Bits over the Air: Pre-Lab 1

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- You can always ask questions (during pre-labs and labs, or via email after the labs)
- During the labs, you can also ask us if you want to know more about a specific aspect!

- We are here to help!

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A short introduction

Wireless communication

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We all communicate!

- **Source**: generates information to be transmitted
- **Channel**: physical medium (air or water)
- **Destination**: entity that receives information

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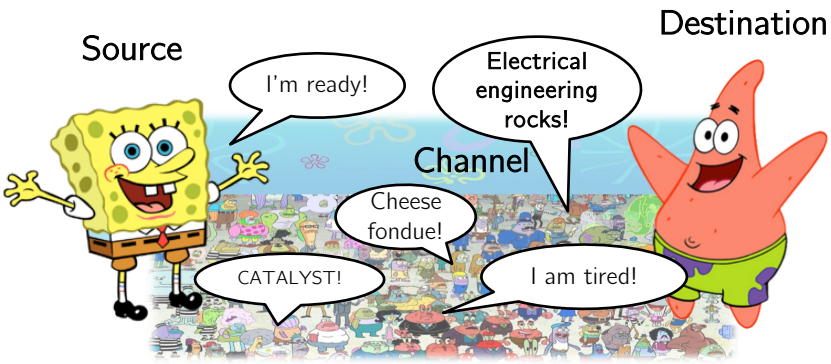
What could go wrong?



- Real-world channels introduce noise and interference → unreliable communication

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How can we make communication reliable?

- Speak louder
- Go closer to destination

} received signal strength

- Repeat message
- Rephrase message
- Change language
- (Change pitch)

} modulation and coding

- We are naturally using concepts that modern communication systems are using

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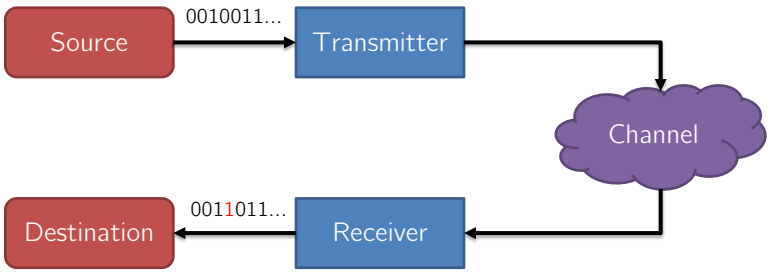
Abstraction of communication systems

- Simple point-to-point system:



- Almost all possible communication systems (Wi-Fi, LTE, Bluetooth, etc.) look like this!

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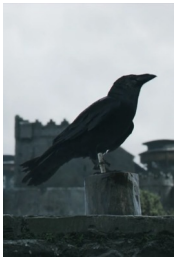
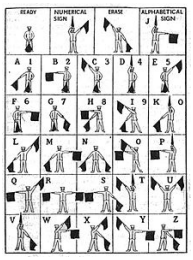
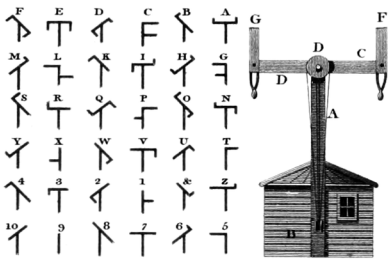
Early history of communication

- Optical telegraphy (wireless):
  - Smoke signals, talking drums, homing pigeons, hydraulic semaphore systems (4BC), beacons, semaphores (until about 1880)







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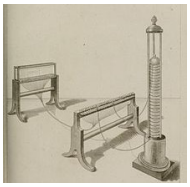
Wired information transfer

- Electrical telegraphy (wired)
  - 1774 : Georges-Louis Le Sage designed first electrical telegraph with wire for each letter
  - 1800 – 1820 : Different electrical telegraph systems with limited distance
  - 1837 : Samuel Morse developed code and machine to transmit and receive over long distances



A •–
B –•••
C –•–•
D –••
E •
F ••–•
G ––•
H ••••
I ••

J •–––
K –•–
L •–••
M ––
N –•
O –––
P •––•
Q ––•–
R •–•

S •••
T –
U ••–
V •••–
W •––
X –••–
Y –•––
Z ––••

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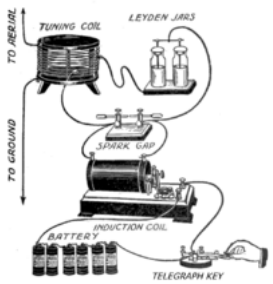
And then came wireless!

- Wireless telegraphy
  - 1890s : Guglielmo Marconi developed the spark-gap transmitter → send pulses wirelessly



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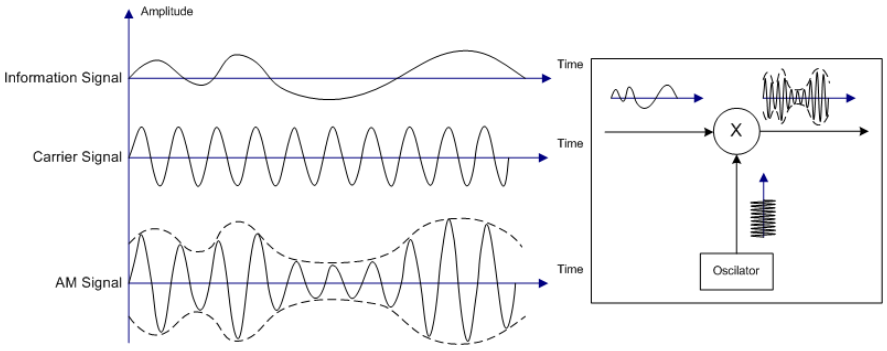
Analog signal transmission

- 1900 – 1920 : amplitude modulation (AM) for wireless audio transmission



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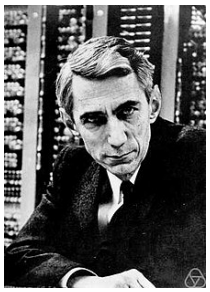
A digital revolution!

- In 1948, Claude Shannon at Bell Labs developed information theory
  - Digital model for communication
  - Builds the basis of all existing communication systems!
  - Data rates (bits/second) double every 18 months



- Since then, digital communication has evolved into Wi-Fi, LTE-A, Bluetooth, DOCSIS, ...

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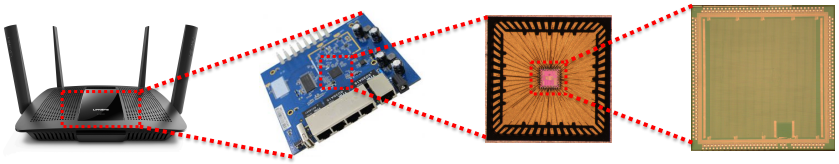
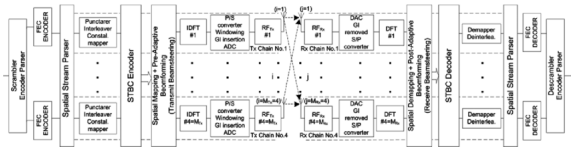
Modern wireless transceivers

- Transceiver: transmit and receive



- Processing of information is carried out in digital circuits at extremely fast rates



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Monday overview

Bits over the air

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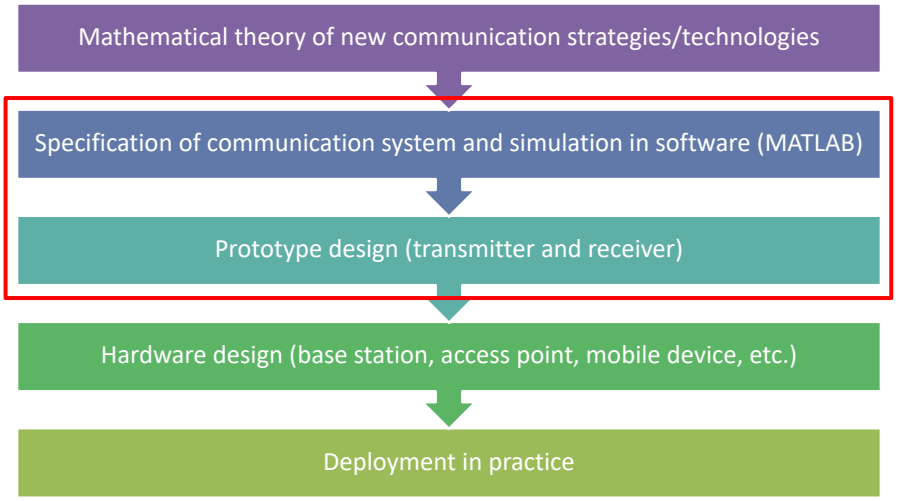
How are comm. systems designed?



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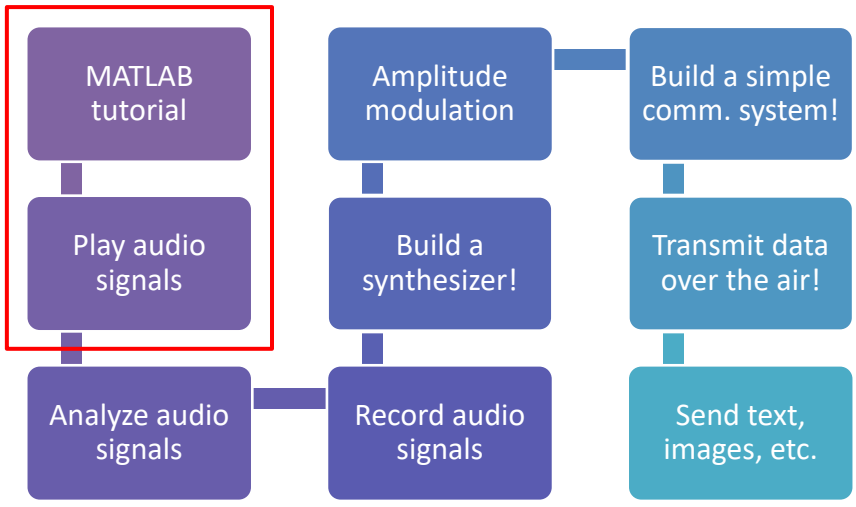
Today's goals:



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Project schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
1pm-2pm	Pre-Lab 1: Introduction to MATLAB and digital communication	Pre-Lab 2: Signal processing, time-domain, spectrum, and spectrogram	Pre-Lab 3: Generating music with MATLAB and communication system basics	Pre-Lab 4: Communication via amplitude modulation and synchronization	Pre-Lab 5: Bits over the air: transmitting text and images over the air (reliably!)
2pm-3pm	Module 1: MATLAB basics 1	Complete previous modules	Complete previous modules	Complete previous modules	Complete previous modules
	15min break	15min break	15min break	15min break	15min break
3pm-4pm	Module 2: MATLAB basics 2	Module 4: Spectrum and spectrogram	Module 6: Generating music in MATLAB	Module 8: Simple communication system 2	Module 10: Transmitting bits over the air
4pm-5pm	Module 3: Play audio in MATLAB	Module 5: Record audio in MATLAB	Module 7: Simple communication system 1	Module 9: Synchronization	Work on presentations

- Scheduled break from 3:15pm to 3:30pm

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Remember: this is group work!

- Groups of 2-3 students (matched by skills)
  - Today's groups are fixed; changes upon request
- Try to help each other (within group)
- Ask us if you have any questions!
- Modules contain examples (to explain new concepts) and activities: do both!
  - Feel free to explore a certain concept in more detail if you are interested (do not forget time)

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Modules 1 and 2

MATLAB tutorial

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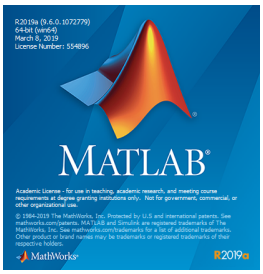
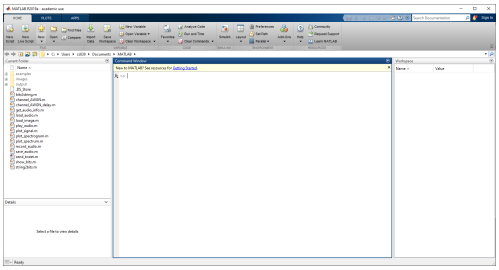
We will use MATLAB extensively





- The standard software for scientific computing in academia as well as industry
- Used in engineering (not only ECE!), computer science, math, physics, etc.

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What is MATLAB?

...a powerful and expensive calculator!

- Proprietary programming language developed by MathWorks
- Particularly useful for matrix operations, digital signal processing, data analysis and visualization, and algorithm design
- Used by virtually every communication system engineer in the world!

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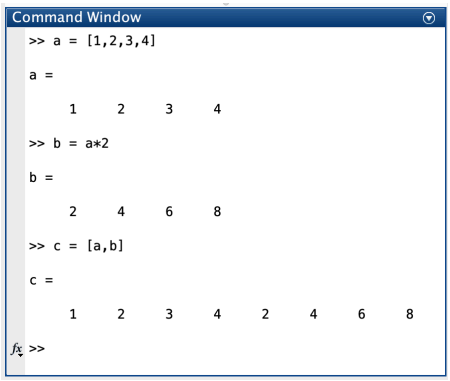
MATLAB is very simple



- Example:
  - Define variable **a** containing a row vector **[1 2 3 4]**
  - Create new vector **b** = **a*2** = **[2 4 5 6]**
  - Concatenate vectors **a** and **b** to create new vector **c**

- A great programming language for beginners (Cornell course CS1112)

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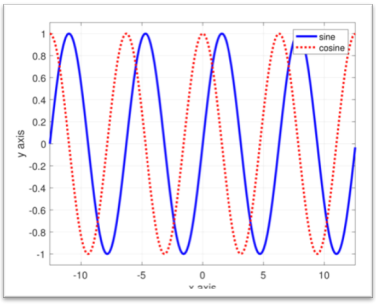
Modules 1 and 2 teach…

- basic calculations with scalars and vectors
- function plotting (display graphs)
- How to write MATLAB scripts & functions




```
function [ z,w ] = test_function( x,y )
%test_function that computes x+y and x*y
%   [z,w] = test_function(x,y)
%   x : input1
%   y : input2
%   z : output1 (z=x+y)
%   w : output2 (w=x*y)
z = x+y;
w = x.*y;
end
```

Module 3

Play audio signals with MATLAB

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First steps with signal processing

- We will use loudspeakers to play back digitized signals with MATLAB

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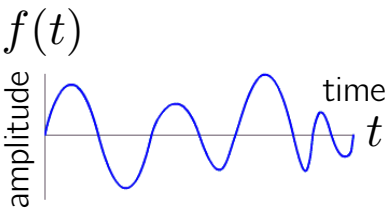
What is signal processing?

- Signals are functions that convey information, e.g., $f(t) = \sin(t)$ where $t \in \mathbb{R}$
- Examples: Music, speech, temperature, FM radio, painting, etc.
- Signal processing: analyzing, modifying, & synthesizing signals



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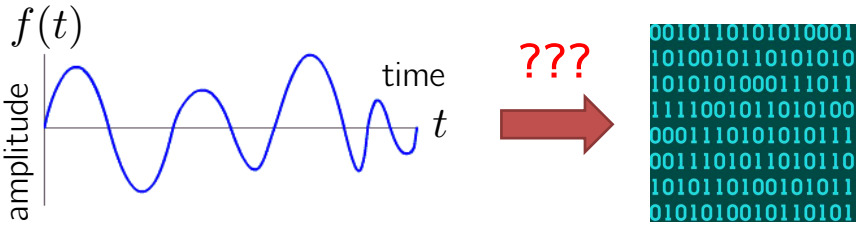
Digital signal processing

- Our world is analog (continuous), computers cannot store or process analog signals
- Digital signal processing requires conversion of continuous signals into digital information (bits)



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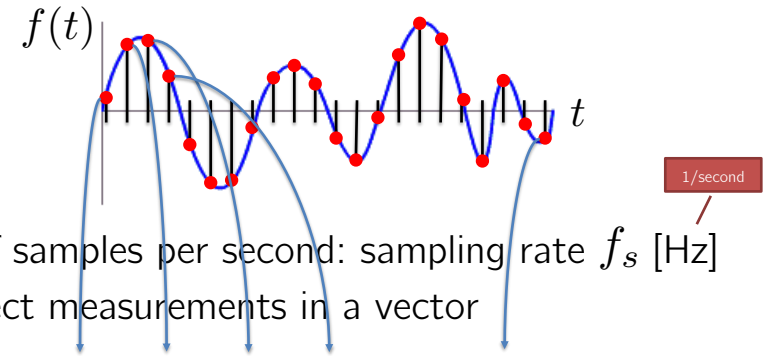
Solution: sampling!

- Take a subset of measurements (samples) of the continuous signal $f(t)$



- # of samples per second: sampling rate f_s [Hz]
- Collect measurements in a vector

$$\mathbf{s} = [0.1, 0.6, 0.7, 0.3, \ldots, -0.2]$$

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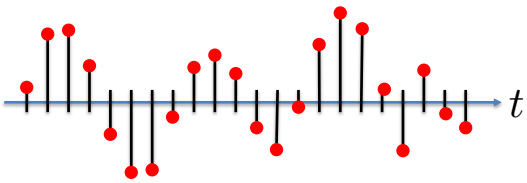
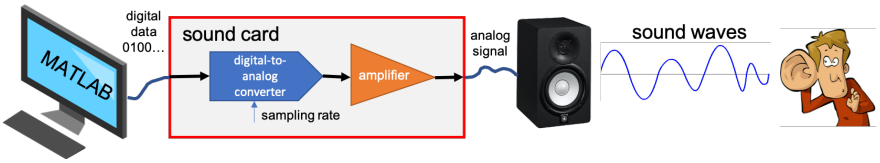
Sampling enables digital processing

- Sampled signals can be processed in software



- Samples can be played back at sampling rate f_s



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Project website: catalyst2019.github.io

- Copy MATLAB files (in a zip-folder)
- Extract to computer
- These functions simplify a lot of the repeating tasks!