EXAMPLE 3-3 A broadcast radio transmitter radiates 10 kilowatts (10 kW) when the modulation percentage is 60. How much of this is carrier power?

SOLUTION

$$P_c = \frac{P_t}{1 + m^2/2} = \frac{10}{1 + 0.6^2/2} = \frac{10}{1.18} = 8.47 \text{ kW}$$

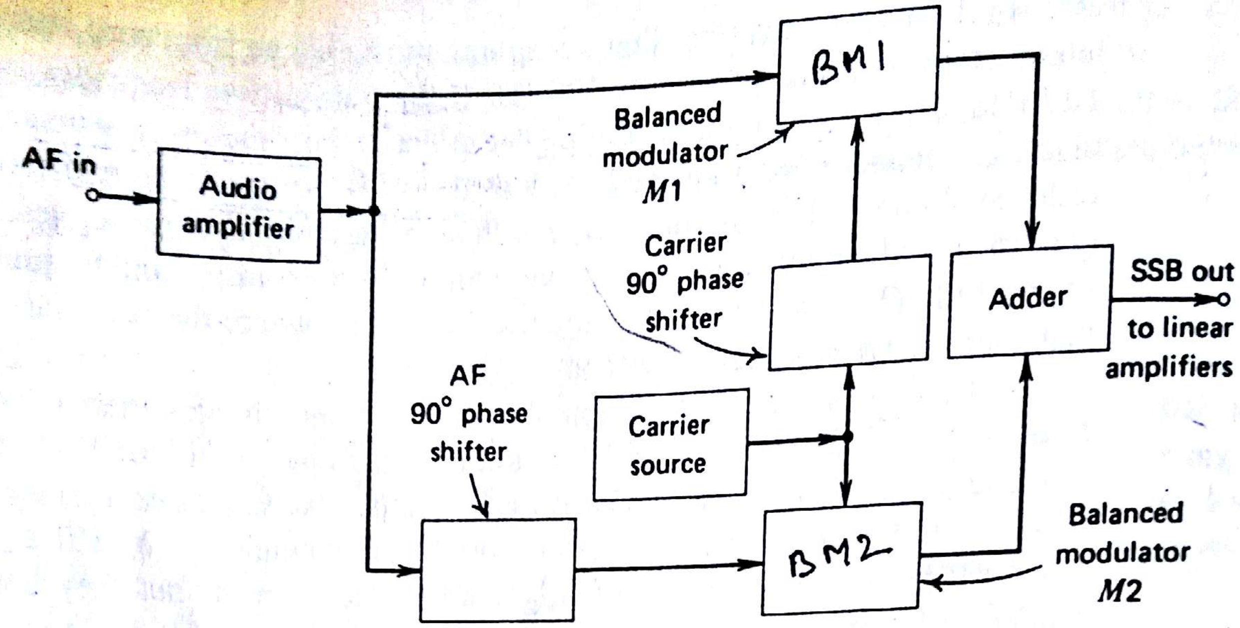

FIGURE 4-5 Single sideband by phase shift.

voltage (shifted through 90°) and the carrier voltage. Sometimes the modulating voltage phase shift is arranged slightly differently. It is made +45° for one of the balanced modulators and −45° for the other, but the result is the same.

Both modulators produce an output consisting only of sidebands. It will be shown that both upper sidebands lead the input carrier voltage by 90°. One of the lower sidebands leads the reference voltage by 90°, and the other lags it by 90°. The two lower sidebands are thus out of phase, and when combined in the adder, they cancel each other. The upper sidebands are in phase at the adder and therefore add, giving SSB in which the lower sideband has been canceled. The previous statements may be proved as follows.

If it is taken for granted that the two balanced modulators are also balanced with respect to each other, then amplitudes may be ignored as they do not affect the result. Note also that both balanced modulators are fed from the same sources. As before, taking $\sin \omega_c t$ as the carrier and $\sin \omega_m t$ as the modulation, we see that the balanced modulator M_1 will receive $\sin \omega_m t$ and $\sin(\omega_c t + 90°)$, whereas M_2 takes $\sin(\omega_m t + 90°)$ and $\sin \omega_c t$. Following the reasoning in the proof of the balanced modulator, we know that the output of M_1 will contain sum and difference frequencies. Thus

$$v_1 = \cos[(\omega_c t + 90°) - \omega_m t] - \cos[(\omega_c t + 90°) + \omega_m t]$$ from eqn 4.1

$$= \underbrace{\cos(\omega_c t - \omega_m t + 90°)}_{\text{(LSB)}} - \underbrace{\cos(\omega_c t + \omega_m t + 90°)}_{\text{(USB)}} \tag{4-14}$$

Similarly, the output of M_2 will contain

$$v_2 = \cos[\omega_c t - (\omega_m t + 90°)] - \cos[\omega_c t + (\omega_m t + 90°)]$$

$$= \cos(\omega_c t - \omega_m t - 90°) - \cos(\omega_c t + \omega_m t + 90°) \tag{4-15}$$

The output of the adder is

$$v_o = v_1 + v_2 = 2\cos(\omega_c t + \omega_m t + 90°) \tag{4-16}$$

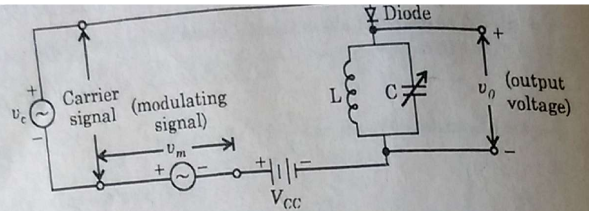

Fig. 3.9. Square-low diode modulation.

It may be observed from the figure (3.9), that carrier and modulating signals are applied across the diode. A *d.c.* battery V_{cc} is connected across the diode to get a fixed operating point on the v–i characteristics of diode. The working of this circuit may be explained by considering the fact when two different frequencies are passed through a non-linear device, the process of amplitude modulation takes place. Hence when carrier and modulating frequencies are applied at the input of diode, then different frequency terms appear at the output of diode. These different frequency terms are applied across a tuned circuit which is tuned to the carrier frequency and has a narrow bandwidth just to pass two sidebands alongwith the carrier and reject other frequencies. Hence at the output of tuned circuit, carrier and two sidebands are obtained *i.e.*, Amplitude Modulated (*AM*) wave is produced.

Mathematical Analysis

Let us consider that carrier voltage is expressed as

$$v_c = V_c \cos\omega_c t \qquad ...(3.55)$$

where ω_c is the carrier frequency.

Let the modulating voltage be expressed as

$$v_m = V_m \cos\omega_m t \qquad ...(3.56)$$

Where w_m is the modulating frequency.

The total *a.c.* voltage across the diode is given as

$$v_s = v_c + v_m \qquad ...(3.57)$$

$$v_s = V_c \cos\omega_c t + V_m \cos\omega_m t \qquad ...(3.58)$$

The non-linear relationship between voltage and current for a diode is expressed as

$$i = a + bv_s + cv_s^2 \qquad ...(3.59)$$

where a, b, and c are constants

i = current through the diode

v_s = voltage across the diode

Putting the value of v_s from equation (3.58) in equation (3.59), we get

$$i = a + bv_s + cv_s^2 = a + b\,(V_c \cos\omega_c t + V_m \cos\omega_m t) + c(V_c \cos\omega_c t + V_m \cos\omega_m t)^2$$

or $$i = a + bV_c \cos\omega_c t + bV_m \cos\omega_m t + c(V_c^2 \cos^2\omega_c t + V_m^2 \cos^2\omega_m t + 2V_c V_m \cos\omega_c t \cos\omega_m t)$$

or $$i = a + bV_c \cos\omega_c t + bV_m \cos\omega_m t + cV_c^2 \cos^2\omega_c t + cV_m^2 \cos^2\omega_m t + 2c.V_c.V_m \cos\omega_c t \cos\omega_m t$$

or $$i = a + bV_c \cos\omega_c t + bV_m \cos\omega_m t + \frac{1}{2} cV_c^2 (2\cos^2\omega_c t) + \frac{1}{2} cV_m^2 (2\cos^2\omega_m t) + cV_c V_m (2 \cos\omega_c t \cos\omega_m t)$$

(1+cos2ω_c t) pg. 909

or $$i = a + bVc \cos\omega_c t + bV_m \cos\omega_m t + \frac{1}{2} cV_c^2 (1 + \cos^2\omega_c t) + \frac{1}{2} cV_m^2 (1 + \cos^2\omega_m t) + cV_c V_m [\cos(\omega_c + \omega_m) t + \cos(\omega_c - \omega_m)t]$$

(cos2ω_m t)

cos2ω_c t

or $$i = a + bV_c \cos\omega_c t + bV_m \cos\omega_m t + \frac{1}{2} cV_c^2 + \frac{1}{2} cV_c^2 \cos^2\omega_c t + \frac{1}{2} cV_m^2 + \frac{1}{2} cV_m^2 \cos 2\omega_m t + cV_c V_m \cos(\omega_c+\omega_m)t + cV_c V_m \cos(\omega_c - \omega_m)t$$

or $$i = \underbrace{\left(a + \frac{1}{2}cV_c^2 + \frac{1}{2}cV_m^2\right)}_{(1)} + \underbrace{bV_c \cos\omega_c t}_{(2)} + \underbrace{bV_m \cos\omega_m t}_{(3)} + \underbrace{\left(\frac{1}{2}cV_c^2 \cos 2wct + \frac{1}{2}cV_m^2 \cos 2wmt\right)}_{(4)} + \underbrace{cV_c V_m \cos(\omega_c+\omega_m)t}_{(5)} + \underbrace{cV_c V_m \cos(\omega_c - \omega_m)t}_{(6)} \qquad ...(3.60)$$

Equation (3.60), consists of six terms in all as follow :

term (1) is the *d.c.* term

term (2) is the carrier signal

term (3) is the modulating signal

term (4) consists of harmonics of carrier and modulating signals

term (5) represents the upper sideband

term (6) represents the lower sideband

As discussed earlier, in the diode modulation circuit, the load impedance is a tuned circuit which is tuned to the carrier frequency ω_c. Therefore, this tuned circuit responds to a narrow band of frequencies centred about the carrier frequency ω_c. Thus the frequency components which are actually developed in the output are terms of frequency ω_c, $(\omega_c + \omega_m)$ and $(\omega_c - \omega_m)$. The rest of the frequency components are rejected by the tuned circuit.

Therefore, the required expression of output current will be

$$i_0 = bV_c \cos\omega_c t + c\,V_c V_m \cos(\omega_c + \omega_m)t + cV_c V_m \cos(\omega_c - \omega_m)t$$

or $$i_0 = bV_c \cos\omega_c t + cV_c. V_m[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$$

or $$i_0 = bV_c \cos\omega_c t + 2\,cV_c V_m \cos\omega_c t \cos\omega_m t$$

or $$i_0 = bV_c \left(1 + \frac{2cV_m}{b} \cos\omega_m t\right) \cos\omega_c t$$

$$i_0 = bV_c (1 + m_a \cos\omega_m t) \cos\omega_c t \qquad ...(3.61)$$

where $m_a = \dfrac{2cV_m}{b}$ is the modulation index. Equation (3.61) is the required expression for AM current.

3.12. Collector Modulation Method

Collector modulation method is a very popular method for AM generation. Figure 3.10 illustrates the circuit diagram of a collector modulation method. Here, the transistor T_1 makes a radio frequency (*RF*) class-C amplifier. At the base of T_1, the carrier signal is applied. V_{cc} makes the collector supply used for biasing purpose. Also, the transistor T_2 makes a class-B amplifier which is used to amplify the audio or modulating signal. The baseband or modulating signal appears across the modulation transformer after amplification. This amplified baseband or modu-

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Subject-Principle of Communication

Attempt all questions. **MM: 20**

(1) Generate the AM wave using Square Law diode modulation method. **(7)**

(2) A broadcast radio transmitter radiates 10 Kw when the percentage of modulation is 60. How much of this is carrier power? **(6)**

(3) Explain the Phase-shift method to generate the SSB-SC signals. **(7)**