

8.1 Binary Phase Shift Keying (BPSK)

In binary phase shift keying (BPSK), binary symbol '1' and '0' modulate the phase of the carrier. Let the carrier be,

$$s(t) = A \cos(2\pi f_0 t) \quad \dots (8.1.1)$$

'A' represents peak value of sinusoidal carrier. In the standard 1Ω load register, the power dissipated will be,

$$P = \frac{1}{2} A^2$$

$$A = \sqrt{2P} \quad \dots (8.1.2)$$

$\therefore$ When the symbol is changed, then the phase of the carrier is changed by 180 degrees (π radians).

Consider for example,

$$\text{Symbol '1'} \Rightarrow s_1(t) = \sqrt{2P} \cos(2\pi f_0 t) \quad \dots (8.1.3)$$

if next symbol is '0' then,

$$\text{Symbol '0'} \Rightarrow s_2(t) = \sqrt{2P} \cos(2\pi f_0 t + \pi) \quad \dots (8.1.4)$$

Since $\cos(\theta + \pi) = -\cos \theta$, we can write above equation as,

$$s_2(t) = -\sqrt{2P} \cos(2\pi f_0 t) \quad \dots (8.1.5)$$

With the above equation we can define BPSK signal combinely as,

$$s(t) = b(t) \sqrt{2P} \cos(2\pi f_0 t) \quad \dots (8.1.6)$$

Here

$$b(t) = +1 \text{ when binary '1' is to be transmitted} \\ = -1 \text{ when binary '0' is to be transmitted}$$

Fig. 8.1.1 shows binary signal and its equivalent signal $b(t)$. (See Fig. 8.1.1 on next page.)

As can be seen from Fig. 8.1.1 (b), the signal $b(t)$ is NRZ bipolar signal. This signal directly modulates carrier $\cos(2\pi f_0 t)$.

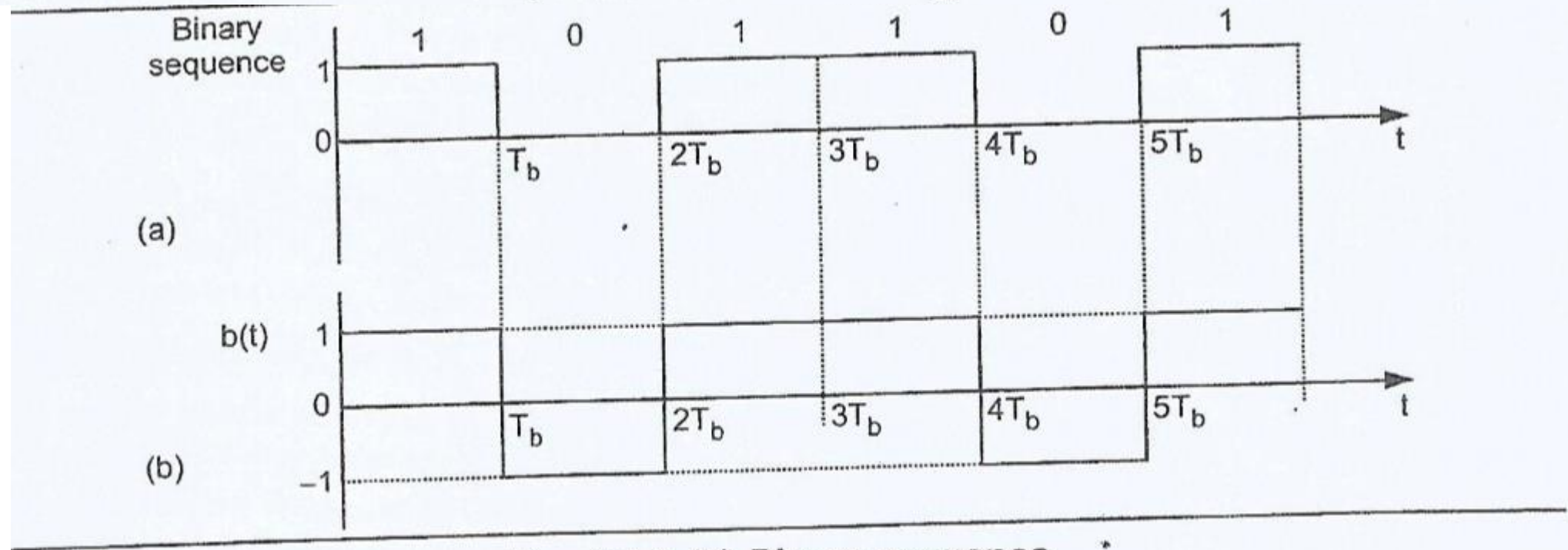


Fig. 8.1.1 (a) Binary sequence
(b) Its equivalent bipolar signal $b(t)$

8.1.1 Generation and Reception of BPSK Signal

8.1.1.1 Generator of BPSK Signal

The BPSK signal can be generated by applying carrier signal to the balanced modulator. The baseband signal $b(t)$ is applied as a modulating signal to the balanced modulator. Fig. 8.1.2 shows the block diagram of BPSK signal generator.

The NRZ level encoder converts the binary data sequence into bipolar NRZ signal.

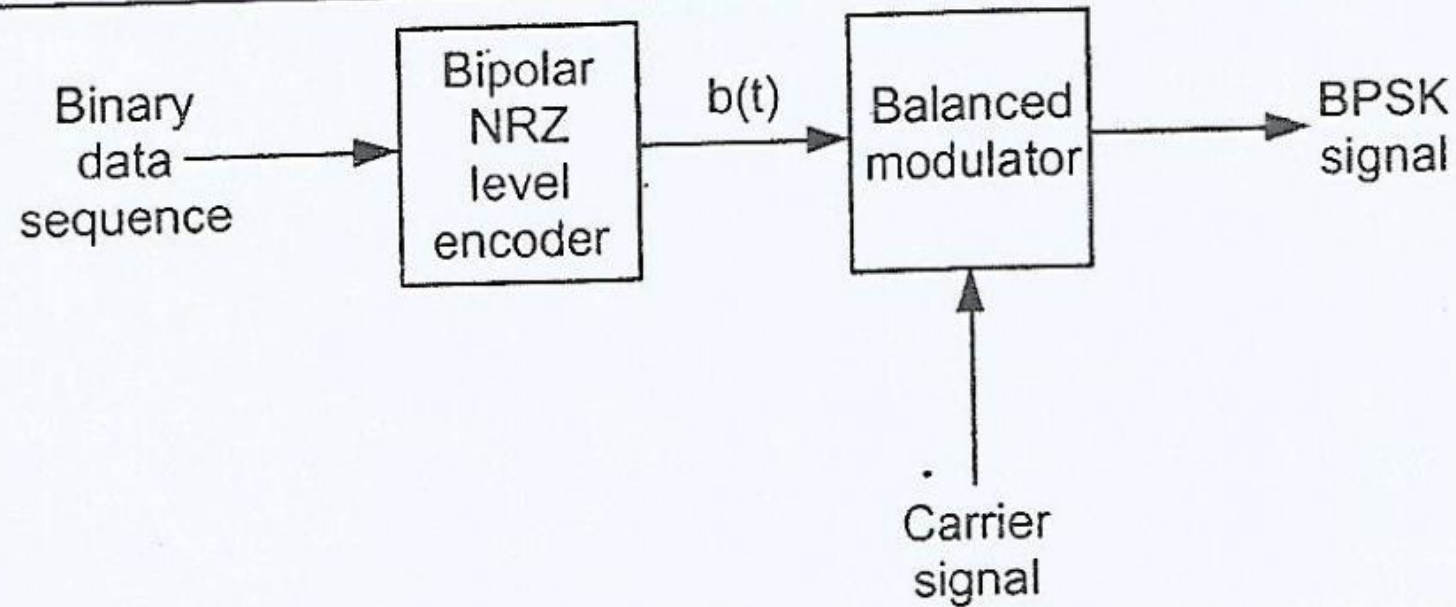


Fig. 8.1.2 BPSK generation scheme

8.1.1.2 Reception of BPSK Signal

Fig. 8.1.3 shows the block diagram of the scheme to recover baseband signal from BPSK signal. The transmitted BPSK signal is,

$$s(t) = b(t) \sqrt{2P} \cos(2\pi f_0 t)$$

This signal undergoes the phase change depending upon the time delay from transmitter to receiver. This phase change is normally fixed phase shift in the transmitted signal. Let the phase shift be θ . Therefore the signal at the input of the receiver is,

$$s(t) = b(t) \sqrt{2P} \cos(2\pi f_0 t + \theta) \quad \dots (8.1.7)$$

Now from this received signal, a carrier is separated since this is coherent detection. As shown in the figure, the received signal is passed through a square law device. At the output of the square law device the signal will be,

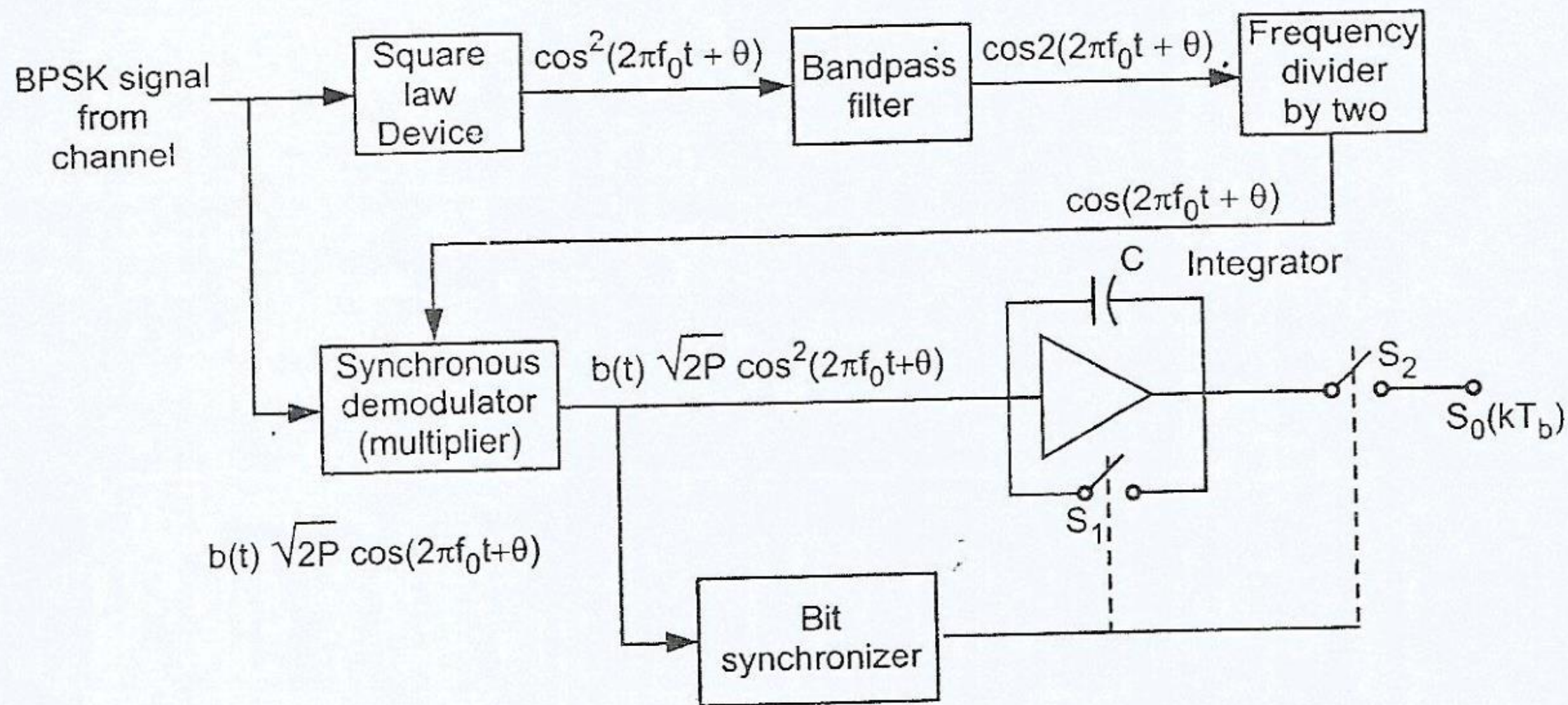


Fig. 8.1.3 Reception BPSK scheme

$$\cos^2 (2\pi f_0 t + \theta)$$

Note here that we have neglected the amplitude, because we are only interested in the carrier of the signal.

We know that,

$$\cos^2 \theta = \frac{1 + \cos 2\theta}{2}$$

$$\therefore \cos^2 (2\pi f_0 t + \theta) = \frac{1 + \cos 2(2\pi f_0 t + \theta)}{2}$$

$$\text{or} \quad = \frac{1}{2} + \frac{1}{2} \cos 2(2\pi f_0 t + \theta)$$

Here $\frac{1}{2}$ represents a DC level. This signal is then passed through a bandpass filter whose passband is centered around $2f_0$. Bandpass filter removes the DC level of $\frac{1}{2}$ and at its output we get,

$$\cos 2(2\pi f_0 t + \theta)$$

$$\cos 2(2\pi f_0 t + \theta)$$

This signal is of frequency $2f_0$. Hence it is passed through a frequency divider by two. Therefore at the output of frequency divider we get a carrier signal whose frequency is f_0 i.e. $\cos(2\pi f_0 t + \theta)$.

The synchronous (coherent) demodulator multiplies the input signal and the recovered carrier. Therefore at the output of multiplier we get,

$$\begin{aligned} b(t) \sqrt{2P} \cos(2\pi f_0 t + \theta) \times \cos(2\pi f_0 t + \theta) &= b(t) \sqrt{2P} \cos^2(2\pi f_0 t + \theta) \\ &= b(t) \sqrt{2P} \times \frac{1}{2} [1 + \cos 2(2\pi f_0 t + \theta)] \end{aligned}$$

$$= b(t) \sqrt{\frac{P}{2}} [1 + \cos 2(2\pi f_0 t + \theta)] \quad \dots (8.1.8)$$

The above signal is then applied to the bit synchronizer and integrator. The integrator integrates the signal over one bit period. The bit synchronizer takes care of starting and ending times of a bit. At the end of bit duration T_b , the bit synchronizer closes switch S_2 temporarily. This connects the output of an integrator to the decision device. It is equivalent to sampling the output of integrator. The synchronizer then opens switch S_2 and switch S_1 is closed temporarily. This resets the integrator voltage to zero. The integrator then integrates next bit. Let us assume that one bit period ' T_b ' contains integral number of cycles of the carrier. That is the phase change occurs in the carrier only at zero crossing. This is shown in Fig. 8.1.4. Thus BPSK waveform has full cycles of sinusoidal carrier.

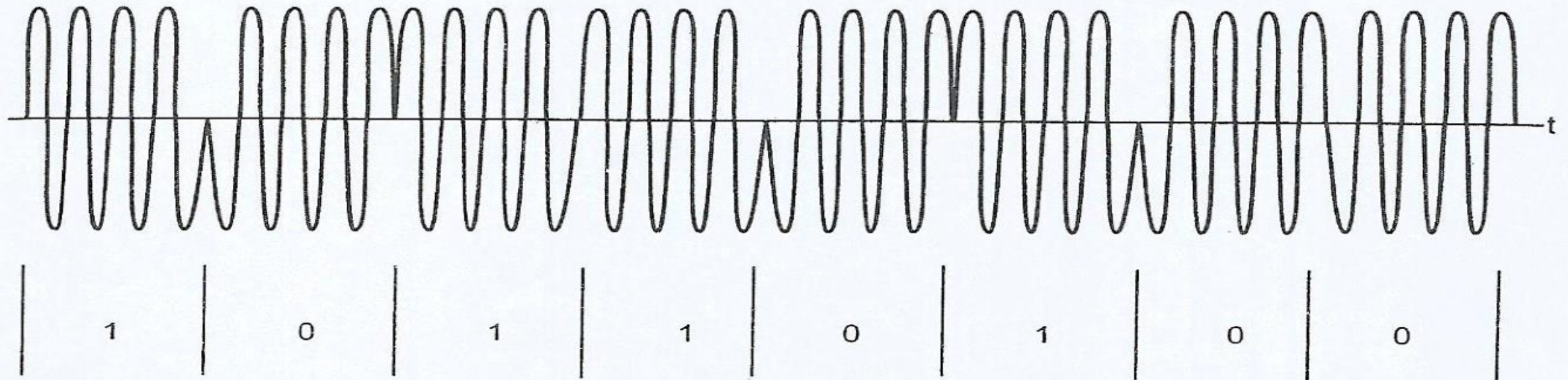


Fig. 8.1.4 BPSK waveform

In the k^{th} bit interval we can write output signal as,

$$s_o(k T_b) = b(k T_b) \sqrt{\frac{P}{2}} \int_{(k-1) T_b}^{k T_b} [1 + \cos 2(2\pi f_0 t + \theta)] dt$$

from equation 8.1.8

The above equation gives the output of an interval for k^{th} bit. Therefore integration is performed from $(k-1) T_b$ to $k T_b$. Here T_b is the one bit period. We can write the above equation as,

$$s_o(k T_b) = b(k T_b) \sqrt{\frac{P}{2}} \left[\int_{(k-1) T_b}^{k T_b} 1 dt + \int_{(k-1) T_b}^{k T_b} \cos 2(2\pi f_0 t + \theta) dt \right]$$

Here $\int_{(k-1) T_b}^{k T_b} \cos 2(2\pi f_0 t + \theta) dt = 0$, because average value of sinusoidal waveform is

zero if integration is performed over full cycles. Therefore we can write above equation as,

$$\begin{aligned}
 s_o(k T_b) &= b(k T_b) \sqrt{\frac{P}{2}} \int_{(k-1) T_b}^{k T_b} 1 dt \\
 &= b(k T_b) \sqrt{\frac{P}{2}} [t]_{(k-1) T_b}^{k T_b} \\
 &= b(k T_b) \sqrt{\frac{P}{2}} \{k T_b - (k-1) T_b\}
 \end{aligned}$$

$$\therefore s_o(k T_b) = b(k T_b) \sqrt{\frac{P}{2}} T_b \quad \dots (8.1.9)$$

This equation shows that the output of the receiver depends on input i.e.

$$s_o(k T_b) \propto b(k T_b)$$

Depending upon the value of $b(k T_b)$, the output $s_o(k T_b)$ is generated in the receiver.

This signal is then given to a decision device (not shown in Fig. 8.1.3), which decides whether transmitted symbol was zero or one.

BANDWIDTH OF BPSK SIGNAL

The spectrum of the BPSK signal is centered around the carrier frequency F_o

if $F_b = 1/T_b$, then for BPSK the maximum frequency in the baseband signal will be F_b , the spectrum of passband signal is centered around carrier frequency and extends from $F_o - F_b$ to $F_o + F_b$

Therefore Bandwidth (BW) of BPSK signal is ,

$$\begin{aligned}\text{BW} &= \text{highest frequency} - \text{lowest frequency} \\ &= F_o + F_b - (F_o - F_b)\end{aligned}$$

$$\text{BW} = 2 F_b$$

Hence the minimum bandwidth of BPSK signal is equal to **twice(2)** the highest frequency contained in baseband signal

DRAWBACKS OF BPSK: AMBIGUITY IN OUTPUT SIGNAL

- The block diagram of BPSK receiver, shows that- to regenerate the carrier signal, we start by squaring

$$b(t) \sqrt{2P} \cos(2\pi F_0 t + \theta)$$

- If the received signal is $- b(t) \sqrt{2P} \cos(2\pi F_0 t + \theta)$ then the squared signal remains same as before.
- Therefore the recovered carrier is unchanged even if the input signal has change has changed its **sign**.
- Therefore it is not possible to determine whether the received signal is equal to **$b(t)$ or $- b(t)$**
- This result in Ambiguity in the output signal.