Chapter 6 Objectives

At the conclusion of this chapter, the reader will be able to:

- Explain the advantages of SSB over conventional AM transmission.
- Describe the various types of SSB transmission.
- Explain the operation of circuits used to generate SSB signals.
- Given the block diagram of a SSB transmitter, describe the nature of the signal at each point in the circuit.
- Draw a block diagram of a SSB receiver.
- Explain how SSB signals are demodulated.
- Given the block diagram of a SSB transceiver, follow the signal flow for receive and transmit conditions.
- Describe typical troubleshooting procedures for SSB transceivers.

Chapter 6: Single Sideband Systems

AM is a widely used method of communication. AM transmitters are relatively simple, and AM receivers can be built very inexpensively with just a handful of components. Despite this, AM suffers from very poor efficiency. As was demonstrated in chapter 3, at best only 33% of the transmitted energy in an AM signal actually carries information (the sidebands). The remainder (about 67%) of the energy is used to transmit the *carrier frequency component*, which itself carries no information.

Furthermore, an AM signal contains two sidebands, each of which carry the same information. Having two sidebands causes the required transmitter bandwidth to be twice as wide as absolutely necessary.

By modifying the AM signal in various ways, we can get various types of *sideband* transmissions. Transmitters and receivers for sideband are more complex than their AM equivalents. However, there are situations where the added complexity is justified. Where many stations must share a limited range of frequency space, sideband techniques are useful since they can reduce bandwidth. Where voice communications must be carried out over a noisy path, sideband methods prove superior to AM and FM.

6-1 SSB Versus AM: Types of Sideband Signals

Figure 6-1 shows a typical AM signal, which can be thought of as a DSB-FC (double-sideband, full-carrier) signal.

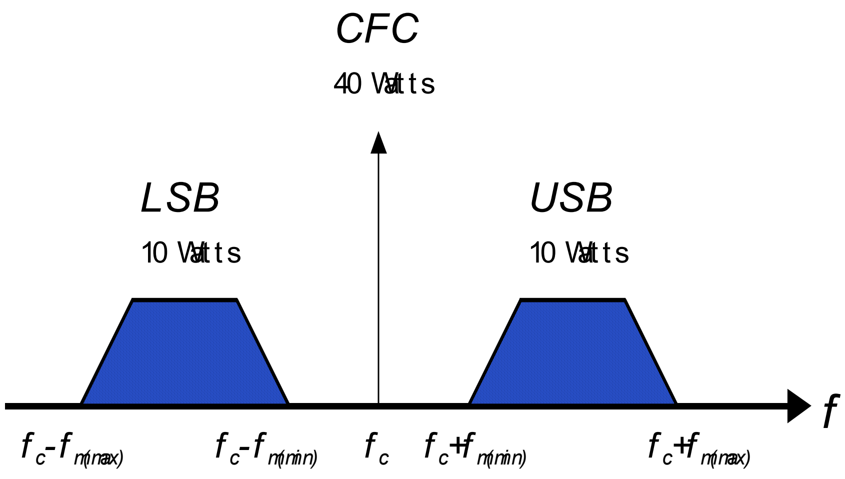

Figure 6-1: A conventional AM (DSB-FC) signal

A conventional AM signal consists of a *carrier frequency component* or *CFC*, a *lower sideband*, and an *upper sideband*. Notice how we have shown the sidebands as *ranges* of frequency, rather than individual frequencies. This is because a real information signal has a *range* of frequencies rather than just a single frequency.

The minimum and maximum information frequencies are marked as $f_{m(min)}$ and $f_{m(max)}$. Therefore, the bandwidth of a conventional AM signal can be expressed as:

6-1 $BW_{AM} = 2f_{m(\max)}$

The Minimum Bandwidth for Speech

In the 1960s, Bell Laboratories conducted research to determine the minimum range of frequencies needed for understandable voice communications. The research was important because the telephone companies were sending many different conversations at the same time through a single copper telephone wire. The technique of sending multiple pieces of information at the same time is called *multiplexing*. Each conversation would be assigned a different range of frequencies. If a certain amount of bandwidth were available on the wire, how many conversations could be sent at once? That would depend, of course, on the bandwidth required for each person's voice. Bell's research efforts demonstrated that most of the information power in human speech is contained in the frequency range 300 Hz to 3000 Hz. Frequencies below 300 Hz add bass "presence" to voice, but little intelligibility. Most of the energy above 3000 Hz is from the unvoiced speech sounds, such as *s*, *f*, and so on. *Therefore, most systems that are intended to send only human voice are designed to reproduce the frequency range 300 Hz [* $f_{m(min)}$ *] to 3000 Hz [* $f_{m(max)}$ *].*

Example 6-1

Speech is to be sent using an AM transmitter. The available carrier power is 40 watts, as in Figure 6-1. The transmitter is operating at 100% modulation.

a) What is the *total power?*

b) What is the power of the information?

c) What bandwidth will be needed?

Solution

a) The total power can be calculated as:

$$P_t = P_c(1+\frac{m^2}{2}) = 40W(1+\frac{1^2}{2}) = \underline{\underline{60 watts}}$$

The 60 watts is the total available power from the transmitter.

b) The sideband power is the same thing as the information power. Since the carrier power is 40 W, the *sideband* power will be:

$$P_{\inf o} = P_{side} = Pc\left(\frac{m^2}{2}\right) = 40W\left(\frac{1^2}{2}\right) = \underline{\underline{20 watts}}$$

Notice how the information power is only 33% of the total power being transmitted!

c) Sending speech requires a bandwidth from 300 Hz to 3000 Hz. The highest information frequency $f_{m(max)}$ is 3000 Hz. Therefore,

$$BW = 2f_{m(\max)} = 2(3000Hz) = \underline{\underline{6kHz}}$$

Note that the minimum information doesn't affect bandwidth at all in a conventional AM transmission.

DSB-SC Operation

The carrier frequency component (CFC) uses up most of the available transmitter power in a conventional AM transmission. By using a special circuit called a *balanced modulator*, we can produce an AM signal with sidebands but no CFC. Such a signal is called a *double-sideband suppressed-carrier* emission, and is pictured in Figure 6-2.

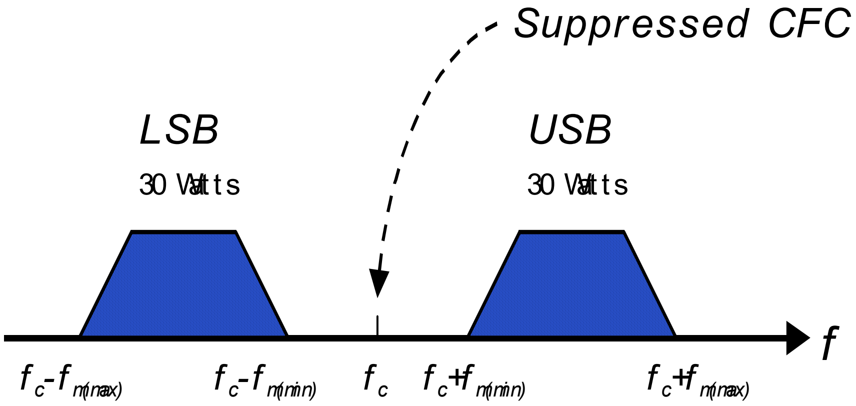

Figure 6-2: A DSB-SC signal

The carrier frequency component is *gone* from the signal above, but something else has happened. Closely compare Figures 6-1 and 6-2. The *sidebands* have suddenly grown in power! Why is this possible?

The total available power was 60 watts for the original AM signal of Figure 6-2. When we removed the 40 watt carrier, those 40 watts of power became available for transmitting information. Therefore, *all* of the transmitted power is information power -- a great improvement over conventional AM.

However, the resulting DSB-SC signal can no longer be properly demodulated by a diode AM detector. Without a carrier frequency component to act as a "reference" signal, a diode detector produces garbled information. Therefore, an oscillator circuit called a *beat frequency oscillator*, or *BFO*, must be added to the detector circuit to reinsert the missing carrier signal.

Since we are now transmitting additional information power, we say that we have gained a *decibel power advantage* over a conventional AM transmitter. The decibel power advantage can be computed as follows:

(6-2) **Decibel power advantage,** $dB = 10\log\left(\left\langle\frac{P_2}{P_1}\right\rangle\left\langle\frac{BW_1}{BW_2}\right\rangle^2\right)$

Where P_2 is the new information power, P_1 is the original information power, BW_2 is the new bandwidth, and BW_1 is the original bandwidth. Note that the squared bandwidth ratio takes into account the *combined* advantage for both the transmitter and receiver. The ratio of powers is *not* squared!

Example 6-2

If the total power of the transmission of Figure 6-2 is 60 watts (same as Figure 6-1), and again human speech is to be transmitted, calculate:

a) The bandwidth of the DSB-SC signal.

b) The decibel power advantage of the DSB-SC signal over the AM-FC signal.

Solution

a) As you can see from Figure 6-2, the bandwidth of the signal will remain unchanged, since we're still sending two sidebands. The bandwidth will therefore remain at (2)(3000 Hz) or <u>6 kHz.</u>

b) Equation 6-2 can be used to calculate the decibel advantage. The information power in the AM signal is 20 watts, and the information power in the DSB signal is 60 watts. There's no change in bandwidth between the two modes:

$$dB = 10\log\left(\left\langle\frac{P_2}{P_1}\right\rangle\left\langle\frac{BW_1}{BW_2}\right\rangle^2\right) = 10\log\left(\left\langle\frac{60W}{20W}\right\rangle\left\langle\frac{6KHz}{6KHz}\right\rangle^2\right) = \underline{\underline{+4.77dB}}$$

In other words, for the conventional AM transmitter to be as effective as the DSB-SC transmitter, the AM transmitter would have to be operating at a power level that is +4.77 dB (three times) stronger than the DSB unit. In other words, the *total* power level (Pt) of the AM transmitter would have to be *180 watts* to equal the information carrying capacity of the DSB-SC unit. This is a great power savings!

SSB-SC Operation

We can improve the efficiency of transmission even further by eliminating one of the redundant sidebands. It does not matter which one is removed; when the upper sideband is kept, we say that we're operating in *USB* mode; when the lower sideband is kept, we're in *LSB* mode. Most people simply refer to this mode as *SSB*; they assume that the carrier is suppressed.

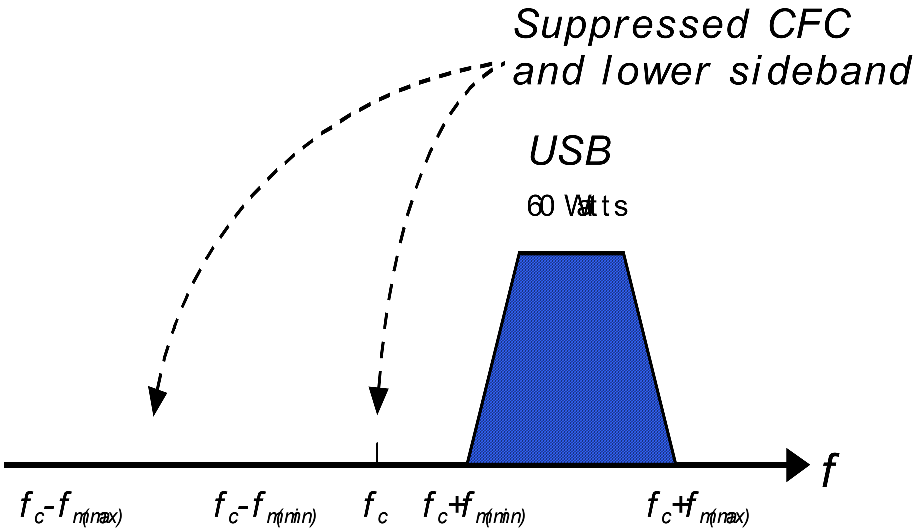

Figure 6-3: A SSB-SC signal in USB mode

A SSB signal has a bandwidth that is slightly less than *half* of a corresponding AM or DSB-SC signal. Look how the entire 60 watts is now concentrated in a much more narrow "slice" of spectrum. This characteristic gives a SSB transmitter much more "talk power" than an AM transmitter of the same power level!

Example 6-3

If the SSB signal of Figure 6-3 is sending a voice signal (300 Hz - 3 kHz), calculate:

a) The bandwidth

b) The decibel power advantage of the SSB signal over the AM signal of Figure 6-1.

c) The power level an AM transmitter would need in order to have equivalent performance.

Solution

a) Since we're only sending one sideband, equation 6-1 doesn't apply. Instead, we can fall back on the basic definition of bandwidth:

$$BW = f_{\max} - f_{\min}$$

In Figure 6-3, f_{min} is equal to $f_c + f_{m(min)}$, and f_{max} is equal to $f_c + f_{m(max)}$, so we can state:

$$BW = f_{\max} - f_{\min} = (f_c + f_{m(\max)}) - (f_c + f_{m(\min)}) = f_{m(\max)} - f_{m(\min)}$$
$$BW = f_{m(\max)} - f_{m(\min)} = 3000Hz - 300Hz = \underline{\underline{2.7KHz}}$$

Notice that the bandwidth is just slightly less than one half of the bandwidth required for an AM-FC transmission.

b) Equation 6-2 calculates decibel power advantage:

$$dB = 10\log\left(\left\langle\frac{P_2}{P_1}\right\rangle\left\langle\frac{BW_1}{BW_2}\right\rangle^2\right) = 10\log\left(\left\langle\frac{60W}{20W}\right\rangle\left\langle\frac{6KHz}{2.7KHz}\right\rangle^2\right) = \underline{\underline{+11.7dB}}$$

Note that we're not transmitting any additional information power; we're just packing the information into a smaller bandwidth "space."

c) The power ratio expressed by an 11.7 dB advantage can be found by simply expressing the terms inside the dB formula for power advantage:

$$G_p = \left\langle\frac{P_2}{P_1}\right\rangle\left\langle\frac{BW_1}{BW_2}\right\rangle^2 = \left\langle\frac{60W}{20W}\right\rangle\left\langle\frac{6KHz}{2.7KHz}\right\rangle^2 = \underline{\underline{14.8:1}}$$

The AM transmitter would need about 14.8 times the power of the SSB transmitter in order to have equivalent performance. That is a total power of (14.8)(60W) or 888 watts.

SSB is much more efficient than AM. In general, most people agree that there is better than a 10 dB (10:1) power advantage for SSB transmission over AM.

Vestigial Sideband (VSB) Mode

One of the disadvantages of DSB-SC and SSB transmission is that neither of these signals can be demodulated with a diode detector. A mode that combines the advantage of conventional AM with the reduced bandwidth requirements of SSB is called *vestigial sideband*, or *VSB*. A VSB signal is shown below in Figure 6-4:

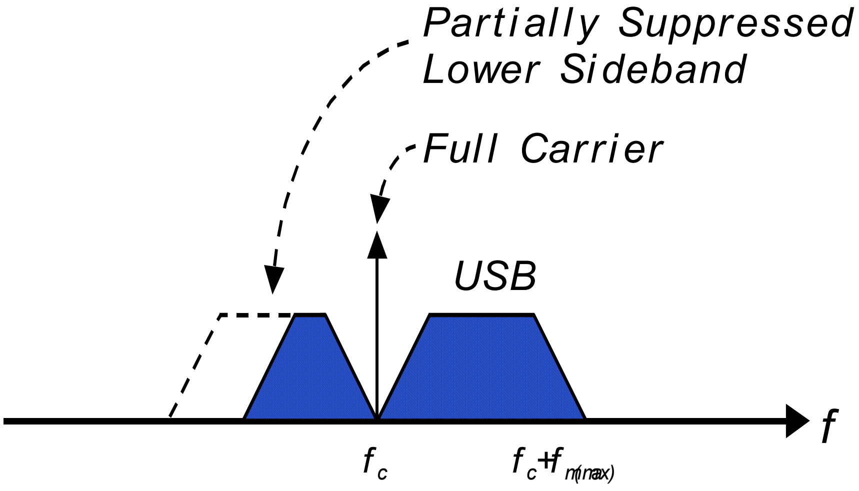

Figure 6-4: VSB operation (USB Mode)

In VSB, the carrier is left intact (thus allowing detection with a diode detector), and most of the lower sideband is filtered out. The resulting signal has a reduced bandwidth when compared to a conventional AM signal. Analog television uses VSB to transmit the