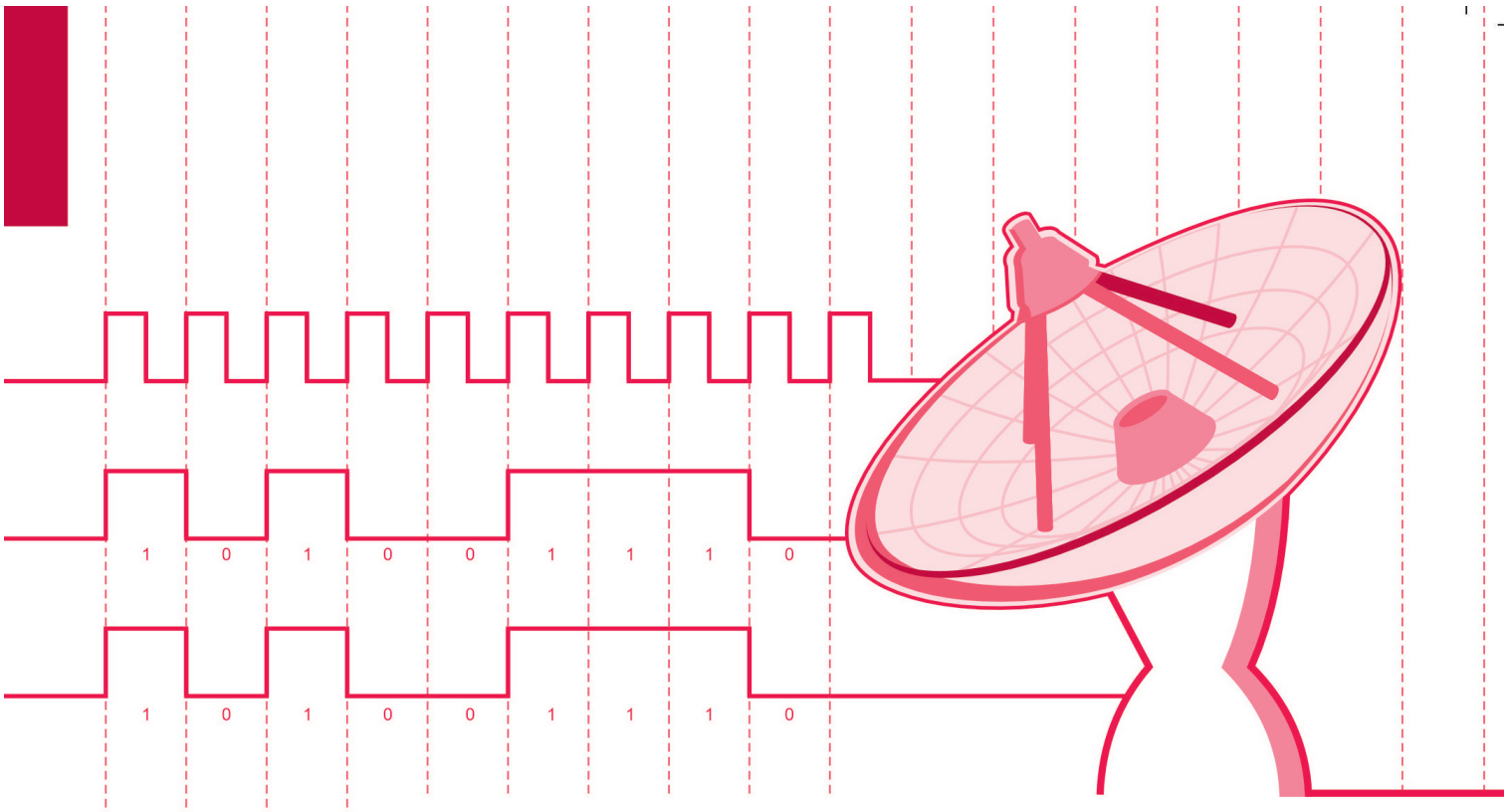

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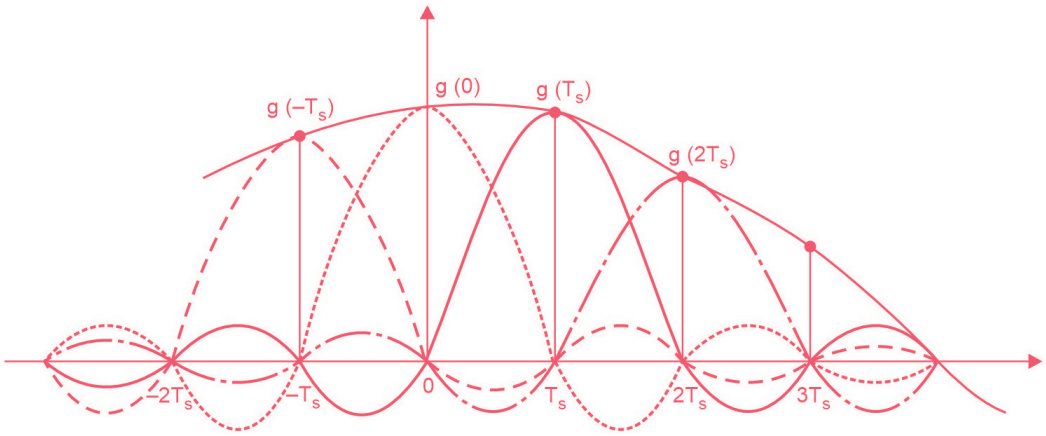

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NIRALI PRAKASHAN
ADVANCEMENT OF KNOWLEDGE

Preface

It gives us great pleasure to present the book **'Digital Communication'** for the students of Electronics and Telecommunication Engineering. Digital communication is used almost everywhere and forms the backbone of any communication system. Almost all the information communicated is in digital format hence every Electronics & Tele-communication engineer should have strong fundamentals of 'Digital Communication'.

The book is written such that all the basic concepts are explained in simplified manner. It is presented in a more conceptual manner with simplified mathematical analysis. It is our objective to keep the presentation systematic, consistent, and intensive and clear through explanatory notes and figures. Main feature of this book is, **Complete Coverage** of the syllabus with large number of Worked (Solved) problems, Examples and Exercises. We are sure that this book will cater to needs of students as well as academicians and professionals.

This book covers fundamental concepts of Analog to Digital Conversion and transmission of analog information in digital format. Modulation Schemes such as PCM, DM, ADPCM etc. are explained in depth. Baseband digital transmission and reception is explained with its performance analysis. Digital modulation schemes such as ASK, PSK, FSK and QAM are explained with their performance analysis. This book also covers topics on information theory and coding techniques.

We take this opportunity to express our sincere thanks to Shri. Dineshbhai Furia, Shri. Jignesh Furia, Mrs. Nirali Verma and entire team of Nirali Prakashan namely Mrs. Deepali Lachake (Engg. Dept. Head), who really have taken keen interest and untiring efforts in publishing this text.

The advice and suggestions of our esteemed readers to improve the text are most welcomed and will be highly appreciated.

Happy Learning!

Authors

Contents

Digital Transmission of Analog Signal

OUTLINE

1.1 INTRODUCTION TO DIGITAL COMMUNICATION SYSTEMS

A communication system consists of three blocks :

(i) Transmitter (ii) Channel (iii) Receiver

Most of the times the system consists of two way transmission, wherein the transmitter and receiver will be there at both ends. A digital communication systems consists of the following at the transmitter end,

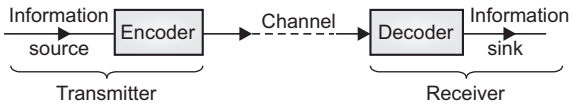

Fig. 1 : A basic block diagram of digital communication system

(i) Information source (ii) Encoder

and at the receiver end,

(i) Decoder (ii) Information sink

The designer has to understand the channel behaviour and design the encoder and decoder accordingly. An errorless transmission of information will be the aim of the designer. With this view, number of techniques are evolved over last few decades viz.

(i) Digital modulation techniques (ii) Error control techniques

(iii) Optimum receiver design (iv) Modeling of channel etc.

It is not only less error transmission that matters, efficient transmission is also a key parameter. Hence, some more blocks are to be added as shown in Fig. 2.

The communication systems used for transmission and receiving the information can be analog or digital.

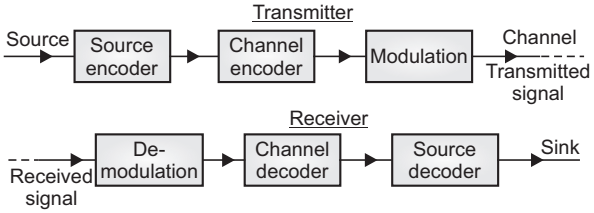

Fig. 2 : A block diagram of digital communication system

In the analog communication course, you must have studied various analog communication systems such as AM, FM, PM etc. Digital communication systems however have added advantages over analog systems. Hence, we find most of the communication systems are digital.

Applications of Digital Communication

- There are number of applications of digital communication influencing our day-to-day activities.
- Popularity of internet and television are two most obvious examples.

Following are some applications of digital communication.

(i) Analog continuous-time signal such as voice, music, video and pictures are transmitted by converting them into digital form.

(ii) Storage systems such as magnetic and optical media (CDs) use digital communication techniques.

(iii) In computer to computer communication the data transmission involves variety of data. Digital communication techniques are used in such transmissions.

Advantages of Digital Communication

Digital communication systems are most prevalent communication systems in today's world of Internet, mobile or any other means of communication. These systems are popular because of number of advantages they offer. Almost all the communication systems are going digital because of following reasons.

- **It is Easy to Regenerate a Digital Signal Compared to an Analog Signal :** The signal when transmitted through a channel gets distorted because of non ideal frequency response of the channel. Unwanted electrical noise and other interference also affects the signal. In case of digital signal it is easy to regenerate the signal using simple circuits called as regenerative repeaters. The process is illustrated in Fig. 3.
- **Noise Immunity :** Digital circuits operate in finite number of states (e.g. two in case of binary). The disturbance and interference must be large enough to change the state. Thus, the noise and other disturbances are prevented in digital circuits.

  In analog circuits there are infinite states hence a small disturbance can entirely change the shape of waveform. The distorted analog signal cannot be regenerated using amplification as in case of digital signal.
- **Flexibility :** With the help of digital signal processors, it is possible to implement digital communication system. These processors can be programmed to make any change in the system.
- **Multiplexing :** Using time division multiplexing, we can combine digital signals so that different types of messages like data, voice, audio, video etc. can be multiplexed. It is simpler than combining analog signals using frequency division multiplexing.
- **Cost :** Because of the Very Large Scale Integration (VLSI) technology the cost of implementing a digital communicating system has reduced drastically.
- **Compact :** The digital communication systems are most compact due to Increased Scale of Integration (VLSI).
- **Reliability :** The digital circuits are more robust compared to analog circuits. They are insensitive to variations is temperature, humidity etc. and mechanical vibrations.
- **Storage and Retrieval :** It is easy and inexpensive to store and retrieve the digital information.
- **Security :** Digital information can be encrypted before transmission and hence can be protected against intruders. It can also be protected against interference and jamming using special signal processing techniques.
- **Trade-off :** Bandwidth, power and time can be traded-off in order to optimize their use.
- **Compression :** Data compression is possible using the source coding techniques, which reduces the bit rate.
- **Suitability :** Most of the communication now a days is from computer to computer or from a digital equipment to computer, hence a digital communication system will be more suitable for such data communication.

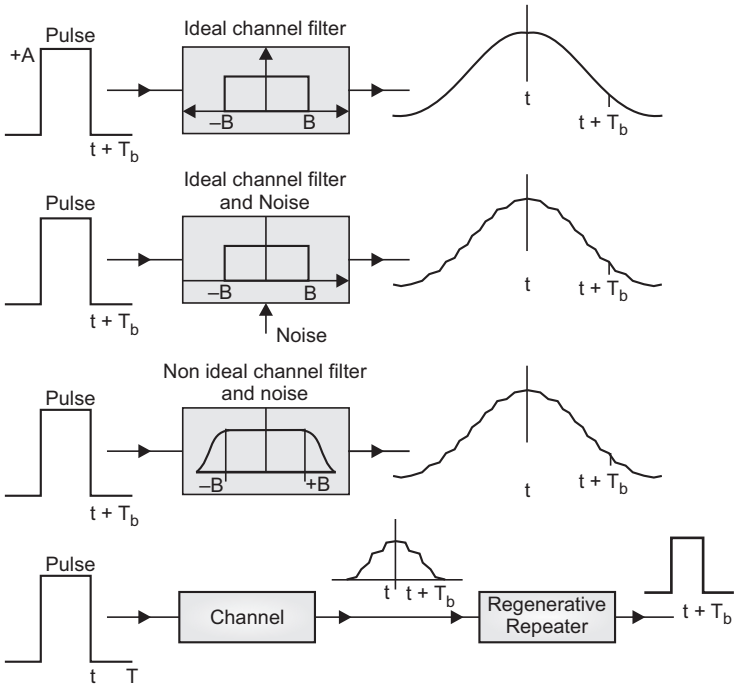

Fig. 3 : Distortion of signal in channel and regenerative repeater

Disadvantages of Digital Communication

- **Signal Processing Complexity :** The signal processing involved in case of digital communication systems is more complex than analog. Intensive signal processing is required in digital communication system compared to analog, hence these systems are more complex.
- **Need of Synchronization :** Synchronization at various levels is required in digital communication. Digital systems are required to allocate significant share of their resources to this task. Lot of attention needs to be provided for synchronization while designing these systems compared to their analog counter parts.
- **Non-graceful Degradation :** When the signal to noise ratio drops, the performance of the digital communication systems drops drastically. When the signal to noise ratio drops below a specified level, the performance of the system becomes very poor. Analog systems on the other hand degrade steadily.
- **Bandwidth Requirement :** They require more bandwidth than the analog communication system.

1.1.1 Block Diagram and Transformations

Block diagram of a typical Digital Communication System (DCS) is shown in Fig. 4. Note that all the blocks may not be present in every digital communication system. It depends on type of message to be transmitted, transmission medium, distance of transmission, transmission power, whether multiplexing and multiple access is required or not etc.

(i) Formatting : The information generated by the source needs to be converted into binary format. The formatting block converts the source message into bits which are grouped to form a message symbol (m_i). e.g. an audio signal is converted into bits using pulse code modulation (PCM). At the receiver end we are required to convert these message symbols into original format. We will study various formatting techniques in this unit.

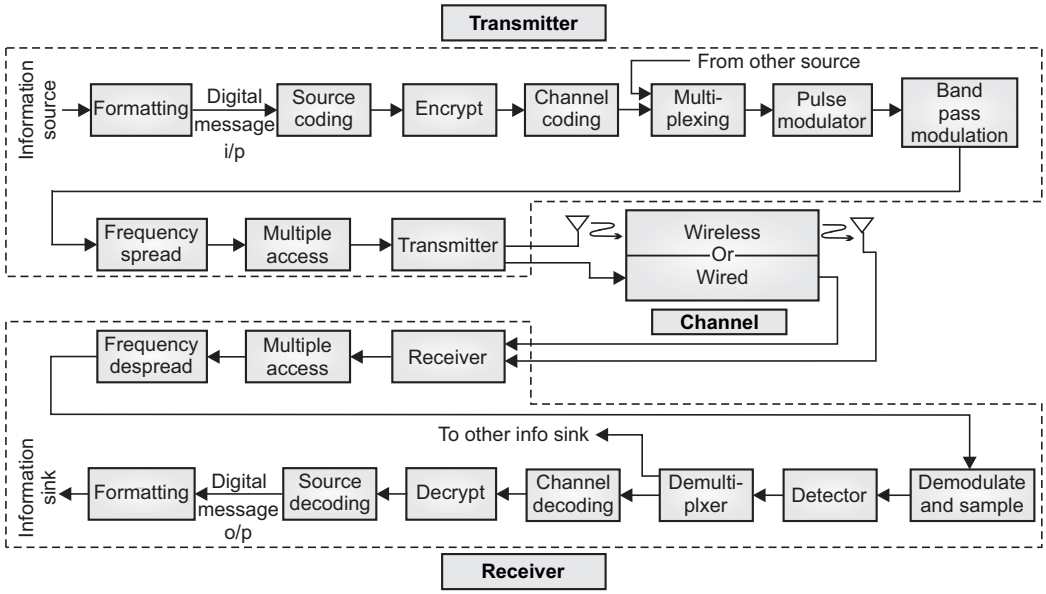

Fig. 4 : Block diagram of a typical digital communication system

(ii) Source Coding : It is applied to the message symbols to take advantage of redundancy in order to compress the message. This is one way of improving transmission efficiency. Source decoding is used at the receiver to decompress this message.

(iii) Encryption and Decryption : In order to protect the transmitted signal from unauthorized users or intruders, a suitable encryption technique can be used at the transmitter so that only authorized users can decrypt the message at the receiver end.

(iv) Channel Coding : There are number of transmission impairments the transmitted signal can undergo when it is transmitted through a noisy channel. The distorted signal gives rise to errors in the detection. Suitable error control coding techniques at the transmitter and decoding technique at the receiver are used to improve the reliability of transmission. The source coding and channel coding techniques will be studied in the next semester subject information theory and coding techniques.

(v) Multiplexing and Demultiplexing : Digital communication techniques give the advantage of Time Division Multiplexing (TDM) because of discretization of the signal. Number of similar or dissimilar messages can be combined and transmitted together using TDM at the transmitter end.
Demultiplexing at the receiver end allows these messages to be distributed to the respective destination sink. Because of this, proper synchronization between transmitter and receiver is required.

(vi) Pulse Modulation and Detections : Till now in previous stages, the signal was in binary format and is ready for transmission. If the channel is wired, the bits of noise are to be represented into electrical pulses. The pulse modulation block represents the bits into suitable line coding format (such as polar unipolar, RZ, NRz etc.). This depends on transmission bandwidth, transmission power, etc. At the receiver end, the received pulses corrupted by noise are to be reshaped and detected. Naturally we require filters to eliminate the noise. Note that we are dealing with signals whose spectrum extends from dc to few megahertz. Such signals are called baseband signals. The multiplexing, demultiplexing, line coding and synchronization aspects of base band transmission in DCS will be studied in onwards.

(vii) If the transmission medium such as wireless channel does not support transmission of pulse like waveforms. We need to translate these signals into high frequency region using carrier. This techniques is called digital bandpass modulation. The bandpass modulator up converts the frequency of baseband signal. At the receiver, we have a frequency down converted in the form of bandpass demodulator.

(viii) Spread spectrum techniques are used now a days to protect the signal from interference and jamming. The frequency spreading block is used to spread the spectrum of original signal over a larger band. At the receiver end, dispreading technique is used to recover the original signal spectra.

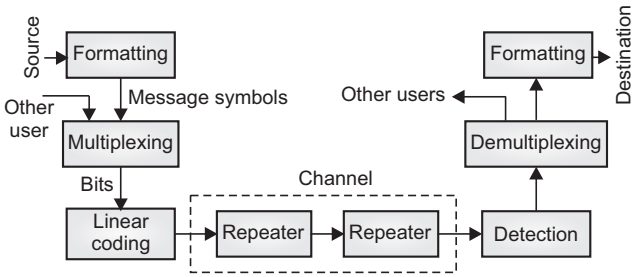

Fig. 5 : A Baseband digital communication system

(ix) A single channel can be shared by multiple users. Multiple access techniques such as Time Division Multiple Access (TDMA), Frequency Division Multiple Access, (FDMA) and Code Division Multiple Access (CDMA) can be used.

As stated above not all the blocks will be used in every digital communication system. Fig. 5. shows a simple baseband DCS and Fig. 6. shows a simple bandpass DCS.

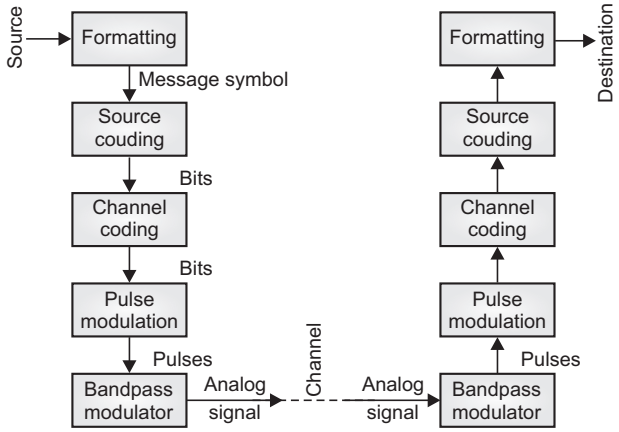

Fig. 6 : Bandpass digital communication system

1.1.2 Basic Digital Communication Nomenclature

(i) Information Source : The device that generalise the information to be transmitted through communication system is called information source. They can be analog or discrete. Analog source can be transformed into digital by sampling and quantization process.

(ii) Textual Message : It is a sequence of characters, either digits or symbols from a set of alphabets.

(iii) Characters : It is an element in the set of alphabets or symbols. For digital transmission, they can be represented in terms of binary codes such as ASCII.

(iv) Bit (Binary Digit) : It is a fundamental unit of information for all digital system.

(v) Bit Stream : It is a sequence of bits. It is also called baseband signal.

(vi) Symbol (Digital Message) : It is a group of a k bits considered as a unit. For example, a message with 4 bits will have 16 different symbols.

(vii) Digital Waveform : A waveform representing a digital message is called digital waveform.

(viii) Data Rate : It is number bits transmitted in one second duration. It is expressed as bits/sec.

SOLVED EXAMPLES

➢ ***Example 1.1 :***

Consider a message word "ABC". Let us use 7 bit ASCII code to encode this message.

The bit stream will be

Message	A	B	C
Bit stream	1000001	1000010	1000011

Let us use M = 8 symbol sets with group of n = 3 bits.

The symbol set will be as below.

S_1	000
S_2	001
S_3	010
S_4	011
S_5	100
S_6	101
S_7	110
S_8	111

Symbols are transmitted using 8 different waveforms.

The bit stream will be converted into symbols as below.

Bit stream	100	000	110	000	101	000	011
Symbols	S_5	S_1	S_7	S_1	S_5	S_1	S_4

1.1.3 Digital Versus Analog Performance Criteria

The performance of an analog communication system is expressed in terms of fidelity criteria such as Signal to Noise Ratio (SNR), expected Mean Square Error (MSE) between transmitted and received waveforms. In digital communication, we deal with digital symbols. We can calculate the number of errors introduced between transmitted and received symbols. The Probability of Error (PE) is the performance criteria used in DCS.

IMPORTANT POINTS

1. *The performance criteria for analog communication system is SNR and MSE.*
2. *The performance criteria for digital communication system is Bit Error Rate (BER) or Error Probability (PE).*

1.2 SAMPLING PROCESS

Sampling is a process of selecting or recording the ordinate values of a continuous function (analog) at specific values of its abscissa. This process is most often required in communication systems to convert analog signal in discrete or digital form. Thus, sampling process is a link between analog signal and its sampled version. When we convert an analog signal into discrete form, we should see to it that the converted signal retains all the information which is there in the original signal. In this chapter we will discuss, what are the conditions under which the information is retained in the sampled signal. Before we analyze this, we will look into some terminologies involved in the sampling process.

DIGITAL COMMUNICATION

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