Communication Fundamentals

Modulation Process 2

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1

Content

- Introduction about the Topic.
- Define the Double Side Band Suppressed Carrier (DSB-SC).
- Describe the difference between the Upper Side Band and the Lower Side Band.
- Explain the Sidebands Calculation.
- Explain Sidebands and the Frequency Domain
- Explain Frequency-Domain Representation of AM
- Explain the Bandwidth of the AM signal
- Activities.

2

2

Introduction

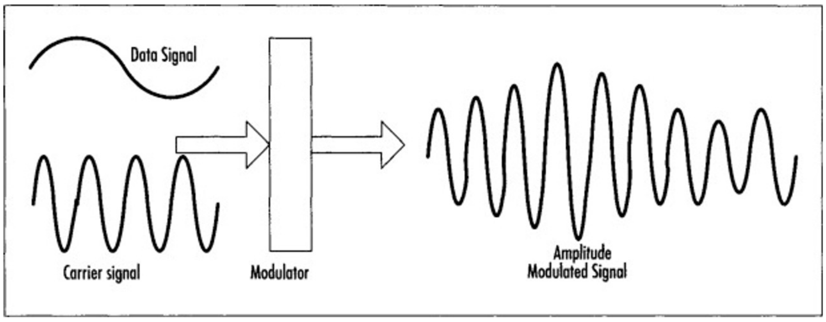
Electronic communication systems can be categorized by the types of information signals transmitted by the system.

- **There are two types of signal "Analog and Digital".**
- **An analog signal is a continuously varying signal, such as a sine wave tone. Voice and video signals are analog signals.**
- **A digital has only two distinct levels, high and low, digital TV signal or ON/OFF.**

3

3

Introduction Modulation



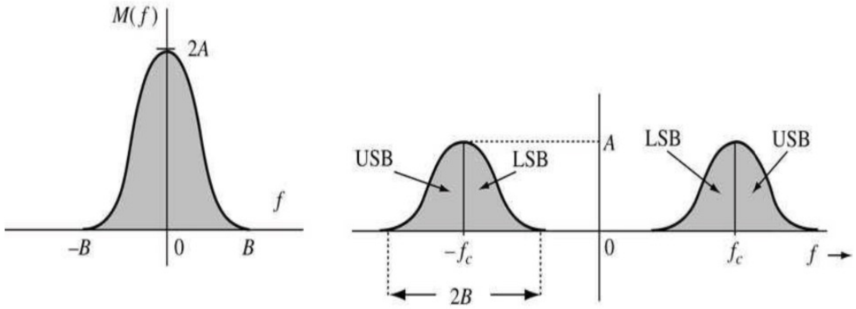
Modulation of AM and FM radio

4

4

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) .**



5

5

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:

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

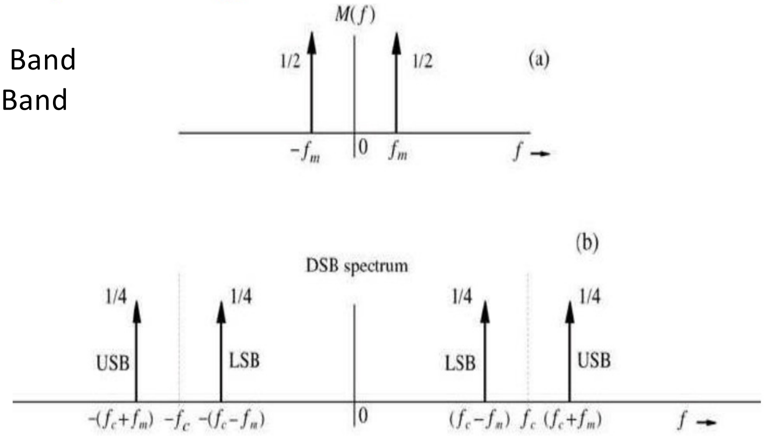
6

6

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



7

7

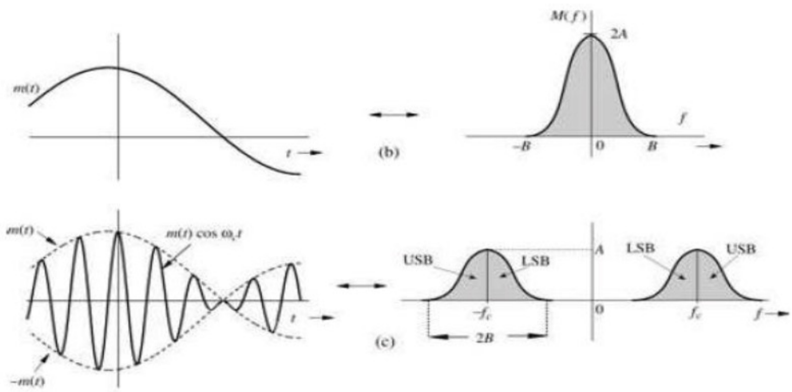
Modulator of Double Side Band Suppressed Carrier (DSB-SC)

Modulating Signal (Information) → **Modulator** → **Modulated Signal**

$\mathrm{m(t)}$

$\cos(\omega_c t)$ ↑ **Carrier Signal**

$\mathrm{m(t)} \cdot \cos(\omega_c t)$



8

8

Sidebands and the Frequency Domain

- Whenever a carrier is modulated by an information signal, new signals at different frequencies are generated as part of the process.
- These new frequencies, which are called Side Frequencies, or Sidebands, occur in the frequency spectrum directly above and directly below the carrier frequency.

9

9

Sidebands Calculation

- When only a single-frequency sine wave modulating signal is used, the modulation process generates two sidebands.
- The modulating signal is a complex wave, such as voice or video
- The upper sideband f_{USB} and lower sideband f_{LSB} are computed as:

$$f_{LSB} = f_c - f_m \qquad f_{USB} = f_c + f_m$$

f_c : The Carrier Frequency.

f_m : The Modulating Frequency.

10

10

Sidebands Calculation

For example, assume that a 400-Hz tone modulates a 300-kHz carrier. The upper and lower sidebands are

$$f_{USB} = f_c + f_m = 300{,}000 + 400 = 300{,}400 \text{ Hz or } 300.4 \text{ kHz}$$

$$f_{LSB} = f_c - f_m = 300{,}000 - 400 = 299{,}600 \text{ Hz or } 299.6 \text{ kHz}$$

11

11

Sidebands Calculation

The existence of sidebands can be demonstrated mathematically, starting with the equation for an AM signal described:

$$v_{AM} = V_c \cos \omega_c t + (V_m \cos \omega_m t) \cos \omega_c t$$

By using the trigonometric identity that says that the product of two cosine waves is:

$$\cos A \cos B = \frac{1}{2}[\cos(A - B) + \cos(A + B)]$$

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

$$= V_c \cos\omega_c t + \frac{V_m}{2}\cos 2\pi(f_c - f_m)t + \frac{V_m}{2}\cos 2\pi(f_c + f_m)t$$

12

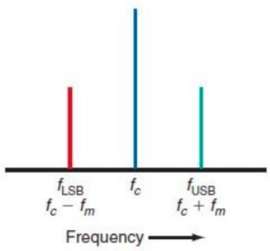
12

Frequency-Domain Representation of AM

Another method of showing the sideband signals is to plot the carrier and sideband amplitudes concerning frequency.

The signals may be voltage, current, or power amplitudes.

A plot of signal amplitude versus frequency is referred to as a frequency-domain display.
A test instrument is known as a spectrum analyser is used to display the frequency domain of a signal.



13

13

Bandwidth of AM signal

- The amount of space in the frequency spectrum required by the signal is called the BANDWIDTH of the signal.
- The bandwidth of a modulated wave is a function of the frequencies contained in the modulating signal.
- For example, when a 100-kilohertz carrier is modulated by a 5-kilohertz audio tone, sideband frequencies are created at 95 and 105 kilohertz. This signal requires 10 kilohertz of space in the spectrum.

$$B.W = f_{USB} - f_{LSB} \quad \text{Or} \quad B.W = 2 f_m$$

14

14

Example:

A standard AM broadcast station is allowed to transmit modulating frequencies up to 5 kHz. If the **AM station is transmitting** on a frequency of 980 kHz, compute the maximum and minimum upper and lower sidebands and the total bandwidth occupied by the AM station.

Solution :

$f_{USB} = f_c + f_m$ = 980 + 5 = 985 kHz

$f_{LSB} = f_c - f_m$ = 980 - 5 = 975 kHz

B.W = $f_{USB} - f_{LSB}$ = 985 - 975 = 10 kHz

B.W = **2** f_m = 2 * 5 = 10 kHz

15

15

Example:

An AM radio transmitter operating on 3.9 MHz is modulated by frequencies up to 4 kHz.
What are the maximum upper and lower side frequencies?
What is the total bandwidth of the AM signal?

Solution :

$f_{USB} = f_c + f_m$ =

$f_{LSB} = f_c - f_m$ =

B.W = $f_{USB} - f_{LSB}$ =

B.W = **2** f_m =

16

16

Example:

An AM radio transmitter operating on 3.9 MHz is modulated by frequencies up to 4 kHz.
What are the maximum upper and lower side frequencies?
What is the total bandwidth of the AM signal?

Solution :

$f_{USB} = f_c + f_m$ = 3900 kHz + 4 kHz = 3904 kHz or 3.904 MHz

$f_{LSB} = f_c - f_m$ = 3900 kHz - 4 kHz = 3896 kHz or 3.896 MHz

B.W = $f_{USB} - f_{LSB}$ = 3904 - 3896 = 8 KHz

B.W = **2** f_m = 2 * 4 = 8 KHz

17

17

Thank you …

18

18