

EEE 461 Communication Systems II

Lecture Presentation 2

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👉 5.10: Multilevel Modulated Bandpass Signaling

In the last lecture we discussed bandpass digital modulation:

The binary and multilevel signals for ASK modulation are shown in Fig. 2.

The binary signals for PSK modulation are shown in Fig. 3.

With **multilevel signaling** digital inputs with more than two levels are allowed on the transmitter input.

Multilevel signals can be generated by using a digital-to-analog converter (DAC).

➔ MPSK

If the transmitter is a PM (phase modulation) transmitter with M -level digital modulation signal, M -ary phase shift keying (MPSK) is generated.

The complex envelope is given by

$$g(t) = A_c e^{j\theta(t)}.$$

The phase $\theta(t)$ is permitted to have only M values.

For example DAC values of $-3V$, $-1V$, $+1V$ and $+3V$ correspond to PSK phases of 0° , 90° , 180° and 270° respectively.

When $M = 4$, we have the resulting signaling is called QPSK (Quadrature phase-shift-keyed).

MPSK can also be generated using two quadrature carriers modulated by the x and y components of the complex envelope:

$$g(t) = A_c e^{j\theta(t)} = x(t) + jy(t)$$

where the permitted values of x and y are

$$x_i = A_c \cos \theta_i$$

and

$$y_i = A_c \sin \theta_i$$

for the permitted phase angles of $\theta_i, i = 1, 2, \dots, M$.

➡ Quadrature Amplitude Modulation (QAM)

QAM signal constellations are not restricted to having signaling points only on a circle of radius A_c (This is unlike MPSK).

The general QAM signal is

$$s(t) = x(t) \cos \omega_c t - y(t) \sin \omega_c t$$

where the complex envelope is

$$g(t) = x(t) + jy(t) = R(t)e^{j\theta(t)}$$

➡ OQPSK and $\pi/4$ QPSK

Offset quadrature phase-shift keying (OQPSK) is $M = 4$ PSK in which the allowed data transition times for the I and Q components are offset by a $1/2$ symbol interval.

A $\pi/4$ quadrature phase-shift keying ($\pi/4$ QPSK) signal is generated by alternating between two QPSK constellations that are rotated by $\pi/4$ with respect to each other.

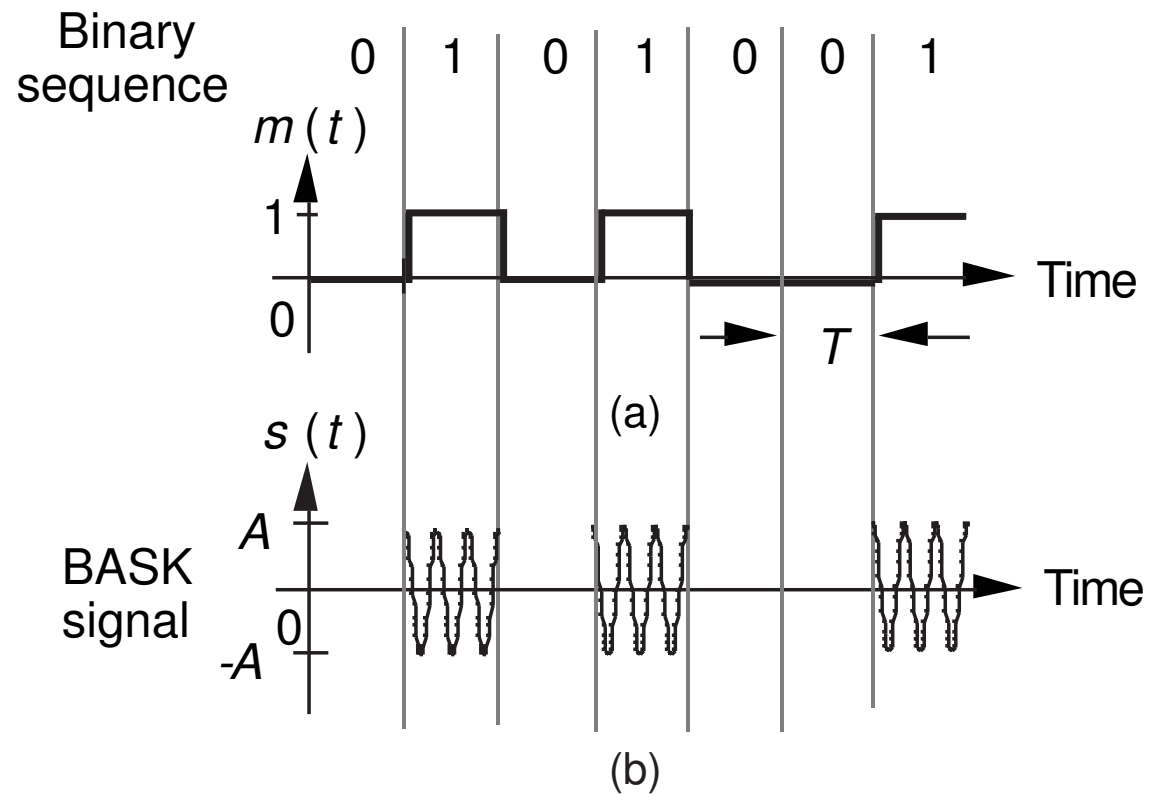


Figure 1: (a) Binary modulating signal, (b) Binary ASK signal. (C. Lee)

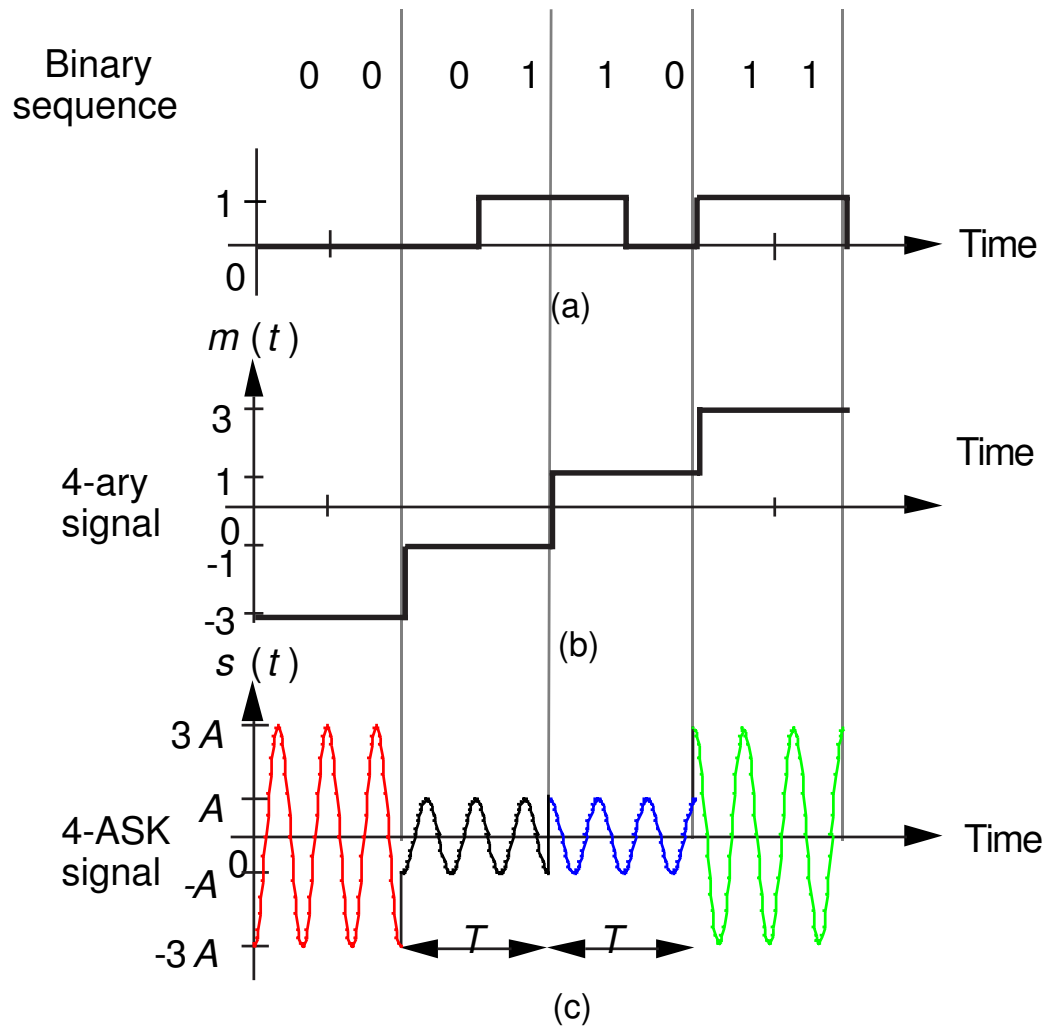


Figure 2: (a) Binary signal, (b) 4'ary signal (c) 4 ASK signal. (C. Lee)

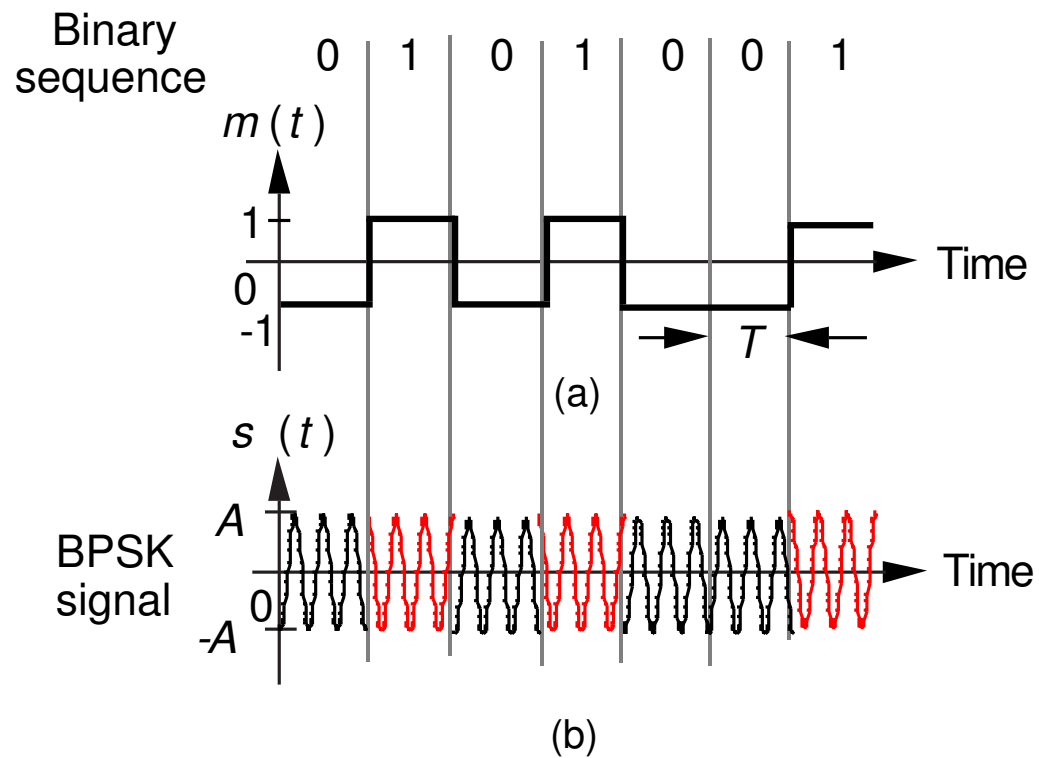


Figure 3: (a) Binary signal, (b) Binary PSK (BPSK) signal. (C. Lee)

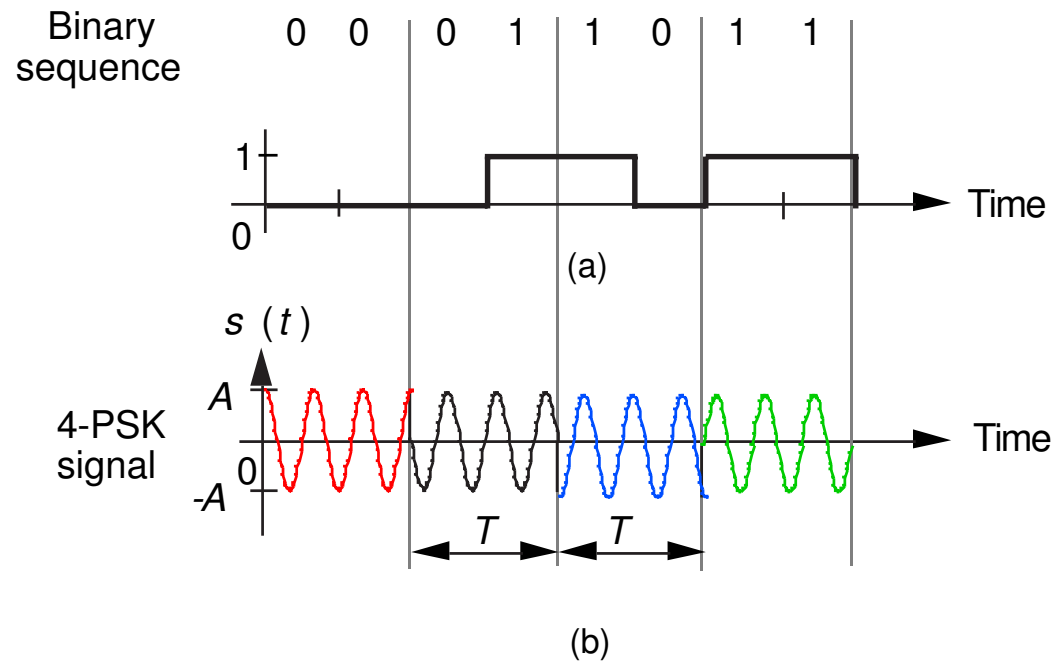


Figure 4: (a) Binary signal, (b) 4 PSK signal. (C. Lee)

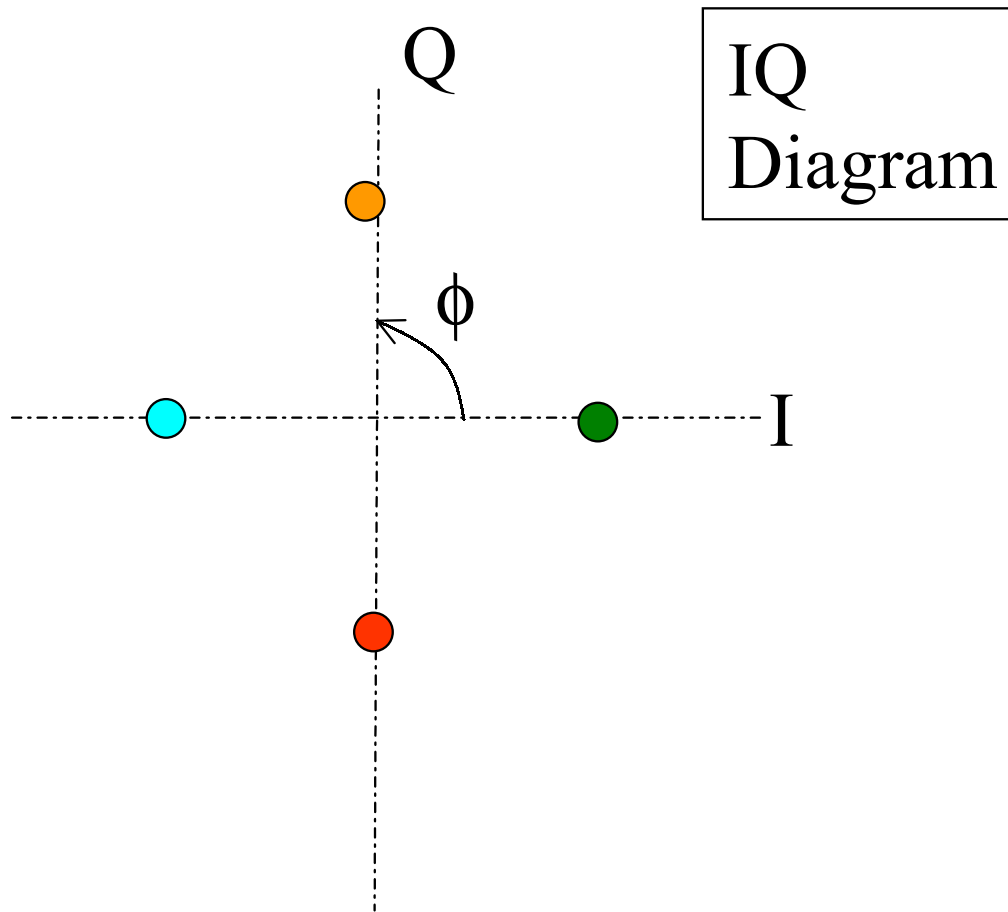


Figure 5: QPSK signal constellation (permitted values of the complex envelope.)(S. Mandayam)

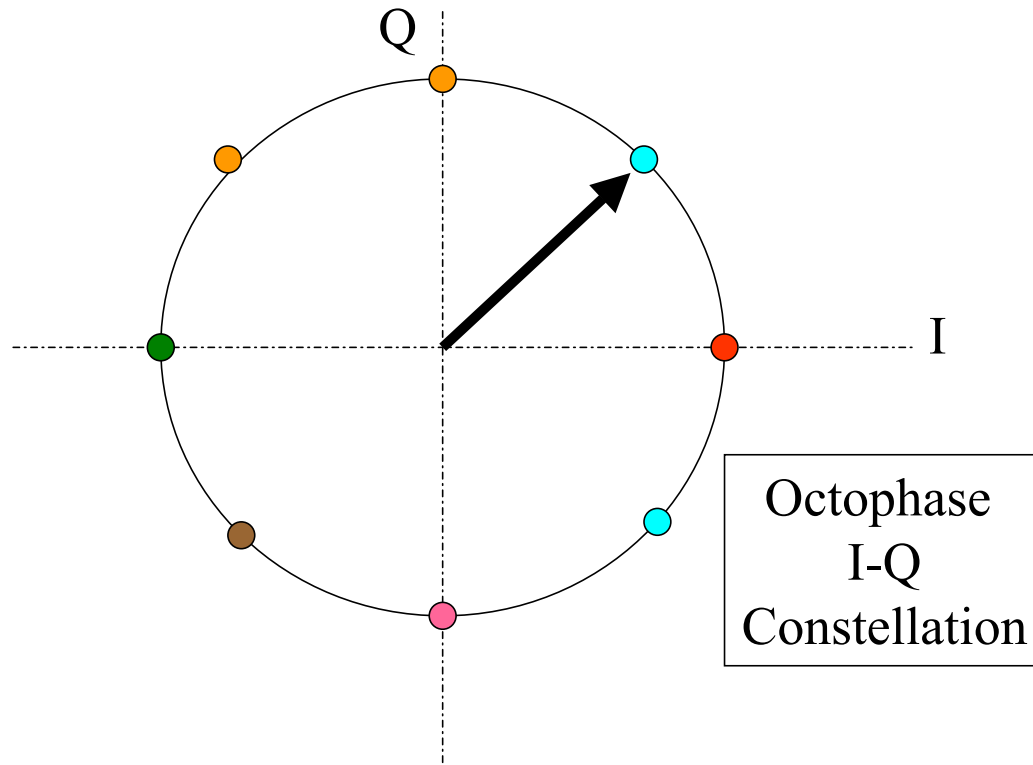


Figure 6: MPSK signal constellation (permitted values of the complex envelope.) (S. Mandayam)

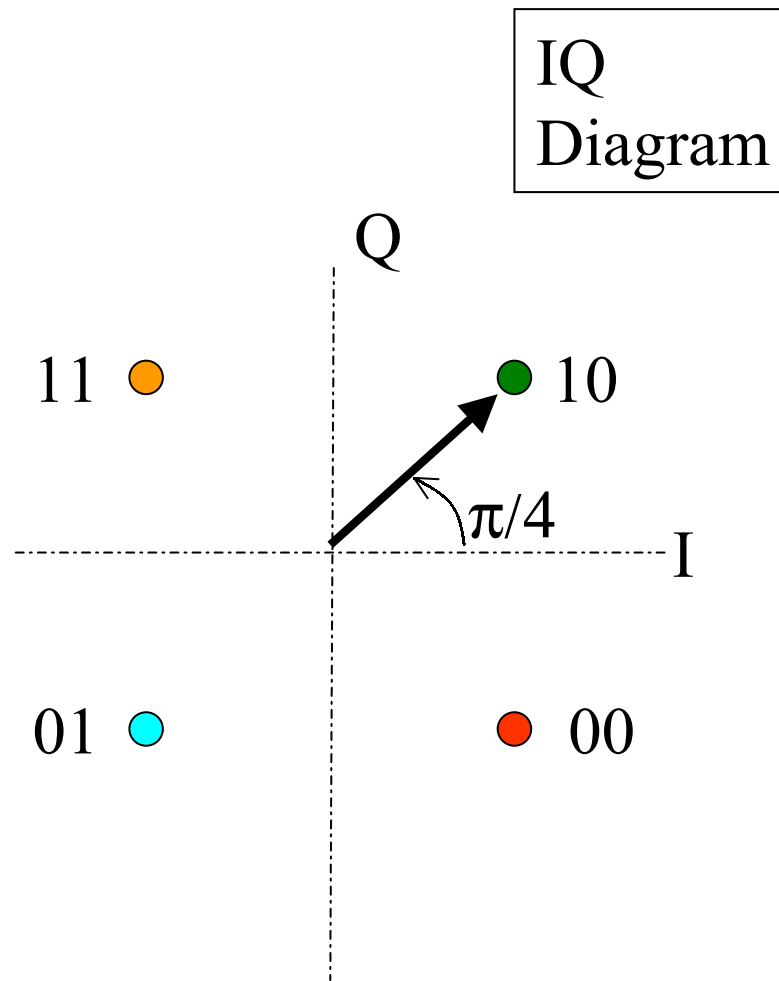


Figure 7: $\pi/4$ QPSK. (S. Mandayam)

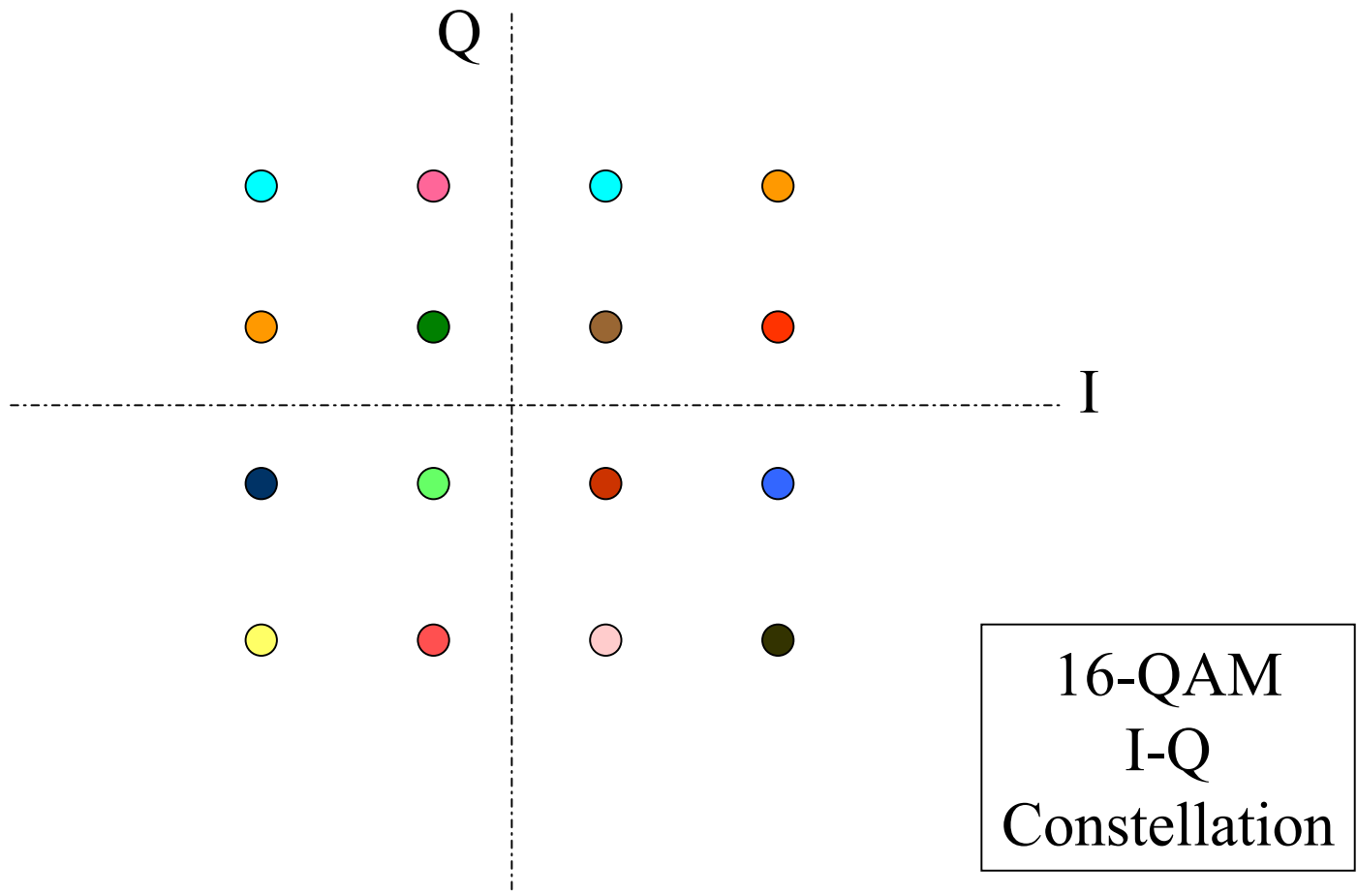


Figure 8: 16 Symbol QAM constellation (four levels per dimension) (S. Mandayam).

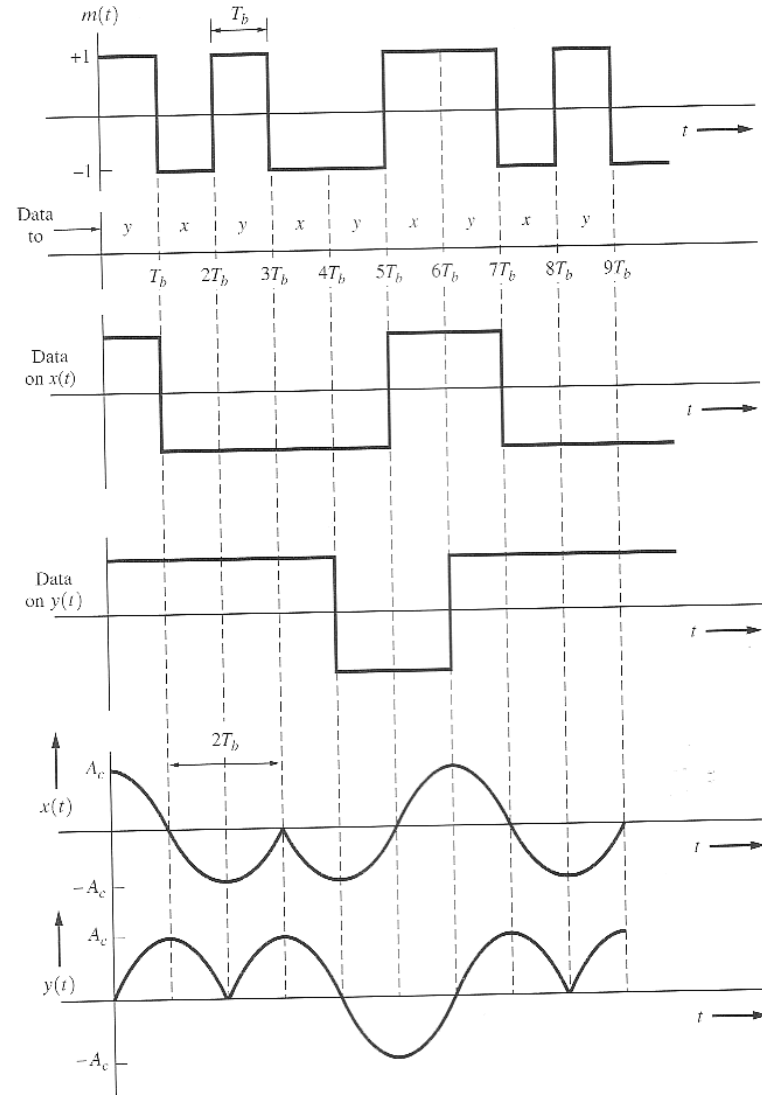


Figure 9: 16 Symbol QAM constellation (four levels per dimension). (Couch 2001)