Communication Fundamentals

AM Modulation

Double Side Band

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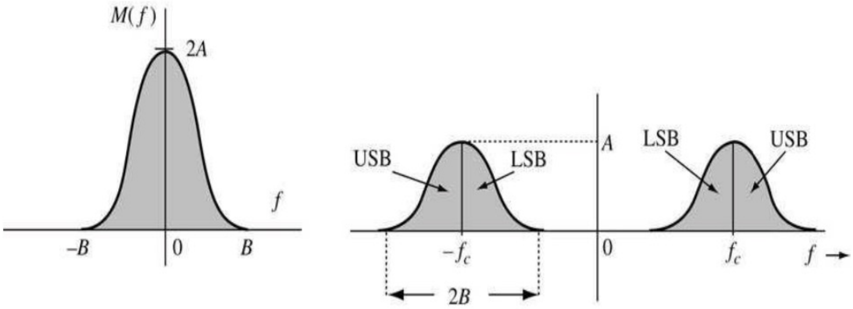
Double Side Band Suppressed Carrier (DSB-SC)

Both side bands are called **Double Side Band (DSB)**. Since the carrier component is not present in the spectrum of the modulated (DSB-SC) signal then the signal is called suppressed carrier (SC). Thus, the signal is called Both side bands are called Double Side Band (DSB). Since the carrier component is not present in the spectrum of the modulated **Double Side Band Suppressed Carrier (DSB-SC) .**



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Double Side Band Suppressed Carrier (DSB-SC)

DSB-SC is the first type of Amplitude Modulation methods:

Time domain expression: $\varphi_{\text{DSB-SC}}(t) = \text{m(t)}.\,v_c(\text{t})$

$$= \text{m(t)}.\,A_c.\cos(\omega_c t)$$

For single tone m(t)= $A_m \cos(\omega_m t)$:

$$\varphi_{\text{DSB-SC}}(t) = A_m.A_c \cos(\omega_m t).\cos(\omega_c t)$$

$$= \frac{A_m.A_c}{2}[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$$

Usually, in DSB-SC the amplitude of the carrier is taken to be 1 ($A_c = 1$). Then above equation can be written as:

$$\varphi_{\text{DSB-SC}}(t) = \frac{A_m}{2}[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$$

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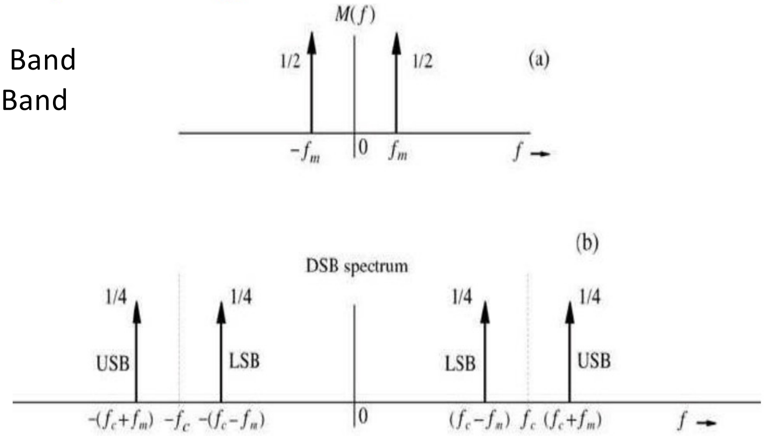
Double Side Band Suppressed Carrier (DSB-SC)

The spectrum of the message M(f) (single tone) and the spectrum of the DSB-SC signals are given below: For $A_c = 1$ and $A_m = 1$

- **USB =** Upper Side Band
- **LSB =** Lower Side Band



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Double Side Band Suppressed Carrier (DSB-SC)

$$v_{DSB} = V_m \cos \omega_m t \times V_c \cos \omega_c t$$

$$= \frac{V_m V_c}{2}[\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t]$$

$$P_{USB} = P_{LSB} = \frac{(V_m V_c / 2\sqrt{2})^2}{R} = \frac{V_m^2 V_c^2}{8R}, \text{ then}$$

$$P_T = P_{LSB} + P_{USB} = \frac{V_m^2 V_c^2}{8R} + \frac{V_m^2 V_c^2}{8R} = \frac{V_m^2 V_c^2}{4R}$$

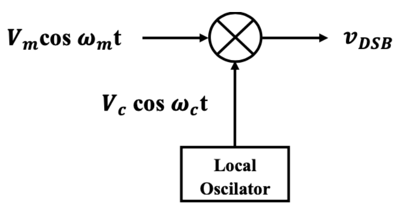

Fig: Generation of DSB Signal

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Amplitude Modulation - Modulating Signal

A modulating signal can be expressed with a similar formula.

$$v_m = V_m \cos \omega_m t \quad \text{Or} \quad v_m = V_m \cos 2\pi f_m t$$

v_m instantaneous value of information signal

V_m peak amplitude of information signal

f_m frequency of modulating signal

$$f_c \gg f_m$$

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Amplitude Modulation - Carrier Signal

$$v_c = V_c \cos \omega_c t \quad \text{Or} \quad v_c = V_c \cos 2\pi f_c t$$

v_c Represents the instantaneous value of the carrier sine wave voltage at some specific time in the cycle.

V_c Represents the peak value of the constant unmodulated carrier sine wave as measured between zero and the maximum amplitude of either the positive-going or the negative-going alterations.

f_c It represents the frequency of the carrier sine wave.

t It represents a particular point in time during the carrier cycle.

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Double Side Band Suppressed Carrier (DSB-SC)

From the spectrum, it is clear that the bandwidth of DSB signal is: **B.W = 2 f_m**

Example: For an AM signal of the form:

$V_{AM} = 40[\cos(2\pi\times120\times10^3)t+\cos(2\pi\times80\times10^3)t]$, determine:

(a) The type of this AM signal. (b) The total power if R = 5Ω. (c) The bandwidth.

Solution:

a) This signal is DSP type (DSB-SC).

b) $P_T = \frac{V_m{}^2 V_c{}^2}{4R} = \frac{40^2}{4\times5} = 80$ W

c) $f_c - f_m = 80\times10^3$ Hz and $f_c + f_m = 120\times10^3$ Hz

It is clearly that $f_m = 20\times10^3$ Hz or 20 kHz

B.W = 2 f_m = 40 kHz

Single Sideband Modulation Technique (AM-SSB-SC)

This type of modulation is represented in two forms:

- ***Single Sideband- Lower Sideband (SSB − LSB)***

$v_{SSB-LSB} = \frac{V_m V_c}{2}[\cos(\omega_c - \omega_m)t]$

- ***Single Sideband- Upper Sideband (SSB − USB)***

$v_{SSB-USB} = \frac{V_m V_c}{2}[\cos(\omega_c + \omega_m)t]$

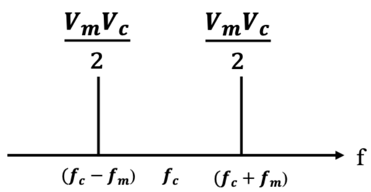

Fig: The Spectrum of DSB signal.

Synchronous or Coherent Demodulation

- The combination of multiplier and LPF is known as a **coherent demodulator**.

$$v_x = v_{DSB} \times V_c \cos \omega_c t$$
$$= V_m \cos \omega_m t \times V_c \cos \omega_c t \times V_c \cos \omega_c t$$
$$= V_m \cos \omega_m t \times V_c^2 \cos^2 \omega_c t$$
$$= V_m \cos \omega_m t \times \frac{V_c^2}{2} (1 + \cos 2\omega_c t)$$
$$= \frac{V_m V_c^2}{2} \cos \omega_m t + \frac{V_m V_c^2}{2} \cos \omega_m t \cos 2\omega_c t$$
$$= \frac{V_m V_c^2}{2} \cos\omega_m t + \frac{V_m V_c^2}{4} [\cos(2\omega_c - \omega_m)t + \cos(2\omega_c + \omega_m)t]$$

Note that the signal above composed from three components the LPF passes the first one only ($\frac{V_m V_c^2}{2} \cos\omega_m t$) and removes the others.

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Advantages of Amplitude Modulation (AM)

Some advantages of AM:

1- AM signals are very easy to generate and detect.
2- It is very cheap to build, due to this reason it is most commonly used in AM radio broadcasting.

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Some Limitations of AM (DSB- LC)

- **Noisy Reception:** As the radio receiver finds it difficult to distinguish between the amplitude variations that represent noise and those with the signals, heavy noise is prone to occur in its reception.
- **Low efficiency:** The power in the sidebands is the only useful power. The power carrier by the sidebands is only 33.3% even when there is 100% modulation. The useful power is small, the AM has low efficiency.
- **Small operating range:** The range of operation is small due to low efficiency i.e. messages cannot be transmitted over larger distances.
- **Lack of audio quality:** To obtain high fidelity reception, all audio frequencies up to 15 KHz must be reproduced and this necessitates the bandwidth of 30 KHz since both sidebands must be reproduced.

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Some advantages or benefits of the DSB

Despite the fact that elimination of the carrier in DSB AM saves considerable power, DSB is not widely used because the signal is difficult to demodulate at the receiver.

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Some advantages or benefits of the SSB

1. The spectrum space it occupies is only one-half that of AM and DSB signals.
2. SSB transmission consolidates power for stronger, more reliable signals over longer distances, offering compactness and reduced weight compared to AM or DSB transmitters.
3. Because SSB signals occupy a narrower bandwidth, the amount of noise in the signal is reduced.
4. There is less selective fading of an SSB signal over long distances.

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Example : Calculate the percentage power saving when the carrier is suppressed in an AM wave modulated to depth of (a) 100 percent and (b) 50 percent. Repeat the same when the carrier and one of the sideband are suppressed.

(i) Power saving in DSB-SC

The total AM power in AM wave is,

(a) When m = 1, $P_T = P_c\,(1 + \frac{m^2}{2}) = P_c\,(1 + \frac{1^2}{2}) = 1.5\,P_c$

Percentage power saving $= \frac{P_T - P_{SB}}{P_T} * 100\%$

$= \frac{P_c}{P_T} * 100\% = \frac{P_c}{1.5\,P_c} * 100\% = 66.66\%$

(b) When m = 0.5, $P_T = P_c\,(1 + \frac{m^2}{2}) = P_c\,(1 + \frac{0.5^2}{2}) = 1.125\,P_c$

Percentage power saving $= \frac{P_T - P_{SB}}{P_T} * 100\%$

$= \frac{P_c}{P_T} *100\% = \frac{P_c}{1.125\,P_c} *100\% = 88.88\%$

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Example : Calculate the percentage power saving when the carrier is suppressed in an AM wave modulated to depth of (a) 100 percent and (b) 50 percent. Repeat the same when the carrier and one of the sideband are suppressed.

(ii) Power saving in SSB

(a) When m=1, P_T= 1.5 P_c and $P_{SB(one)} = \frac{1}{2} P_{SB} = \frac{m^2}{4} P_c = 0.25\ P_c$

$$\text{Percentage power saving} = \frac{P_T - P_{SB(one)}}{P_T} * 100\%$$

$$= \frac{1.5\ P_c - 0.25\ P_c}{1.5\ P_c} * 100\% = 83.33\%$$

(b) When m=0.5, P_T=1.125P_c and $P_{SB(one)} = \frac{1}{2} P_{SB} =$

$\frac{m^2}{4} P_c = 0.0625 P_c$

$$\text{Percentage power saving} = \frac{P_T - P_{SB(one)}}{P_T} * 100\%$$

$$= \frac{1.125\ P_c - 0.0625\ P_c}{1.125\ P_c} * 100\%$$

$$= 94.44\%$$

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Thank you …

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