TELE303/404 Wireless Communications

Lecture 4 – Signal Encoding

Jeremiah Deng
TELE Programme / InfoSci
University of Otago, 2016

Encoding Techniques in Wireless

- Digital-to-analog
  - Digital data and digital signals must be converted to analog signals for wireless transmission
- Analog-to-analog
  - Baseband signals must be modulated onto a higher-frequency carrier for transmission.
- Analog-to-digital
  - Digitising analog signals for digital transmission so as to improve quality and take advantage of TDM schemes.
- Digital-to-digital

Outline

- Basic forms of “encoding”
- What is a good encoding?
- Encoding schemes in a nutshell

Signal Encoding Criteria

- What determines how successful a receiver will be in interpreting an incoming signal?
  - Signal-to-noise ratio
  - Data rate
  - Bandwidth

☹ An increase in data rate increases bit error rate
☺ An increase in SNR decreases bit error rate
☺ An increase in bandwidth allows an increase in data rate

D➔A

• • •

Digital data to analog signal

- Basic encodings
  - Amplitude-shift keying (ASK)
    - Amplitude difference of carrier frequency
  - Frequency-shift keying (FSK)
    - Frequency difference near carrier frequency
  - Phase-shift keying (PSK)
    - Phase of carrier signal shifted

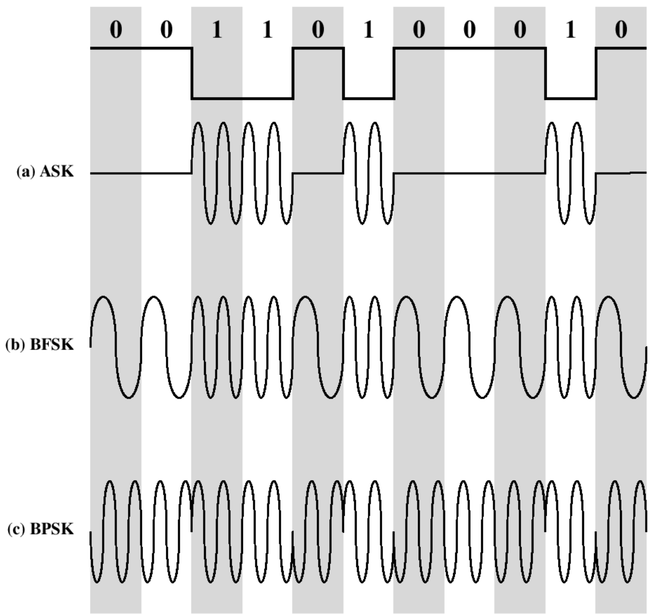


Fig. 6.2 Modulation of Analog Signals for Digital Data

Amplitude-Shift Keying (ASK)

- One binary digit represented by presence of carrier, at constant amplitude
- Other binary digit represented by absence of carrier

$$s(t) = \begin{cases} A\cos(2\pi f_c t) & \text{binary } 1 \\ 0 & \text{binary } 0 \end{cases}$$

  - where the carrier signal is $A\cos(2\pi f_c t)$
- Susceptible to sudden gain changes
- Inefficient modulation technique

Binary Frequency-Shift Keying (BFSK)

- Two binary digits represented by two different frequencies near the carrier frequency

$$s(t) = \begin{cases} A\cos(2\pi f_1 t) & \text{binary } 1 \\ A\cos(2\pi f_2 t) & \text{binary } 0 \end{cases}$$

  - where f_1 and f_2 are offset from carrier frequency f_c by equal but opposite amounts
- Less susceptible to error than ASK
- Used for high-frequency (3 to 30 MHz) radio transmission

Using Multiple Frequencies (MFSK)

- More than two frequencies are used in FSK
- More bandwidth efficient
- Used for ***frequency hopping*** in spread spectrum

$$s_i(t) = A\cos 2\pi f_i t \qquad 1 \le i \le M$$

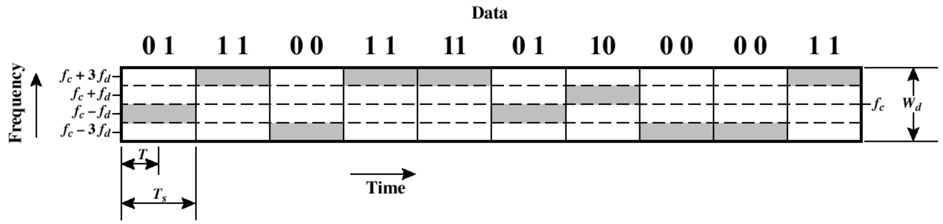


Fig. 6.4 MFSK Frequency Use (M=4)

Phase-Shift Keying (PSK)

- Two-level PSK (BPSK)
  - Uses two phases to represent binary digits

$$s(t) = \begin{cases} A\cos(2\pi f_c t) & \text{binary } 1 \\ A\cos(2\pi f_c t + \pi) & \text{binary } 0 \end{cases}$$

- Differential PSK (DPSK)
  - Phase shift with reference to previous bit
    - Binary 0 – signal burst of same phase as previous signal burst
    - Binary 1 – signal burst of opposite phase to previous signal burst

Phase-Shift Keying (PSK)

- Four-level PSK (QPSK)
  - Each element represents two bits
  - Phase shift in multiples of π/4

$$s(t) = \begin{cases} A\cos\left(2\pi f_c t + \frac{\pi}{4}\right) & 11 \\ A\cos\left(2\pi f_c t + \frac{3\pi}{4}\right) & 01 \\ A\cos\left(2\pi f_c t - \frac{3\pi}{4}\right) & 00 \\ A\cos\left(2\pi f_c t - \frac{\pi}{4}\right) & 10 \end{cases}$$

- OQPSK: Introducing a time-delay
  - Phase change less than π/2
  - Therefore less interference

QPSK & OQPSK Diagram

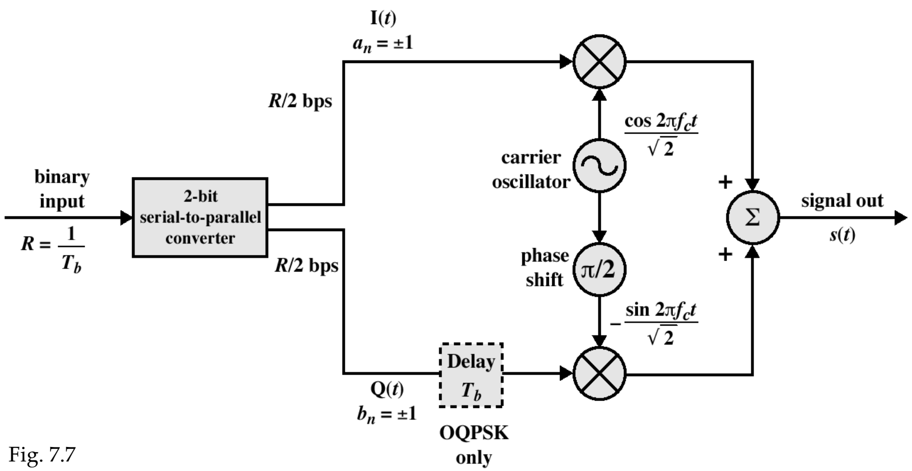


Fig. 7.7

QPSK & OQPSK Example

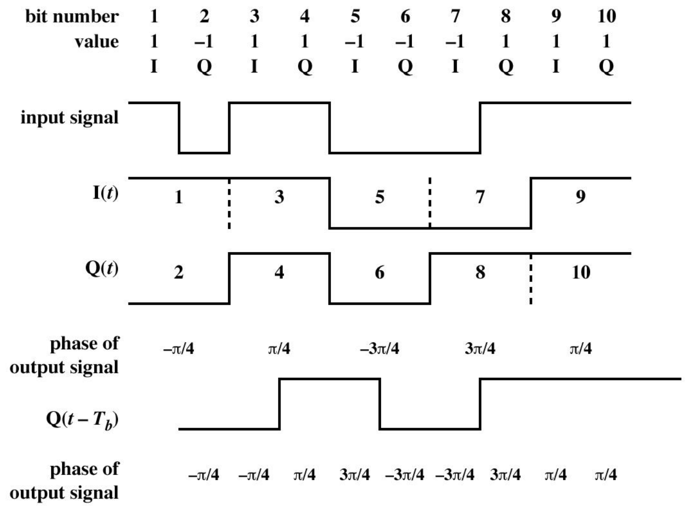
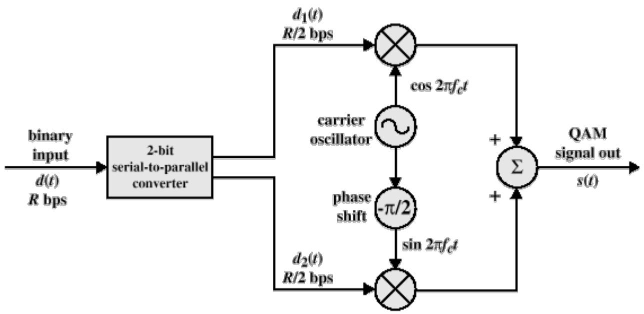


Fig. 7.8

Quadrature Amplitude Modulation

- QAM is a combination of ASK and PSK
  - Two different signals sent simultaneously on the same carrier frequency

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



Modulation of QAM

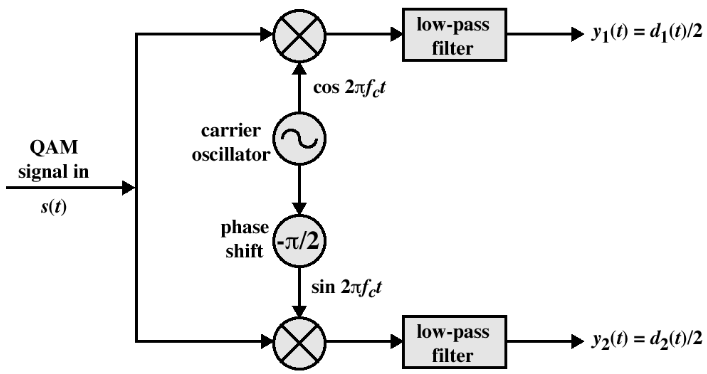


Figure 6.20 QAM Demodulator

A➔A

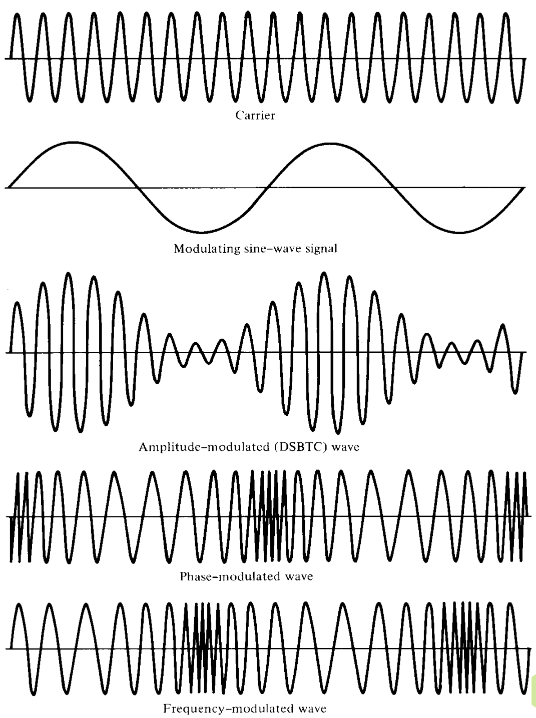
• • •

Reasons for Analog Modulation

- Modulation of digital signals
  - When only analog transmission facilities are available; digital to analog conversion required

- Modulation of analog signals
  - A higher frequency may be needed for effective transmission
  - Modulation permits frequency division multiplexing

Analog Modulation



A➔D

• • •

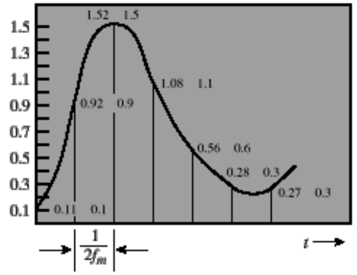
Analog data to digital signal

- Basic modulation methods
  - Pulse code modulation (PCM)
  - Delta modulation (DM)

- Once analog data have been converted to digital signals, the digital data
  - can be transmitted e.g. using NRZ-L
  - can be converted back to an analog signal

Pulse Code Modulation

- Based on the sampling theorem
- Each analog sample is assigned a binary code
  - Analog samples are referred to as pulse amplitude modulation (PAM) samples
- The digital signal consists of block of *n* bits, where each *n*-bit number is the amplitude of a PCM pulse

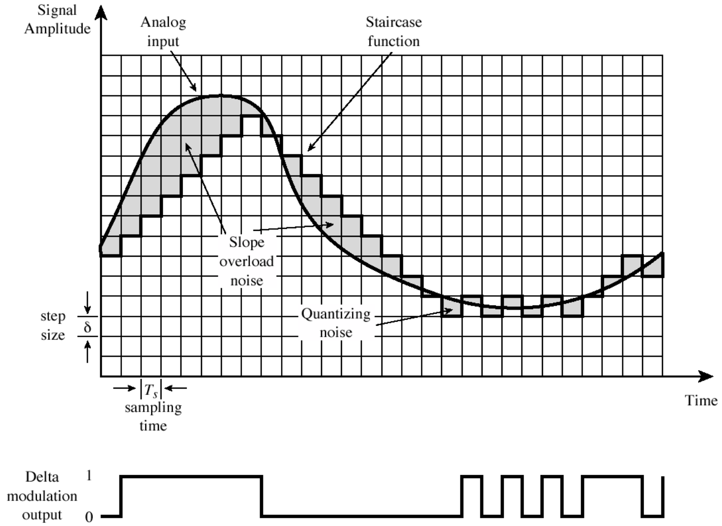


Pulse Code Modulation

- By quantizing the PAM pulse, original signal is only approximated
- Leads to quantizing noise
- Signal-to-noise ratio for quantizing noise
- Each additional bit typically increases SNR by 6 dB, or a factor of 4.
- SNR ratio can be improved by nonlinear encoding such as non-uniform quantization.

Delta Modulation (DM)

- In DM, analog input is approximated by staircase function
  - Moves up or down by one quantization level (δ) at each sampling interval
- The bit stream approximates derivative of analog signal (rather than amplitude)
  - 1 is generated if function goes up
  - 0 otherwise
- Two important parameters
  - Size of step assigned to each binary digit (δ)
  - Sampling rate
- Accuracy improved by increasing sampling rate
  - However, this increases the data rate



- Advantage of DM over PCM is the simplicity of its implementation.
- Used for audio signal encoding in Bluetooth.
- PCM exhibits better SNR at the same data rate.

Recap

- Signal encoding
- Basic encoding techniques
  - Analog to analog
  - Digital to analog
  - Analog to digital
- Coming next:
  - Spread Spectrum
  - Lab **THIS week**