22. Amplitude-Shift Keying (ASK) Modulation

Introduction

The transmission of digital signals is increasing at a rapid rate. Low-frequency analogue signals are often converted to digital format (PAM) before transmission. The source signals are generally referred to as *baseband* signals. Of course, we can send analogue and digital signals directly over a medium. From electro-magnetic theory, for efficient radiation of electrical energy from an antenna it must be at least in the order of magnitude of a wavelength in size; $c = f\lambda$, where c is the velocity of light, f is the signal frequency and λ is the wavelength. For a 1kHz audio signal, the wavelength is 300 km. An antenna of this size is not practical for efficient transmission. The low-frequency signal is often frequency-translated to a higher frequency range for efficient transmission. The process is called *modulation*. The use of a higher frequency range reduces antenna size.

In the modulation process, the baseband signals constitute the *modulating signal* and the high-frequency *carrier signal* is a sinusiodal waveform. There are three basic ways of modulating a sine wave carrier. For binary digital modulation, they are called binary amplitude-shift keying (BASK), binary frequency-shift keying (BFSK) and binary phase-shift keying (BPSK). Modulation also leads to the possibility of frequency multiplexing. In a frequency-multiplexed system, individual signals are transmitted over adjacent, non-overlapping frequency bands. They are therefore transmitted in parallel and simultaneously in time. If we operate at higher carrier frequencies, more bandwidth is available for frequency-multiplexing more signals.

Binary Amplitude-Shift Keying (BASK)

A *binary amplitude-shift keying* (BASK) signal can be defined by

$$s(t) = A\, m(t) \cos 2\pi f_c t, \qquad 0 \le t \le T \tag{22.1}$$

where A is a constant, $m(t) = 1$ or 0, f_c is the carrier frequency, and T is the bit duration. It has a power $P = A^2/2$, so that $A = \sqrt{2P}$. Thus equation (22.1) can be written as

$$\begin{aligned} s(t) &= \sqrt{2P} \cos 2\pi f_c t, && 0 \le t \le T \\ &= \sqrt{PT}\sqrt{\frac{2}{T}} \cos 2\pi f_c t, && 0 \le t \le T \\ &= \sqrt{E}\sqrt{\frac{2}{T}} \cos 2\pi f_c t, && 0 \le t \le T \end{aligned} \tag{22.2}$$

where $E = PT$ is the energy contained in a bit duration. If we take $\phi_1(t) = \sqrt{\frac{2}{T}} \cos 2\pi f_c t$ as the orthonormal basis function, the applicable signal space or constellation diagram of the BASK signals is shown in Figure 22.1.

Figure 22.1 BASK signal constellation diagram.

Figure 22.2 shows the BASK signal sequence generated by the binary sequence 0 1 0 1 0 0 1. The amplitude of a carrier is switched or keyed by the binary signal $m(t)$. This is sometimes called on-off keying (OOK).

Figure 22.2 (a) Binary modulating signal and (b) BASK signal.

The Fourier transform of the BASK signal $s(t)$ is

$$S(f) = \frac{A}{2} \int_{-\infty}^{\infty} [m(t)\ e^{j 2\pi f_c t}]\ e^{-j2\pi ft}\ dt + \frac{A}{2} \int_{-\infty}^{\infty} [m(t)\ e^{-j 2\pi f_c t}]\ e^{-j2\pi ft}\ dt$$

$$S(f) = \frac{A}{2} M(f - f_c) + \frac{A}{2} M(f + f_c) \qquad (22.3)$$

The effect of multiplication by the carrier signal $A\cos 2\pi f_c t$ is simply to shift the spectrum of the modulating signal $m(t)$ to f_c. Figure 22.3 shows the amplitude spectrum of the BASK signals when $m(t)$ is a periodic pulse train.

Figure 22.3 (a) Modulating signal, (b) spectrum of (a), and (c) spectrum of BASK signals.

Since we define the bandwidth as the range occupied by the baseband signal $m(t)$ from 0 Hz to the first zero-crossing point, we have B Hz of bandwidth for the baseband signal and $2B$ Hz for the BASK signal. Figure 22.4 shows the modulator and a possible implementation of the coherent demodulator for BASK signals.

Figure 22.4 (a) BASK modulator and (b) coherent demodulator.

M-ary Amplitude-Shift Keying (*M*-ASK)

An *M-ary amplitude-shift keying* (*M*-ASK) signal can be defined by

$$s(t) = \begin{cases} A_i \cos 2\pi f_c t, & 0 \le t \le T \\ 0, & elsewhere \end{cases} \qquad (22.4)$$

where

$$A_i = A[2i - (M - 1)] \quad (22.5)$$

for $i = 0, 1, ..., M - 1$ and $M \geq 4$. Here, A is a constant, f_c is the carrier frequency, and T is the symbol duration. The signal has a power $P_i = A_i^2/2$, so that $A_i = \sqrt{2P_i}$. Thus equation (22.4) can be written as

$$\begin{aligned} s(t) &= \sqrt{2P_i}\cos 2\pi f_c t, && 0 \leq t \leq T \\ &= \sqrt{P_i T}\sqrt{\frac{2}{T}}\cos 2\pi f_c t, && 0 \leq t \leq T \\ &= \sqrt{E_i}\sqrt{\frac{2}{T}}\cos 2\pi f_c t, && 0 \leq t \leq T \end{aligned} \quad (22.6)$$

where $E_i = P_i T$ is the energy of $s(t)$ contained in a symbol duration for $i = 0, 1, ..., M - 1$. Figure 22.5 shows the signal constellation diagrams of M-ASK and 4-ASK signals.

Figure 22.5 (a) M-ASK and (b) 4-ASK signal constellation diagrams.

Figure 22.6 shows the 4-ASK signal sequence generated by the binary sequence 00 01 10 11.

Figure 22.6 4-ASK modulation: (a) binary sequence, (b) 4-ary signal, and (b) 4-ASK signal.

Figure 22.7 shows the modulator and a possible implementation of the coherent demodulator for M-ASK signals.

Figure 22.7 (a) M-ASK modulator and (b) coherent demodulator.

References

[1] M. Schwartz, Information Transmission, Modulation, and Noise, 4/e, McGraw Hill, 1990.

[2] P. Z. Peebles, Jr., Digital Communication Systems, Prentice Hall, 1987.

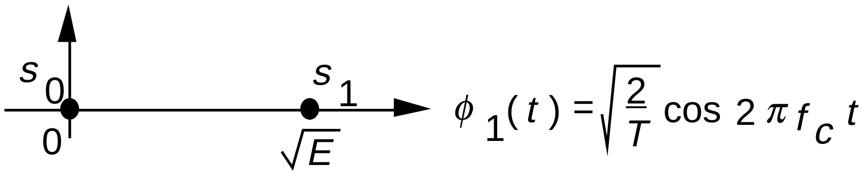

Figure 22.1 BASK signal constellation diagram.

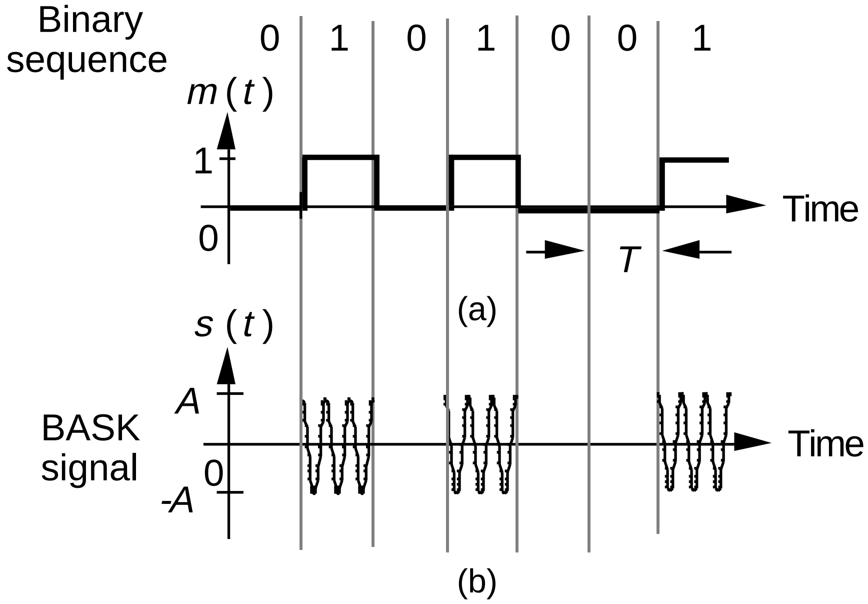

Figure 22.2 (a) Binary modulating signal and (b) BASK signal.

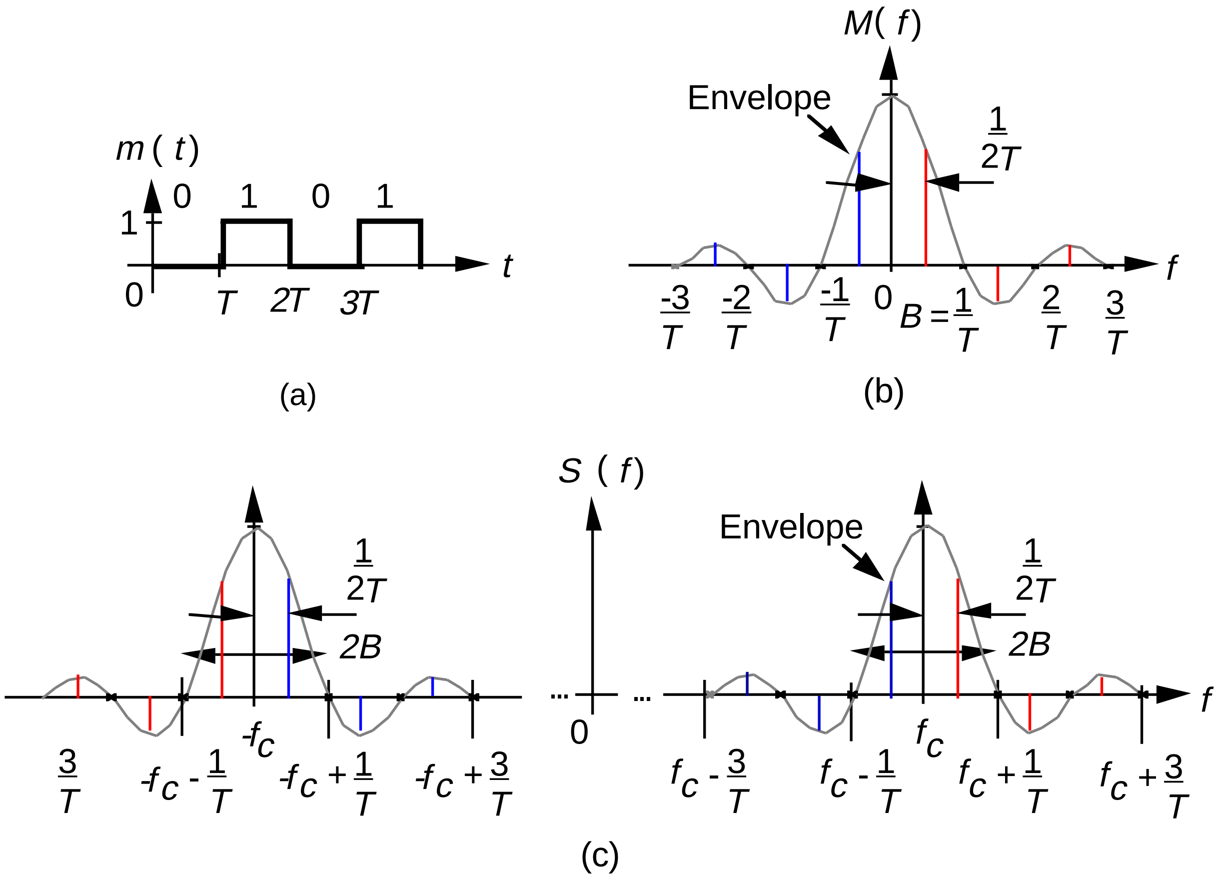

Figure 22.3 (a) Modulating signal, (b) spectrum of (a), and (c) spectrum of BASK signals.

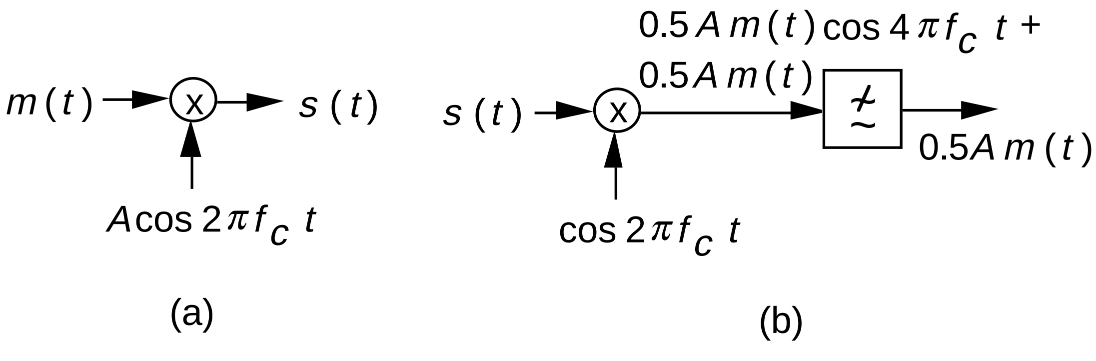

Figure 22.4 (a) BASK modulator and (b) coherent demodulator.

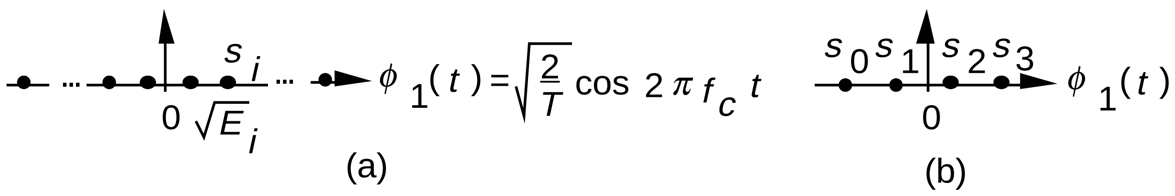

Figure 22.5 (a) *M*-ASK and (b) 4-ASK signal constellation diagrams.

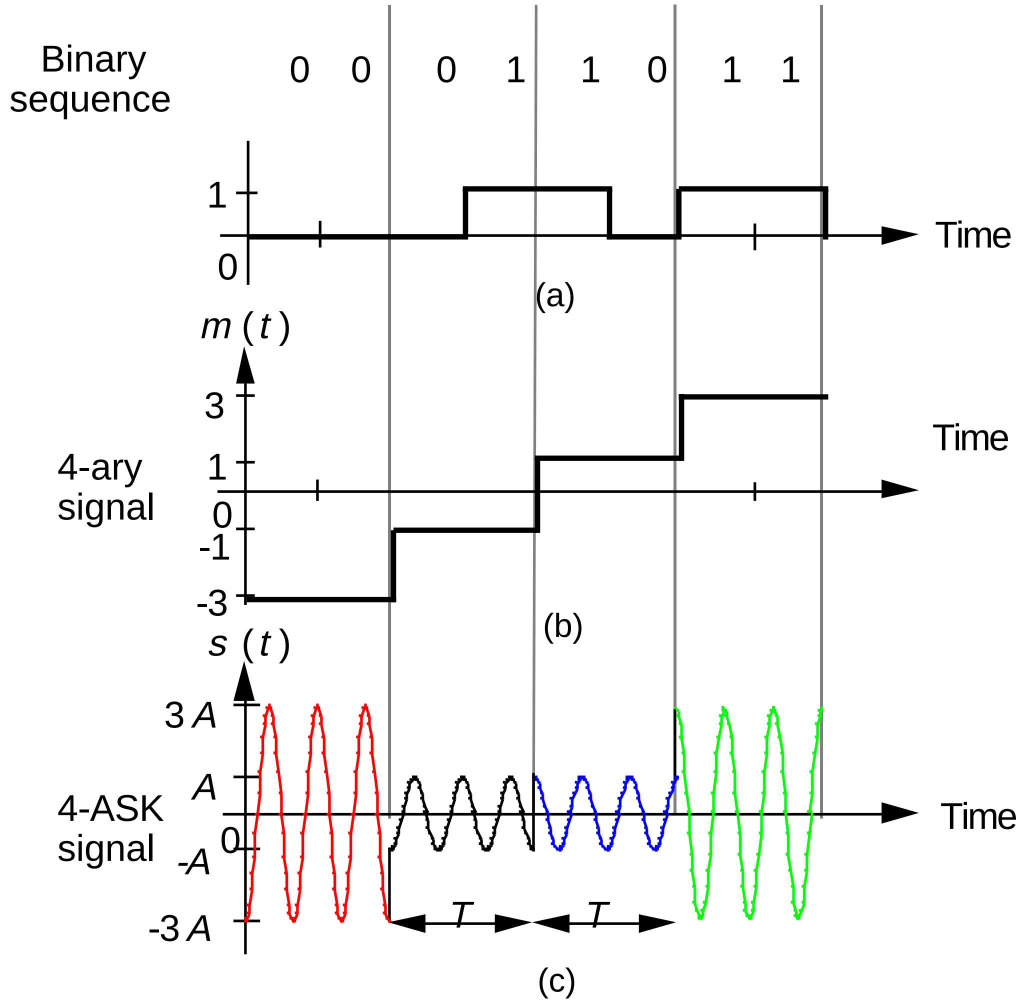

Figure 22.6 4-ASK modulation: (a) binary sequence, (b) 4-ary signal, and (b) 4-ASK signal.

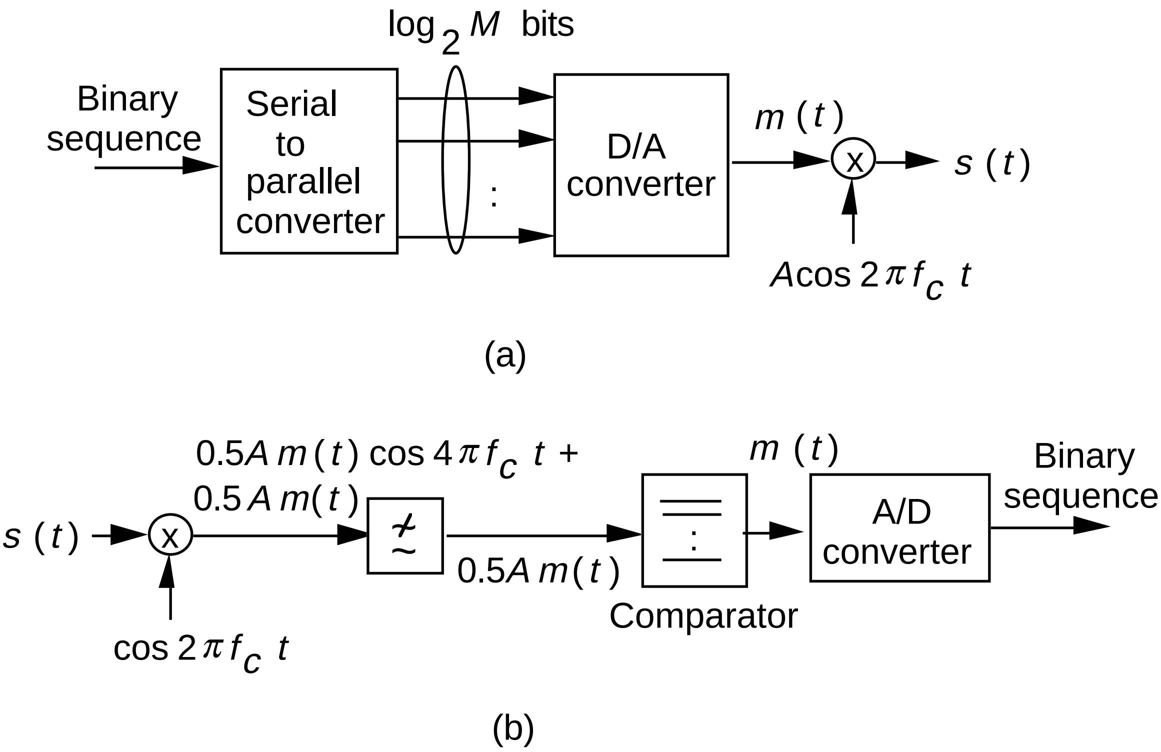

Figure 22.7 (a) *M*-ASK modulator and (b) coherent demodulator.