Course Introduction

ECE-GY 6023: WIRELESS COMMUNICATIONS

PROF. SUNDEEP RANGAN

People and Time

- Professor: Sundeep Rangan, srangan@nyu.edu
  - 370 Jay St.
  - Office Hours: Thursdays, 2-4pm
- TA: TBD
  - Ask for all questions regarding homeworks and labs
- Online lectures: All lectures will be made available on YouTube.
  - Listen to these whenever you like
- Zoom class time: Tuesday 2 to 4:30pm
  - Go over problems and labs
  - Attendance is optional

What is Wireless Communications?

Any communication of information via electromagnetic radio waves without a conductor

Wireless channel

Transmitter

Receiver

Wireless Communications Examples

Smartphones

Cellular base stations

WiFi Access points

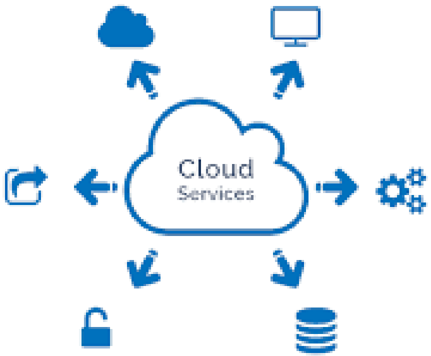
Bluetooth devices

Wireless sensors

Satellite communications

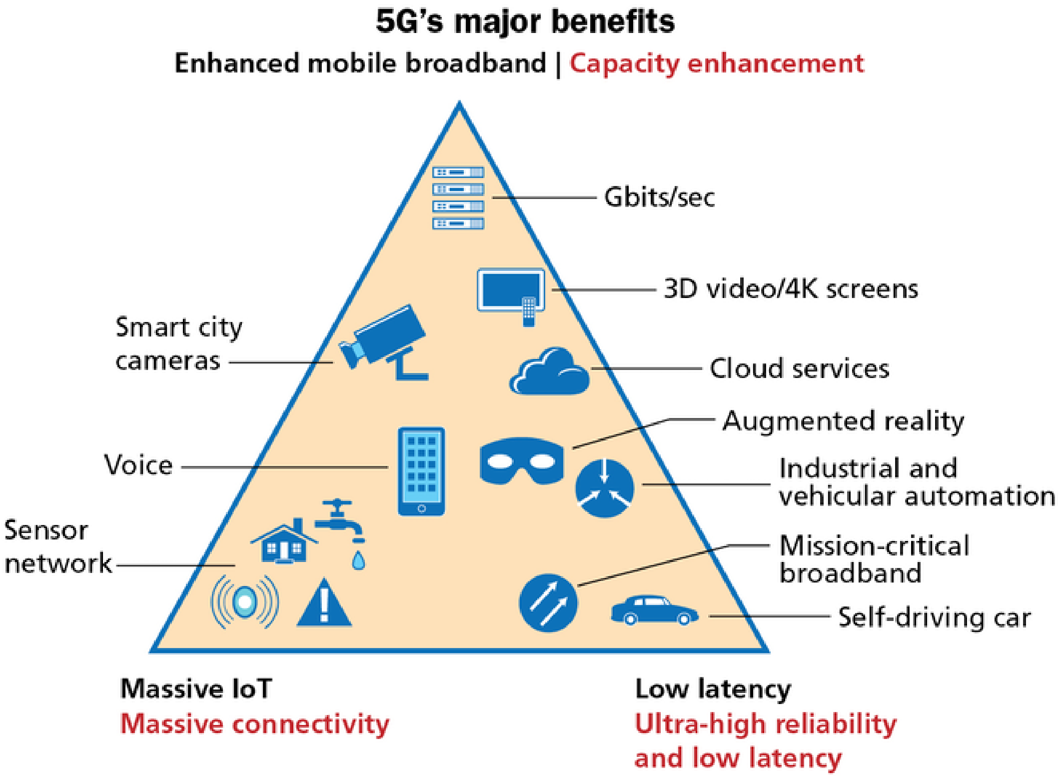
Many New Applications are Coming

- Wireless connectivity can provide:
  - Portability and mobility
  - High data rates or low delay
  - Ubiquitous access to cloud services and data

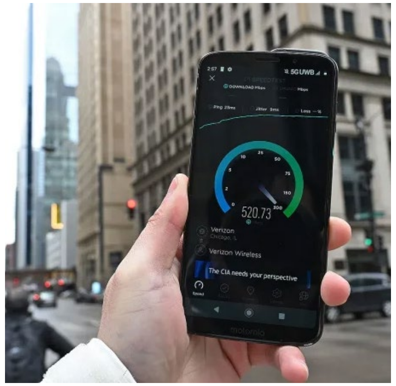


Virtually every electronic device can benefit from wireless connectivity!

5G and Wireless Evolving Today



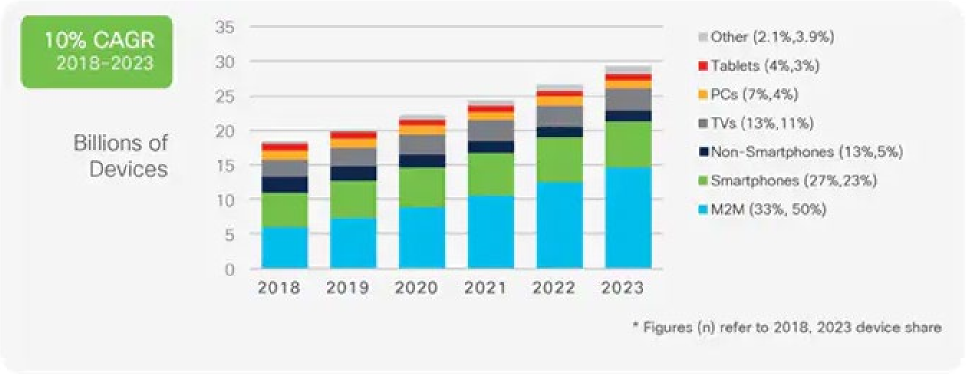
Source: ETSI/3GPP presentation, 2016



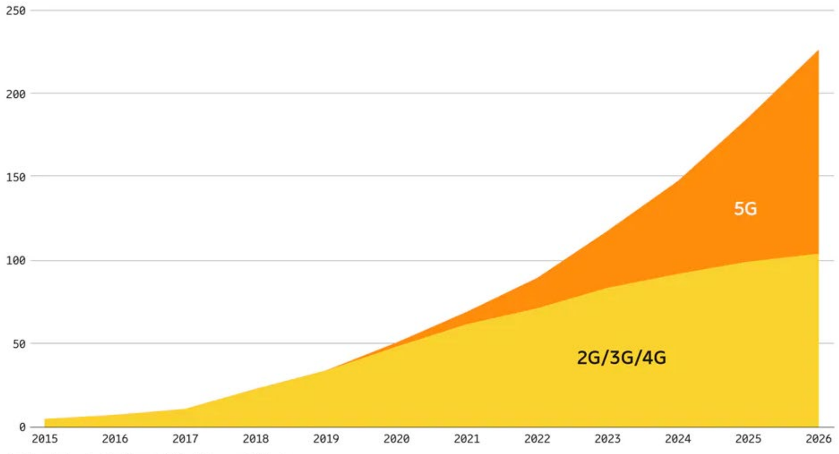
Photos from Sam Rutherford,
[Wind, Sleet, and Dead Zones: My Quest to Map Chicago's Spotty 5G]

Trial results in VZ 5G Chicago network

Wireless Continues to Grow



By 2023: >25 billion wirelessly connected devices
–Cisco Annual Internet Report (2018–2023)



Note: This graph does not include traffic generated by fixed wireless access (FWA) services.

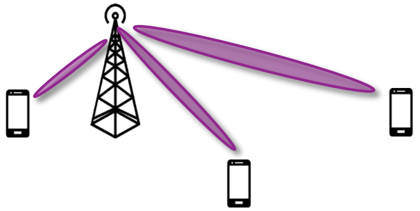
Figure 12: Global mobile data traffic (EB per month)

By 2026:

- 54% of cellular traffic will be 5G
- > 200 EtaBytes / month = 10^6 TB

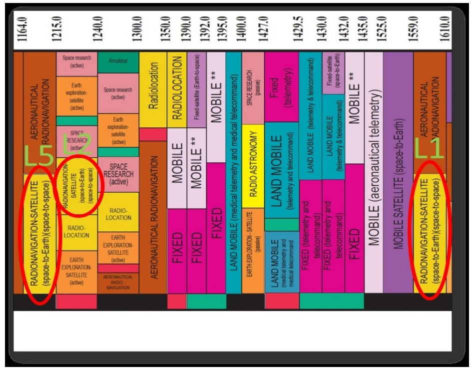
-Ericcson Mobile Data Traffic Outlook

Key Challenges for Wireless



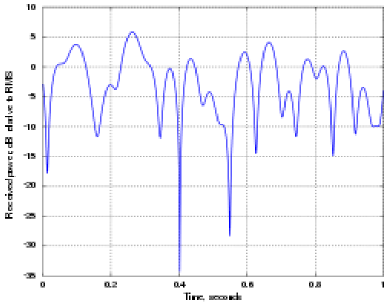
Interference and multiple users

Wireless signals radiate in all directions



Limited spectrum

Licensed and unlicensed communications



Fading and propagation

Signals have limited range

Channel quality fluctuates in time with motion

Power consumption

Limited battery and processing

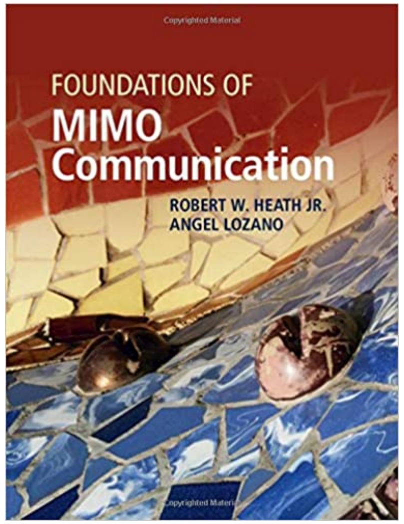
Course Learning Objectives

- Mathematically model and simulate wireless propagation
  - Antennas, EM waves
  - Multipath channels, statistical models, multi-antenna systems
- Simulate and build simple wireless transceivers
  - Filtering, synchronization, equalization, coding, …
  - MAC and network layer protocols
  - Connect it all together for a simple end-to-end system
- Analyze and optimize the system
  - Define and measure key performance metrics
  - Model impairments in the channel and devices
- Describe and analyze commercial wireless systems in use today
  - 4G, 5G cellular systems, WiFi, many others

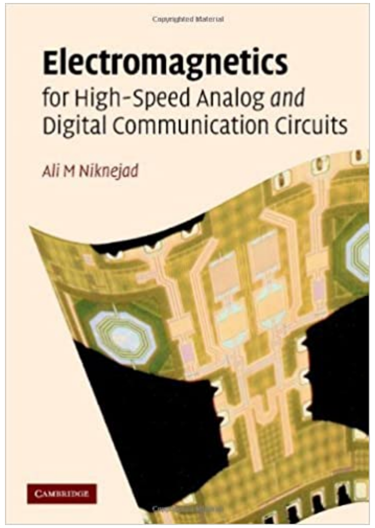
Pre-Requisites

- Graduate-level class intended for MS and PhD students in Electrical Engineering
- Also of interest to:
  - Working engineers in the field
  - Related areas: Robotics or vision
- Graduate probability and digital communications
  - NYU students: ECE-GY 6013 Digital communications
  - Basics of modeling key components: mixing, synchronization, sampling, equalization, channel coding
  - Probability: Random variables and random processes
- Programming:
  - Exercises are in MATLAB and Python
  - Any programming experience is probably suitable

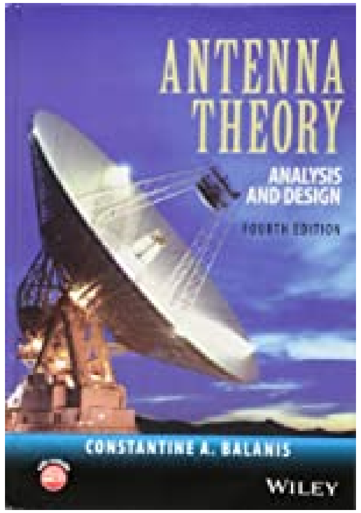
Supplementary Texts



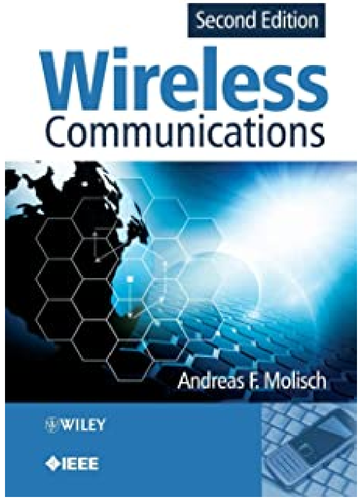
Up-to-date information theoretic perspective



EM from wireless comm perspective.
Great material on high-speed RF



Classic text on antennas



Encyclopedic reference for wireless

- No required text, but there are many good references

GitHub

- All material can be found on GitHub: https://github.com/sdrangan/wirelesscomm
  - Lecture slides
  - Links to lecture videos
  - In-class MATLAB exercises
  - Problems and labs
- Clone this repository
- Pull to get latest material
- Solutions to problems and labs:
  - Given to NYU students enrolled in class

ECE-GY 6023. Introduction to Wireless Communications

This repository is currently a collection of lecture material for ECE-GY 6023 Introduction to Wireless Communications at NYU taught by Prof. Sundeep Rangan. The class is intended to be for MS and PhD students in Electrical Engineering. Right now, only a small amount of material is available, but we are hoping to add more over the course of the semester.

Pre-requisites

The course assumes you are familiar with digital communications at the graduate level. There are many resources for digital communications, including some lecture notes I created for the NYU class.

Additionally, some lecture notes (and problems to be added later) assume you have access to MATLAB along with the communications, phased array and antenna toolboxes.

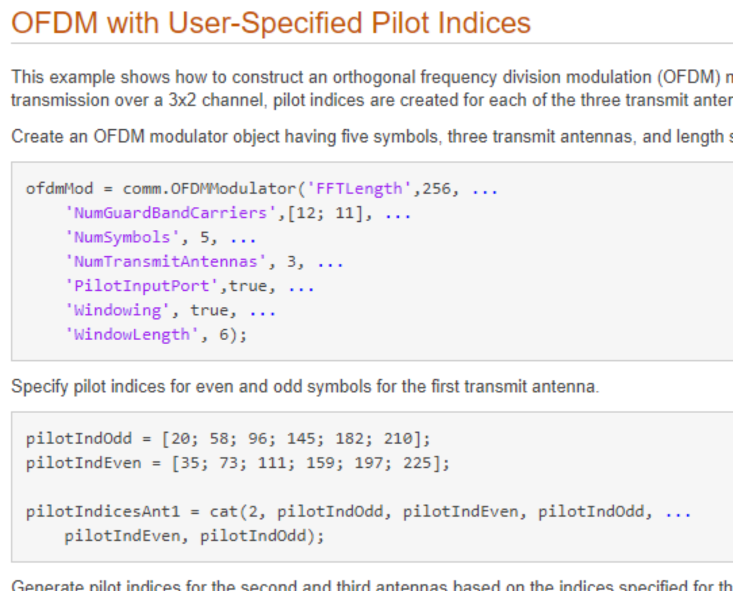
Lecture Sequence

The tentative plan for the lectures are below. Right now, only a few lectures have full material. We will be hoping to add to this material over the course of the semester. Other topics may be added at the end depending on time.

- Course Introduction
- Unit 1. Basics of Antennas and Free-space Propagation
  - Lecture: [PDF] [PPT]
  - Demo: Calculating and displaying antenna patterns [PDF] [Matlab]
  - Problems: [PDF] [Latex]
  - Lab: Simulating a 28 GHz antenna for a UAV [PDF] [Matlab]

MATLAB

- Most labs, demos and in-class exercises will be in MATLAB
  - Some parts may also use Python
- Download the latest MATLAB
- NYU students can get this for free:
  - https://www.mathworks.com/academia/tah-portal/new-york-university-618777.html
  - Make sure you get R2020B (Latest version)
- Communications, Antenna and Phased Array Toolboxes
  - Very powerful set of tools for simulating wireless systems
  - Building blocks for all common parts
  - Antennas, phased arrays
  - 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

MATLAB Live Editor

- Some course material MATLAB Live Editor
  - Will be used for in-class exercises, some labs
- Similar to Pyhton jupyter notebook
  - All code and text cells
  - Rich content and links
  - But you need to view them in MATLAB IDE
  - Cannot view in browser

Antenna and Free-Space Propagation In-Class Exercises

These exercises follow the lectures and are to be done at the end of each section.

Problem 1: Computing Wavelength and E-Field Amplitude

Suppose that an EM-plane wave:

- Power flux density is 1 nW/m^2
- Freq = 2.3 GHz

Print the:

- Maximum E-field value
- Wavelength. You may use the `physconst('Lightspeed')` command to get the speed of light.

Make sure you print the units.

```
% TODO
```

Grading

- Grading:
  - 40% homework and labs
  - 30% midterm, 30% final

- Exams: Midterm and final will be given remotely
  - May use any material in the class or Internet
  - Just cannot talk to a friend