_c)+\frac{1}{2}\Phi_{VSB}(\omega-\omega_c)]_{LPF}$$

$$=\frac{1}{4}F(\omega)H_V(\omega+\omega_c)+\frac{1}{4}F(\omega)H_V(\omega-\omega_c)$$

$$=\frac{1}{4}F(\omega)[H_V(\omega+\omega_c)+H_V(\omega-\omega_c)]$$

Vestigial-Sideband Demodulation

Consider the demodulation process

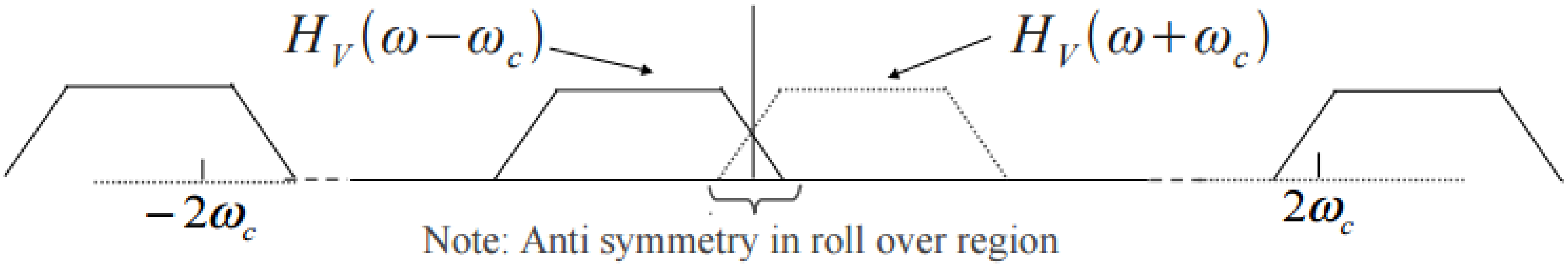


Vestigial-Sideband Modulation (VSB)

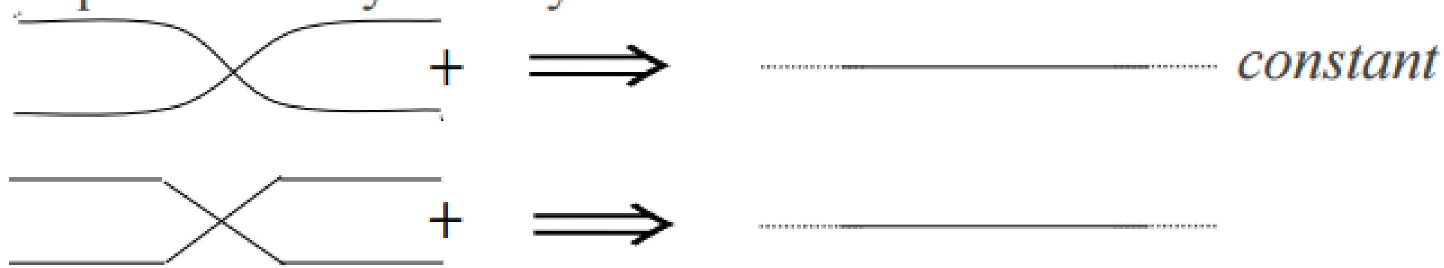
- Thus we need to arrange

$$[H_V(\omega+\omega_c)+H_V(\omega-\omega_c)]=\text{constant}$$

The illustration shows the spectrum after the mixer.



- Examples of antisymmetry roll off.



- VSB is used for analogue television transmissions to conserve bandwidth.
- South Africa uses the "PAL-I" standard for analogue TV broadcasts, same as UK. It is similar to the NTSC standard used in the USA.
- There are many different variants of the PAL standard.

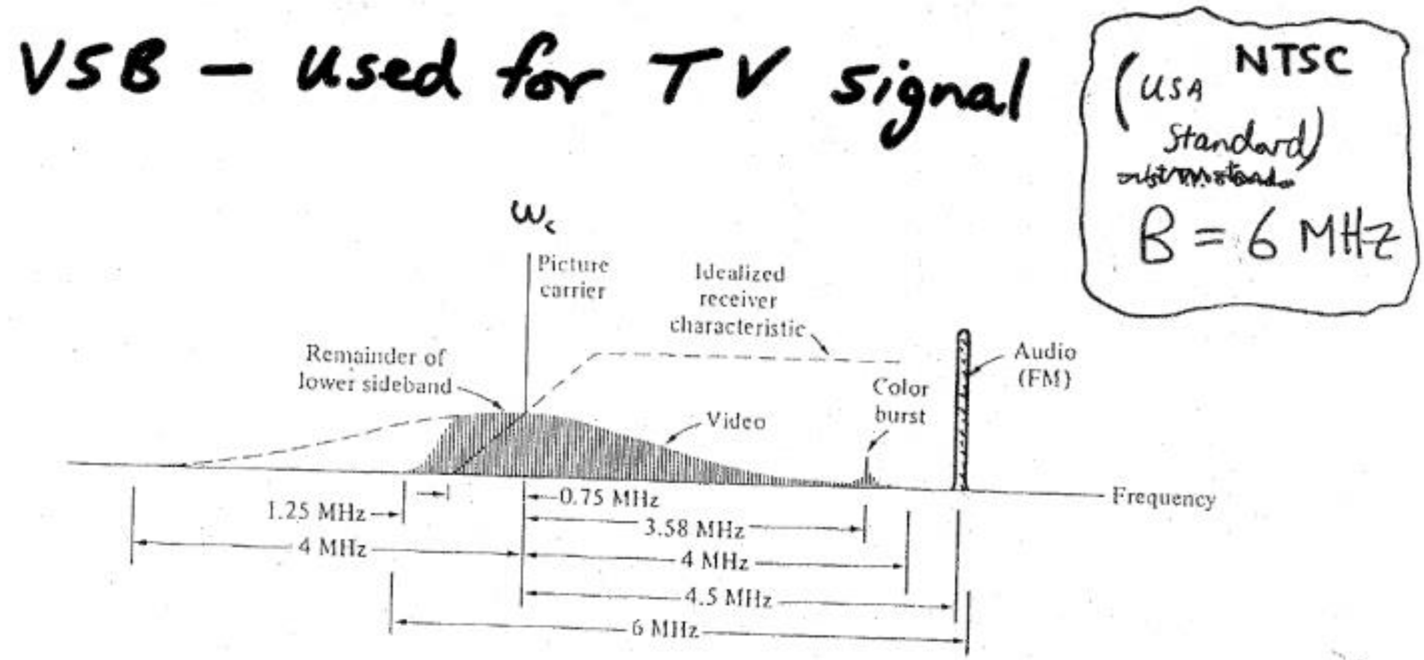


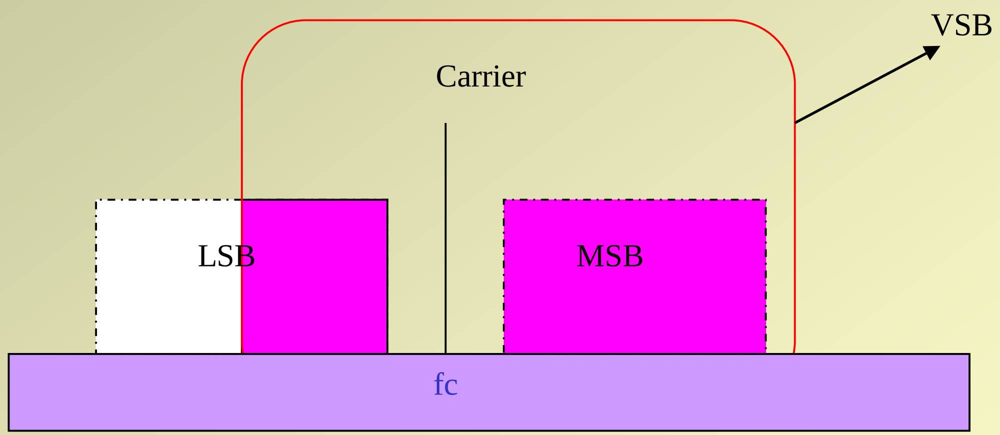
Figure 5.38 Spectrum of a public television transmission.

Cont’d

- AM wave is applied to a vestigial sideband filter, producing a modulation scheme – VSB + C
- Mainly used for television video transmission.

Cont'd…vsb

- VSB Frequency Spectrum



Cont'd…vsb

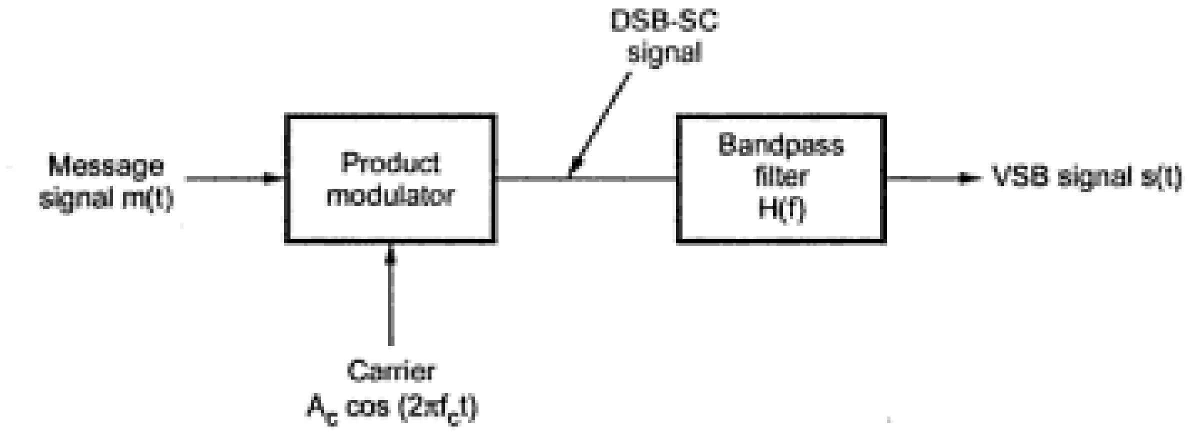
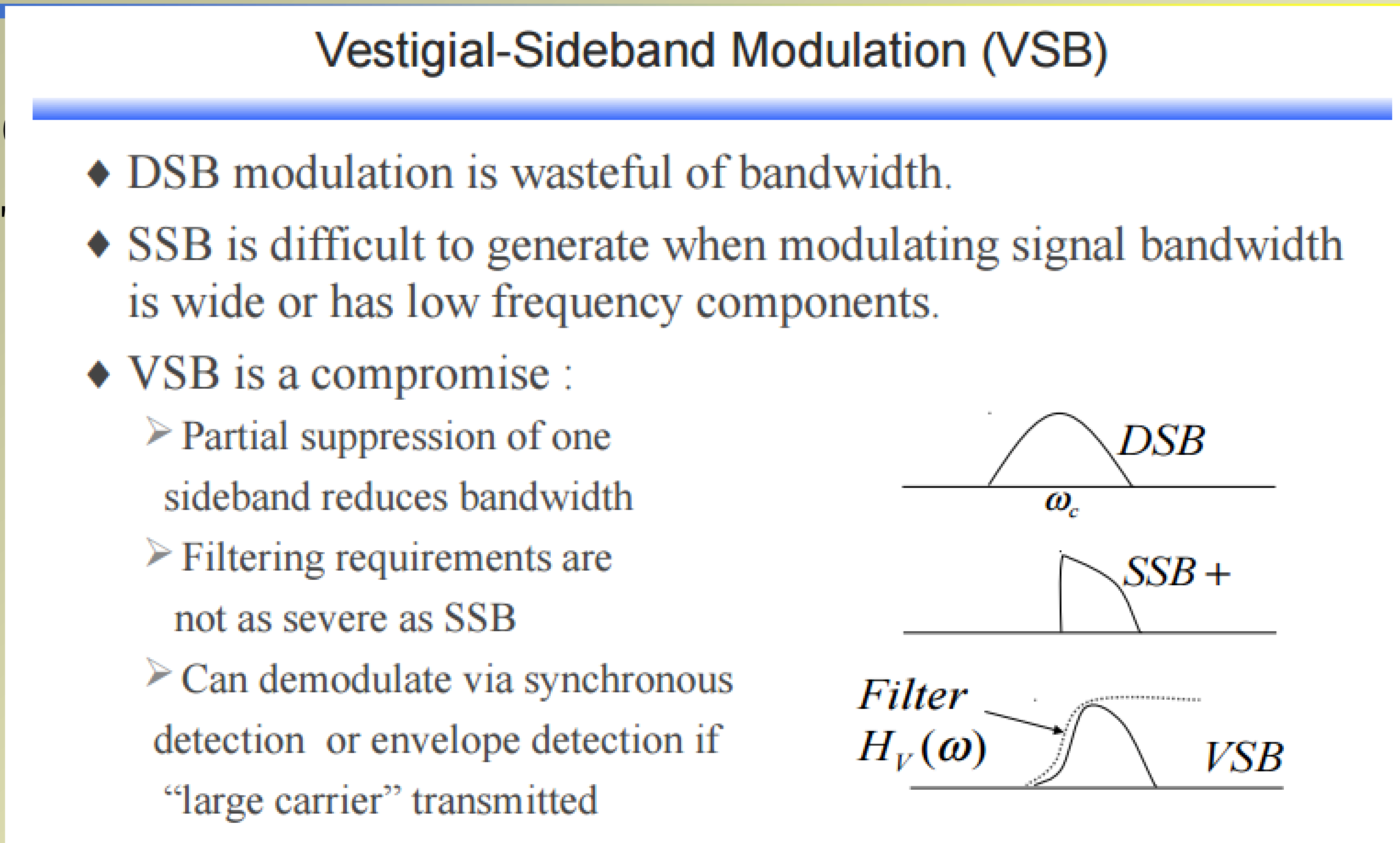


Fig. 1.6.1 Generation of VSB signal

Advantages/Benefits of SSB

- Power consumption
- Bandwidth conservation
- Selective fading
- Noise reduction

Disadvantages of SSB



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