EC 744 Wireless Communications
Spring 2007

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Digital Modulation Techniques

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Syllabus

- Tentatively

Week 1	Overview, Probabilities, Random variables, Random process
Week 2	Wireless channels, Statistical Channel modelling, Path loss models
Week 3	Cellular concept and system design fundamentals
Week 4	Modulation techniques, single and multi-carrier
Week 5	Diversity techniques
Week 6	Equalization techniques
Week 7	Mid Term exam
Week 8	802.11 and Mac evaluation
Week 9	Energy models in 802.11
Week 10	Wimax and Mac layer
Week 11	Presentations
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Week 14	Presentations
Week 15	Final Exam

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Chapter 6

Passband Data Transmission

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Figure 6.1

Illustrative waveforms for the three basic forms of signaling binary information. (*a*) Amplitude-shift keying. (*b*) Phase-shift keying. (*c*) Frequency-shift keying with continuous phase.

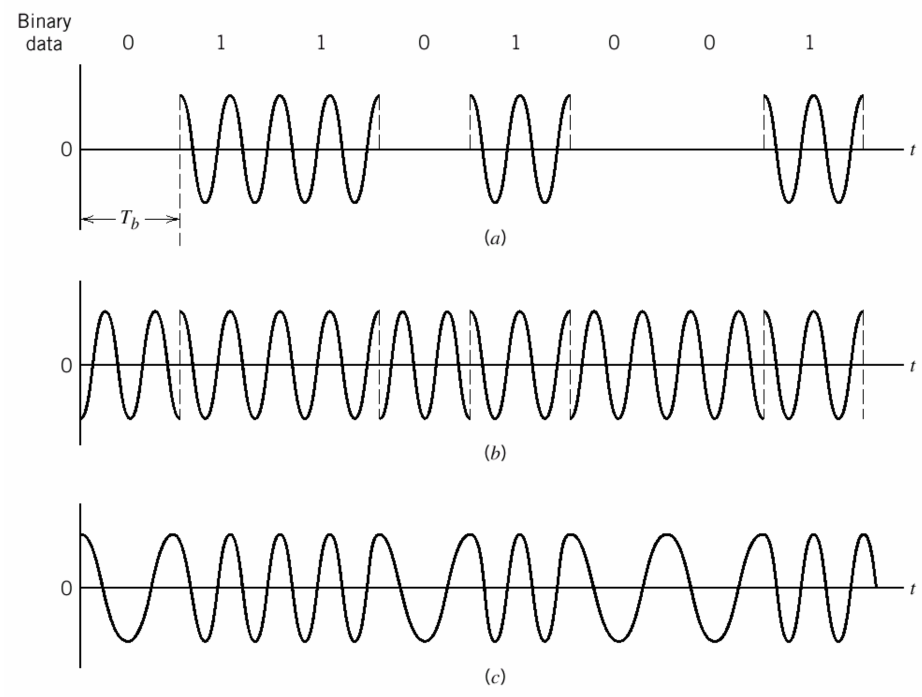

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Figure 6.2
Functional model of passband data transmission system.

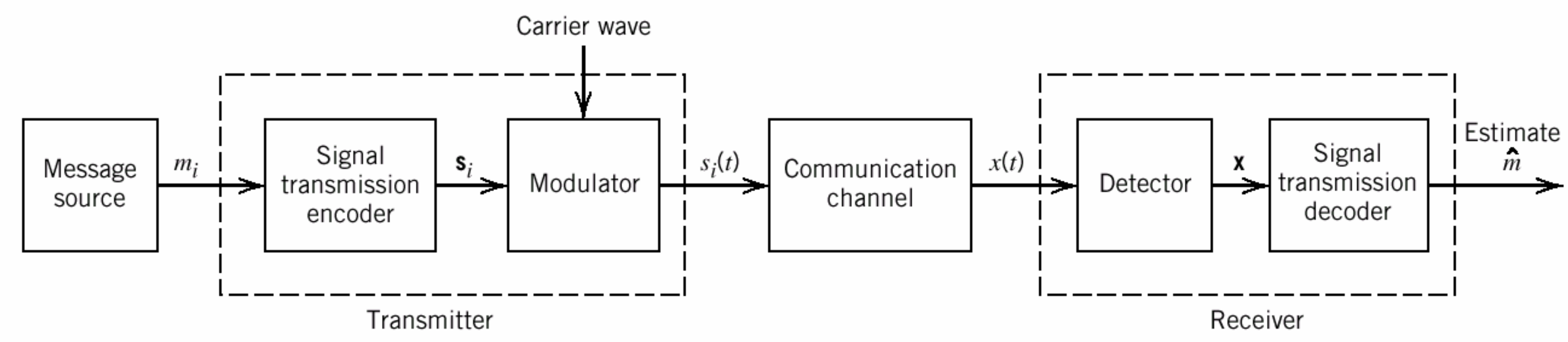

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Figure 6.3

Signal-space diagram for coherent binary PSK system. The waveforms depicting the transmitted signals $s_1(t)$ and $s_2(t)$, displayed in the inserts, assume $n_c = 2$.

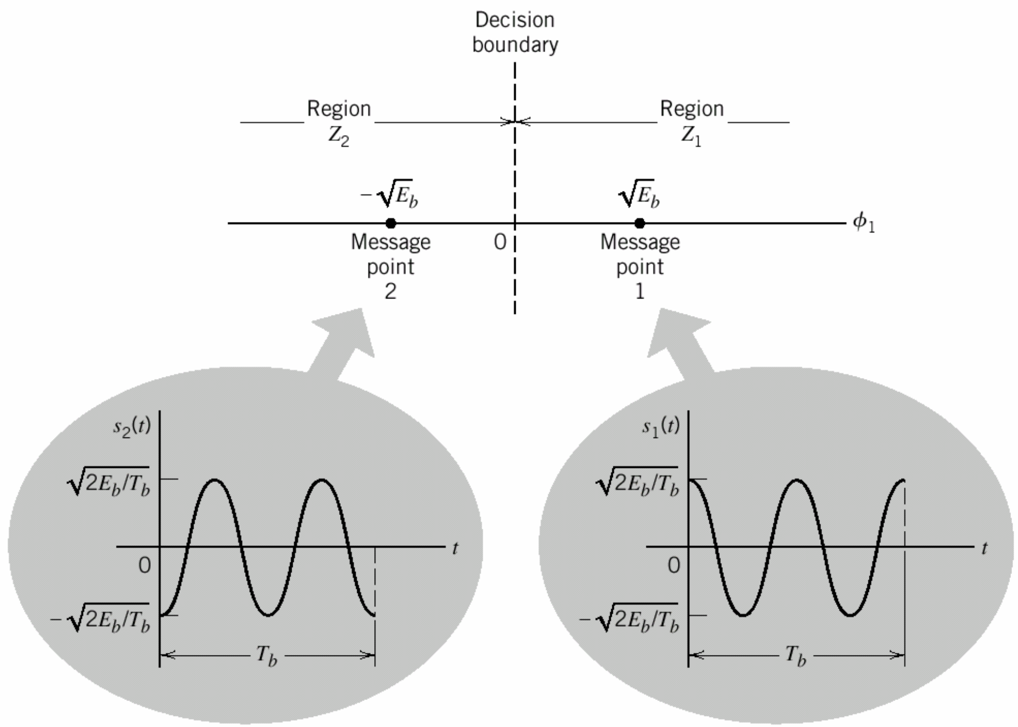

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Figure 6.4

Block diagrams for (*a*) binary PSK transmitter and (*b*) coherent binary PSK receiver.

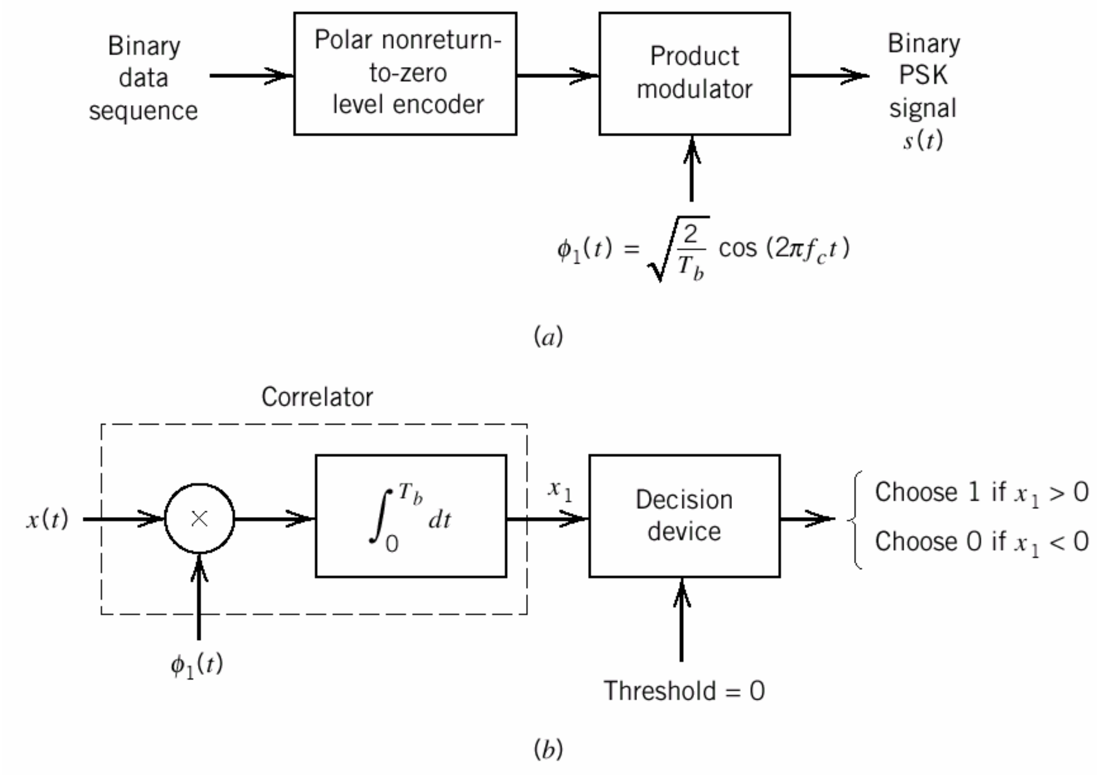

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Figure 6.5

Power spectra of binary PSK and FSK signals.

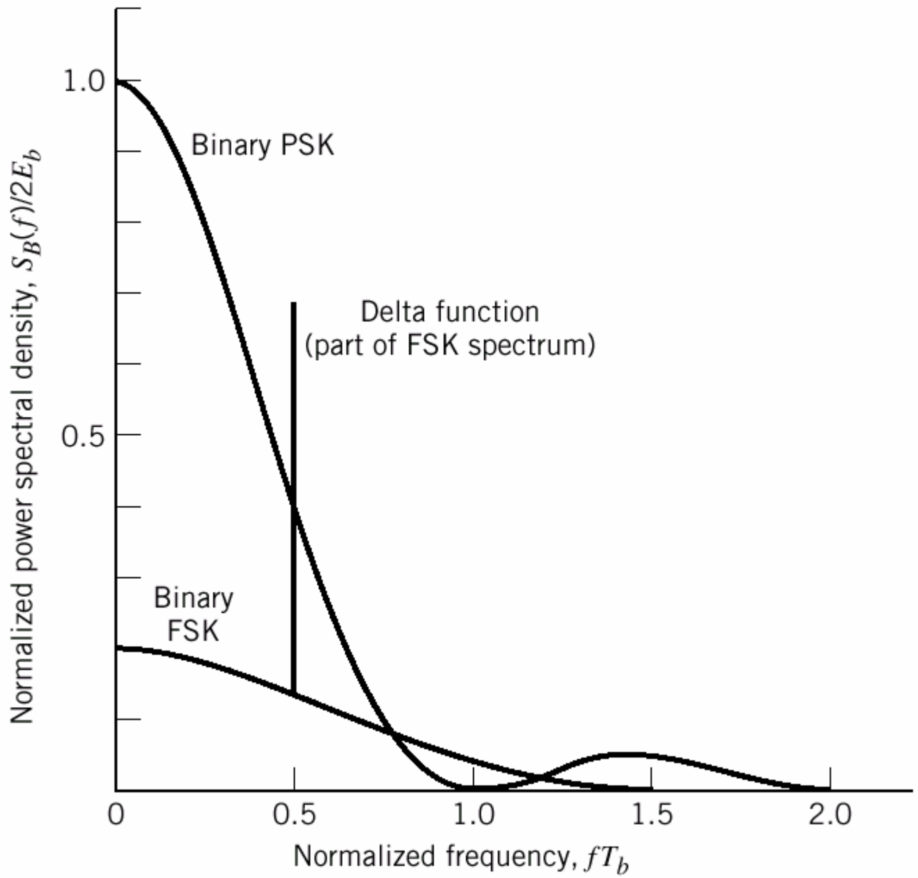

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Figure 6.6

Signal-space diagram of coherent QPSK system.

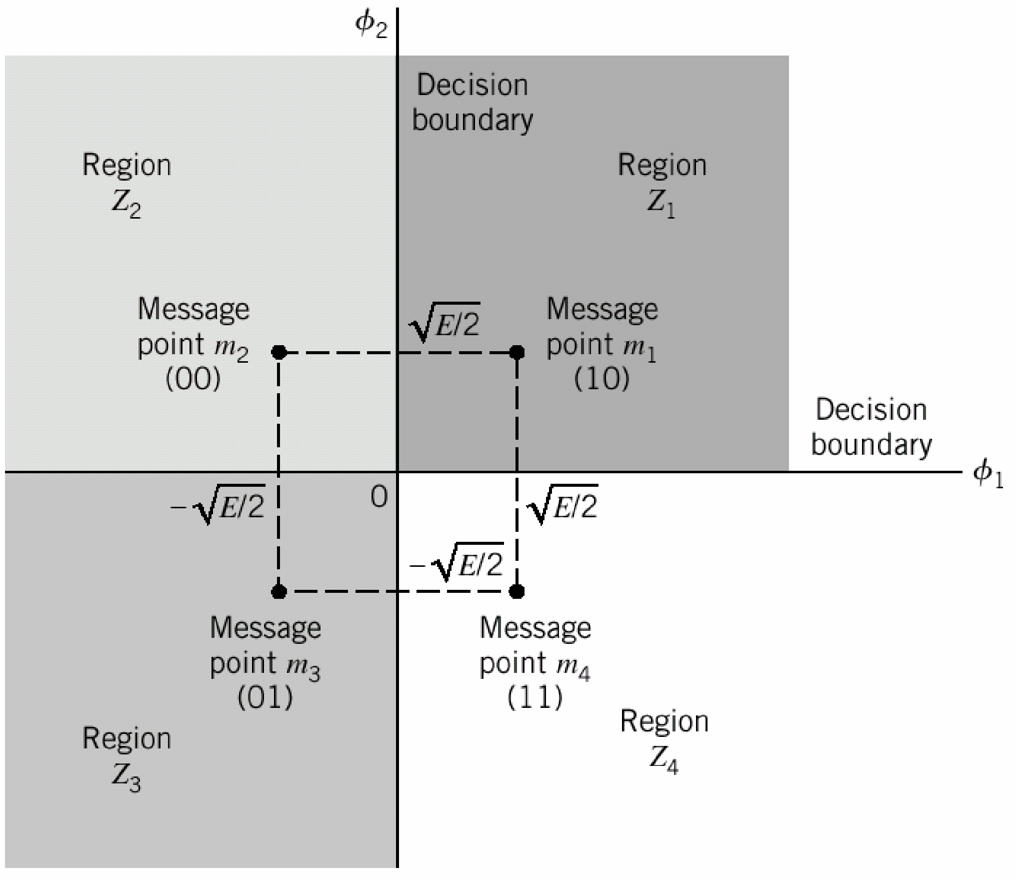

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Figure 6.7

(a) Input binary sequence. (b) Odd-numbered bits of input sequence and associated binary PSK wave. (c) Even-numbered bits of input sequence and associated binary PSK wave. (d) QPSK waveform defined as $s(t) = s_{i1}\phi_1(t) + s_{i2}\phi_2(t)$.

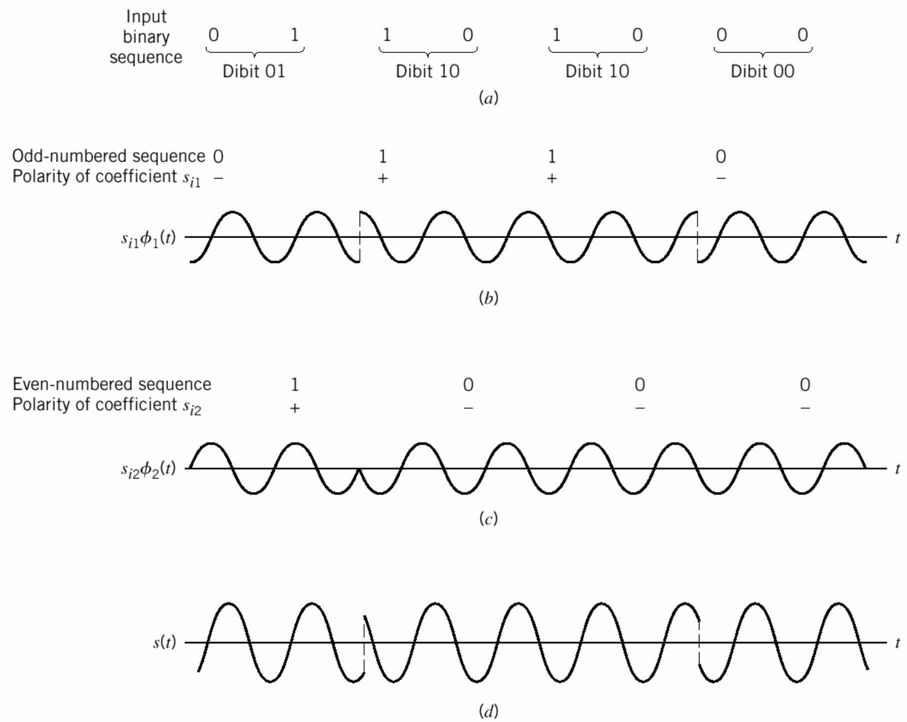

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Figure 6.8

Block diagrams of (*a*) QPSK transmitter and (*b*) coherent QPSK receiver.

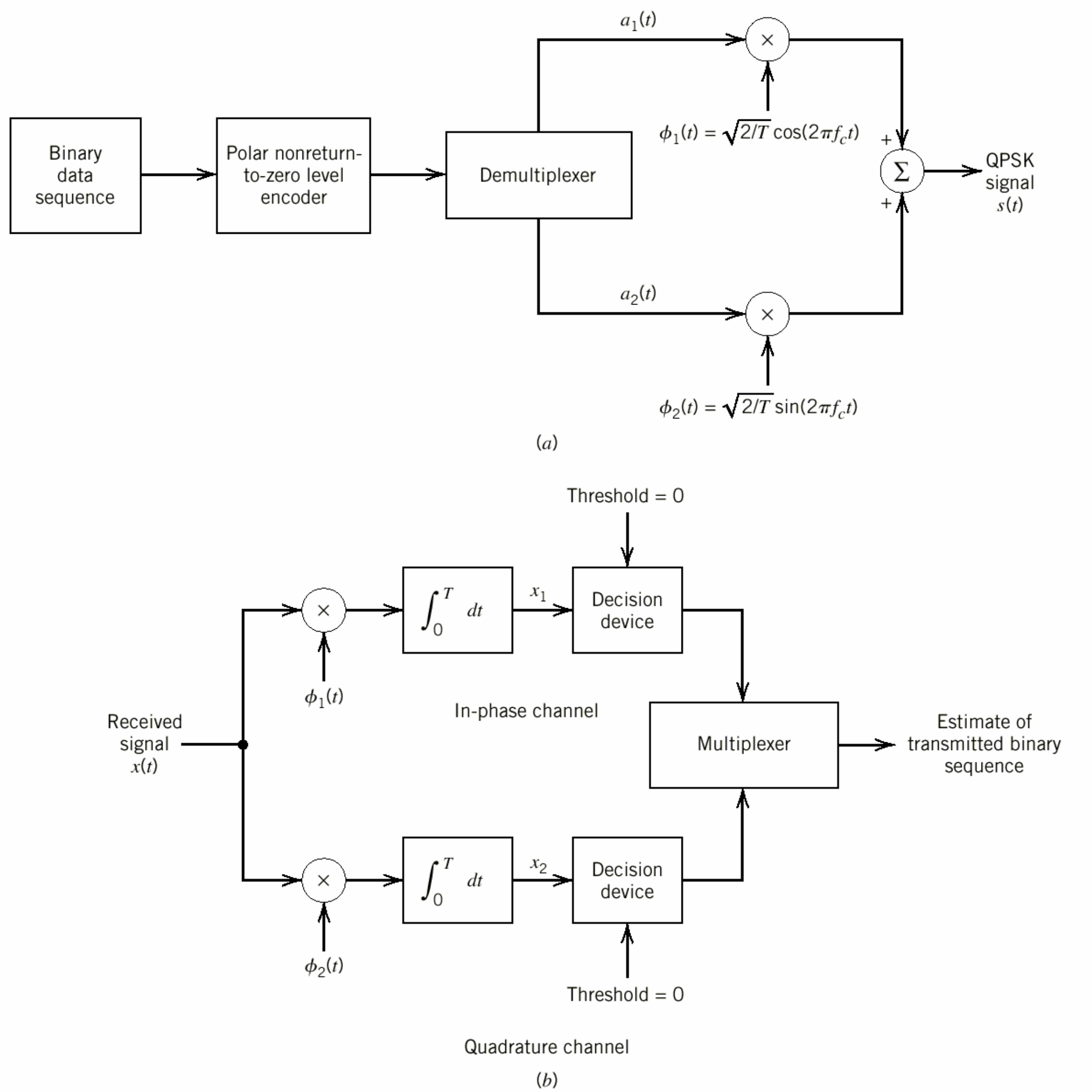

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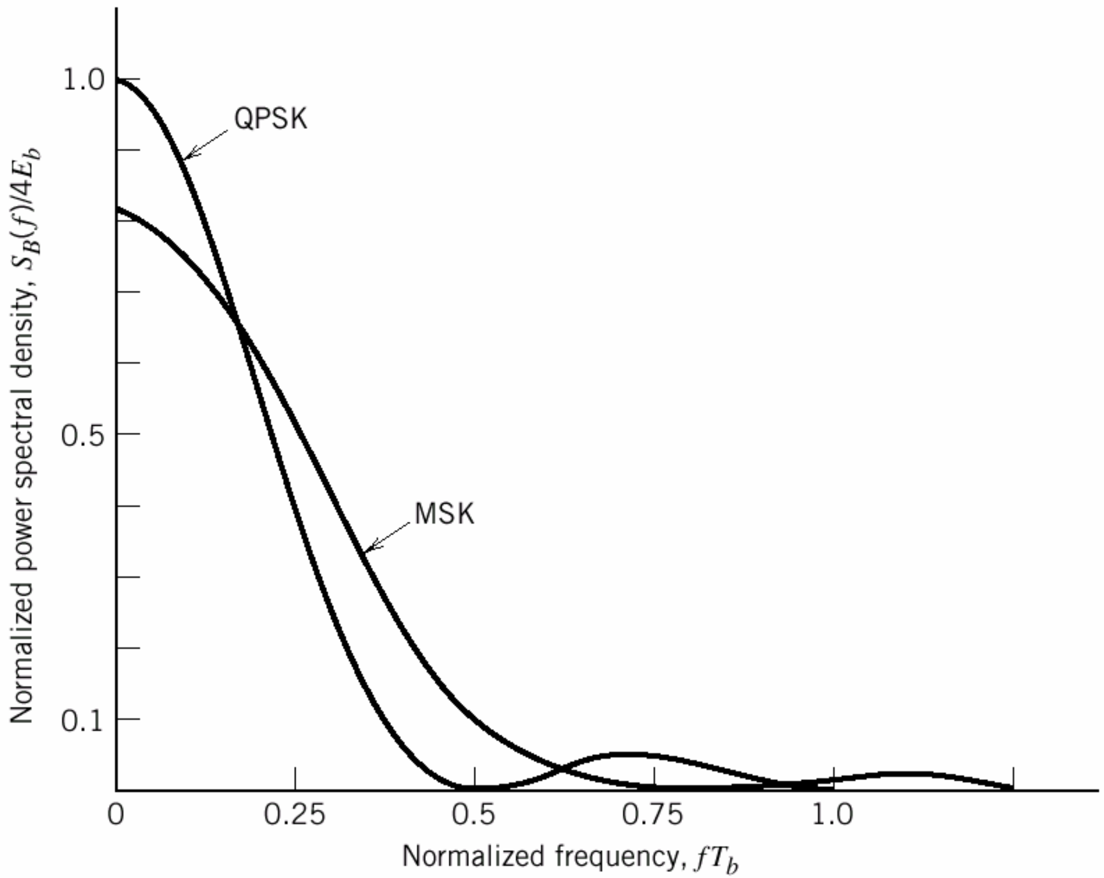
Figure 6.9

Power spectra of QPSK and MSK signals.



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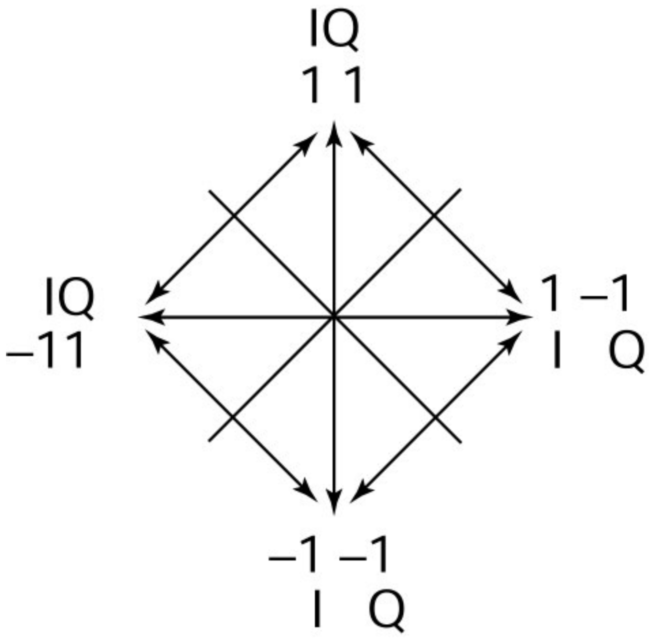
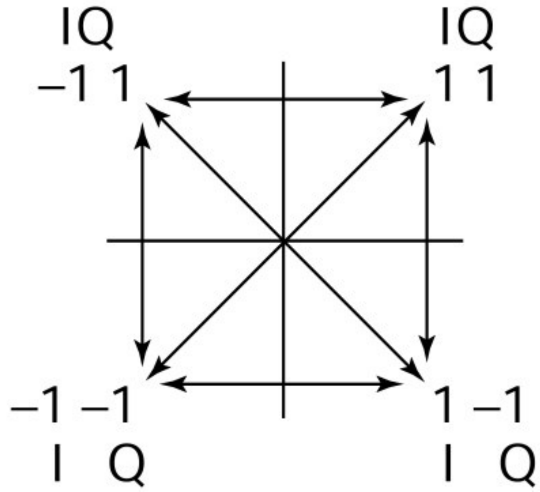


(*a*) QPSK



(*b*) QPSK (carrier shifted by π/4)

The two QPSK constellations. Note that they differ by $\pi/4$. When going from (1,1) to (-1, -1), the phase is shifted by π. When going from (1, -1) to (1,1), the phase shifts by $\pi/2$. Thus, depending on the incoming symbol, transitions from (1,1) can occur to (1,1), (1,-1), (-1, 1),
or (-1, -1) or vice versa, leading to phase shifts of 0, $\pm\pi/2$, or $\pm\pi$ in QPSK. I and Q represent the in-phase and quadrature bits, respectively. Arrows show all possible transitions.

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The pairing of bits to form symbols.

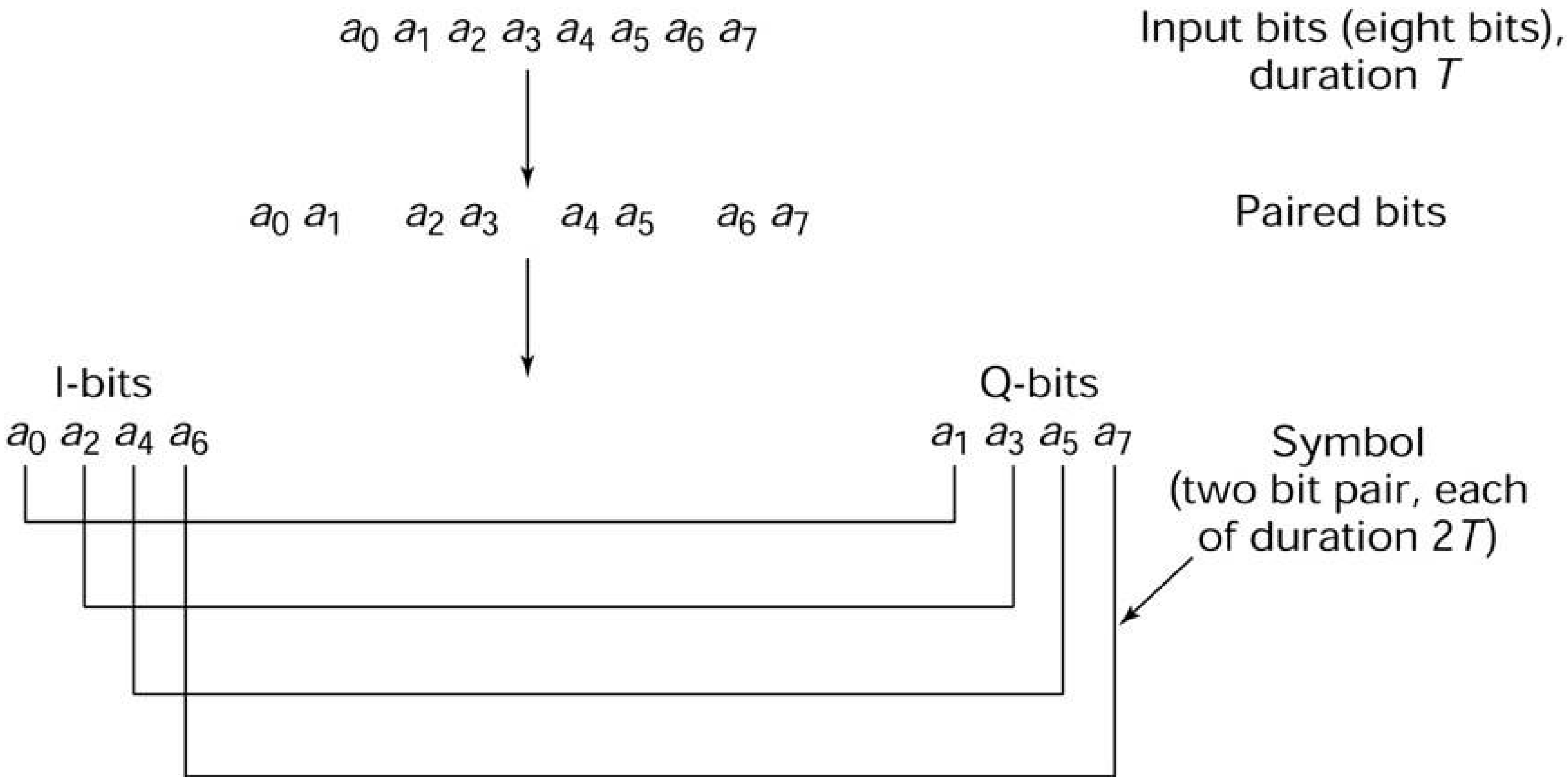

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Figure 3.36. Explanation of the phase shifts observed in QPSK, indicating the phases of the symbols and the phase difference between symbols.

What happens to the phase at intervals of $2T$ in QPSK?

Phases of the symbols: All possible combinations:

$1\ 1 \longrightarrow \pi/4 \qquad -1\ 1 \longrightarrow 3\pi/4 \qquad -1\ -1 \longrightarrow 5\pi/4 \qquad 1\ -1 \longrightarrow 7\pi/4$

The bit stream is 1 1 –1 –1 –1 1 1 1.

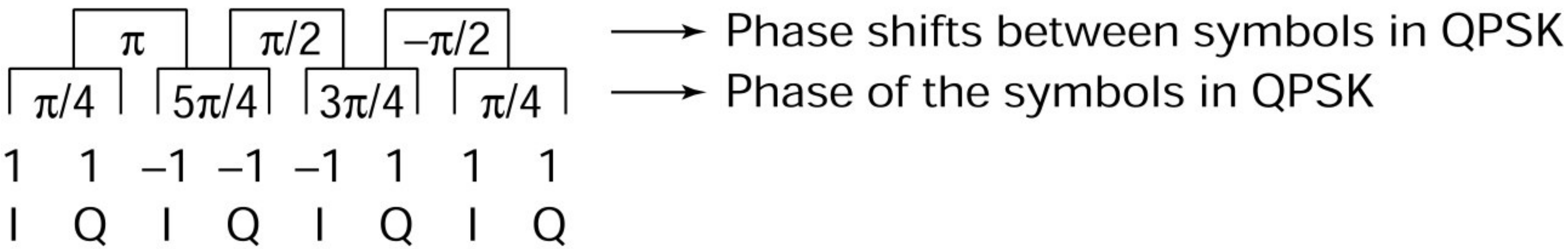

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Figure 3.37.
(*a*) QPSK transmitter. (*b*) QPSK receiver.

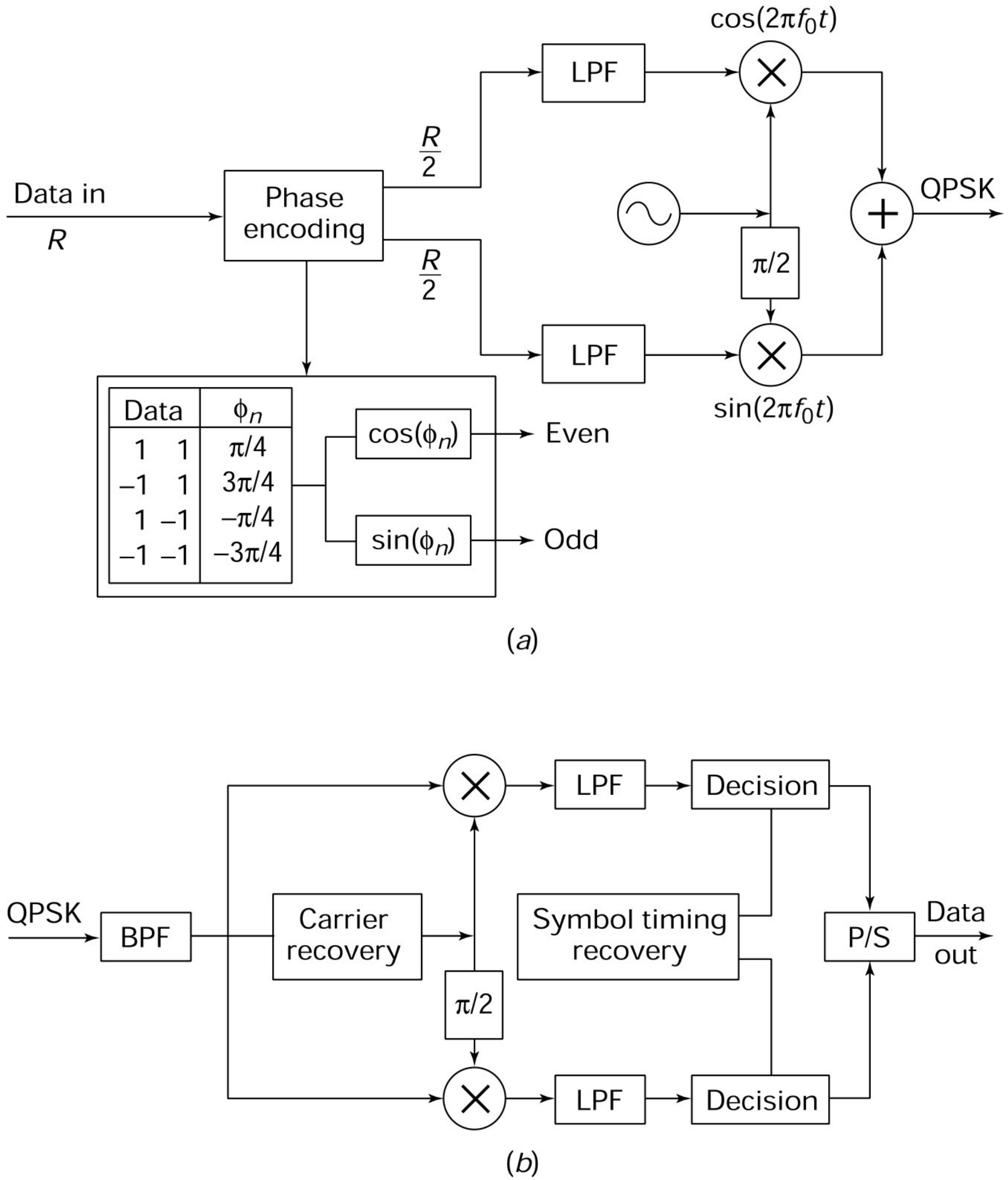

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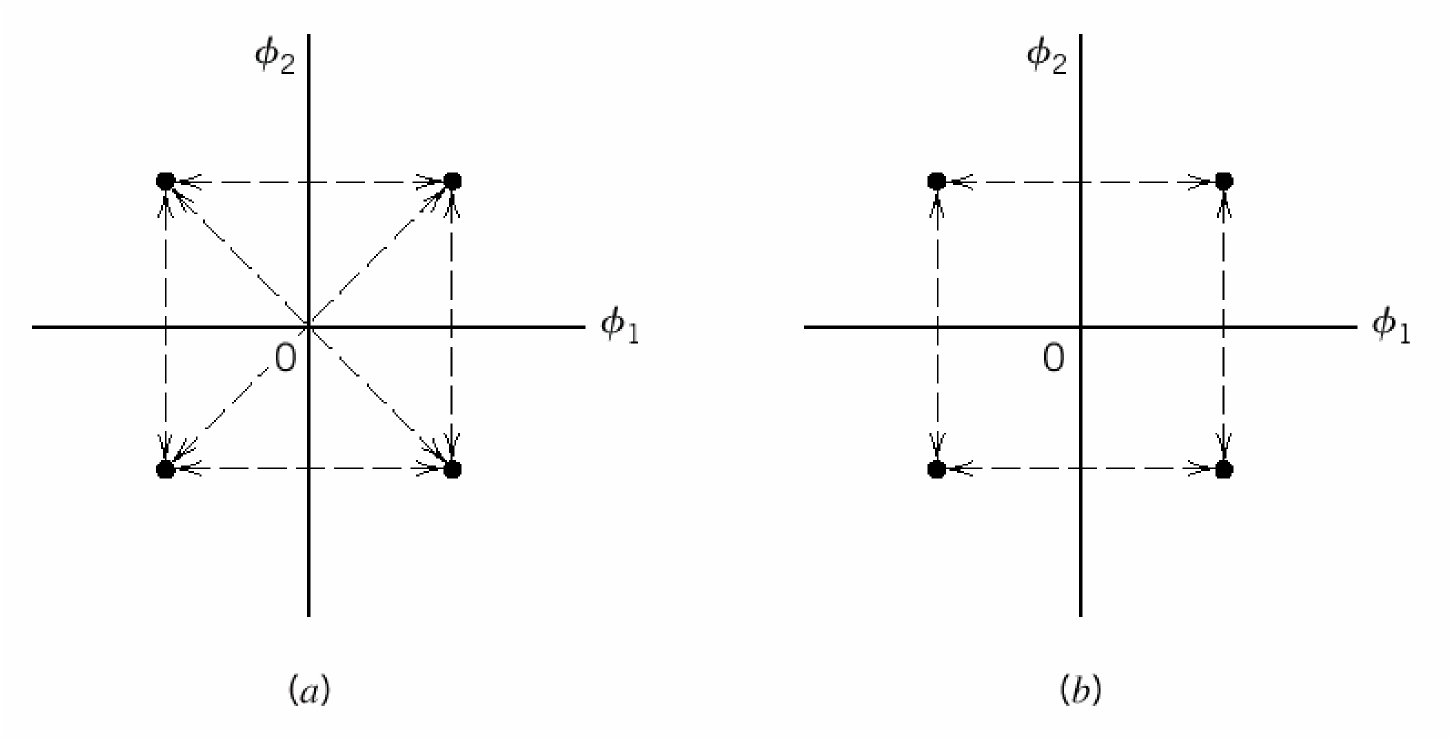
Figure 6.10

Possible paths for switching between the message points in (*a*) QPSK and (*b*) offset QPSK.



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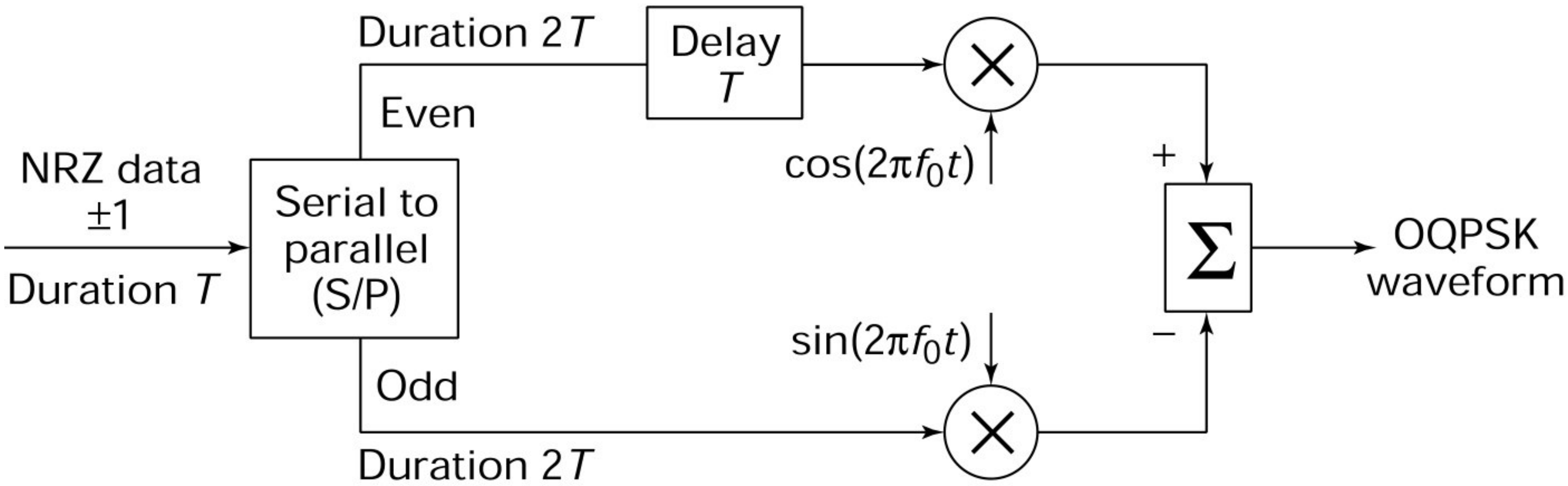
Block diagram of the OQPSK modulator.



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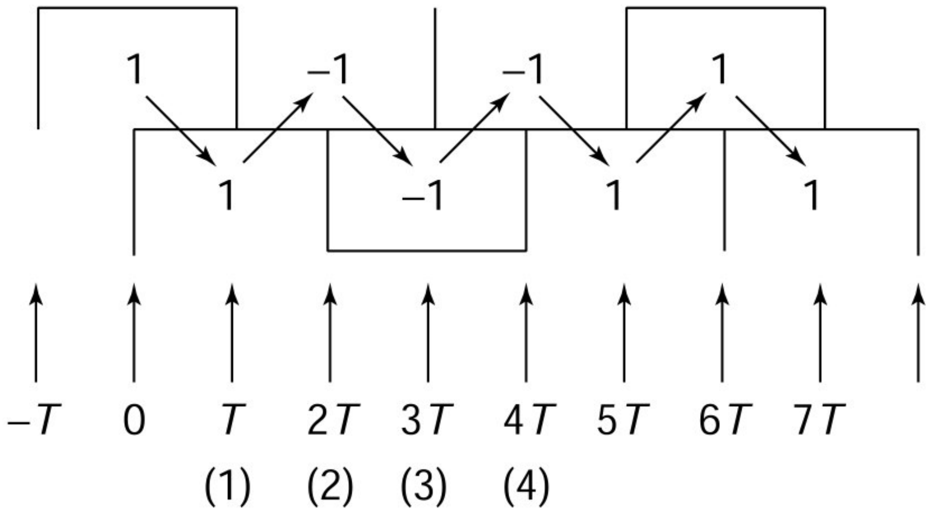
Explanation of the phase transitions in OQPSK.

What happens to the phase at intervals of T in OQPSK



At (1), the symbols are (1, 1) and (–1, 1): The phase change is $\pm\pi/2$.
At (2), the symbols are (–1, 1) and (–1, –1): The phase change is $\pm\pi/2$.
At (3), the symbols are (–1, –1) and (–1, –1): The phase change is 0.
At (4), the symbols are (–1, –1) and (–1, 1): The phase change is $\pm\pi/2$, and so on.
Thus in OQPSK, the phase changes are limited to 0 or $\pm\pi/2$.

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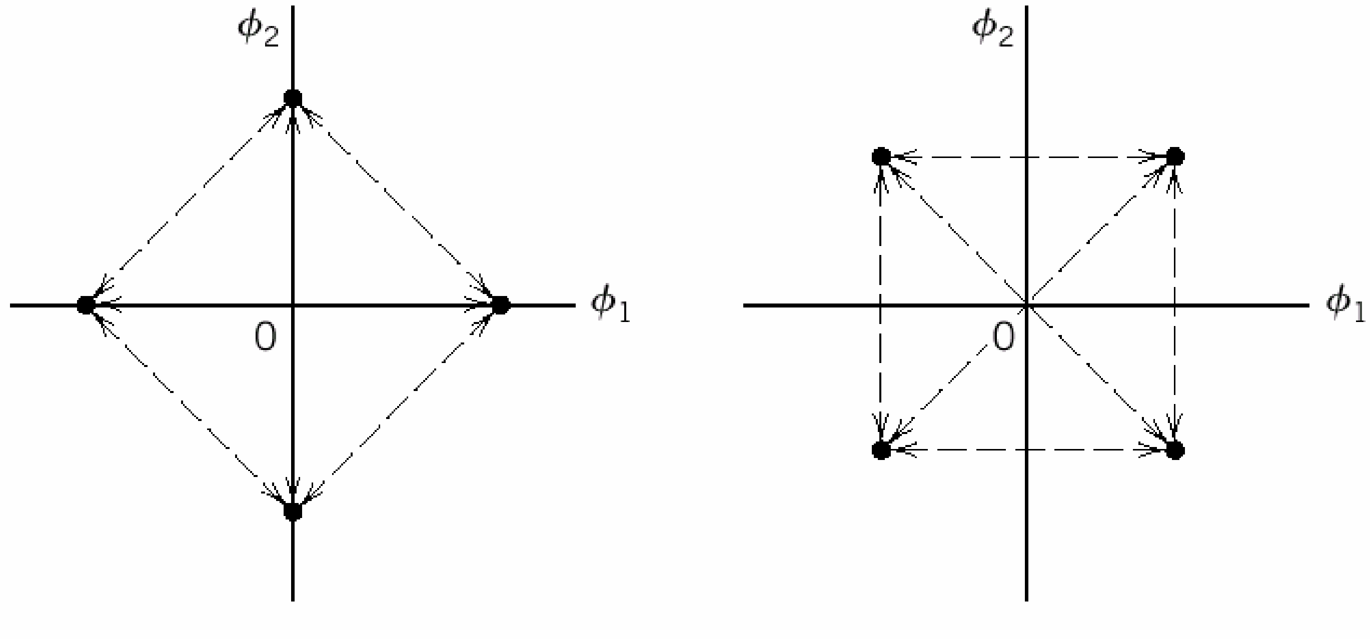
Figure 6.11

Two commonly used signal constellations of QPSK; the arrows indicate the paths along which the QPSK modulator can change its state.



(a) (b)

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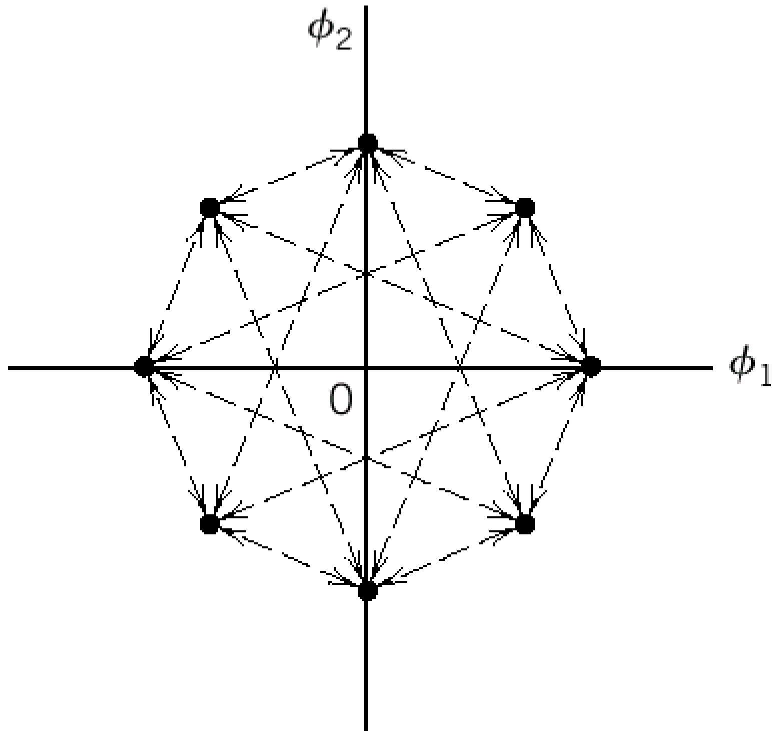
Figure 6.12

Eight possible phase states for the $\pi/4$-shifted QPSK modulator.



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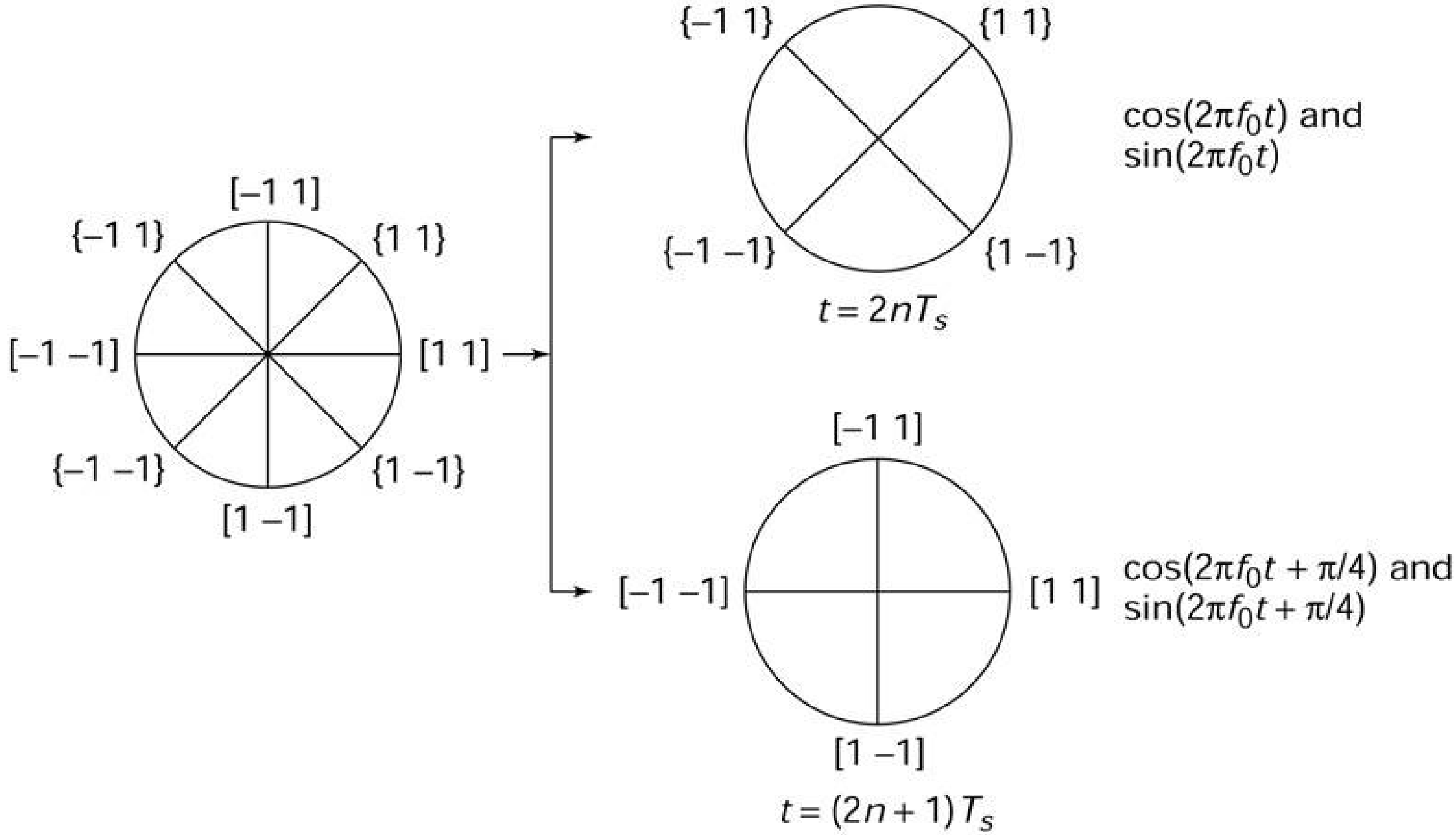
Phase encoding for π /4-QPSK. The brackets [ ] and { } correspond to the two respective constellations.



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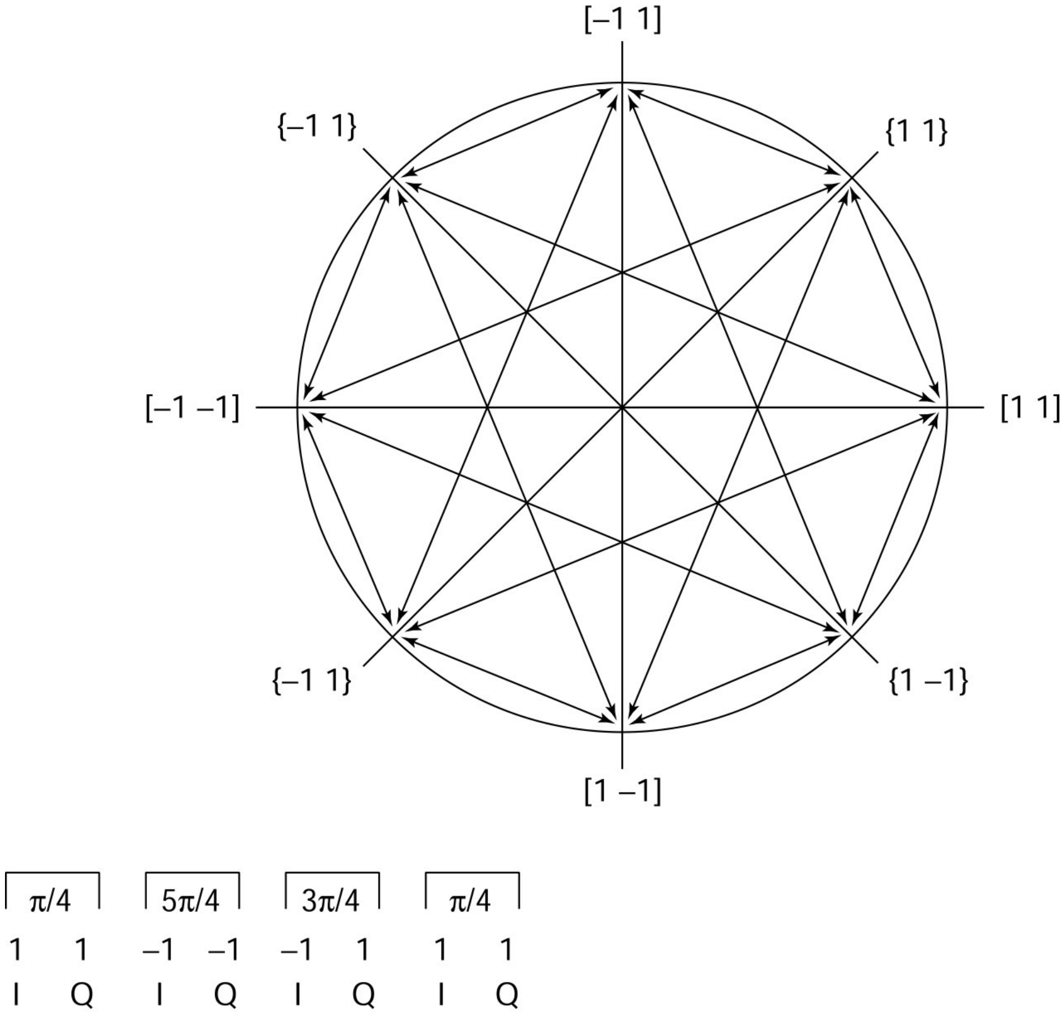
Details of the phase constellation associated with $\pi/4$-QPSK. For every alternate symbol, the carrier waves are changed. From (1,1) to (-1, -1), we go from [1 1] to {-1, -1}, or from {1,1} to [-1, -1], resulting in a phase change of $3\pi/4$, as opposed to $\pi/2$ in QPSK. In QPSK we can go from [1, 1] to [-1, -1] or from {1 1} to {-1, -1}, resulting in a phase change of $\pm\pi$. Also, when we go from (1, 1) to (1, 1) in $\pi/4$-QPSK, we go from [1, 1] to {1, 1}, resulting in a phase change of $\pi/4$. The phase changes in $\pi/4$-QPSK are limited to $\pm 3\pi/4$ or $\pm\pi/4$. There are no phase changes of 0, $\pm\pi/2$, or $\pm\pi$. All the possible transitions are shown by arrows.



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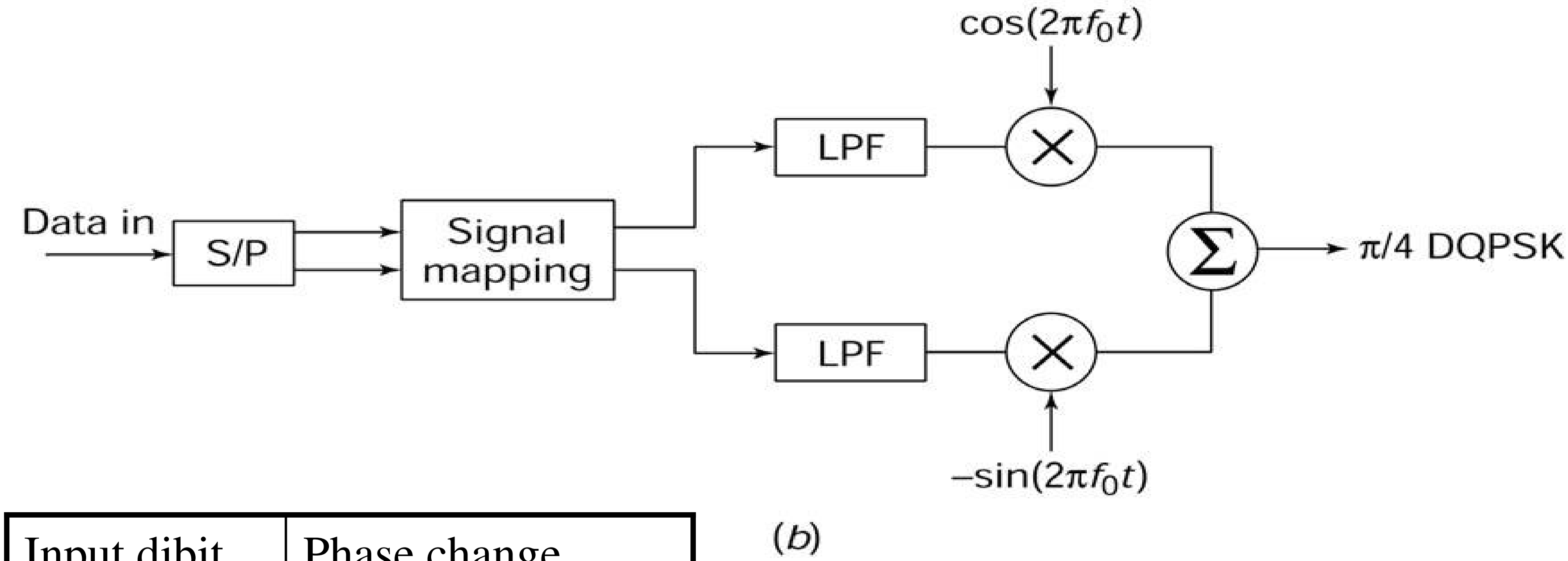
Block diagram of the π /4-DQPSK transmitter.



Input dibit	Phase change
00	Pi/4
01	3pi/4
11	-3pi/4
10	-pi/4

$$\vartheta_k = \vartheta_{k-1} + \Delta$$

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Figure 6.13

Block diagram of the $\pi/4$-shifted DQPSK detector.

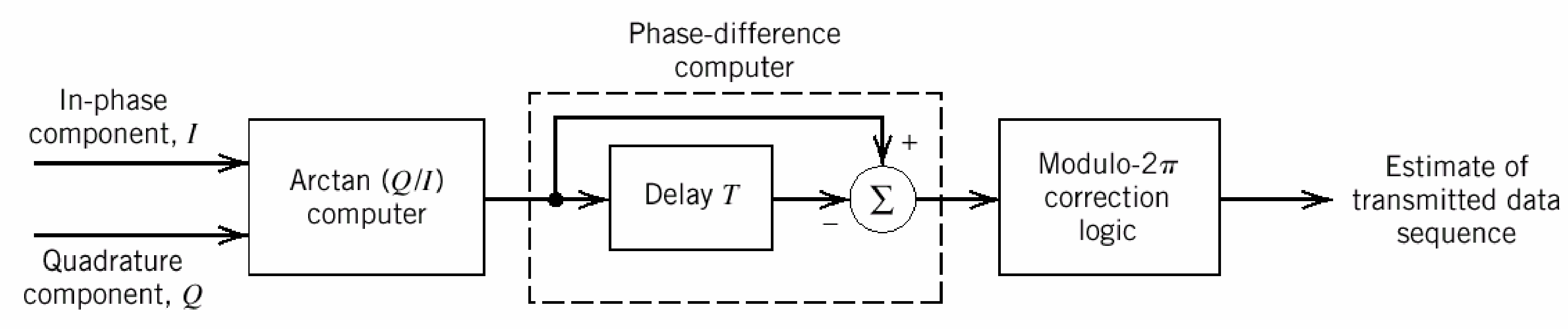

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Figure 6.14

Illustrating the possibility of phase angles wrapping around the positive real axis.

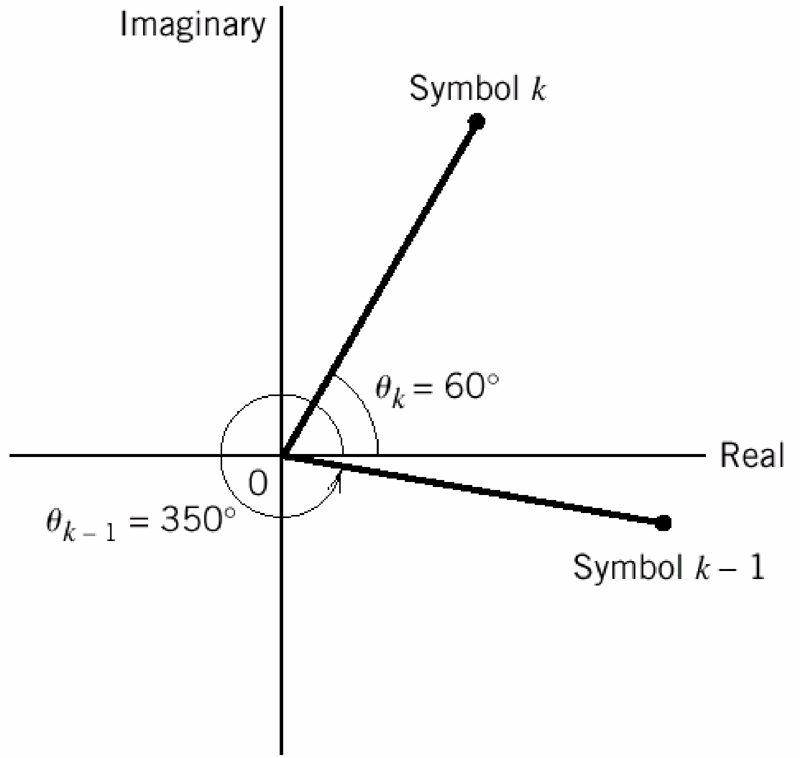

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Figure 6.15

(*a*) Signal-space diagram for octaphase-shift keying (i.e., $M = 8$). The decision boundaries are shown as dashed lines. (*b*) Signal-space diagram illustrating the application of the union bound for octaphase-shift keying.

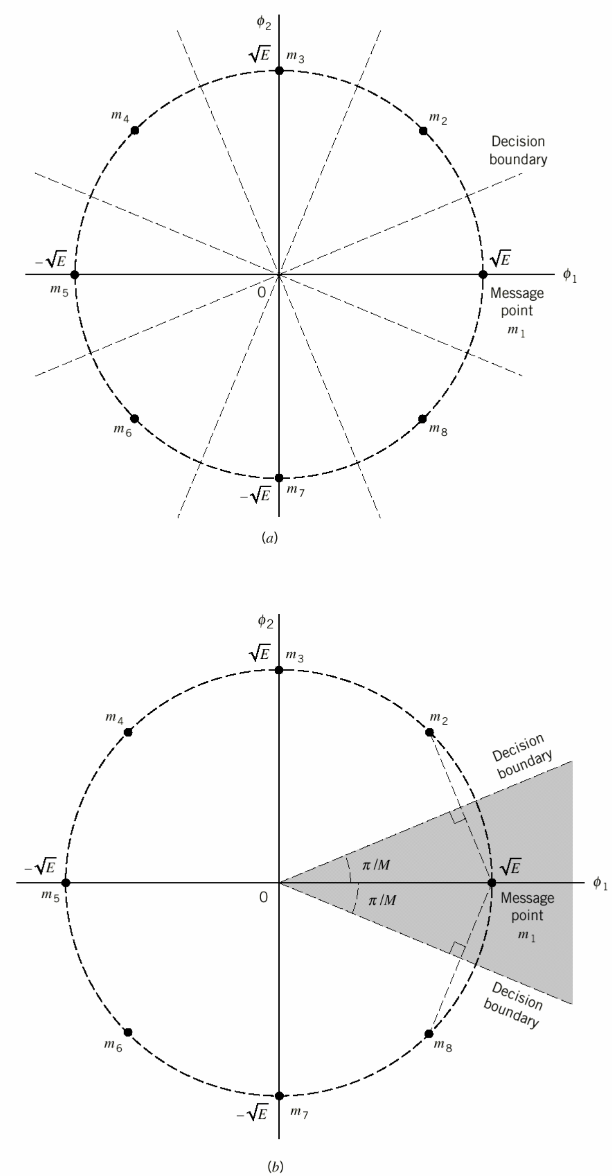

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Figure 6.16

Power spectra of *M*-ary PSK signals for M = 2, 4, 8.

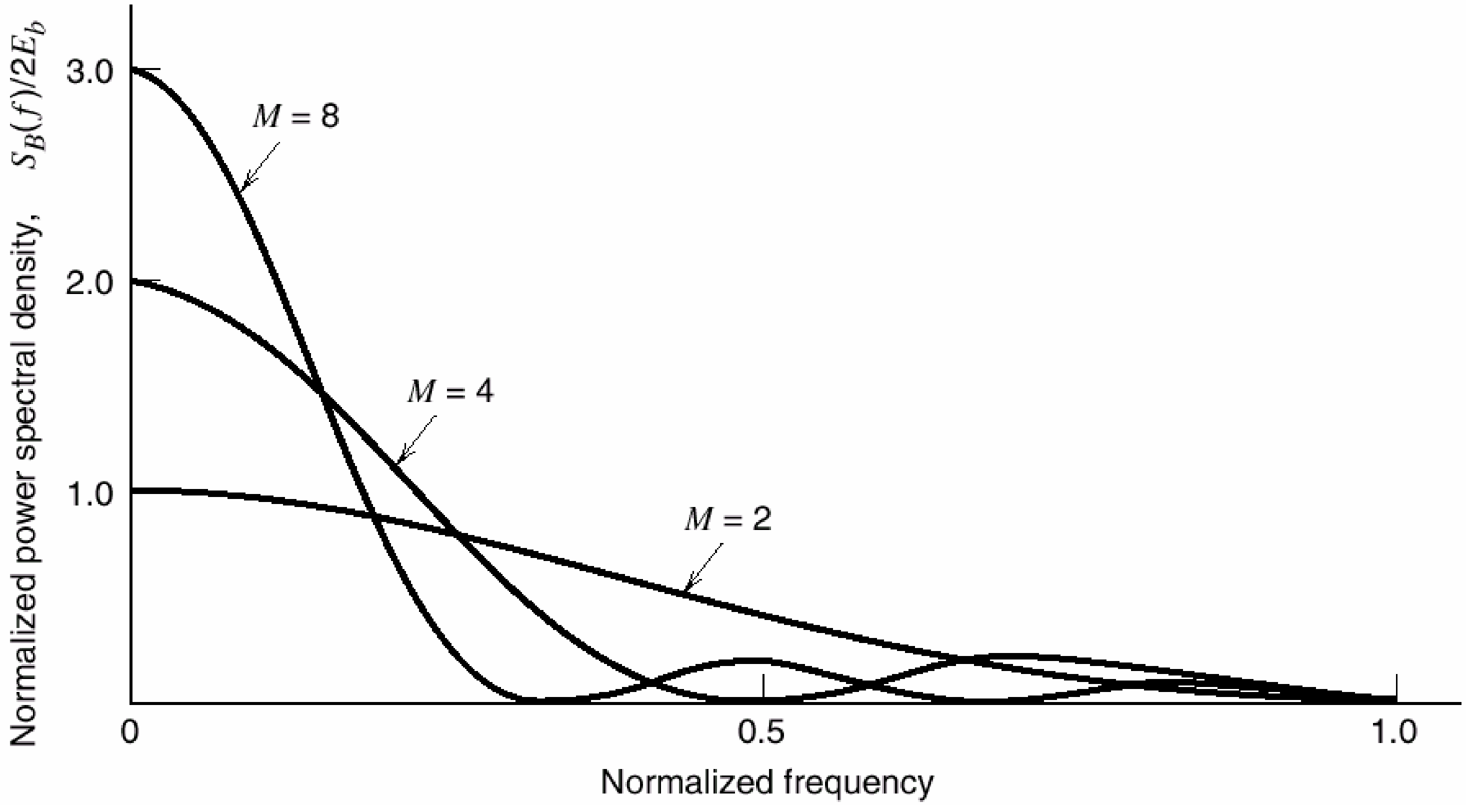

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Figure 6.17

(*a*) Signal-space diagram of *M*-ary QAM for M = 16; the message points in each quadrant are identified with Gray-encoded quadbits. (*b*) Signal-space diagram of the corresponding 4-PAM signal.

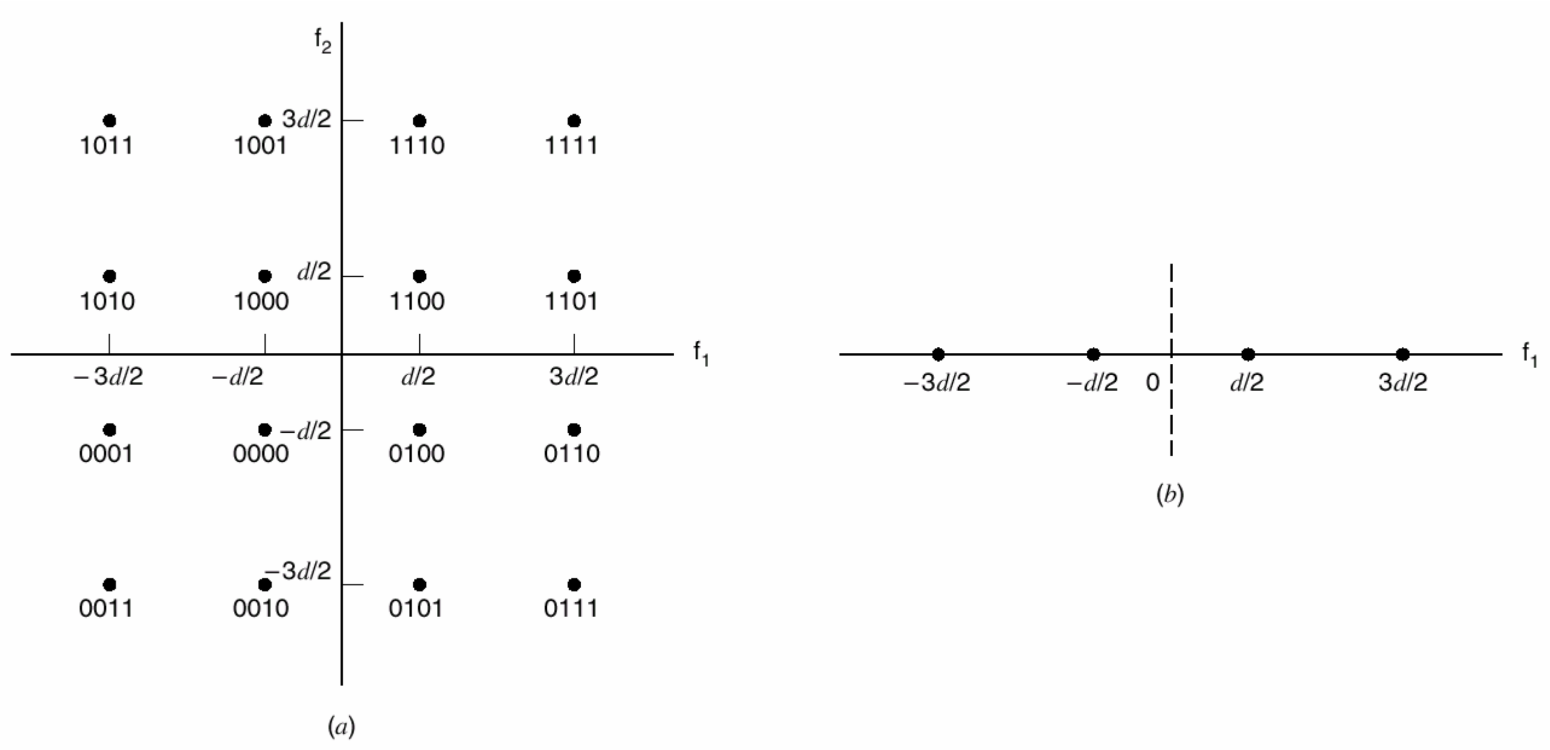

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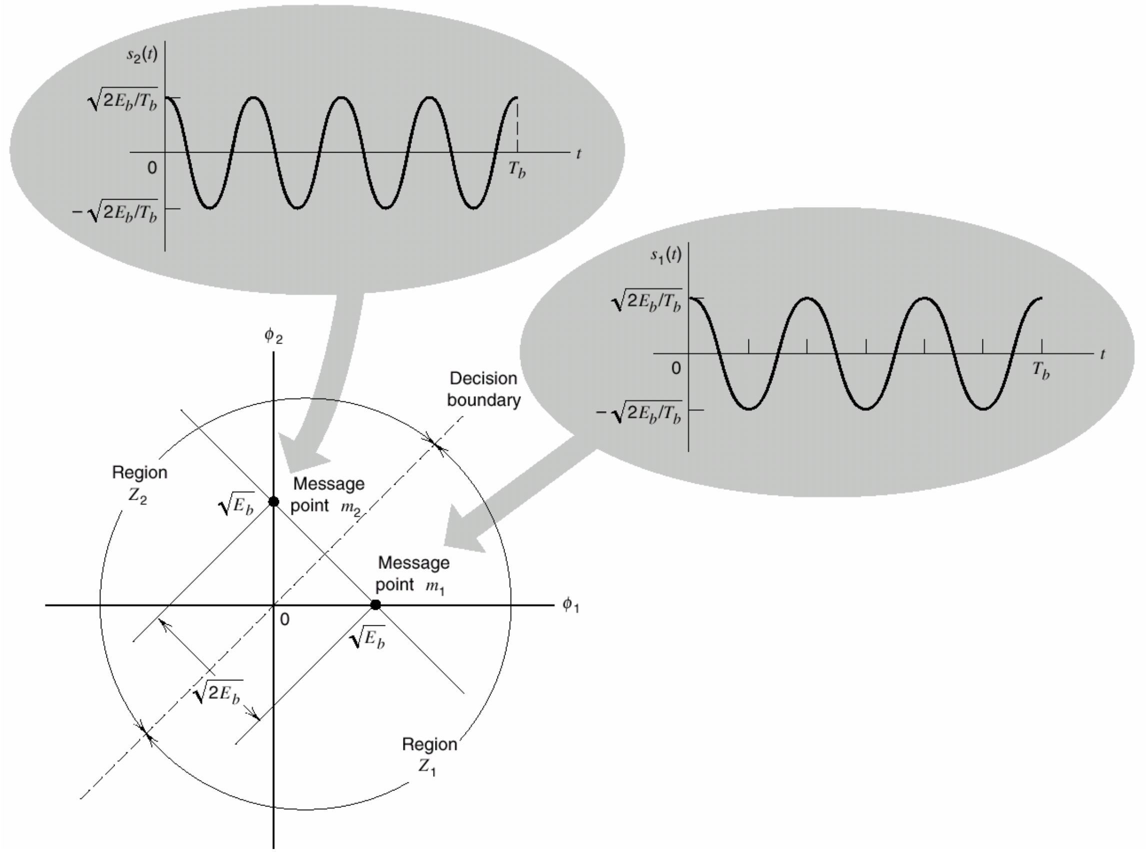
Figure 6.25

Signal-space diagram for binary FSK system. The diagram also includes two inserts showing example waveforms of the two modulated signals $s_1(t)$ and $s_2(t)$.



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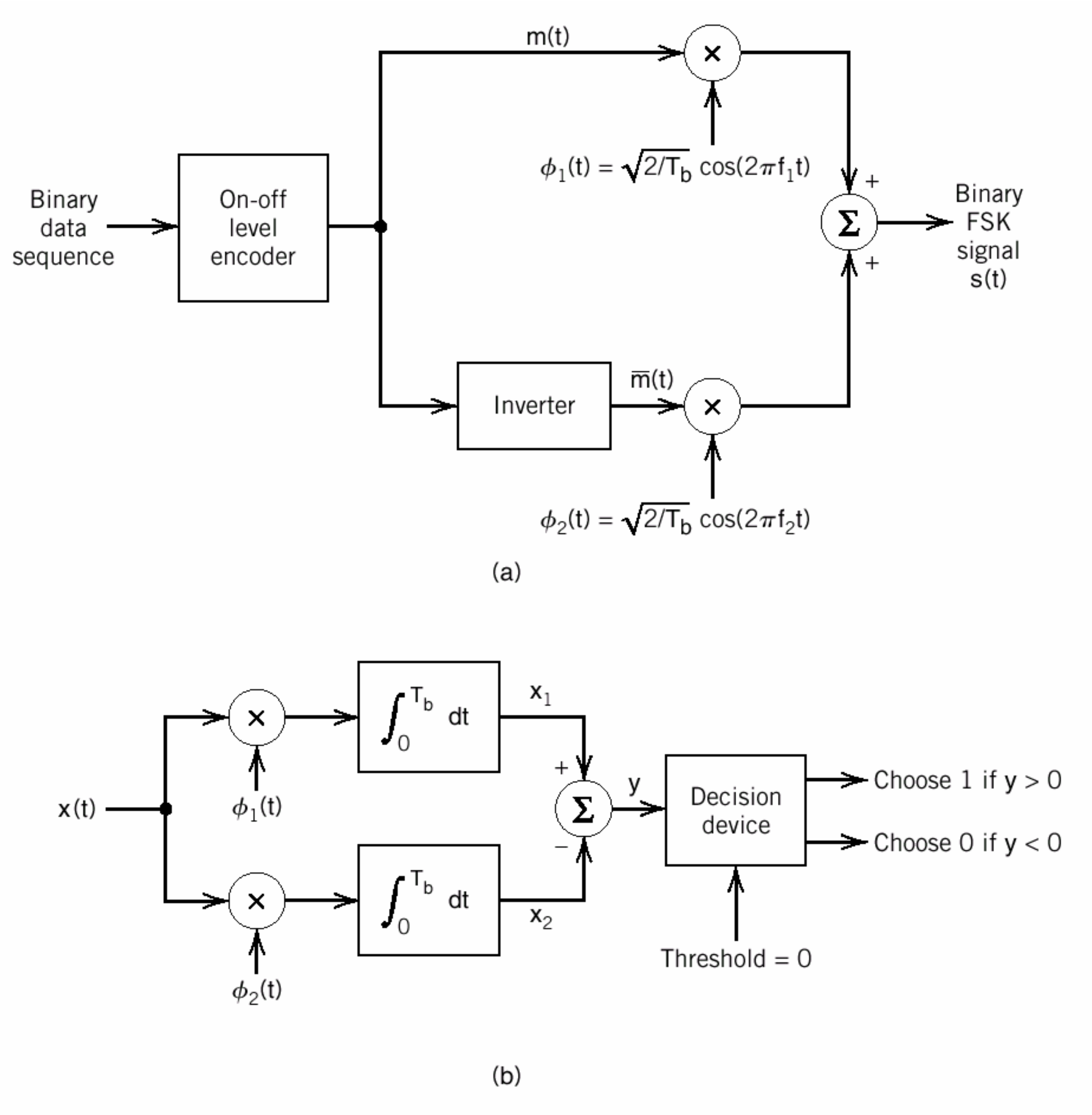

Figure 6.26

Block diagrams for (*a*) binary FSK transmitter and (*b*) coherent binary FSK receiver.

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Figure 6.27

Phase tree of CFM.

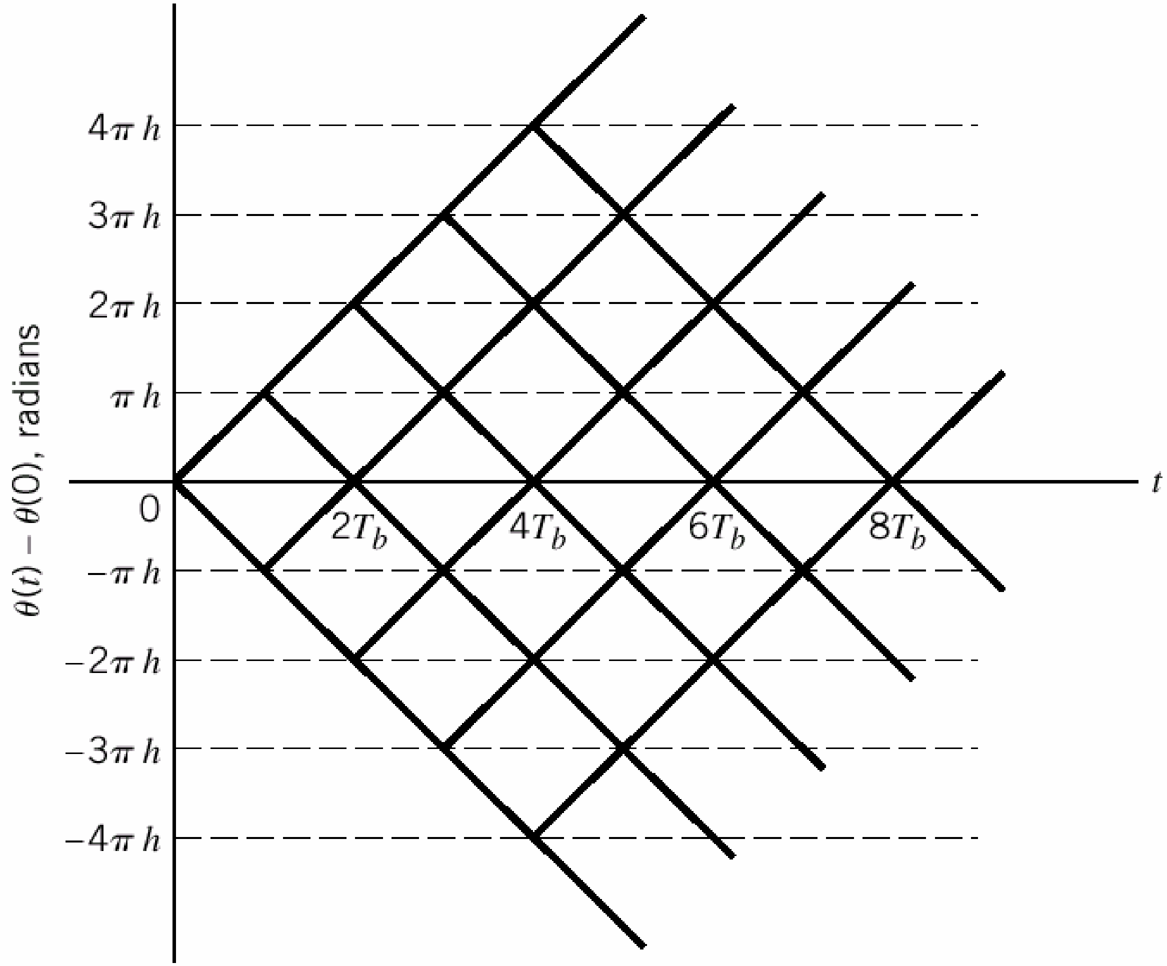

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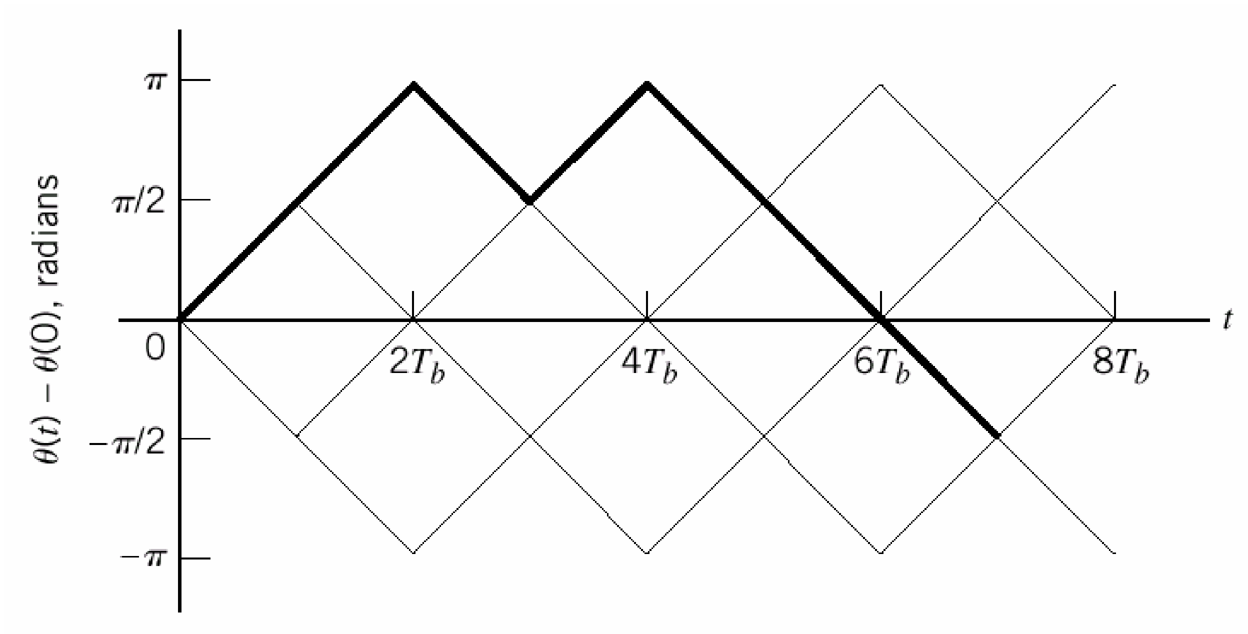
Figure 6.28

Phase trellis; boldfaced path represents the sequence 1101000.



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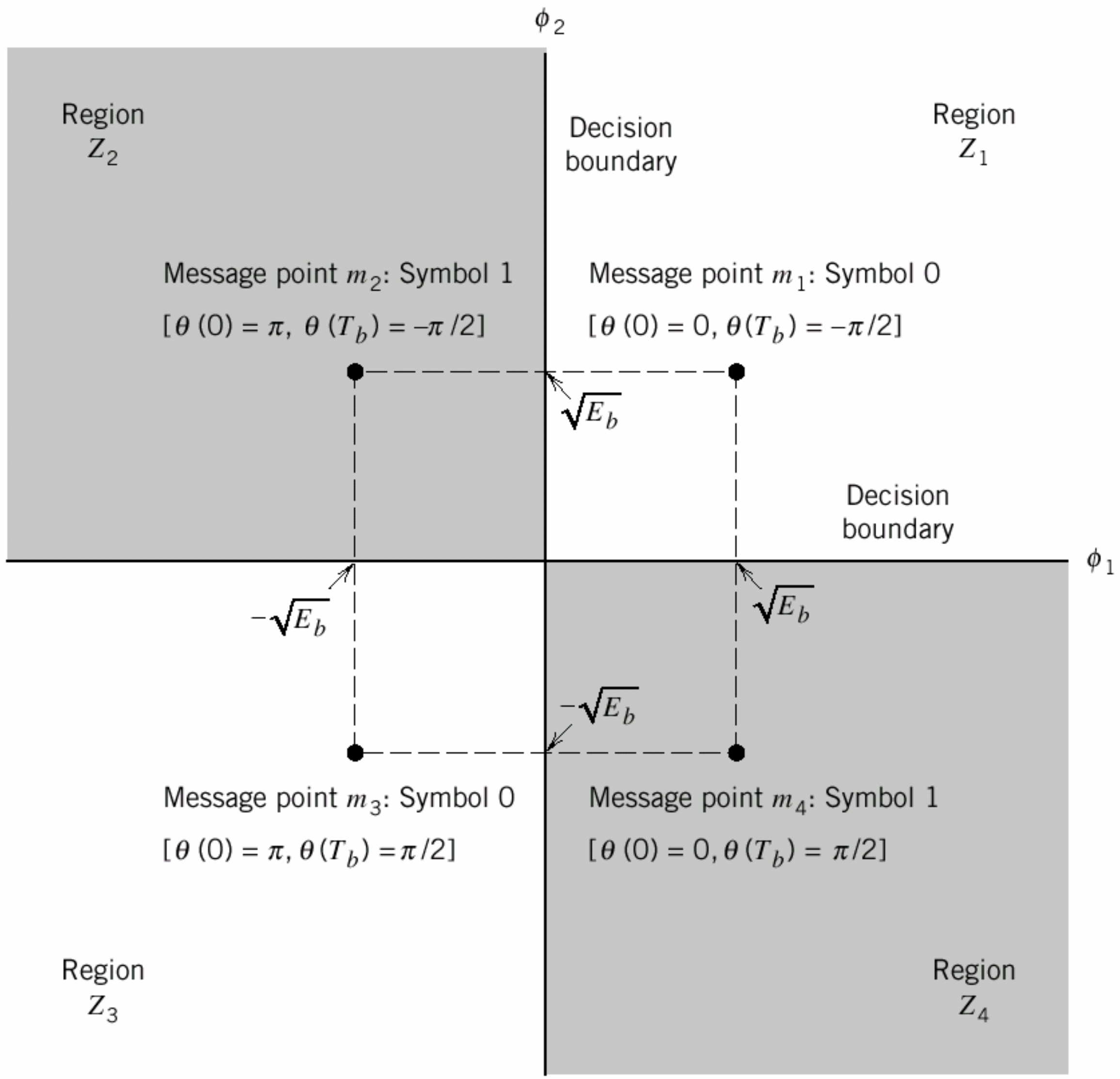

Figure 6.29
Signal-space diagram for MSK system.

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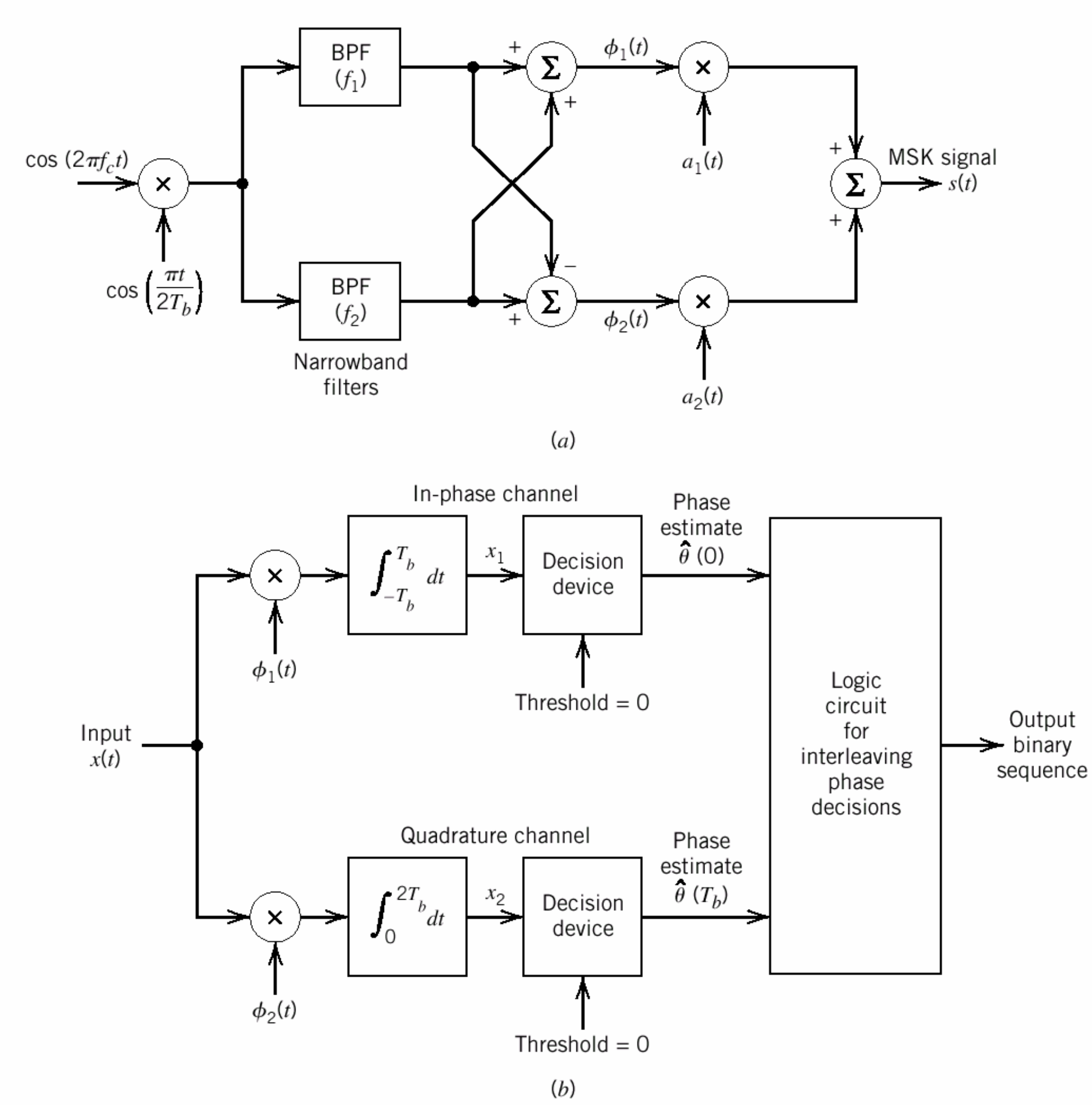

Figure 6.31

Block diagrams for (*a*) MSK transmitter and (*b*) coherent MSK receiver.

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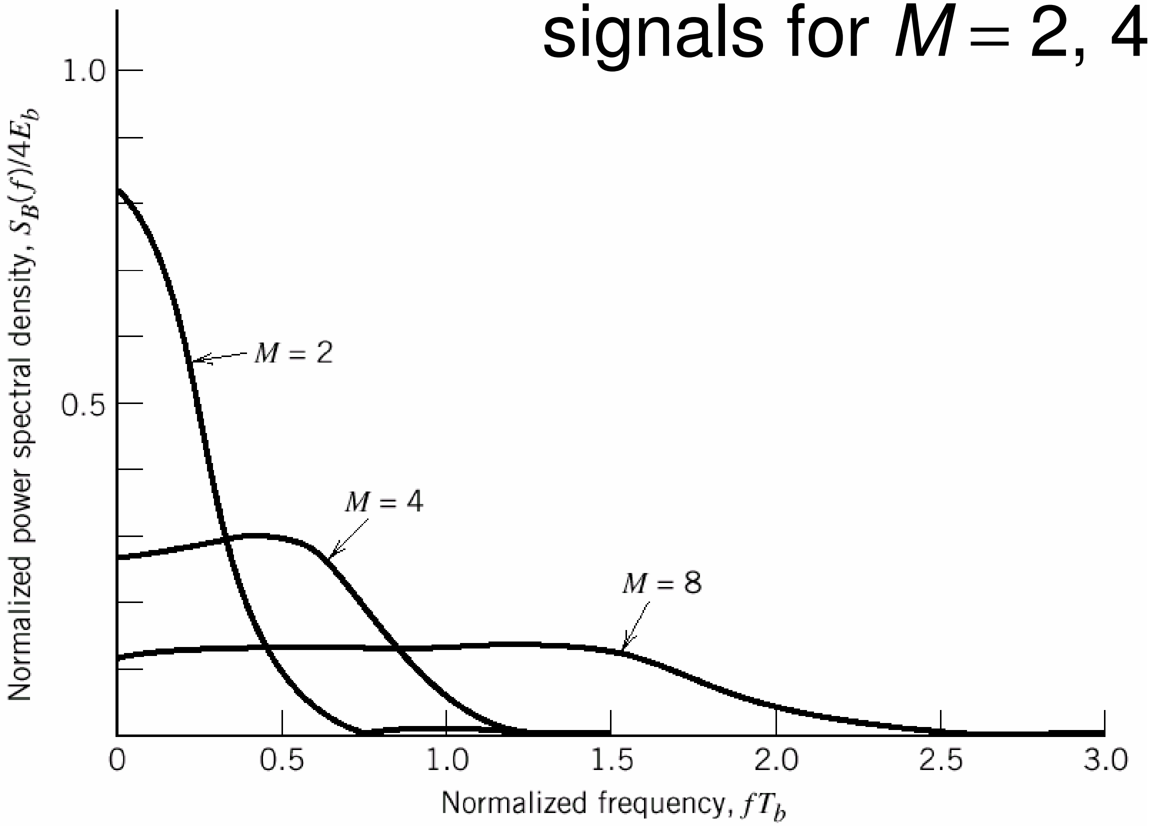
Figure 6.36

Power spectra of *M*-ary FSK signals for $M = 2, 4, 8$.



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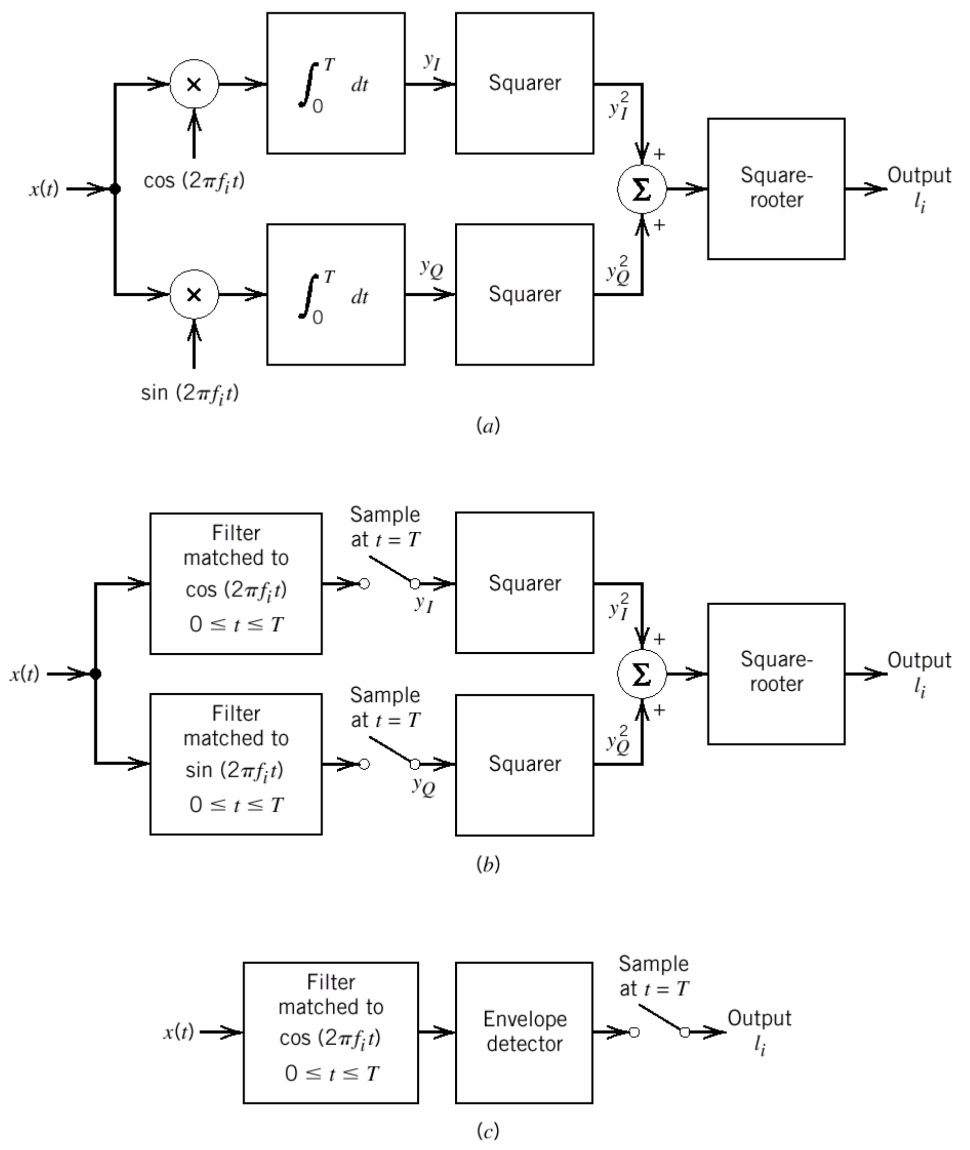

Figure 6.37

Noncoherent receivers.
(*a*) Quadrature receiver using correlators.
(*b*) Quadrature receiver using matched filters.
(*c*) Noncoherent matched filter.

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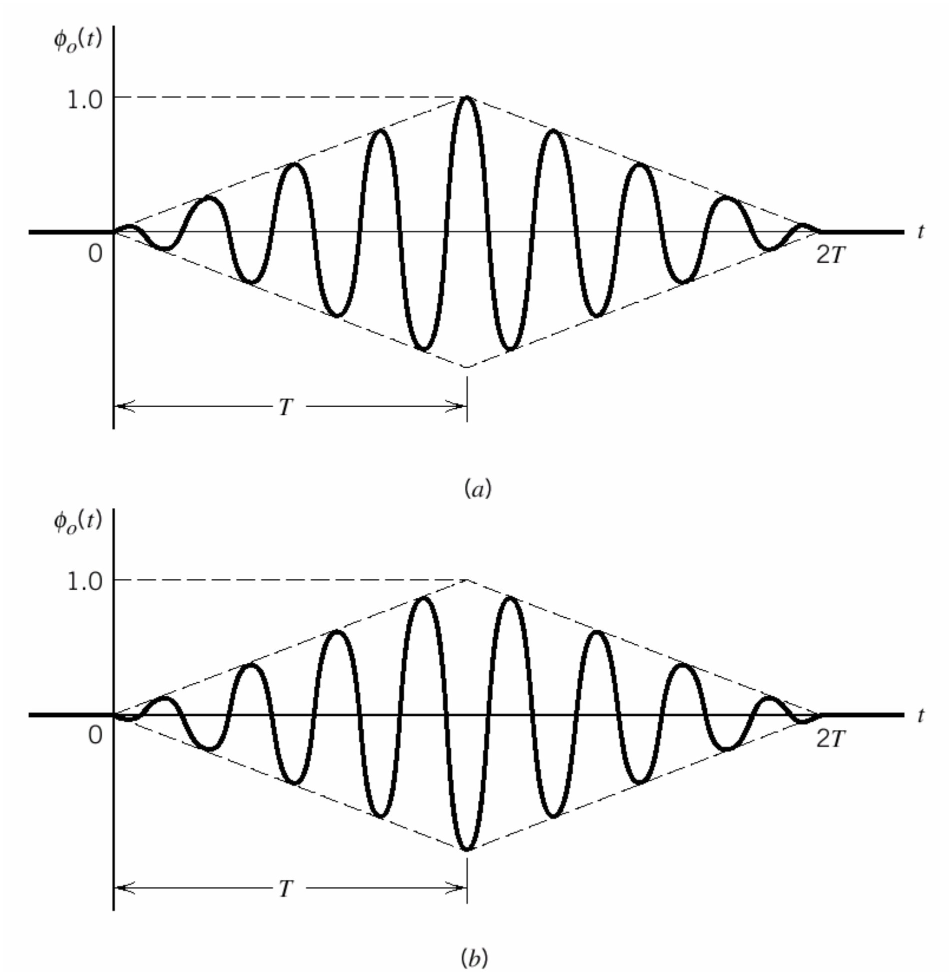

Figure 6.38
Output of matched filter for a rectangular RF wave: (*a*) $\theta = 0$, and (*b*) $\theta = 180$ degrees.

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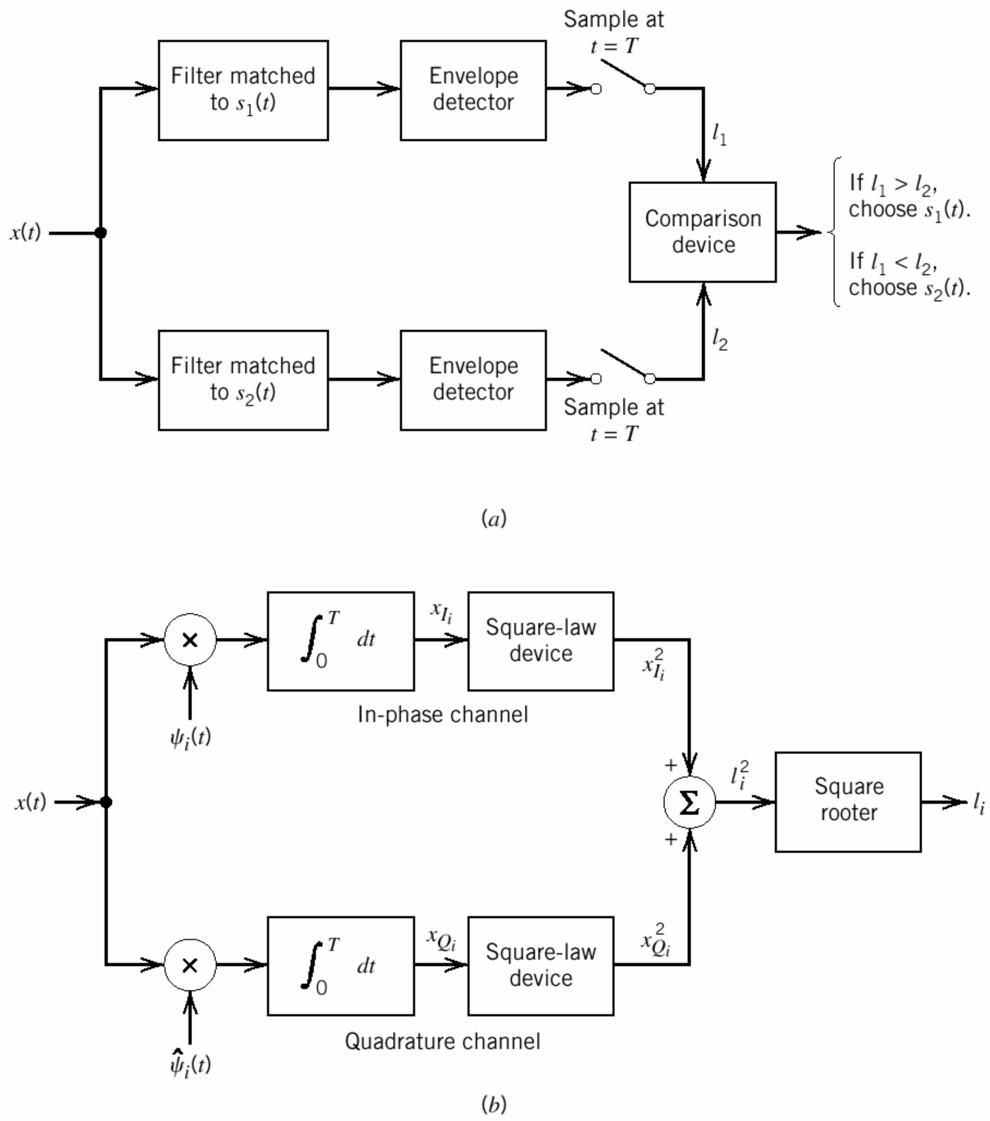

Figure 6.39

(*a*) Generalized binary receiver for noncoherent orthogonal modulation. (*b*) Quadrature receiver equivalent to either one of the two matched filters in part (a); the index $i = 1, 2$.

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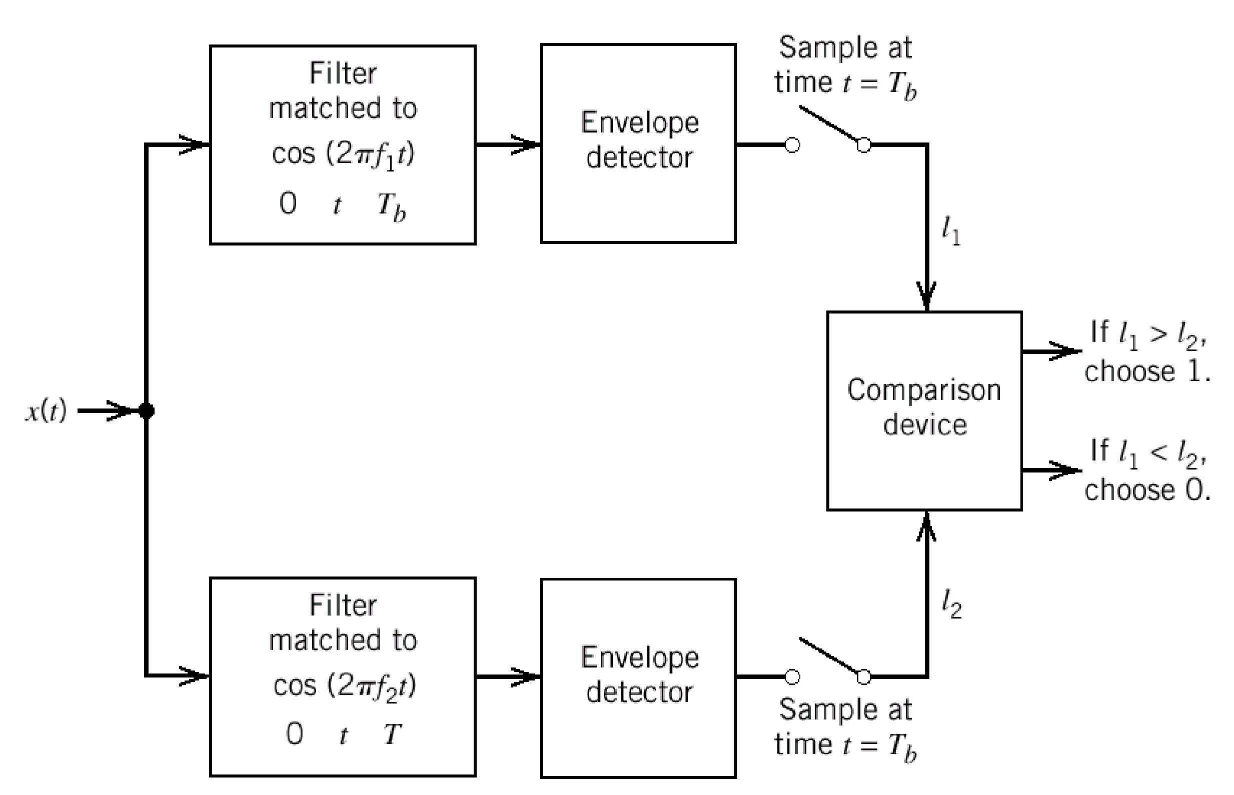
Figure 6.42

Noncoherent receiver for the detection of binary FSK signals.



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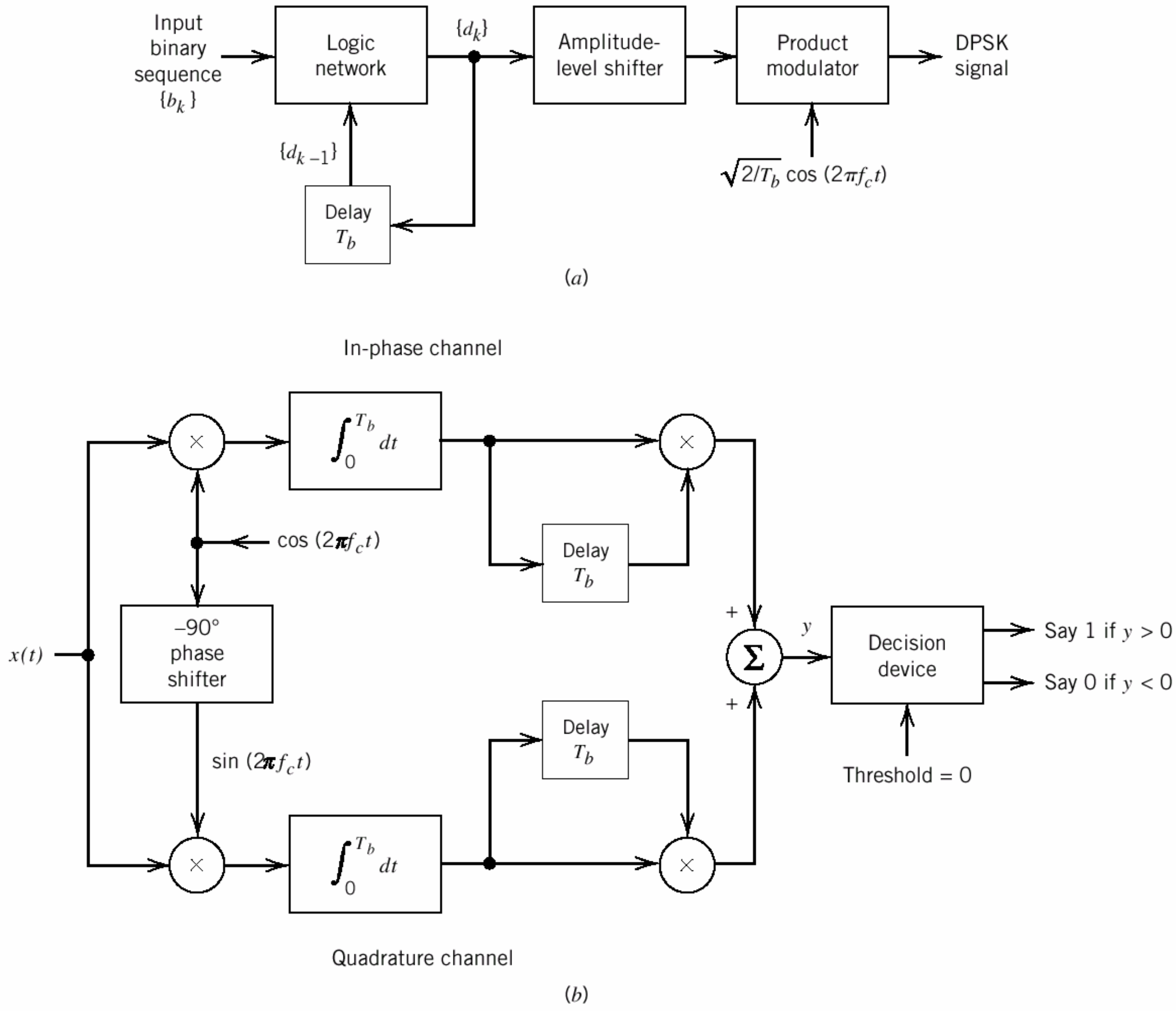

Figure 6.43

Block diagrams of (*a*) DPSK transmitter and (*b*) DPSK receiver.

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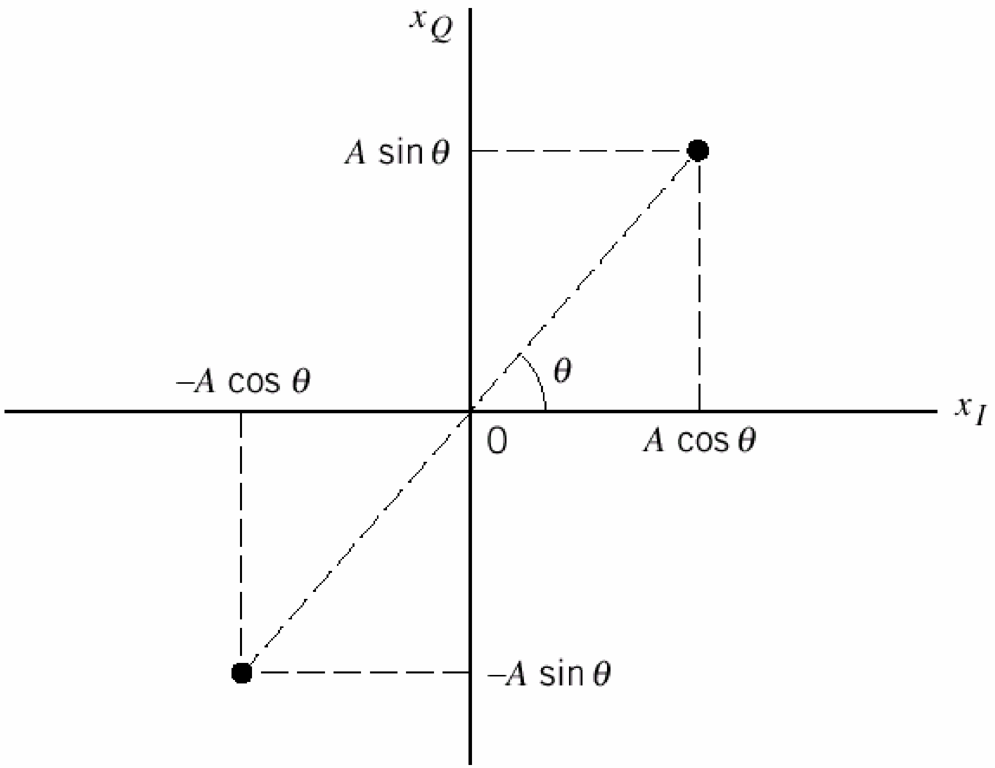
Figure 6.44

Signal-space diagram of received DPSK signal.



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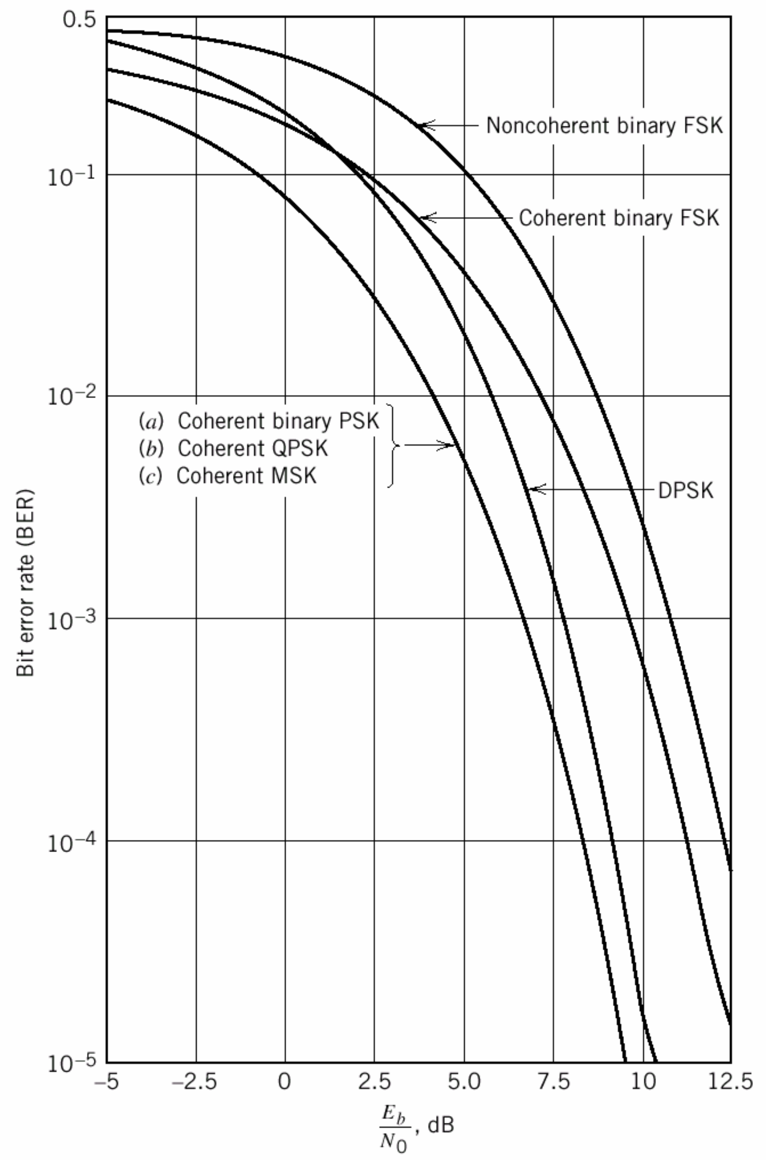

Figure 6.45

Comparison of the noise performance of different PSK and FSK schemes.

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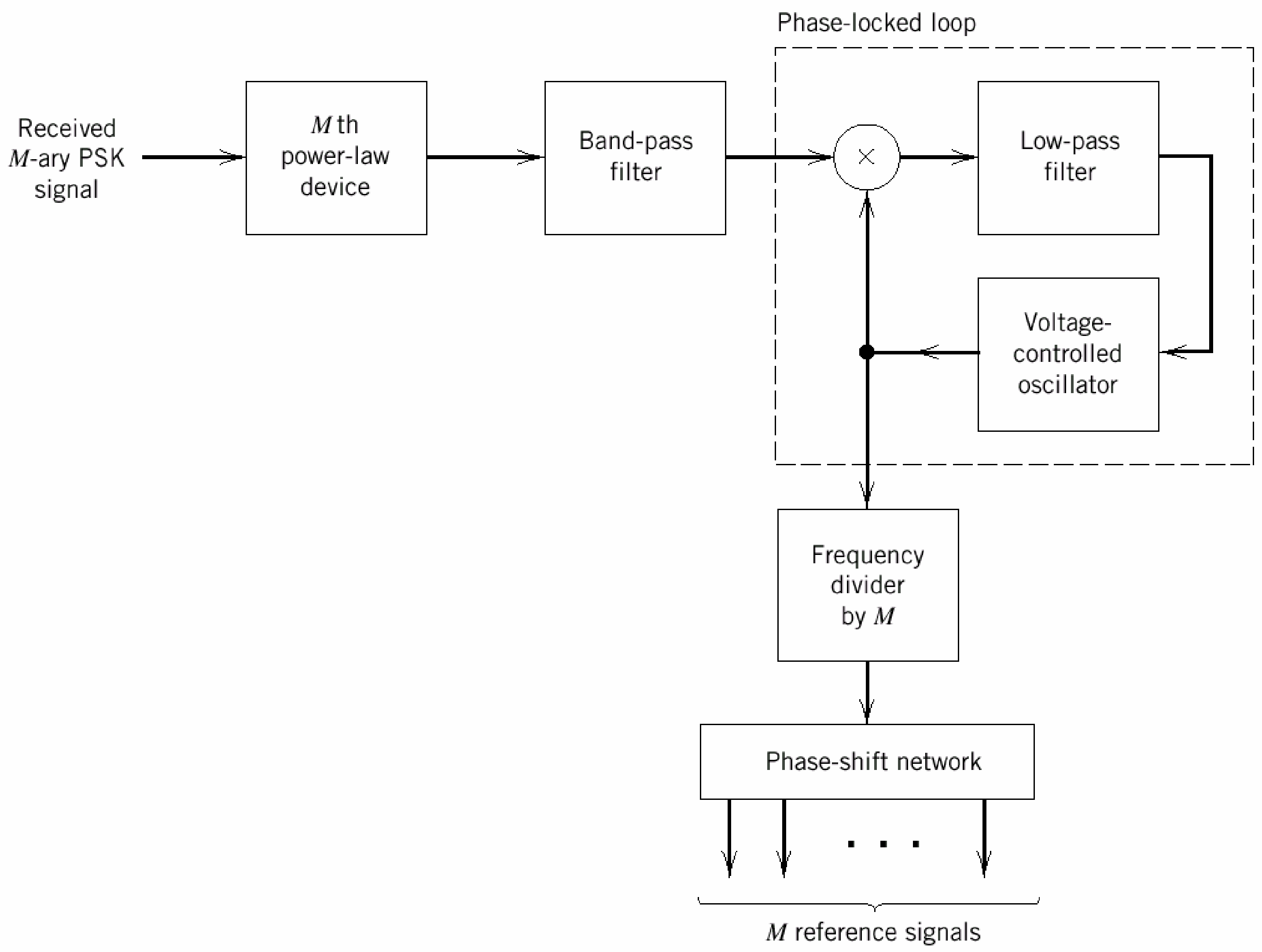

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