Digital Modulation Techniques

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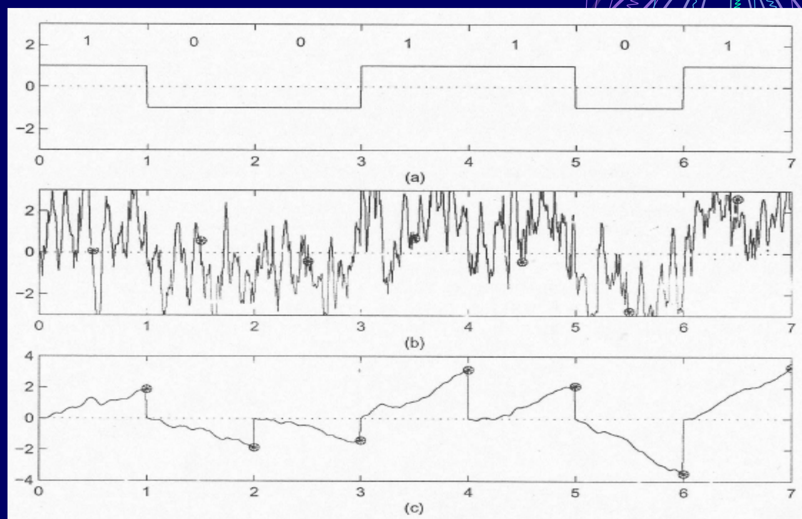
Introduction

- Digital modulation is required when we want to transmit analog signals via a digital communication system
- but is unnecessary if that information is already in digital form.
- The major purpose of this chapter is to focus on methods used in various digital modulation and demodulation schemes

Baseband Pulse Transmission



Baseband Pulse Transmission

- Figure 5-1 Signals for baseband pulse transmission:
  - (a) baseband pulse signal;
  - (b) the received signal corrupted by noise, and the sampled points;
  - (c) the output of the correlator and the corresponding sampling points

$$s(t) = \begin{cases} +A & \text{if} \quad m = 1 \\ -A & \text{if} \quad m = 0 \end{cases}$$

Baseband Pulse Transmission

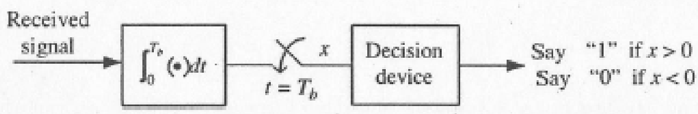


Figure 5-2 Receiver for baseband pulse transmission

- Receiver side

Baseband Pulse Transmission

- For digital communication, the digital signals are transmitted consecutively one-by-one.
- Therefore, we may express the transmitted signal as

$$s(t) = \sum_{k=-\infty}^{\infty} b_k h(t - kT_b),$$

Power Spectral Density

- Let $s_T(t)$ be a truncated signal of s(t) given by

$$s_T(t) = \begin{cases} s(t) & -T/2 \le t \le T/2 \\ 0 & \text{otherwise.} \end{cases}$$

The power spectral density for s(r) is defined as ($S_T(f)$ is the Fourier transform of $s_T(t)$)

$$P_s(f) = \lim_{T\to\infty} \frac{1}{T} |S_T(f)|^2$$

Power Spectral Density

- The power of the signal s(t) is defined as

$$P_s = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} |s(t)|^2 dt.$$

- A very useful theorem, called Parseval's theorem, is as follows:

$$\int_{-T/2}^{T/2} |s(t)|^2 dt = \int_{-\infty}^{\infty} |S_T(f)|^2 df.$$

$$P_s = \int_{-\infty}^{\infty} P_s(f) df.$$

Power Spectral Density

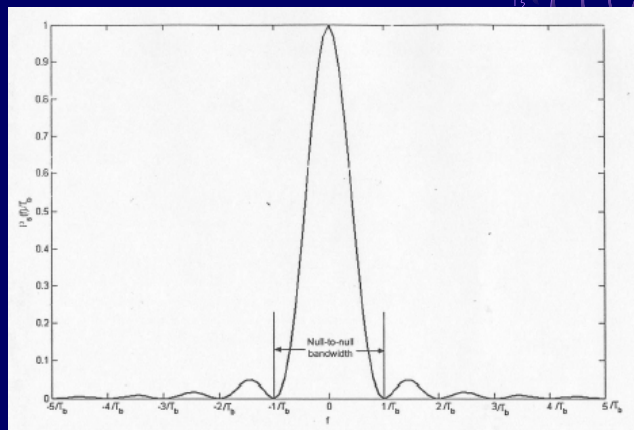


Figure 5-3 Power spectral density of the transmitted baseband signal $s(t)$

Data Rate and Signal Bandwidth

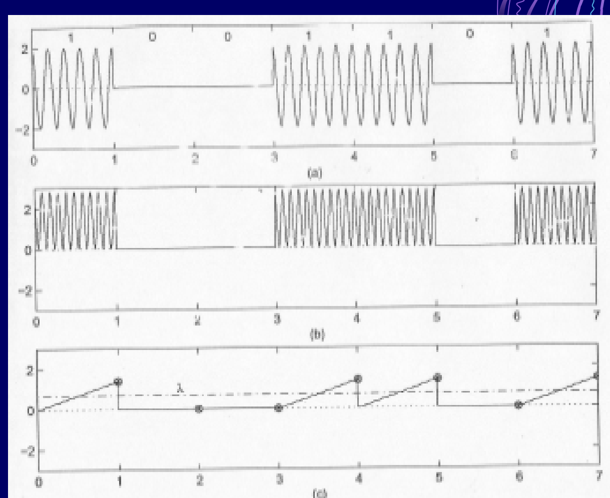
- Tire data rate is defined as the number of bits transmitted per second. For example, a data rate of 1 Mbits/s means that the system is capable of transmitting 1 megabits every second.
- The sigrral bandwidth is defined as the bandwidth in which most of the signal power is concentrated. For example, we may define the bandwidth of a signal as the width of the spectrum in which 99% of the power of the signal is concentrated. Or, we may simply use the null-to-null bandwidth. For example, from Figure 5-3, the null-to-null bandwidth of the transmitted signal is 2/Tb.
  - It can be seen that the bandwidth is proportional to the bit rate. If the bit rate k high, Tb is small and the bandwidth becomes very large. This means that the communication system handling high data rate transmission must be able to cope with a wide range of frequencies.

Amplitude-shift Keying (ASK)

- For ASK, the transmitted waveforms can be expressed as

$$s_1(t) = \sqrt{\frac{4E_b}{T_b}}\cos(2\pi f_c t)$$
$$s_2(t) = 0$$

Amplitude-shift Keying (ASK)



Amplitude-shift Keying (ASK)

- figure 5-4 Signals for ASK:
- (a) transmitted signal;
- (b) the signal y(t) = s(t) x $\sqrt{2/T_b}\cos(2\pi f_c t)$;
- (c) the output of the integrator and the corresponding sampling points

Amplitude-shift Keying (ASK)

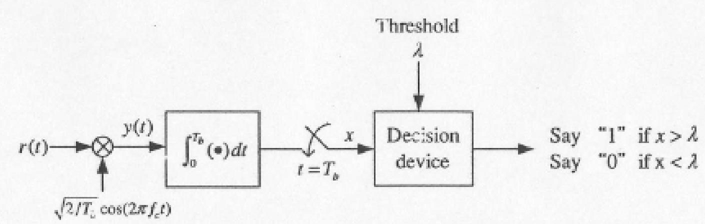


Figure 5.5 A receiver for amplitude-shift keying

$$x = \begin{cases} \sqrt{2E_b} & \text{if 1 is transmitted} \\ 0 & \text{if 0 is transmitted.} \end{cases}$$

Amplitude-shift Keying (ASK)

- The detection method described requires a carrier with the same frequency and phase as those of the carrier in the transmitter. These types of receiver are called coherent detectors.
- It is also possible to detect an ASK signal without exact knowledge of the carrier frequency and phase. Those detectors are called non-coherent detectors.

Amplitude-shift Keying (ASK)

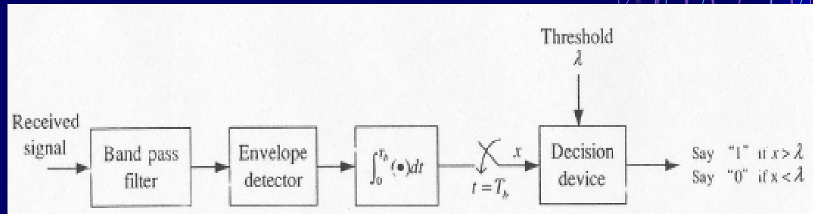


Figure 5-6 Noncoherent detector for amplitude-shift keying

Amplitude-shift Keying (ASK)

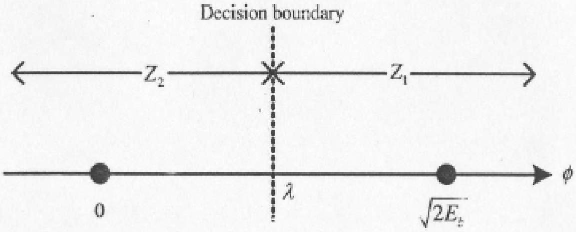


Figure 5-7 Geometric representation of binary ASK signals

Amplitude-shift Keying (ASK)

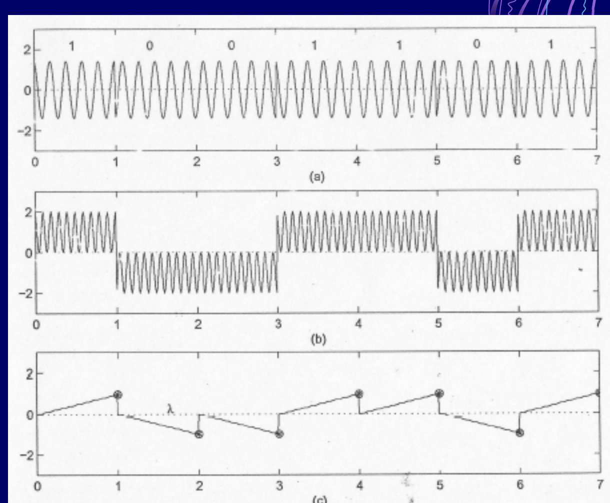
- Note that the digital information is now transmitted es analog signals.
- In wireless communication systems, only analog signals can be transmitted.

Binary Phase-shift Keying (BPSK)

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t)$$

$$s_2(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi) = -\sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t),$$

Binary Phase-shift Keying (BPSK)



Binary Phase-shift Keying (BPSK)

- Figure 5-8 Signals for BPSK:
  - (a) transmined signal;
  - (b) the signal y(t)
  - (c) the output of the correlator and the corresponding sarnpling points

$$x = \begin{cases} +\sqrt{E_b} & \text{if 1 was transmitted} \\ -\sqrt{E_b} & \text{if 0 was transmitted.} \end{cases}$$

Binary Phase-shift Keying (BPSK)

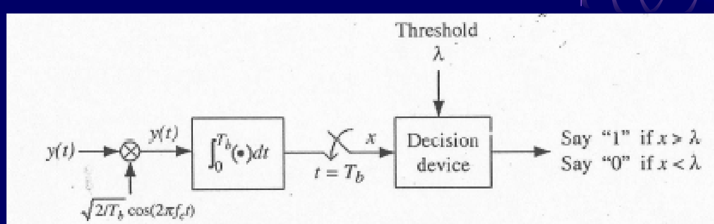


Figure 5-9 Coherent detector for BPSK

Binary Phase-shift Keying (BPSK)

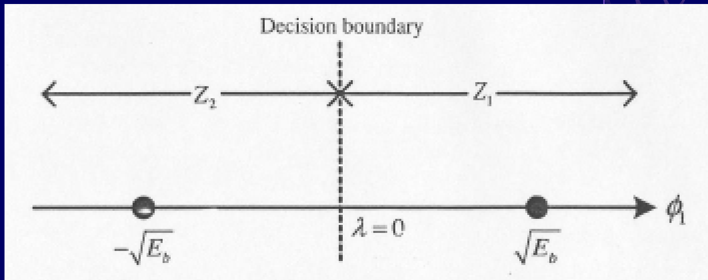


Figure 5-10 Signal-space diagram for coherent BPSK

Binary Phase-shift Keying (BPSK)

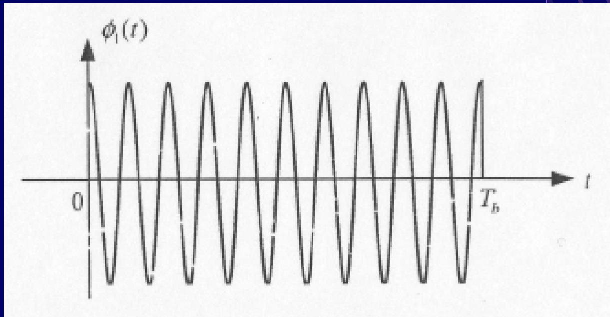


Figure 5-11 A truncated cosine waveform $\phi_1(t)$

Binary Phase-shift Keying (BPSK)

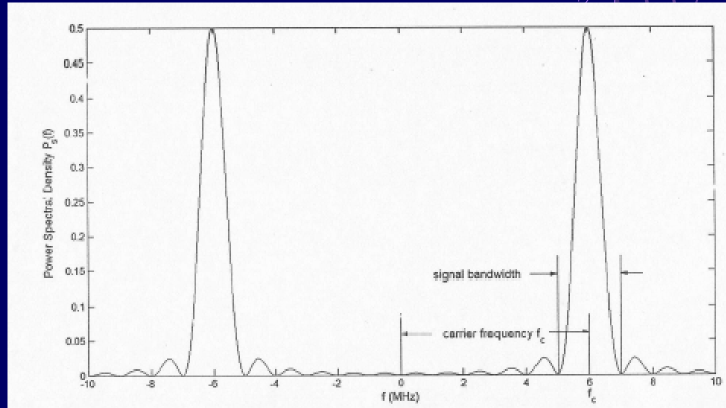


Figure 5-12 Power spectral density for a BPSK signal

Binary Phase-shift Keying (BPSK)

- The above discussion b valid not onl! for the BPSK case, it is also valid for the ASK case.

Binary Frequency-shift Keying (FSK)

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_1 t)$$

$$s_2(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_2 t)$$

Binary Frequency-shift Keying (FSK)

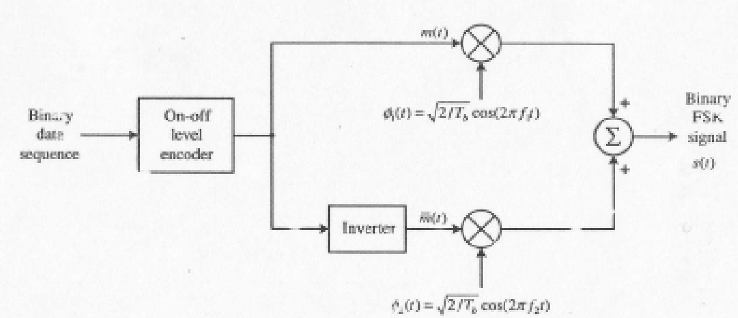


Figure 5-13 Modulator for an FSK system

Binary Frequency-shift Keying (FSK)

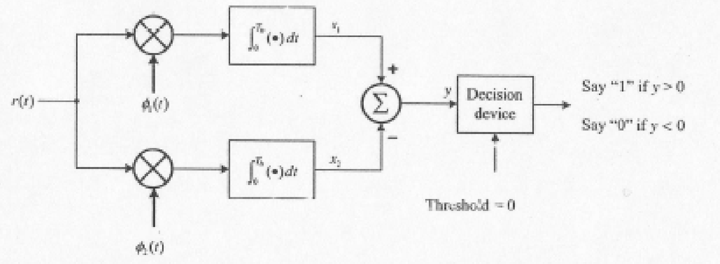


Figure 5-15 Coherent detector for an FSK system

Binary Frequency-shift Keying (FSK)

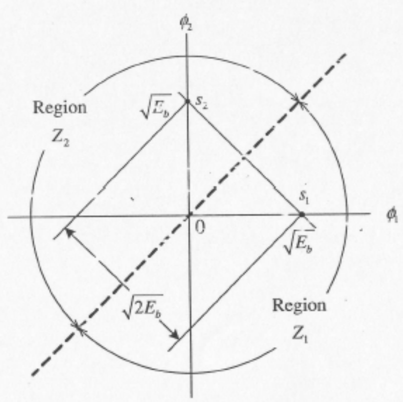


Figure 5-16 Signal space diagram for binary FSK