Double-sideband suppressed-carrier transmission (DSB-SC)

Double-sideband suppressed-carrier transmission (DSB-SC) is transmission in which frequencies produced by amplitude modulation (AM) are symmetrically spaced above and below the carrier frequency and the carrier level is reduced to the lowest practical level, ideally being completely suppressed.

DSB-SC Spectrum

DSB-SC is basically an amplitude modulation wave without the carrier, therefore reducing power waste, giving it a 50% efficiency. This is an increase compared to normal AM transmission (DSB), which has a maximum efficiency of 33.333%, since 2/3 of the power is in the carrier which carries no intelligence, and each sideband carries the same information. Single Side Band (SSB) Suppressed Carrier is 100% efficient is shown in Figure 1.2.1 .

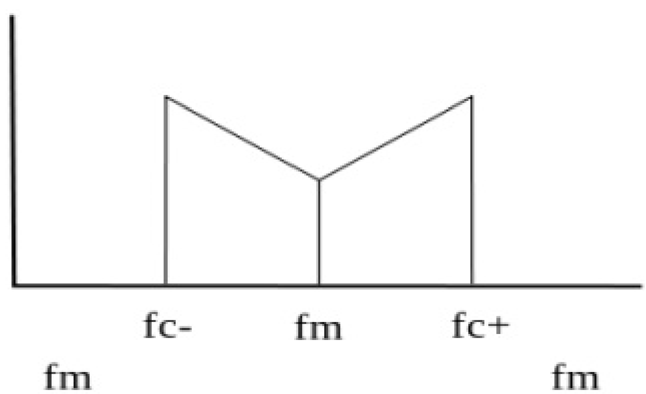


Figure 1.2.1 Spectrum plot of an DSB-SC Signal

Diagram Source : Electronic Tutorials

Generation:

DSB-SC is generated by a mixer. This consists of a message signal multiplied by a carrier signal. The mathematical representation of this process is shown below, where the product-to-sum trigonometric identity is used. Figure shows the 1.2.2 Generation of DSB Signals

$$\underbrace{V_m \cos(\omega_m t)}_{\text{Message}} \times \underbrace{V_c \cos(\omega_c t)}_{\text{Carrier}} = \underbrace{\frac{V_m V_c}{2}\left[\cos\left((\omega_m + \omega_c)\, t\right) + \cos\left((\omega_m - \omega_c)\, t\right)\right]}_{\text{Modulated Signal}}$$

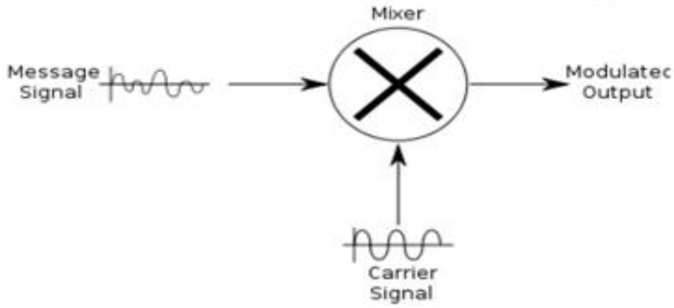


Figure 1.2.2 Generation of DSB Signals

Diagram Source : Electronic Tutorials

Demodulation:

Demodulation is done by multiplying the DSB-SC signal with the carrier signal just like the modulation process. This resultant signal is then passed through a low pass filter to produce a scaled version of original message signal. DSB-SC can be demodulated if modulation index is less than unity.

$$\overbrace{\frac{V_m V_c}{2}\left[\cos\left((\omega_m + \omega_c)\, t\right) + \cos\left((\omega_m - \omega_c)\, t\right)\right]}^{\text{Modulated Signal}} \times \overbrace{V_c' \cos(\omega_c t)}^{\text{Carrier}}$$

$$= \left(\frac{1}{2} V_c V_c'\right) \underbrace{V_m \cos(\omega_m t)}_{\text{original message}} + \frac{1}{2} V_c V_c' V_m \left[\cos((\omega_m + 2\omega_c)t) + \cos((\omega_m - 2\omega_c)t)\right]$$

The equation above shows that by multiplying the modulated signal by the carrier signal, the result is a scaled version of the original message signal plus a second term. Since , $\omega c >> \omega m$ wthis second term is much higher in frequency than the original message. Once this signal passes through a low pass filter, the higher frequency component is removed, leaving just the original message.

Distortion and Attenuation:

For demodulation, the demodulation oscillator's frequency and phase must be exactly the same as modulation oscillator's, otherwise, distortion and/or attenuation will occur.

To see this effect, take the following conditions:

- Message signal to be transmitted: $f(t)$
- Modulation (carrier) signal: $V_c \cos(\omega_c)$
- Demodulation signal (with small frequency and phase deviations from the modulation signal): $V_c' \cos[(\omega_c + \Delta\omega)t + \theta]$

The resultant signal can then be given by

$$f(t) \times V_c \cos(\omega_c) \times V_c' \cos[(\omega_c + \Delta\omega)t + \theta]$$

$$= \frac{1}{2}V_c V_c' f(t) \cos(\Delta\omega \cdot t + \theta) + \frac{1}{2}V_c V_c' f(t) \cos[(2\omega_c + \Delta\omega)t + \theta]$$

$$\xrightarrow{\text{After low pass filter}} \frac{1}{2}V_c V_c' f(t) \cos(\Delta\omega \cdot t + \theta)$$

The $\cos(\Delta\omega \cdot t + \theta)$ terms results in distortion and attenuation of the original message signal. In particular, $\Delta\omega \cdot t$ contributes to distortion while θ adds to the attenuation.

In the process of Amplitude Modulation, the modulated wave consists of the carrier wave and two sidebands. The modulated wave has the information only in the sidebands. Sideband is nothing but a band of frequencies, containing power, which are the lower and higher frequencies of the carrier frequency. The transmission of a signal, which contains a carrier along with two sidebands can be termed as Double Sideband Full Carrier system or simply DSBFC. It is plotted as shown in the following figure 1.2.3.

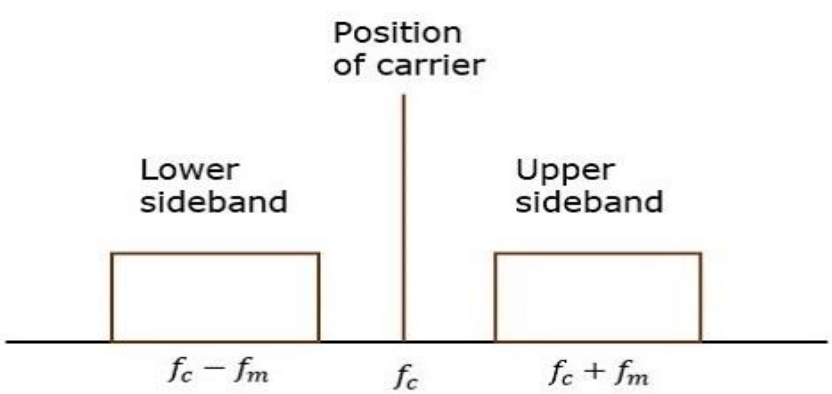


Figure 1.2.3 Spectrum of Double Sideband Full Carrier system

Diagram Source : Brain Kart

However, such a transmission is inefficient. Because, two-thirds of the power is being wasted in the carrier, which carries no information. If this carrier is suppressed and the saved power is distributed to the two sidebands, then such a process is called as Double Sideband Suppressed Carrier system or simply DSBSC. It is plotted as shown in the following figure 1.2.4.

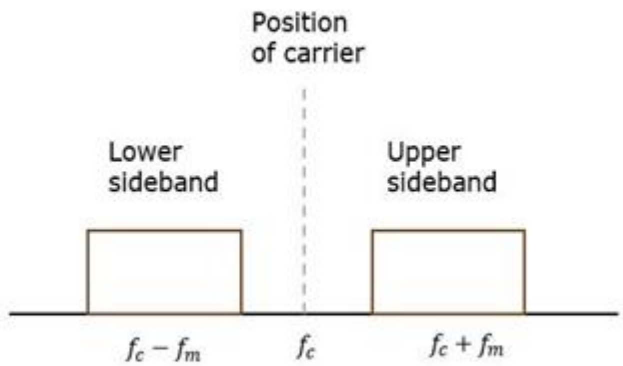


Figure 1.2.4 Carrier is suppressed and side bands are allowed for transmission

Diagram Source : Electronic Tutorials

Mathematical Expressions

Let us consider the same mathematical expressions for modulating and carrier signals as we have considered in the earlier chapters.

i.e., Modulating signal

$$m(t)=Amcos(2\pi fmt)m(t) \quad (1)$$

Carrier signal

$$c(t)=Accos(2\pi fct) \quad (2)$$

Mathematically, we can represent the equation of DSBSC wave as the product of modulating and carrier signals.

$$s(t)=m(t)c(t)s(t)$$

$$s(t)=AmAccos(2\pi fmt)cos(2\pi fct) \quad (3)$$

Bandwidth of DSBSC Wave

We know the formula for bandwidth (BW) is

$$BW=fmax-fmin$$

$$BW=fmax-fmin$$

Consider the equation of DSBSC modulated wave.

$$s(t)=A_mA_c\cos(2\pi f_mt)\cos(2\pi f_ct) \qquad (4)$$

$$s(t)=AmAc2\cos[2\pi(fc+fm)t]+AmAc2\cos[2\pi(fc-fm)t]$$

The DSBSC modulated wave has only two frequencies. So, the maximum and minimum frequencies are fc+fmfc+fm and fc−fmfc−fm respectively.

i.e.,

$$f_{max}=f_c+f_m \text{ and}$$

$$f_{min}=f_c-f_m$$

Substitute, fmax and fmin values in the bandwidth formula.

$$BW=fc+fm-(fc-fm)$$

$$BW=fc+fm-(fc-fm)$$

$$\text{Band Width (BW)} =2f_m$$

Thus, the bandwidth of DSBSC wave is same as that of AM wave and it is equal to twice the frequency of the modulating signal.nConsider the following equation of DSBSC modulated wave.

$$s(t)=A_mA_c/2\cos[2\pi(fc+fm)t]+AmAc/2\cos[2\pi(fc-fm)t]$$

Power of DSBSC wave is equal to the sum of powers of upper sideband and lower sideband frequency components.

$Pt=PUSB+PLSB$

We know the standard formula for power of cos signal is

$$P=(Vrms/\sqrt{2})^2/R$$

$$=(Vm/\sqrt{2})^2 / R$$

First, let us find the powers of upper sideband and lower sideband one by one.

Upper sideband power

$$P_{USB}=(A_mA_c/2/\sqrt{2})^2/R$$
$$=A_m^2A_c^2/8R \tag{5}$$

Similarly, we will get the lower sideband power same as that of upper sideband power.

$$PUSB=Am^2Ac^2/8R$$

Now, let us add these two sideband powers in order to get the power of DSBSC wave.

$$P_t=Am^2Ac^2/8R+Am^2Ac^2/8R$$
$$Pt=Am^2Ac^2/4R \tag{6}$$

Therefore, the power required for transmitting DSBSC wave is equal to the power of both the sidebands.

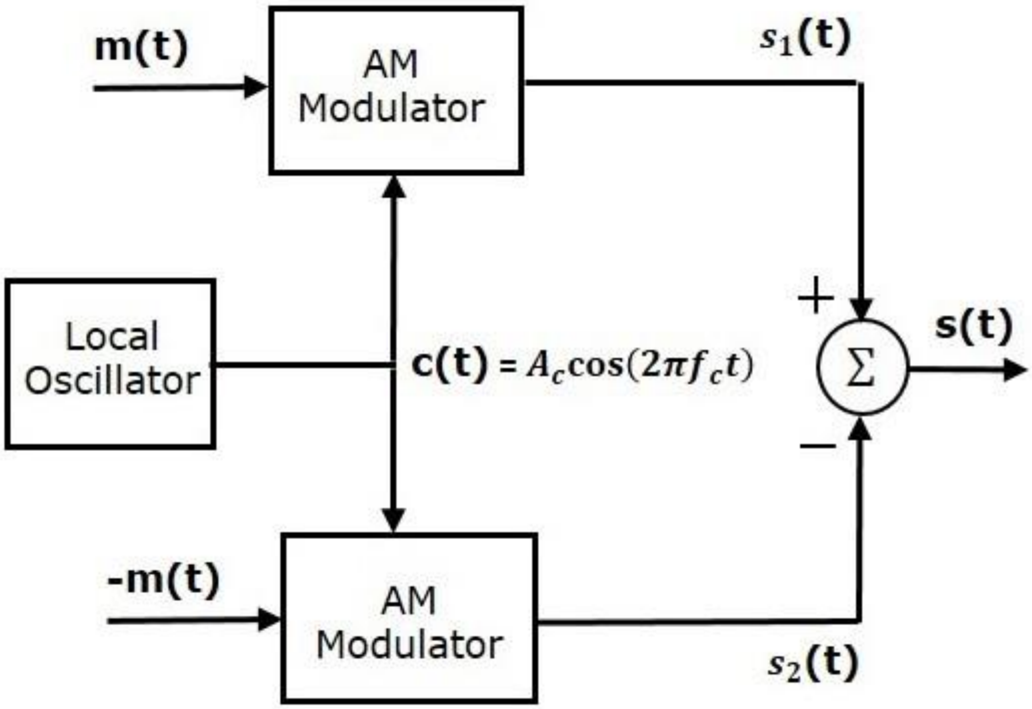
The following two modulators generate DSBSC wave.

- ✓ Balanced modulator
- ✓ Ring modulator

Balanced Modulator

Following is the block diagram of the Balanced modulator shown in figure. Balanced modulator consists of two identical AM modulators. These two modulators are arranged in a balanced configuration in order to suppress the carrier signal. Hence, it is called as Balanced modulator.

The same carrier signal $c(t)=A_c\cos(2\pi f_ct)$is applied as one of the inputs to these two AM modulators. The modulating signal m(t) is applied as another input to the upper AM modulator. Whereas, the modulating signal m(t)m(t) with opposite polarity, i.e., -m(t) is applied as another input to the lower AM modulator.



Output of the upper AM modulator is

$$s_1(t)=Ac[1+k_am(t)]\cos(2\pi f_ct)$$

Output of the lower AM modulator is

$$s_2(t)=Ac[1-k_am(t)]\cos(2\pi f_ct)$$

We get the DSBSC wave s(t) by subtracting $s_2(t)$ from $s_1(t)$. The summer block is used to perform this operation. $s_1(t)$with positive sign and $s_2(t)$ with negative sign are applied as inputs to summer block. Thus, the summer block produces an output s(t) which is the difference of $s_1(t)$ and $s_2(t)$.

$$s(t)=Ac[1+kam(t)]Cos(2\pi fct)-Ac[1-kam(t)]Cos(2\pi fct)$$

$$s(t)=Accos(2\pi fct) + Ackam(t)Cos(2\pi fct)-AcCos(2\pi fct)+ Ackam(t)Cos(2\pi fct) \quad (7)$$

$$s(t)=2Ackam(t)cos(2\pi fct)$$

We know the standard equation of DSBSC wave is

$$s(t)=Acm(t)\cos(2\pi fct) \qquad (8)$$

By comparing the output of summer block with the standard equation of DSBSC wave, we will get the scaling factor as 2ka.

Ring Modulator

Following is the block diagram of the Ring modulator shown in Figure 1.2.5.

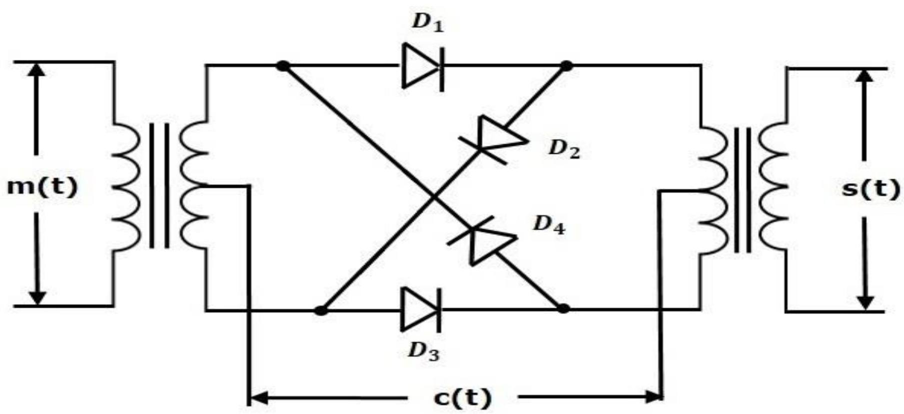


Figure 1.2.5 Ring Modulator

Diagram Source : Electronic Tutorials

In this diagram, the four diodes D1,D2,D3 and D4 are connected in the ring structure. Hence, this modulator is called as the ring modulator. Two center tapped transformers are used in this diagram. The message signal m(t)m(t) is applied to the input transformer. Whereas, the carrier signals c(t)c(t) is applied between the two center tapped transformers.

For positive half cycle of the carrier signal, the diodes D1 and D3 are switched ON and the other two diodes D2 and D4 are switched OFF. In this case, the message signal is multiplied by +1.

For negative half cycle of the carrier signal, the diodes D2D2 and D4D4 are switched ON and the other two diodes D1 and D3 are switched OFF. In this case, the message signal is multiplied by -1. This results in 180 degree phase shift in the resulting DSBSC wave. From the above analysis, we can say that the four diodes D1, D2, D3 and D4 are controlled by the carrier signal.

We will get DSBSC wave s(t)s(t), which is just the product of the carrier signal c(t)c(t) and the message signal m(t)m(t) i.e.,

$$s\left(t\right)=\frac{4}{\pi}\sum_{n=1}^{\infty}\frac{\left(-1\right)^{n-1}}{2n-1}\cos[2\pi f_c t\left(2n-1\right)]m\left(t\right) \tag{9}$$

The above equation represents DSB-SC wave, which is obtained at the output transformer of the ring modulator. DSBSC modulators are also called as product modulators as they produce the output, which is the product of two input signals.