ETEC 303: Digital Communication

Odd Semester 2020-2021

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Objective: To enable the students

1. To distinguish between analog and digital communication.

2. To understand the concept of digital communication system.

3. To understand the concept of random variables and random process.

4. To learn the digital modulation techniques.

Overview

UNIT- I Introduction to Digital Communication:

Line coding: NRZ, RZ, Manchester encoding, differential Manchester encoding, AMI coding, high density bipolar code, binary with n-zero substitution codes, Review of Sampling theorem, uniform and non-uniform quantization, companding, μ-Law and A-Law compressors, Concept and Analysis of PCM, DPCM, DM and ADM modulators and demodulators, M-ary waveforms, S/N ratio for all modulation, probability of error for PCM in AWGN Channel and other modulation techniques, Duo Binary pulse. **[T1, R2][No. of Hours: 11]**

UNIT- II Random Signal Theory:

Probability, Concept of Random variable (Stationary, Non stationary, WSS, SSS), Random process, CDF, PDF, Joint CDF, Joint PDF, marginal PDF, Mean, Moments, Central Moment Auto-correlation & Cross-correlation, covariance functions, ergodicity, power spectral density, Gaussian distribution, Uniform distribution, Rayleigh distribution, Binomial distribution, Poission distribution, Weiner distribution, Wiener-Khinchin theorem, Central limit theorem. **[T1, T2, R2] [No. of Hours: 11]**

UNIT- III Designing of Receiver:

Analysis of digital receiver, Prediction Filter, Design and Property of Matched filter, Correlator Receiver ,Orthogonal Signal, Gram-Schmidt Orthogonalization Procedure, Maximum likelihood receiver, Coherent Receiver design, Inter Symbol Interference, Eye Pattern.

[T1, T2, R1, R2] [No. of Hours: 11]

UNIT- IV Digital modulation schemes:

Coherent Binary Schemes: ASK, FSK, PSK, QPSK, MSK, G-MSK. Coherent M-ary Schemes, Incoherent Schemes (DPSK and DEPSK), Calculation of average probability of error for different modulation schemes,

Power spectra of digitally modulated signals, Performance comparison of different digital modulation schemes. Review of 2 Latest Research Paper.

[T1, T2, R2][No. of Hours: 11]

Text Books:
[T1] Simon Haykin, "Communication Systems" John Wiley & Sons, Inc 4th Edition.
[T2] Taub Schilling, "Principles of Communication Systems" TMH, 2nd Edition

Reference Books:
[R1] George Kennedy, "Communication System" TMH – 4th Edition
[R2] B. P. Lathi, "Modern Digital and Analog Communication System" Oxford University Press – 3rd Edition.
[R3] Digital Communications by John G.Proakis; McGraw Hill.

Additional References :
- A. Papoulis, "Probability, Random variables and stochastic processes.
- **NPTEL**

Pre-requisite :
-Fourier Domain Analysis

Why Digital Communication ?

1) Withstand channel noise and distortion much better than analog.
2) With regenerative repeater it is possible to transmit over long distance.
3) Digital hardware implementation is flexible
4) Digital coding provide further error reduction, high fidelity and privacy.
5) Easier to multiplex several digital signals.
6) More efficient in exchanging SNR for bandwidth.
7) Digital signal storage is relatively easy and inexpensive.
8) Reproduction with digital messages is reliable without deterioration.
9) Cost of digital hardware is cheaper and continue to decrease.

Features of a Good Communication System

- Small signal power (measured in Watts or dBm)
- Large data rate (measured in bits/sec)
- Small bandwidth (measured in Hertz)
- Low distortion (measured in SNR or bit error rate)
- Low cost - with digital communications, large complexity does not always result in large cost

In practice, there must be tradeoffs made in achieving these goals

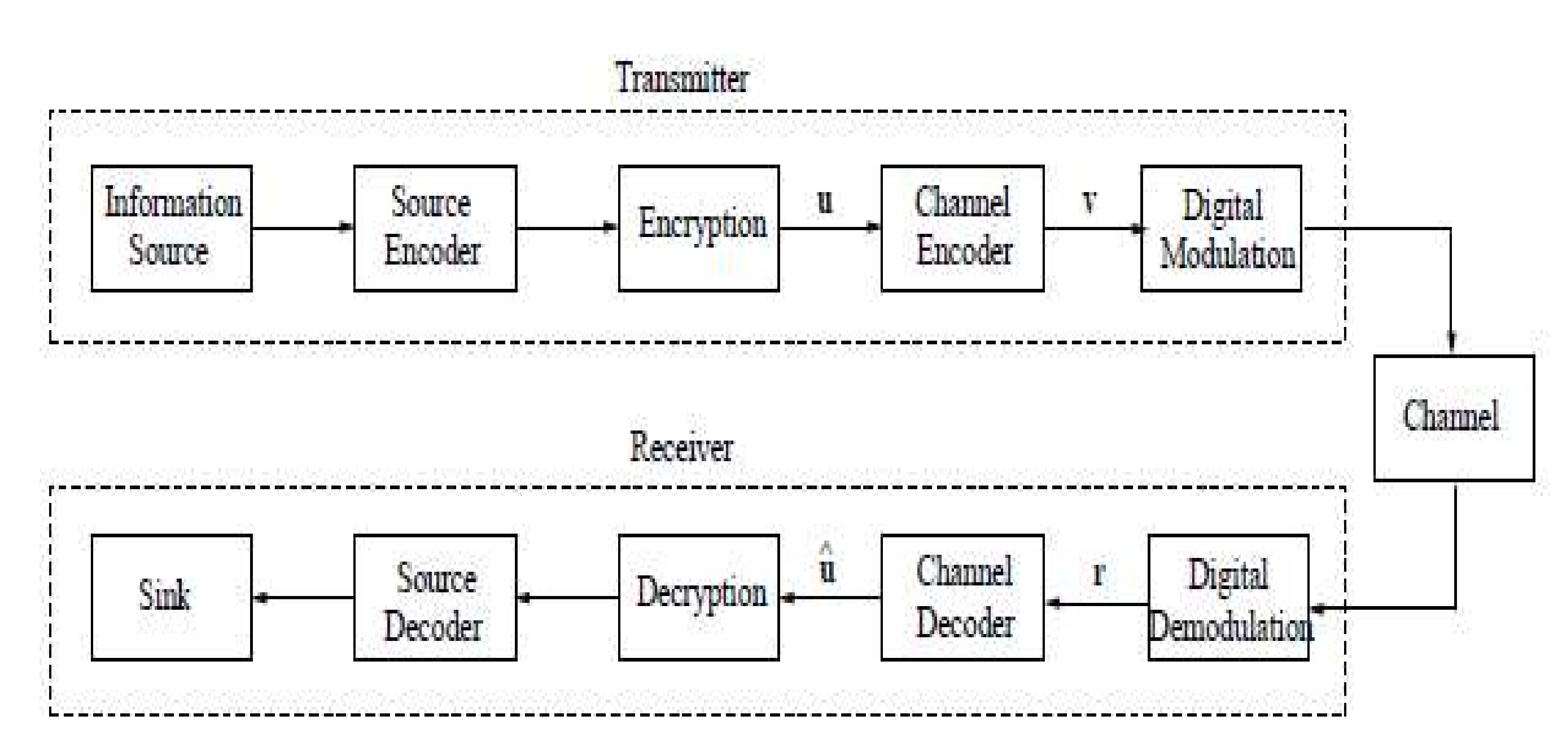

Figure 1. Block diagram of digital communication system

Source Coding

- To minimize the number of bits per unit time required to represent the source output.
- This process is known as source coding or data compression.
- Examples: Huffman coding, Lempel-Ziv algorithm.
- The output of the source encoder is referred to as the information sequence.

Encryption

- To make source bits transmission secure.

- This process of converting source bits (message text) into a source stream that looks like meaningless random bits of data (cipher text) is known as encryption.

- Examples: Data Encryption Standard (DES), RSA system.

Channel Coding

- To correct transmission errors introduced by the channel.

- The process of introducing some redundant bits to a sequence of information bits in a controlled manner to correct transmission errors is known as channel coding or error control coding.

- Example: Block code, Convolutional code.
  Repetition code, Reed-Solomon codes, CRC codes.
  $0 \rightarrow 000$
  $1 \rightarrow 111$

- The encoded sequence that is the output of the channel encoder is referred to as codeword.

- Shannon's paper : A mathematical Theory of Communication, 1948.

Modulation

- To map the codewords into waveforms.
- which are then transmitted over the physical medium known as the channel.
- Examples: Phase shift keying (PSK), quadrature amplitude modulation (QAM).

Channel

- The physical transmission medium.
- It can be wireless or wireline.
- It corrupts transmitted waveforms due to various effects such as noise, interference, fading, and multipath transmission.
- Examples: Binary erasure channel (BEC), Additive white Gaussian noise (AWGN) channel.

Demodulation

- To convert received noisy waveform to a sequence of bits, which is an estimate of the transmitted data bits.
- This is known as hard demodulation.
- If the demodulator outputs are unquantized (or has more than two quantization levels), this is known as soft demodulation.
- Soft demodulation has significant improvement over hard demodulation.
- Examples : Mached filter Receiver , Correlator Receiver

Channel Decoding

- To estimate the information bits û, and correct the transmission errors.
- If û≠u, decoding errors have occurred.
- The performance of the channel decoder is usually measured by the bit error rate (BER) or the frame error rate (FER) of the decoded information sequence.
- The BER is defined as the expected number of information bit decoding errors per decoded information bit.
- The coded sequences can be broken up into blocks of data frames. A frame error occurs if any information bit in that data frame is in error.
- The decoded FER is the percentage of frames in error.
- Examples : Viterbi Algorithm, BCJR Algorithm.

Decryption

- To recover the plain text from the cipher text with the help of key.

- It is in the key that the security of a modern cipher lies, not in the details of the cipher.

Source Decoding

- To reconstruct the original source bits from the decoded information sequence.
- Due to channel errors, the final reconstructed signal may be distorted.
- Look up table can be used.

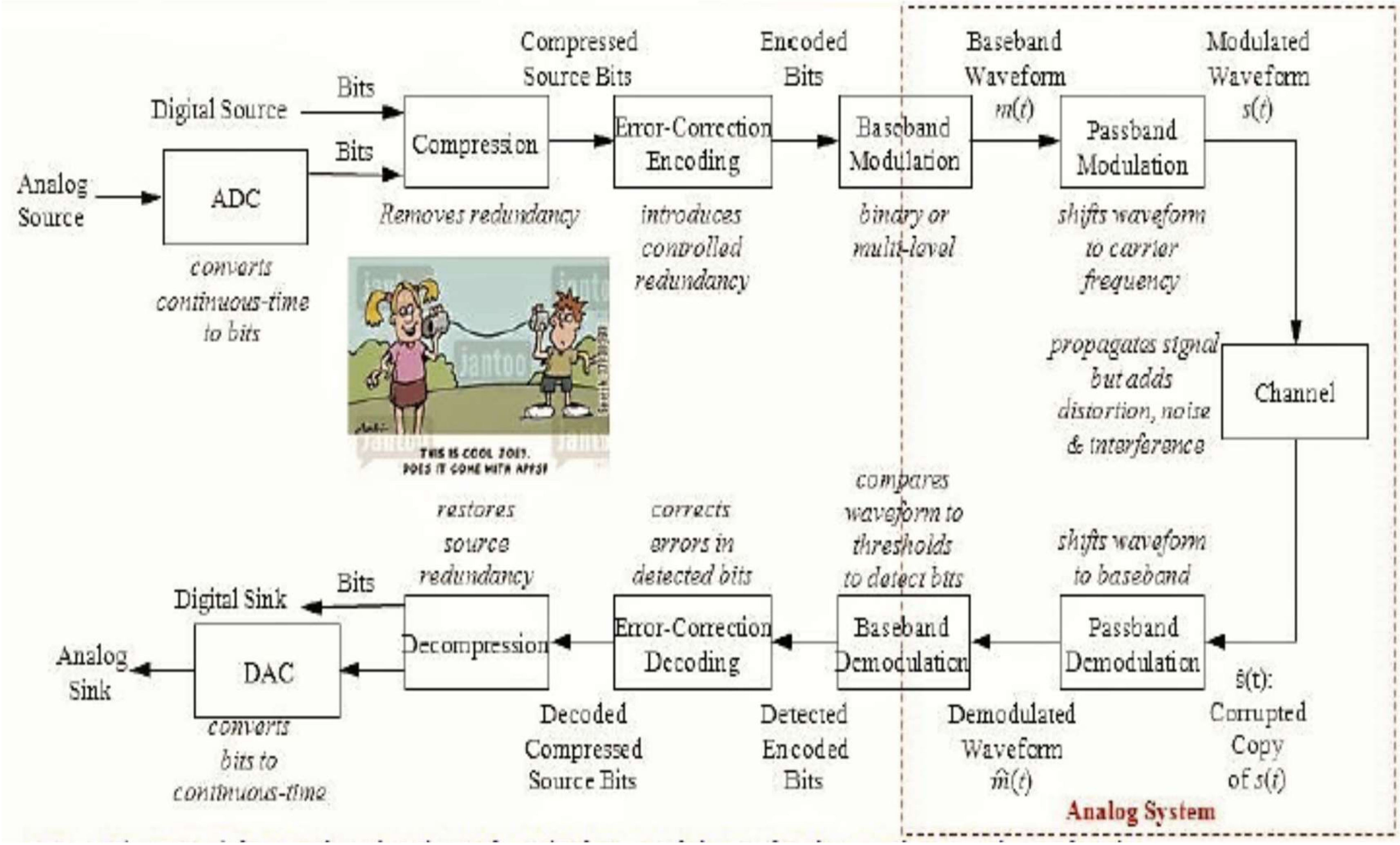

Figure 2: Block diagram of digital communication system

Year / Period	Achievements
1838	Samuel F. B. Morse demonstrated the technique of telegraph
1876	Alexander Graham Bell invents telephone
1897	Guglielmo Marconi patents wireless telegraph system. A few years earlier, Sir J. C. Bose demonstrated the working principle of electromagnetic radiation using a 'solid state coherer'
1918	B. H. Armstrong develops super heterodyne radio receiver
1931	Teletype service introduced
1933	Analog frequency modulation invented by Edwin Armstrong
1937	Alec Reeves suggests pulse code modulation (PCM)
1948-49	Claude E. Shannon publishes seminal papers on 'A Mathematical Theory of Communications'
1956	First transoceanic telephone cable launched successfully
1960	Development of Laser
1962	Telstar I, first satellite for active communication, launched successfully
1970-80	Fast developments in microprocessors and other digital integrated circuits made high bit rate digital processing and transmission possible; commercial geostationary satellites started carrying digital speech, wide area computer communication networks started appearing, optical fibers were deployed for carrying information through light., deep space probing yielded high quality pictures of planets.
1980-90	Local area networks (LAN) making speedy inter-computer data transmission became widely available; Cellular telephone systems came into use. Many new applications of wireless technology opened up remarkable scopes in business automation.
1990-2000	Several new concepts and standards in data network, such as, wireless LAN (WLAN), AdHoc networks, personal area networks (PAN), sensor networks are under consideration for a myriad of potential applications.

Table 1 : ***Some milestones in the history of electrical communications***

Frequency Band	Wavelength	Name	Transmission Media	Some Applications
3 – 30 KHz	100–10 Km	Very Low Frequency (VLF)	Air, water, copper cable	Navigation, SONAR
30–300 KHz	10 Km- 1 Km	Low Frequency (LF)	Air, water, copper cable	Radio beacons, Ground wave communication
300KHz – 3 MHz	1 Km – 100 m	Medium Frequency (MF)	Air, copper cable	AM radio, navigation, Ground wave communication
3 MHz – 30 MHz	100 m– 10 m	High Frequency (HF)	Air, copper and coaxial cables	HF communication, Citizen's Band (CB) radio, ionosphere communication
30MHz- 300 MHz	10 m – 1 m	Very High Frequency (VHF)	Air, free space, coaxial cable	Television, Commercial FM broadcasting, point to point terrestrial communication
300 MHz – 3 GHz	1m – 10 cm	Ultra High Frequency (UHF)	Air, free space, waveguide	Television, mobile telephones, satellite communications,
3GHz – 30 GHz	10cm–1cm	Super / Extra High Frequency (SHF / EHF)	Air, free space, waveguide	Satellite communications, wireless LAN, Metropolitan Area network (WMAN), Ultra Wideband communication over a short distance
30 GHz – 300 GHz	1 cm – 1 mm			Mostly at experimental stage
30 Tera Hz – 3000 Tera Hz	10 μm – 0.1μm (approx)	Optical	Optical fiber	Fiber optic communications

Table 2 : Electromagnetic Bands with typical applications

Name / Description	Frequency Range	Application
AM Broadcast Radio	540 KHz – 1600 KHz	Commercial audio broadcasting using amplitude modulation
FM Broadcast Radio	88 MHz – 108 MHz	Commercial audio broadcasting using frequency modulation
Cellular Telephony	806 MHz – 940 MHz	Mobile telephone communication systems
Cellular Telephony and Personal Communication Systems (PCS)	1.8 GHz – 2.0 GHz	Mobile telephone communication systems
ISM (Industrial Scientific and Medical) Band	2.4 GHz – 2.4835 GHz	Unlicensed band for use at low transmission power
WLAN (Wireless Local Area Network)	2.4 GHz band and 5.5 GHz	Two unlicensed bands are used for establishing high speed data network among willing computers
UWB (Ultra Wide Band)	3.7 GHz – 10.5 GHz	Emerging new standard for short distance wireless communication at a very high bit rate (typically, 100 Mbps)

Table 3 : Some Popular Bands

Transmission medium	Frequency	Power loss in [dB/km]
Twisted copper wire [16 AWG]	1 KHz 100KHz	0.05 3.0
Co-Axial Cable [1cm dia.]	100 KHz 3 MHz	1.0 4.0
Wave Guide	10 GHz	1.5
Optical Fiber	$10^{14} – 10^{16}$ Hz	<0.5

Table 4 : Typical power losses during transmission through a few media

Review Problems

Q. 1.1) Mention the two reasons justifying the digital modulation operation in a digital communication system.

Q. 1.2) Give examples of three channels, which are used for purpose of communication

Q. 1.3) Mention the main contribution of Claude E. Shannon in context to digital communication.

“I Hear and I Forget, I See and I Remember, I Do and I Understand”

-Confucius (551BC-479BC)