Data Encoding

Contents

Digital Data, Digital Encoding

Nonreturn to Zero-level (NRZ-L)

Nonreturn to Zero Inverted: FDDI, 100Base-FX

Bipolar-AMI: T-1, T-3

Pseudoternary

Manchester: IEEE802.3 10Base Ethernet

Differential Manchester: IEEE 802.5 token ring

B8ZS: T-1, T-3

HDB3

Digital Data, Digital Encoding

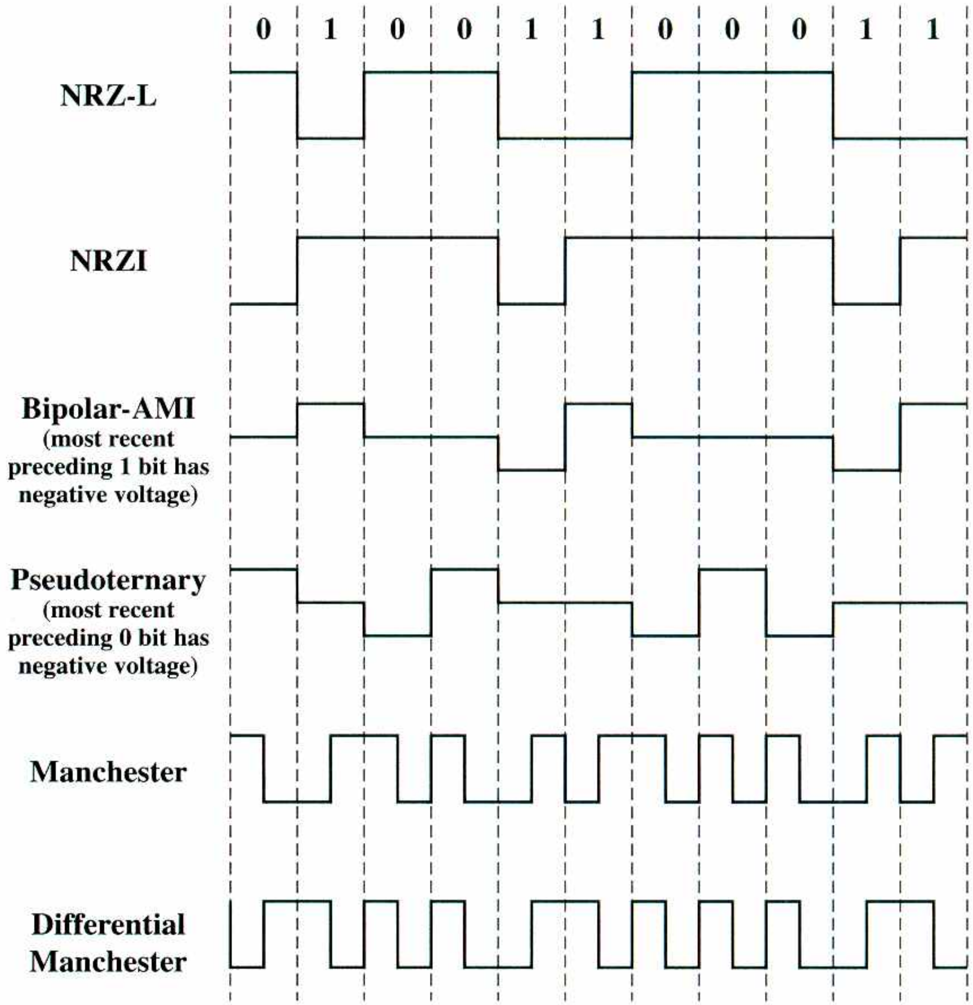


Figure 5.2 Digital Signal Encoding Formats

Digital Data, Analog Encoding

Digital Modulation

Bits → Symbols → Pulses → Put into Carrier

Carrier signal: digital information is carried by means of a **modem** that modulates one of the three characteristics of the carrier

Amplitude-shift keying (ASK)

Frequency-shift keying (FSK)

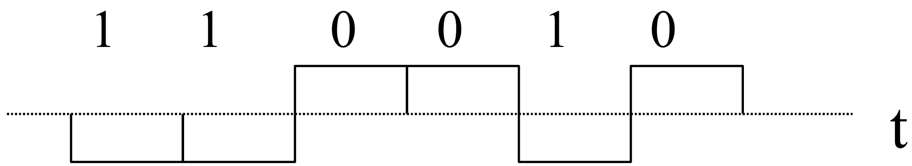
Phase-shift keying (PSK)

Digital Modulation

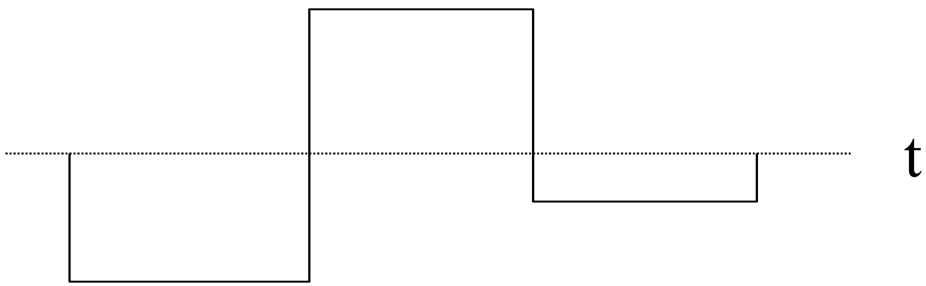
Mapping data bits to signal elements

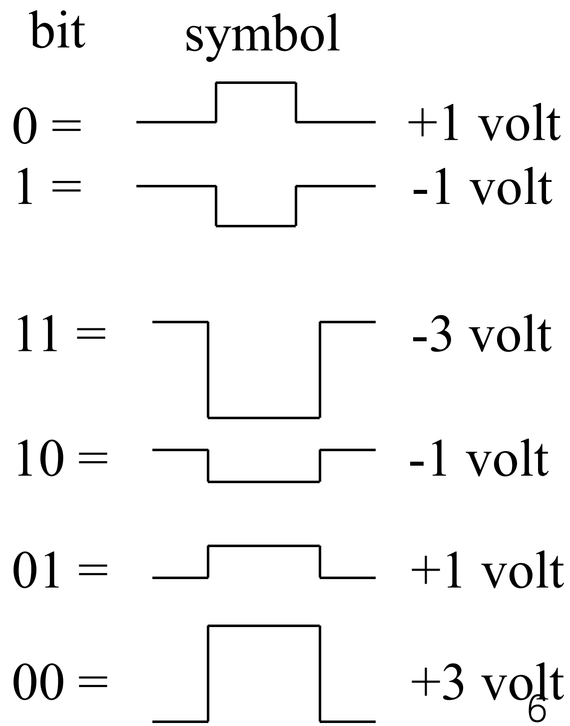
bits → symbols → pulses

Ex) 1 bit/symbol



2 bits/symbol





ASK/FSK/PSK

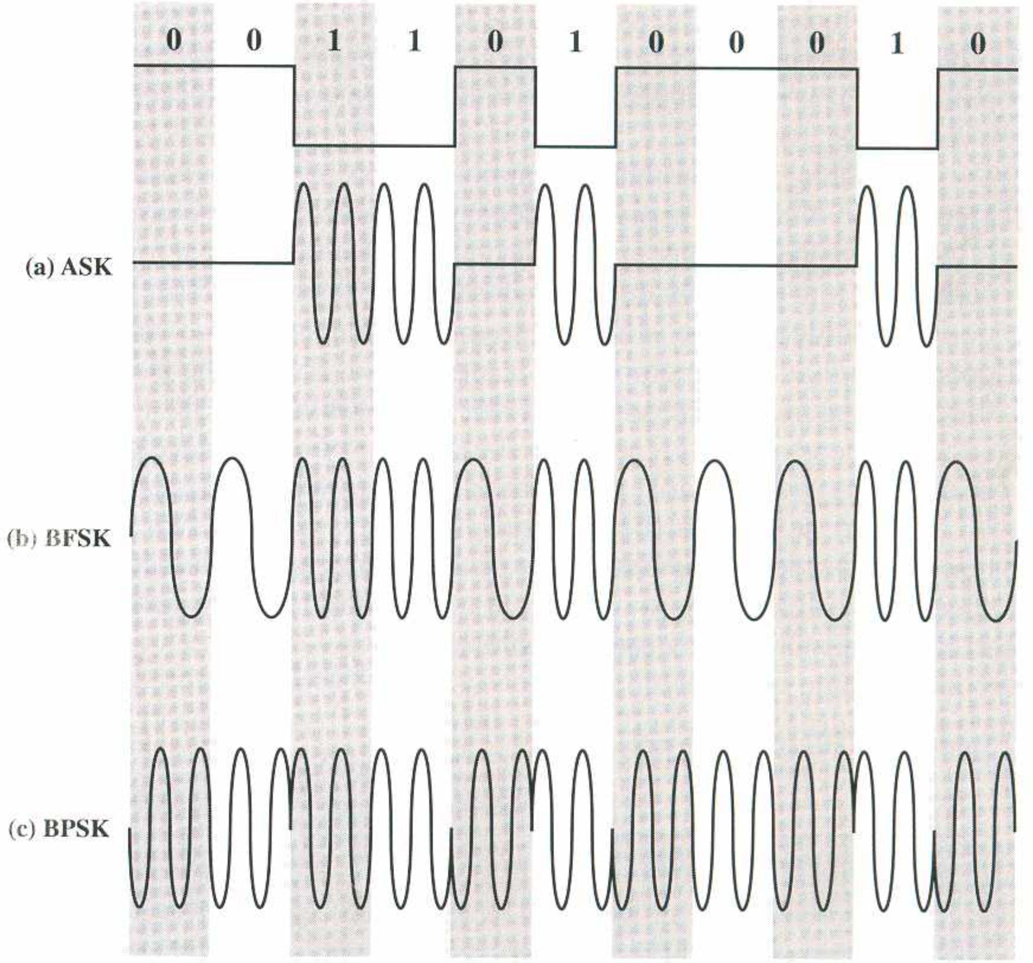


Figure 5.7 Modulation of Analog Signals for Digital Data

ASK

ASK is susceptible to error and is a rather inefficient modulation technique

On voice-grade lines, it is typically used up to 1200 bps

Commonly used to transmit digital data over optical fiber

FSK

- **FSK** is less susceptible to error than is ASK
- On voice-grade line, it is typically used up to 1200 bps
- Commonly used for high-frequency (3-30 MHz) radio transmission
- Use of FSK in a modem for full-duplex operation over a voice-grade line (derived four-wire circuit)

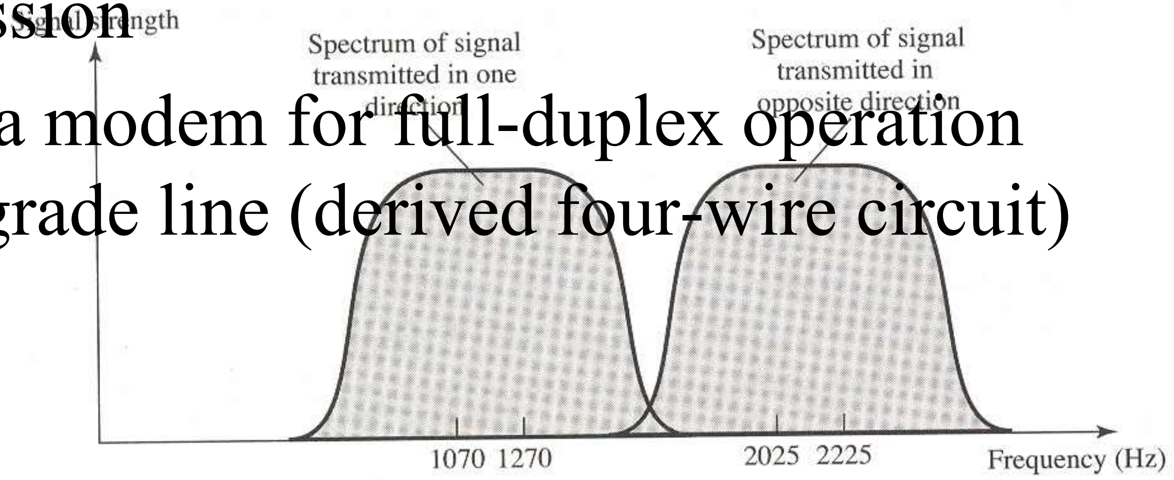


Figure 5.8 Full-Duplex FSK Transmission on a Voice-Grade Line

PSK

PSK (180º phase shift) is more noise-resistant and efficient than FSK

Absolute phase

Differential PSK (**DPSK**)

Variation of PSK

Absolute phase reference is not necessary for demodulation of the data

Differential: referenced to the phase of the carrier during the previously encoded interval

DPSK

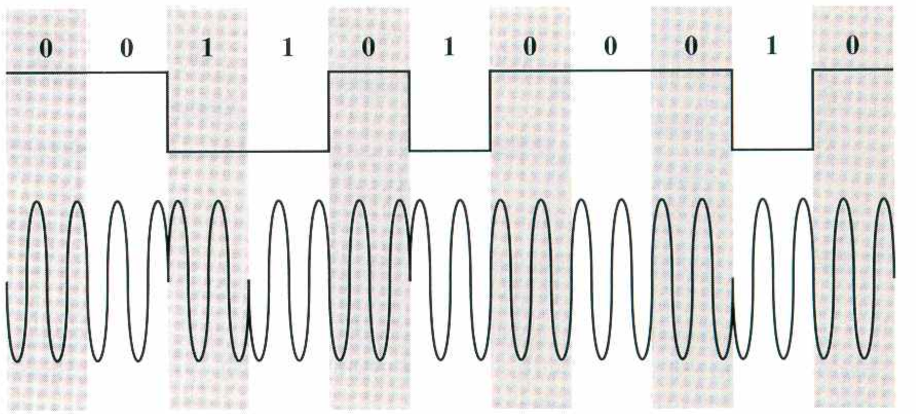


Figure 5.10 Differential Phase Shift Keying (DPSK)

DPSK

Rubust encoding without burst of phase shift

PSK

$m_k = t_k$:	0	0	1	1	0	1	0	0	0	1	0
r_k:	0	0	1	1	0	0	1	1	1	0	1

DPSK

If $m_k = 0$ then $t_k = t_{k-1}$ If $m_k = 1$ then $t_k = (t_{k-1})^c$

t_k:	0	0	1	0	0	1	1	1	1	0	0
r_k:	0	0	1	0	0	0	0	0	0	1	1
m_k:	0	0	1	1	0	0	0	0	0	1	0

PSK/QPSK

PSK (180º phase shift) is more noise-resistant and efficient than FSK

Differential PSK: referenced to the phase of the carrier during the previously encoded interval

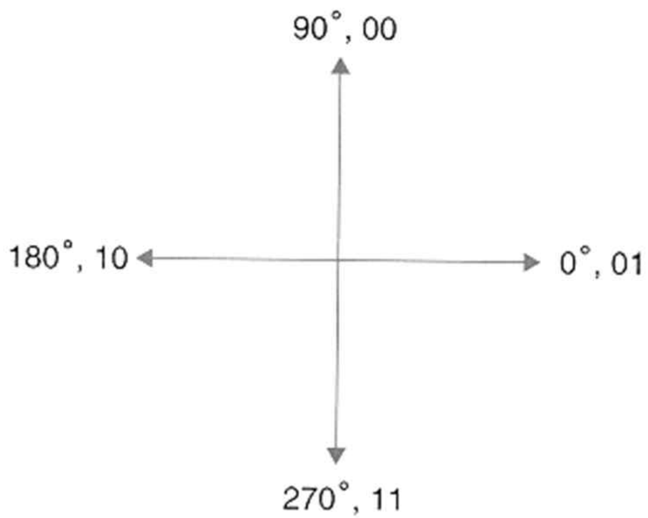
QPSK (90° phase shift)

Each symbol represents two bits

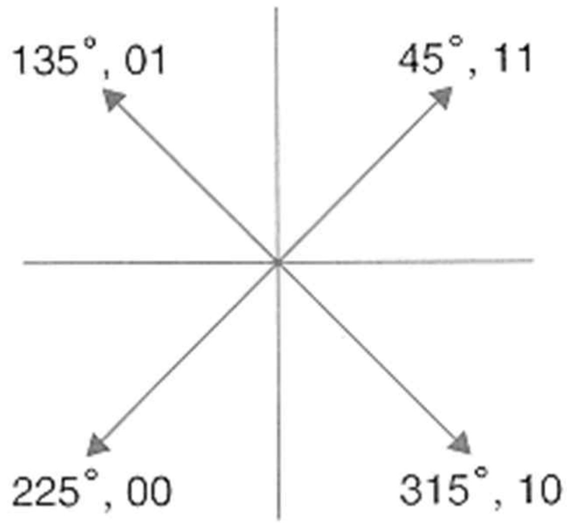
$D = R/b = R/\log_2 L$

QPSK

QPSK (90° phase shift)



Phasor diagram for the Bell 212A modem



Phasor diagram for the Bell 201B/C modem

QPSK Modulation

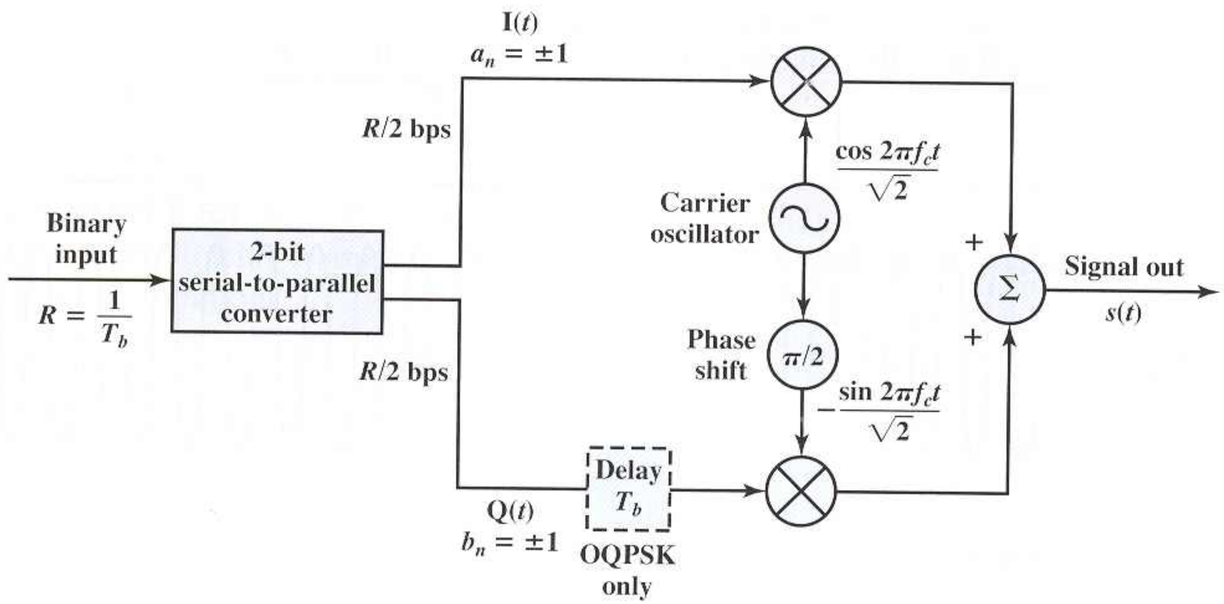


Figure 5.11 QPSK and OQPSK Modulators

QPSK Modulation

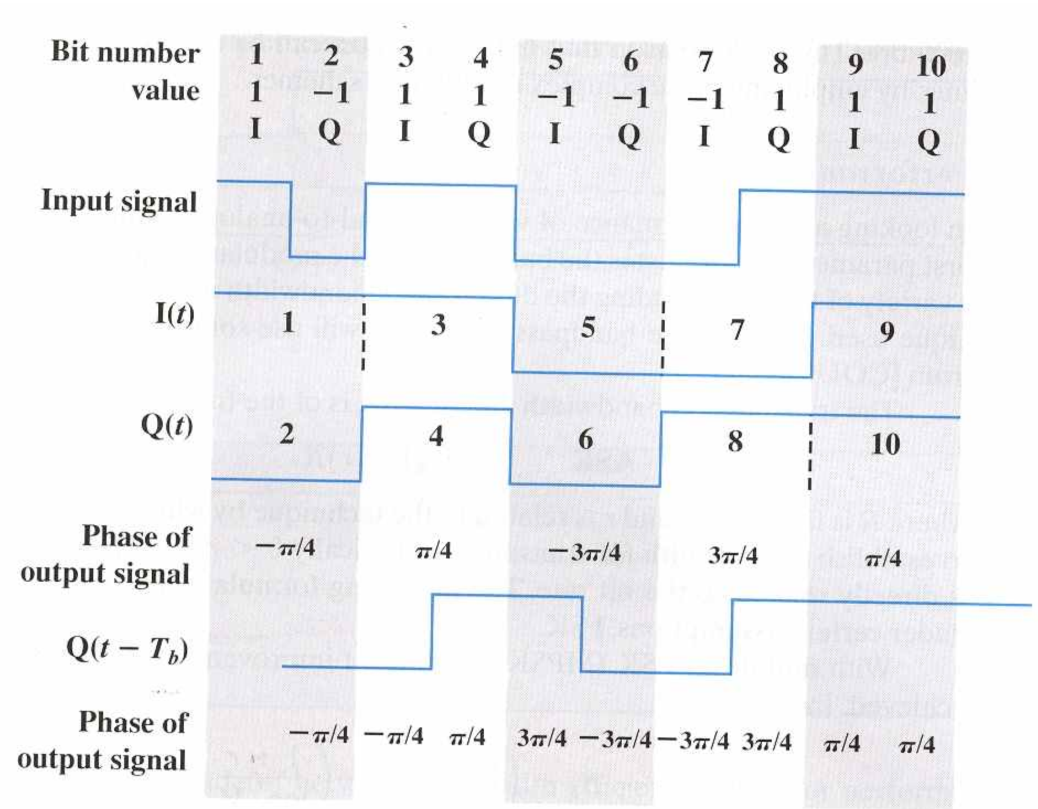
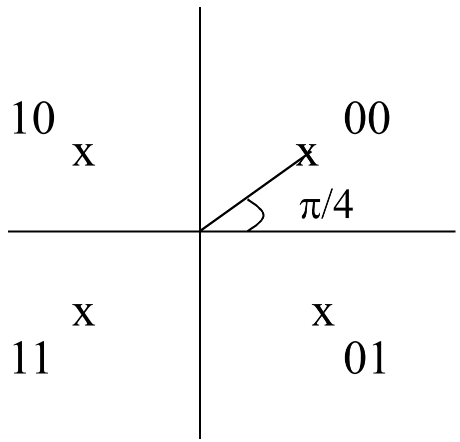


Figure 5.12 Example of QPSK and OQPSK Waveforms



QAM

Combination of the techniques: PSK + ASK

On voice-grade line, rates up to 9600 bps (12 phases, three amplitudes)

Symbol rate (Baud rate): $D = R/b = R/\log_2 L$

QAM is used in ADSL and some wireless standards

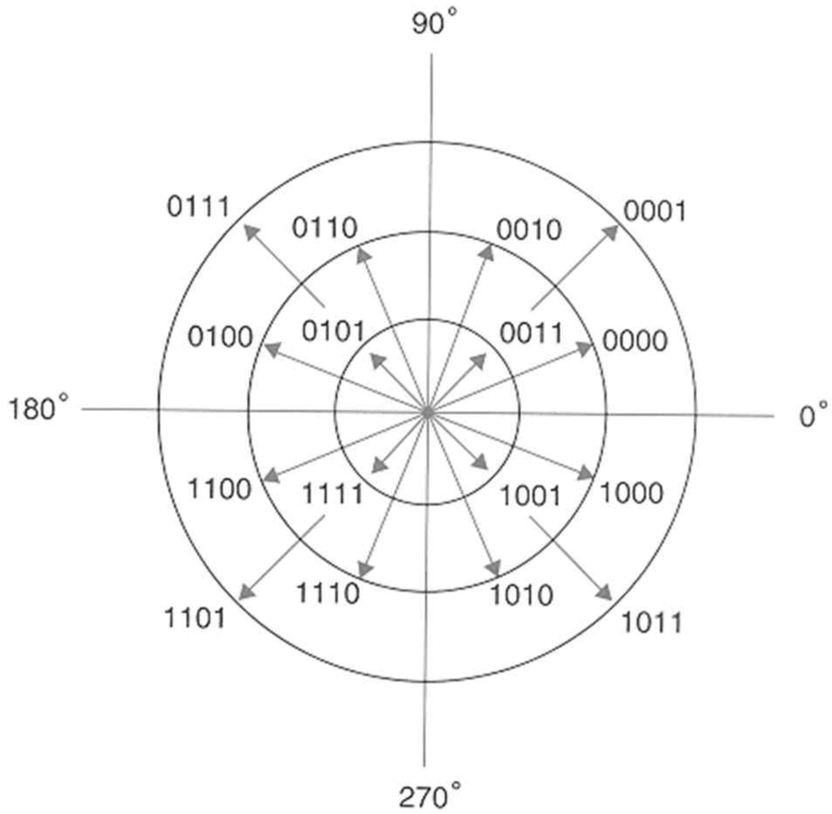
16QAM:

2bits/I x 2bits/Q = 4 levels x 4 levels = 16 states

64QAM:

256QAM:

QAM



Phasor diagram for the Bell 209A modem depicting 9600bps QAM

QAM: $s(t) = d_1(t)\cos 2\pi f_c t + d_2(t)\sin 2\pi f_c t$

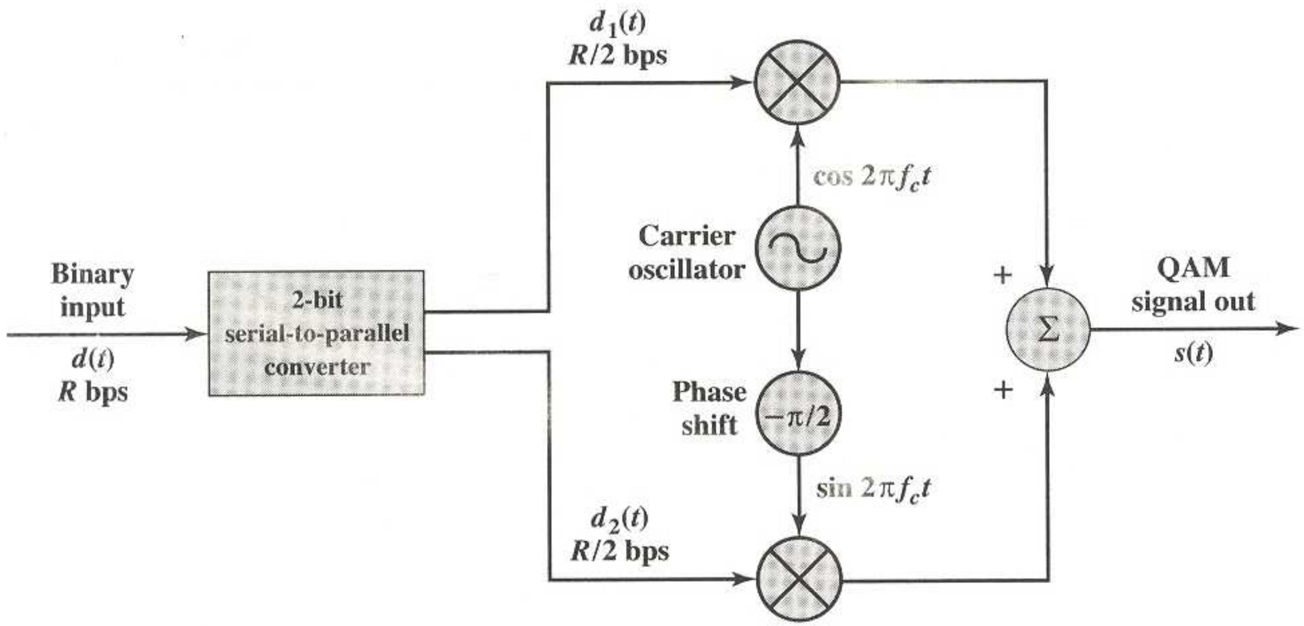


Figure 5.14 QAM Modulator

Analog Data, Digital Signals

Pulse-code modulation (PCM): the best known technique for voice digitization used in **codec**

PCM is based on sampling theorem

Nyquist Sampling Theorem

$f_s > 2BW$

2×4 KHz = 8000 samples/sec = 8000 PAM pulses

Each sample is approximated by being quantized into one of 2^8 different levels

Quantizing

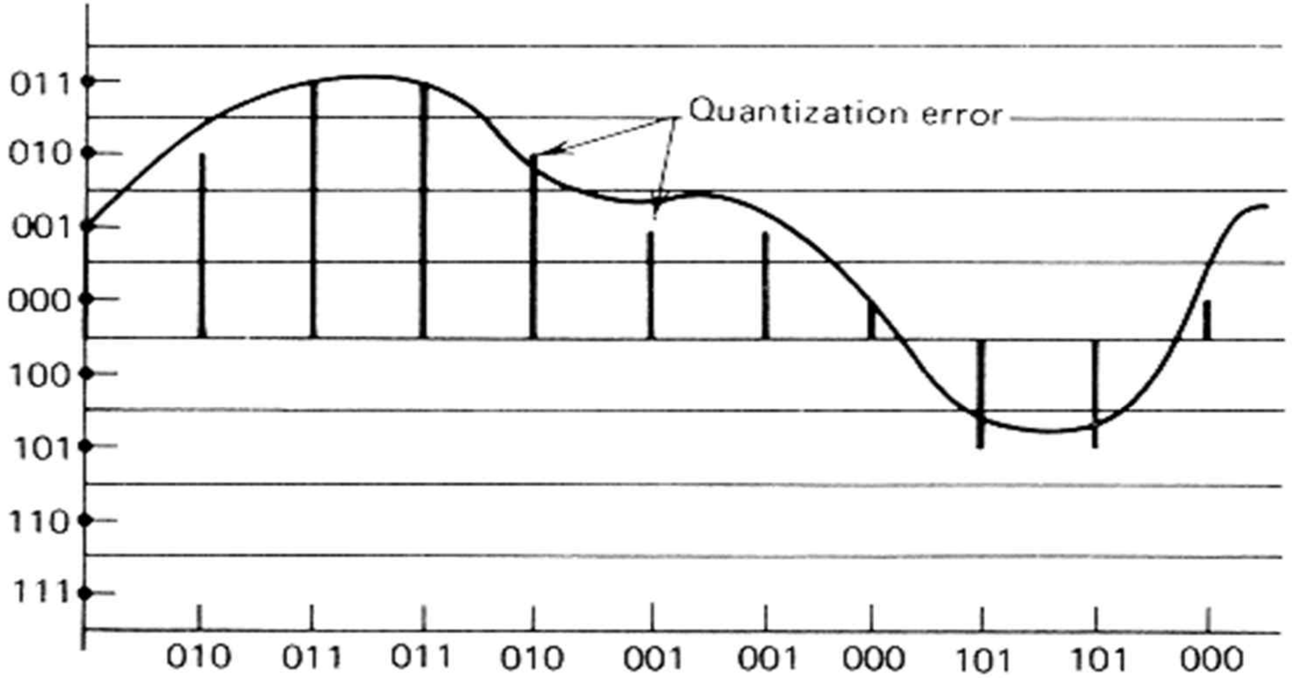


Figure 3.8. Quantization of analog samples.

Analog Data, Analog Signals

Analog information can be converted directly into an analog signal that occupies the same bandwidth: baseband signal

Voice signal is directly transmitted on a voice-grade telephone line (local loop)

It is possible to use an analog signal to modulate a carrier to produce a new analog signal that conveys the same information but occupies a different frequency band: Modulation

Analog Data, Analog Signals

- Why?
  - A higher frequency may be needed for effective transmission
  - Analog-to-analog modulation permits frequency-division multiplexing
- Analog-to-analog modulation
  - Amplitude modulation (AM)
  - Frequency modulation (FM)
  - Phase modulation (PM)

Summary

Digital data, Digital encoding:

- **Bipolar-AMI, Manchester, …**

Digital data, Analog encoding

- **ASK, FSK, PSK, QPSK, QAM**
- **More bits in one symbol increases data rate**

Analog data, Digital signals

- **PCM for voice digitization**

Analog data, Analog signals

- **AM, FM, PM**