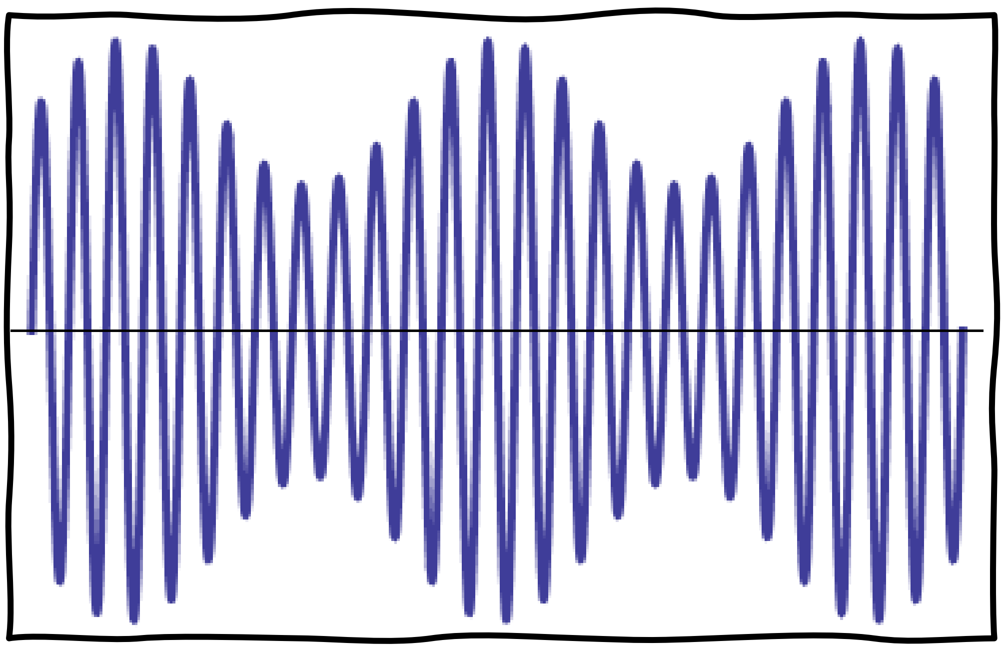
Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Systems
Lecturer: Prof. Dr. Bayan Mahdi Sabbar & M.Sc. Huda Wasfi Hassoon
Lecture: 6

Lecture 6

Part 2

AM Modulation



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Double Sideband Suppressed Carrier (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. The expression of DSB-SC modulation is given by:

$$E_{DSB-SC}(t) = m(t)\cos(w_c t)$$

$$m(t) = E_m\, cos(w_m t)$$

$$E_{DSB-SC}(t) = E_m \cos(w_m t)\cos(w_c t)$$

$$E_{DSB-SC}(t) = \frac{E_m}{2}\cos(w_c - w_m)\,t + \frac{E_m}{2}\cos(w_c + w_m)t$$

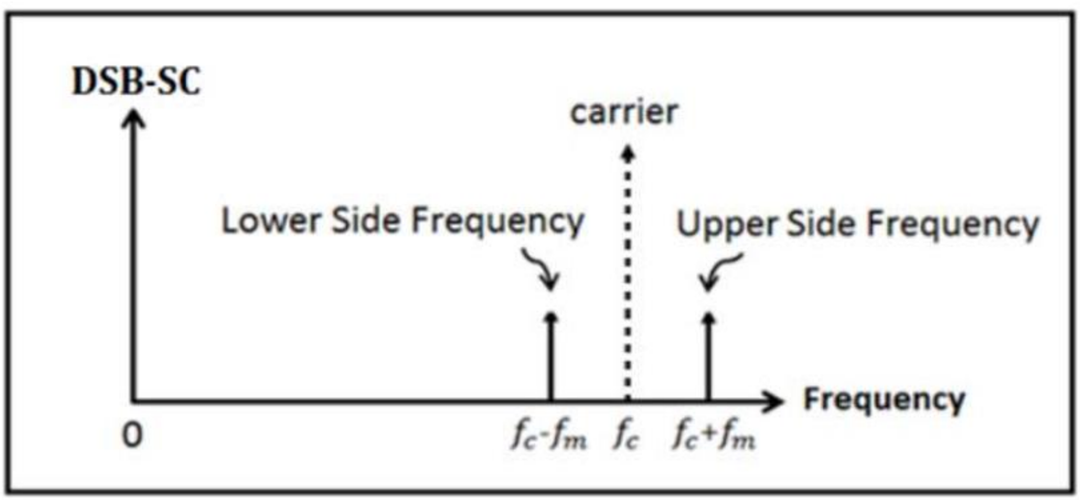

Fig. 1: Frequency Spectrum of DSB-SC.

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The bandwidth of the modulated waveform is twice the information bandwidth:

$$BW = Maximum\ Freq. - Minimum\ Freq.$$

$$BW = (f_c + f_m) - (f_c - f_m)$$

$$BW = 2f_m$$

Generation of Double Sideband Suppressed Carrier (DSB-SC):

The process of generating a DSB-SC is shown in Figure below.

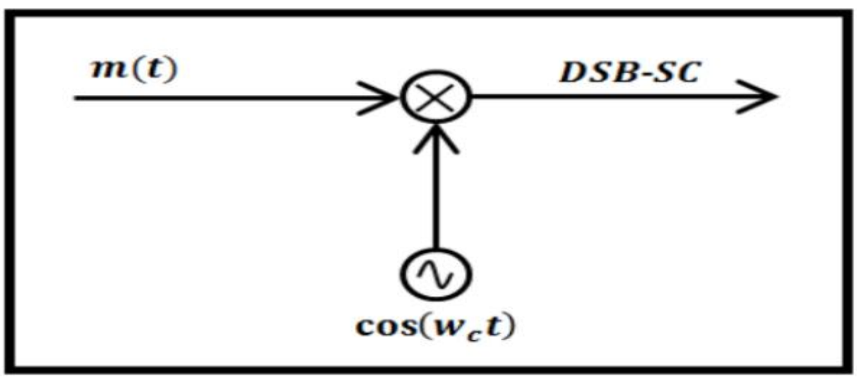

Fig. 2: The Generation of DSB-SC.

The double-sideband suppressed-carrier (DSB-SC) form of amplitude modulation is typically generated using a ring modulator circuit. This circuit consists of two center-tapped transformers and four diodes arranged in a ring configuration to cancel out the carrier frequency, producing a double-sideband signal without the carrier.

Afterward, the resulting signal is passed through a band-pass filter to isolate the desired frequency range and enhance the quality of the modulated signal.

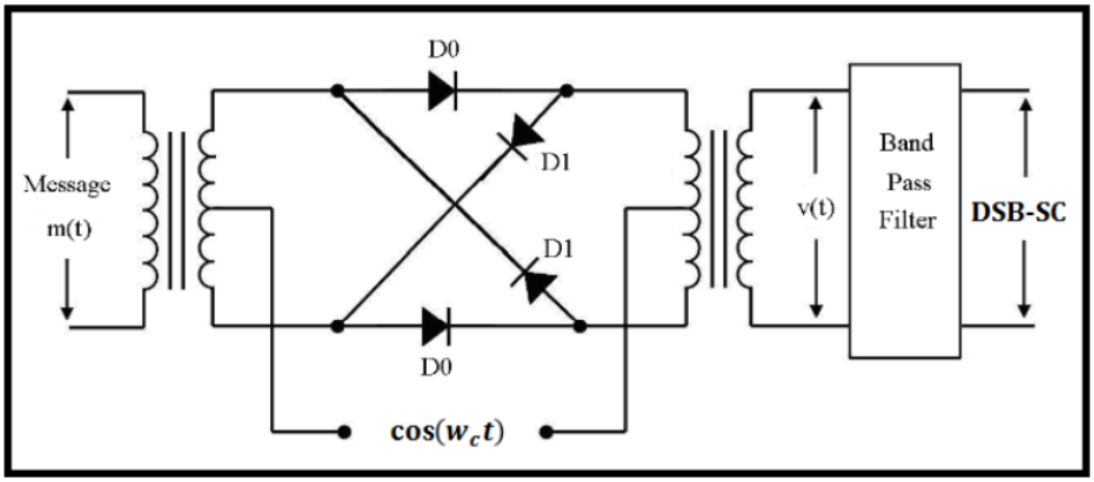

Fig. 3: The ring modulator circuit.

Power of DSB-SC:

There are two components for the DSB-SC waveform, the upper sideband and the lower sideband frequency. If the powers in the two of these are added up, the total power in the modulated signal will be:

$$P_t = P_{USB} + P_{LSB}$$

$$P_{USB} = \frac{(E_m)^2}{8R} \qquad P_{LSB} = \frac{(E_m)^2}{8R}$$

$$\therefore P_t = \frac{(E_m)^2}{4R}$$

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Demodulation of DSB-SC:

In order to demodulate a double-sideband suppressed-carrier (DSB-SC) signal, the signal is first fed into a product modulator. In this modulator, the incoming DSB-SC wave is multiplied by a locally generated carrier signal, represented as $cos(w_c t)$. This locally generated carrier must be "coherent," meaning it is perfectly synchronized in both frequency and phase with the original carrier wave used during the generation of the DSB-SC signal.

This technique is known as ***coherent detection*** or ***synchronous detection*** because of the precise alignment needed between the locally generated carrier and the original carrier.

After modulation, the output from the product modulator contains both the message signal and various other frequency components. To isolate and retrieve only the message signal, the output is passed through a low-pass filter (LPF). The LPF removes all the unnecessary higher-frequency components, leaving only the original message signal as the final output.

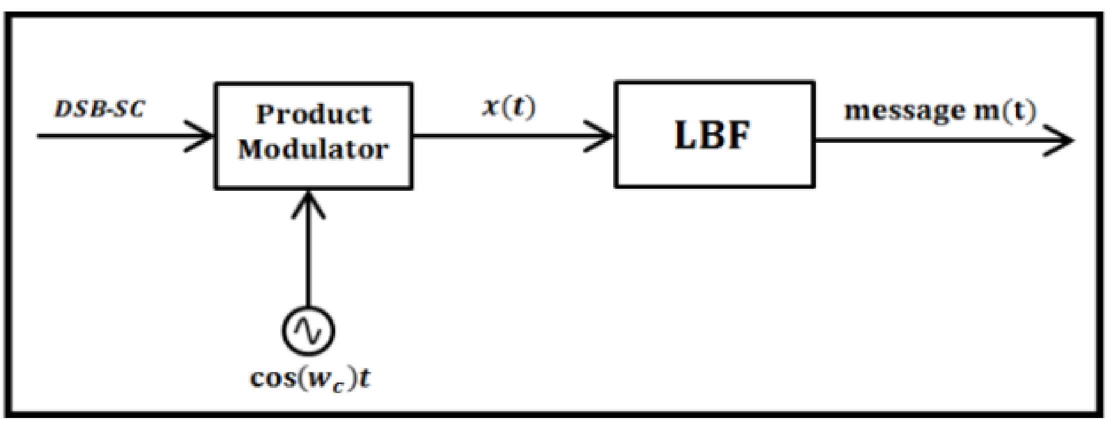

Fig. 4: Coherent Detection of DSB-SC modulated wave.

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Single Sideband (SSB)

In both double-sideband large carrier (DSB-LC) and double-sideband suppressed carrier (DSB-SC) modulation methods, the required transmission bandwidth is twice that of the original message signal $m(t)$. This is because both sidebands — the upper sideband (USB) and the lower sideband (LSB) — contain identical information about the message. However, since either sideband alone fully represents the message content, we can save bandwidth by transmitting only one of the sidebands, either the USB or the LSB. This approach is known as *Single Sideband (SSB) modulation*, and it is a more bandwidth-efficient method compared to DSB-LC and DSB-SC.

Generation of Single Sideband (SSB):

There are two common methods to generate a Single Sideband (SSB) signal.

1. **Filtering Method:** One common technique for generating a Single Sideband (SSB) signal is by using a band-pass filter (BPF) to remove one of the sidebands. This filtering process eliminates either the upper sideband (USB), which contains the higher frequency components, or the lower sideband (LSB), which contains the lower frequency components, leaving only one sideband to be transmitted. In SSB transmission, the carrier signal is often reduced or completely suppressed to further save bandwidth and power. This is known as *Single Sideband Suppressed Carrier (SSBSC)* modulation. By suppressing the carrier and transmitting only one sideband, SSBSC efficiently transmits the essential message information using minimal bandwidth.

Figure (5) illustrates the process of generating an SSB signal using this filter-based method.

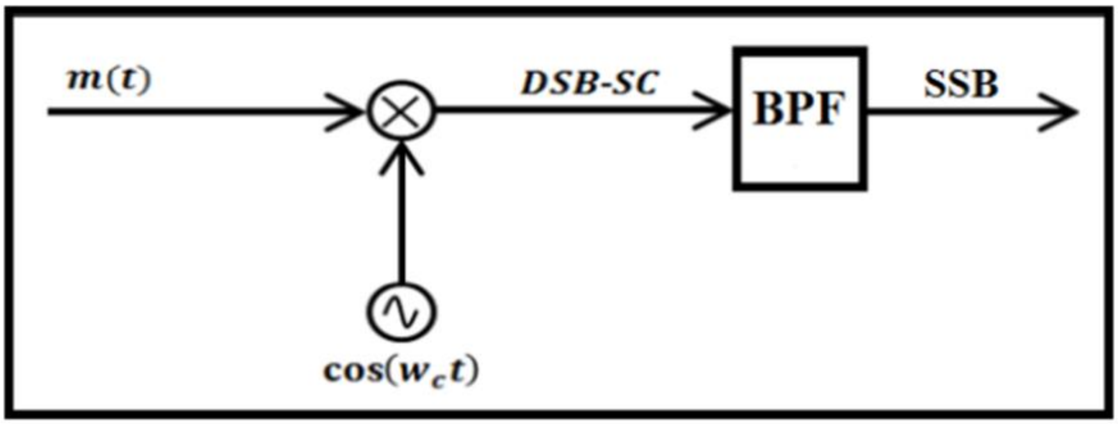

Fig. 5: Generation of SSB signal using Filter method.

2. **Phasing Method:** An alternative method for generating a Single Sideband (SSB) signal is called the *Phasing Method*, commonly implemented using a Hartley modulator. This approach uses phase shifting to cancel out the unwanted sideband. In the phasing method, two versions of the original message signal are created, each shifted by 90° with respect to the other, for every frequency within the desired bandwidth. These two versions are then used to modulate two carrier signals, which are themselves 90° out of phase. By carefully adding or subtracting the resulting modulated signals, either the lower sideband (LSB) or the upper sideband (USB) can be isolated, depending on the configuration.

   This technique effectively generates an SSB signal by phase cancellation, eliminating the need for complex filtering. Figure (6) illustrates the generation of an SSB signal using this phasing method.

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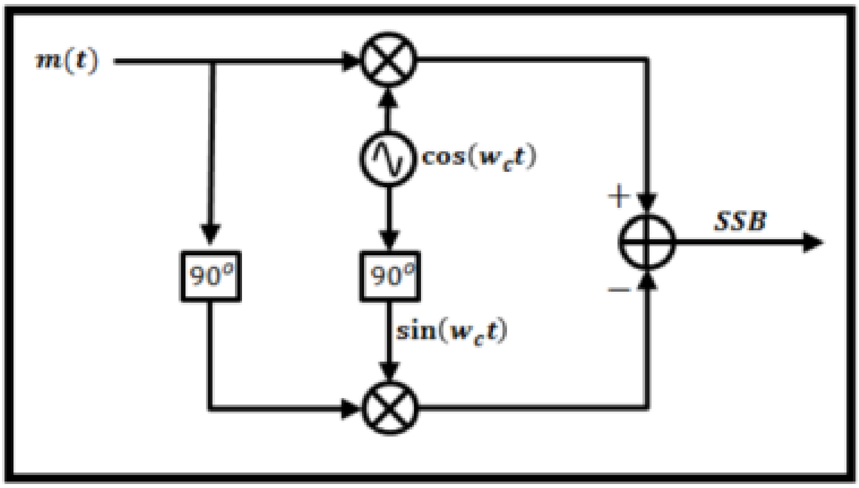

Fig. 6: Generation of SSB signal using phasing method.

Power of SSB: The power of the SSB modulated signal is less than what would be obtained using DSB modulation.

$$P_{SSB-SC} = P_{USB}$$

$$P_{SSB-LC} = P_c + P_{USB}$$

Demodulation of SSB:

Demodulation of SSB signals can be accomplished by using a synchronous detector as used in the demodulation of DSB-SC.

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Vestigial Sideband (VSB)

Vestigial Sideband (VSB) modulation is a technique that combines one complete sideband with a portion of the other sideband, known as the "vestigial" sideband. In contrast, *Double Sideband (DSB)* modulation transmits both full sidebands, while *Single Sideband (SSB)* modulation transmits only one full sideband. VSB, however, transmits one full sideband along with a partial "vestige" of the opposite sideband.

The bandwidth required for VSB falls between the requirements of DSB and SSB. This makes VSB especially useful in cases where the input signal has a very wide frequency range, and it is essential to save spectrum space. The total bandwidth of a VSB signal ranges from 1 to 2 times the bandwidth of the original message signal, depending on the size of the transmitted vestigial sideband.

Frequency Division Multiplexing (FDM):

In communication engineering, one of the primary challenges is to design a system that allows multiple individual user signals to be transmitted simultaneously over a single communication channel. The most common solution to this problem is to shift each individual signal from one frequency range to another, allowing them to occupy separate frequency bands. This frequency shifting is achieved by multiplying a low-frequency signal (the information or modulating signal) by a high-frequency carrier signal.

Frequency Division Multiplexing (FDM) is a technique in which multiple signals are combined and transmitted together on a single communication line or channel. In this method, each signal is allocated a unique frequency band, known as a sub-channel, within the main channel. This enables the simultaneous transmission of multiple signals without interference, as each operates in its own frequency range. Figure (7-8) shows the transmitter and receiver of a 3-FDM system.

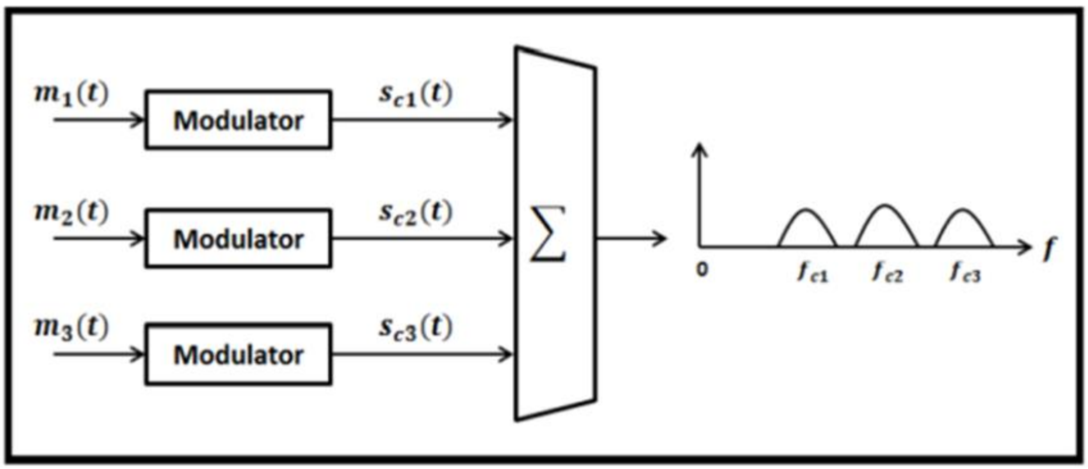

Fig. 7: FDM Transmitter.

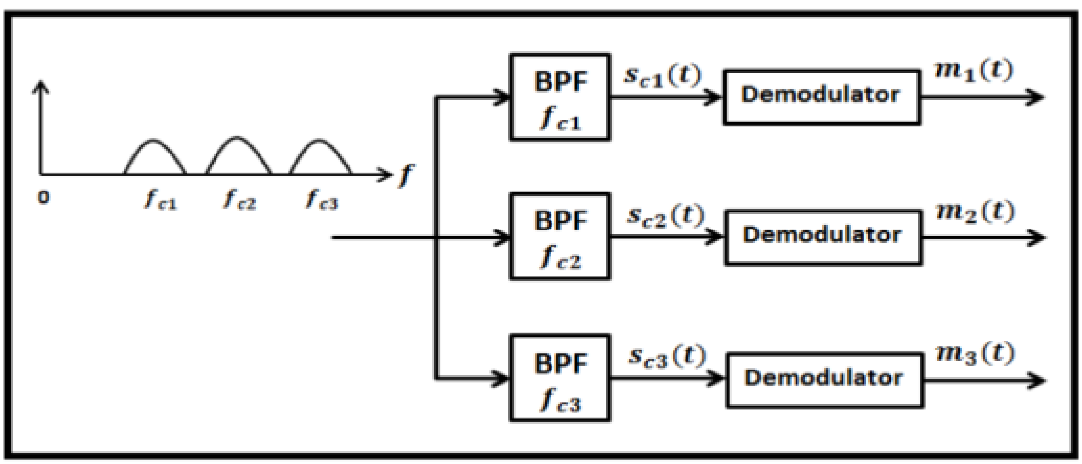

Fig. 8: FDM Receiver.

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Example: For a particular DSB-SC modulator with a carrier frequency of $1000\,rad/sec$, a load resistance of $50\,\Omega$, and a modulating signal $m(t) = 10\,cos(20t)$. Find the following:

1. The peak voltage (Em).
2. The modulating frequency.
3. The DSB-SC bandwidth.
4. The USB bandwidth and frequencies.
5. The LSB bandwidth and frequencies.
6. The total power.

Solution:

1. $E_m = 10$ V.
2. $f_m = \frac{w_m}{2\pi} = \frac{20}{2\pi} = 3$ Hz.
3. The DSB-SC bandwidth is $2f_m = 6$ Hz.
4. The USB bandwidth = 3 Hz.

   The USB start at $f_c = 159$ Hz and extends to $(f_c + f_m) = 162$ Hz.
5. The LSB bandwidth = 3 Hz.

   The LSB start at $(f_c - f_m) = 156$ Hz and extends to $f_c = 159$ Hz.
6. $P_t = \frac{(E_m)^2}{4R} = \frac{100}{200} = 0.5$ W.

Example: A signal $m(t)$ is band-limited to a frequency range of $0 - 10\ KHz$. This frequency is translated by multiplying it by the signal $c(t) = cos(2\pi fct)$. Find fc so that the bandwidth of the translated signal is 1% of the frequency fc.

Solution:

Message Signal $m(t)$: Band-limited to a frequency range of $0 - 10\ kHz$.

Therefore, the bandwidth of $m(t) = 10\ kHz$.

The Bandwidth of the translated signal = $2f_m$

$BW = 2 \times 10k = 20kHz$

Thus,

$20k = 0.01 \times f_c$

$$f_c = \frac{20k}{0.01} = 2MHz$$

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