Signals and Systems

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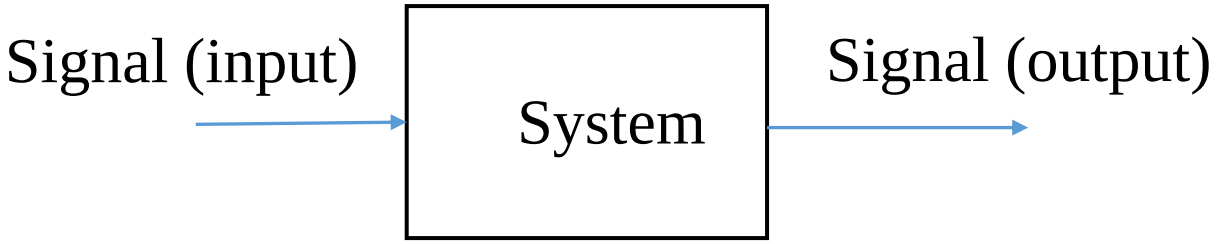
ShanghaiTech University

Course introduction

- Global content
- Exams and grades
- Text book and materials
- Organization
- Motivation
- Pre-knowledge

Global content



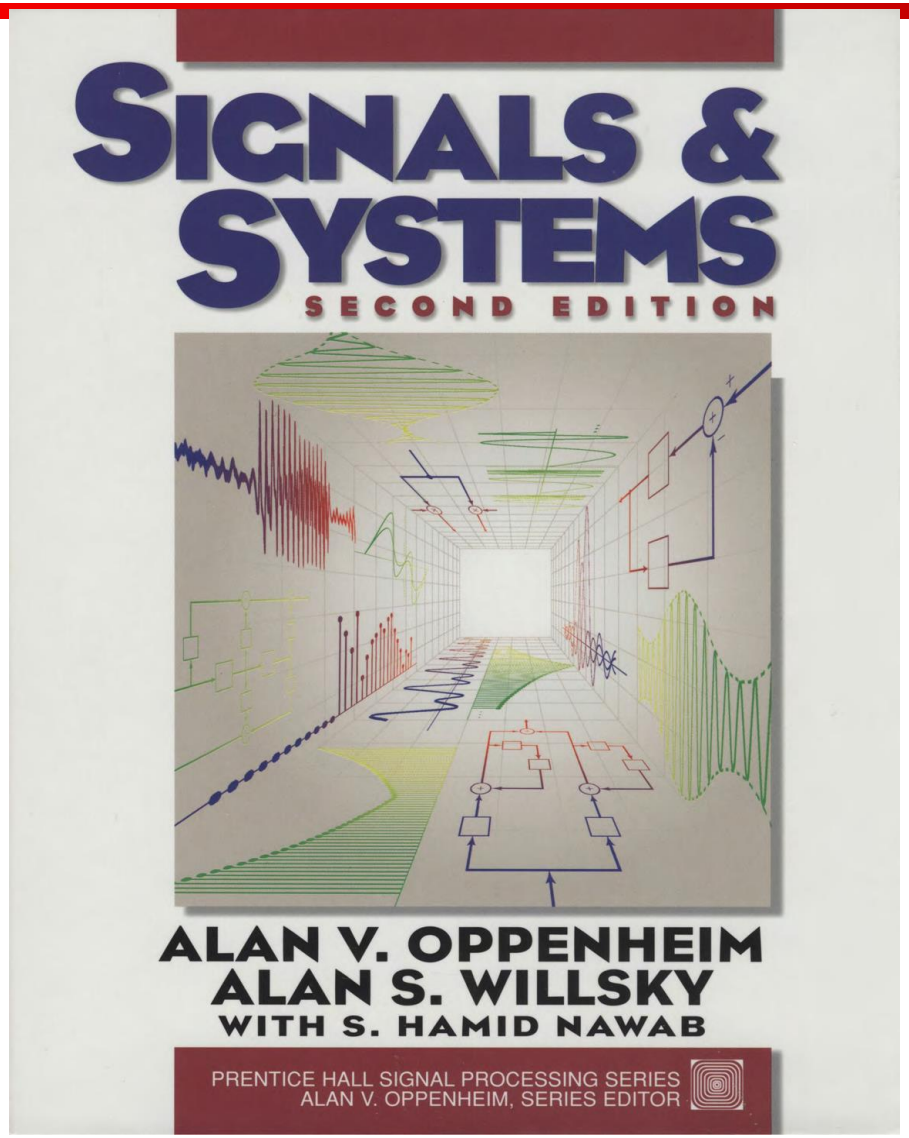
- Overview of Signals and Systems
- Linear-Time-Invariant Systems
- Fourier Series Representation of Periodic Signals
- The Continuous-Time Fourier Transform
- The Discrete-Time Fourier Transform
- Time and Frequency Characterization of Signals and Systems
- Sampling
- The Laplace Transform
- The Z-Transform

Exams and Grades

- Homework: 15% (Delay <=2 days, *0.8; >2 days, *0)
- Mid-term (written, close-book): 30%
- Final Exam (written, close-book): 50%
- Attendance: 5% (-1% point per absence, no late than 5 mins)
- All in English, otherwise *0.8
- Plagiarism:
  - one time: the assignment ZERO score
  - two times: the assignment ZERO score + course score * 0.8
  - three times: course ZERO score

Text book and materials

- Book
  - Signals and Systems (2nd Edition), by A. V. Oppenheim, A. S. Willsky, and S. Hamid. ISBN: 978-0138147570.
  - Signals and Systems using Matlab (2nd Edition), by Luis Chaparro. ISBN: 978-0123948120.
- These slides
- All materials will be available in the BB system

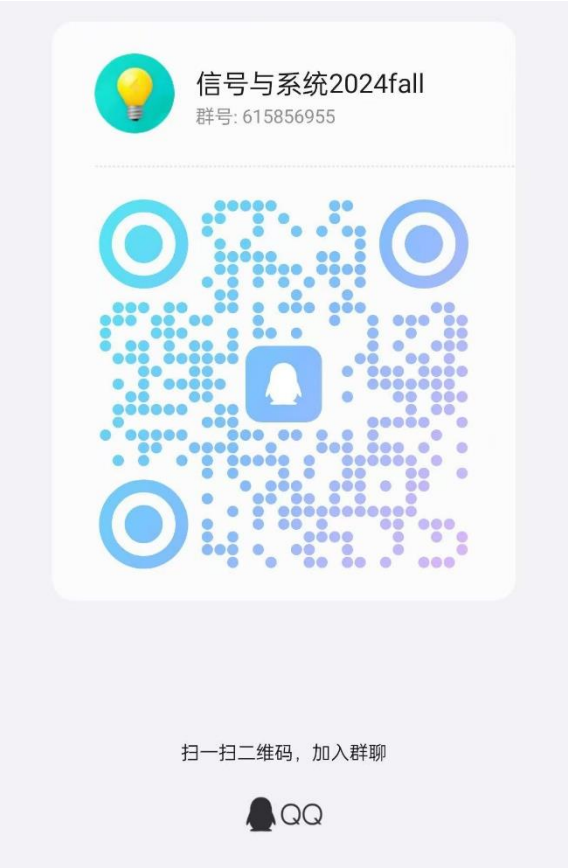


Organization

- **Lecture:** week 1-16; Teaching Center 101; Tue. and Thu. 08:15-9:55
- **Exercise:** once per week, time and location TBD
- **Office hour:** email us to find a suitable time slot
- **Experiment:** by Dr. Linyan Lu, start from the 2nd week
- **BB system**: slides and text book, homework release
- **Gradescope:** homework submission and grading, entry code: already sent

Support team

- TAs:
  - 周随安 zhousa@shanghaitech.edu.cn
  - 王润华 wangrh1@shanghaitech.edu.cn
  - 张宸治 zhangchzh2022@shanghaitech.edu.cn
- QQ group:
  - QR code

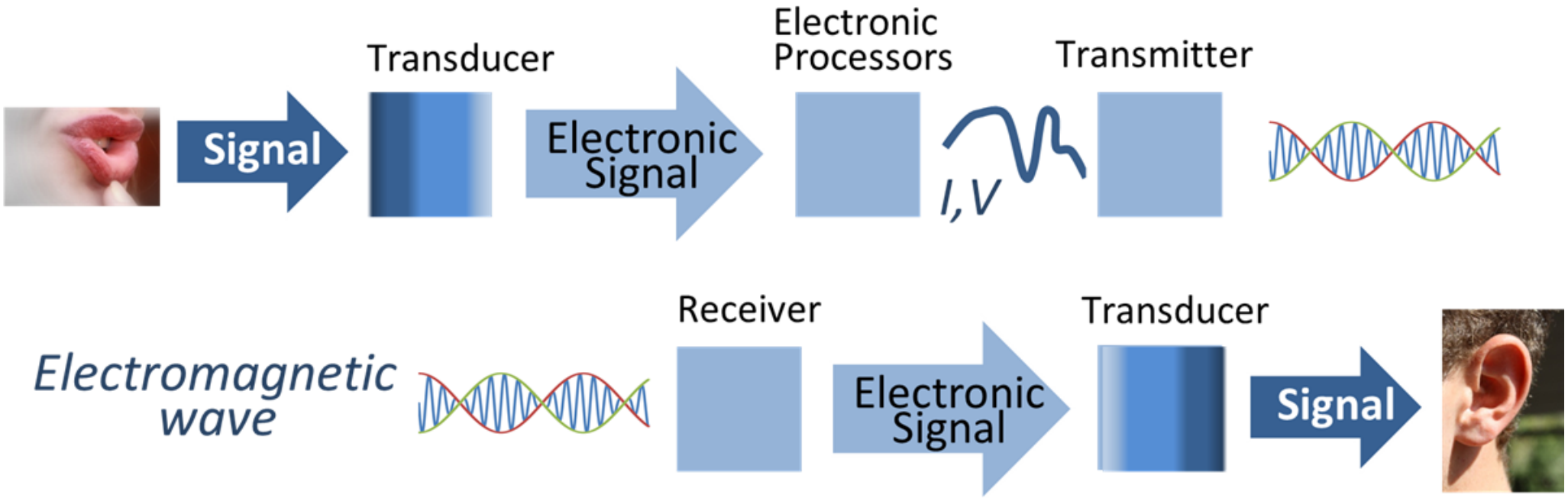


Definition

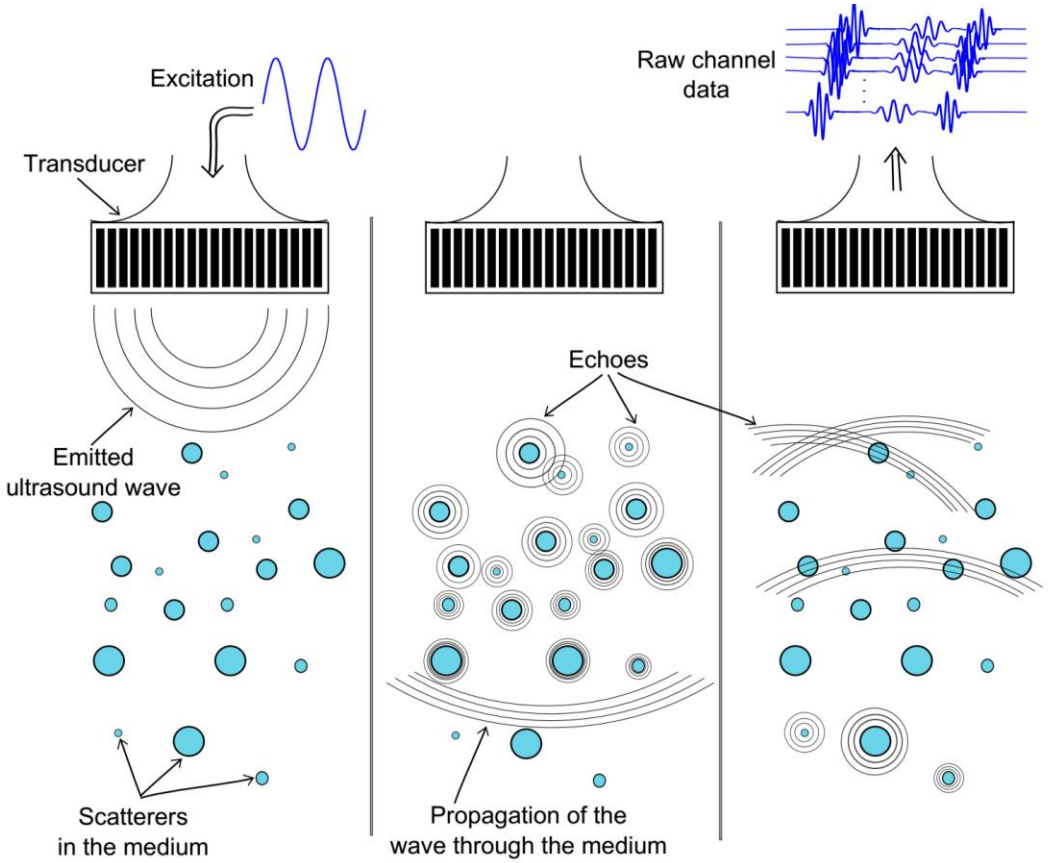
- **Signals**: functions containing information about the behavior or nature of some phenomenon.

- **Systems**: respond to particular signals by producing other signals or some desired behavior.

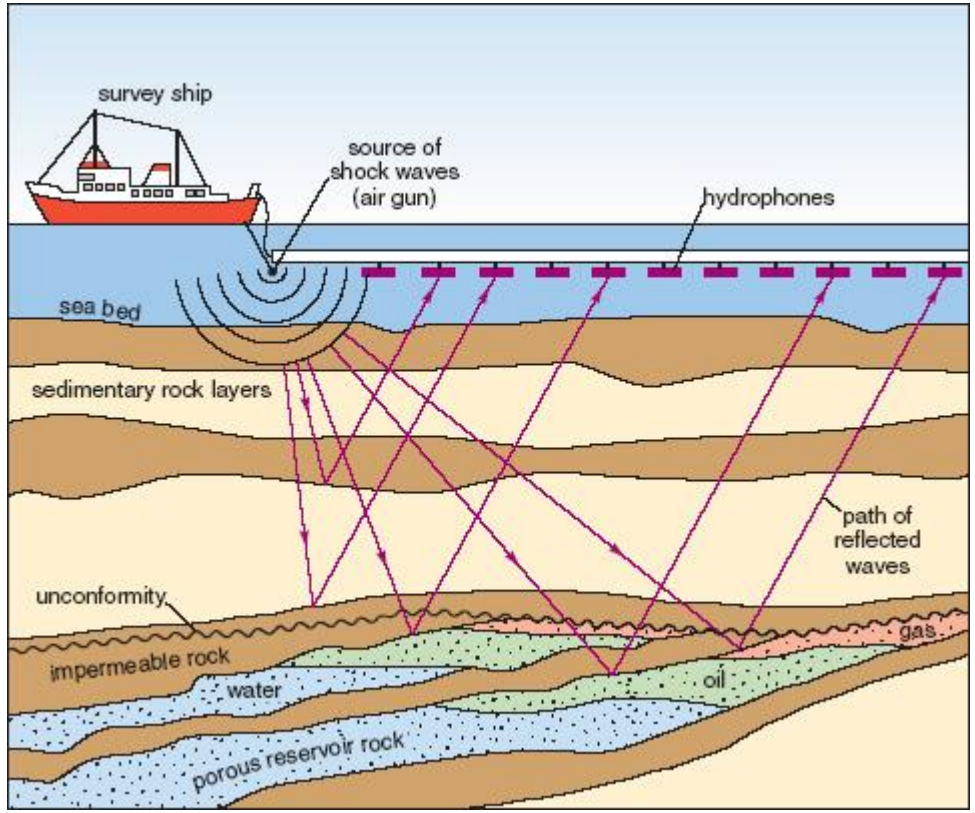
Communication systems

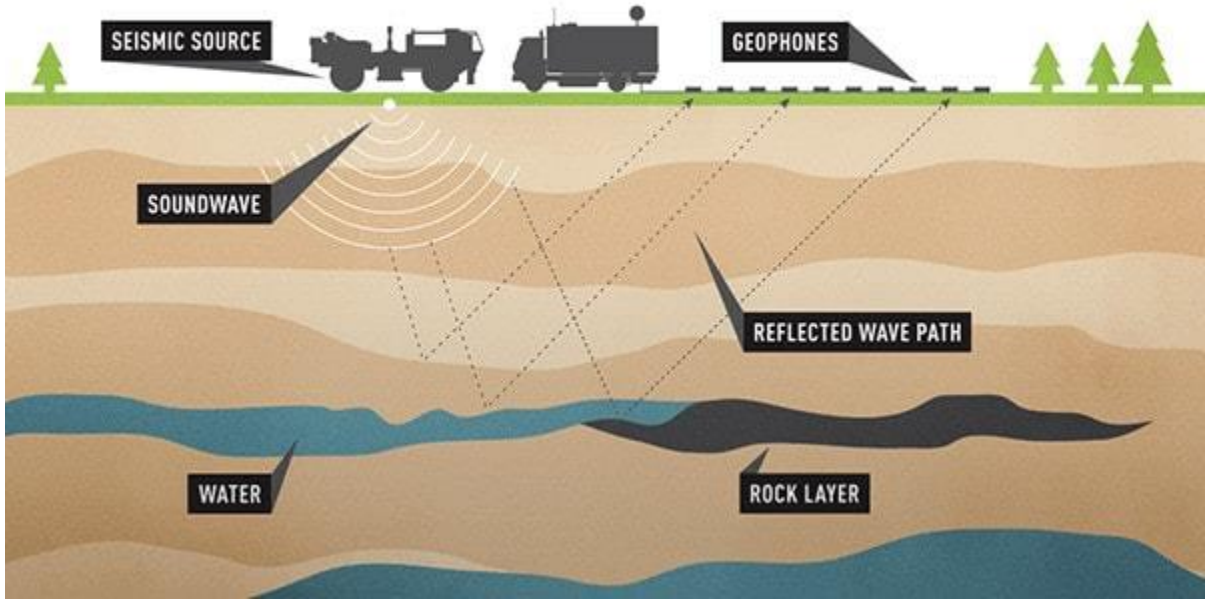


Medical imaging

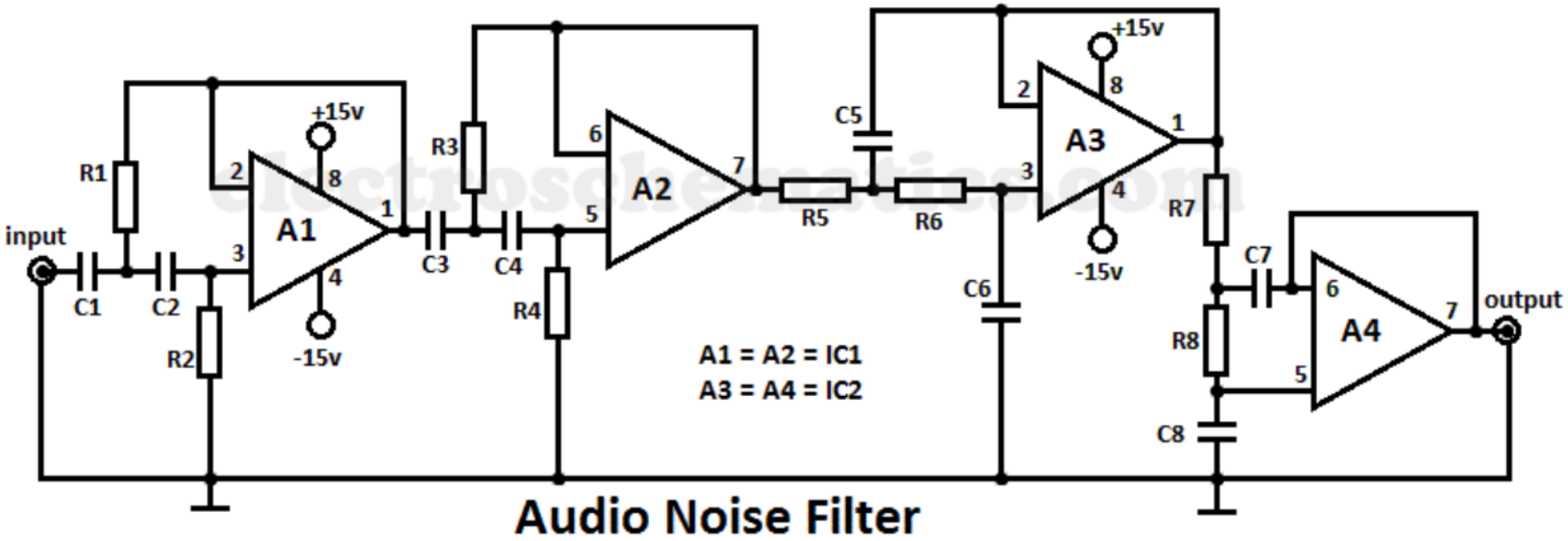


Geophysics

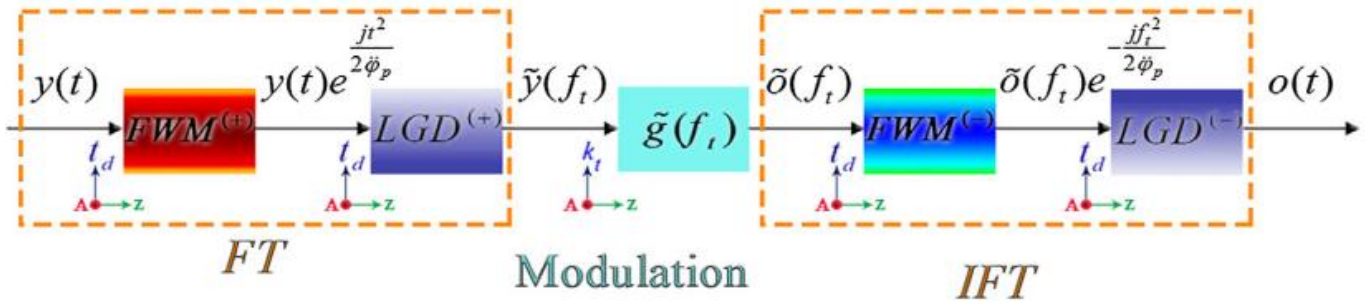


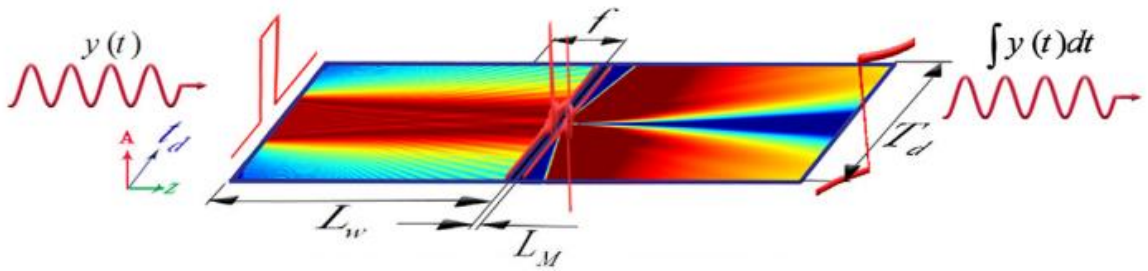


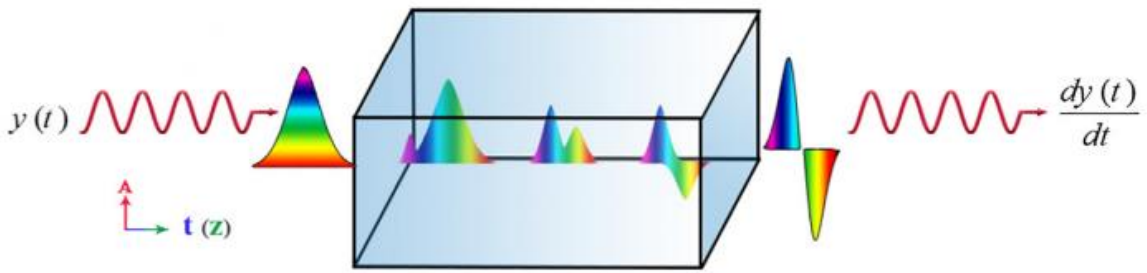
Signal processing



Optical computing







Babashah et. al., Optics and Laser Technology 111:66-74, 2019

Pre-knowledge

Complex numbers

Cartesian notation:

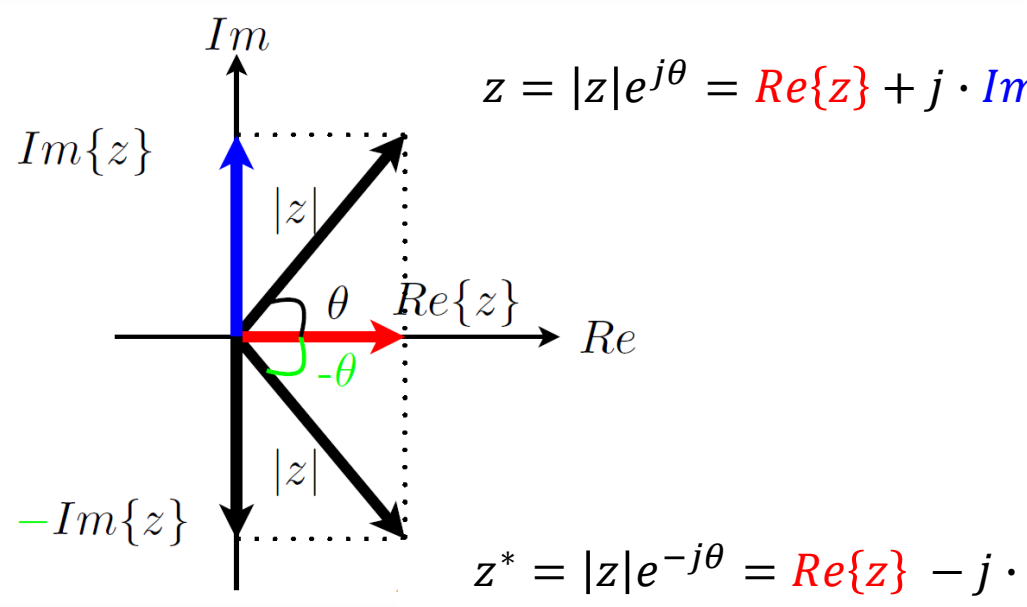
$$z = Re\{z\} + j \cdot Im\{z\}$$

Polar notation:

$$z = |z|e^{j\theta}$$

Complex conjugation: $j \Rightarrow -j$

Euler: $e^{j\theta} = \cos(\theta) + j\sin(\theta)$



$$z = |z|e^{j\theta} = Re\{z\} + j \cdot Im\{z\}$$

$$z^* = |z|e^{-j\theta} = Re\{z\} - j \cdot Im\{z\}$$

$$\cos(\theta) = \frac{e^{j\theta} + e^{-j\theta}}{2}$$

$$\sin(\theta) = \frac{e^{j\theta} - e^{-j\theta}}{2j}$$

Pre-knowledge

Important geometric series

With z_0 some (possibly complex) number:

$$\boxed{\sum_{n=0}^{\infty}(z_0)^n = \frac{1}{1-z_0}} \quad \text{iff} \quad |z_0| < 1$$

'Proof' via long tail division:

$$\frac{1}{1-z_0} = 1 + z_0 + (z_0)^2 + (z_0)^3 + \cdots = \sum_{n=0}^{\infty}(z_0)^n$$

$$\boxed{\sum_{n=0}^{M-1}(z_0)^n = \frac{1-z_0^M}{1-z_0}}$$

Pre-knowledge

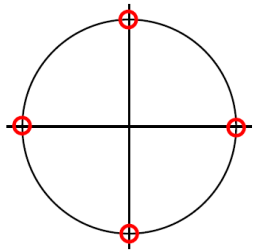
Zeros of a complex equation

With a some (complex) number, find zeros of: $\boxed{z^N - a = 0}$

$$z^N = a = a e^{j k \cdot 2\pi} \quad \Rightarrow \quad \boxed{z_k = a^{\frac{1}{N}} \cdot e^{j k \cdot \frac{2\pi}{N}}} \text{ for } k = 0, 1, \cdots, N-1$$

Example: $a = 1, N = 4$

$$\Rightarrow \quad z_k = e^{j k \cdot \frac{\pi}{2}}$$



Example: $a = -1, N = 3$

$$\begin{aligned} \Rightarrow \quad z_k &= (-1)^{\frac{1}{3}} \cdot e^{j k \cdot \frac{2\pi}{3}} \\ &= (e^{j\pi})^{\frac{1}{3}} \cdot e^{j k \cdot \frac{2\pi}{3}} \\ &= e^{j \frac{\pi}{3} + k \cdot \frac{2\pi}{3}} \end{aligned}$$