EECS4214

Digital Communications

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York University

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Week 1

Introduction

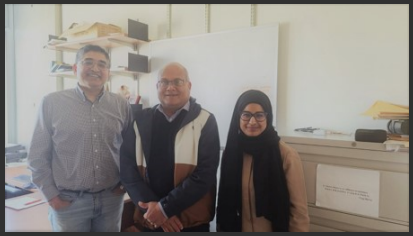
Land Acknowledgement

- A land acknowledgement remains a way of recognizing and expressing gratitude to the First Nations, Inuit, or Métis land that you are on

"York University acknowledges its presence on the traditional territory of many Indigenous Nations. The area known as Tkaronto has been care taken by the Anishinabek Nation, the Haudenosaunee Confederacy, and the Huron-Wendat. It is now home to many First Nation, Inuit and Métis communities. We acknowledge the current treaty holders, the Mississaugas of the Credit First Nation. This territory is subject of the Dish with One Spoon Wampum Belt Covenant, an agreement to peaceably share and care for the Great Lakes region."

Who Am I?

- **Name:** Sunila Akbar
- **Job Title:** Assistant Professor
- **Where:** Department of Electrical Engineering and Computer Science
- **Call me:** Sunila



"In theory there is no difference between theory and practice. In practice, there is . . . "
Yogi Berra (American Baseball Catcher)

Who Am I?

- **Education**
  - Bachelors in Electrical Engineering – 1994 - 1998
    - NED University of Eng. & Tech., Karachi, Pakistan
  - Masters in Electrical Engineering – 2004 -2008
    - NED University of Eng. & Tech., Karachi, Pakistan
  - PhD in Wireless Communications – 2014 - 2018
    - King's College London, London, UK

Who Am I?

- **Teaching**
  - Two years as an Instructor at University of Toronto (U of T)
  - Three years as a Teaching Assistant at King's College London – 2015 to 2018
  - About fifteen years' experience as an Assistant Professor at the Faculty of Electrical and Computer Engineering, NED University – 2004 to 2021
- **Research**
  - Cognitive radar resource management using deep reinforcement learning techniques – while doing Postdoctoral Fellowship at U of T
  - Statistical signal processing for wireless communications with spectral and energy efficient techniques

Who are You?

- Open question!
- You may share anything
  - Your interests, your hobbies, your passion/s
  - What excites you about this course?
  - What scares you about this course?
  - ...
  - Maybe your favourite quote :)

One of my Favourite Quote

"There are no secrets to success. It is the result of preparation, hard work, and learning from failure."

Colin Powell (American Baseball Catcher)

Introduction to the Course

Course Learning Outcomes (CLOs)

- Express and manipulate random signals in terms of probabilities and statistical averages
- Understand and quantify the performance of key pulse code modulation systems
- Understand and apply the theory of optimum detectors and filters for M-Ary pulse amplitude modulation and band pass modulation systems
- Quantify the performance of a variety of modulation schemes in terms of their transmission bandwidth, energy consumption, and error performance
- Understand electromagnetic pollution and analyze the societal and environmental impacts of wired and wireless communications
- Design and build system components capable of enabling optimum digital communication

Contact

- **Instructor:** Sunila Akbar
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  - **Office Hours:** 5:30 pm to 7:00 pm Wednesdays or by email appointments
- **Teaching Assistants**
  - Amirhossein Mohammadi
    - **Email:** amirmhd@yorku.ca
  - Muhammad Khan
    - **Email:** umarwr1@yorku.ca

Course Website, Emails, and Office Hours

- Course Website - at eClass
  - Lecture Notes - posted Weekly
  - Labs, Home Assignments
  - Grades
  - Announcements
- Before sending an email, check the eClass carefully. If the answer is available you may not receive a reply
- ALWAYS put your full name and course number in the emails
- Expect a response in 24 - 48 hours
- Office hours can be done both remotely or in-person during the mentioned timings

Lectures and Labs

- Lectures

Lec.	Days	Time	Location
1	Monday	4:00 to 5:30 pm	LSB 107
2	Wednesday	4:00 to 5:30 pm	LSB 107

- Labs

Lab	Days	Time	Location
1	Friday	8:30 to 11:30 am	LAS 1002
2	Friday	8:30 to 11:30 am	LAS 1002

Grading

S. No.	Assessment	Percentage	Due Date/ Time
1	3 Home Assignments	10	**Jan 24, Feb 14, Mar 7**/ 11:59 pm
2	12 Labs	25	Each Saturday/ 11:59 pm
3	Midterm Exam 1	15	**Feb 24**/ 4:00 - 5:15 pm
4	Midterm Exam 2	15	**Mar 24**/ 4:00 - 5:15 pm
5	Final Exam	35	Date/time to be announced

- Worst assignment will be removed
- Group work is allowed for the labs
- BONUS with in-class random questions

Instructions - Labs

- Students are expected to attend scheduled lab sessions fully for all 12 weeks to complete arranged lab assignments
- Lab reports should be submitted individually. NO duplicate submissions on eClass for a group of students
- Labs require report submission along with the MATLAB codes
- There will be random interactive sessions during labs to gauge the understanding of students. This will count towards lab participation marks

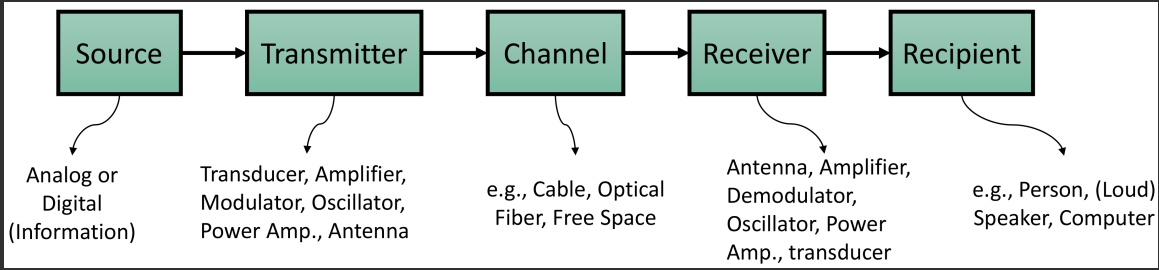
Books

- Bernard Sklar, *Digital Communications: Fundamentals and Applications*, NY: Prentice Hall, 2001, 2nd Ed
- Simon Haykin, *Digital Communications*, John Wiley Sons
- John G. Proakis, *Digital Communications*, Third Edition, McGraw Hill, 3rd Ed

Communication System

Basic Communication System (Review)

- The main purpose of communication is to transfer **information** from a source to a recipient via a **channel** or medium
- Here is a basic block diagram of a communication system:



Basic Communication System (Review)

Information

- Voice/ Music / Video
- Temperature/ Pressure/ Medical Data
- ...

Information Representation for Transmission via Channel

- The information produced by a source, normally, is not in a form suitable for a transmission medium
- At the **transmitter**, an input transducer converts the physical signals to a time varying electrical/ optical/ electromagnetic signal appropriate for the **channel**
- At the **receiver**, an output transducer converts the electrical waveform to the original form of information

Basic Communication System (Review)

Phenomena affecting signals during transmission

- **Distortion:** Due to non ideal response of transmission line/ circuits
- **Noise:** Unwanted electrical signals in the system
- **Interference:** Unwanted signals from other sources

Basic Communication System (Review)

Communication Systems - Examples

- Public Switched Telephone Network (voice, fax, modem)
- Satellite systems
- Radio, TV broadcasting
- Cellular phones
- Computer networks (LANs, WANs, WLANs)

Analog versus Digital Communication System

Analog	Digital
Signal comes from set of infinite waveform shapes (with theoretically infinite resolution).	Signal comes from a finite set of waveform shapes.
Exact reproduction of signal at destination is required.	The objective is to determine which waveform from the finite set was sent.
Performance Metrics: Signal to Noise Ratio, Bandwidth Efficiency	**Performance Metrics:** Probability of Error (P_E), Bandwidth Efficiency

Why Digital?

Why Digital?

1. Digital Signals are easy to regenerate as compared to Analog Signals
   - e.g. Binary digital circuits operate in one of the two states fully ON or fully OFF, which prevents Noise and other disturbances from accumulating in transmission
   - Use of regenerative repeaters before the transmission is degraded to an ambiguous state

Why Digital?

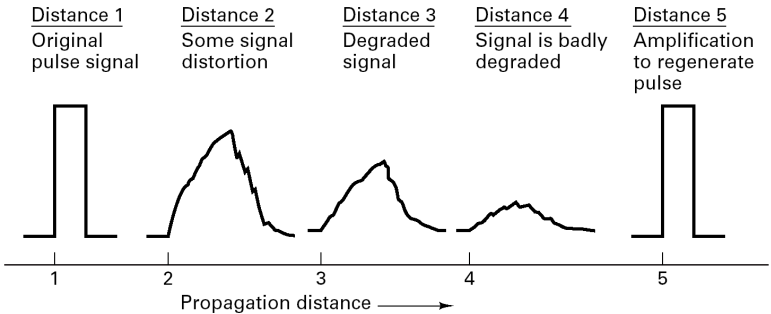


Figure 1.1 Pulse degradation and regeneration.

Why Digital?

2 Digital Circuits are

- More reliable
- Low cost
- More flexible implementation
- Shorter design and production cycle

Why Digital?

3 Good processing techniques are available for digital signals, such as

- Data compression (or source coding)
- Error Detection / Error Correction (or channel coding)
- Equalization
- Encryption and Privacy
- Security

Why Digital?

4. Different types of digital signals (voice, video, telegraph, etc.) can be treated as identical signals
   - A bit is a bit
5. Easy to mix signals and data using digital techniques
   - TDM/CDM is easier than FDM

Why Digital?

6. Digital signals - Low error rate - High fidelity
7. Best suited for data communication from computer to computer
   - Such digital termination are naturally best served by digital communication links

Downsides of Digital Communication Systems

Downsides of Digital Communication Systems

1. Intensive signal processing (compared to analog)
   - Encoding and Decoding (Analog to Digital Conversion)
   - Complex modulation schemes like PSK, QAM, or OFDM, which require advanced algorithms to process
   - Error Detection and Correction, Compression
   - Synchronization
   - Multiplexing and Multiple Access

Downsides of Digital Communication Systems

2 Requires larger bandwidth

- High Data Rate Transmission (video streaming, IoT, 5G)
  - The data rate (bits per second) is directly proportional to the required bandwidth, as per the Nyquist theorem
- Pulse Shaping (e.g., using a raised cosine filter)
- Noise Immunity and Encoding
- Multiplexing Requirements

Technological Advances Enhancing Digital Communication

- Terahertz communication for even higher data rates
- Intelligent Reflecting Surfaces (IRS) for signal enhancement
- Integration of AI to optimize network operations
- Quantum networks for secure and ultra-fast communication, leveraging principles of quantum entanglement
- ...