UNIT1, M5: Concept of Single side band generation and detection

NOTES:

Introduction:

The Amplitude modulated signal has two sidebands and a carrier. Since, the two sidebands carry the same information, there is no need to transmit both sidebands. We can eliminate one sideband.

The process of suppressing one of the sidebands along with the carrier and transmitting a single sideband is called as Single Sideband Suppressed Carrier system or simply SSBSC.

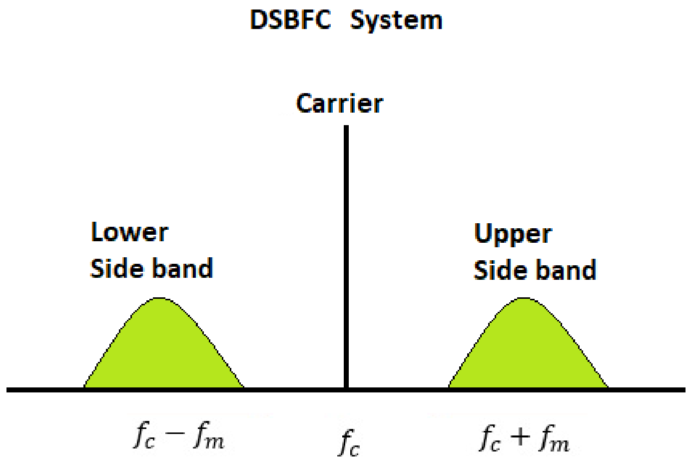


Fig: Representation of amplitude modulated wave in the frequency domain.

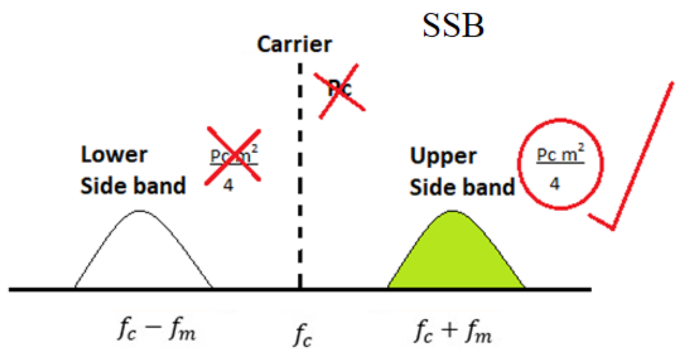
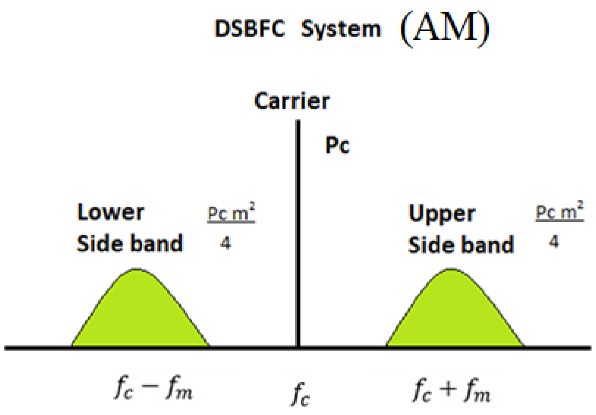


Fig: Single Sideband supressed carrier

- By removing some of the components of the ordinary AM signal it is possible to significantly improve its efficiency.



Improvement in efficiency in terms of Power and Bandwidth Requirement

Bandwidth Required for AM transmission = 2 fm

Whereas for SSB transmission it is = fm

Power required for transmission of AM with modulation Index = 50%

Pt = 1.125 Pc

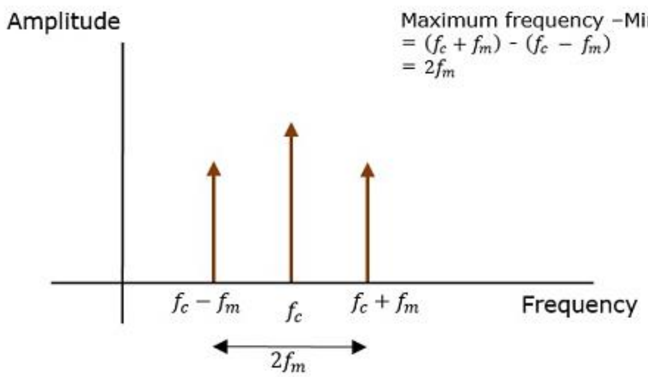
Whereas for SSB transmission it is 0.0625 Pc

Thus resulting in Power Saving of 94.4 %

Single Sideband Modulation (SSB)

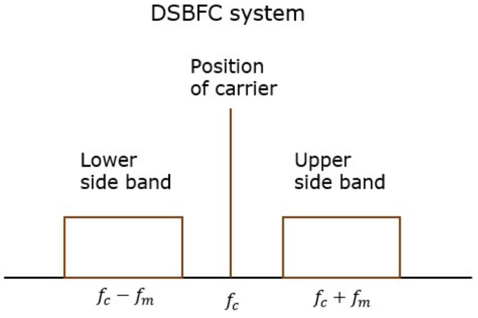
SSB TECHNIQUES

A **Sideband** is a band of frequencies, containing power, which are the lower and higher frequencies of the carrier frequency. Both the sidebands contain the same information. The representation of amplitude modulated wave in the frequency domain is as shown in the following figure.



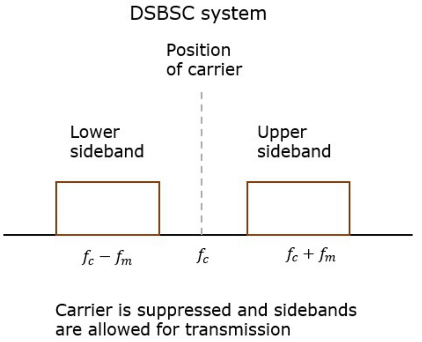
Double Sideband Full Carrier

Both the sidebands in the image contain the same information. The transmission of such a signal which contains a carrier along with two sidebands, can be termed as **Double Sideband Full Carrier** system, or simply **DSB-FC**. It is plotted as shown in the following figure.



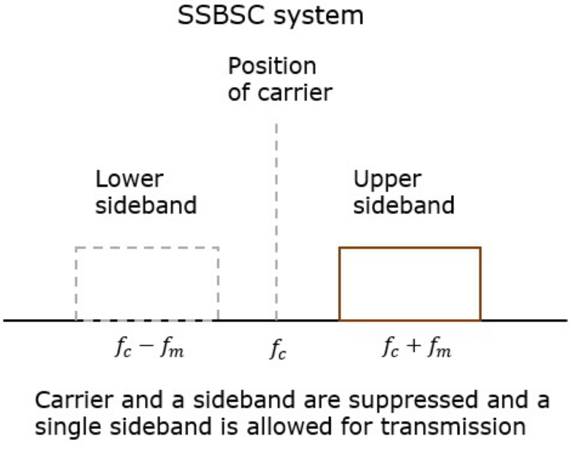
Double Sideband Suppressed Carrier

If this carrier is suppressed and the power saved is distributed to the two sidebands, such a process is called as **Double Sideband Suppressed Carrier** system, or simply **DSBSC**. It is plotted as shown in the following figure.



SINGLE SIDEBAND (SSB):

The SSB-SC or SSB system, which transmits a single sideband has high power, as the power allotted for both the carrier and the other sideband is utilized in transmitting this **Single Sideband (SSB)**.



Sideband Modulation – Advantages

Bandwidth or spectrum space occupied is lesser than AM and DSB signals.
Transmission of more number of signals is allowed.

Power is saved.
High power signal can be transmitted.
Less amount of noise is present.
Signal fading is less likely to occur.

Sideband Modulation – Disadvantages

The cost of a single side band SSB receiver is higher than the double side band DSB counterpart be a ratio of about 3:1.

The average radio user wants only to flip a power switch and dial a station. Single side band SSB receivers require several precise frequency control settings to minimize distortion and may require continual readjustment during the use of the system.

The generation and detection of SSB signal is a complex process.

Quality of the signal gets affected unless the SSB transmitter and receiver have an excellent frequency stability.

Sideband Modulation – Applications

For power saving requirements and low bandwidth requirements.
In land, air, and maritime mobile communications.
In point-to-point communications.
In radio communications.
In television, telemetry, and radar communications.
In military communications, such as amateur radio, etc.

ILLUSTRATION TO SHOW POWER SAVING WITH SIDEBAND TECHNIQUES

EXAMPLE 4-1 Calculate the percentage power saving when the carrier and one of the sidebands are suppressed in an AM wave modulated to a depth of *(a)* 100 percent and *(b)* 50 percent.

SOLUTION

(a)

$$P_t = P_c\left(1 + \frac{m^2}{2}\right) = P_c\left(1 + \frac{1^2}{2}\right) = 1.5P_c$$

$$P_{SB} = P_c\frac{m^2}{4} = P_c\frac{1^2}{4} = 0.25P_c$$

$$\text{Saving} = \frac{1.5 - 0.25}{1.5} = \frac{1.25}{1.5} = 0.833 = 83.3\%$$

(b)

$$P_t = P_c\left(1 + \frac{0.5^2}{2}\right) = 1.125P_c$$

$$P_{SB} = P_c\frac{0.5^2}{4} = 0.0625P_c$$

$$\text{Saving} = \frac{1.125 - 0.0625}{1.125} = \frac{1.0625}{1.125} = 0.944 = 94.4\%$$

Example 4-1 indicates how wasteful of power it is to send the carrier and both sidebands in situations in which only one sideband would suffice. A further check shows that the use of SSB immediately halves the bandwidth required for transmission, as compared with A3E.

In practice, SSB is used to save power in applications where such a power saving is warranted, i.e., in mobile systems, in which weight and power consumption must naturally be kept low. Single-sideband modulation is also used in applications in which bandwidth is at a premium. Point-to-point communications, land, air and maritime mobile communications, television, telemetry, military communications, radio navigation and amateur radio are the greatest users of SSB in one form or another.

Waveforms showing SSB are illustrated in Figure 4-1, together with the modulating voltage, the corresponding AM voltage, and a wave with the carrier removed. Two different modulating amplitudes and frequencies are shown for comparison. This demonstrates that here the SSB wave is a single radio frequency. Its amplitude is proportional to the amplitude of the modulating voltage, and its frequency varies with

SSB WAVEFORMS

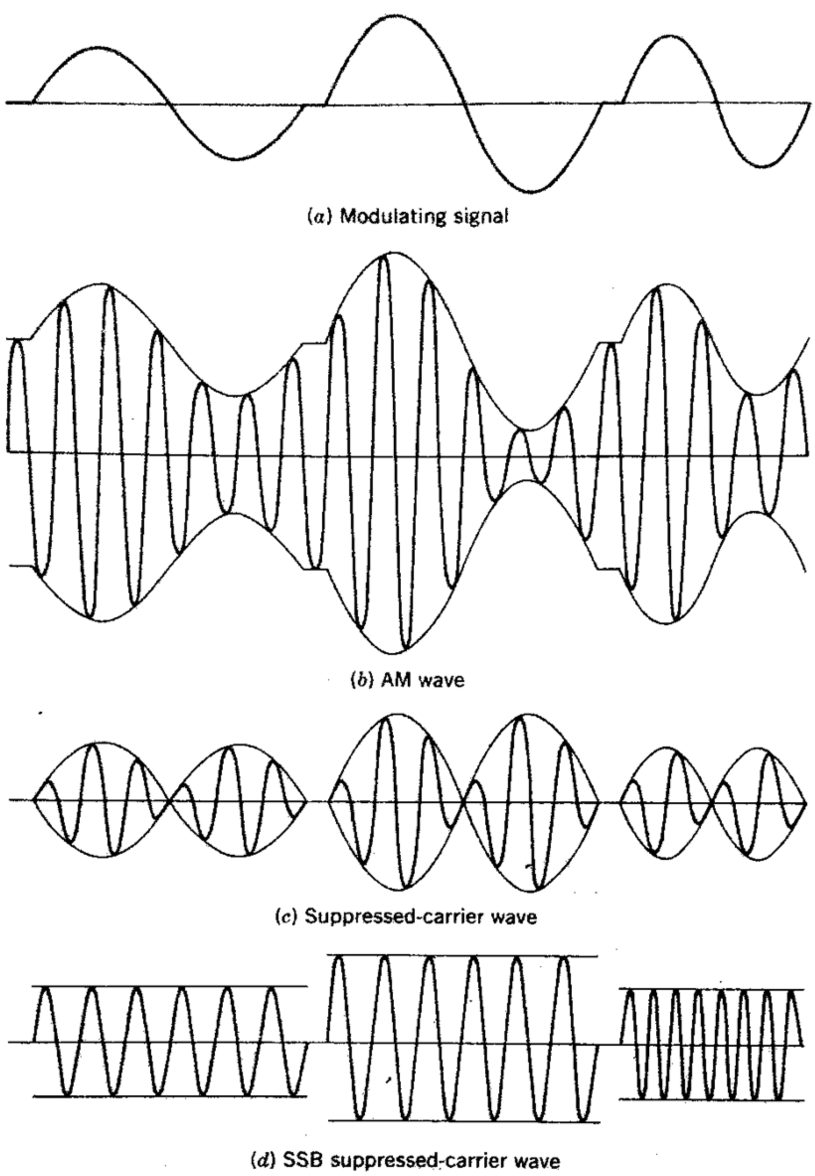
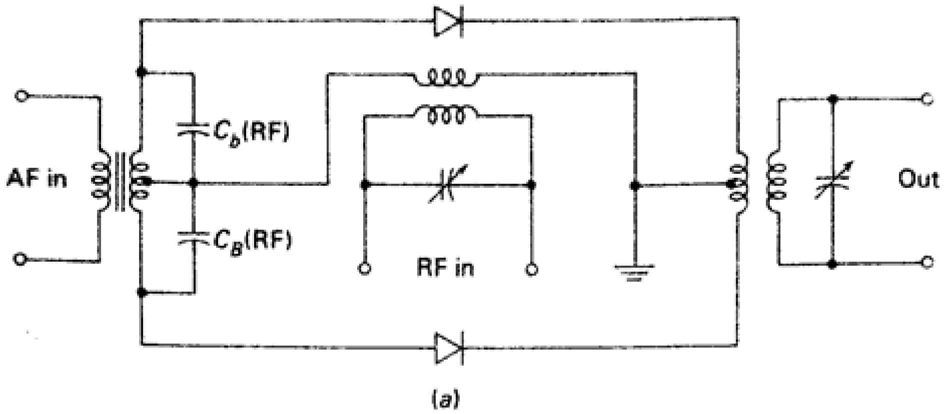


FIGURE 4-1 Waveforms for various types of amplitude modulation. (*a*) Modulating signal; (*b*) AM wave; (*c*) suppressed-carrier wave; (*d*) SSB suppressed-carrier wave.

the frequency of the modulating signal. An upper sideband is shown so that its frequency increases with that of the modulation, but please note that this frequency increase is exaggerated here to indicate the effect clearly.

BALANCED MODULATOR



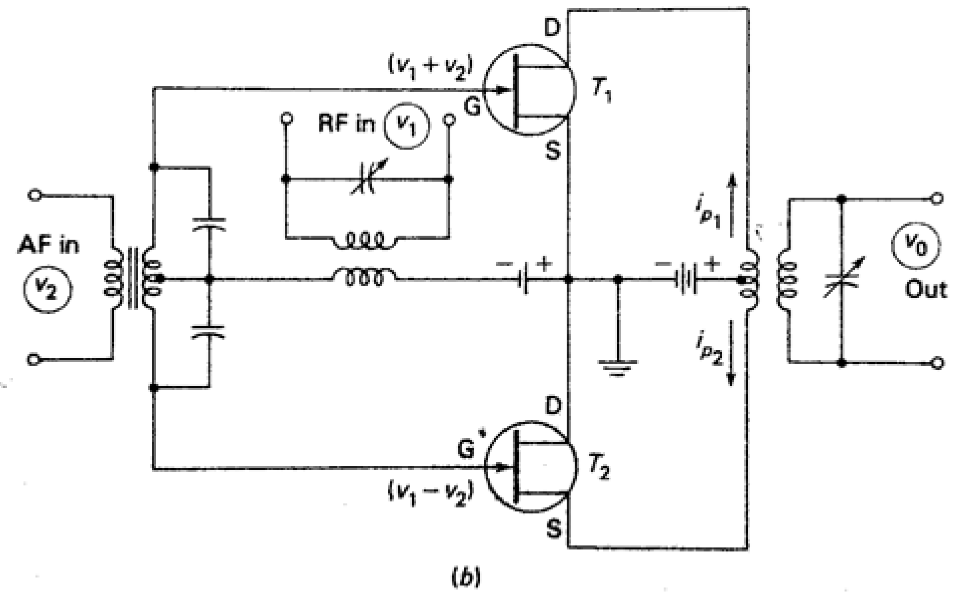


FIGURE 4-3 Balanced modulators. (a) Diode; (b) FET.

The Balanced Modulator

Two circuits of the balanced modulator are shown in Figure (4-3). Each utilizes the nonlinear principles just discussed. The modulation voltage v_2 is fed in push-pull, and the carrier voltage v_1 in parallel, to a pair of identical diodes or class A (transistor or FET) amplifiers. In the FET circuit, the carrier voltage is thus applied to the two gates in phase; whereas the modulating voltage appears 180° out of phase at the gates, since they are at the opposite ends of a center-tapped transformer. The modulated output currents of the two FETs are combined in the center-tapped primary of the push-pull output transformer. They therefore subtract, as indicated by the direction of the arrows in Figure 4-3*b*. If this system is made completely symmetrical, the carrier frequency will be completely canceled. No system can of course be perfectly symmetrical in practice, so that the carrier will be heavily suppressed rather than completely removed (a 45-dB suppression is normally regarded as acceptable). The output of the balanced modulator contains the two sidebands and some of the miscellaneous components which are taken care of by the tuning of the output transformer's secondary winding. The final output consists only of sidebands.

Since it is not immediately apparent how and why only the carrier is suppressed, a mathematical analysis of the balanced modulator is now given.

As indicated, the input voltage will be $v_1 + v_2$ at the gate of T_1 (Figure 4-3*b*) and $v_1 - v_2$ at the gate of T_2. If perfect symmetry is assumed (it should be understood that the two devices used in the balanced modulator, whether diodes or transistors, must be matched), the proportionality constants will be the same for both FETs and may be called a, b, and c as before. The two drain currents, calculated as in the preceding section, will be

$$\begin{aligned} i_{d_1} &= a + b(v_1 + v_2) + c(v_1 + v_2)^2 \\ &= a + bv_1 + bv_2 + cv_1^2 + cv_2^2 + 2cv_1v_2. \end{aligned} \quad \textbf{(4-9)}$$

$$\begin{aligned} i_{d_2} &= a + b(v_1 - v_2) + c(v_1 - v_2)^2 \\ &= a + bv_1 - bv_2 + cv_1^2 + cv_2^2 - 2cv_1c_2 \end{aligned} \quad \textbf{(4-10)}$$

As previously indicated the primary current is given by the difference between the individual drain currents. Thus

$$i_1 = i_{d_1} - i_{d_2} = 2bv_2 + 4cv_1v_2 \quad \textbf{(4-11)}$$

when Equation (4-10) is subtracted from (4-9).

We may now represent the carrier voltage v_1 by $V_c \sin \omega_c t$ and the modulating voltage v_2 by $V_m \sin \omega_m t$. Substituting these into Equation (4-11) gives

$$\begin{aligned} i_1 &= 2bV_m \sin \omega_m t + 4cV_mV_c \sin \omega_c t \sin \omega_m t \\ &= 2bV_m \sin \omega_m t + 4cV_mV_c \tfrac{1}{2}[\cos (\omega_c - \omega_m)t - \cos (\omega_c + \omega_m)t] \end{aligned} \quad \textbf{(4-12)}$$

The output voltage v_0 is proportional to this primary current. Let the constant of proportionality be α. Then

$$v_0 = \alpha i_1$$
$$= 2\alpha b V_m \sin \omega_m t + 2\alpha c V_m V_c [\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t]$$

Simplifying, we let $P = 2\alpha b V_m$ and $Q = 2\alpha c V_m V_c$. Then

$$v_O = \underbrace{P \sin \omega_m t}_{\text{Modulation frequency}} + \underbrace{Q \cos(\omega_c - \omega_m)t}_{\text{Lower sideband}} - \underbrace{Q \cos(\omega_c + \omega_m)t}_{\text{Upper sideband}} \quad \textbf{(4-13)}$$

Equation (4-13) shows that (under ideally symmetrical conditions) the carrier has been canceled out, leaving only the two sidebands and the modulating frequencies.

SSB TRANSMISSION

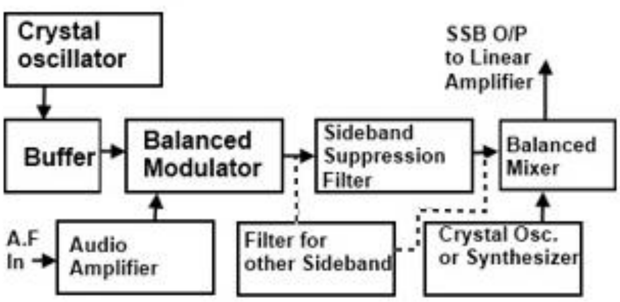
There are three methods used for SSB Transmission.

Filter Method

Phase Shift Method

Third Method

FILTER METHOD



SSB Single Side Band Transmission Filter Method

A crystal controlled master oscillator produces a stable carrier frequency fc (say 100 KHz)

This carrier frequency is then fed to the balanced modulator through a buffer amplifier, which isolates these two stages.

The audio signal from the modulating amplifier modulates the carrier in the balanced modulator. Audio frequency range is 300 to 2800 Hz. The carrier is also suppressed in this stage but allows only to pass the both side bands. (USB & LSB).

A band pass filter (BPF) allows only a single band either USB or LSB to pass through it, depending on the requirements.

If we want to pass the USB then LSB will be suppressed.

In this case fc = 100 KHz

Audio range = 300 - 2800 Hz

USB frequency range = fc + 300 to fc + 2800

= 100000 + 300 to 100000 + 2800

= 100300 to 102800 Hz

So this band of frequency will be passed on through the USB filter section

This side band is then heterodyned in the balanced mixer stage with 12 MHz frequency produced by crystal

Three Major Types of SSB Filters.

LC Filter

Disadvantages: Sharp filter response curve is needed, however to achieve this the Q of the tuned circuits used must be very high

As the transmitting frequency is raised, so must the Q be raised, until a situation is reached where the necessary Q is so high that there is no practicable method of achieving it.

Multistage LC filters cannot be used for RF values much greater than about 100KHz, Above this frequency the attenuation outside the band pass is insufficient.

Mechanical Filter

Mechanical filters can be used at frequencies up to 500 kHz.

Advantages: small size, good bandpass, very good attenuation characteristics and an adequate upper frequency limit

Crystal or Ceramic Filters

Crystal or ceramic filters can be used up to about 20 MHz
They are cheaper, but are preferable only at frequencies above 1 MHz

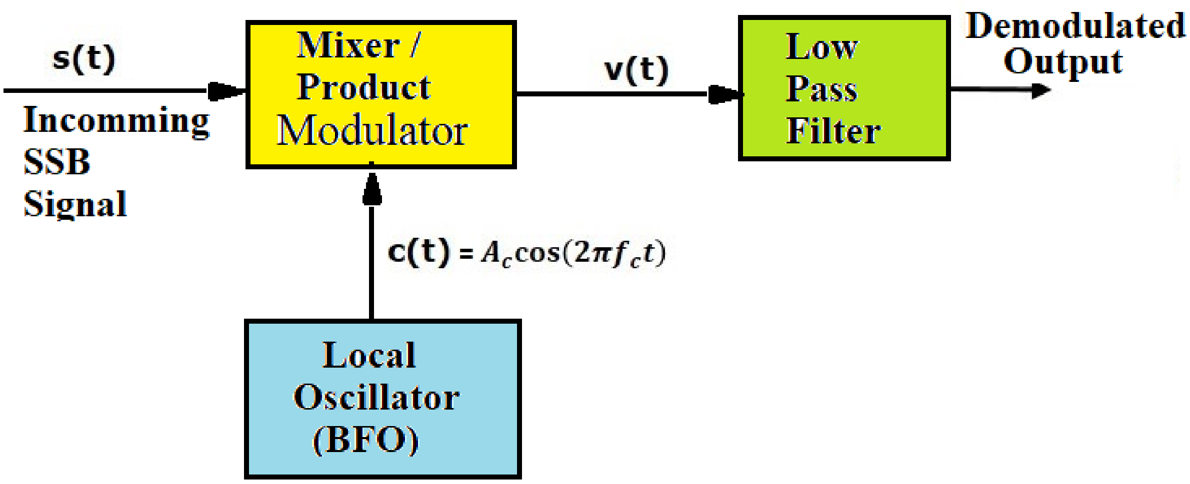
Demodulation/Detection of SSB signal

The process of extracting an original message signal from SSBSC wave is known as detection or demodulation of SSBSC. Coherent detector is used for demodulating SSBSC wave.

In order to demodulate SSB signal, it is necessary to reintroduce the carrier. To achieve this two main elements are required:

Local oscillator: The local oscillator signal is needed to provide the locally produced carrier signal to re-introduce into the signal.

Mixer: The mixer is used to mix the local oscillator signal and the incoming single sideband signal together. The output from the mixer is the demodulated audio signal.



Single Sideband demodulation

Coherent Detector

Here, the same carrier signal (which is used for generating SSBSC wave) is used to detect the message signal. Hence, this process of detection is called as coherent or synchronous detection.

In this process, the message signal can be extracted from SSBSC wave by multiplying it with a carrier, having the same frequency and the phase of the carrier used in SSBSC modulation. The resulting signal is then passed through a Low Pass Filter. The output of this filter is the desired message signal.

Sideband Modulation – Advantages

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