QPSK - Quadrature Phase Shift Keying

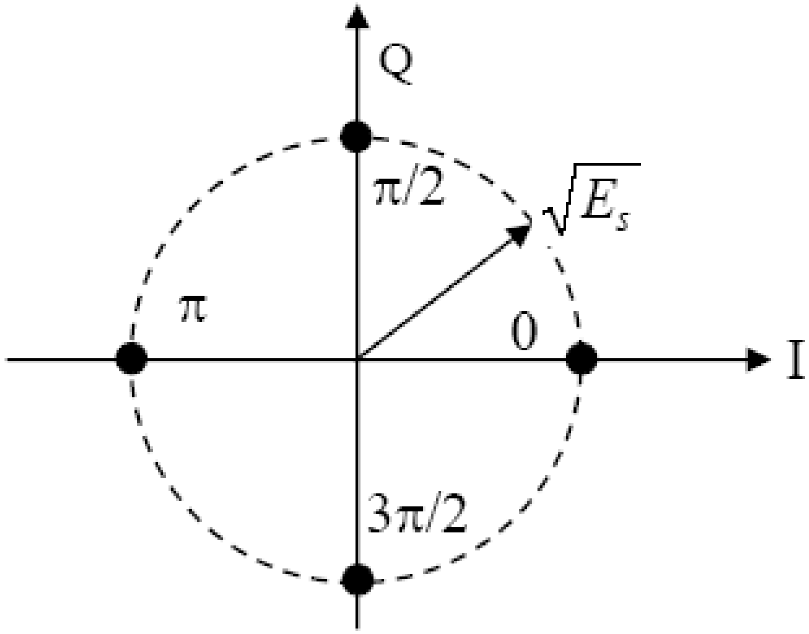
- **Four** different phase states in **one** symbol period
- **Two** bits of information in each symbol

  Phase: 0 $\pi/2$ π $3\pi/2$ → possible phase values

  Symbol: 00 01 11 10

Note that we choose binary representations so an error between two adjacent points in the constellation only results in a single bit error

- For example, decoding a phase to be π instead of $\pi/2$ will result in a "11" when it should have been "01", only one bit in error.



- Now we have two basis functions
- $E_s = 2\ E_b$ since 2 bits are transmitted per symbol
- I = in-phase component from $s_I(t)$.
- Q = quadrature component that is $s_Q(t)$.

QPSK RF Signal BW

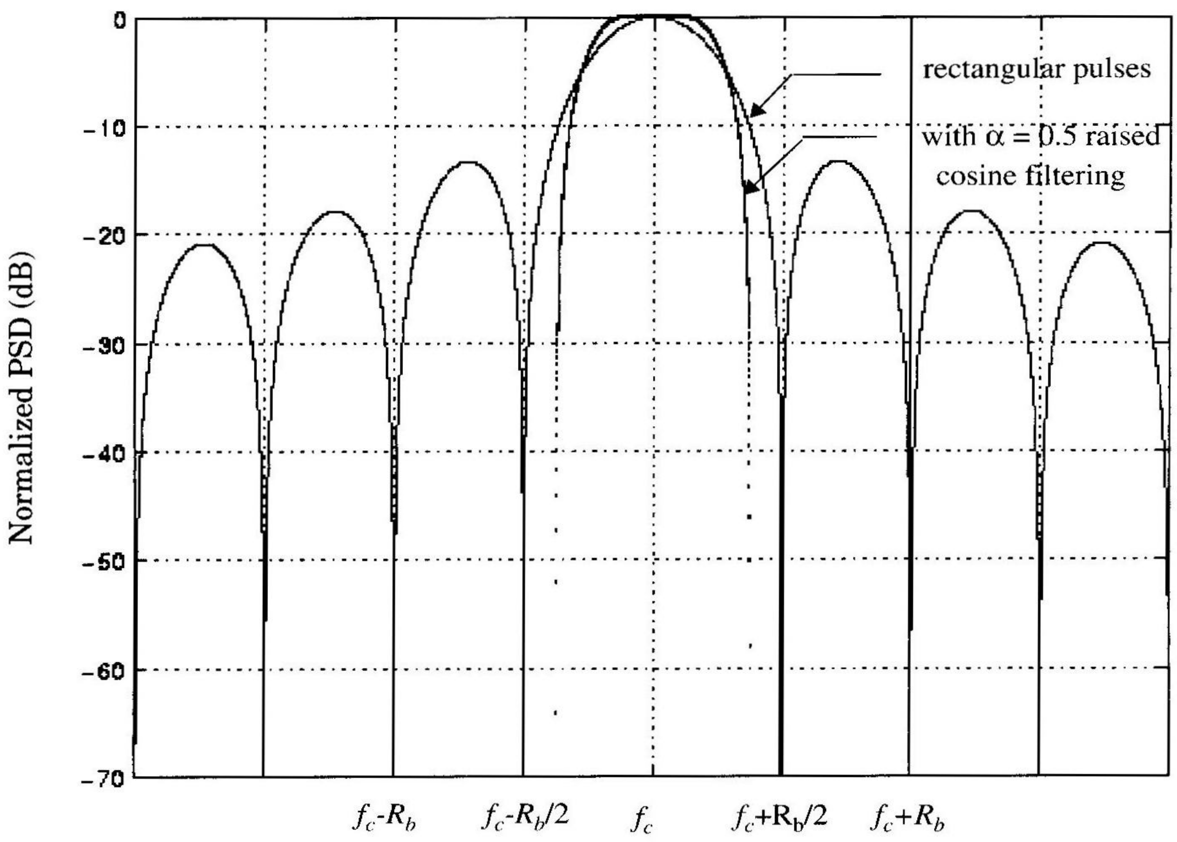


Figure 6.27 Power spectral density of a QPSK signal.

- null-to-null RF BW = R_b = $2R_S$ (2 bits / one symbol time) = 2 / T_s
- double the BW efficiency of BPSK → or **twice** the data rate in same signal BW

- BER is once again related to the distance between constellation points.

$$\text{Prob}\{\text{bit error}\} \le Q\left(\frac{d}{\sqrt{2N_0}}\right)$$

  - *d* is distance between nearest constellation points.

  - Here $d = \sqrt{2E_s}$ so $\text{Prob}\{\text{bit error}\} \le Q\left(\sqrt{\frac{E_s}{N_0}}\right)$

    But $E_s = 2\,E_b$ so $\text{Prob}\{\text{bit error}\} \le Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$

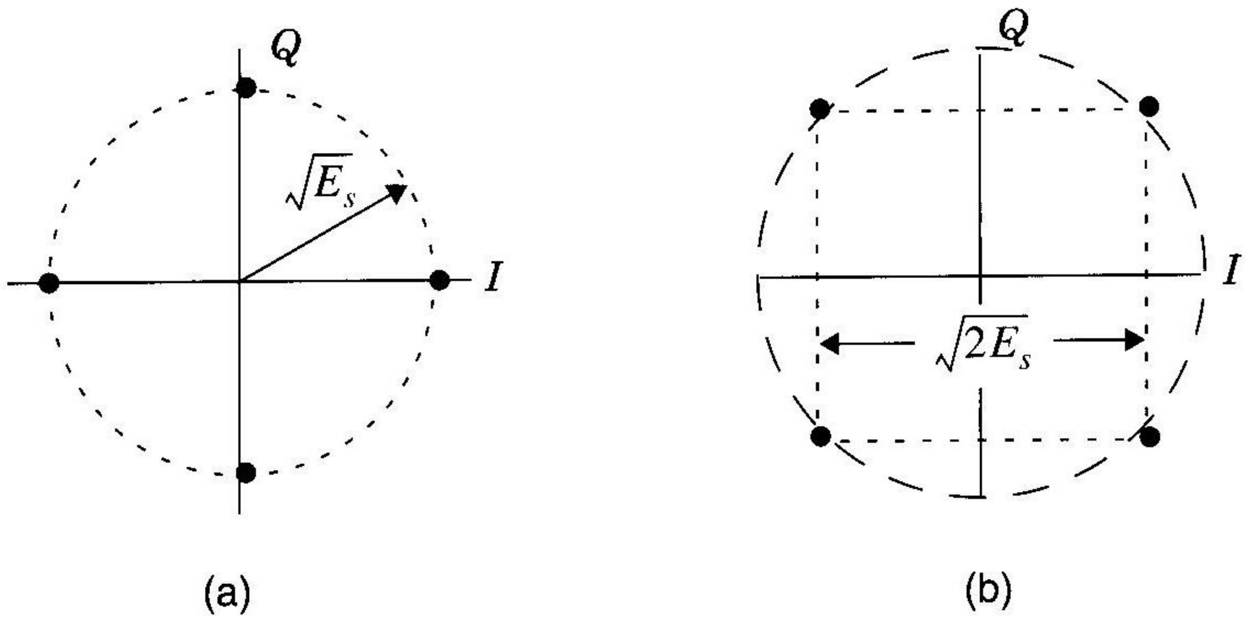


Figure 6.26 (a) QPSK constellation where the carrier phases are 0, $\pi/2$, π, $3\pi/2$; (b) QPSK constellation where the carrier phases are $\pi/4$, $3\pi/4$, $5\pi/4$, $7\pi/4$.

QPSK Transmission and Detection Techniques

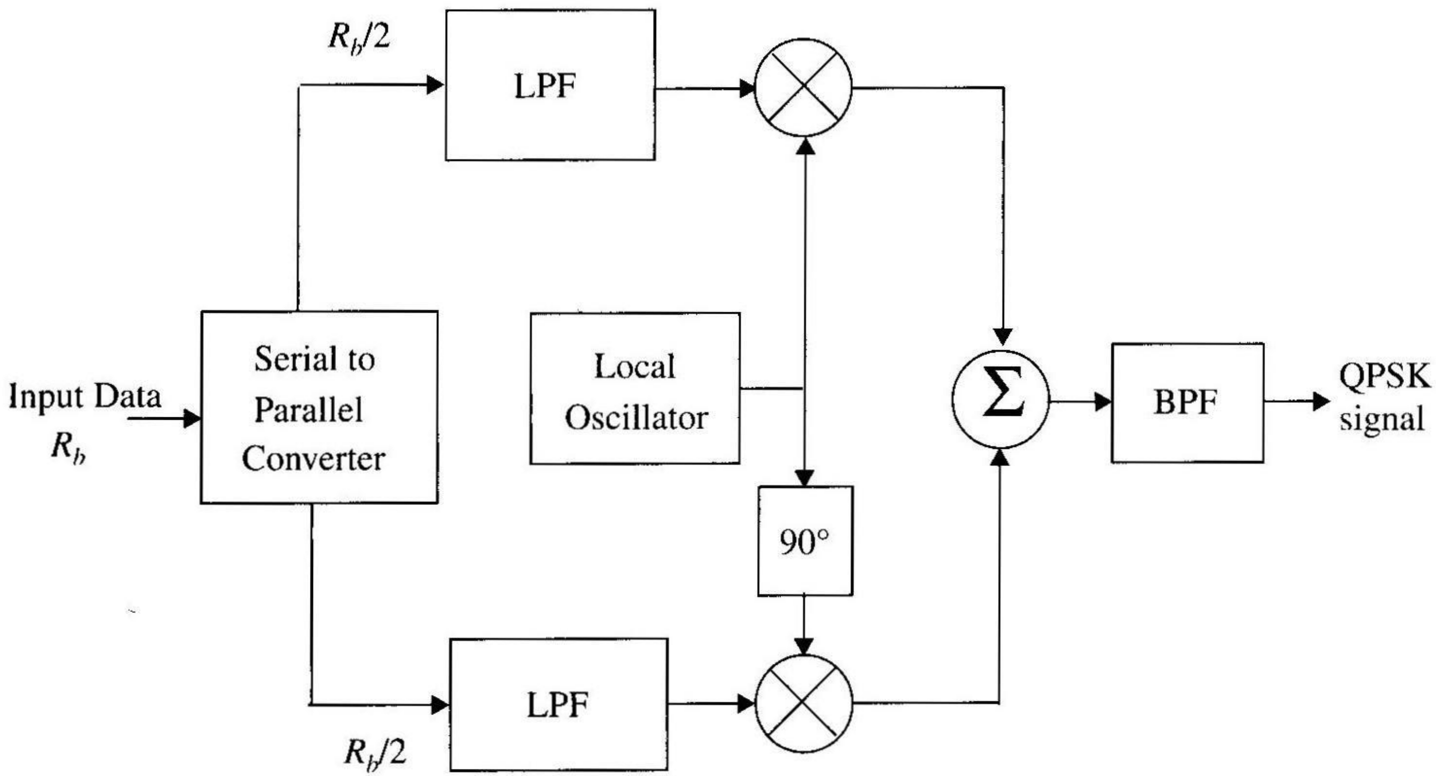


Figure 6.28 Block diagram of a QPSK transmitter.

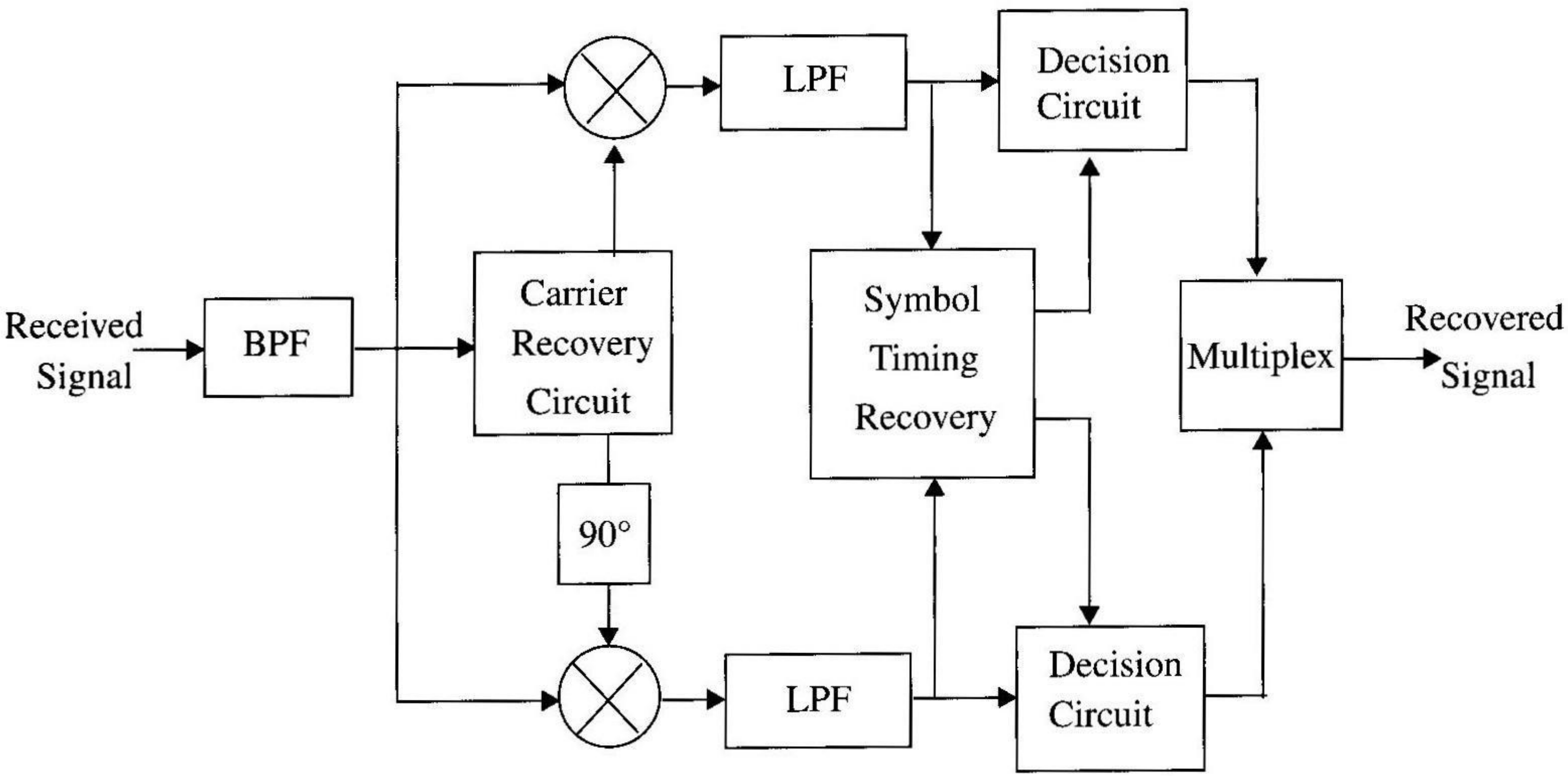


Figure 6.29 Block diagram of a QPSK receiver.

QPSK or Quadrature Phase Shift Keying, involves the splitting of a data stream $m_k(t) = m_0, m_1, m_2, \ldots$, into an in-phase stream $m_I(t) = m_0, m_2, m_4, \ldots$ and a quadrature stream $m_Q(t) = m_1, m_3, m_5, \ldots$. Both the streams have half the bit rate of the data stream $m_k(t)$, and modulate the cosine and sine functions of a carrier wave simultaneously. As a result, phase changes across intervals of $2T_b$, where T_b is the time interval of a single bit (the $m_k(t)$s). The phase transitions can be as large as $\pm\pi$ as shown in Figure 1.

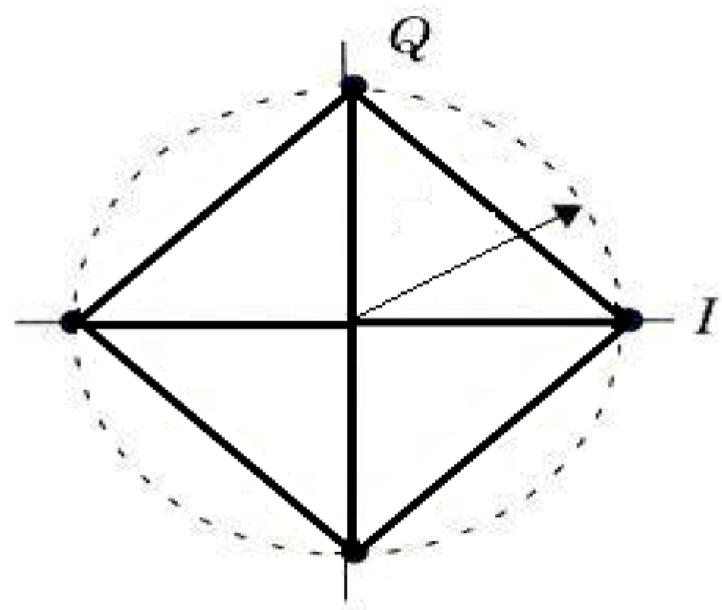


Figure 1: The figure shows a QPSK constellation. The dark black lines show all possible phase changes.

Sudden phase reversals of $\pm\pi$ can throw the amplifiers into saturation. As shown in Figure 2 [1], the phase reversals of $\pm\pi$ cause the envelope to go to zero momentarily. This may make us susceptible to *non-linearities* in amplifier circuitry. The above may be prevented using linear amplifiers but they are more *expensive and power consuming.* A solution to the above mentioned problem is the use of OQPSK.

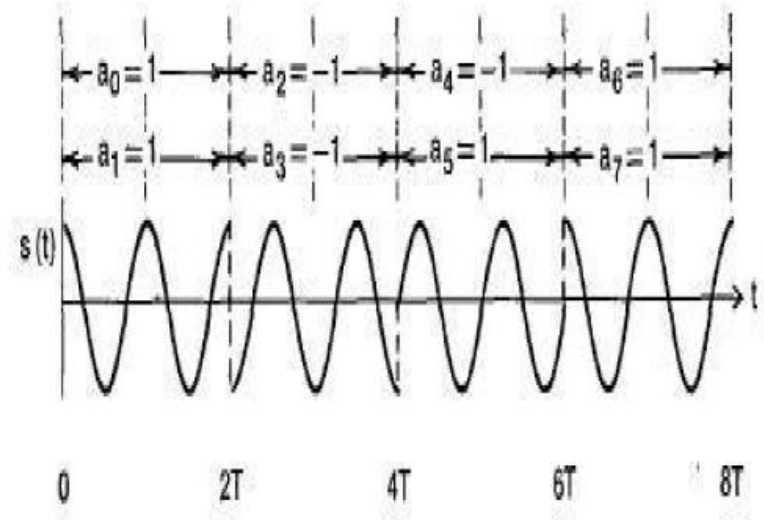


Figure 2: The figure shows a QPSK waveform. As is seen across the dotted line corresponding to a phase shift of π, the envelope reduces to zero temporarily.

OQPSK modulation is such that phase transitions about the origin are avoided. The scheme is used in IS-95 handsets. In OQPSK the pulse streams $m_I(t) = m_0, m_2, m_4, \ldots$ and $m_Q(t) = m_1, m_3, m_5, \ldots$ are *offset in alignment*, in other words are staggered, by one bit period (half a symbol period). Figure 3 [2], shows the staggering of the data streams in time. Figure 4 [1], shows the OQPSK waveform undergoing a phase shift of $\pm\pi/2$. The result of *limiting* the phase shifts to $\pm\pi/2$ is that the envelope will not go to zero as it does with QPSK.

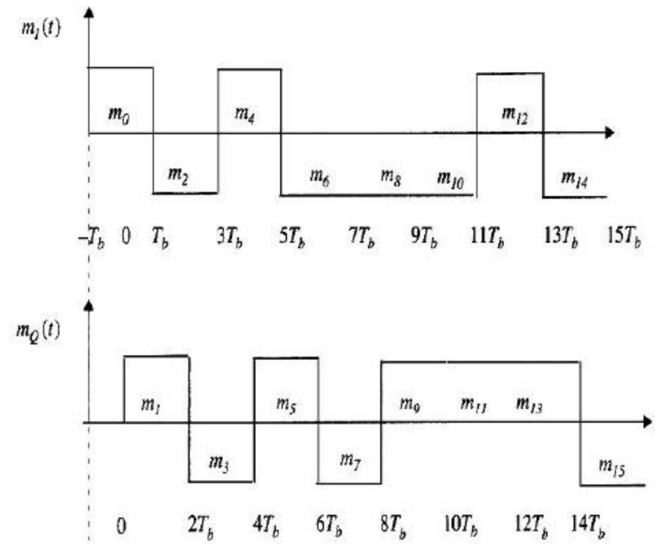


Figure 3: The figure shows the staggering of the in phase and quadrature modulated data streams in OQPSK. The staggering restricts the phase changes to ±90 as shown in Figure 4.

- the maximum phase shift of the transmitted signal at any given time is limited to ± 90^o

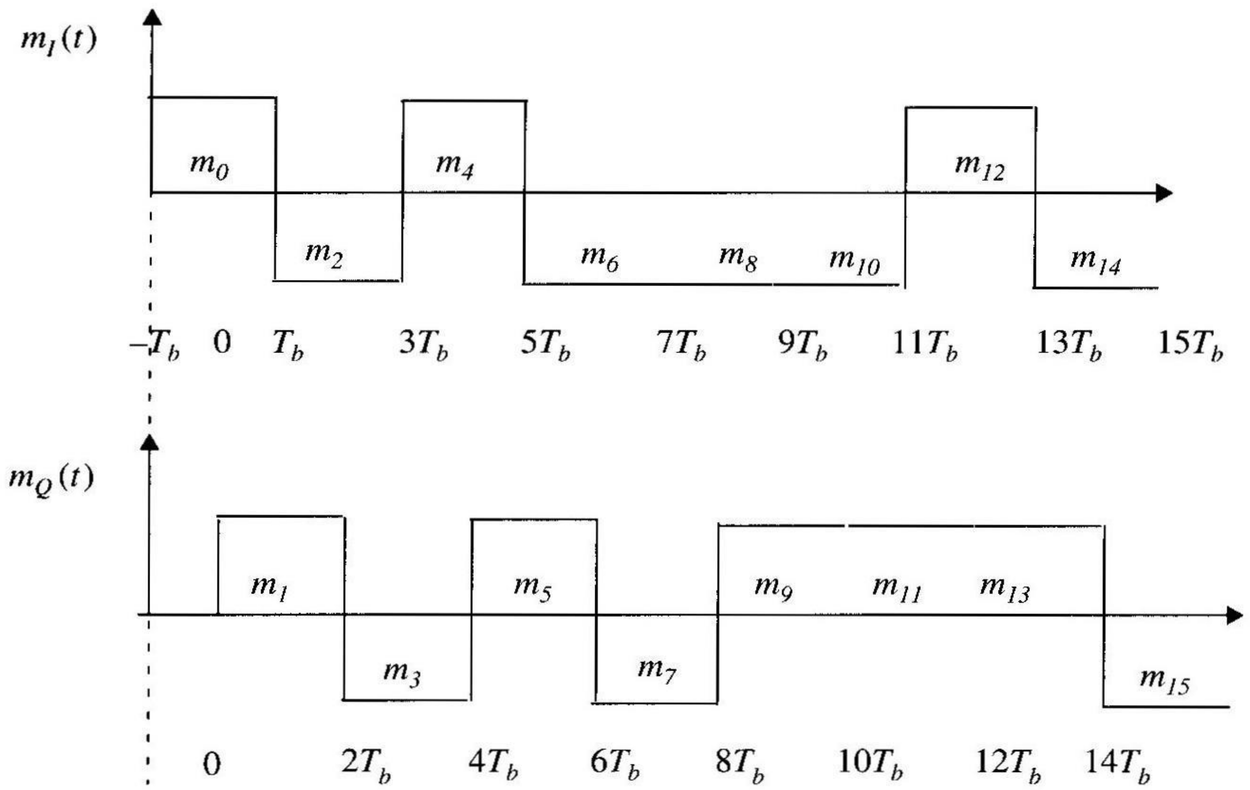


Figure 6.30 The time offset waveforms that are applied to the in-phase and quadrature arms of an OQPSK modulator. Notice that a half-symbol offset is used.

In OQPSK, the phase transitions take place every T_b seconds. In QPSK the transitions take place every $2T_b$ seconds.

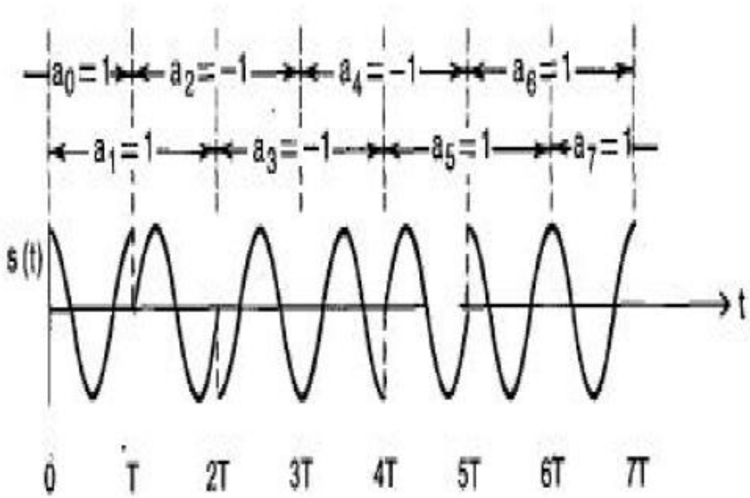


Figure 4: The figure shows a QPSK waveform. As is seen across the dotted lines the phase changes are of $\pm\pi/2$.

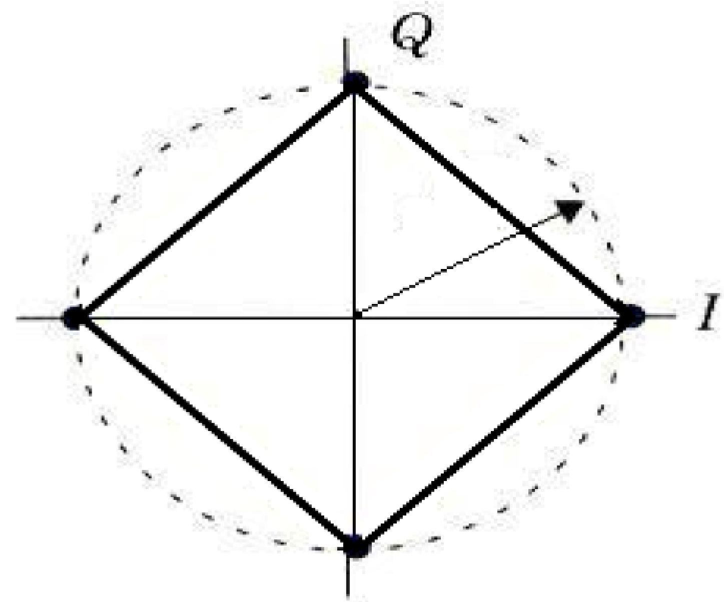


Figure 5: The figure shows a OQPSK constellation. The dark black lines show all possible phase changes. The signal space is the same as in the case of QPSK, though phase changes are restricted to ± 90.

The spectrum of an OQPSK signal is identical to that of a QPSK signal, hence both signals occupy the same bandwidth