

Implementation of Digital Modulation Technique using MATLAB

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Abstract The transmission of message signal (be it in analog or digital form) over a band pass communication channel requires a shift in the range of frequencies contained in the signal into other frequency range is suitable for transmission. A shift of the range of frequency in a signal is accomplished by using modulation. In this paper we are implementing the digital modulation techniques which are binary amplitude shift keying (BASK), BFSK, that are used to transmit binary data over a band pass communication channel with fixed frequency limits set by the channel with the help of MATLAB software tool.

Keyword: Modulation, BASK, BFSK

1. INTRODUCTION

The transmission of digital signals is increasing at a rapid rate. Low-frequency analog 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 analog 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; $c = \lambda f$, where c is the velocity of light, f is the signal frequency and λ is the wavelength. For a 1 kHz audio signal, the wavelength is 300 km. 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 sinusoidal waveform.

There are three basic ways of modulating a cosine 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.

2. BINARY AMPLITUDE-SHIFT KEYING (BASK)

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

$$s(t) = A m(t) \cos 2\pi f_c t \quad 0 \leq t \leq T \tag{1.1}$$

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 (1.1) can be written as

$$\begin{aligned} s(t) &= \sqrt{2P} \cos 2\pi f_c t, & 0 \leq t \leq T \\ &= \sqrt{PT} \sqrt{2/T} \cos 2\pi f_c t, & 0 \leq t \leq T \\ &= \sqrt{E} \sqrt{2/T} \cos 2\pi f_c t, & 0 \leq t \leq T \end{aligned} \tag{1.2}$$

Where $E = P T$ is the energy contained in a bit duration. If we take $\phi_1(t) = \sqrt{2/T} \cos 2\pi f_c t$ as the orthonormal basis function, the applicable signal space or constellation diagram of the BASK signals is shown in Figure 1.1.

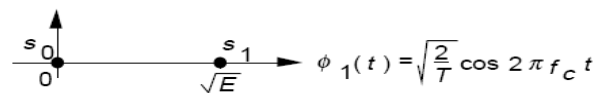


Figure 1.1 BASK signal constellation diagram.

Figure 1.2 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).

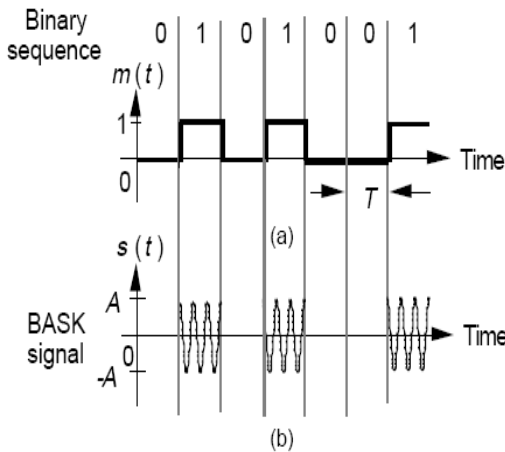


Figure 1.2 (a) Binary modulating signal and (b) BASK signal.

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

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

$$S(f) = A/2M(f - fc) + A/2M(f + fc) \tag{1.3}$$

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 1.3 shows the amplitude spectrum of the BASK signals when $m(t)$ is a periodic pulse train.

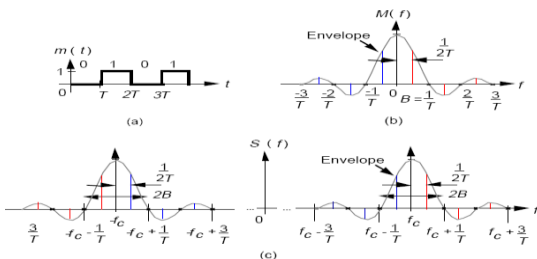


Figure 1.3 (a) Modulating signal, (b) spectrum of (a), and (c) spectrum of BASK signals.

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 1.4 shows the modulator and a possible implementation of the coherent demodulator for BASK signals.

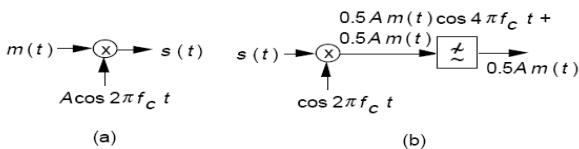


Figure 1.4 (a) BASK modulator and (b) coherent demodulator.

3. BINARY FREQUENCY-SHIFT KEYING (BFSK)

A binary frequency-shift keying (BFSK) signal can be defined by

$$s(t) = \begin{cases} A \cos 2\pi f_0 t, & 0 \leq t \leq T \\ A \cos 2\pi f_1 t, & \text{elsewhere} \end{cases} \tag{2.1}$$

Where A is a constant, f_0 and f_1 are the transmitted frequencies, and T is the bit duration. The signal has a power $P = A^2/2$, so that $A = \sqrt{2P}$. Thus equation (2.1) can be written as

$$s(t) = \begin{cases} \sqrt{PT} \sqrt{2/T} \cos 2\pi f_0 t, & 0 \leq t \leq T \\ \sqrt{PT} \sqrt{2/T} \cos 2\pi f_1 t, & \text{elsewhere} \end{cases}$$

$$= \begin{cases} \sqrt{E} \sqrt{2/T} \cos 2\pi f_0 t, & 0 \leq t \leq T \\ \sqrt{E} \sqrt{2/T} \cos 2\pi f_1 t, & \text{elsewhere} \end{cases} \tag{2.2}$$

Where $E = PT$ is the energy contained in a bit duration. For orthogonality, $f_0 = m/T$ and $f_1 = n/T$ for integer $n > m$ and $f_1 - f_0$ must be an integer multiple of $1/2T$. We can take $\phi_{01}(t) = \sqrt{2/T} \cos 2\pi f_0 t$ and $\phi_{02}(t) = \sqrt{2/T} \sin 2\pi f_1 t$ as the orthonormal basis functions [3]. The applicable signal constellation diagram of the orthogonal BFSK signal is shown in Figure 2.1.

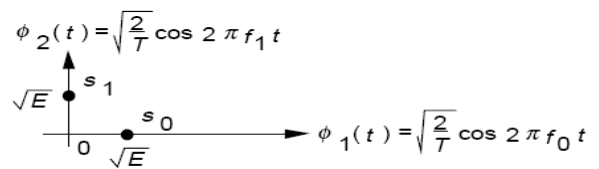


Figure 2.1 Orthogonal BFSK signal constellation diagram.

Figure 2.2 shows the BFSK signal sequence generated by the binary sequence 0 1 0 1 0 0 1.

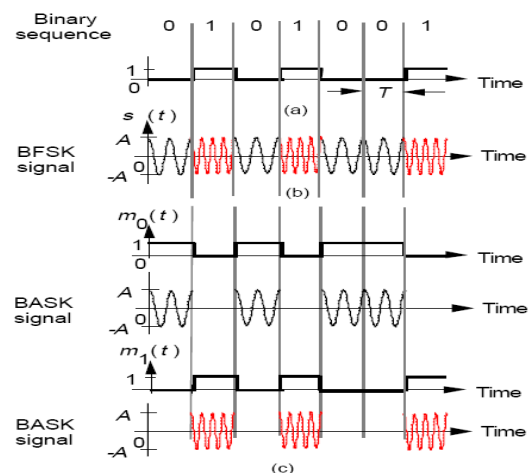


Figure 2.2 (a) Binary sequence, (b) BFSK signal, and (c) binary modulating and BASK signals.

It can be seen that phase continuity is maintained at transitions. Further, the BFSK signal is the sum of two BASK signals generated by two modulating signals $m_0(t)$ and $m_1(t)$. Therefore, the Fourier transform of the BFSK signal $s(t)$ is

$$\begin{aligned}
 S(f) &= A/2 \int_{-\infty}^{\infty} [m_0(t) e^{j2\pi f_0 t}] e^{-j2\pi f t} dt + A/2 \int_{-\infty}^{\infty} [m_1(t) e^{j2\pi f_1 t}] e^{-j2\pi f t} dt \\
 &= A/2 M_0(f - f_0) + A/2 M_0(f + f_0) + A/2 M_1(f - f_1) + A/2 M_1(f + f_1)
 \end{aligned}
 \tag{2.3}$$

Figure 2.3 shows the amplitude spectrum of the BFSK signal when $m_0(t)$ and $m_1(t)$

are periodic pulse trains.

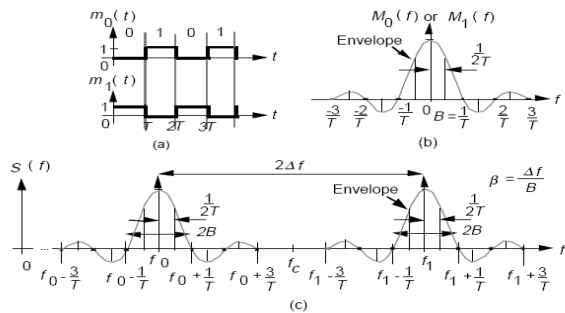


Figure 2.3 (a) Modulating signals, (b) Spectrum of (a), and (c) spectrum of BFSK signal (positive frequencies only).

An alternative representation of the BFSK signal consists of letting $f_0 = f_c - \Delta f$ and $f_1 = f_c + \Delta f$.

Then

$$f_1 - f_0 = 2\Delta f \tag{2.4}$$

and

$$s(t) = A \cos 2\pi (f_c + \Delta f) t \tag{2.5}$$

where f_c is the carrier frequency, $\Delta f = \beta B$ is the frequency deviation, β is the modulation index, and $B = 1/T$ is the bandwidth of the modulating signal. When $\beta \gg 1$, we have a wide band BFSK signal. The bandwidth is approximately equal to $2\Delta f$. When $\beta \ll 1$, we have a narrow band BFSK signal. The bandwidth is approximately equal to $2B$.

Figure 2.4 shows the modulator and coherent demodulator for BFSK signals.

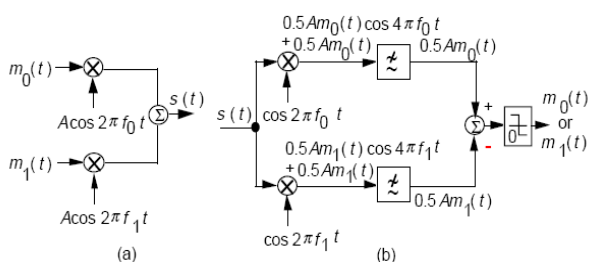


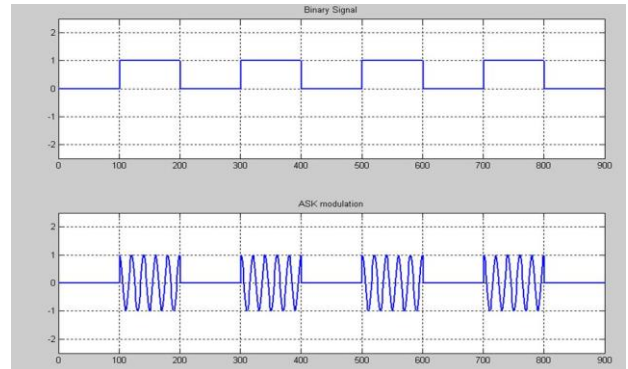
Figure 2.4 (a) BFSK modulator and (b) coherent demodulator.

4. SIMULATION AND RESULTS

After simulating the program on the MATLAB, the following will appear in the command window:-
 Enter the Input Sequence= [0 1 0 1 0 1 0 1 0]
 Enter your choice of Modulation: Amplitude shift Keying(1), Frequency Shift Keying(2), Phase Shift Keying(3)=1

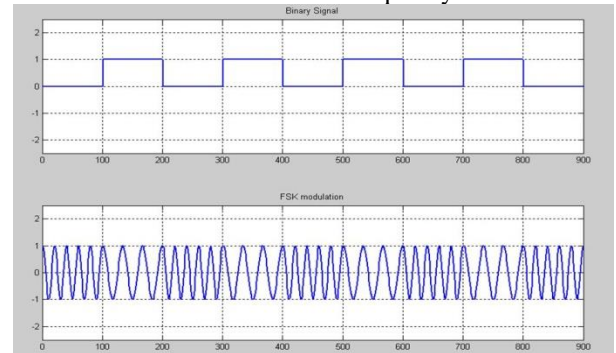
Enter the value of carrier frequency=5

And following graph will appear on the figure window for the choice of modulation as ASK.



For the choice as FSK-Enter The Input Sequence=[0 1 0 1 0 1 0 1 0]

Enter your choice of Modulation: Amplitude shift Keying(1), Frequency Shift Keying(2), Phase Shift Keying(3)=2
 enter the value of first carrier frequency=5
 enter the value of second carrier frequency=3



CONCLUSION

It is clear that after successfully running the program written in MATLAB, the resultant waveform obtained is in accordance with the theoretical waveforms of the basic digital modulation techniques. Thus we are successful in attaining our objective in this paper. ASK : Strength of carrier signal is varied to represent binary 1 or 0. Both frequency & phase remains constant while amplitude changes, commonly, one of the amplitude is zero. ASK is used to transmit digital data over optical fiber. FSK: Frequency of carrier signal is varied to represent binary 1 or 0. Peak amplitude & peak phase remains constant during each bit interval. FSK is less susceptible to error than ASK receiver looks for specific frequency changes over a number of intervals. So voltage (noise) spikes can be ignored. FSK is used over voice lines, in high frequency radio transmission etc.

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