CHAPTER 1

Introduction to a Digital Communication System

LEARNING OBJECTIVES

This chapter introduces the features, constituent building blocks, and basic processes involved with reference to a fundamental digital communication system.

After going through this chapter, the reader will be able to:

- understand the basic building blocks of a digital communication system and the principles of digital data transmission and reception
- explain the pros and cons of digital data transmission, relative to analog communication systems
- understand the principles of regenerative repeaters used in digital data transmission

1.0 Basic Communication System

A basic communication system broadly is constituted by a Transmitter, communication channel and a Receiver. To have a relatively better insight, an information source and the final user (in terms of Information Theory, referred to as Sink) also will be the two more building blocks of the system.

It can be represented as:

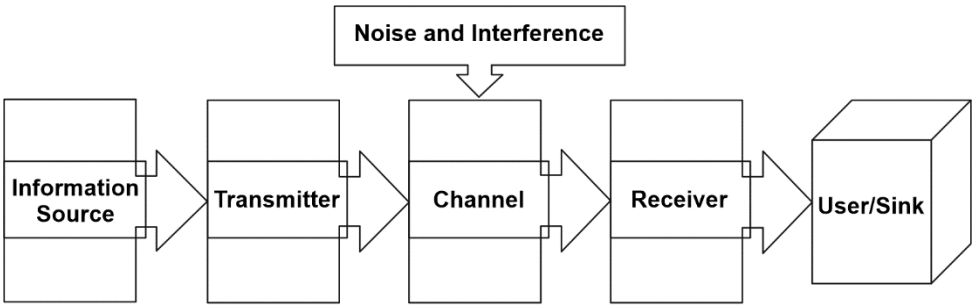

Fig.1.1 A General Communication System.

The channel can be a Guided or an Unguided medium. The process of communication is considered to be fruitful, when the output of the source is the input for the user, under the specific constraints such as Transmitter power, Channel Bandwidth, interference, channel noise, and the internal noise of the system etc. which greatly affects the quality of the communication system specified in terms of Signal Power to Noise Power ratio $\frac{S}{N}$.

The effect of channel noise on the signal cannot be completely avoided, but can be made reduced to the required level, through the design. During the design process, importance will be given to the efficient transmission of the information i.e., the system should be able to deliver maximum amount of information (with minimized loss) under efficient utilization of communication resources such as Power and Bandwidth.

In an analog communication system, the output of the source (referred to as baseband signal) which is continuous and analog is send to the receiving end of the system through a channel being guided medium (Baseband communication) or an unguided medium (Carrier communication), the carrier being a sinusoidal signal.

1.1 Basic Digital Communication System

A digital communication system, more significantly deals with the transmission and reception of binary digital data.

A typical digital communication system can be represented as:

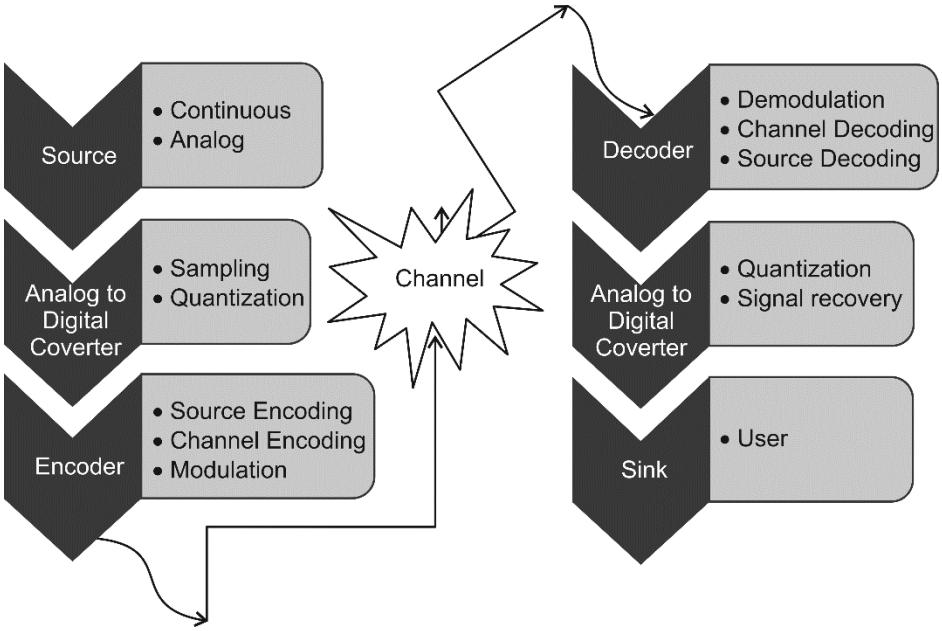

Fig.1.2 Basic Digital Communication System.

As any naturally existing source generates continuous and analog information only, to transmit such information using digital means, additional stages are to be included both at transmitting and receiving ends of a digital communication system, relative to Analog communication system.

Since, there is no discrete process or digital process naturally existing, to transmit the output of the naturally existing source which is continuous and analog, through digital communication means, it is first to be converted into discrete process and then to digital. Discretization with respect to time axis is done by Sampling process and discretization with respect to amplitude axis is done by quantization. The quantizer converts each sampled level into one of the permitted amplitude levels, that are referred to Quantization levels. This total process of getting the digital data from the output of a naturally existing source is referred to Analog to Digital Conversion.

To make efficient utilization of the channel bandwidth, redundancy in the data being transmitted is removed by using Source Encoder. Source encoding is the efficient way of representing the output of a source and is a one to one mapping between the message stream and code word stream.

Due to the channel noise, at the receiving side, the data received may be in corrupted form i.e. a transmitted one may be received as a zero or the other way, and these are referred to as errors. To account for the effects of channel noise, channel encoding is the principle used. A channel encoder introduces redundancy (parity bits) to the digital word to be transmitted at the transmitting side itself. The parity introduced will facilitate the detection and correction of errors.

The channel encoded data can be sent to the receiver using guided medium or unguided medium, similar to Analog communication system. When the medium is unguided, the digital data modulates a sinusoidal carrier and the modulated carrier carrying the baseband information travels in the communication channel.

At the receiving side, after demodulation, the channel decoder detects and corrects errors if any, in the received data stream and the source decoder performs the reverse mapping to that performed by source encoder.

A quantizer similar to that at the transmitting side is available at the receiving side also and recovers the corresponding quantization level from the received voltage level. The reconstruction filter recovers the continuous and analog signal from the output of the quantizer. At the receiving side, this total process of getting back the continuous and analog signal is referred to as Digital to Analog Conversion. The output of the Digital to Analog Converter is the input to the final recipient of the information i.e. the user.

1.2 Comparison of a Digital Communication System with an Analog Communication System

- In a Digital communication system, under carrier communication, the carrier used is a sinusoidal carrier, similar to Analog communication system.

- Digital communication differs from the analog communication system with respect to the nature of the baseband signal, carrier being the same.
- During the digitization process, Quantization is done to convert many number of amplitude levels in the sampled signal into a few permitted levels. At any instant of time, always there is a difference between the original sample of the baseband signal and the corresponding quantization level generated. This difference is referred to as Quantization error or Quantization Noise, which is unavoidable. But, can be made to be within the tolerable limits, by the proper selection of parameters of a quantizer (discussed in detail in Chapter-4). Thus, a digital communication system suffers from inaccuracy, relative to its analog counterpart.
- The same quantizer available at the receiver will avoid the effect of channel noise (depending on the parameters of the quantizer) on the received signal level, thereby improving the overall Signal to Noise ratio of the system.
- In an analog communication system, the output of the receiver should be the baseband signal sent without any envelope distortion and the frequency difference. In other words, it can be considered that, based on the received signal, the receiver should specify the envelope and frequency of the baseband signal sent.

But, in the case of digital communication, demodulation cannot be considered as a similar process. With different line encoding formats used under different applications, because of the filter characteristics of the communication channel, the abrupt transitions available in the baseband data prior to transmission may not get retained at the receiving side and may appear as gradual transitions at the receiving side.

From these received, it is not possible to retrieve the envelope of the signal sent. Hence, in digital data transmission, at the receiver, getting back the envelope of the transmitted signal is not a part of demodulation, but, based on the received signal, the receiver has to make a decision whether the sent was a 1/0. For this purpose, a process called Threshold Detection is used (discussed in detail in Chapter-6).

Thus, relative to Analog communication system, in a digital communication system, demodulation is simple, as it is simply a decision making irrespective of the envelope of the received signal, unlike Analog communication system where Envelope of the signal sent is to be retained at the receiving side.

- Depending on noise level, this decision made may be sometimes wrong and these wrong decisions are referred to as errors. The receiver cannot identify the presence of errors. To provide the error detection and correction ability for the receiver, channel encoder provides redundancy for the information being transmitted. This results in an increase the data rate and thus demands for more channel bandwidth requirement.

Thus, relative to analog communication system, the following advantages and limitations of a digital communication can be inferred:

***Advantages*:**

- Better Noise Performance
- Demodulation is simple

***Limitations*:**

- Inaccuracy
- Redundancy leading to increased bandwidth requirements
- Along the channel, the strength of the signal transmitted goes on reducing as the length of the channel is increasing and thus is more prone to the effect of channel noise. To provide the required signal level throughout the system, repeaters (basically amplifiers) are located at various points along the length of the channel. A repeater should receive, amplify and retransmit the signal. These repeaters are spaced sufficiently close to each other such that the signal is prevented from getting attenuated to a low level, which then becomes more noise prone. This is the general scenario during the signal transmission.

During the transmission of digital data through medium, repeaters referred to as regenerative repeaters are located along the length of the channel and are used for reconstruction of the signals, unlike the conventional repeaters which are used for signal amplification.

A regenerative repeater should reshape, retime and regenerate the signal.

When an attenuated and distorted pulse is received at a regenerative repeater, it is subjected to pre-amplification and equalization and thus will be subjected to reshaping. The associated DC component (if any) is removed using filtering.

A Timing circuit is used to fix the proper sampling instant to sample the received and to decide whether is a one or a zero by comparing the sample against the Threshold level in the process of Threshold detection.

Thus a repeater in digital data transmission is different from a conventional repeater.