Example 3–1

Suppose that on an AM signal, the $V_{\max(p-p)}$ value read from the graticule on the oscilloscope screen is 5.9 divisions and $V_{\min(p-p)}$ is 1.2 divisions.

a. What is the modulation index?

$$m\frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} = \frac{5.9 - 1.2}{5.9 + 1.2} = \frac{4.7}{7.1} = 0.662$$

b. Calculate V_c, V_m, and m if the vertical scale is 2 V per division. (*Hint:* Sketch the signal.)

$$V_c = \frac{V_{\max} + V_{\min}}{2} = \frac{5.9 + 1.2}{2} = \frac{7.1}{2} = 3.55 \ @ \ \frac{2\text{ V}}{\text{div}}$$

$$V_c = 3.55 \times 2\text{ V} = 7.1\text{ V}$$

$$V_m = \frac{V_{\max} - V_{\min}}{2} = \frac{5.9 - 1.2}{2} = \frac{4.7}{2}$$

$$= 2.35 \ @ \ \frac{2\text{ V}}{\text{div}}$$

$$V_m = 2.35 \times 2\text{ V} = 4.7\text{ V}$$

$$m = \frac{V_m}{V_c} = \frac{4.7}{7.1} = 0.662$$

3–3 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. More specifically, the sidebands occur at frequencies that are the sum and difference of the carrier and modulating frequencies. When signals of more than one frequency make up a waveform, it is often better to show the AM signal in the frequency domain rather than in the time domain.

Sideband

Sideband Calculations

When only a single-frequency sine wave modulating signal is used, the modulation process generates two sidebands. If the modulating signal is a complex wave, such as voice or video, a whole range of frequencies modulate the carrier, and thus a whole range of sidebands are generated.

The upper sideband f_{USB} and lower sideband f_{LSB} are computed as

$$f_{\text{USB}} = f_c + f_m \quad \text{and} \quad f_{\text{LSB}} = f_c - f_m$$

where f_c is the carrier frequency and f_m is the modulating frequency.

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

$$v_{\text{AM}} = V_c \sin 2\pi f_c t + (V_m \sin 2\pi f_m t)(\sin 2\pi f_c t)$$

Example 3-6

What is the power in one sideband of the transmitter in Example 3-4?

$$P_{SB} = m^2 \frac{P_c}{4} = \frac{(0.9)^2(921.6)}{4} = \frac{746.5}{4} = 186.6 \text{ W}$$

Despite its inefficiency, AM is still widely used because it is simple and effective. It is used in AM radio broadcasting, CB radio, TV broadcasting, and aircraft tower communication. Some simple control radios use ASK because of its simplicity. Examples are garage door openers and remote keyless entry devices on cars. AM is also widely used in combination with phase modulation to produce quadrature amplitude modulation (QAM) which facilitates high-speed data transmissions in modems, cable TV, and some wireless applications.

3-5 Single-Sideband Modulation

Single-sideband modulation

In amplitude modulation, two-thirds of the transmitted power is in the carrier, which itself conveys no information. The real information is contained within the sidebands. One way to improve the efficiency of amplitude modulation is to suppress the carrier and eliminate one sideband. The result is a single-sideband (SSB) signal. SSB is a form of AM that offers unique benefits in some types of electronic communication.

DSB Signals

Double-sideband suppressed carrier (DSSC or DSB)

The first step in generating an SSB signal is to suppress the carrier, leaving the upper and lower sidebands. This type of signal is referred to as a *double-sideband suppressed carrier (DSSC* or *DSB)* signal. The benefit, of course, is that no power is wasted on the carrier. Double-sideband suppressed carrier modulation is simply a special case of AM with no carrier.

A typical DSB signal is shown in Fig. 3-15. This signal, the algebraic sum of the two sinusoidal sidebands, is the signal produced when a carrier is modulated by a single-tone sine wave information signal. The carrier is suppressed, and the time-domain DSB signal is a sine wave at the carrier frequency, varying in amplitude as shown. Note that the envelope of this waveform is not the same as that of the modulating signal, as

Time-domain display

Figure 3-15 A time-domain display of a DSB AM signal.

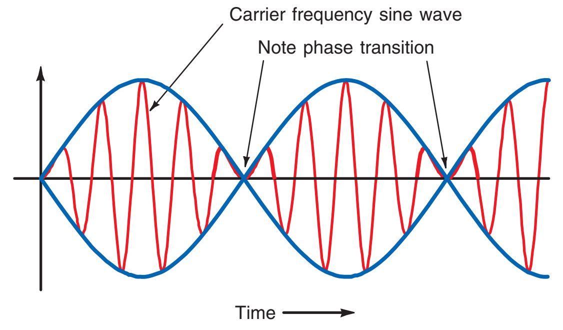
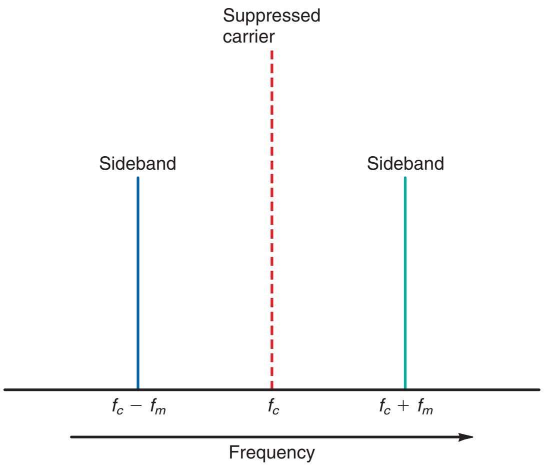


Figure 3-16 A frequency-domain display of DSB signal.



it is in a pure AM signal with carrier. A unique characteristic of the DSB signal is the phase transitions that occur at the lower-amplitude portions of the wave. In Fig. 3-15, note that there are two adjacent positive-going half-cycles at the null points in the wave. That is one way to tell from an oscilloscope display whether the signal shown is a true DSB signal.

Frequency-domain display

A *frequency-domain display* of a DSB signal is given in Fig. 3-16. As shown, the spectrum space occupied by a DSB signal is the same as that for a conventional AM signal.

Double-sideband suppressed carrier signals are generated by a circuit called a *balanced modulator.* The purpose of the balanced modulator is to produce the sum and difference frequencies but to cancel or balance out the carrier. Balanced modulators are covered in detail in Chap. 4.

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 (recover) at the receiver. One important application for DSB, however, is the transmission of the color information in a TV signal.

SSB Signals

Single-sideband suppressed carrier (SSSC or SSB)

In DSB transmission, since the sidebands are the sum and difference of the carrier and modulating signals, the information is contained in both sidebands. As it turns out, there is no reason to transmit both sidebands in order to convey the information. One sideband can be suppressed; the remaining sideband is called a *single-sideband suppressed carrier (SSSC* or *SSB)* signal. SSB signals offer four major benefits.

1. The primary benefit of an SSB signal is that the spectrum space it occupies is only one-half that of AM and DSB signals. This greatly conserves spectrum space and allows more signals to be transmitted in the same frequency range.
2. All the power previously devoted to the carrier and the other sideband can be channeled into the single sideband, producing a stronger signal that should carry farther and be more reliably received at greater distances. Alternatively, SSB transmitters can be made smaller and lighter than an equivalent AM or DSB transmitter because less circuitry and power are used.
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. An AM signal is really multiple signals, at least a carrier and two sidebands. These are on different

GOOD TO KNOW

Although eliminating the carrier in DSB AM saves a great deal of power, DSB is not widely used because the signal is difficult to demodulate at the receiver. DSB is, however, used to transmit the color information in a TV signal.

CHAPTER REVIEW

Summary

In amplitude modulation, an increase or a decrease in the amplitude of the modulating signal causes a corresponding increase or decrease in both the positive and the negative peaks of the carrier amplitude. Interconnecting the adjacent positive or negative peaks of the carrier waveform yields the shape of the modulating information signal, known as the envelope.

Using trigonometric functions, we can form mathematical expressions for the carrier and the modulating signal, and we combine these to create a formula for the complete modulated wave. Modulators (circuits that produce amplitude modulation) compute the product of the carrier and modulating signals.

The relationship between the amplitudes of the modulating signal and the carrier is expressed as the modulation index m, a number between 0 and 1. If the amplitude of the modulating voltage is higher than the carrier voltage $m > 1$, then distortion, or overmodulation, will result.

When a carrier is modulated by an information signal, new signals at different frequencies are generated. These side frequencies, or sidebands, occur in the frequency spectrum directly above and below the carrier frequency. An AM signal is a composite of several signal voltages, the carrier, and the two sidebands, each of which produces power in the antenna. Total transmitted power is the sum of the carrier power and the power in the two sidebands.

AM signals can be expressed through time-domain displays or frequency-domain displays.

In AM transmission, two-thirds of the transmitted power appears in the carrier, which itself conveys no information. One way to overcome this wasteful effect is to suppress the carrier. When the carrier is initially suppressed, both the upper and the lower sidebands are left, leaving a double-sideband suppressed (DSSC or DSB) signal. Because both sidebands are not necessary to transmit the desired information, one of the remaining sidebands can be suppressed, leaving a single-sideband (SSB) signal. SSB signals offer important benefits: they conserve spectrum space, produce strong signals, reduce noise, and result in less fading over long distances.

In SSB, the transmitter output is expressed as peak envelope power (PEP), the maximum power produced on voice amplitude peaks.

Both DSB and SSB techniques are widely used in communication. Two-way SSB communication is used in marine applications, in the military, and by hams. In some TV applications, to reduce the signal bandwidth to the 6-MHz maximum allowed by the FCC for TV signals, a vestigial sideband signal is used to suppress the lower sideband of the TV signal.

Questions

1. Define modulation.
2. Explain why modulation is necessary or desirable.
3. Name the circuit that causes one signal to modulate another, and give the names of the two signals applied to this circuit.
4. In AM, how does the carrier vary in accordance with the information signal?
5. True or false? The carrier frequency is usually lower than the modulating frequency.
6. What is the outline of the peaks of the carrier signal called, and what shape does it have?
7. What are voltages that vary over time called?
8. Write the trigonometric expression for a sine wave carrier signal.
9. True or false? The carrier frequency remains constant during AM.
10. What mathematical operation does an amplitude modulator perform?
11. What is the ideal relationship between the modulating signal voltage V_m and the carrier voltage V_c?
12. What is the modulation index called when it is expressed as a percentage?
13. Explain the effects of a modulation percentage greater than 100.
14. What is the name given to the new signals generated by the modulation process?
15. What is the name of the type of signal that is displayed on an oscilloscope?
16. What is the type of signal whose amplitude components are displayed with respect to frequency called, and on what instrument is this signal displayed?
17. Explain why complex nonsinusoidal and distorted signals produce a greater bandwidth AM signal than a simple sine wave signal of the same frequency.
18. What three signals can be added to give an AM wave?
19. What is the name given to an AM signal whose carrier is modulated by binary pulses?
20. What is the value of phasor representation of AM signals?
21. True or false? The modulating signal appears in the output spectrum of an AM signal.
22. What percentage of the total power in an AM signal is in the carrier? One sideband? Both sidebands?
23. Does the carrier of an AM signal contain any information? Explain.