BINARY FREQUENCY SHIFT KEYING (BFSK)

Introduction

Binary Frequency Shift Keying (BFSK)

- **In this type of digital modulation, the frequency of the carrier is shifted according to the binary symbol.**
- **The amplitude and phase of the carrier stay constant.**
- **That we have two different frequency signals according to binary symbols.**
- **Let there be a frequency shift(difference) by Ώ, then we can write following equations.**

if b(t) = '1' $S_H = \sqrt{2\,Ps}\ Cos\,(2\pi fo + \Omega)\,t$

if b(t) = '0' $S_L = \sqrt{2\,Ps}\ Cos\,(2\pi fo - \Omega)\,t$

- **Thus there is increase or decrease in frequency by Ώ**

Thus there is increase or decrease in frequency by Ω. Let us use the following conversion table to combine above two FSK equations.

Table 8.7.1 Conversion table for BPSK representation

$b(t)$ Input	$d(t)$	$P_H(t)$	$P_L(t)$
1	+1V	+1V	0V
0	−1V	0V	+1V

We can write equation 8.7.1 and equation 8.7.2 combinely as,

$$s(t) = \sqrt{2P_s}\cos\left[(2\pi f_0 + d(t)\,\Omega)\,t\right] \quad \ldots (8.7.3)$$

Thus when symbol '1' is to be transmitted, the carrier frequency will be $f_0 + \left(\frac{\Omega}{2\pi}\right)$.

If symbol '0' is to be transmitted, the carrier frequency will be $f_0 - \left(\frac{\Omega}{2\pi}\right)$. i.e.,

$$f_H = f_0 + \frac{\Omega}{2\pi} \quad \text{for symbol '1'} \quad \ldots (8.7.4)$$

$$f_L = f_0 - \frac{\Omega}{2\pi} \quad \text{for symbol '0'} \quad \ldots (8.7.5)$$

8.7.1 BFSK Transmitter

From the table 8.7.1, we know that $P_H(t)$ is same as $b(t)$. And $P_L(t)$ is inverted version of $b(t)$. The block diagram of BFSK transmitter is shown in Fig. 8.7.1.

We know that input sequence $b(t)$ is same as $P_H(t)$. An inverter is added after $b(t)$ to get $P_L(t)$. $P_H(t)$ and $P_L(t)$ are unipolar signals. The level shifter converts the '+1' level to $\sqrt{P_s T_b}$. Zero level is unaffected. Thus the output of the level shifters will be either $\sqrt{P_s T_b}$ (if '+1') or zero (if input is zero). Further there are product modulators after level shifter. The two carrier signals $\phi_1(t)$ and $\phi_2(t)$ are used. $\phi_1(t)$ and $\phi_2(t)$ are orthogonal to each other. In one bit period of input signal (i.e. T_b), $\phi_1(t)$ or $\phi_2(t)$ have integral number of cycles.

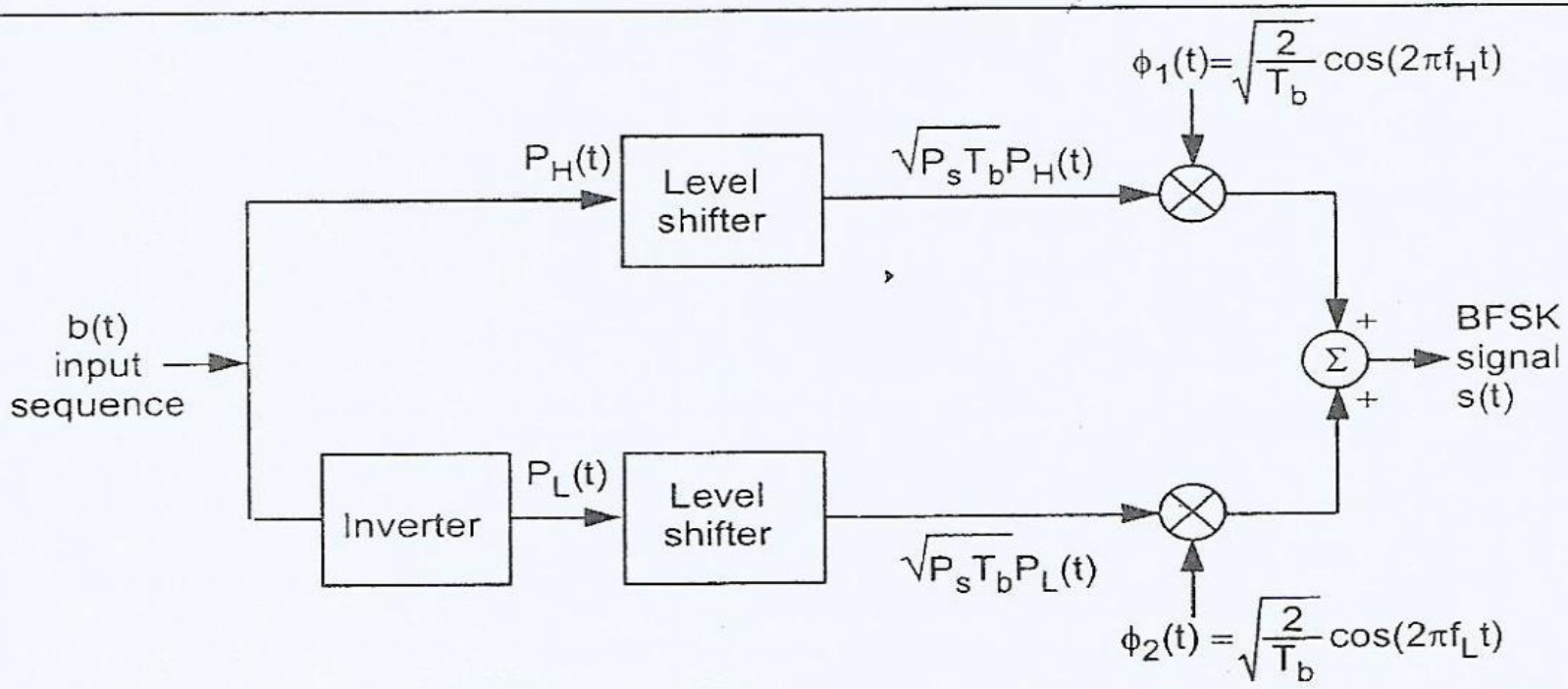

Fig. 8.7.1 Block diagram of BFSK transmitter

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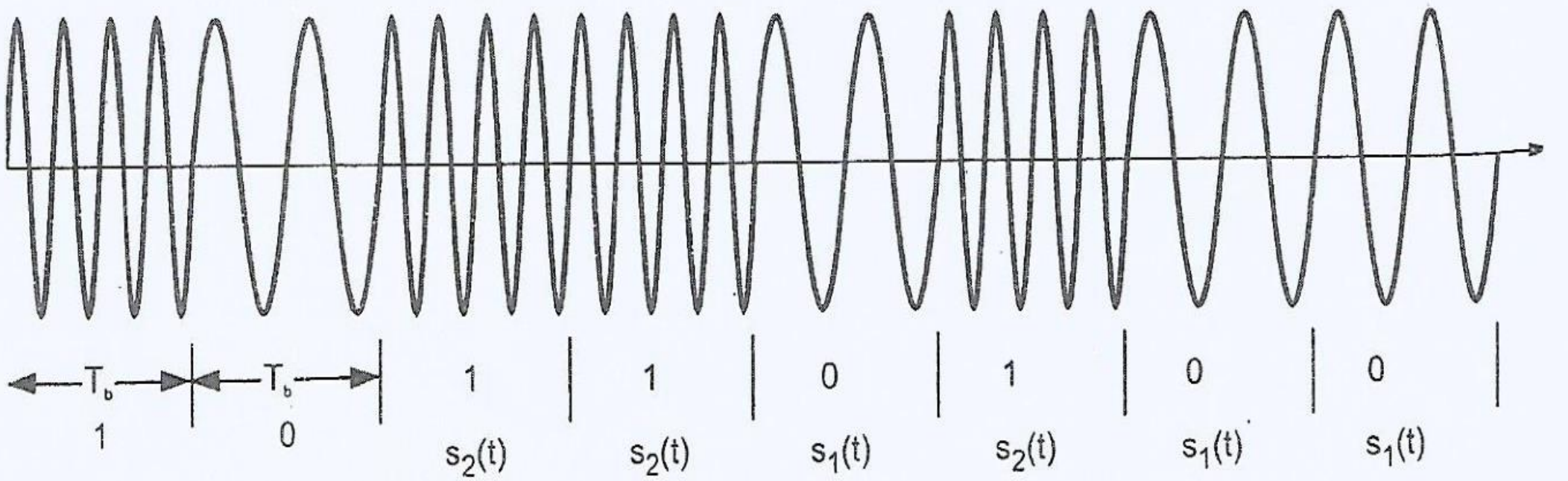
Therefore the modulated signal has continuous phase. Such BFSK signal is shown in Fig. 8.7.2. The adder then adds the two signals.

Here note that outputs from both the multipliers are not possible at a time. This is because $P_H(t)$ and $P_L(t)$ are complementary to each other. Therefore if $P_H(t) = 1$, then output will be only due to upper modulator and lower modulator output will be zero (since $P_L(t) = 0$).



Bandwidth of Binary Frequency Shift Keying (BFSK

Bandwidth of BFSK Signal :

From Fig. 8.7.3 it is clear that the width of one lobe is $2f_b$. The two main lobes due to f_H and f_L are place such that the total width due to both main lobes is $4f_b$. i.e.,

$$\text{Bandwidth of BFSK} = 2f_b + 2f_b$$

or

$$BW = 4f_b \quad \ldots (8.7.13)$$

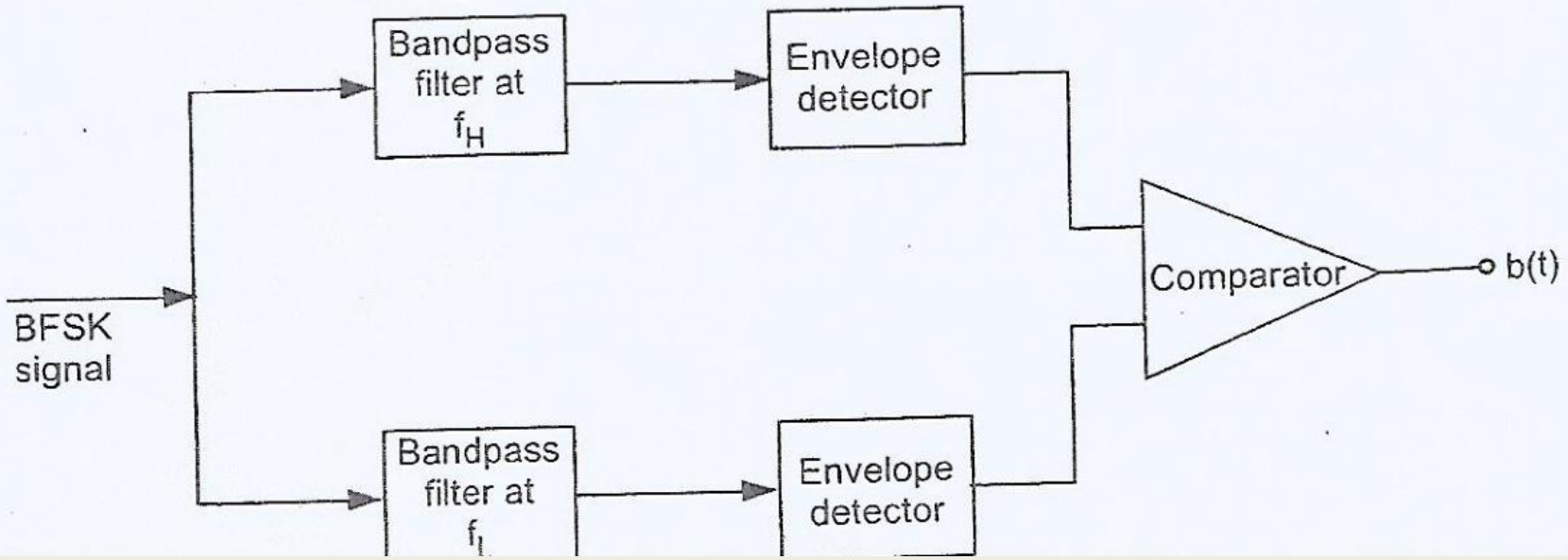
If we compare this bandwidth with that of BPSK given by equation 8.1.21, we observe that,

$$BW\,(BFSK) = 2 \times BW\,(BPSK)$$

BFSK receiver

8.7.3 BFSK Receiver

Fig. 8.7.4 shows the block diagram of BFSK receiver. The receiver consists of two bandpass filters ; one with centre frequency f_H and other with centre frequency f_L.



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- Since $F_H - F_L = 2F_b$, the outputs of filters do not overlap. The bandpass filters pass their corresponding main lobes without much distortion.

- The outputs of filters are applied to envelop detectors. The outputs of detectors are compared by the comparator. If unipolar comparator is used, then the output of comparator is the bit sequence b(t)

8.7.6 Advantages and Disadvantages of BFSK

Even though the generation of BFSK is easier it has many disadvantages compared to BPSK. First thing is that its bandwidth is greater than $4f_b$, which is almost double the bandwidth of BPSK. The distance between the signal points is less in BFSK. Hence the error rate of BFSK is more compared to BPSK.

From equation 8.7.3 we can write,

$$s(t) = \sqrt{2P_s}\cos\{d(t)\,\Omega t\}\cos(2\pi f_0 t) - \sqrt{2P_s}\sin\{d(t)\,\Omega t\}\sin(2\pi f_0 t)$$

Since $d(t) = \pm 1$

$\therefore$ $\cos\{\pm\Omega t\} = \cos(\Omega t)$

and $\sin\{\pm\Omega t\} = \pm\sin(\Omega t) = d(t)\sin(\Omega t)$ By standard trigonometric relations

$$s(t) = \sqrt{2P_s}\cos(\Omega t)\cos(2\pi f_0 t) - \sqrt{2P_s}\,d(t)\sin(\Omega t)\sin(2\pi f_0 t) \quad \ldots (8.7.23)$$

In the above relation the first term, $\sqrt{2P_s}\cos(\Omega t)\cos(2\pi f_0 t)$ carries no information. The second term, $\sqrt{2P_s}\,d(t)\sin(\Omega t)\sin(2\pi f_0 t)$ carries the information signal $d(t)$. Thus only half of the transmitted energy carries the information signal.