Unit-4
Digital Modulation & Transmission

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Objective

1. To discuss about digital modulation and its types

2. Introduction to base band modulation technique

3. Types of pass band modulation technique

4. Introduction to binary modulation techniques

Digital Modulation

- As we know, a computer needs to communicate between various devices like mouse, keyboard, and printer or between various IC's. The information stored in these devices and computers are in binary format. (0's and 1's). But the devices are connected only by means of electrical connection. Hence, we must requires conversion of binary data into analog signal prior to transmission through the electrical wires. This type of conversion or mapping is called as Digital Modulation.

Types of Digital modulation

- Types of Digital Modulation:

  Baseband technique and

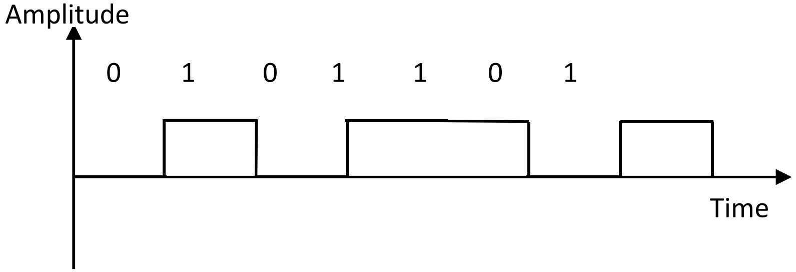
  Pass band technique

- Baseband Modulation:

  Low frequency modulation is called the baseband modulation approach. Some of the examples are popular line coding approaches, like unipolar and polar formats.

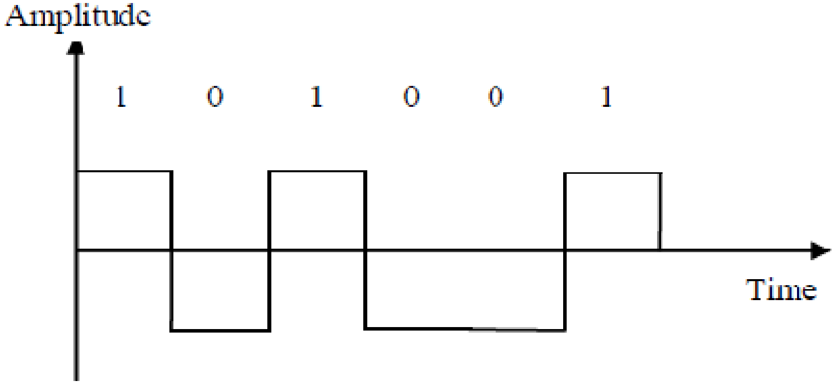
- Unipolar format:

  In this format, binary 1 is represented by some voltage and binary 0 by 0 V. For example, binary 1 by +5V and binary 0 by 0V. It is shown in the figure



- Polar format:

In this format, a positive voltage is used to represent binary 1 and a negative voltage are used represent binary 0. For example, binary 1 by +5V and binary 0 by -5V. It is shown in the figure



- *Pass band Modulation:*

It is a high frequency modulation. In this approach, user binary data are multiplied by high frequency (RF) carrier at the transmitter side.

- *Major types of pass band modulation are:*

  Binary and M-ary modulation techniques.

- *Binary Pass band modulation:*

  In binary modulation technique, bit 0 or 1 can be transmitted for every symbol time interval. The various binary modulation approaches are: ASK (Amplitude shift keying), PSK (Phase shift keying), FSK (Frequency Shift keying) are binary modulation technique.

- *M-ary modulation:*

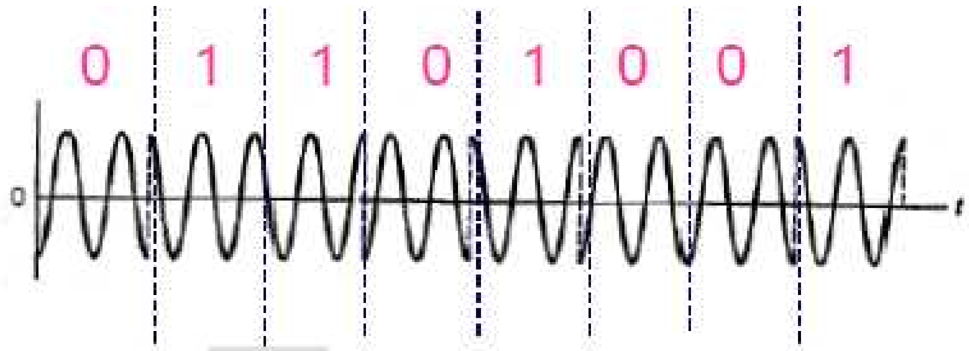
  In this type, more than one bit can be transmitted for every symbol period. Some of the techniques are: QPSK (Quadrature Phase Shift Keying)-Here we transmit two binary digit at a time. M-PSK, M-FSK and QAM (Quadrature Amplitude modulation). Here M represents the number of input levels. For example: in 8-PSK 8 different input conditions can be transmitted or 3 binary digits at a time.

Binary Modulation Techniques

- ASK-Amplitude Shift Keying
- FSK-Frequency Shift Keying
- PSK-Phase Shift Keying

Binary Phase Shift Keying (BPSK)

- In PSK, binary digit 1 or symbol 1 is represented by some phase angle (for example 0°) and binary digit 0 or symbol 0 represented another phase angle (for example 180°). It is shown in figure



- **Mathematical representation**

PSK can be represented as follows,

Binary 1 or symbol 1 represented as $S_1(t)$ and binary 0 or symbol 0 represented as $S_2(t)$. and can be written as,

$$S_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t \qquad 0 \le t \le T_b \qquad \text{For Symbol 1 or Binary digit 1}$$

$$S_2(t) = -\sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t \qquad 0 \le t \le T_b \qquad \text{For Symbol 0 or Binary digit 0}$$

Where E_b is signal energy per bit, T_b is bit duration and f_c is carrier frequency.

Here orthonornal basis signal (or simply carrier signal) is

$$\phi(t) = \sqrt{\frac{2}{T_b}} \cos 2\pi f_c t \qquad 0 \le t \le T_b$$

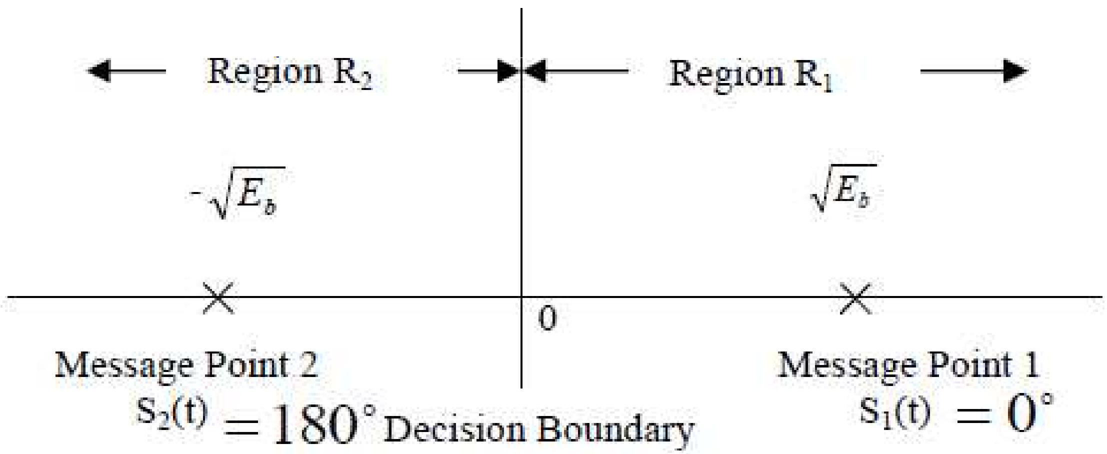
Now we can represent $S_1(t)$ and $S_2(t)$ in terms of orthonormal basis function by,

$$S_1(t) = \sqrt{E_b}\,\phi(t) \qquad 0 \le t \le T_b$$ For Symbol 1 or Binary digit 1

$$S_2(t) = -\sqrt{E_b}\,\phi(t) \qquad 0 \le t \le T_b$$ For Symbol 0 or Binary digit 0

Signal space representation or constellation diagram

Signal space diagram help us to define the amplitude and phase of the signal in pictorial way. Figure shows the constellation diagram of PSK modulation.

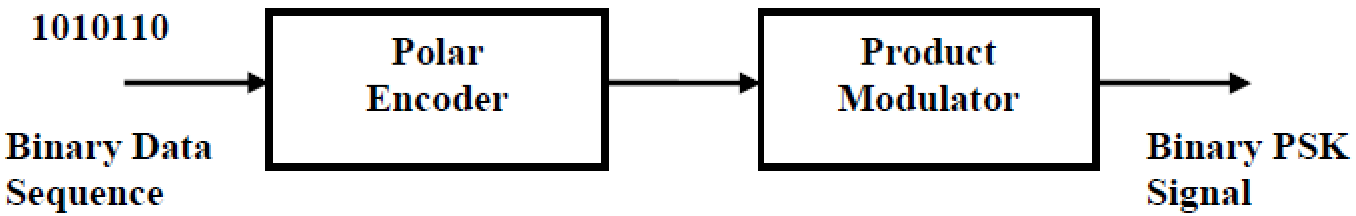


In BPSK, signals $S_1(t)$ and $S_2(t)$ are differentiated with the help of phase angle 180°. Also $S_1(t) = \sqrt{E_b}$ and $S_2(t) = -\sqrt{E_b}$.

Signals of this type are called as Antipodal signal.

PSK Generation

- Generation of a binary PSK signal requires representation of the input binary sequence in polar format with symbol 1 and 0 by $+\sqrt{E_b}$ and $-\sqrt{E_b}$ respectively. The resulting binary wave (polar format) and sinusoidal carrier (Basis signal) $\phi(t)=\sqrt{\frac{2}{T_b}}\cos 2\pi f_c t$ are applied to the product modulator. The desired PSK signals are obtained at the modulator output. The circuit is shown in figure



$$\phi(t) = \sqrt{\frac{2}{T_b}} Cos 2\pi f_c t$$

PSK reception or demodulation

The noisy PSK signal is received at the receiver side. Detection of binary 1's and 0's from noisy PSK signal is done by applying x(t) to the product modulator. The other input for the product modulator is a locally generated carrier signal $\phi(t) = \sqrt{\frac{2}{T_b}} \cos 2\pi f_c t$. Now, this multiplication is sent to the correlator integrator. The basic principle for correlator detector is orthonormal basis operation.

Othonormal basis operation is

$$\int_0^{T_b} \phi_i(t)\phi_j(t) = 1$$

when $i = j$ and 0 for $i \neq j$

1. Assuming receipt of binary 1, x(t) is $\sqrt{\frac{2E_b}{T_b}}\cos 2\pi f_c t$ (or) $\sqrt{E_b}\phi(t)$ and the other input of the product modulator is $\phi(t)=\sqrt{\frac{2}{T_b}}\cos 2\pi f_c t$. When x(t) and $\phi(t)$ are integrated the output is $\sqrt{E_b}$.

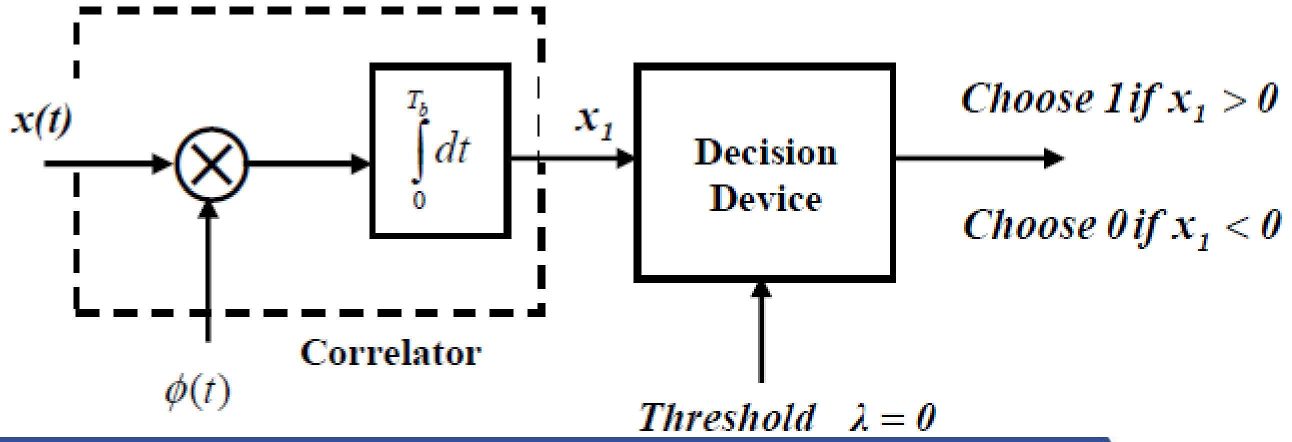
$$\left\{\int\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t).\sqrt{\frac{2}{T_b}}\cos 2\pi f_c t=\sqrt{E_b}\right\}$$

(since received signal carrier frequency and locally generated carrier signal both are equal in phase). The correlator output is $x_1=\sqrt{E_b}$ compared with a threshold λ, where $\lambda=0$. Therefore $x_1>\lambda$, receiver decides in favor of symbol 1.

2. Assuming receipt of binary 0, x(t) is $-\sqrt{\frac{2E_b}{T_b}}\cos 2\pi f_c t$ and the other input of the product modulator is $\phi(t)=\sqrt{\frac{2}{T_b}}\cos 2\pi f_c t$. When x(t) and $\phi(t)$ are integrated, the output is $-\sqrt{E_b}$.

Since, $$\left\{\int(-)\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t).\sqrt{\frac{2}{T_b}}\cos 2\pi f_c t=-\sqrt{E_b}\right\}$$

The correlator output $x_1=-\sqrt{E_b}$ is compared with a $\lambda,$ threshold where $\lambda=0$. Therefore, $x_1<\lambda,$ receiver decides in favor of symbol 0. The receiver circuit is shown in figure



Probability of Error

$$P_e = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

Error probability of the modulation technique depends on the distance between two signal points, called "Euclidean distance". The distance between the two points $S_1(t)$ and $S_2(t)$ are $2\sqrt{E_b}$

Now the decision rules for detecting symbol $S_1(t)$. and $S_2(t)$. are as follows:

1. The set of received message points closest to the region R1 are termed as Symbol 1 or $S_1(t)$.
2. The set of received message points closest to the region R2 are termed as Symbol 0 or $S_2(t)$.

Hence probability of the error equation for ASK is: