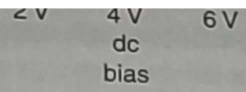

FIGURE 4-21 AM envelope for Example 4-7

4-5 AM TRANSMITTERS

4-5-1 Low-Level Transmitters

Figure 4-22 shows a block diagram for a low-level AM DSBFC transmitter. For voice or music transmission, the source of the modulating signal is generally an acoustical transducer, such as a microphone, a magnetic tape, a CD, or a phonograph record. The *preamplifier* is typically a sensitive, class A linear voltage amplifier with a high input impedance. The function of the preamplifier is to raise the amplitude of the source signal to a usable level while producing minimum nonlinear distortion and adding as little thermal noise as possible. The driver for the modulating signal is also a linear amplifier that simply amplifies the information signal to an adequate level to sufficiently drive the modulator. More than one drive amplifier may be required.

The RF *carrier oscillator* can be any of the oscillator configurations discussed in Chapter 3. The FCC has stringent requirements on transmitter accuracy and stability; therefore, crystal-controlled oscillators are the most common circuits used. The *buffer amplifier* is a low-gain, high-input impedance linear amplifier. Its function is to isolate the oscillator from the high-power amplifiers. The buffer provides a relatively constant load to the oscillator, which helps to reduce the occurrence and magnitude of short-term frequency variations. Emitter followers or integrated-circuit op-amps are often used for the buffer. The modulator can use either emitter or collector modulation. The intermediate and final power amplifiers are either linear class A or class B push–pull modulators. This is

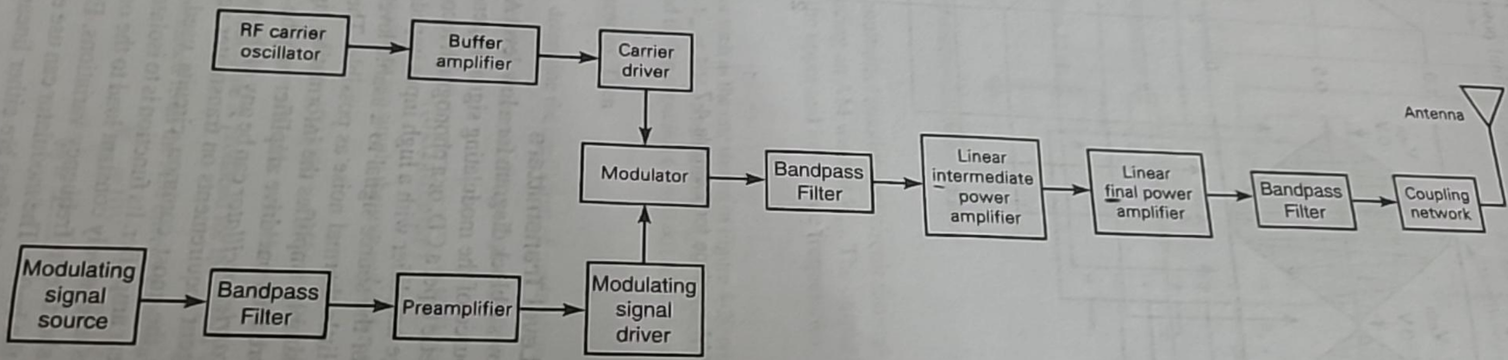

FIGURE 4-22 Block diagram of a low-level AM DSBFC transmitter

required with low-level transmitters to maintain symmetry in the AM envelope. The antenna coupling network matches the output impedance of the final power amplifier to the transmission line and antenna.

Low-level transmitters such as the one shown in Figure 4-22 are used predominantly for low-power, low-capacity systems, such as wireless intercoms, remote-control units, pagers, and short-range walkie-talkies.

5-3-2 Superheterodyne Receiver

The nonuniform selectivity of the TRF led to the development of the *superheterodyne receiver* near the end of World War I. Although the quality of the superheterodyne receiver has improved greatly since its original design, its basic configuration has not changed much, and it is still used today for a wide variety of radio communications services. The superheterodyne receiver has remained in use because its gain, selectivity, and sensitivity characteristics are superior to those of other receiver configurations.

Heterodyne means to mix two frequencies together in a nonlinear device or to translate one frequency to another using nonlinear mixing. A block diagram of a noncoherent superheterodyne receiver is shown in Figure 5-4. Essentially, there are five sections to a superheterodyne receiver: the RF section, the mixer/converter section, the IF section, the audio detector section, and the audio amplifier section.

5-3-2-1 RF section. The RF section generally consists of a preselector and an amplifier stage. They can be separate circuits or a single combined circuit. The preselector is a broad-tuned bandpass filter with an adjustable center frequency that is tuned to the desired carrier frequency. The primary purpose of the preselector is to provide enough initial bandlimiting to prevent a specific unwanted radio frequency, called the *image frequency*, from entering the receiver (image frequency is explained later in this section). The preselector also reduces the noise bandwidth of the receiver and provides the initial step toward reducing the overall receiver bandwidth to the minimum bandwidth required to pass the information signals. The RF amplifier determines the sensitivity of the receiver (i.e., sets the signal threshold). Also, because the RF amplifier is the first active device encountered by a received signal, it is the primary contributor of noise and, therefore, a predominant factor in determining the noise figure for the receiver. A receiver can have one or more RF amplifiers, or it may not have any, depending on the desired sensitivity. Several advantages of including RF amplifiers in a receiver are as follows:

1. Greater gain, thus better sensitivity
2. Improved image-frequency rejection
3. Better signal-to-noise ratio
4. Better selectivity

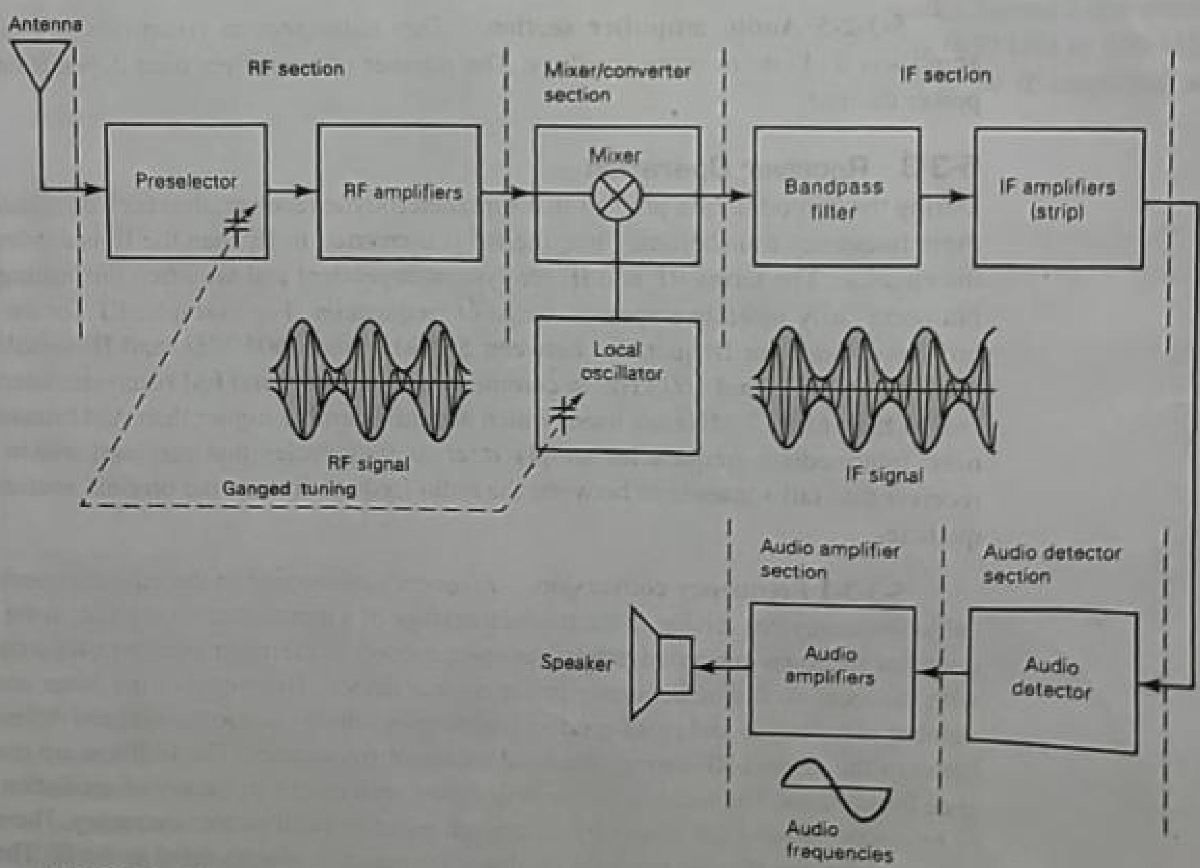

FIGURE 5-4 AM superheterodyne receiver block diagram

5-3-2-2 Mixer/converter section. The mixer/converter section includes a radio-frequency oscillator stage (commonly called a *local oscillator*) and a mixer/converter stage (commonly called the *first detector*). The local oscillator can be any of the oscillator circuits discussed in Chapter 2, depending on the stability and accuracy desired. The mixer stage is a nonlinear device and its purpose is to convert radio frequencies to intermediate frequencies (RF-to-IF frequency translation). Heterodyning takes place in the mixer stage, and radio frequencies are down-converted to intermediate frequencies. Although the carrier and sideband frequencies are translated from RF to IF, the shape of the envelope remains the same and, therefore, the original information contained in the envelope remains unchanged. It is important to note that although the carrier and upper and lower side frequencies change frequency, the bandwidth is unchanged by the heterodyning process. The most common intermediate frequency used in AM broadcast-band receivers is 455 kHz.

5-3-2-3 IF section. The IF section consists of a series of IF amplifiers and bandpass filters and is often called the *IF strip*. Most of the receiver gain and selectivity is achieved in the IF section. The IF center frequency and bandwidth are constant for all stations and are chosen so that their frequency is less than any of the RF signals to be received. The IF is always lower in frequency than the RF because it is easier and less expensive to construct high-gain, stable amplifiers for the low-frequency signals. Also, low-frequency IF amplifiers are less likely to oscillate than their RF counterparts. Therefore, it is not uncommon to see a receiver with five or six IF amplifiers and a single RF amplifier or possibly no RF amplification.

5-3-2-4 Detector section. The purpose of the detector section is to convert the IF signals back to the original source information. The detector is generally called an *audio detector* or the *second detector* in a broadcast-band receiver because the information signals are audio frequencies. The detector can be as simple as a single diode or as complex as a phase-locked loop or balanced demodulator.

5-3-2-5 Audio amplifier section. The audio section comprises several cascaded audio amplifiers and one or more speakers. The number of amplifiers used depends on the audio signal power desired.

5-3-3 Receiver Operation

During the demodulation process in a superheterodyne receiver, the received signals undergo two or more frequency translations: First, the RF is converted to IF, then the IF is converted to the source information. The terms RF and IF are system dependent and are often misleading because they do not necessarily indicate a specific range of frequencies. For example, RF for the commercial AM broadcast band are frequencies between 535 kHz and 1605 kHz, and IF signals are frequencies between 450 kHz and 460 kHz. In commercial broadcast-band FM receivers, intermediate frequencies as high as 10.7 MHz are used, which are considerably higher than AM broadcas[illegible] nals. Intermediate frequencies simply refer to frequencies that are used within a [illegible] receiver that fall somewhere between the radio frequencies and the original source in[illegible] quencies.

5-3-3-1 Frequency conversion. *Frequency conversion* in the mixer/converter stage is id[illegible] cal to frequency conversion in the modulator stage of a transmitter except that, in the receiver, t[illegible] quencies are down-converted rather than up-converted. In the mixer/converter, RF signals are com[illegible] with the local oscillator frequency in a nonlinear device. The output of the mixer contains an infi[illegible] number of harmonic and cross-product frequencies, which include the sum and difference frequencies between the desired RF carrier and local oscillator frequencies. The IF filters are tuned to the differ-

4-3 AM MODULATING CIRCUITS

The location in a transmitter where modulation occurs determines whether the circuit is a *low-* or a *high-level transmitter.* With low-level modulation, the modulation takes place prior to the output element of the final stage of the transmitter, in other words, prior to the collector of the output transistor in a transistorized transmitter, prior to the drain of the output FET in a FET transmitter, or prior to the plate of the output tube in a vacuum-tube transmitter.

An advantage of low-level modulation is that less modulating signal power is required to achieve a high percentage of modulation. In high-level modulators, the modulation takes place in the final element of the final stage where the carrier signal is at its maximum amplitude and, thus, requires a much higher amplitude modulating signal to achieve a reasonable percent modulation. With high-level modulation, the final modulating signal amplifier must supply all the sideband power, which could be as much as 33% of the total transmit power. An obvious disadvantage of low-level modulation is in high-power applications when all the amplifiers that follow the modulator stage must be linear amplifiers, which is extremely inefficient.

4-3-1 Low-Level AM Modulator

A small signal, class A amplifier, such as the one shown in Figure 4-14a, can be used to perform amplitude modulation; however, the amplifier must have two inputs: one for the carrier signal and the second for the modulating signal. With no modulating signal present, the circuit operates as a linear class A amplifier, and the output is simply the carrier amplified by the quiescent voltage gain. However, when a modulating signal is applied, the amplifier operates nonlinearly, and signal multiplication as described by Equation 4-10 occurs. In Figure 4-14a, the carrier is applied to the base and the modulating signal to the emitter. Therefore, this circuit configuration is called *emitter modulation.* The modulating signal varies the gain of the amplifier at a sinusoidal rate equal to the frequency of the modulating signal. The depth of modulation achieved is proportional to

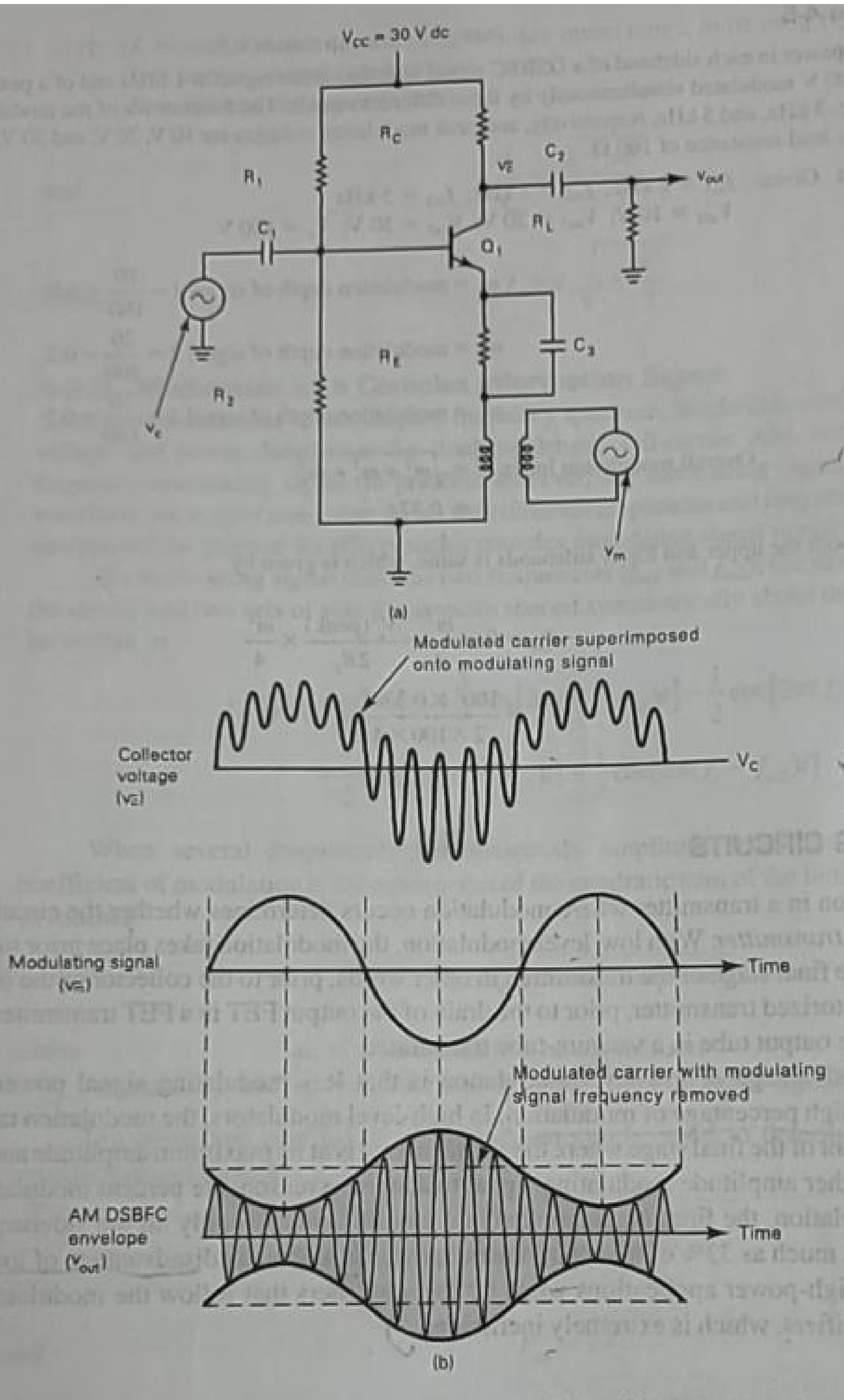

FIGURE 4-14 (a) Single transistor, emitter modulator; (b) output waveforms

the amplitude of the modulating signal. The voltage gain for an emitter modulator is expressed mathematically as

$$A_v = A_q\,[1 + m \sin(2\pi f_m t)] \tag{4-34}$$

where A_v = amplifier voltage gain with modulation (unitless)
A_q = amplifier quiescent (without modulation) voltage gain (unitless)

Sin($2\pi f_m t$) goes from a maximum value of +1 to a minimum value of −1. Thus, Equation 4-35 reduces to

$$A_v = A_q(1 \pm m) \tag{4-35}$$

where m equals the modulation coefficient. At 100% modulation, m = 1, and Equation 4-35 reduces to

$$A_{v(\max)} = 2A_q$$
$$A_{v(\min)} = 0$$

Figure 4-14b shows the waveforms for the circuit shown in Figure 4-14a. The modulating signal is applied through isolation transformer T_1 to the emitter of Q_1, and the carrier is applied directly to the base. The modulating signal drives the circuit into both saturation and cutoff, thus producing the nonlinear amplification necessary for modulation to occur. The collector waveform includes the carrier and the upper and lower side frequencies as well as a component at the modulating signal frequency. Coupling capacitor C_2 removes the modulating signal frequency from the AM waveform, thus producing a symmetrical AM envelope at V_{out}.

With emitter modulation, the amplitude of the output signal depends on the amplitude of the input carrier and the voltage gain of the amplifier. The coefficient of modulation depends entirely on the amplitude of the modulating signal. The primary disadvantage of emitter modulation is the amplifier operates class A, which is extremely inefficient. Emitter modulators are also incapable of producing high-power output waveforms.

Example 4-6

For a low-level AM modulator similar to the one shown in Figure 4-14 with a modulation coefficient m = 0.8, a quiescent voltage gain A_q = 100, an input carrier frequency f_c = 500 kHz with an amplitude V_c = 5 mV, and a 1000-Hz modulating signal, determine

a. Maximum and minimum voltage gains.
b. Maximum and minimum amplitudes for V_{out}. Then
c. Sketch the output AM envelope.

Solution a. Substituting into Equation 4-34,

$$A_{\max} = 100(1 + 0.8) = 180$$
$$A_{\min} = 100(1 - 0.8) = 20$$

b.

$$V_{out(\max)} = 180(0.005) = 0.9\ \text{V}$$
$$V_{out(\min)} = 20(0.005) = 0.1\ \text{V}$$

c. The AM envelope is shown in Figure 4-15.

4-3-2 Medium-Power AM Modulator

Early medium- and high-power AM transmitters were limited to those that used vacuum tubes for the active devices. However, since the mid-1970s, solid-state transmitters have been available with output powers as high as several thousand watts. This is accomplished by placing several final power amplifiers in parallel such that their output signals combine in phase and are, thus, additive.

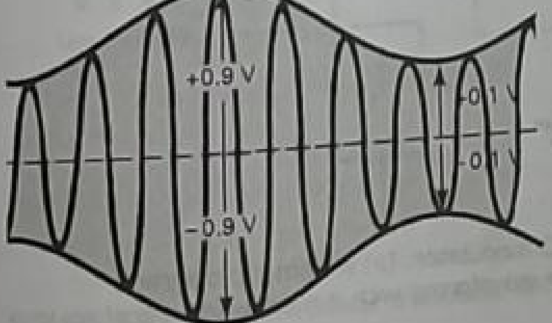

FIGURE 4-15 AM envelope for Example 4-6