

Quadrature Phase Shift keying(QPSK)

continue

- QPSK Receiver
- Ambiguity in the output
- Bandwidth of QPSK signal
- Advantages of QPSK
- Examples

QPSK Receiver

- We have seen that the output of QPSK transmitter(modulated signal $s(t)$) is given by:

transmitter output $S(t)$ = odd modulated signal $S_o(t)$ + even modulated signal $S_e(t)$

and

$$S_e(t) = b_o(t) \sqrt{P_s} \sin(2\pi F_o t)$$

$$S_o(t) = b_e(t) \sqrt{P_s} \cos(2\pi F_o t)$$

$$S(t) = S_o(t) + S_e(t) = b_o(t) \sqrt{P_s} \cos(2\pi F_o t) + b_e(t) \sqrt{P_s} \sin(2\pi F_o t)$$

this signal is transmitted by transmission channel to the receiver

8.4.1.3 The QPSK Receiver

Fig. 8.4.4 shows the QPSK receiver. This is synchronous reception. Therefore coherent carrier is to be recovered from the received signal $s(t)$. The received signal $s(t)$ is first raised to its 4th power, i.e. $s^4(t)$. Then it is passed through a bandpass filter centered around $4f_0$. The output of the bandpass filter is a coherent carrier of frequency $4f_0$. This is divided by 4 and it gives two coherent quadrature carriers $\cos(2\pi f_0 t)$ and $\sin(2\pi f_0 t)$. These coherent carriers are applied to two synchronous demodulators. These synchronous demodulators consist of multiplier and an integrator.

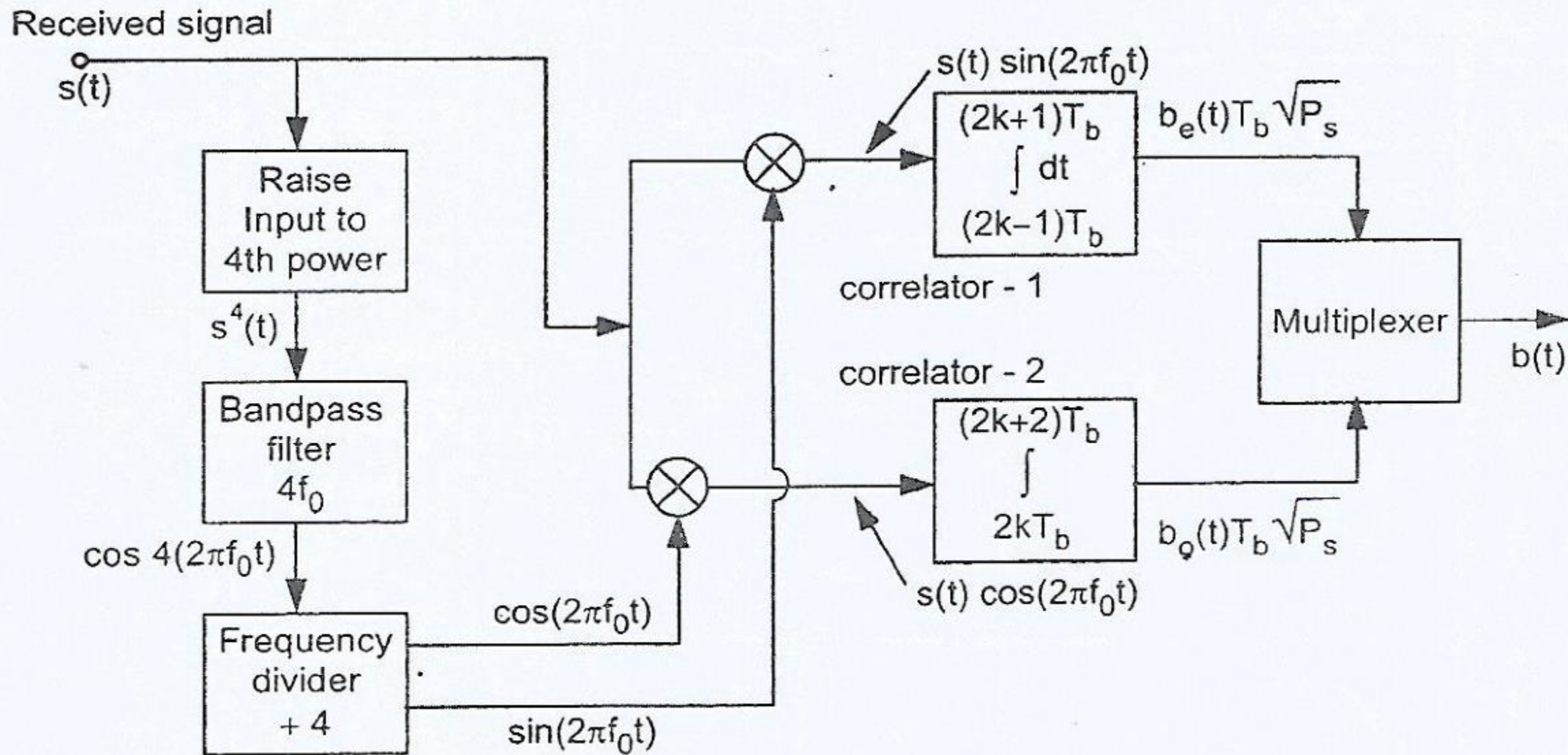


Fig. 8.4.4 QPSK receiver

The incoming signal is applied to both the multipliers. The integrator integrates the product signal over two bit interval (i.e. $T_s = 2T_b$). At the end of this period, the output of integrator is sampled. The outputs of the two integrators are sampled at the offset of one bit period, T_b . Hence the output of multiplexer is the signal $b(t)$. That is, the odd and even sequences are combined by multiplexer.

Let's consider the product signal at the output of upper multiplier.

$$s(t) \sin(2\pi f_0 t) = b_o(t) \sqrt{P_s} \cos(2\pi f_0 t) \sin(2\pi f_0 t) + b_e(t) \sqrt{P_s} \sin^2(2\pi f_0 t) \quad \dots (8.4.4)$$

This signal is integrated by the upper integrator in Fig. 8.4.4.

$$\begin{aligned} \therefore \int_{(2k-1)T_b}^{(2k+1)T_b} s(t) \sin(2\pi f_0 t) dt &= b_o(t) \sqrt{P_s} \int_{(2k-1)T_b}^{(2k+1)T_b} \cos(2\pi f_0 t) \sin(2\pi f_0 t) dt \\ &\quad + b_e(t) \sqrt{P_s} \int_{(2k-1)T_b}^{(2k+1)T_b} \sin^2(2\pi f_0 t) dt \end{aligned}$$

Since $\frac{1}{2} \sin(2x) = \sin x \cdot \cos x$

and $\sin^2(x) = \frac{1}{2} [1 - \cos(2x)]$

Using the above two trigonometric identities in the above equation,

$$\int_{(2k-1)T_b}^{(2k+1)T_b} s(t) \sin(2\pi f_0 t) dt = \frac{b_o(t) \sqrt{P_s}}{2} \int_{(2k-1)T_b}^{(2k+1)T_b} \sin 4\pi f_0 t dt + \frac{b_e(t) \sqrt{P_s}}{2} \int_{(2k-1)T_b}^{(2k+1)T_b} 1 \cdot dt$$

$$- \frac{b_e(t) \sqrt{P_s}}{2} \int_{(2k-1)T_b}^{(2k+1)T_b} \cos 4\pi f_0 t dt$$

In the above equation, the first and third integration terms involves integration of sinusoidal carriers over two bit period. They have full (integral number of) cycles over two bit period and hence integration will be zero.

$$\begin{aligned} \int_{(2k-1)T_b}^{(2k+1)T_b} s(t) \sin(2\pi f_0 t) dt &= \frac{b_e(t) \sqrt{P_s}}{2} [t]_{(2k-1)T_b}^{(2k+1)T_b} \\ &= \frac{b_e(t) \sqrt{P_s}}{2} \times 2T_b \\ &= b_e(t) \sqrt{P_s} T_b \end{aligned} \quad \dots (8.4.5)$$

Thus the upper integrator responds to even sequence only. Similarly we can obtain the output of lower integrator as $b_o(t) \sqrt{P_s} T_b$.

Eventhough bit synchronizer is not shown in Fig. 8.4.4, it is assumed to be present with the integrator to locate starting and ending times of integration. The multiplexer is also operated by bit synchronizer. The amplitudes of signals marked in Fig. 8.4.4 are arbitrary. They can change depending upon the gains of integrator.

Ambiguity in the output :

In Fig. 8.4.4 observe that even if the received signal is negative, the recovered carrier remains unaffected because of the 4th power conversion of the signal. Therefore it will not be possible to determine whether the transmitted signals were positive or negative [i.e. $+b_e(t)$ or $-b_e(t)$ and $+b_o(t)$ or $-b_o(t)$]. This is phase ambiguity in output similar to BPSK. This problem can be recovered by employing differential encoding and decoding of $b(t)$.

8.4.4 Bandwidth of QPSK Signal

We have seen that the bandwidth of BPSK signal is equal of $2f_b$. Here $T_b = \frac{1}{f_b}$ is the one bit period. In QPSK the two waveforms $b_e(t)$ and $b_o(t)$ from the baseband signals. One bit period for both of these signals is equal to $2T_b$. Therefore bandwidth of QPSK signal is,

$$BW = 2 \times \frac{1}{2T_b} \quad \text{or} \quad BW = f_b \quad \dots (8.4.24)$$

Thus the bandwidth of QPSK signal is half of the bandwidth of BPSK signal. Earlier we have seen that noise immunity of QPSK and BPSK is same. This shows that in spite of the reduction in bandwidth in QPSK, the noise immunity remains same as compared to BPSK. BW of QPSK can also be obtained by plotting equation 8.4.20 as shown in Fig. 8.4.7 below.

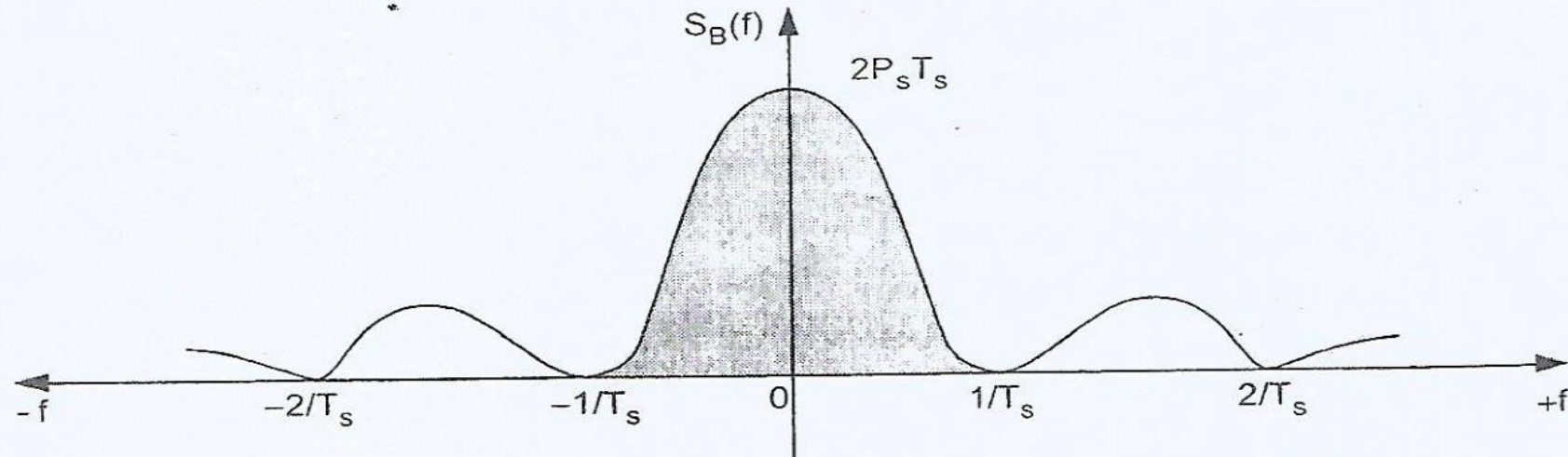


Fig. 8.4.7 Plot of power spectral density of QPSK signal

$$\begin{aligned}
 BW &= \text{Highest frequency} - \text{Lowest frequency in main lobe} \\
 &= \frac{1}{T_s} - \left(-\frac{1}{T_s}\right) \text{ since carrier frequency } f_0 \text{ cancels out} \\
 &= \frac{2}{T_s}
 \end{aligned}$$

We know that $T_s = 2T_b$

$$\therefore BW = \frac{2}{2T_b} = \frac{1}{T_b} = f_b$$

which is same as we obtained in equation 8.4.24.

8.4.5 Advantages of QPSK

QPSK has some definite advantages and disadvantages as compared to BPSK and DPSK.

Advantages :

- 1) For the same bit error rate, the bandwidth required by QPSK is reduced to half as compared to BPSK.
- 2) Because of reduced bandwidth, the information transmission rate of QPSK is higher.
- 3) Variation in OQPSK amplitude is not much. Hence carrier power almost remains constant.

Ex. 8.4.1 Write the waveforms for a binary sequence 101100 modulated under QPSK.

Sol. : Let us assume the offset QPSK or OQPSK system. The waveforms are drawn similar to those in Fig. 8.4.2. Fig. 8.4.8 shows the waveforms for given sequence. The input sequence is written at the top alongwith bit numbers Fig.(a) shows NRZ waveform for odd numbered bits. Fig.(b) shows the NRZ waveform for even numbered bits. Observe that the signal is assumed '0' at the beginning for even numbered bit sequence i.e. $b_e(t)$. The two quadrature carriers are shown in Fig. (c) and (d). Fig. (e) shows the binary PSK signal generated due to $b_o(t)$, i.e. $s_o(t)$. Fig. (f) shows the binary PSK signal generated due to $b_e(t)$, i.e. $s_e(t)$. The signals $s_o(t)$ and $s_e(t)$ are added to get the final QPSK waveform $s(t)$. It is shown in Fig. 8.4.8(g). Observe that the phase shifts of $\frac{\pi}{2}$ occur in this waveform. The individual binary PSK waveforms are staggered due to offset QPSK. (See Fig. 8.4.8 on next page)

Ex. 8.4.2 In a QPSK system, the bit rate of NRZ stream is 10 Mbps and carrier frequency is 1 GHz. Find the symbol rate of transmission and bandwidth requirement of the channel. Sketch the power spectral density of the QPSK signal.[Dec-2002, 5 Marks]

Sol. : (i) To obtain symbol rate and bandwidth

Bit rate $f_b = 10 \text{ Mbps}$

Bandwidth of the QPSK system is equal to bit rate.

Hence $BW = f_b = 10 \text{ MHz}$

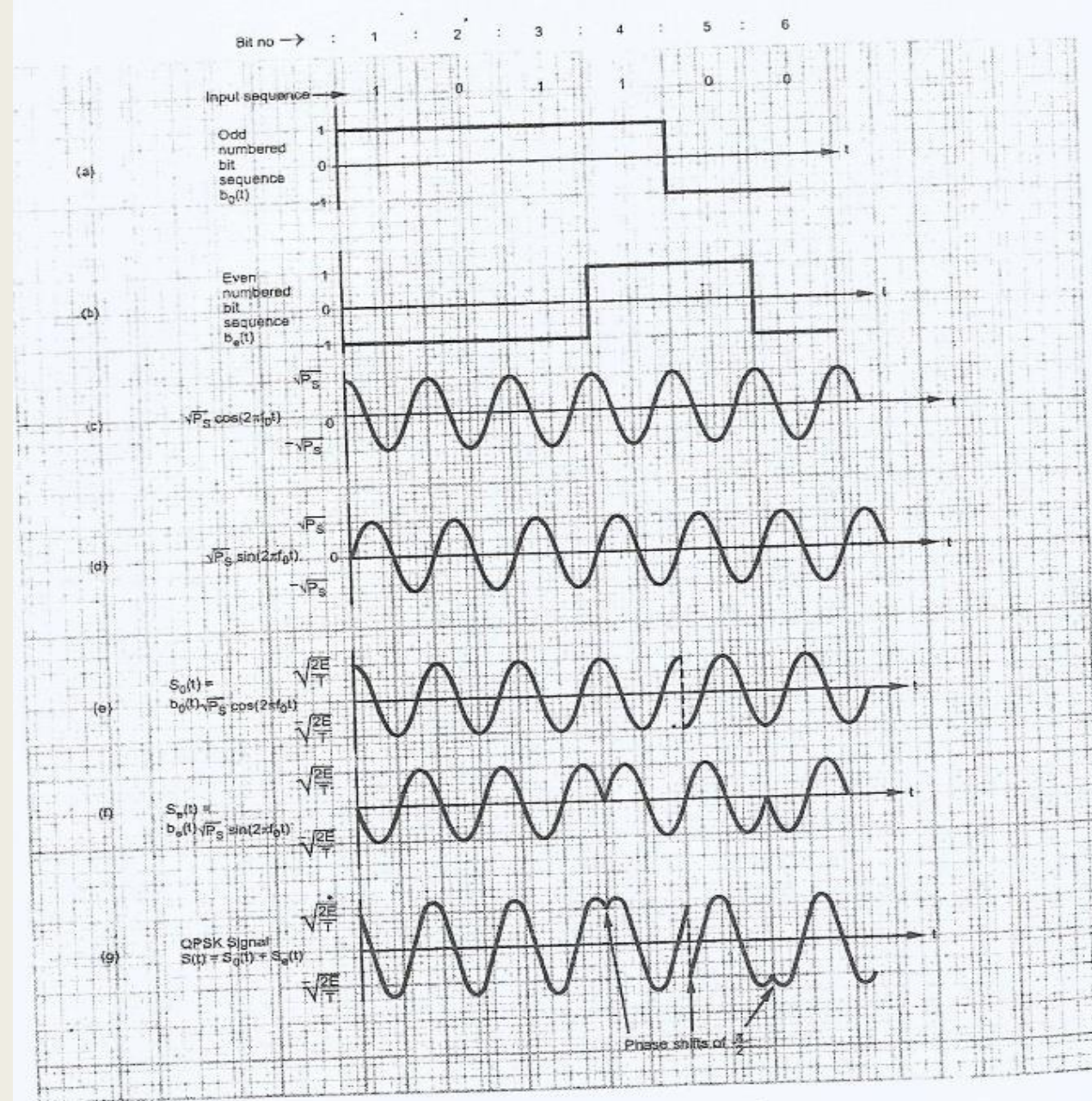


Fig. 8.4.8 QPSK waveform

Symbol duration and bit duration are related as,

$$T_s = 2T_b$$

$$\therefore \text{Symbol rate} = \frac{1}{T_s} = \frac{1}{2T_b} = \frac{f_b}{2}$$

$$= 5 \text{ MHz}$$

(ii) To obtain power spectral density :

Carrier frequency $f_o = 1 \text{ GHz}$

psd of NRZ signal is given as,

$$S_B(f) = 2P_s T_s \left[\frac{\sin(\pi f T_s)}{\pi f T_s} \right]^2$$

Upon modulation of the carrier of frequency f_o , the spectral density given by above equation is shifted at $\pm f_o$.

Fig. 8.4.9 shows the psd plot.

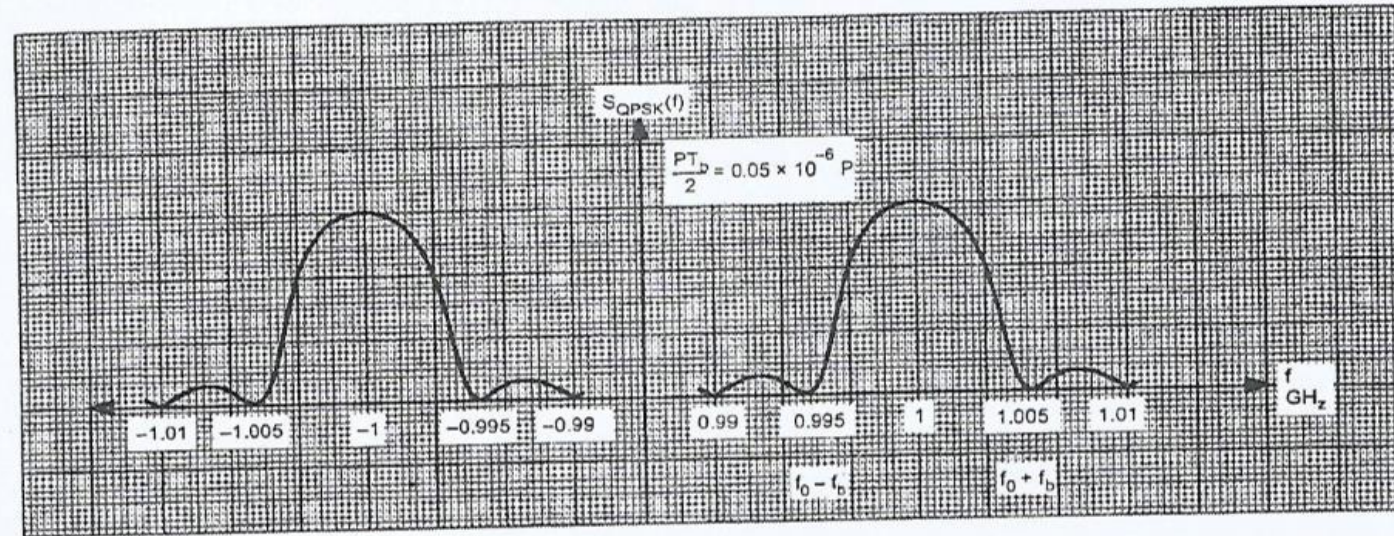


Fig. 8.4.9 Spectral density plot of QPSK

continue

- In above figure observe that the two lobes are placed at ± 1 GHz.
- Width of the main lobe is $(1 + 0.005)$ GHz to $(1 - 0,005)$ GHz
- This is equal to **bandwidth** requirement of the system

that is $BW = 1.005 - 0.995 = 0.01 \text{ GHz} = 10 \text{ MHz}$