# **ELG3175: Introduction to Communication Systems** (in-person)

- **Instructor:** Dr. Sergey Loyka (CBY A608).
- **Course Web page:** http://www.site.uottawa.ca/~sloyka/ . Some info and course material (lecture slides, lab guidelines, references etc.) will be posted there.
- **Lectures:** Wed. 16:00 - 17:20 (SITE J0106), Fri. 14:30 – 15:50 (LMX 220). 1st Lecture: Wed. Jan. 8, 16:00.
- **Tutorials:** Begin on Jan. 17 (no tutorial 1st week); Fri. 11:30 - 12:50 (MNO C211).
- **Labs:** Begin on Jan. 22 (no labs first 2 weeks), Wed. 13:00-15:50 (CBY B519).

- **Office hours:** Wed. 5:45-7pm. You are encouraged to ask questions during and after lectures. All assignment and lab questions – to the respective TA.
- **Assignments & quizzes**: about 8.
- **Midterm exam**: Fri. Feb. 14, 14:30-15:50 (regular lecture time)
  - Includes everything covered in the class before the midterm; closed book (1 page of reference material is allowed).
  - Individual (no collaboration is allowed).
  - The regular plagiarism policies apply.
  - Marked exam papers will be returned within 2-3 weeks.
  - All students writing exams must present a valid student ID (will not be allowed to write an exam otherwise).
- **Final exam – the same rules but…**
  - Includes everything covered in the class during the semester (lectures, labs, tutorials, assignments); closed book (2 pages of reference material is allowed).
  - It is for evaluation purposes only and will not be returned to the students.
  - Marks are final and will not be negotiated.

- **Marking Scheme:**
  - Assignments + quizzes 10%
  - Labs 10%
  - Midterm Examination 20%
  - Final Examination 60%
  - Bonus points to everybody who takes active part in the course.
- **Note that:**
  - All the course components (lectures, tutorials, labs, assignments) are mandatory. Miss at your own risk. INC grade if not all labs completed.
  - Marking scheme is final and will not be changed.
  - Marks are determined by academic performance only (not by bargaining abilities).
  - Marks will not be negotiated.
  - All questions are to be answered during the semester (no guarantee afterwards).

- **Absence:** for medical reasons only, valid if medical certificate.

- **Required textbook (must have)**:
  - L.W. Couch II, Digital and Analog Communication Systems, 8th Edition, Prentice Hall, 2013 (2007 is OK, but watch for section/problem #s).

- **Additional texts:**
  - W.M. Siebert, Circuits, Signals, and Systems, The MIT Press, 1986.
    - very good book, with intuitive engineering discussions/examples
  - A.V. Oppenheim, A.S. Willsky, Signals and Systems, Prentice Hall, 1997.
    - the standard textbook on signals & systems (ELG3125)
  - H.P. Hsu, Analog and Digital Communications, McGraw Hill, 1993 or 2002.
    - tons of examples

- **Alternative textbooks:**
  - R.E. Ziemer, W.H. Tranter, Principles of Communications, Wiley, New York, 2009.
  - B.P.Lathi, Modern Digital and Analog Communication Systems, Oxford University Press, 1998.
  - A.B. Carlson, P.B. Crilly, J.C. Rutledge, Communication Systems, McGraw Hill, 2002.
  - J.G. Proakis, M.Salehi, Fundamentals of Communications Systems, Prentice Hall, 2005.

- **Prerequisite:** ELG3125 (very important)
  - Complex numbers/functions
  - Linear systems and signals (impulse/frequency response etc.)
  - Fourier analysis (continuous/ discrete time, spectra etc.)

- **Co-requisite**: ELG3126 (basic probability theory)

- **Plagiarism:** copying solutions to assignments, quizzes, exams and lab reports from anywhere is a serious academic crime that carries significant penalty. Plagiarism is absolutely not acceptable.
- While working in groups on assignments is not a plagiarism, submitting identical or nearly identical solutions is and will be severely penalized. Every student is expected to submit his own **individual solutions**.
- If two (or more) identical or almost identical sets of solutions are found, each student involved receives 0 (zero) for that particular assignment. If this happens twice, the students involved receive 0 (zero) for the entire assignment component of the course in the marking scheme and the case will be send to the Dean's office for further investigation.
- From the past experience, the students who copy assignments/labs, do **poorly in exams**.
- All students writing exams must present a valid student ID (will not be allowed to write an exam otherwise).

# ELG3175: Introduction to Communication Systems

- **Purpose:** to introduce basic principles and techniques for the analysis and design of modern communication systems.
- **Contents:**
  - Introduction.
  - Review of Fourier analysis, linear systems & sampling theorem. Baseband & bandpass signals & systems.
  - Amplitude modulation: DSB AM, DSB-SC AM. Modulators & demodulators, superheterodyne receiver.
  - Angle modulation: phase & frequency. Modulators & demodulators of FM & PM.
  - Basic digital modulation techniques: ASK, PSK, FSK. Bandwidth requirements of PAM. PCM & SQNR. Inter-symbol interference & Nyquist criterion; sync and raised-cosine pulses.
  - Brief introduction to information theory and coding (if time permits).

# How to Study: Learning Efficiency Pyramid

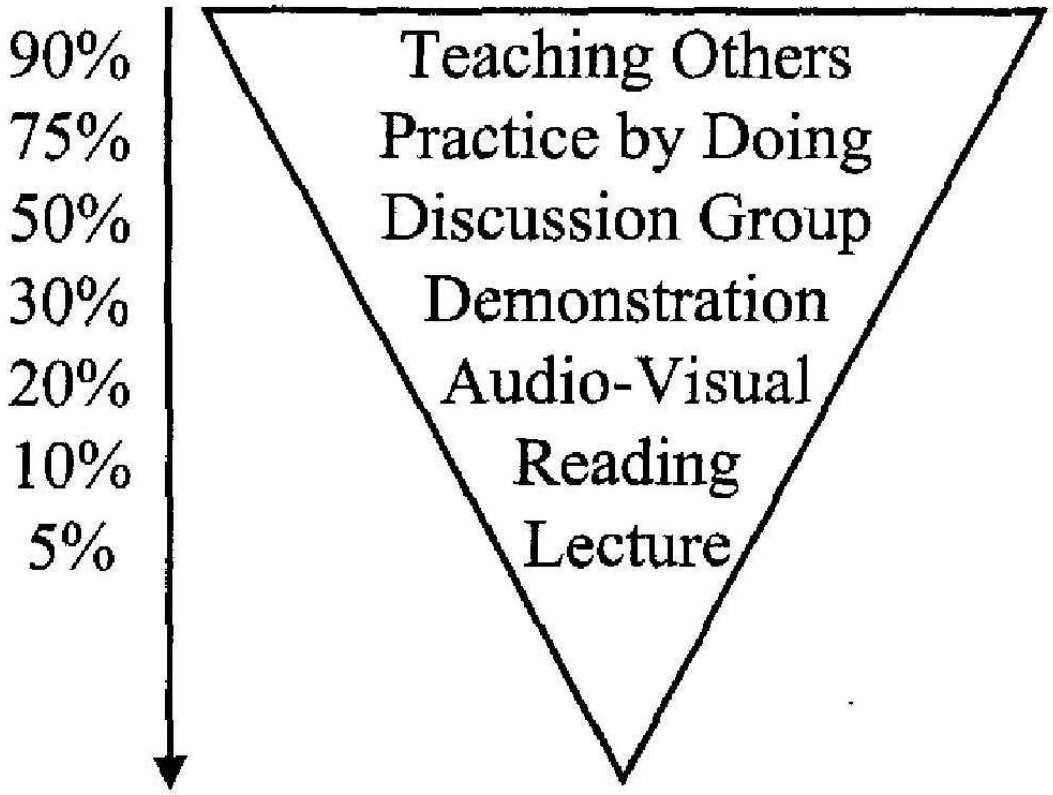



**Figure 1. The Learning Pyramid, adapted from David Sousa, *How the Brain Learns*, Reston, VA, The National Association of Secondary School Principals, 1995, ISBN 0-88210-301-6.**

"Tell me and I'll forget; show me and I may remember; involve me and I'll understand." – old Chinese proverb.

"I hear, I forget; I see, I remember; I do, I understand".

"No pain, no gain" – common wisdom.

# How to Study ?

"Education is the accumulation of understanding, not just an accumulation of facts" [D. Pozar]

- Learning efficiency pyramid is a good guideline
- Reading is necessary, but taken alone is not efficient
- Solving problems ("practice by doing")
  - is much more efficient
  - examples, assignments, end-of-chapter problems
- Group discussions
  - help provided you contribute something
- Systematic study during the semester
  - is a key to a success.
  - do not leave everything to the last day/night before exams!
- Lectures
  - should be supplemented by the items above

# Introduction to Communication Systems

- What is a communication system? Any means for transmission of information.
- Types of communication systems: wireline & wireless, digital & analog, point-to-point & broadcasting, low frequency/high frequency etc.
- Examples:
  - cell phone, landline
  - WiFi
  - Internet, optical fiber systems
  - TV, radio
  - remote control, wireless key
  - hard disk, USB memory stick

# Historical Review

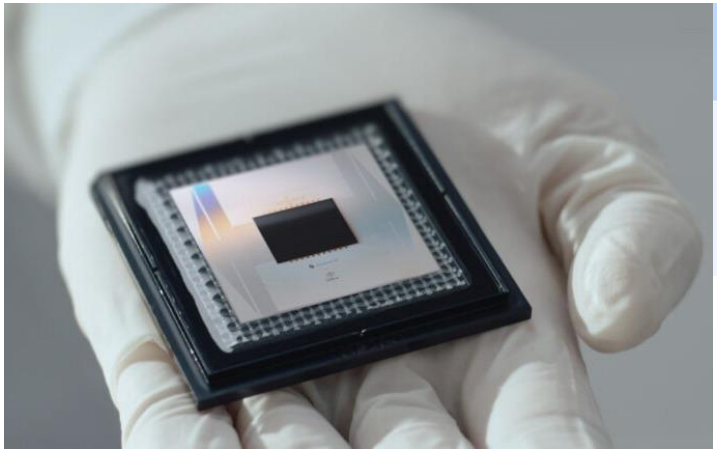
- telegraph by Morse, 1837 (operational in 1844).
- telephone by Bell, 1876 (Bell Telephone Company in 1877).
- radio (wireless) by A. Popov in 1895 & G. Marconi in 1896.
- first transcontinental wireless transmission in 1901 by Marconi
- vacuum diode by Fleming (1904) & vacuum triode by De Foster (1906)
- Superheterodyne receiver by Armstrong (during WWI)
- transcontinental telephone transmission in 1915 (operational)
- AM broadcast, 1920
- first TV system by Zworykin, 1929 (broadcasting in London, 1936)
- first FM communication system by Armstrong, 1933

# Historical Review

- 1st digital computer ENIAC at the University of Penn., 1945
- invention of transistor by Brattain, Bardeen & Shockley, 1947
- fundamental work of Shannon & birth of information theory, 1948
- transatlantic cable & telephone service between Europe and USA, 1953
- 1st Earth satellite is launched by USSR, 1957
- invention of IC by Kilby, 1958
- 1st commercial communication satellite, 1965
- single-chip microprocessor by Intel, 1971
- 1st cellular phone by Motorola, 1972
- personal computers, 1976
- Internet, 1990s
- Smartphone, 1993
- Google (?), Youtube (?), Facebook, Twitter
- ChatGPT (?)
- Quantum computers (IBM, Google, Amazon, etc.)

# Historical Review: Quantum Computers

- Google's quantum chip 'Willow' (Dec. 2024): $10^{30}$ faster than the fastest supercomputer

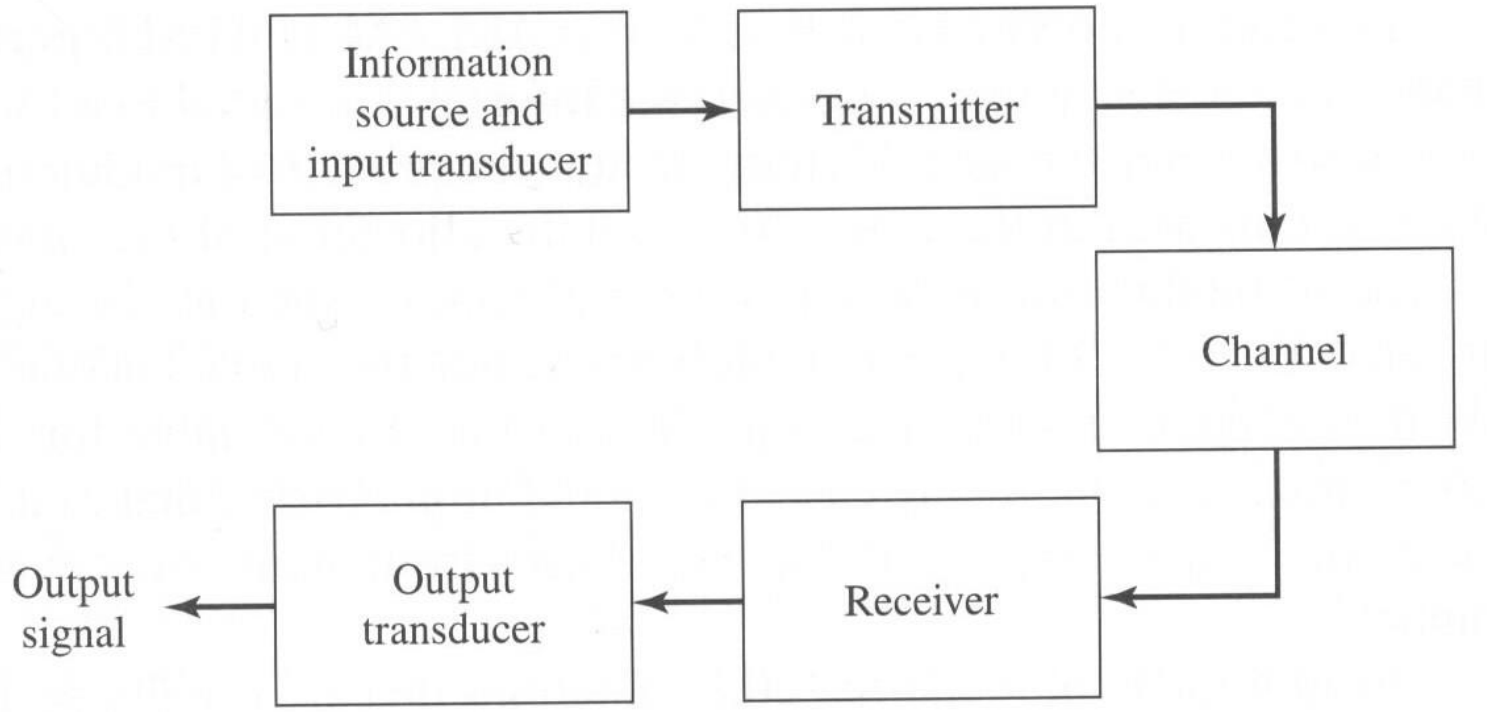


| Willow System Metrics | |
|---|---|
| Number of qubits | 105 |
| Estimated time on Willow vs classical supercomputer | 5 minutes vs. $10^{25}$ years |

- "…*Willow performed a standard benchmark computation in under five minutes that would take one of today's fastest supercomputers 10 septillion (that is, $10^{25}$) years — a number that vastly exceeds the age of the Universe*." H. Neven, Founder and Lead, Google Quantum AI.

# Elements of Communication System

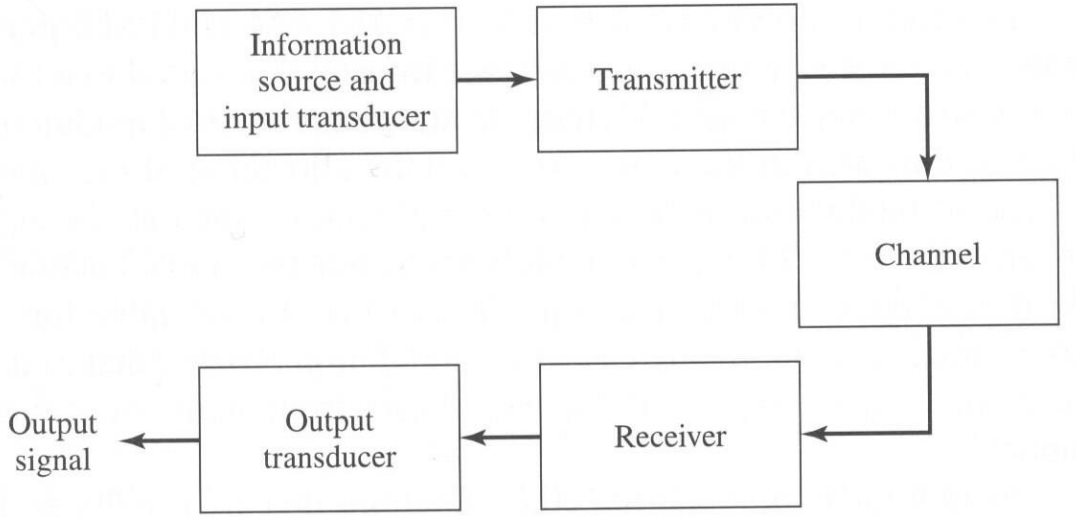
high-level block diagram




J.Proakis, M.Salehi, Communications Systems Engineering, Prentice Hall, 2002

# Elements of Communication System

- source – generates information (speech, video, text, data etc.)
- transducer – transforms source output into electrical signal (e.g. a microphone) and back (at Rx end)
- *three major parts*:
  - transmitter (Tx)
  - channel
  - receiver (Rx)

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# Transmitter

- Converts electrical signal into a form suitable for transmission through the channel (physical medium)
- Need to do this because the transducer output signal cannot, in most cases, be transmitted directly (doesn't match the channel)
- Conversion is made through modulation: amplitude (AM), frequency (FM) & phase (PM). Examples: AM & FM radio broadcast
- Other functions: filtering, amplification, radiation

# Channel

- This is the physical medium between the transmitter and the receiver
- Can be wired (telephone line) or wireless (radio)
- Whatever the medium, the signal is corrupted by noise and interference
- Examples: thermal noise, lightning discharge, automobile ignition noise, interference from other users etc.
- Channel may be highly non-stationary (i.e., fading)
- Significant signal attenuation may be introduced (100-200dB)
- Other types of signal distortions (i.e., spectrum distortion)

# Receiver

- Main function: to recover the message from the received signal
- Somewhat inverse of the transmitter function
- Demodulation: inverse of the modulation
- Operates in the presence of noise & interference. Hence, some distortions are unavoidable.
- Some other functions: filtering, suppression of noise & interference

# Characteristics of Communication Channels

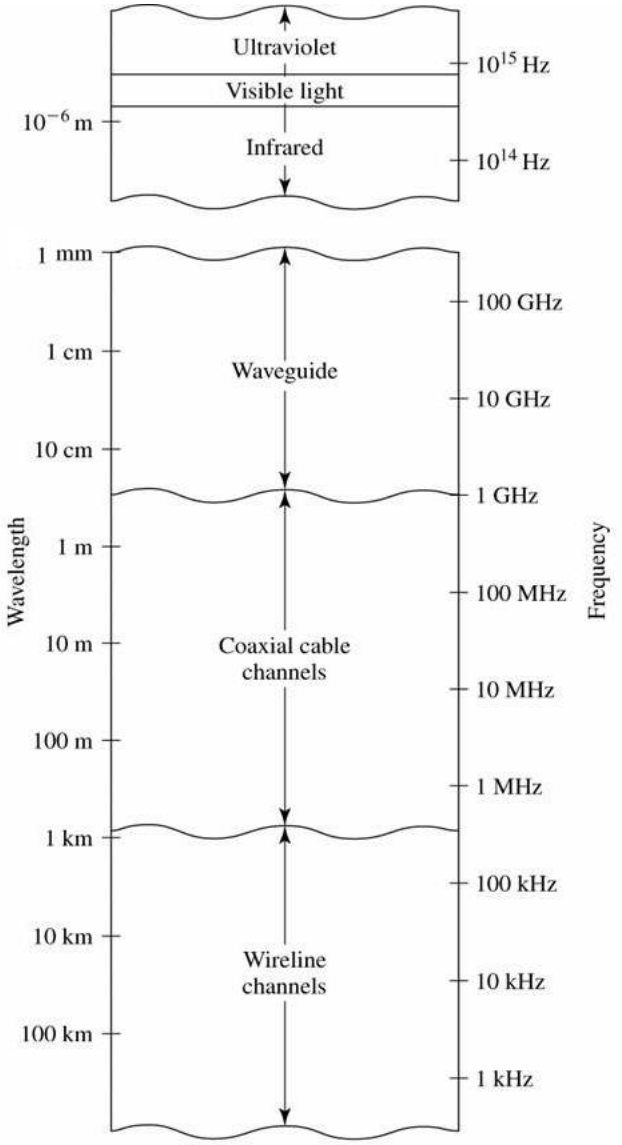
## Wireline channels:

- twisted-wire pair
- coaxial cable
- waveguides
- optic fiber

Signals are distorted in amplitude and phase. Some measures are required to reduce the effect of distortions.

Bandwidth of (up to)

- twisted pair: 10s kHz to 30 MHz
- coax cable: 10s GHz
- wave guide: 100s GHz
- optical fiber: 10-100 THz

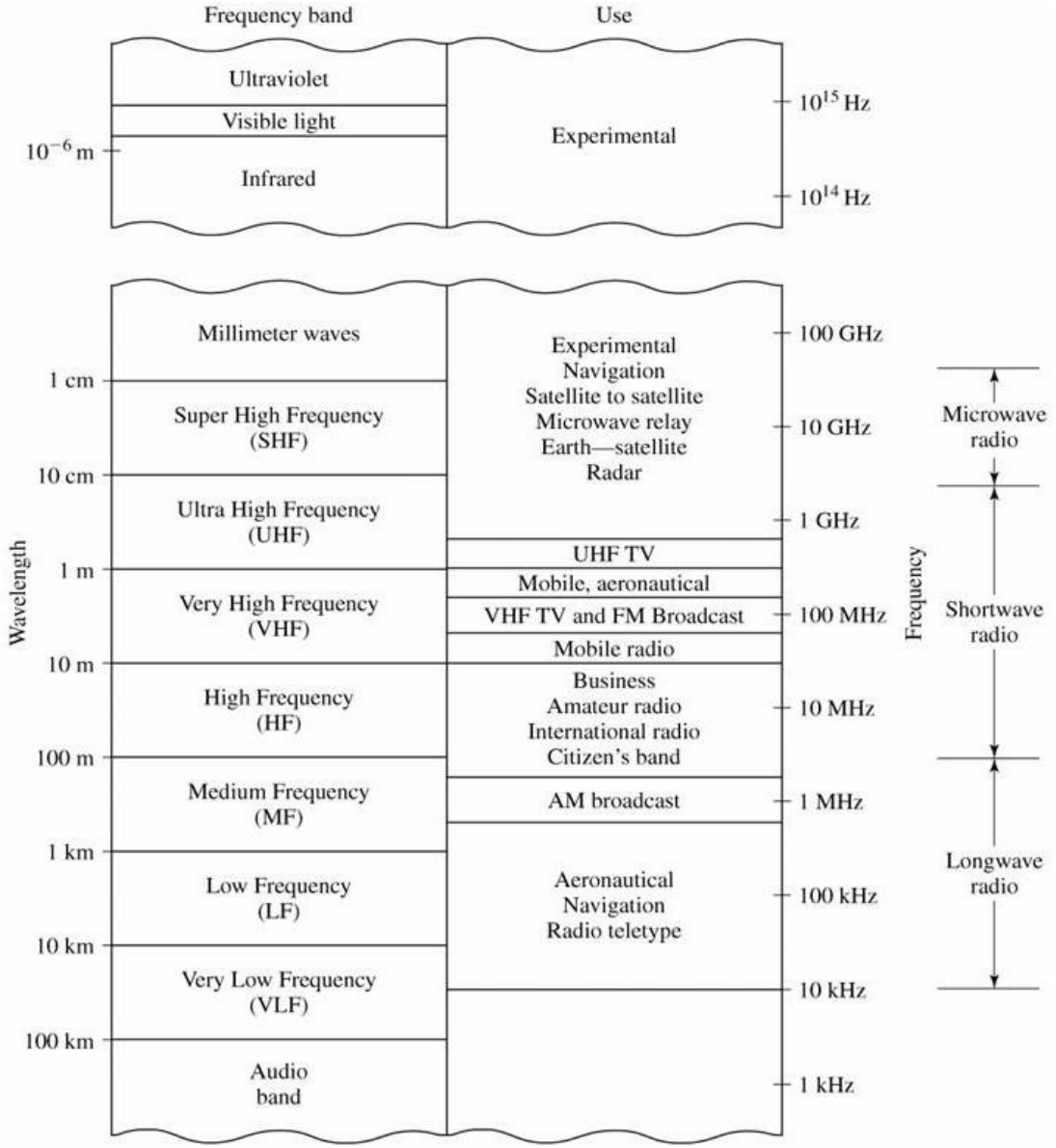



J.Proakis, M.Salehi, Communications Systems Engineering, Prentice Hall, 2002

# Radio Communication Channels

(wireless)

- Unguided electromagnetic wave, radiated by the Tx antenna, is a carrier of the signal
- Strong signal attenuation (up to 100-200 dB). Hence, high Tx power is required
- Susceptible to external interference
- Antennas are required. Size of antenna: comparable with wavelength



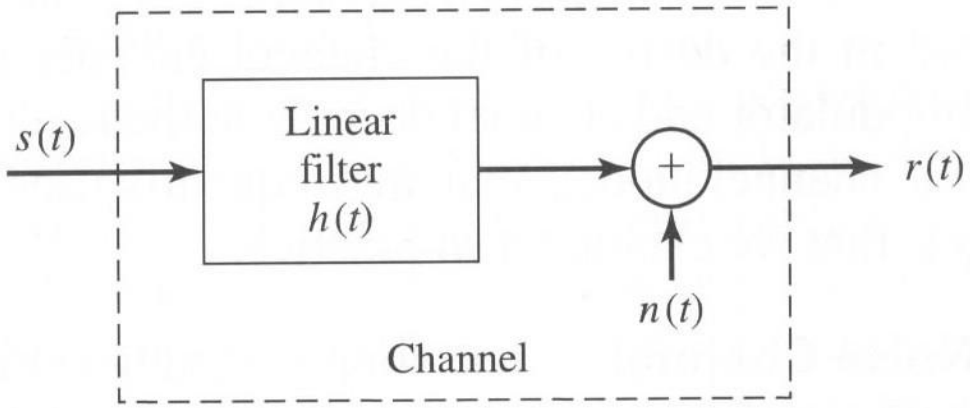

J.Proakis, M.Salehi, Communications Systems Engineering, Prentice Hall, 2002

# Typical Frequencies

- Cell phone: 1-2 GHz
- Cordless phone: 43-50 MHz, 900 MHz, 2.4 and 5.8 GHz.
- Cable phone: 300-3400 Hz
- WiFi: 2.5, 5 GHz
- VDSL-2 (Internet over phone cable): 30 kHz-30MHz
- TV (satellite): 10-12 GHz
- TV (cable/broadcast): 50-950 MHz
- AM broadcast: 300kHz – 1.5 MHz
- FM broadcast: 80-110 MHz
- Optical: 100s THz

# Mathematical Models of Channels

System-level model: linear time-invariant system




J.Proakis, M.Salehi, Communications Systems Engineering, Prentice Hall, 2002

$$r(t) = s(t) * h(t) + n(t) =$$

$$= \int_{-\infty}^{+\infty} h(\tau) s(t-\tau)\, d\tau + n(t)$$

Detailed model: based on electromagnetics (i.e., radio wave propagation)

# Summary

- Definition of communication systems and their types. Examples.
- Historical review
- Block diagram and its elements.
- Main elements: transmitter, channel and receiver