RADIO SYSTEMS – ETIN15

Lecture no: 1

Introduction

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Contents

- Course information
- What is a radio system?
- Some concepts

COURSE INFORMATION

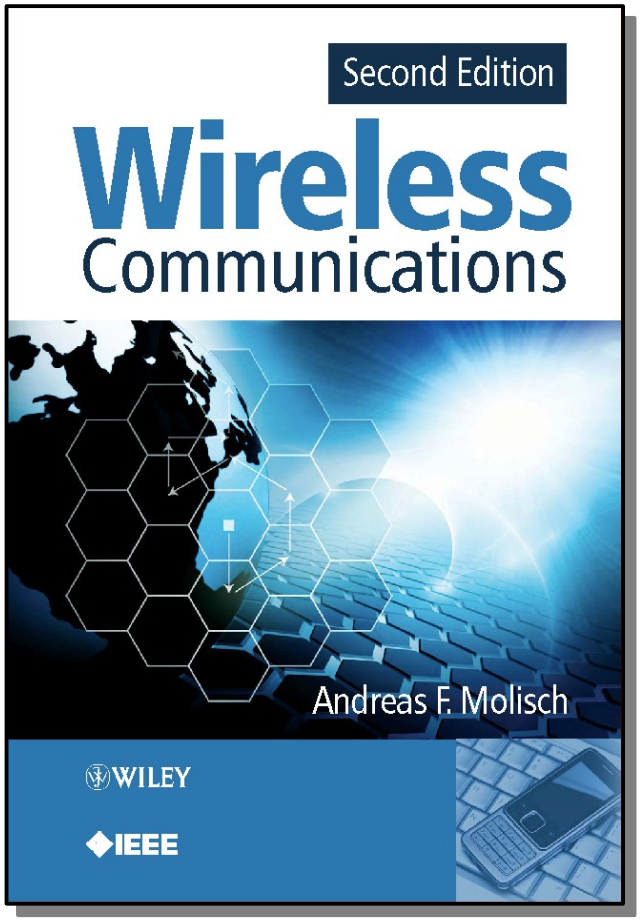
Course web-site

- All course information is available at:

  http://www.eit.lth.se/course/ETIN15

- Most important:
  - Continuously updated schedule
  - Lecture handouts (available before each lecture)
  - Exercises
  - Any additional material

Textbook



- Published by Wiley/IEEE, Press, 2nd ed. Nov 2010.
- Available through most on-line web book stores
- Same book as in the Channel Modelling course (ETIN10)
- Authored by Andreas F. Molisch, former professor of Radio Systems at Lund University/LTH.

Schedule

- Three recurring components
  - **Lectures**: [Ove Edfors]
    Two lectures per week.
    Often Mondays and Wednesdays, but this changes at the end of the course.
  - **Exercise classes**: [Jose Flordelis]
    One exercise class per week.
    Often on Fridays, but not every week.

    SEE DETAILED SCHEDULE ON COURSE HOME PAGE!

- Examination
  - **Student presentations**:
    At the end of the course
  - **Written exam**:
    Monday, June 2, 08.00-13.00

Problems with the schedule?!

- Collisions between this and other courses (lectures & exercises)?

- Moving Lectures/Exercise classes around at the end:
  - Lecture Mon May 11 → Exercise class
  - Exercise Class Wed May 13 → Lecture
  - Lecture Mon May 18 → Exercise class
  - Exercise Class Fri May 22 → Lecture

OK?

Lectures

- Overview of the contents in the textbook
- Additional material
- Application examples

Exercise classes

- Exercises from the textbook + sometimes extra exercises published on course web page
- During exercise classes, some of the exercises will be analysed in detail
- By working through the exercises beforehand, you can give valuable input on which exercises to focus on during classes

Reading and presenting a journal paper

- During the course you will read and give a short presentation of a recent (scientific) journal paper in the area.
- Performed in groups of TWO or THREE students.
- Propose your own topic/paper or select from a list of suitable papers.
- Presentations (about 10 minutes each) will be done at the end of the course.

- **THIS IS A COMPULSORY PART OF THE COURSE!**
  - ✓ **Participate in a group that reads and presents a paper.**
  - ✓ **Attend the presentations given by other students.**

Written exam

- How?
  - **Total of 5 hours**
  - **Part A**: 1.5 hours – closed book questions (15 points)
  - **Part B**: 3.5 hours – open book problems (15 points)

- When?
  Tuersday, Jun 2, 08.00-13.00

Here you can also bring a mathematical handbook and (clean!) hard copies of lecture slides.

WHAT IS A RADIO SYSTEM?

Radio system?

- From Merriam-Webster Dictionary
  - Radio:
    1 : of, relating to, or operated by radiant energy
    2 : of or relating to electric currents or phenomena (as electromagnetic radiation) of frequencies between about 15 kHz and 100 GHz
  - System:
    1 : a regularly interacting or interdependent group of items forming a unified whole
- ”Radio systems” can be used for many purposes, e.g.
  - Detection and ranging (Radar)
  - Astronomical observation (Radio telescope)
  - Heating food (Microwave oven)
  - Navigation (GPS, etc.)
  - Communication (Cellular telephony, etc.)

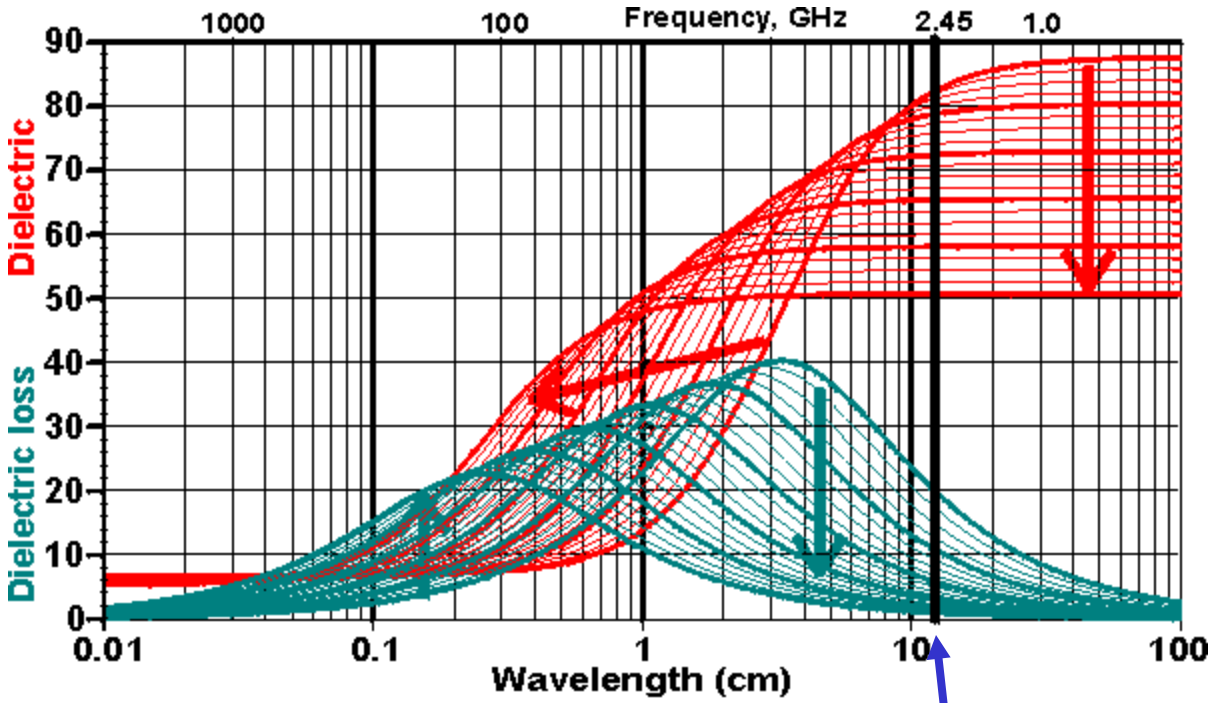
Some questions to ask

- What do we want to achieve with our system?
  - This gives us design constraints (system requirements)
- What frequency band should we use?
  - Properties of the radio channel changes with frequency
  - Radio spectrum is firmly regulated
- Which technology should we use?
  - Not all technologies can perform the task
  - Cost is important (design, production, deployment, etc.)

Example: Microwave oven

Why is 2.45 GHz used?

Dielectric permittivity and dielectric loss of water between 0°C and 100°C



Most absorbtion here

Microwave oven here

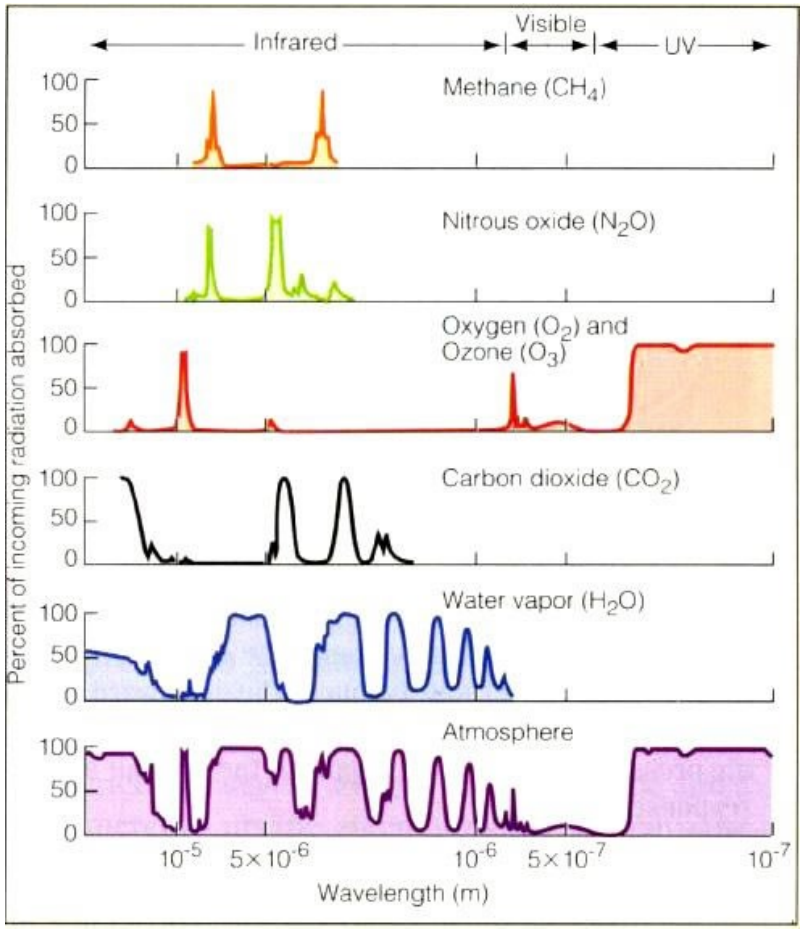
Graph from www.sbu.ac.uk/water/ microwave.html

Example: Human eye

Why is the human eye sensitive at the electromagnetic wavelengths (frequency band) we call visible light?

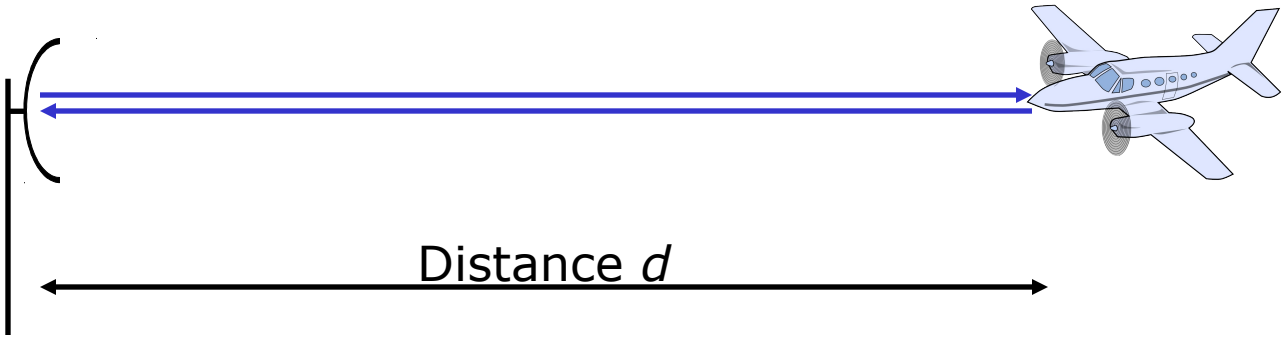
Is it a coincidence or a clever adaption?

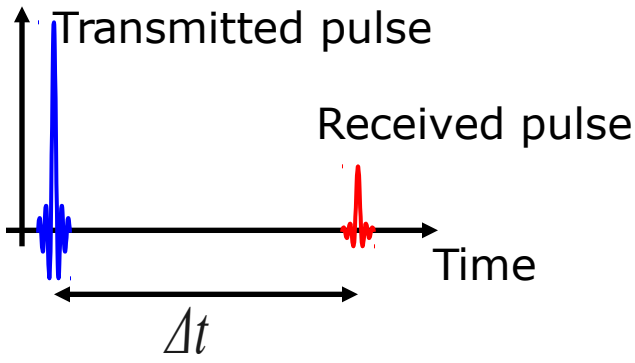
(This is not radio waves, but it illustrates the importance of the used frequency band.)



Graph from http://earth.usc.edu/geol150/weather/

Example: Radar





Calculation of distance

$$d = \frac{c \times \Delta t}{2} = \frac{3 \times 10^8 \times \Delta t}{2}$$

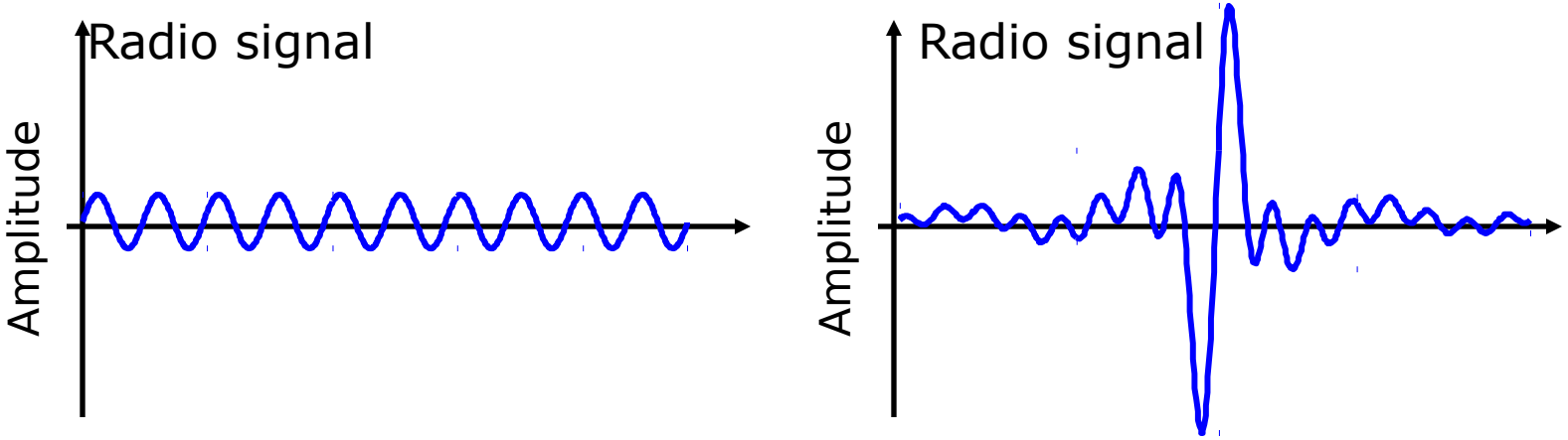
The accuracy of our ”measured” time delay determines the accuracy of the ”measured” distance.

Does this have any influence on the bandwidth requirement?

Example: Mobile telephony

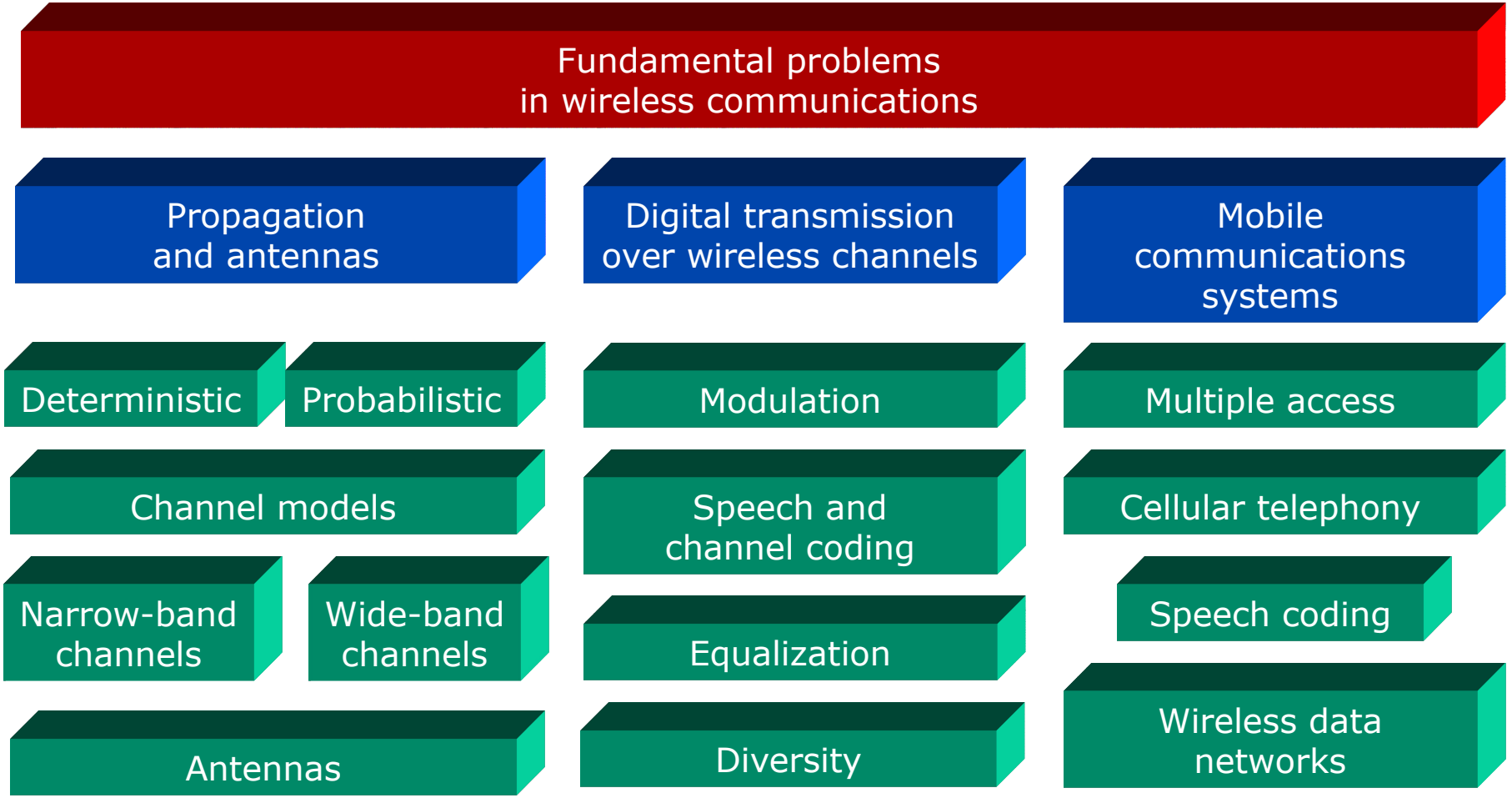
Amplifiers with low dynamic range can be made more power efficient than highly linear amplifiers.

Does this affect the choice of modulation technique?

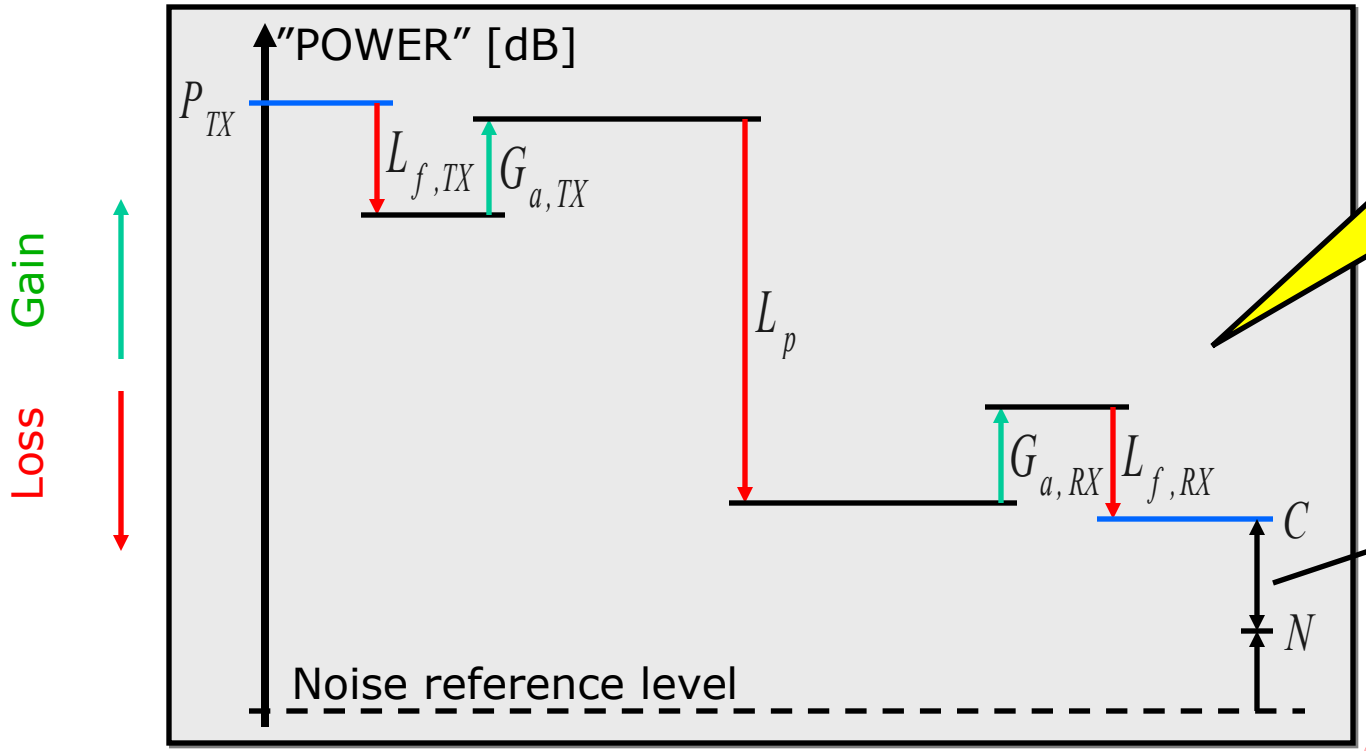


SOME CONCEPTS

A rough breakdown into areas

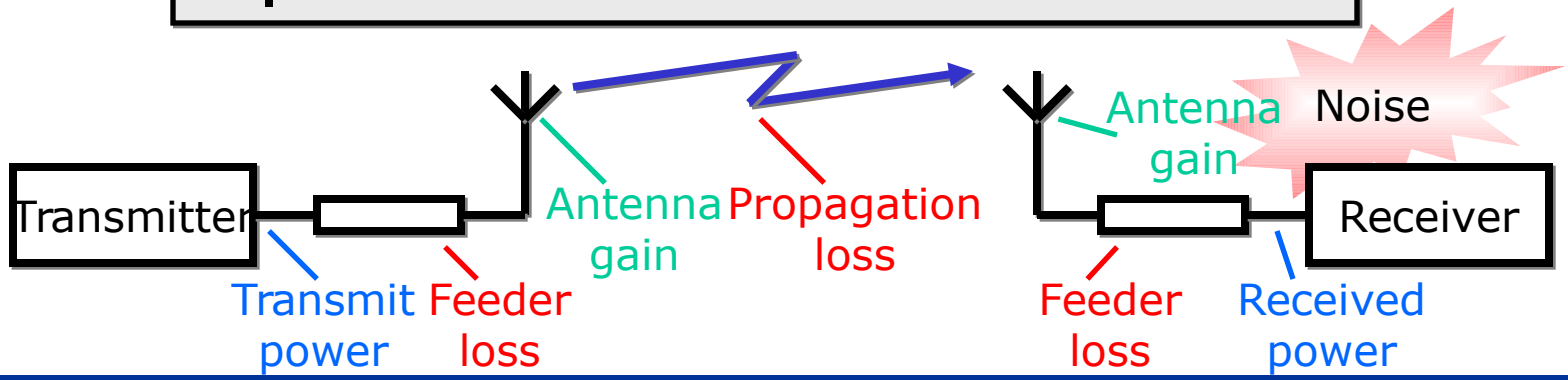


SINGLE LINK
Link budget – a central concept



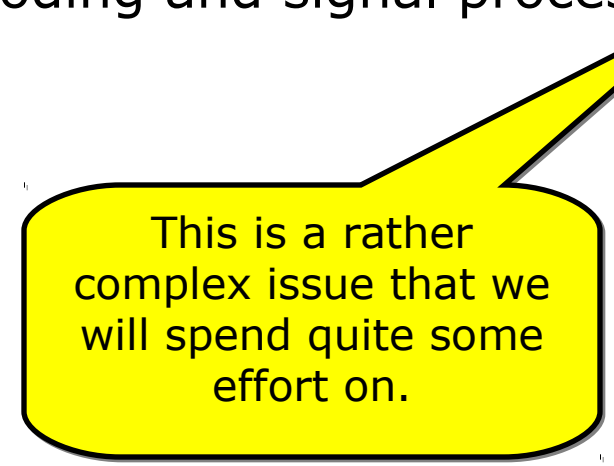
This is a simple version of the link budget.

CRITERION TO MEET:
Required C/N at receiver input

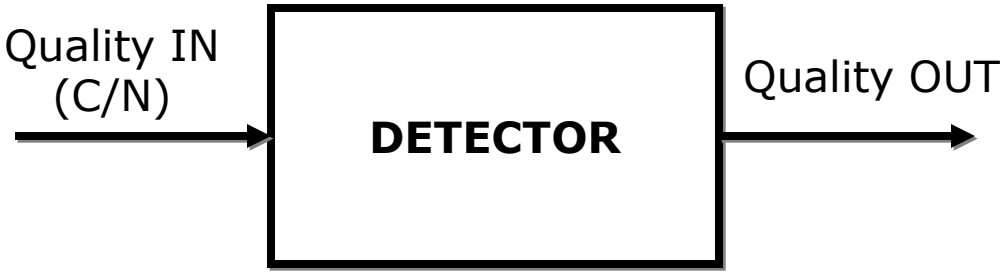


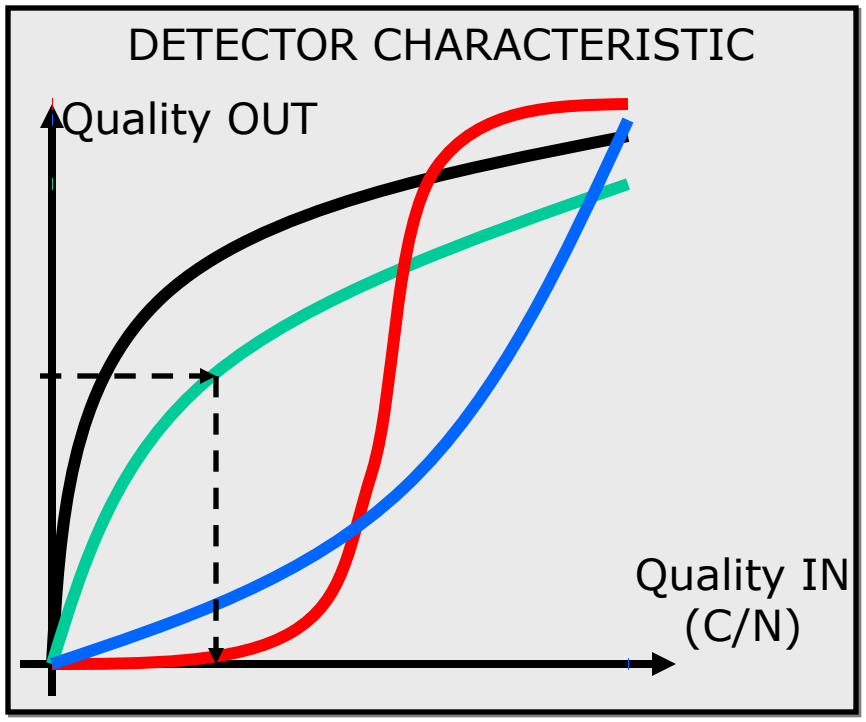
SINGLE LINK
Link budget – depends on what?

- Some examples:
  - Regulations (transmit power, etc.)
  - Antenna placement (feeder loss)
  - Antenna type and quality (antenna gain)
  - Frequency band and environment (propagation loss)
  - Receiver design (noise power)
  - Modulation, coding and signal processing (required C/N)



SINGLE LINK
Required C/N – a central concept





The detector characteristic is different for different system design choices.

REQUIRED QUALITY OUT:

Audio SNR
Perceptive audio quality
Bit-error rate
Packet-error rate
etc.

SINGLE LINK
Required C/N – depends on?

- The most important:
  - Required output quality

This one is usually determined by the application

- ... then, through the detector characteristic:
  - Signal constellation
  - Modulation type
  - Error-correcting codes
  - Equalization
  - Antenna processing
  - Synchronization
  - etc.

All these will have to be chosen in a system design process

THE RADIO CHANNEL
Some properties

- Path loss

  Roughly, received power decays with some exponent of distance

$$\text{Received power} \propto \text{Transmitted power} \times \text{Distance}^{-\text{Propagation exponent}}$$

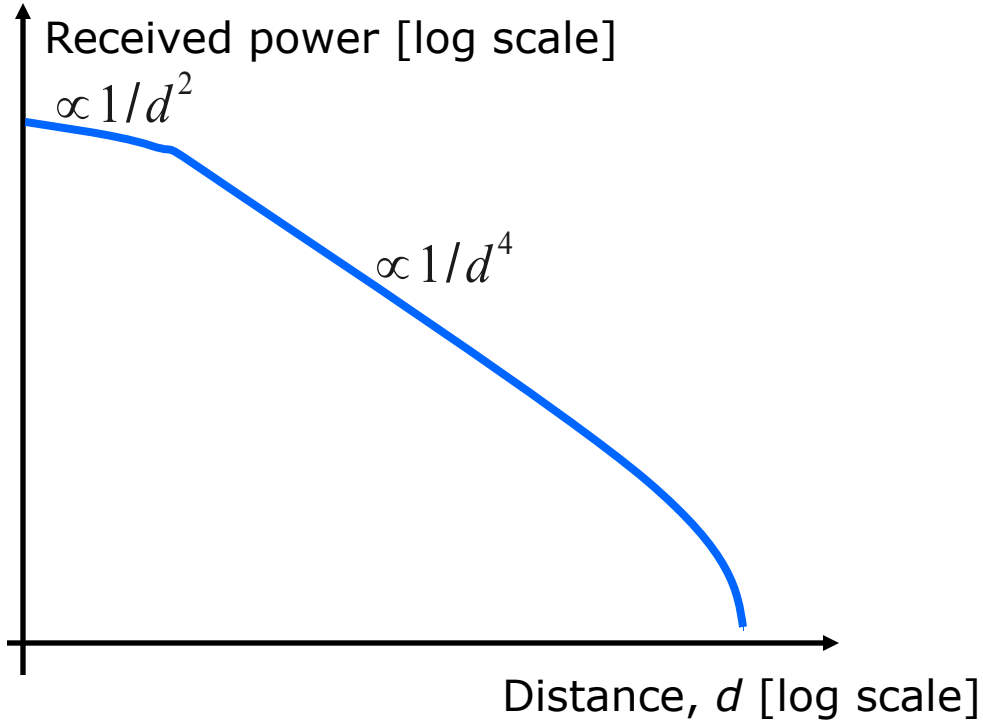
- Large-scale fading

  Large objects, compared to a wavelength, in the signal path obstruct the signal

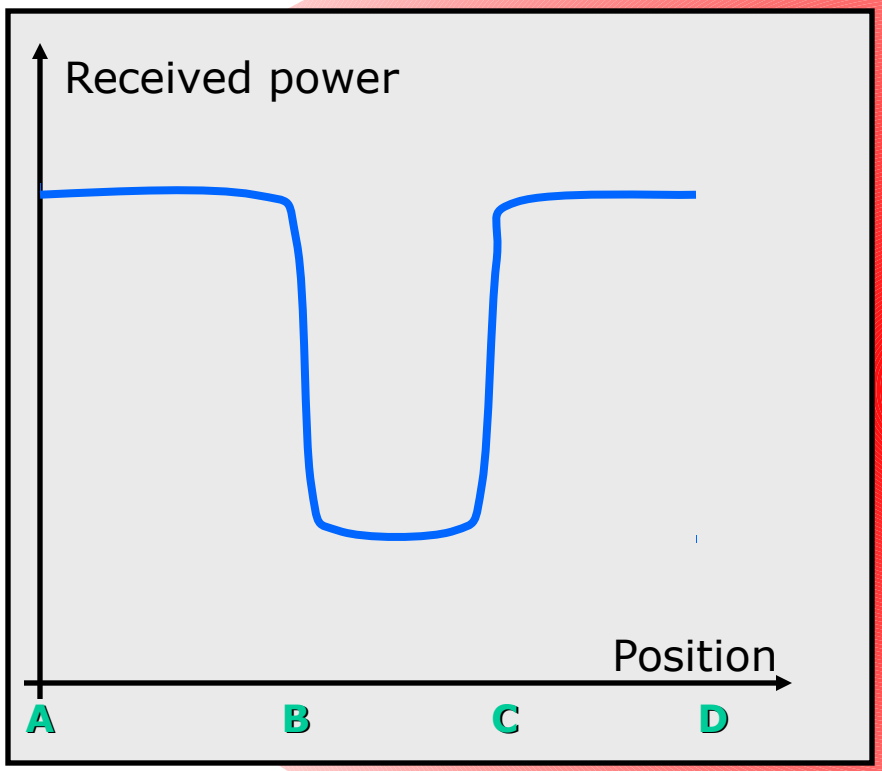
- Small-scale fading

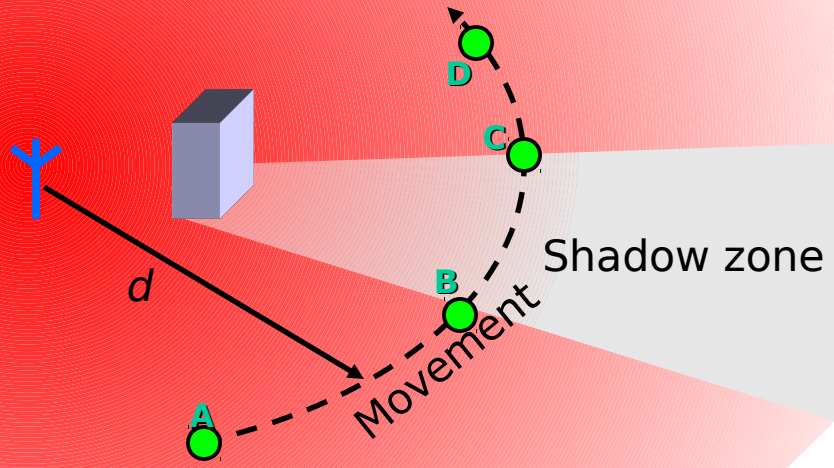
  Objects reflecting the signal causes multipath propagation from transmitter to receiver

THE RADIO CHANNEL
Path loss

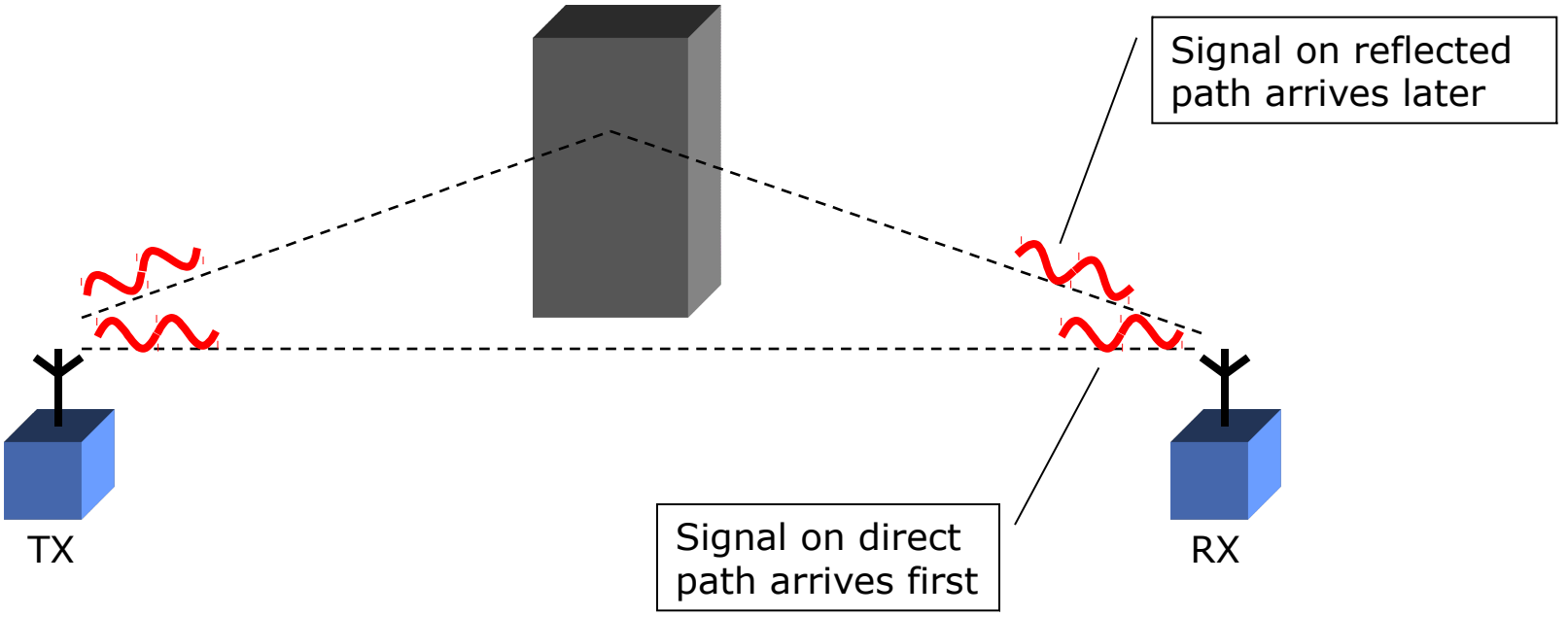


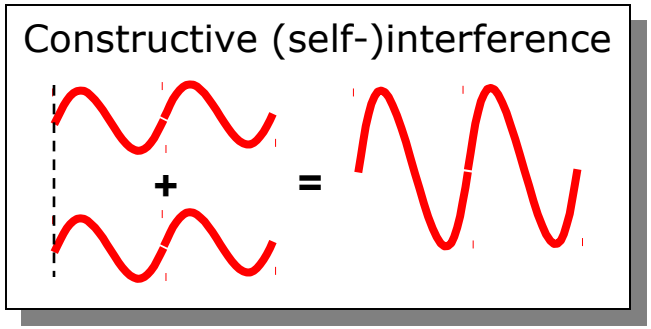
THE RADIO CHANNEL
Large-scale fading

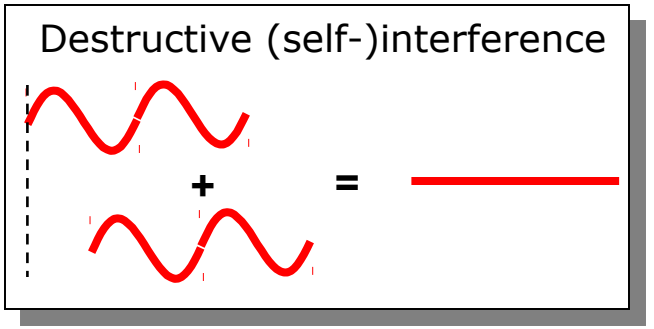




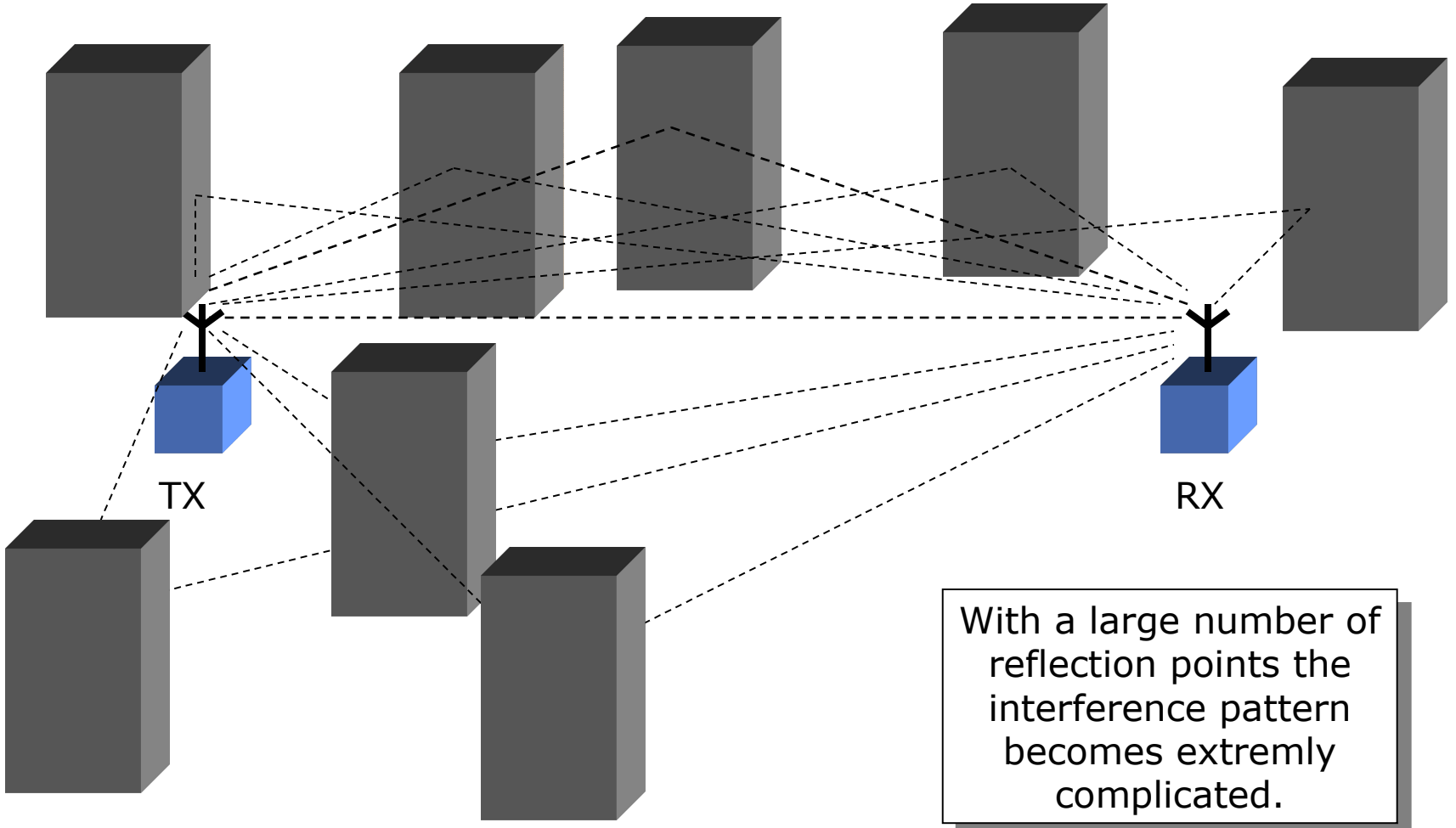
THE RADIO CHANNEL
Small-scale fading







THE RADIO CHANNEL
Small-scale fading (cont.)



With a large number of reflection points the interference pattern becomes extremly complicated.

THE RADIO CHANNEL
Small-scale fading (cont.)

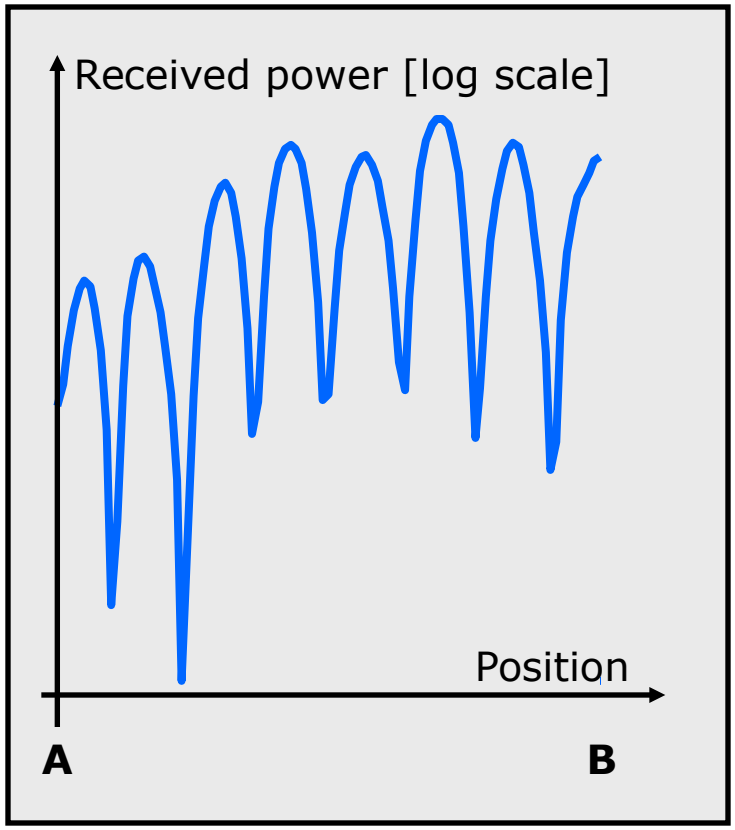
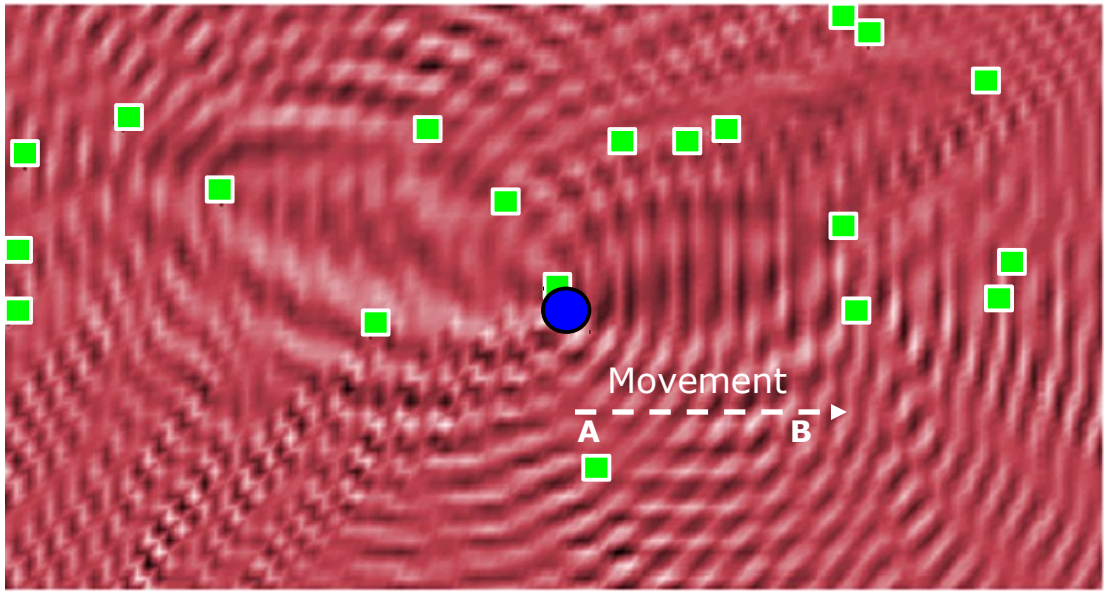


Illustration of interference pattern from above



Transmitter

Reflector

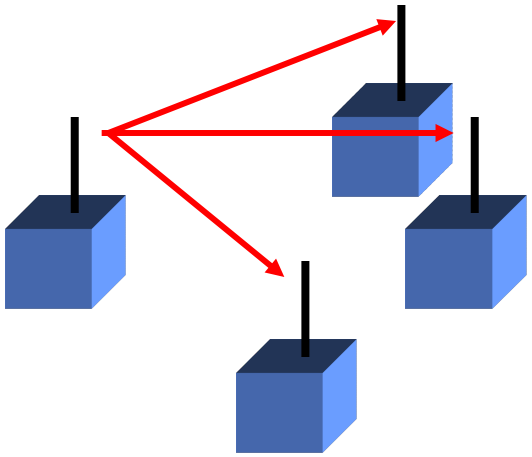
MULTIPLE LINKS
Conceptual changes (cf. single link)

- The same ”radio spectrum” resource has to be shared
  - Multiple access schemes
  - Access schemes have different properties

- Interference becomes a major design issue
  - Interference can become a much bigger issue than noise
  - Even these cases can cause significant interference:
    - A close transmitter on a different channel
    - A distant transmitter on the same channel
  - Network planning to minimize effects of interference

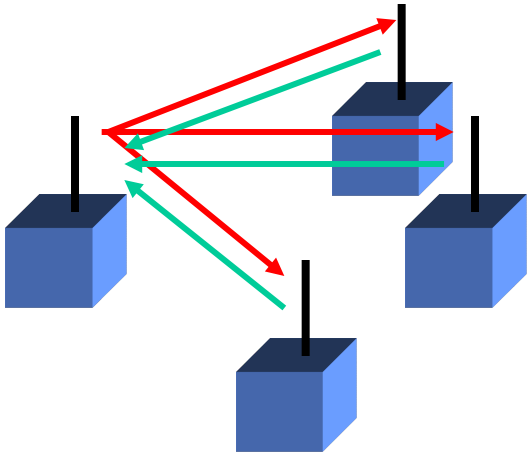
DUPLEX AND MULTIPLE ACCESS
Overview

Garage openers, car alarm, ...



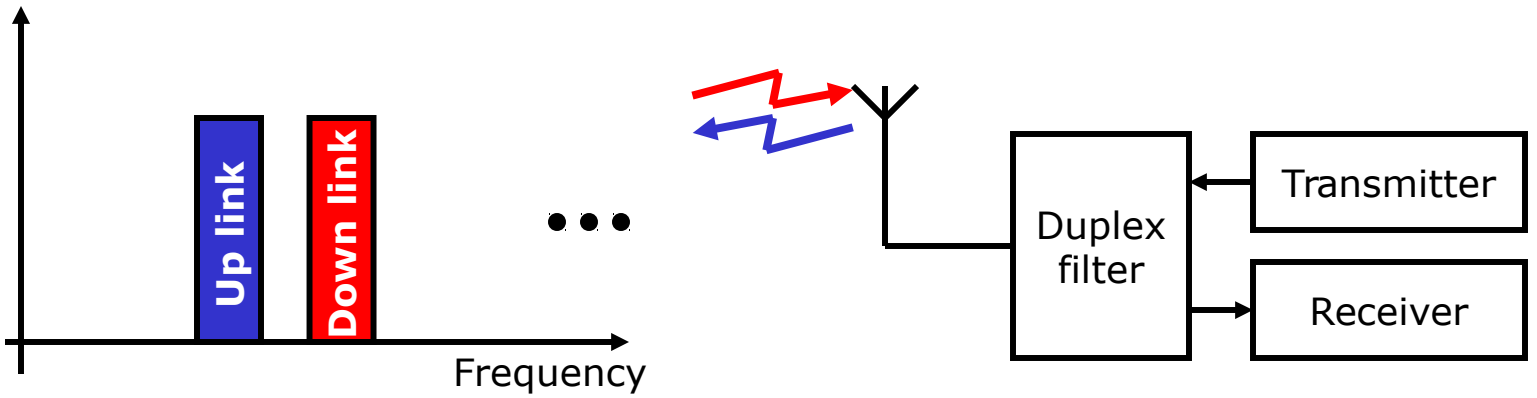
Audio and video broadcasting, paging, ...

Microwave links, ...



Mobile telephony, wireless LAN, ...

DUPLEX
Frequency-division Duplex (FDD)

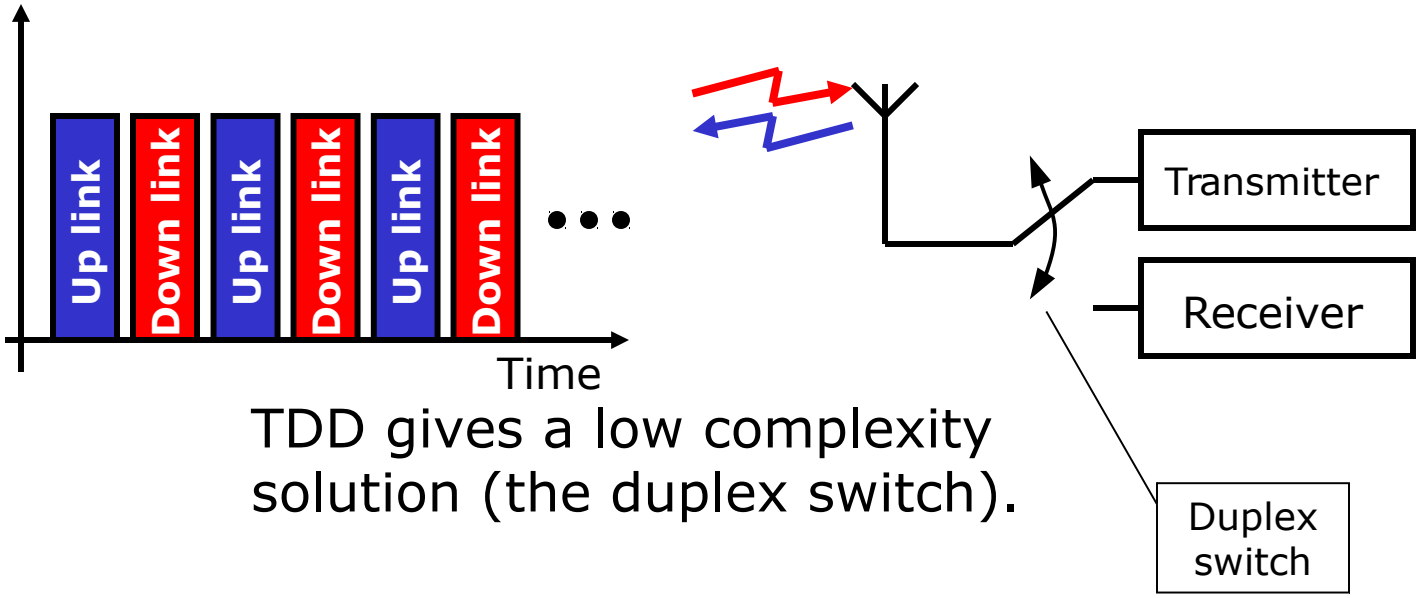


FDD gives a more complex solution (the duplex filter).

Can be used for continuous transmission.

Examples: Nodic Mobile Telephony (NMT), Global System for Mobile communications (GSM), Wideband CDMA (WCDMA), Long Term Evolution (LTE)

DUPLEX
Time-division duplex (TDD)

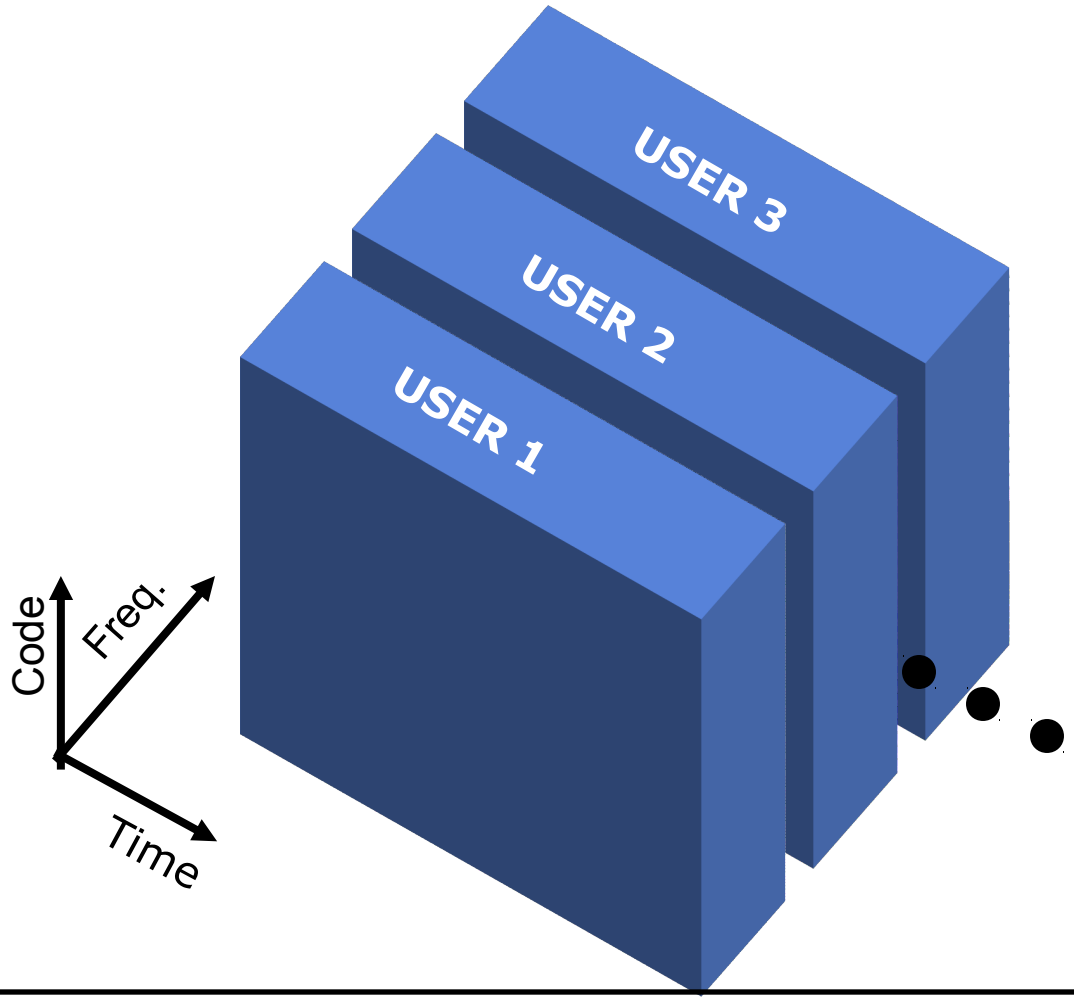


TDD gives a low complexity solution (the duplex switch).

Cannot be used for continuous transmission.

Examples: Global System for Mobile communications (GSM), Wideband CDMA (WCDMA)

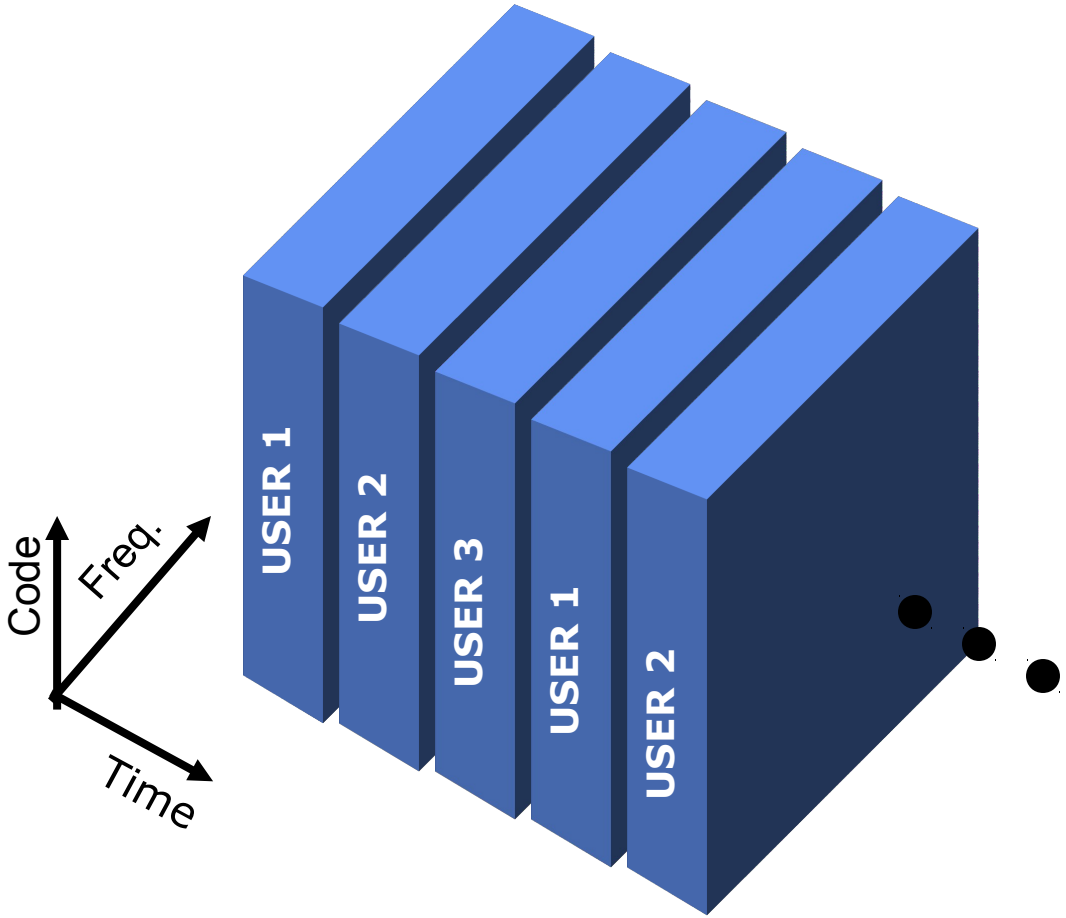
MULTIPLE ACCESS
Freq.-division multiple access (FDMA)



Users are separated in frequency bands.

Examples: Nordic Mobile Telephony (NMT), Advanced Mobile Phone System (AMPS)

MULTIPLE ACCESS
Time-division multiple access (TDMA)

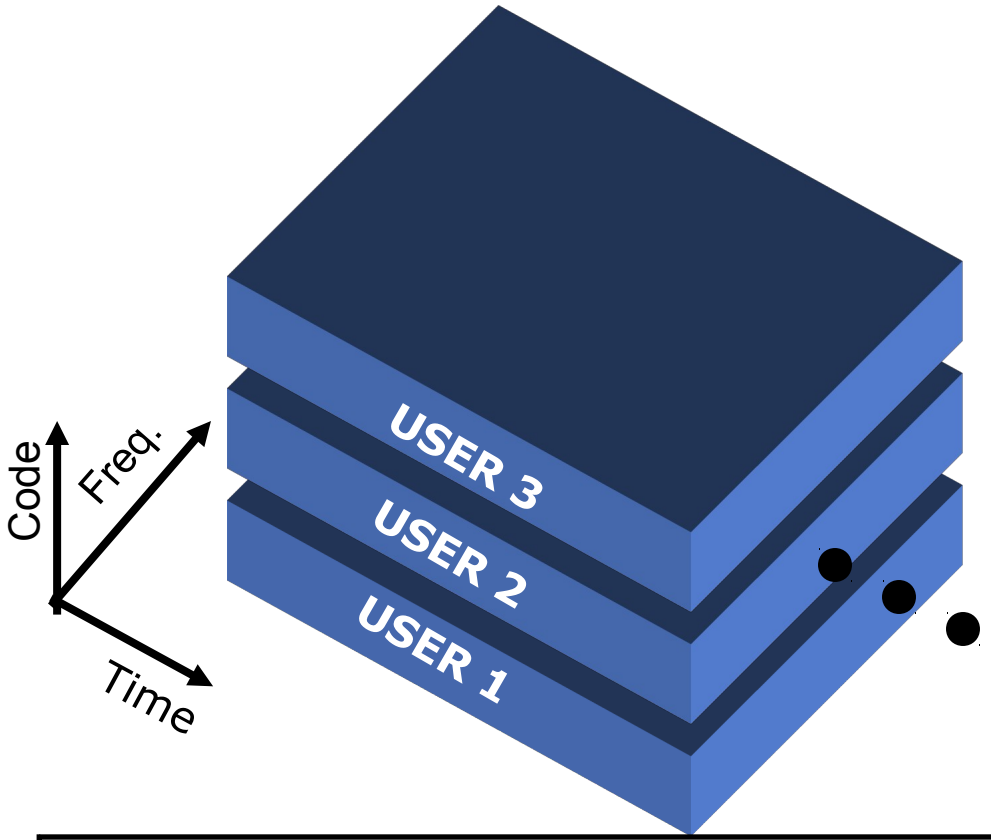


Users are separated in time slots.

Example: Global System for Mobile communications (GSM)

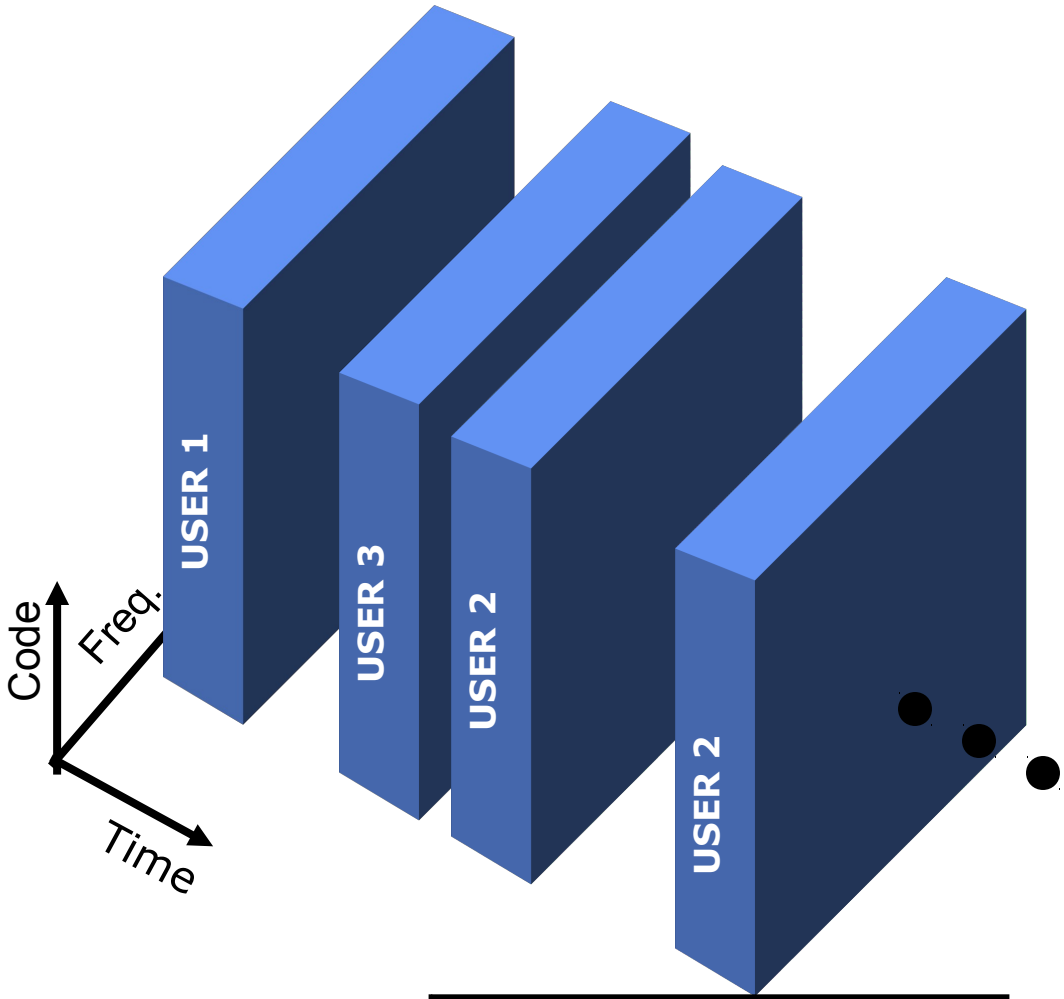
MULTIPLE ACCESS
Code-division multiple access (CDMA)

Users are separated by spreading codes.



Examples: CdmaOne, Wideband CDMA (WCDMA), Cdma2000

MULTIPLE ACCESS
Carrier-sense multiple access (CSMA)

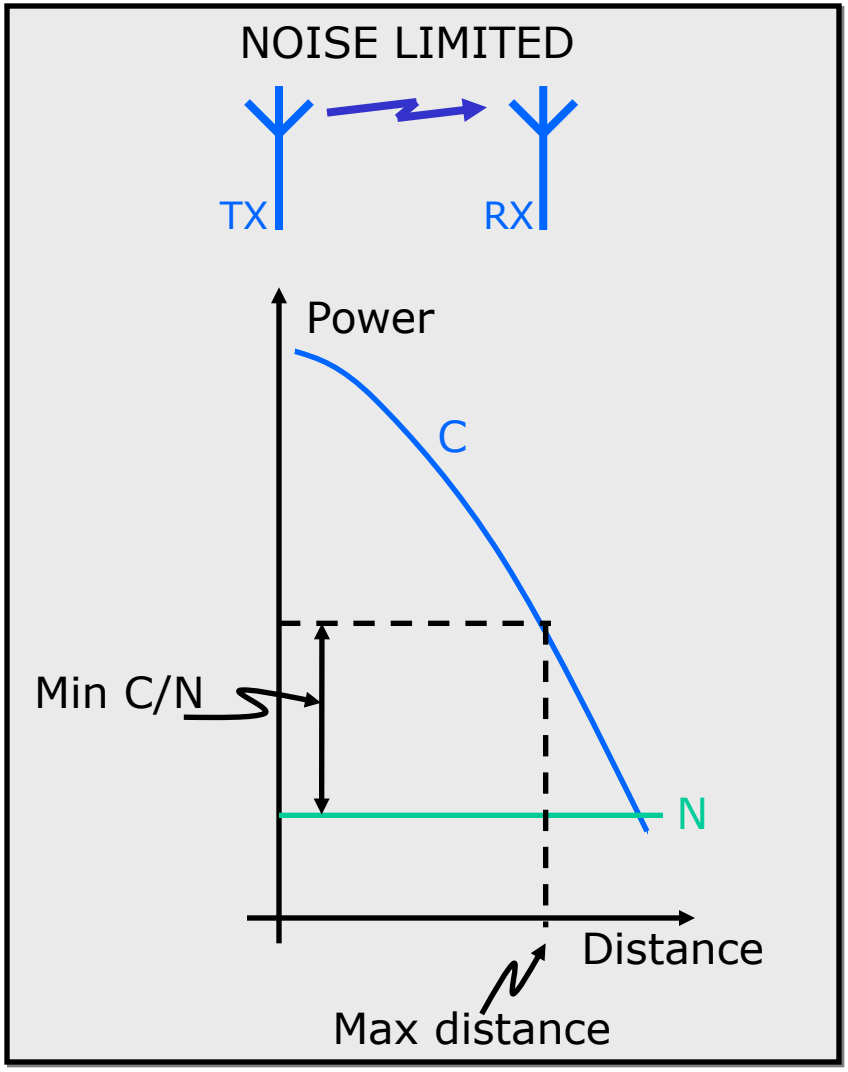


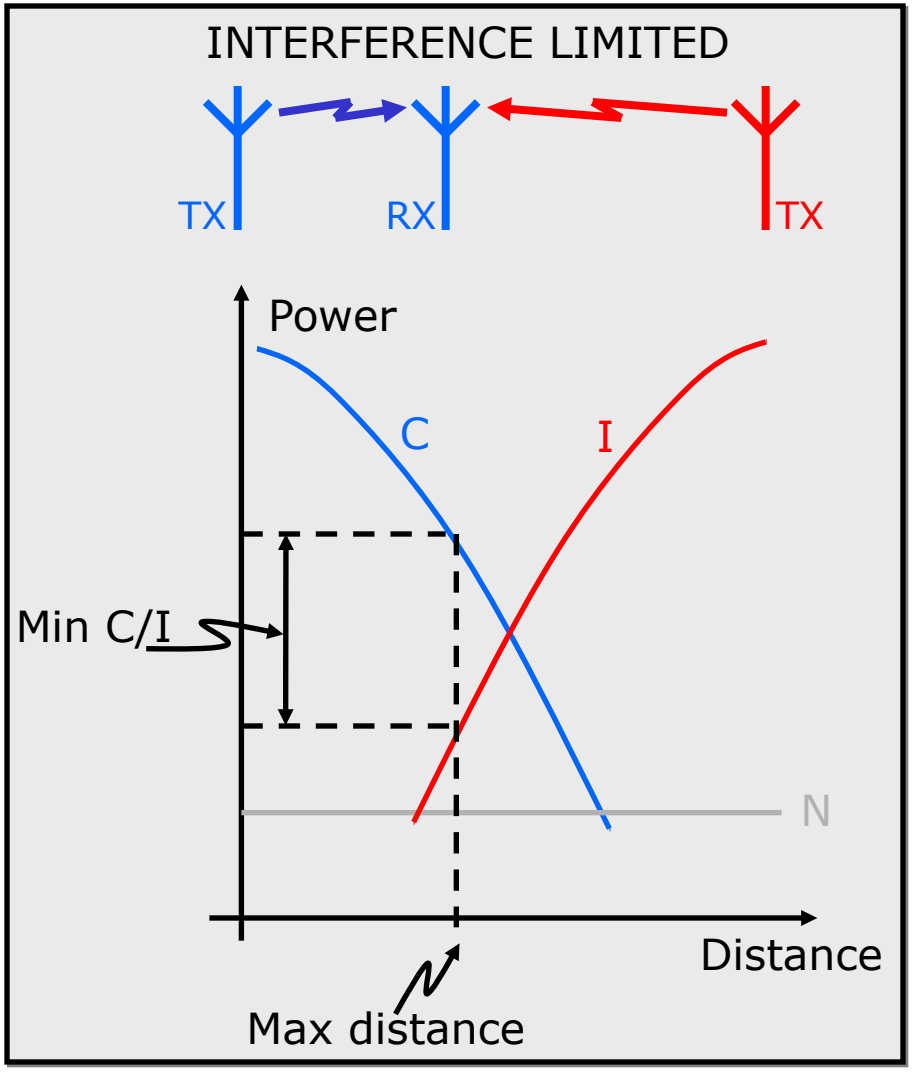
Example: IEEE 802.11 (WLAN)

Users are separated in time but not in an organized way. The terminal listens to the channel, and transmits a packet if it's free.

Collissions can occur and data is lost.

LINK LIMITATIONS
Noise and interference limited links





Summary

- Reading and presenting a **journal paper** – compulsory!
  - Start thinking about a subject you would like to study
- The **link budget** concept
- The **detector characteristic** concept
- Overview on propagation: **Path loss**, **large-** and **small-scale fading**
- Duplex schemes: **FDD** and **TDD**
- Multiple access: **FDMA**, **TDMA**, **CDMA** and **CSMA**
- Link limitations: **Noise-limited** and **interference-limited**