Lecture One

Objective of Lecture:

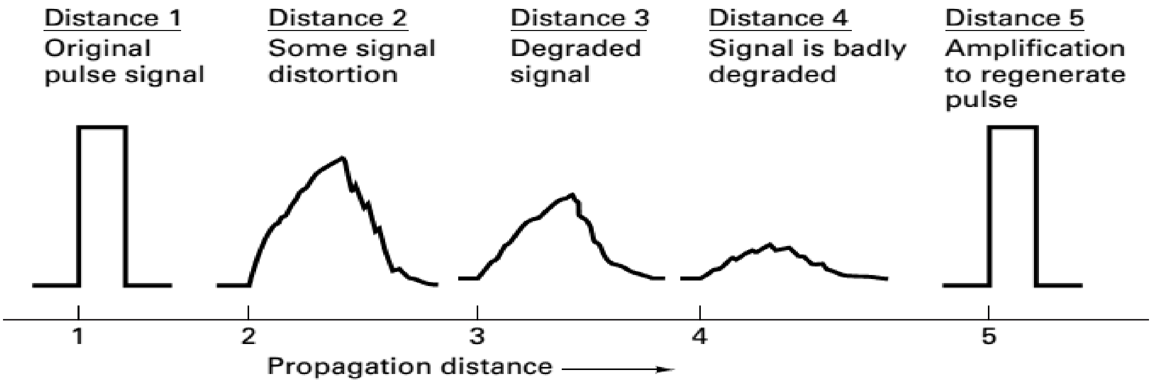
- Understanding layout of digital communication systems
- Signal types
- General block diagram of digital communication
- Advantage and disadvantage of digital modulation, digital coding

1.1 Introduction:

Digital communication systems are becoming increasingly attractive because of the ever-growing demand for data communication and because digital transmission offers data processing options and flexibilities not available with analog transmission. The principal feature of a digital communication system (DCS) is that during a finite interval of time, it sends a waveform from a finite set of possible waveforms, in contrast to an analog communication system, which sends a waveform from an infinite variety of waveform shapes with theoretically infinite resolution. In a DCS, the objective at the receiver is not to reproduce a transmitted waveform with precision; instead, the objective is to determine from a noise-perturbed signal which waveform from the finite set of waveforms was sent by the transmitter. An important measure of system performance in a DCS is the probability of error (P_E).

1.2 Advantages of Digital Communication:

There are many reasons. The primary advantage is the ease with which digital signals, compared with analog signals, are regenerated. Figure 1 illustrates an ideal binary digital pulse propagating along a transmission line.



During the time that the transmitted pulse can still be reliably identified (before it is degraded to an ambiguous state), the pulse is amplified by a digital amplifier that recovers its original ideal shape. The pulse is thus “reborn” or regenerated. Circuits that perform this function at regular intervals along a transmission system are called regenerative repeaters.

Digital circuits are less subject to distortion and interference than are analog circuits. Because binary digital circuits operate in one of two states—fully on or fully off—to be meaningful, a disturbance must be large enough to change the circuit operating point from one state to the other.

With digital techniques, extremely low error rates producing high signal fidelity are possible through error detection and correction but similar procedures are not available with analog.

Ssecurity is another priority of messaging services in modern days. Digital communication provides better security to messages than the analog communication. It can be achieved through various coding techniques available in digital communication.

Digital circuits are more reliable and can be produced at a lower cost than analog circuits. Also, digital hardware lends itself to more flexible implementation than analog hardware.

1.3 Disadvantages of Digital Communications:

Digital communications require greater bandwidth than analogue to transmit the same information.

The detection of digital signals requires the communications system to be synchronized, whereas generally speaking this is not the case with analogue systems.

The noise of sampling error.

When the signal-to-noise ratio drops below a certain threshold, the quality of service can change suddenly from very good to very poor. In contrast, most analog communication systems degrade more gracefully.

1.4 Typical Block Diagram and Transformations

The functional block diagram is shown in Fig.2. The upper blocks—format, source encode, encrypt, channel encode, multiplex, pulse modulate, bandpass modulate, frequency spread, and multiple access—denote signal transformations from the source to the transmitter (XMT). The lower blocks denote signal transformations from the receiver (RCV) to the sink, essentially reversing the signal processing steps performed by the upper blocks. The modulate and demodulate/detect blocks together are called a modem.

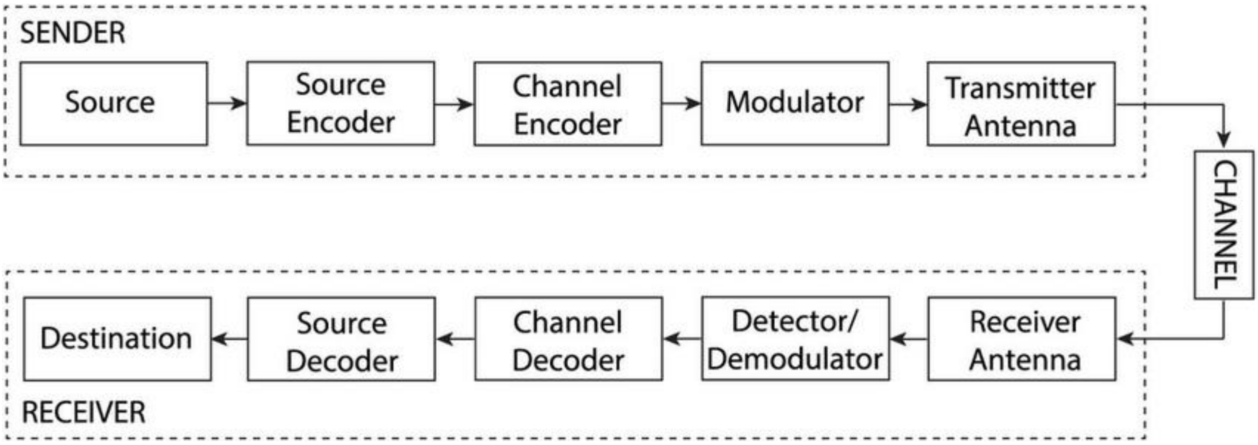


Figure 2 Block diagram of a typical digital communication system.

Information source. This is the device producing information to be communicated by means of the DCS. Information sources can be analog or discrete. Analog information sources can be transformed into digital sources through the use of sampling and quantization. Sampling and quantization techniques called formatting and source coding.

Binary digit (bit). This is the fundamental information unit for all digital systems. The term bit also is used as a unit of information content.

Bit stream. This is a sequence of binary digits (ones and zeros). A bit stream is often termed a baseband signal, which implies that its spectral content extends from (or near) dc up to some finite value, usually less than a few megahertz.

Symbol (digital message). A symbol is a group of k bits considered as a unit. We refer to this unit as a message symbol m_i (i=1, . . . , M) from a finite symbol set or alphabet. The size of the alphabet, $M, is\ M = 2^k$, where k is the number of bits in the symbol. For baseband transmission, each m_i symbol will be represented by one of a set of baseband pulse waveforms $g_1(t), g_2(t), \ldots \ldots g_M(t)$. When transmitting a sequence of such pulses, the unit baud is sometimes used to express pulse rate (symbol rate). For typical bandpass transmission, each $g_i(t)$ pulse will then be represented by one of a set of bandpass waveform $s(t), s_2(t), \ldots \ldots s_M(t)$.

Digital waveform. This is a voltage or current waveform (a pulse for baseband transmission, or a sinusoid for bandpass transmission) that represents a digital symbol.

Data rate. This quantity in bits per second (bits/s) is given by $R = \frac{K}{T} = \left(\frac{1}{T}\right) log_2 M$bits/s, where k bits identify a symbol from an $M = 2^k$-symbol alphabet, and T is the k-bit symbol duration.

1.5 Classification of Signals:

1- **Deterministic and Random Signals:** Deterministic signals or waveforms are modeled by explicit mathematical expressions, such as $x(t) = 5 \cos 10t$. For a random waveform it is not possible to write such an explicit expression. However, when examined over a long period, a random waveform, also referred to as a random process, may exhibit certain regularities that can be described in terms of probabilities and statistical averages.

2- **Periodic and Nonperiodic Signals:** A signal x(t) is called periodic in time if there exists a constant $T_0 > 0$ such that

$$x(t) = x(t + T_0) \qquad for \quad -\infty < t < \infty$$

where t denotes time. The smallest value of T_0 that satisfies this condition is called the period of x(t). The period T_0 defines the duration of one complete cycle of x(t). A signal for which there is no value of T_0 that satisfies above Equation is called a nonperiodic signal.

3- **Analog and Discrete Signals:** An analog signal x(t) is a continuous function of time; that is, x(t) is uniquely defined for all t. An electrical analog signal arises when a physical waveform (e.g., speech) is converted into an electrical signal by means of a transducer. By comparison, a discrete signal x(kT) is one that exists only at discrete times; it is characterized by a sequence of numbers defined for each time, kT, where k is an integer and T is a fixed time interval.

1.6 Fourier Transform: It is a technique used to transform nonperiodic and periodic signal from time domain to frequency domain and vise versa.

Foureir Transform:

$$X(w) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt$$

Or

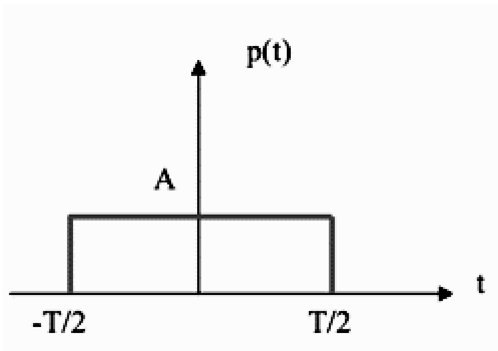
$$X(f) = \int_{-\infty}^{\infty} x(t)e^{-j2\pi ft}dt \qquad sinc\ w = 2\pi f$$

Invers Fourier Transform:

$$x(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(w)e^{j\omega t}dw$$

$$x(t) = \int_{-\infty}^{\infty} X(f)e^{j2\pi t}df$$

Example 1 : Obtain the Fourier transform of rectangular pulse of duration T and amplitude A shown below:



The rectangular pulse represented by:

$$rect\frac{t}{T} = \begin{cases} A & for\ \ -\frac{T}{2} < t < \frac{T}{2} \\ 0 & elsewhere \end{cases}$$

$$x(t) = A\,rect\left(\frac{t}{T}\right)$$

FT for $x(t)$

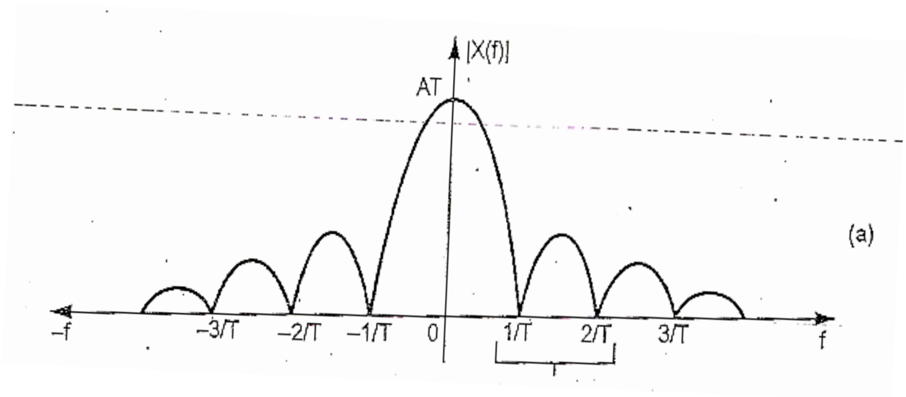
$$X(f) = \int_{-\infty}^{\infty} x(t)e^{-j2\pi ft}dt$$

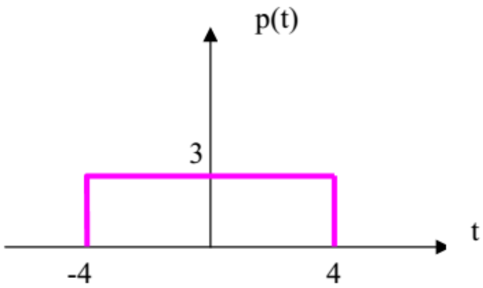
$$= \int_{-\frac{T}{2}}^{\frac{T}{2}} Ae^{-j2\pi ft}dt = \frac{A}{-j2\pi f}\left[e^{-j2\pi ft}\right]_{-\frac{T}{2}}^{\frac{T}{2}}$$

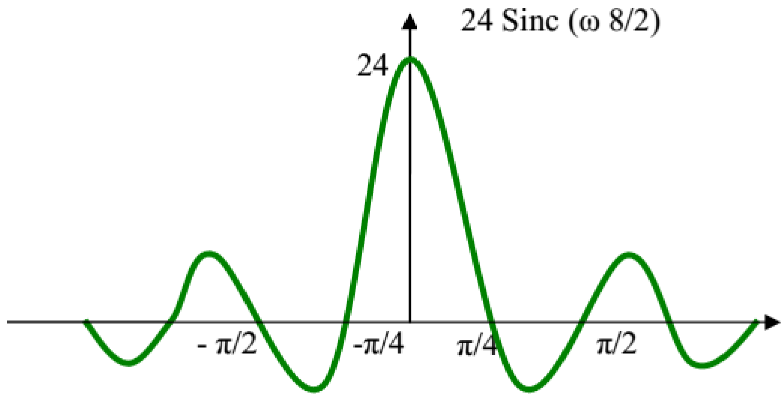
$$= \frac{A}{-j2\pi f}\left[e^{-j\pi fT} - e^{j\pi fT}\right] = \frac{A}{\pi f}\left[\frac{e^{-j\pi fT} - e^{j\pi fT}}{2j}\right]$$

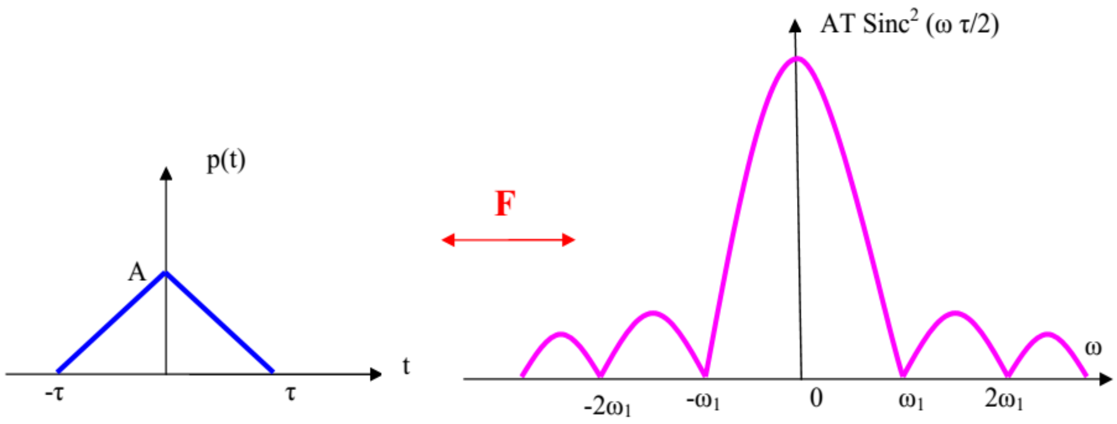
$$= \frac{A}{\pi f}\sin(\pi f T) = AT\frac{\sin(\pi f T)}{\pi f T}$$

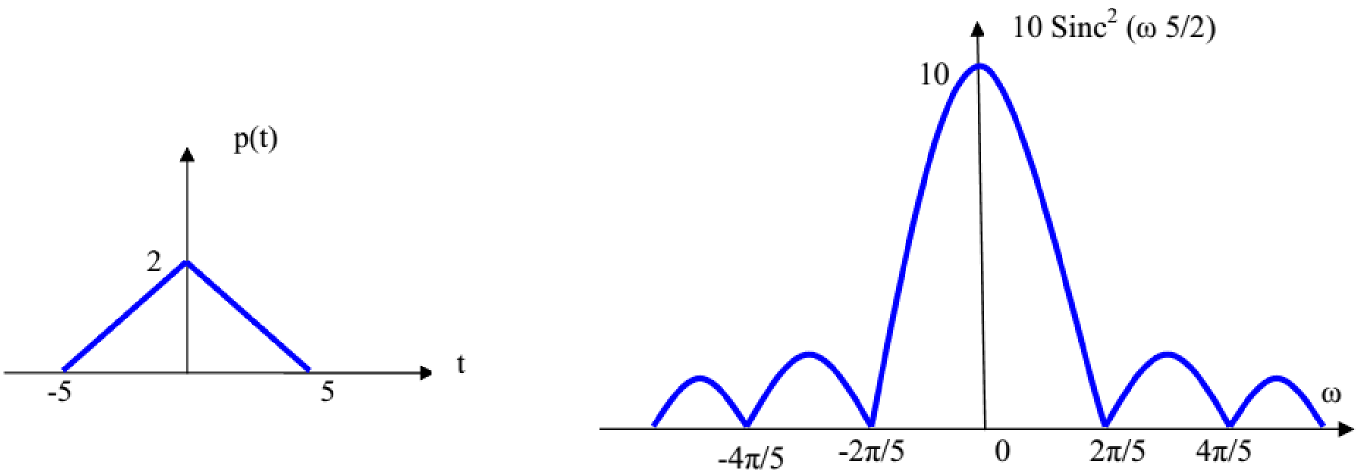
$$\therefore X(f) = AT sinc(\pi f T)$$








p(t)
A
-τ
τ
t
F
AT Sinc² (ω τ/2)
-2ω₁
-ω₁
0
ω₁
2ω₁
ω


p(t)
2
-5
5
t
10 Sinc² (ω 5/2)
10
-4π/5
-2π/5
0
2π/5
4π/5
ω