. Calculate the power efficiency of AM signals

- The ratio of useful power, **power efficiency** :

$$\frac{sidebands\ power}{total\ power} = \frac{m^2/2}{1+m^2/2} = \frac{m^2}{2+m^2}$$

- In terms of **power efficiency**, for *m=1* modulation, only 33% power efficiency is achieved which tells us that only one-third of the transmitted power carries the useful information.

Double Side Band Suppressed Carrier (DSB-SC) Modulation

- The carrier component in full AM or DSB-LC does not convey any information. Hence it may be removed or suppressed during the modulation process to attain higher power efficiency.
- The trade off of achieving a higher power efficiency using DSB-SC is at the expense of requiring a complex and expensive receiver due to the absence of carrier in order to maintain transmitter/receiver synchronization.

. Derive the Frequency Spectrum for Double Sideband Suppressed Carrier Modulation (DSB-SC)

1 Consider the carrier

$$s_c(t) = A_c \cos(\omega_c t) \quad \text{where } \omega_c = 2\pi f_c$$

2 modulated by a single sinusoidal signal

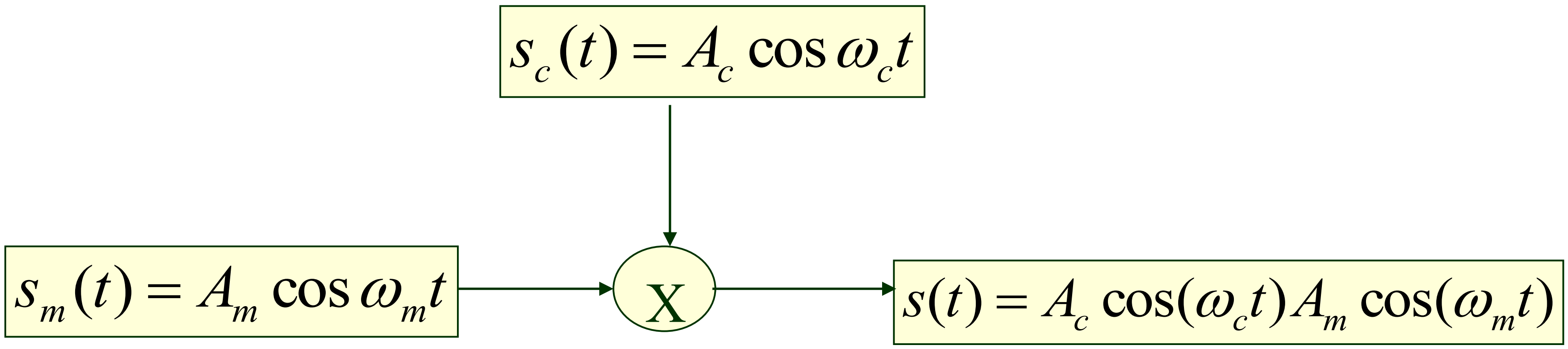
$$s_m(t) = A_m \cos \omega_m t \quad \text{where } \omega_\text{m} = 2\pi f_m$$

3 The modulated signal is simply the product of these two

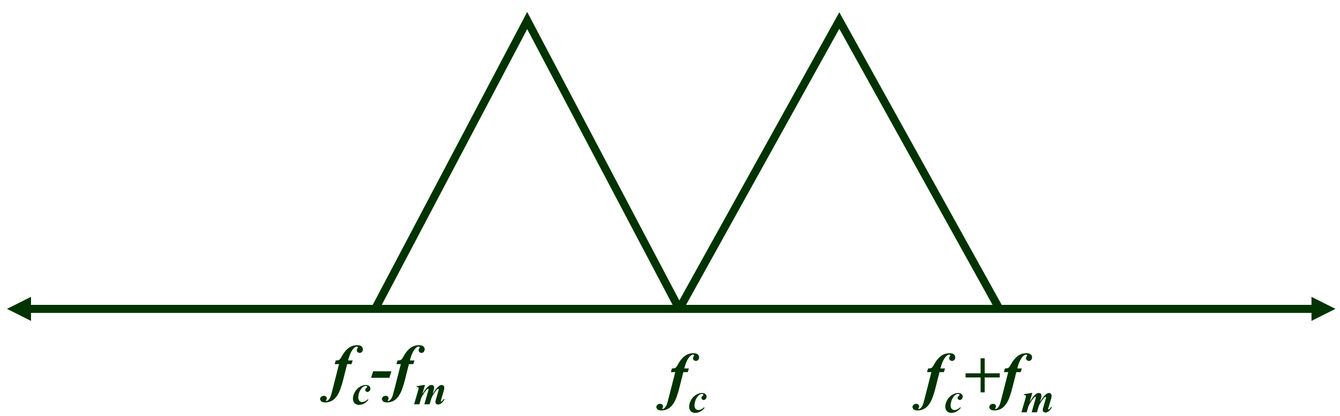
$$\begin{aligned} s(t) &= A_c \cos(\omega_c t) A_m \cos(\omega_m t) \\ &= A_c A_m \cos(\omega_c t) \cos(\omega_m t) \end{aligned}$$

$$\text{since } \cos A \cos B = \frac{1}{2}\left(\cos(A+B) + \cos(A-B)\right)$$

$$= \underbrace{\frac{A_m A_c}{2} \cos(\omega_c + \omega_m)t}_{USB} + \underbrace{\frac{A_m A_c}{2} \cos(\omega_c - \omega_m)t}_{LSB}$$



Frequency Spectrum of a DSB-SC AM Signal

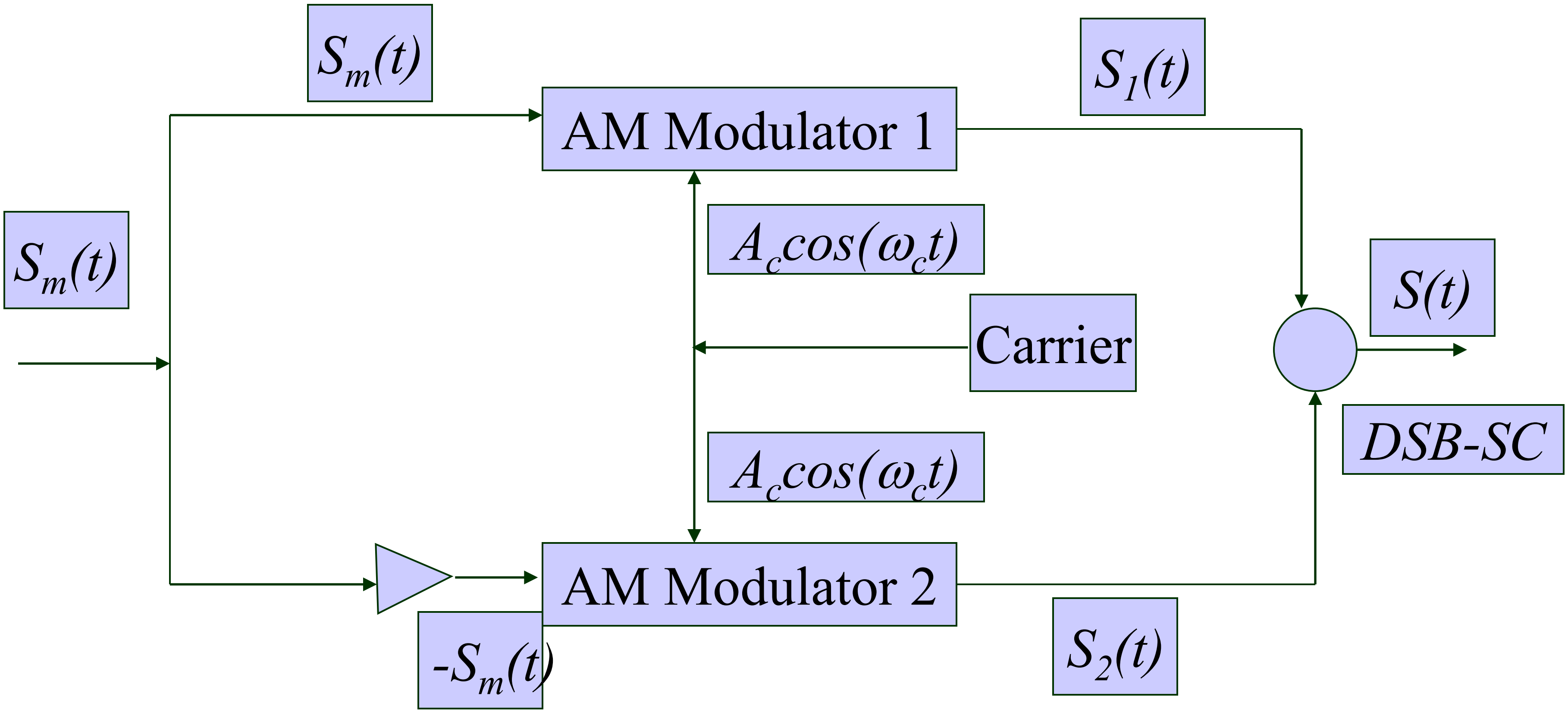


- All the transmitted power is contained in the two sidebands (no carrier present).
- The bandwidth is twice the modulating signal bandwidth.
- USB displays the positive components of $s_m(t)$ and LSB displays the negative components of $s_m(t)$.

Generation and Detection of DSB-SC

- The simplest method of generating a DSB-SC signal is merely to filter out the carrier portion of a full AM (or DSB-LC) waveform.
- Given carrier reference, modulation and demodulation (detection) can be implemented using product devices or balanced modulators.

BALANCED MODULATOR



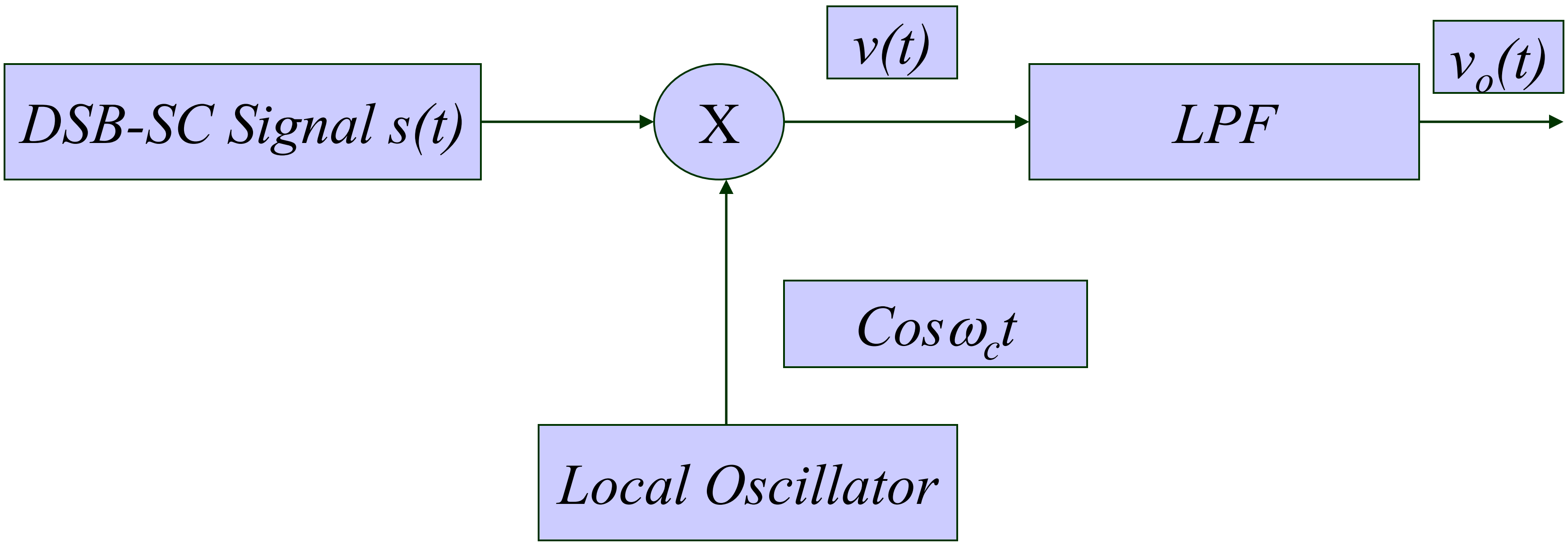
- The two modulators are identical except for the sign reversal of the input to one of them. Thus,

$$s_1(t) = A_c(1 + m\cos(\omega_m t))\cos(\omega_c t)$$

$$s_2(t) = A_c(1 - m\cos(\omega_m t))\cos(\omega_c t)$$

$$\begin{aligned} s(t) &= s_1(t) - s_2(t) \\ &= 2mA_c\cos(\omega_m t)\cos(\omega_c t) \end{aligned}$$

COHERENT (SYNCHRONOUS) DETECTOR OR DSB-SC (PRODUCT DETECTOR)



- Since the carrier is suppressed the envelope no longer represents the modulating signal and hence <u>envelope detector which is of the non-coherent type cannot be used</u>.

$$v(t) = s(t)\cos(\omega_c t) = \left[2mA_c \cos(\omega_m t)\cos(\omega_c t)\right]\cos(\omega_c t)$$

$$= 2\frac{A_m}{A_c}A_c \cos(\omega_m t)\cos^2(\omega_c t)$$

$$= 2A_m \cos(\omega_m t)\left(\frac{1+\cos 2\omega_c t}{2}\right)$$

$$= A_m \cos(\omega_m t) + A_m \cos(\omega_m t)\cos(2\omega_c t)$$

since $s_m(t) = A_m \cos(\omega_m t)$

$$= s_m(t) + \underbrace{s_m(t)\cos(2\omega_c t)}_{Unwanted\ term\ (removed\ by\ LPF)}$$

- It is necessary to have synchronization in both frequency and phase between the transmitter (modulator) & receiver (demodulator), when DSB-SC modulation ,which is of the coherent type, is used.

  Both phase and frequency must be known to demodulate DSB-SC waveforms.

LACK OF PHASE SYNCHRONISATION

Let the received DSB-SC signal be

$$s_{DSB-SC}(t) = s_m(t)\cos\left(\omega_c t + \theta\right)A_c$$

if θ is unknown,

$$\begin{aligned} v(t) &= s_{DSB-SC}(t)\cos\omega_c t \\ &= A_c s_m(t)\cos\left(\omega_c t + \theta\right)\cos\omega_c t \\ &= \frac{A_c}{2} s_m(t)\left[\cos\theta + \cos\left(2\omega_c t + \theta\right)\right] \end{aligned}$$

Output of LPF

$$v_o(t) = \frac{A_c}{2} s_m(t)\cos\theta$$

But we want just

$$v_o(t) = \frac{A_c}{2} s_m(t)$$

Due to lack of phase synchronization, we will see that the wanted signal at the output of LPF will be attenuated by an amount of **cosθ.**

In other words, phase error causes an attenuation of the output signal proportional to the cosine of the phase error.

The worst scenario is when **θ=π/2,** which will give rise to zero or no output at the output of the LPF.

LACK OF FREQUENCY SYNCHRONISATION

Suppose that the local oscillator is not stable at f_c but at $\mathbf{f_c+\Delta f}$, then

$$v(t) = s_{DSB-SC}(t)\cos(\omega_c + \Delta\omega)t$$
$$= A_c s_m(t)\cos\omega_c t\cos(\omega_c + \Delta\omega)t$$
$$= \frac{A_c}{2}s_m(t)\left[\cos\Delta\omega t + \cos(2\omega_c t + \Delta\omega)\right]$$

Output of LPF

$$v_o(t) = \frac{A_c}{2}s_m(t)\cos\Delta\omega t$$

Thus, the recovered baseband information signal will vary sinusoidal according to **cos Δ ωt**

This problem can be overcome by adding an extra synchronization circuitry which is required to detect **θ** and **Δ ωt** and by providing the carrier signal to the receiver.

A synchronizer is introduced to curb the synchronization problem exhibited in a coherent system.

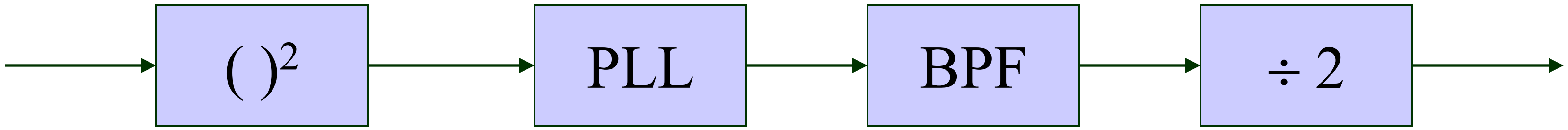
Let the baseband signal be

$$s_m(t) = A_m \cos \omega_m t$$

Received DSB-SC signal

$$s(t) = A_c s_m(t) \cos \omega_c t$$

SYNCHRONISER



Mathematical analysis of the synchronizer is shown below:

$$s^2(t) = A_c^2 A_m^2 \cos^2 \omega_m t \cos^2 \omega_c t$$

$$= \frac{A_c^2 A_m^2}{4} [1 + \cos 2\omega_m t][1 + \cos 2\omega_c t]$$

$$= \frac{A_c^2 A_m^2}{4} [1 + \cos 2\omega_m t + \cos 2\omega_c t + \cos 2\omega_m t \cos 2\omega_c t]$$

$$= \frac{A_c^2 A_m^2}{4} \left[1 + \cos 2\omega_m t + \cos 2\omega_c t + \frac{1}{2} \cos 2(\omega_c - \omega_m) t + \frac{1}{2} \cos 2(\omega_c + \omega_m) t \right]$$

Output of BPF

$$\frac{A_c^2 A_m^2}{4} \cos 2\omega_c t$$

Output of frequency divider $k\cos\omega_c t$

where k is a constant of proportionality.

DISADVANTAGE OF USING COHERENT SYSTEMS

- The frequency and phase of the local oscillator signal must be very precise which is very difficult to achieve.

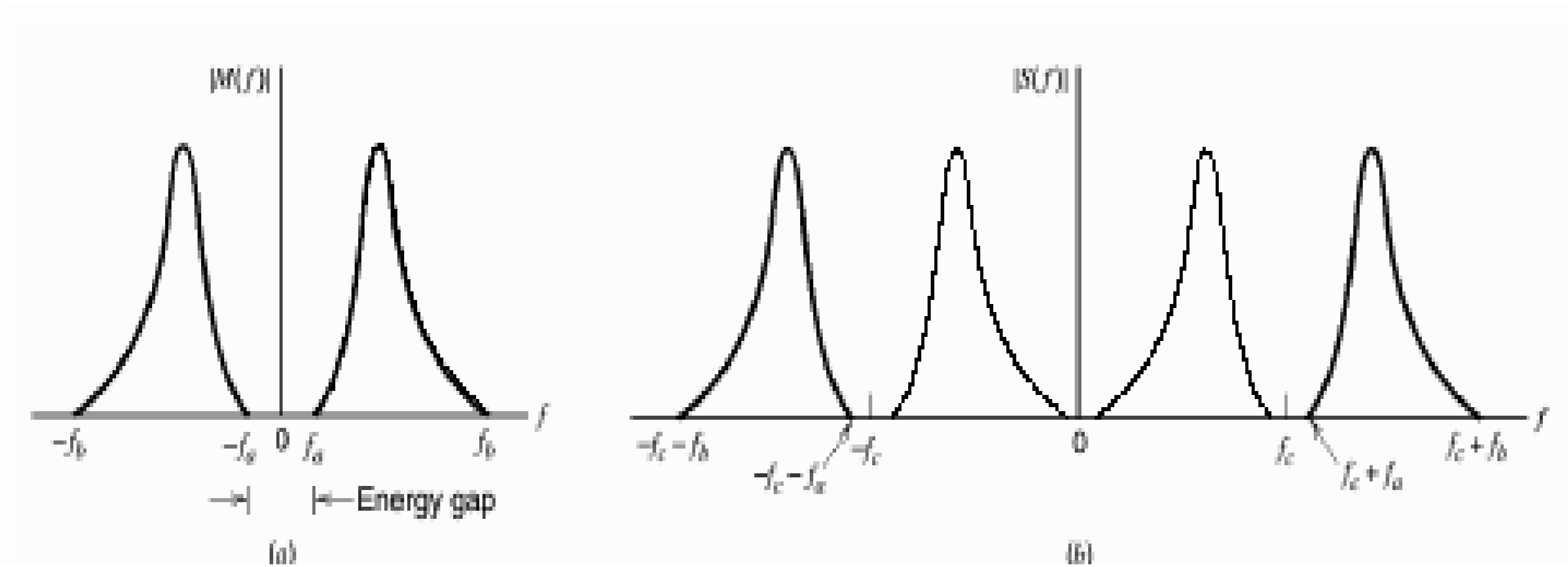
  It requires additional circuitry such as synchronizer circuit and hence the cost is higher.

Single Side Band Modulation (SSB)

How to generate SSB signal?

- Generate DSB-SC signal
- Band-pass filter to pass only one of the sideband and suppress the other.

For the generation of an SSB modulated signal to be possible, the message spectrum must have an *energy gap* centered at the origin.



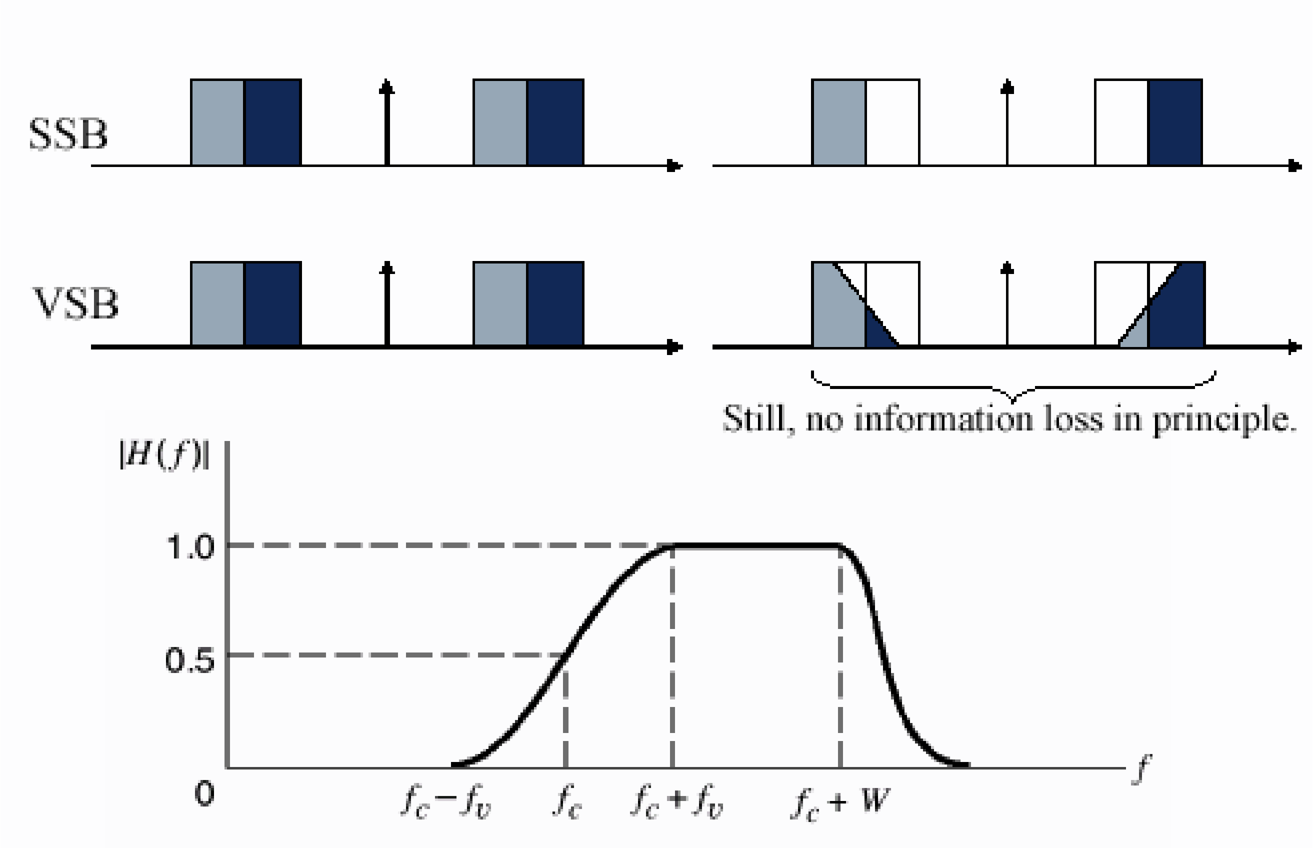
- Example of signal with -300 Hz ~ 300 Hz energy gap

  Voice : A band of 300 to 3100 Hz gives good articulation

- Also required for SSB modulation is a highly selective filter

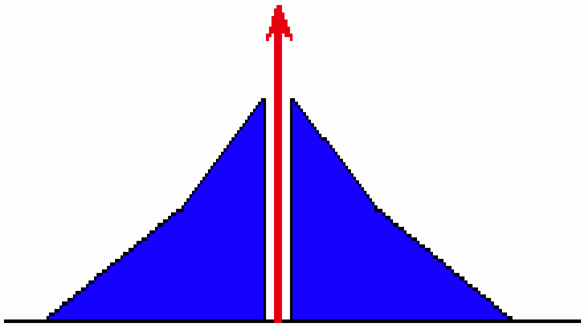
Vestigial Side Band Modulation (VSB)

Instead of transmitting only one sideband as SSB, VSB modulation transmits a partially suppressed sideband and a vestige of the other sideband.

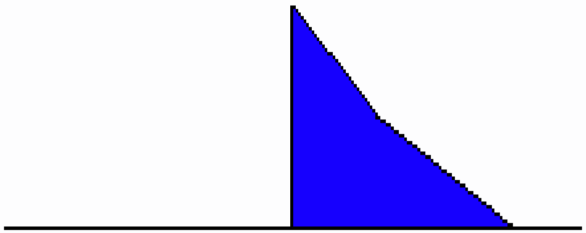


Comparison of Amplitude Modulation methods

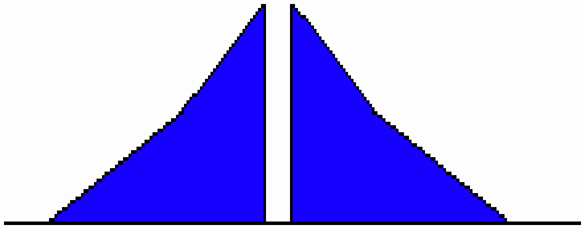
- DSBTC



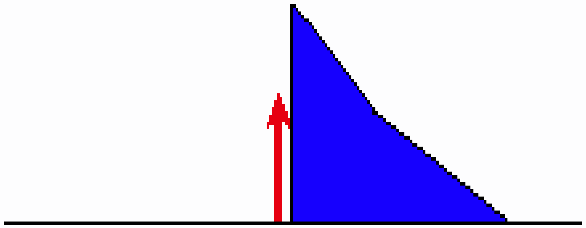
- SSB



- DSBSC



- VSB



Comparison of Amplitude Modulation methods

Full AM (or DSB-LC)

- Sidebands are transmitted in full with the carrier.
- Simple to demodulate / detect
- Poor power efficiency
- Wide bandwidth (twice the bandwidth of the information signal)
- Used in commercial AM radio broadcasting, one transmitter and many receivers.

Comparison of Amplitude Modulation methods

DSB-SC

- Less transmitted power than full AM and all the transmitted power is useful.
- Requires a coherent carrier at the receiver; This results in increased complexity in the detector(i.e. synchroniser)
- Suited for point to point communication involving one transmitter and one receiver which would justify the use of increased receiver complexity.

Comparison of Amplitude Modulation methods

SSB

- Good bandwidth utilization (message signal bandwidth = modulated signal bandwidth)
- Good power efficiency
- Demodulation is harder as compares to full AM; Exact filter design and coherent demodulation are required
- Preferred in long distance transmission of voice signals

Comparison of Amplitude Modulation methods

VSB

- Offers a compromise between SSB and DSB-SC
- VSB is standard for transmission of TV and similar signals
- Bandwidth saving can be significant if modulating signals are of large bandwidth as in TV and wide band data signals.

• For example with TV the bandwidth of the modulating signal can extend up to 5.5MHz; with full AM the bandwidth required is 11MHz