Lecture One

Introduction to Digital Communication

Layout:

1. Introduction to digital communication
2. General block diagram of digital communication

Objective of Lecture:

Understanding layout of digital communication systems

Objective of Behavioral:

Design digital communication systems and avoid unnecessary process which may burden the system, make it expensive, and increase complexity.

1.1. Introduction to digital communication

In the design of large and complex digital systems, it is often necessary to have one device communicate digital information to and from other devices. One advantage of digital information is that it tends to be far more resistant to transmitted and interpreted errors than information symbolized in an analog medium. This accounts for the clarity of digitally-encoded telephone connections, compact audio disks, and for much of the enthusiasm in the engineering community for digital communications technology. However, digital communication has its own unique pitfalls, and there are multitudes of different and incompatible ways in which it can be sent. Hopefully, this chapter will enlighten you as to the basics of digital communication, its advantages, disadvantages, and practical considerations.

1.2. Analog to digital communication systems

In the process of telecommunication, one may be interested to transmit directly the natural signal (analog signal) with or without modulation (base band transmission). There, all the processors/systems used for transmission process are analog processors

On the other hand, the system which specifically deals with digital data and digitally pre-processed signals is a digital communication system. But, as we know, all the natural understandable signals are analog, extra hardware for analog to digital conversion and digital to analog conversion are needed at the transmitter and receiver end, respectively. Such extra devices are analog to digital conversion (ADC) and digital to analog conversion (DAC).

1.2.1. Advantage of digital communication

Q: why digital communication system is preferred over analog communication system?

1. Ease re-generation of digital signals if compared with analog signals generation as shown in Fig.1.3. Due to transmitting digital information, formatting is very essential, i.e., two pulses square wave are to be assigned for logic zero and logic one respectively. In case of binary transmission. Noise immunity into such formatted digital information is greater than that of an analog signal.
2. Digital hardware is more flexible implementation than analog hardware (e.g. microprocessor, digital switching and large scale integrated (LSI) circuit).
3. Different type of digital signals (data, telegraph, telephone, television) can be treated as identical signals in transmission and switching.
4. Digital techniques protect themselves against interference and jamming by using error correction codes, signal processing and cryptography.
5. *Memory:* Analog signals are generally stored in devices like magnetic tapes, floppy disks, etc. It requires many magnetic tapes to store the analog signals. Moreover these are easily affected by the magnetic and other mechanical and physical phenomenon. On the other hand, digital information is stored in devices like CDs and registers.

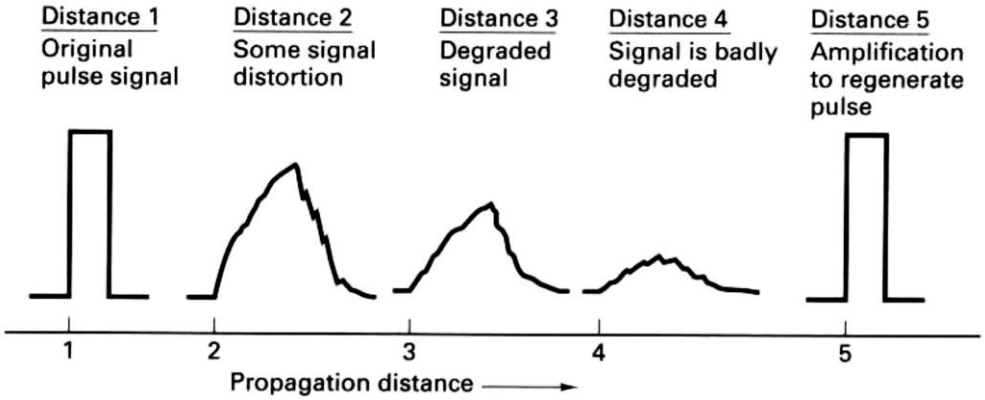

Figure 1.3. Digital signal degradation (performance reduction) and easy re-generation.

6. *Aging:* Aging signifies growing older of the system. It is obviously less effective in case of digital systems. In case of analog systems, the output may change after a few years due to aging of the discrete analog components like diode. As time goes, the cut-in voltage of the diode increases slowly and unsteadily. This causes

fluctuation in the system performance. In digital systems, the system error due to the problem of aging is totally absent.

1.2.2. Disadvantage of digital communication

Digital communication has some drawbacks, which are numerated bellow:

1. Signal processing for digital communication is more complex than for analog communication.
2. Synchronization for digital communication is more complex than analog communication.
3. Digital communication system is non graceful for degradation, however, analog system degrade more graceful.
4. High power consumption due to extra circuitry and hence consumes more power.

2.4. Elements of Digital Communication System

Digital communication block diagram consist two parts:

1. Upper parts which consist 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 (TR).
2. Lower parts which consist signal transformation from the receiver (RC) to the sink , essentially reversing the signal processing steps performed by the upper blocks

In fact, block diagram of digital communication (DC) consist two style of blocks, shaded and clear blocks. Shaded blocks are optional, it mean there existence depend on designer and in which scenario digital communication is required. For example, in military circumstance encryption is needful, while in broadcasting isn't needed.

Now, let discuss each blocks diagram in Fig.1.4.

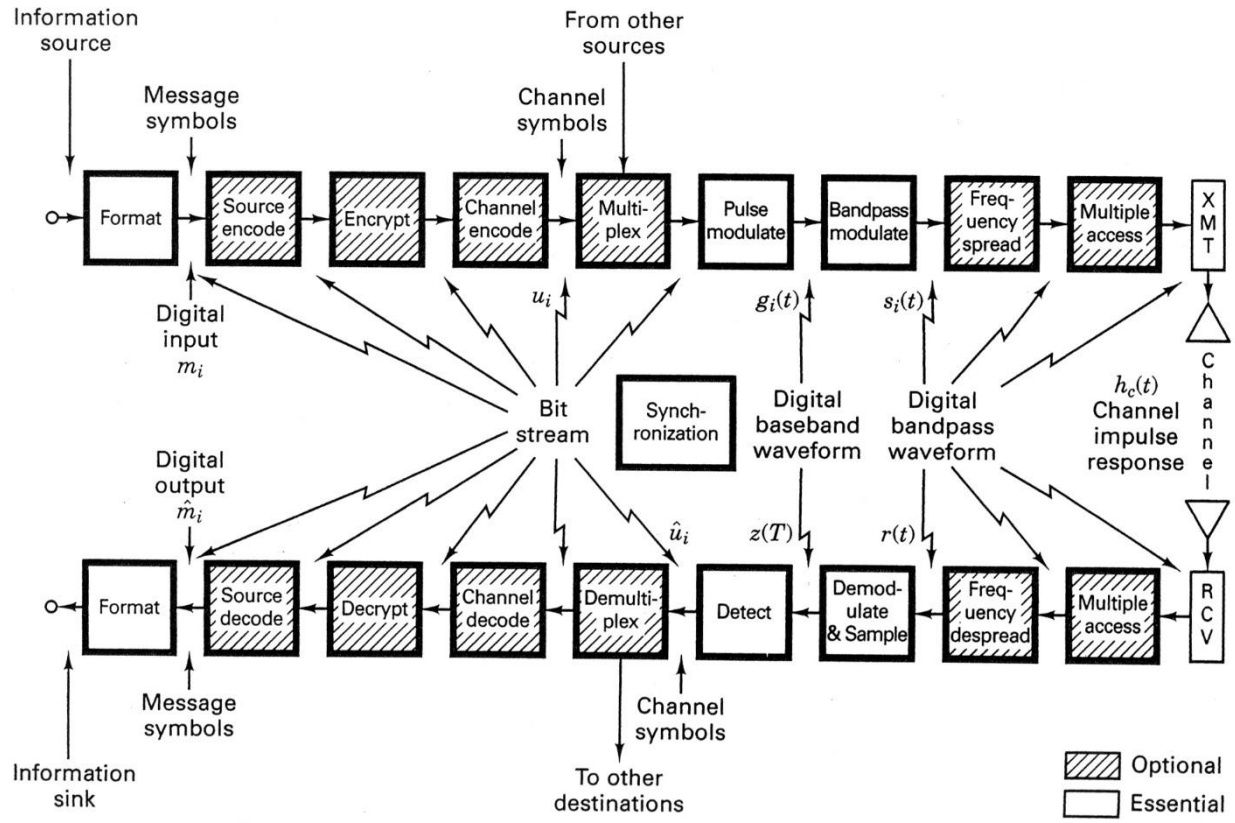

Figure 1.4. Bloch diagram of typical digital communication system

1. **Information source:** information divided into two types, digital information such CD, computer data, and analog information such as voice. In case, information source is analog, quantization process is needed to convert analog information to digital information, otherwise the digital information forwarded to format block.

2. **Format:** in fact, this block depend on information types that will be generated by the source, information generally divided into three types: a) voice, b) video and c) text information. Where, if the information is video or voice, the format block convert information to digital form using analog to digital conversion. On the other hand, if the information text, then simply we covert the text information to digital format using ASCII (**American Standard Code for Information Interchange**), see WiKi.

3. **Source encoder:** The primary task of a source codec is to represent a signal with the minimum number of (binary) symbols without exceeding an "acceptable level of distortion", which is determined by the application. In other word, source coding is compression technique by which number of binary bits reduced to minimum taking into account the compressed data can recovered without any distortion. A well-known use for this type of compression for picture signals is JPEG.

4. **Encryption**: Encryption is used to provide privacy for communication channel between two users or more.

5. **Channel encoding:** Channel coding is unique feature of digital communication. Channel coding deals with error control techniques, i.e., error detection and correction of the signals. If the data at the output of a communications system has errors that are too frequent for the desired use, the errors can often be reduced by the use of a number of techniques The two main methods of error control are: **Automatic Repeat Request (ARQ)** when a receiver circuit detects errors in a block of data, it requests that the data is retransmitted. **Forward Error Correction (FEC)** the transmitted data is encoded so that the data can correct as well as detect errors caused by channel noise.

6. **Pulse modulation** is the process of conversion (translation) each message symbols a channel symbols from binary representation to a base band waveform which are **Pulses**. The term of a base band refers to a signal whose spectrum extend from (or near) dc up to some finite value of frequencies (refer two low frequencies), usually less than a few megahertz. When pulse modulation is applied to binary symbol the resulting binary form is called pulse code modulation (PCM) waveform. When pulse modulation is applied to non-binary form, the resulting waveform is called an M-ary pulse modulation waveform or digital and analog pulse modulation.

7. **Bandpass modulation (digital carrier modulation)**, is the process by which digital pulse symbols are transformed into waveforms that are compatible with characteristic of the channel over which digital symbol to be transport. In case baseband modulation, the waveform is are pulses but in the case of Bandpass modulation the desired information signal modulate a sinusoid known as the carrier wave. Types of digital modulation as amplitude shift keying ASK and frequency shift keying FSK.

   Q: why modulation is important? Answer in chapter 6.

8. **Frequency Spread (Spread Spectrum):** spread-spectrum techniques are methods by which a signal (e.g. an electrical, electromagnetic, or acoustic signal) spread over large bandwidth (spectrum) is purposely to spread in the frequency domain, resulting in a signal with a wider bandwidth. These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference, noise and jamming.

9. **Multiplexing and multiple access** are combine signals that might have different characteristics or might originate from different sources. The main difference between the two is that multiplexing takes place locally at transmitter and multiple access takes place remotely such as BaseStation (e.g. multiple users need to share the satellite transponder).

Not that lower part of Fig.1.4 is receiver blocks, which are opposite in function to transmitter blocks, for example de-speading process is the process by which original signal regenerated from spread signal.