Chapter 1: Overview of Communication Systems

Selected from Chapter 1 of *Fundamentals of Communications Systems*, Pearson Prentice Hall 2005, by Proakis & Salehi
Staff

- Lecturer:
  - Meixia Tao (陶梅霞)
    - Office: Room 5-301A, SEIEE Building
    - Tel: 3420-7494-8004
    - Email: mxtao@sjtu.edu.cn
    - Web: http://iwct.sjtu.edu.cn/personal/mxtao/

- TA:
  - TBD
Textbook

Lecture Nodes (*Very Important!*):
- http://iwct.sjtu.edu.cn/personal/mxtao/teaching.html

J. G. Proakis, 2005

樊昌信改编, 2007
References

- 《通信原理》，韩声栋、蒋铃鸽、刘伟 编著，机械工业出版社, 2008.6
- 通信原理实验，杨宇红，袁焱，李安琪，陈大华，自编教材
Objective

- The primary objective of this course is
  - to introduce the basic techniques used in modern communication systems, and
  - to provide fundamental tools and methodologies in analysis and design of these systems

- After this course, the students are expected to
  - Understand the principles and technique of modulation, coding and transmission.
  - Analyze the merits and demerits of current communication systems and to eventually design improved new systems
Syllabus (1/2)

- Ch01: Introduction (1 week)
- Ch02: Signal, random process, and spectra (2 weeks)
- Ch03: Analog modulation (2 weeks)
- Ch04: Analog to digital conversion (1 week)
- Ch05: Digital transmission through baseband channels (2 weeks)
- Ch06: Signal space presentation (1 week)
- Ch07: Optimal receivers (1 week)
- Ch08: Digital modulation techniques (2 weeks)
- Ch09: Information theory (1 week)
- Ch10: Channel Coding (1 week)
- Ch11: Synchronization (1 week)
Syllabus (2/2)

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NI LabVIEW + USRP

- Lab 1: Analog modulation
- Lab 2: Binary digital modulation techniques
- Lab 3: BPSK/QPSK-modulated wireless transmission system
Assessment

- **Homework:** 15%
  - 5 sets of homework
  - 5-level grading (A+, A, B+, B, C) for each homework
- **Labs:** 15%
  - 3 Lab reports + on-site demonstration
- **Mid-term Test:** 10%
  - In-class open-book test
- **Final Exam:** 60%
What is Communication?

“The systems and processes that are used to convey information from a source to a destination efficiently and reliably, especially by means of electricity or radio waves.”
Historical Review

- 1838: telegraph (S. Morse)
- 1876: telephone (A. Bell)
- 1895: radio by Marconi
- 1901: trans-atlantic communication

Early 20th century:
- Most communication systems are analog.
- Engineering designs are ad-hoc, tailored for each specific application

Nobel Prize for Physics (1909)
Modern Communication Systems
Fundamental Questions

- Is there a general methodology for designing communication systems?

- Is there a limit to how fast one can communicate?
Harry Nyquist (1928)


Sampling Theorem

Continuous-time $\leftrightarrow$ Discrete-time
Claude Shannon (1948)

"A Mathematical Theory of Communication", 
Bell System Technical Journal. 1948

Information Theory

Fundamental limits of source compression rate and channel transmission rate

Analog communication  Digital communication
Basic Elements of Communications

A slight variation from Shannon’s diagram of a general communication system
Communication Channels

- Common characteristics

- Attenuation
- Distortion
- Noise
Wireless Electromagnetic Channels
Radio Spectrum
Radio Spectrum

Some everyday uses of the radio frequency spectrum

- Radio
- Remote control
- TV
- Cellphones
- GP
- Medical
- WiFi, Bluetooth, microwaves, pagers, satellite and cordless phones, walkie-talkies
- Weather
- Public safety, alarms, toll tags

Value of spectrum compared with real state

Fifth Avenue, New York City
Upscale suburb
Productive farmland
Desert

SOURCE: New America Foundation; FCC

JOAN McLAUGHLIN/GLOBE STAFF
Propagation

- Free-space propagation model

\[ P_r = P_t G_t G_r \left( \frac{\lambda}{4\pi d} \right)^2 \]

- $P_t$: transmit power
- $P_r$: receive power
- $G_t$: transmit antenna gain
- $G_r$: receive antenna gain
- $\lambda$: wavelength
- $d$: distance

100 meters

200 meters

Receives 1/4 of the power

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Mathematical Models

- The additive noise channel

\[ r(t) = s(t) + n(t) \]

- Linear filter channel

\[ r(t) = s(t) * h(t) + n(t) = \int_{0}^{\infty} h(\tau)s(t-\tau)d\tau + n(t) \]
Linear time-variant filter channel

Consider a multi-path signal propagation

\[ h(\tau; t) = \sum_{k=1}^{L} a_k(t) \delta(t - \tau_k) \]
Types of Communications Systems

- Analog Communications

- Digital Communications
Analog Communication Systems
Digital Communication Systems

Source \rightarrow A/D converter \rightarrow Source encoder \rightarrow Channel encoder \rightarrow Modulator

Transmitter

Absent if source is digital

User \rightarrow D/A converter \rightarrow Source decoder \rightarrow Channel decoder \rightarrow Detector

Receiver

Noise \rightarrow Channel

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Why Digital Communications?

- Robustness to channel noise and external Interference
- Security of information during its transmission from source to destination
- Integration of diverse sources information into a common format
- Low cost DSP chips by very cheap VLSI designs
Performance Metrics of Communication Systems

- Reliability
  - SNR for analog systems
  - Bit error rate for digital systems

- Efficiency
  - Bandwidth efficiency
  - Energy efficiency

Performance Tradeoff
Bandwidth Efficiency

\[ \text{bandwidth efficiency} = \frac{\text{data rate } R}{\text{bandwidth } W} \text{ bits/sec/Hz} \]
Energy Efficiency

\[
\text{energy efficiency} = \frac{\text{bit energy}}{\text{noise power spectral density}} = \frac{E_b}{N_0}
\]