Course Admin

EL-GY 6013: DIGITAL COMMUNICATIONS

PROF. SUNDEEP RANGAN

People and Time

- Professor: Sundeep Rangan, srangan@nyu.edu
  - 370 Jay St, 9.104
  - Office Hours: Thursdays, 2-4 pm

- TA: Ruth Gebremedhin
  - Office Hours: TBD
  - Ask for all questions regarding homeworks and labs
- Location: Rogers Hall 204
  - Tuesdays, 5 to 7:30pm

Pre-requisites

- EL6303 Graduate probability
  - May also be taken as co-requisite
  - Chapters 1-7 and chapter 9 from Papoullis, Pillai
  - This class is offered this semester
- Undergraduate signals & systems:
  - Fourier transforms, filters, sampling, bandwidth
- We will review stochastic processes only very briefly.

Github Site

https://github.com/sdrangan/digitalcomm

Digital Communications

Prof. Sundeep Rangan, NYU:

This repository provides instructional material for digital commu
Communications*, a graduate level class at NYU Tandon.

Anyone is free to use and copy this material (at their own risk!).
your own class.

- All material is open-source on github
- Contains:
  - Lecture notes
  - Problems
  - MATLAB demos
  - MATLAB problems
- Solutions are given in class

MATLAB

- All labs will be in MATLAB
- Download the latest MATLAB with Communications Toolbox
- NYU students can get this for free:
  - https://www.mathworks.com/academia/tah-portal/new-york-university-618777.html
  - Make sure you get latest version
- Communications Toolbox
  - Very powerful set of tools for simulating communications systems
  - Building blocks for all common parts
  - Channels, modulators, demod, coding, decoding, …
  - Can integrate with Simulink
  - Can even export to HDL for synthesis

OFDM with User-Specified Pilot Indices

This example shows how to construct an orthogonal frequency division modulation (OFDM) n
transmission over a 3x2 channel, pilot indices are created for each of the three transmit anter

Create an OFDM modulator object having five symbols, three transmit antennas, and length s

```
ofdmMod = comm.OFDMModulator('FFTLength',256, ...
    'NumGuardBandCarriers',[12; 11], ...
    'NumSymbols', 5, ...
    'NumTransmitAntennas', 3, ...
    'PilotInputPort',true, ...
    'Windowing', true, ...
    'WindowLength', 6);
```

Specify pilot indices for even and odd symbols for the first transmit antenna.

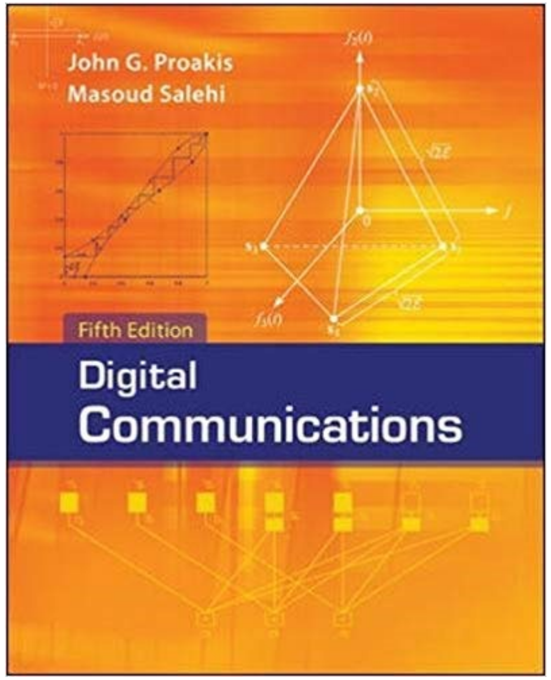
```
pilotIndOdd = [20; 58; 96; 145; 182; 210];
pilotIndEven = [35; 73; 111; 159; 197; 225];

pilotIndicesAnt1 = cat(2, pilotIndOdd, pilotIndEven, pilotIndOdd, ...
    pilotIndEven, pilotIndOdd);
```

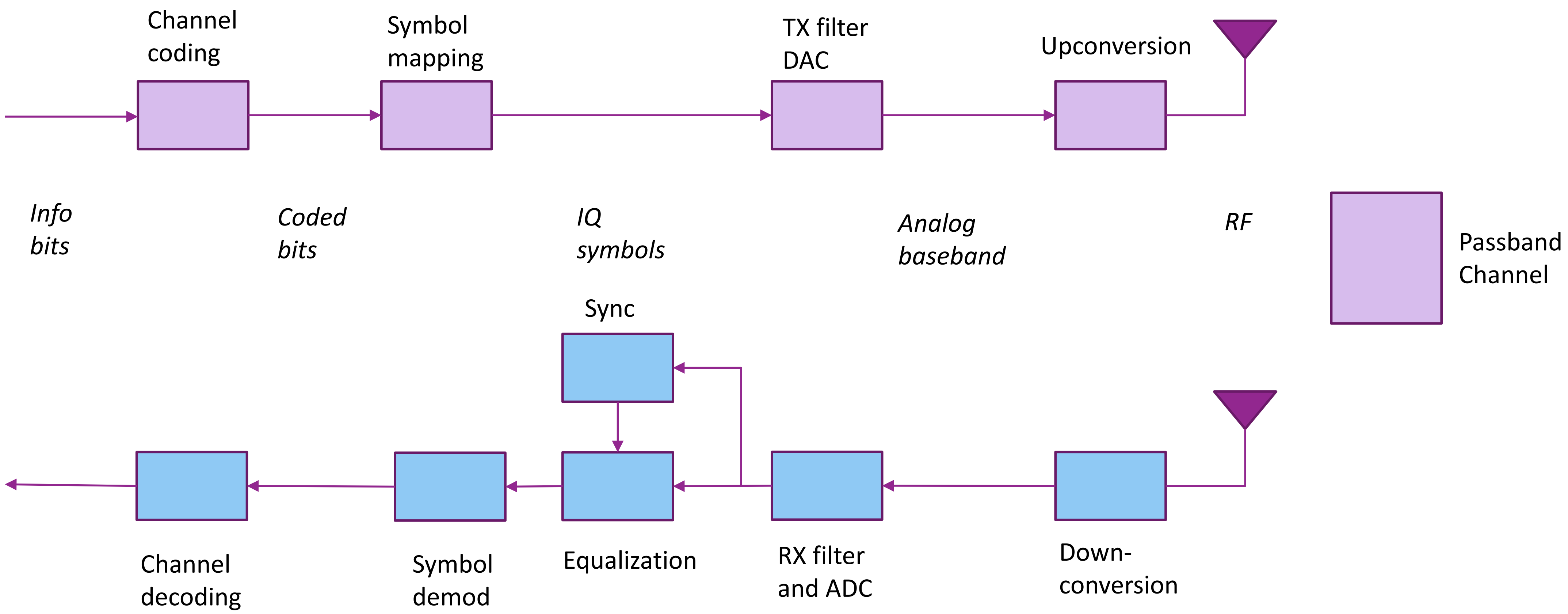
Generate pilot indices for the second and third antennas based on the indices specified for th

Text

- Proakis, Salehi, "Digital Communications"
  - Fifth edition
- Good points:
  - Very comprehensive. Widely-used
  - Lots of problems
- But, extremely abstract
  - I will try to make it more concrete
- It is OK if you have an older version
  - TA will post the questions when we use problems from the book



Class will Follow This Diagram



Tentative Schedule

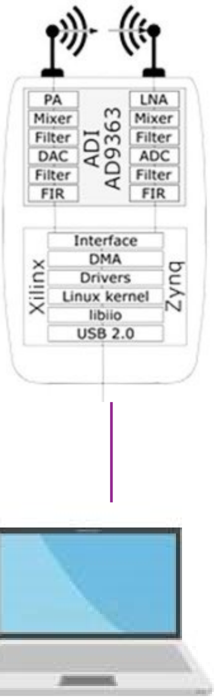
Week	Date	Unit	Topic
1	9/6/2022	1	Introduction. Passband modulation
2	9/13/2022	2	Symbol mapping, TX filtering
3	9/20/2022	3	Receive filtering
4	9/27/2022	4	Signal space theory
5	10/4/2022	5	Random process review
6	10/11/2022	6	Symbol demodulation
7	10/18/2022		Midterm review
8	10/25/2022		Midterm
9	11/1/2022	7	Synchronization, matched filtering
10	11/8/2022	8	Equalization
11	11/15/2022	9	Linear codes
12	11/22/2022		Thanksgiving week. No class
13	11/29/2022	10	Convolutional and turbo codes
14	12/6/2022	11	Information theory
15	12/13/2022		Final exam

Grading

- Grading:
  - 40% homework, labs, 30% midterm, 30% final
- Homework and labs:
  - Written problems
  - MATLAB exercises
  - Software-Defined Radio (SDR) labs (see next slide)
- Exams: Midterm and final are take home
  - ~24 hours to complete
  - Will ask questions on written and MATLAB component

Software-Defined Radio (SDR) Labs

- Based on ADALM-Pluto devices
  - Simple, but powerful
  - Low cost
- Used in non-real-time mode
  - TX and RX signals over the air
  - Analyze offline in MATLAB
- You will learn to implement:
  - Implement up and down-conversion
  - Measure SNR, PSD
  - Synchronization
  - Timing and frequency correction
  - Basic OFDM-based communication link



MATLAB

SDR Github Site

https://github.com/sdrangan/sdrlab

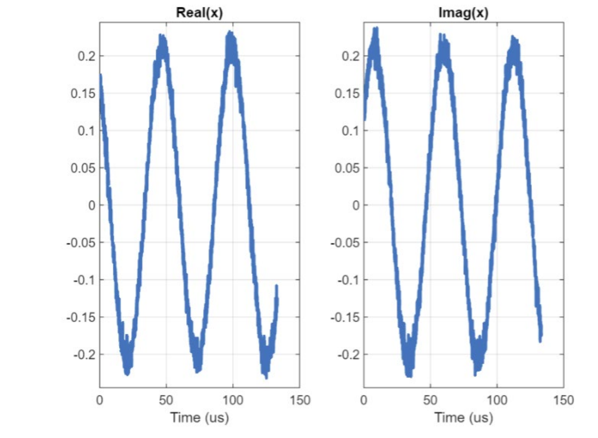
Setting Up and Capturing Samples with the

The ADALM-Pluto is a simple, but powerful software defined radio (SDR)
this first lab, you will learn to:

- Initalize and configure the ADALM-Pluto device
- Connect one or more Pluto devices to the host computer for single
- Transmit complex baseband samples in a repeated loop from a Pl
- Receive a single frame of complex baseband sampes to perform
- Capture multiple frames and detect and visualize overflow

Submissions: Perform the lab in pairs so that you will have two Pluto dev
two hosts). Either way, fill in all sections labeled `TODO`. Print and submit t

- SDR labs are on a second github site
- Contains:
  - Instructions for setting up the labs
  - MATLAB code skeletons
  - Some slides
- Still in progress
  - Will be completed over the course of the semester



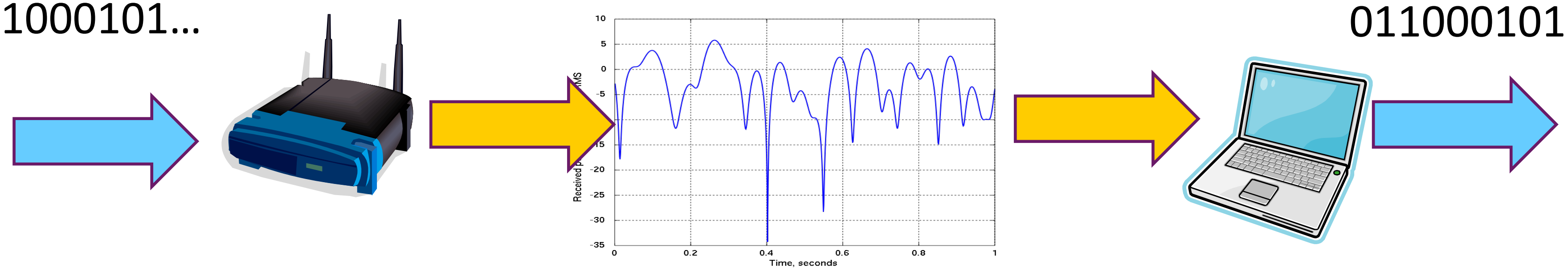
What is Digital Communications?

Transmission of digital data through a channel

Digital data
011000101…

Analog waveform

Digital data
011000101…

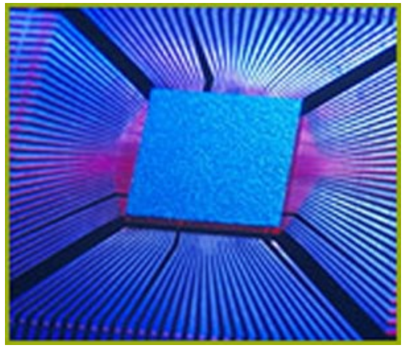


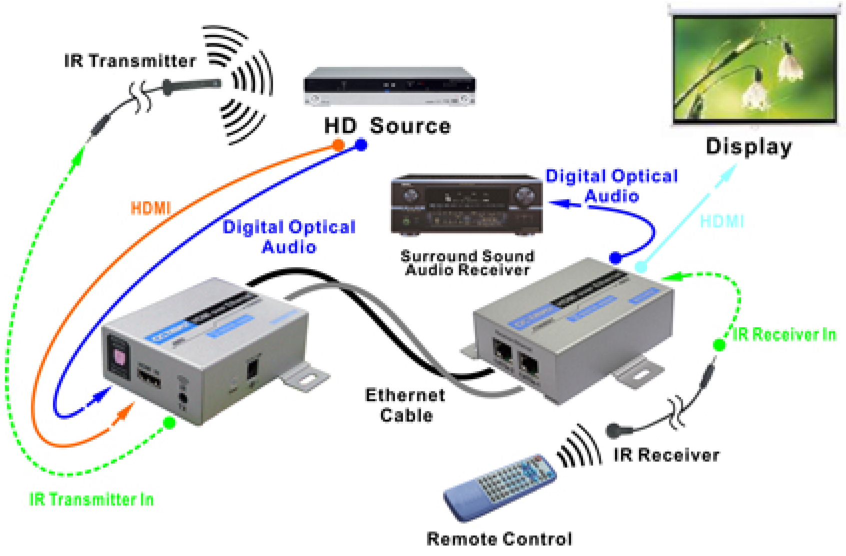
Transmitter

Channel

Receiver

Digital Communications is Everywhere!





- Systems vary with
  - Scales
  - Data rates
  - Channel media,
  - Ranges, …

What do Communications Theorists Do?

- Try to make communication:
  - Reliable,
  - Fast,
  - Cheap, …

- Basic tools in this class:
  - Look at point-to-point links.
  - Model transmission and reception as a statistical estimation problem.
  - Develop mathematical methods for good communication

Course Learning Objectives

- ❑ Mathematically describe the components of a basic communication link
  - Mixing, filtering, symbol modulation, synchronization, equalization, channel coding, …
- ❑ Simulate the system
- ❑ Implement simple systems on software defined radios
- ❑ Mathematical analyze the performance of the system
  - Model impairments in the channel and devices
  - Measure the performance such as bit error rate, power, …
- ❑ Optimize the parameters of the design to maximize various performance metric
  - Account for constraints such as power, complexity, …

Research at NYU WIRELESS

RESEARCH | TERAHERTZ, 5G & BEYOND

Researchers at NYU WIRELESS are at the forefront of beyond 5G technologies, 6G Terahertz networks and devices, software defined networks, quantum sensors and nano devices, position location, and massive broadband applications built on Machine Learning.

Our current research focus areas are: