

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, Fri. 14:30 – 15:50 (LMX 220). 1st Lecture: Wed. Jan. 10, 16:00.
- **Tutorials:** Begin on Jan. 19 (no tutorial 1st week); Fri. 11:30 - 12:50 (SITE C0136).
- **Labs:** Begin on Jan. 24 (no labs first 2 weeks), Wed. 13:00-15:50 (CBY B519).

- **Office hours:** Wed. 5:30-7pm. 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. 16, 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.)

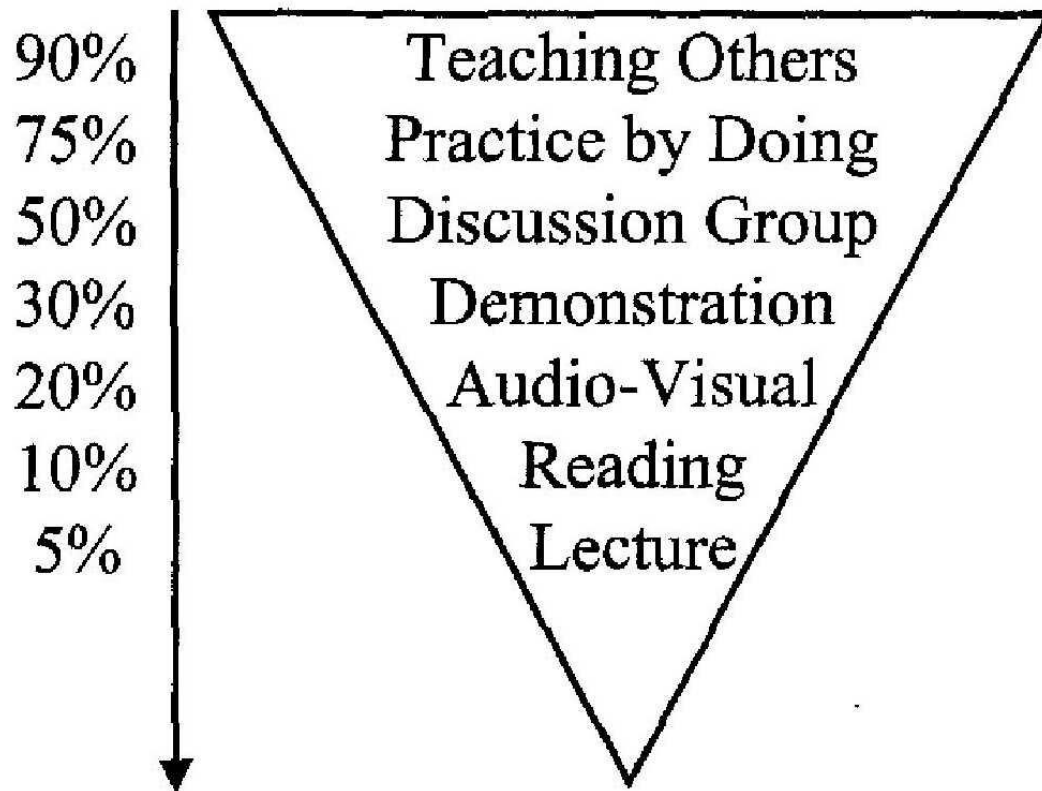
- **Co-requisite:** ELG3126 (basic probability theory)

- **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



“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.

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.

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

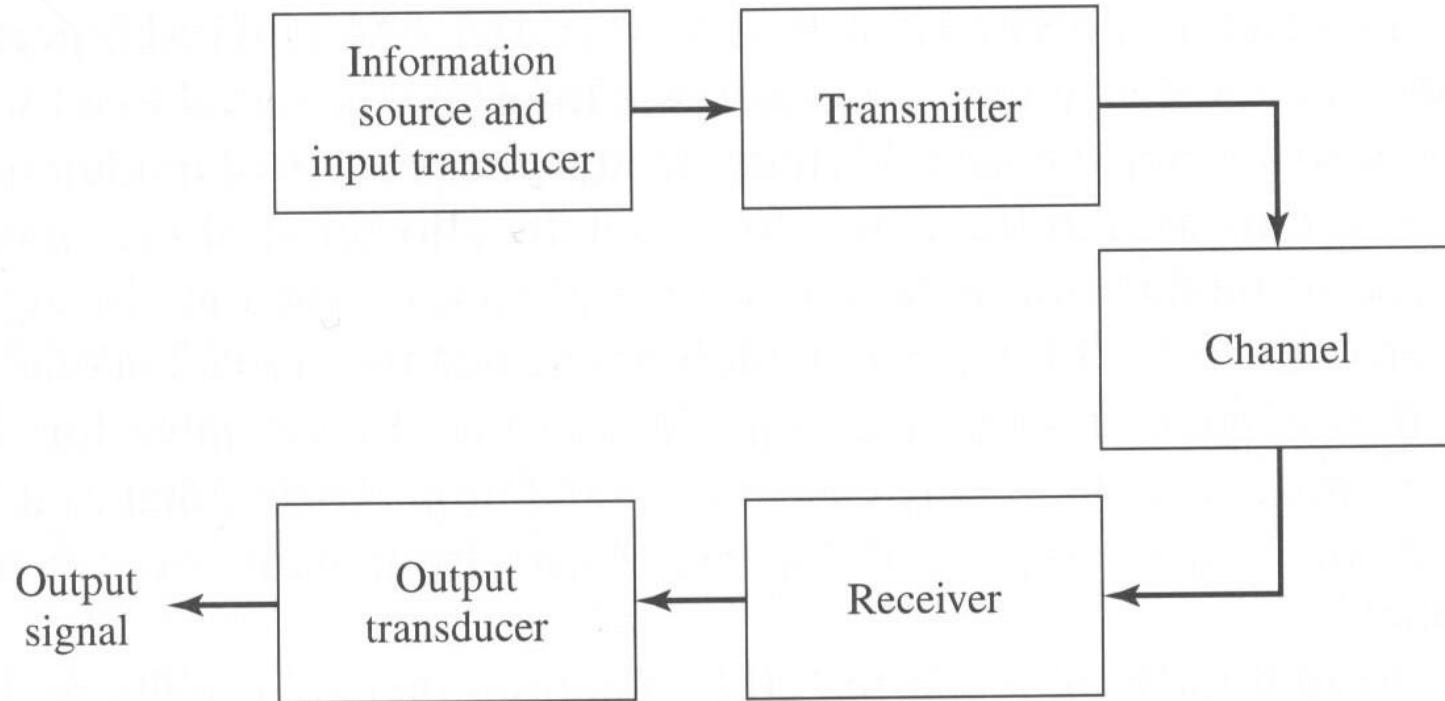
- telegraph by Morse, 1837 (operational in 1844).
- telephone by Bell, 1876 (Bell Telephone Company in 1877).
- radio (wireless) by A. Popov in 1895 & G. Marconi in 1896.
- first transcontinental wireless transmission in 1901 by Marconi
- vacuum diode by Fleming (1904) & vacuum triode by De Foster (1906)
- 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 (?)

Elements of Communication System

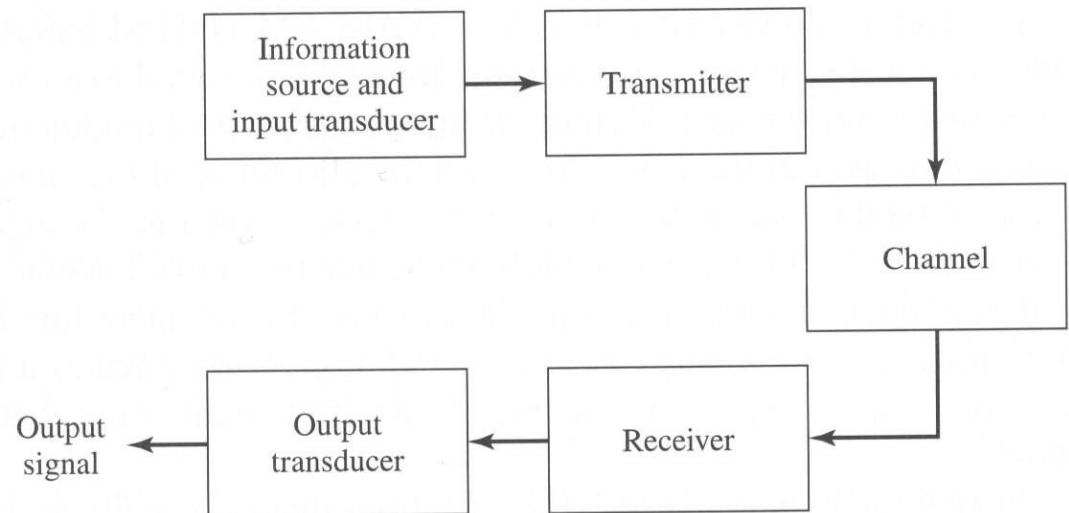
high-level block diagram



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)



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

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

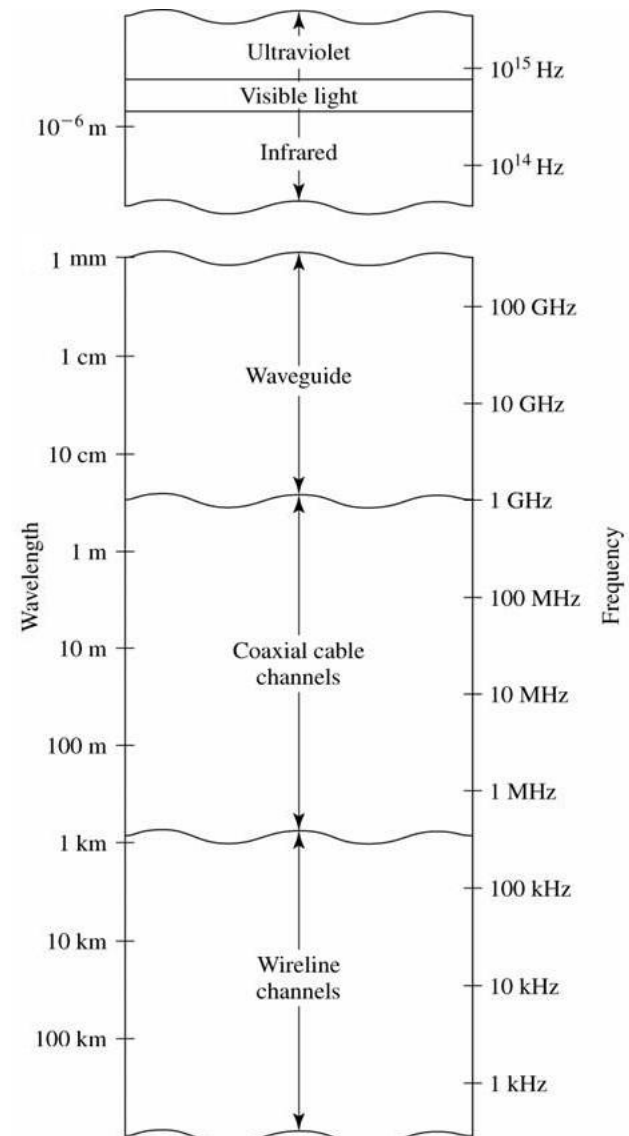
Wireline channels:

- 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

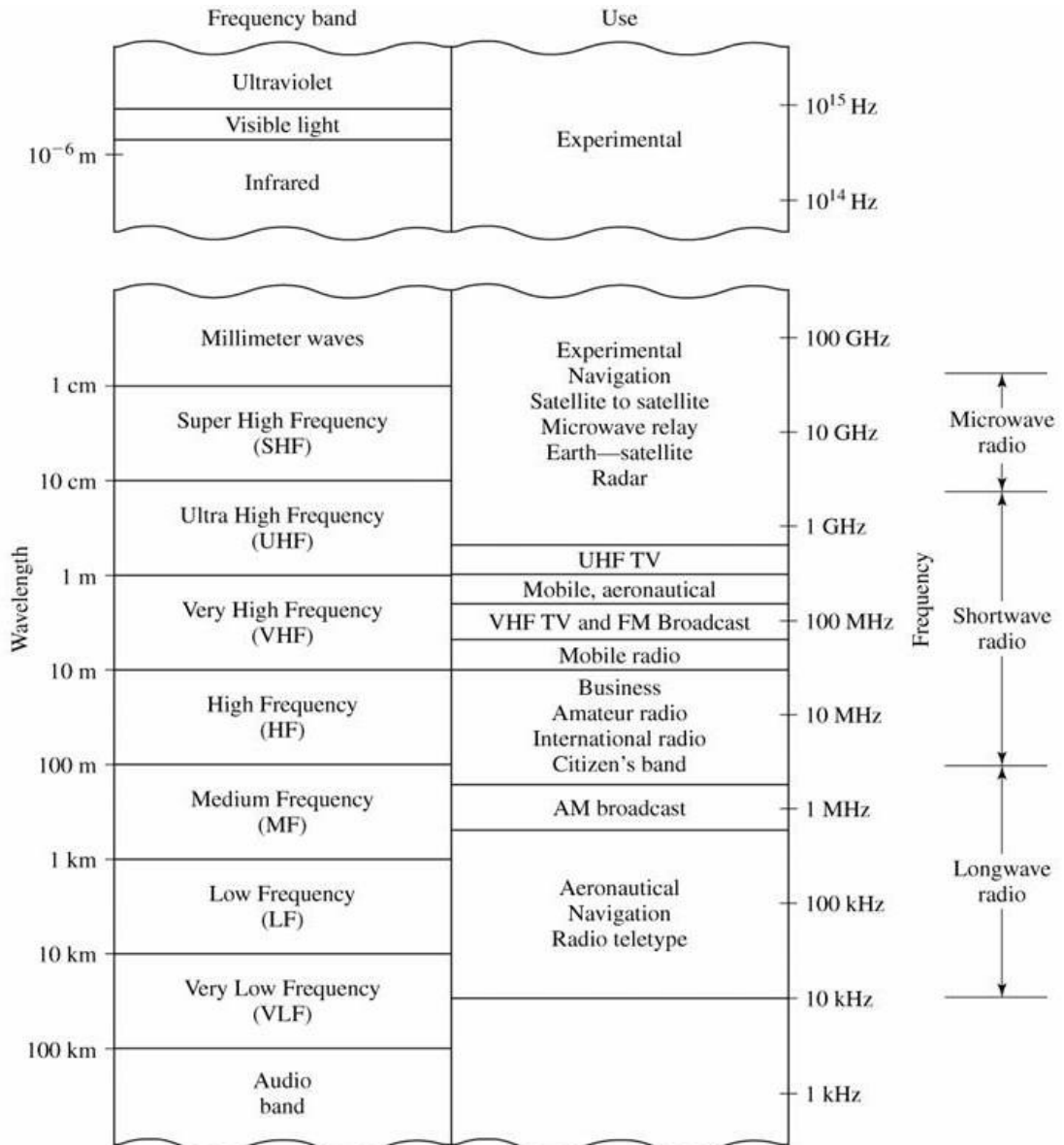


J.Proakis, M.Salehi, Communications Systems Engineering, Prentice Hall, 2002

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

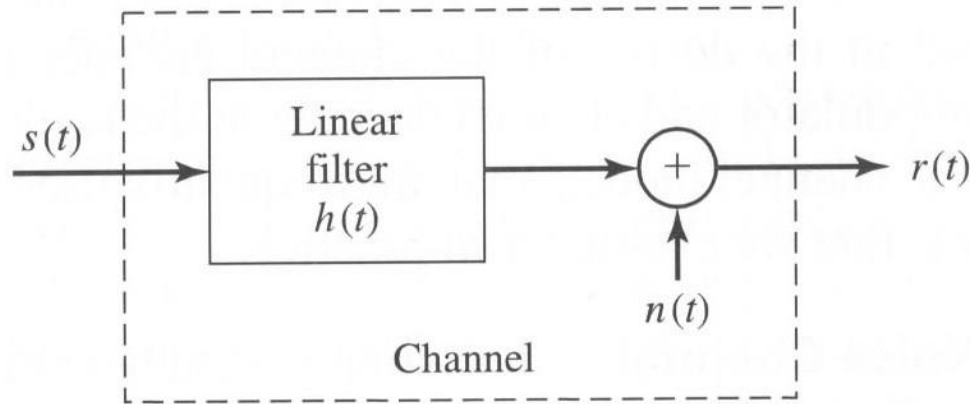


Typical Frequencies

- 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



$$\begin{aligned} r(t) &= s(t) * h(t) + n(t) = \\ &= \int_{-\infty}^{+\infty} h(\tau) s(t - \tau) d\tau + n(t) \end{aligned}$$

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

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