EITN75

Design of wireless systems

Welcome!

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  - Course responsible
  - Lecturer
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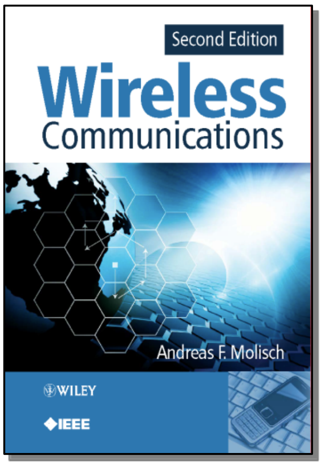
  - Mark email with subject starting with: EITN75
- Christian Nelson
  - Exercises

Course in short

- Lectures
  - Guest lecture 16 April
    - Liesbet Van der Perre, KU Leuven, Belgium
- Exercises
- Laboration
  - Done at home
  - 2 students per report/system
  - Analyze (reverse engineer) an existing or proposed link
- Exam
  - Gives grade (3-5)

Book: Wireless Communications



- Published by Wiley/IEEE, Press, 2^{nd} 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.

Exercises

- 1 per week

- Set of standard problems
- Sets of extra problems

The only way to learn ~~mathematics~~ ENGINEERING is to do mathematics.

PAUL HALMOS

Laboration

- "At home"
  - Analyze one radio link, either existing or proposed.
  - Present findings on two pages.
  - Work in pairs

- Starts: 7 May
- Due date: 25 May

Exam

- How?

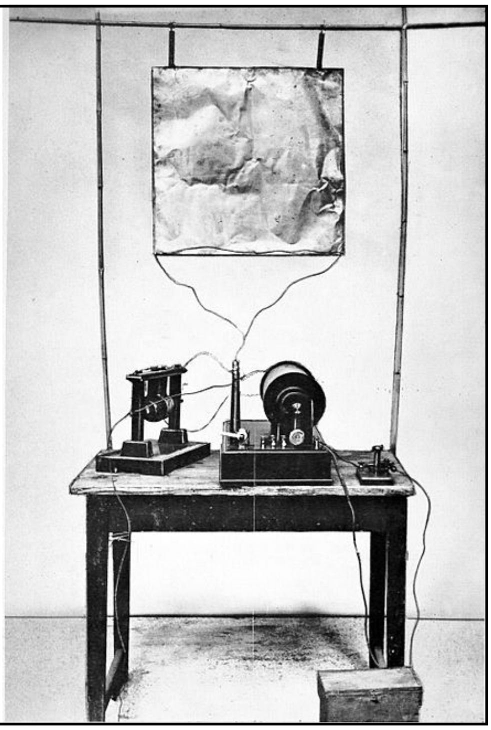
–**Total of 5 hours**
–**Part A**: 1.5 hours – closed book questions (15 points)
–**Part B**: 3.5 hours – open book problems (15 points)

What?

- What is the course about?
  - To send information from one place to another without wires.

Wireless systems

- First wireless transmitter in 1890 by Marconi.



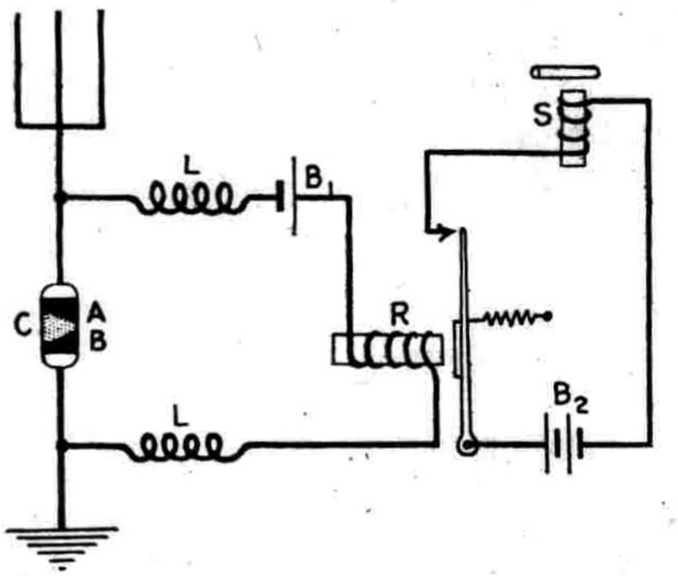
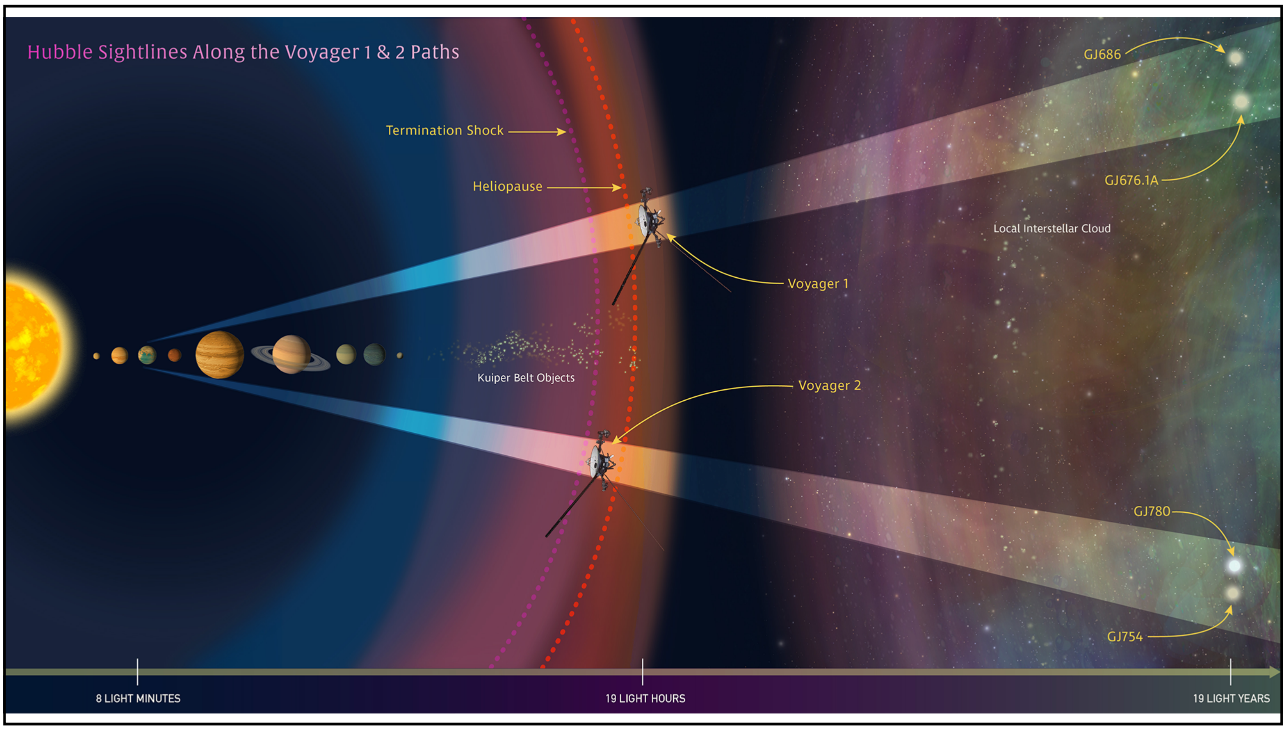
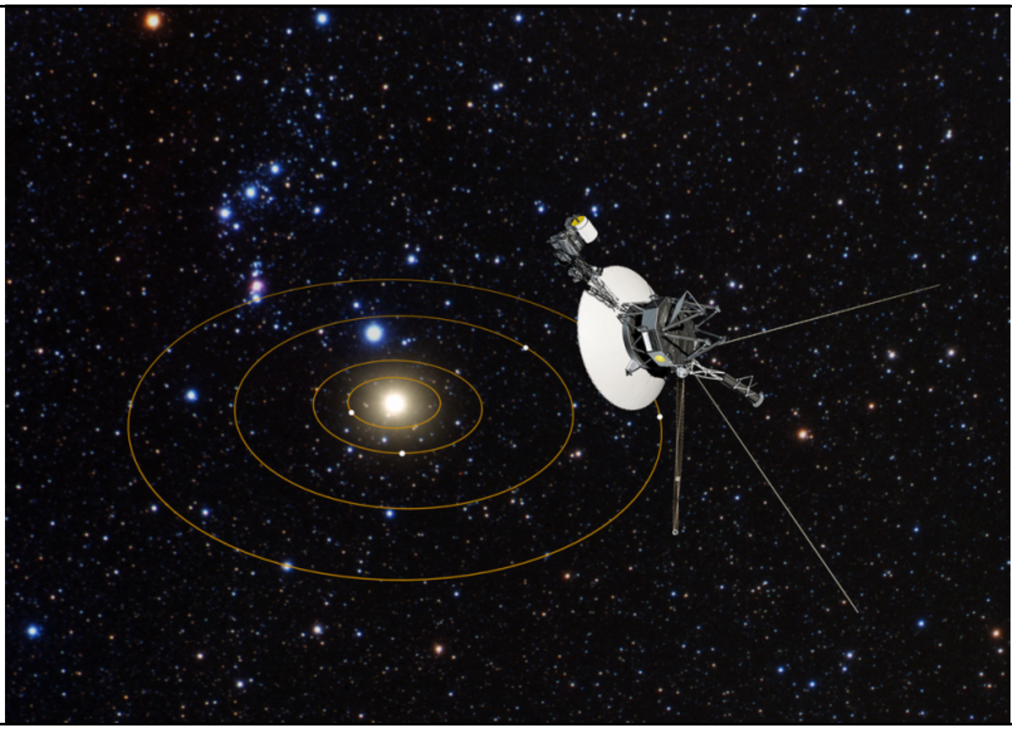


Fig. 101. Marconi 1896 Receiver.


Hubble Sightlines Along the Voyager 1 & 2 Paths
Termination Shock
Heliopause
Voyager 1
Voyager 2
Kuiper Belt Objects
Local Interstellar Cloud
GJ686
GJ676.1A
GJ780
GJ754
8 LIGHT MINUTES
19 LIGHT HOURS
19 LIGHT YEARS



Voyager link

- Probe
  - 22 W transmitter
  - 3.7 m antenna
- Earth
  - 20 kW transmitter
  - 70 m antenna
- Speed
  - 16 bits/second (uplink) (?)

Questions:

- How does it work?
- Is it only the antennas that makes it possible to go from 2 m to 1.7×10^{13} m?
- Why the discrepancy of power? Is it related to the antenna?
- Why the low bitrate?
- How would we do it today?

Another aspect:

- 802.11ax
  - 4 – 1201 Mbit/s
  - BPSK/QPSK/16-QAM/64-QAM/256-QAM/1024-QAM
  - Coding rate ½, ¾, 2/3, 5/6,…
  - Guard interval 800, 1600, 3200 ns
  - Symbol duration 3.2, 6.4, 12.8 us
  - OFDM
  - MuMIMO
  - Triggerbased random access, spatial frequency reuse,
  - NAV, TWT, …

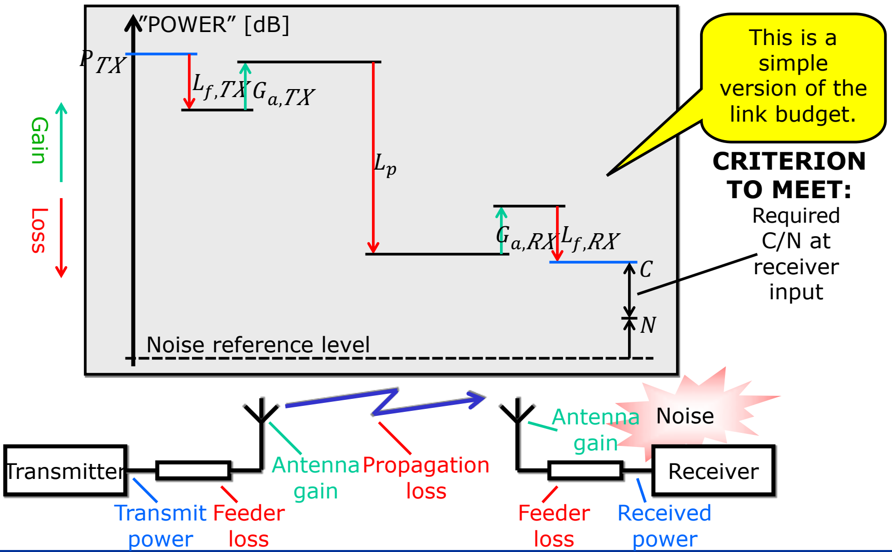
What?

- What is the course about?
  - To send information from one place to another without wires
  - Bits per second per square meter
  - Bits per second per watt
  - Bits per per second per joule
  - Bits per joule

Todays agenda:

- Link budget
- Channel effects
- decibels

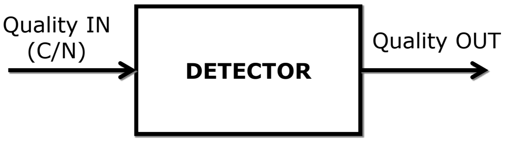
Link budget – a central concept

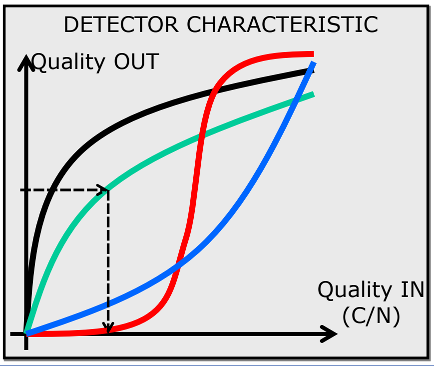


SINGLE LINK
Link budget – depends on what?

•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)

Required C/N





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

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

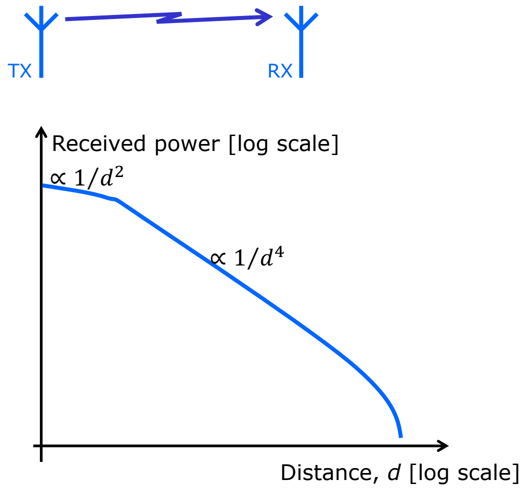
•Large-scale fading

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

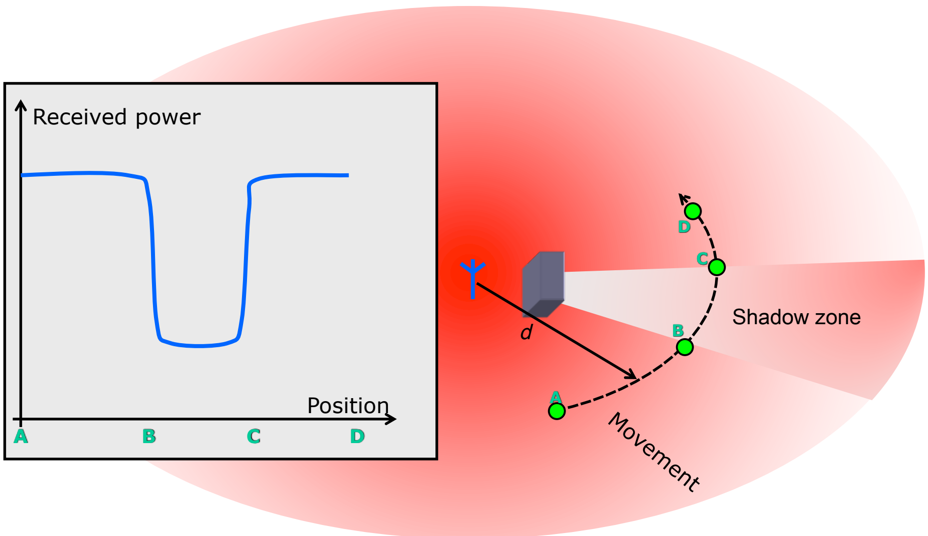
•Small-scale fading

Objects reflecting the signal causes multipath propagation from transmitter to receiver

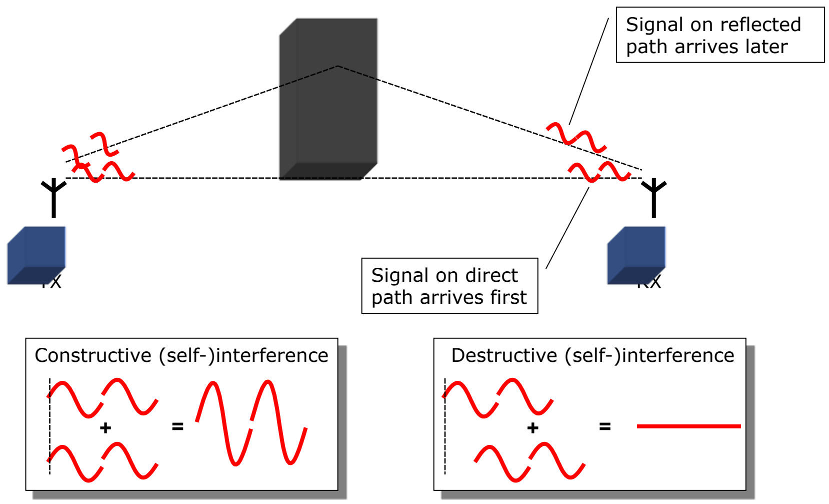
THE RADIO CHANNEL
Path loss



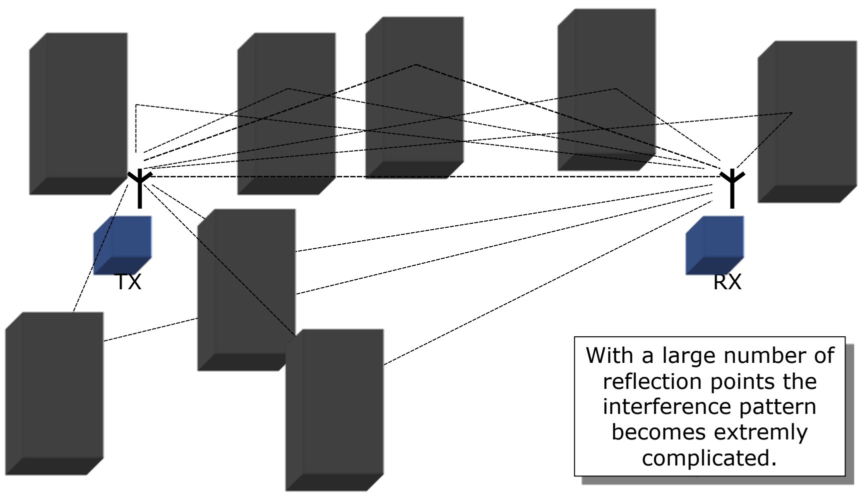
THE RADIO CHANNEL
Large-scale fading



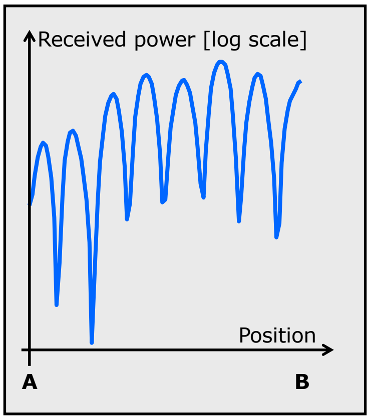
THE RADIO CHANNEL
Small-scale fading

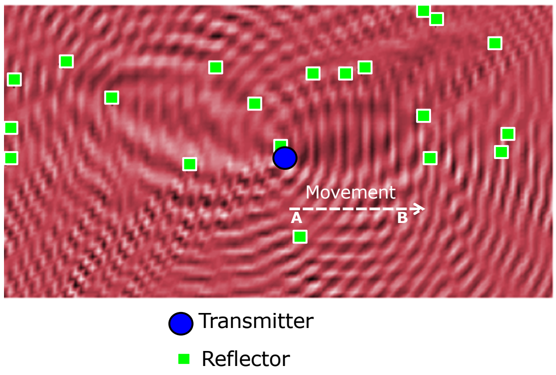


THE RADIO CHANNEL
Small-scale fading (cont.)



THE RADIO CHANNEL
Small-scale fading (cont.)



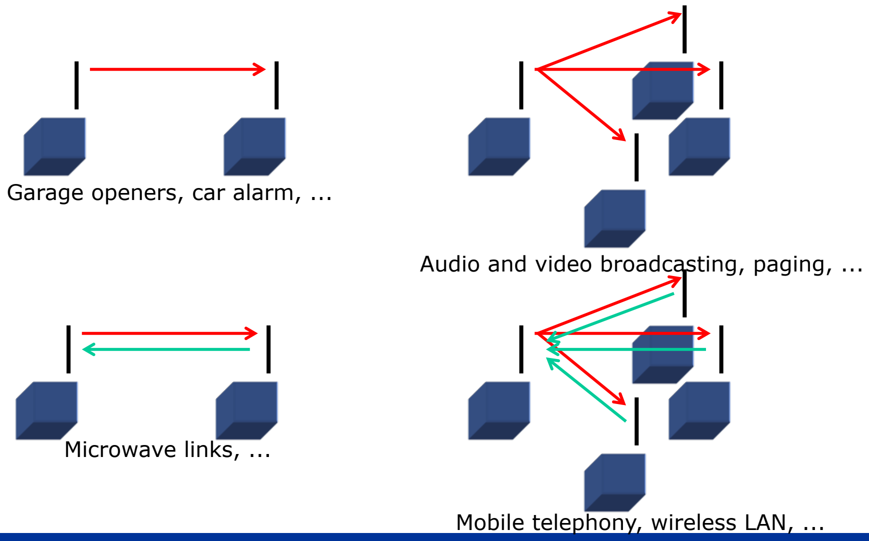


MULTIPLE LINKS
Conceptual changes (cf. single link)

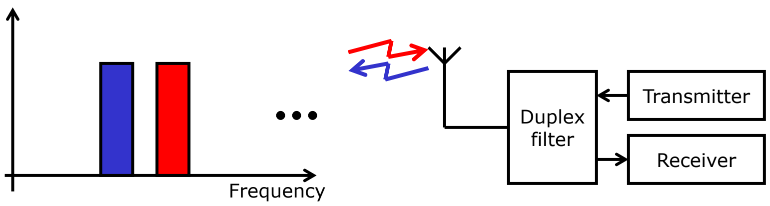
•The same ”radio spectrum” resource has to be shared
–Multiple access schemes
–Access schemes have different properties

•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



DUPLEX
Frequency-division Duplex (FDD)

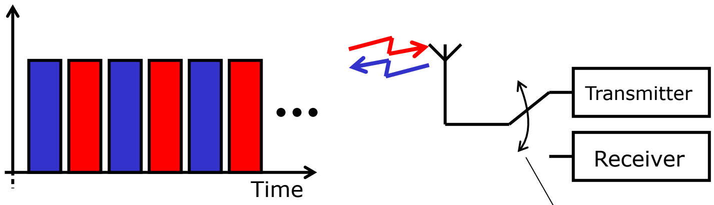


FDD gives a more complex solution (the duplex filter).

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)

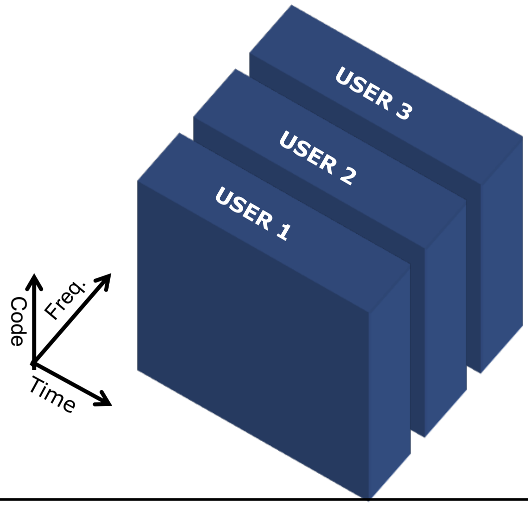


TDD gives a low complexity solution (the duplex switch).

Cannot be used for continuous transmission.

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

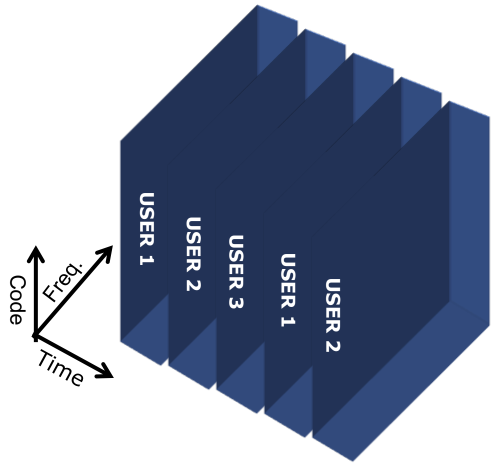
MULTIPLE ACCESS
Freq.-division multiple access (FDMA)



Users are separated in frequency bands.

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

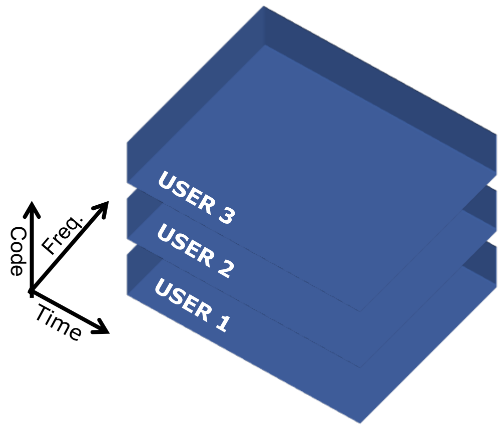
MULTIPLE ACCESS
Time-division multiple access (TDMA)



Users are separated in time slots.

Example: Global System for Mobile communications (GSM)

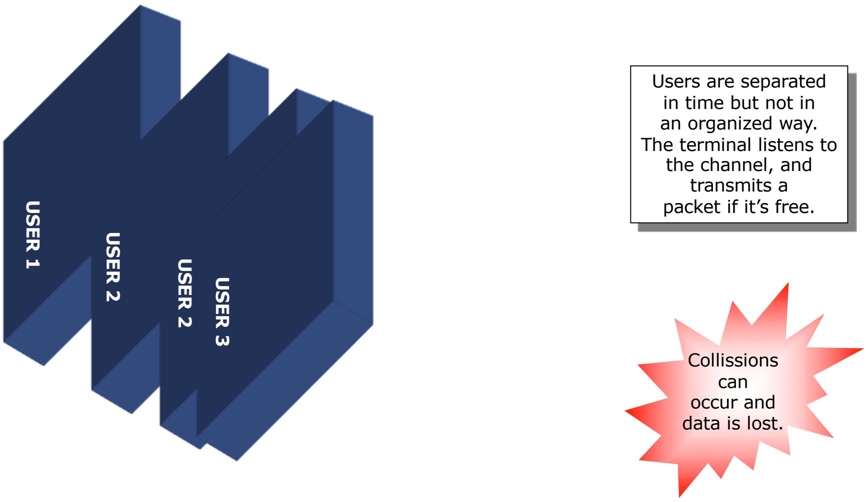
MULTIPLE ACCESS
Code-division multiple access (CDMA)



Users are separated by spreading codes.

Examples: CdmaOne, Wideband CDMA (WCDMA), Cdma2000

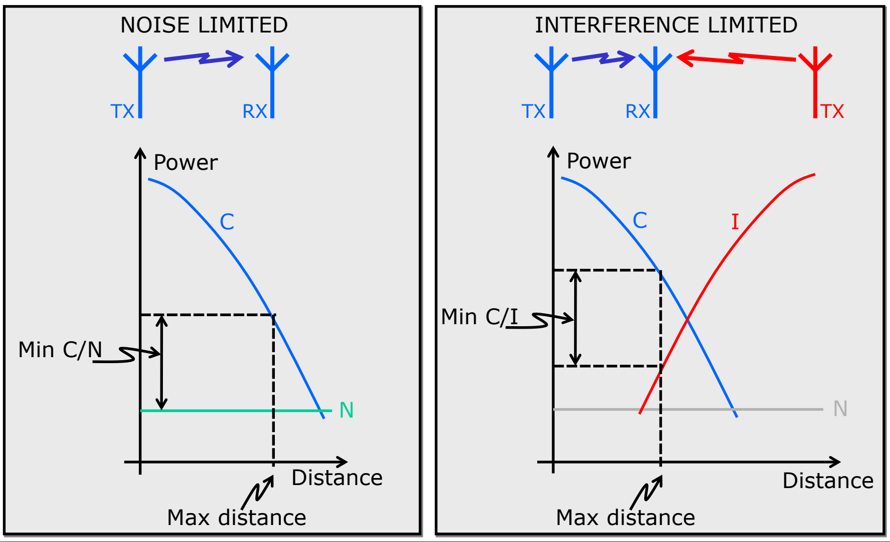
MULTIPLE ACCESS
Carrier-sense multiple access (CSMA)



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.

Example: IEEE 802.11 (WLAN)

LINK LIMITATIONS
Noise and interference limited links



Decibels

- Decibels: written as dB
- Is always a relation: the size of a power in relation to a reference power.

- Comes from Bels: log(value / reference value)
- Decibels as in decimeter: 10 x Bels, or:
  10 x log (value / reference value)

- Logarithmic scale

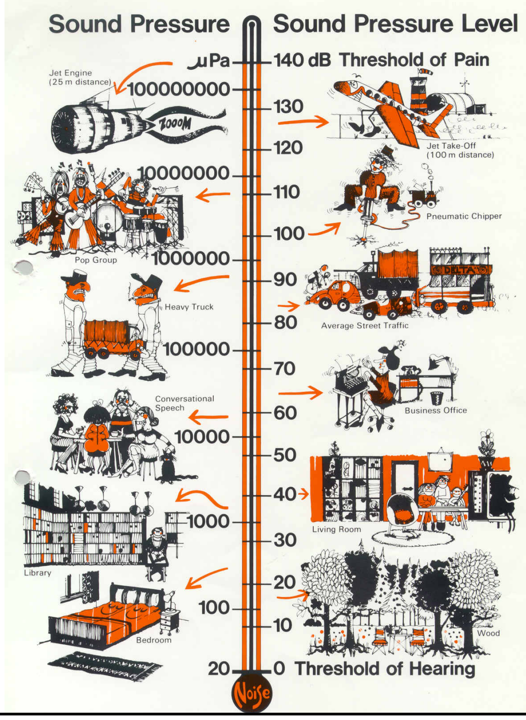
Conversion

- +10 dB = 10 x
- +20 dB = 100 x
- +30 dB = 1000 x

- +3 dB = 2 x
- -3 dB = 0.5 x

- Example 26 dB = 10 x 10 x 2 x 2 = 400 x

Example:



Example: Sound pressure

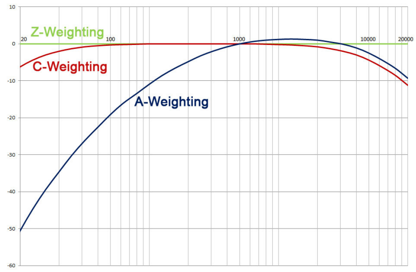
- L_p=20 log (P_{rms} / P_{ref})
- P_{ref} = 20 micropascal

- Square of an amplitude gives power, in a constant impedance.
- 20 log(A/B) = 10 log(A^2/B^2)

Example: Sound pressure

- L_p=20 log (P_{rms} / P_{ref})
- P_{ref} = 20 micropascal

- Often is weighted according to a filter curve:
  - dBZ : Flat weight
  - dBA : Human hearing
  - dBC : Human hearing in loud environments



dB in Wireless science

- Relate to power (Typical used for power in cables and waveguides)
  - dBW *decibelwatt*
    - P_{ref} = 1 W 10log(P/1)
  - dBm *decibelmilliwatt*
    - P_{ref} = 1 mW 10log($P/10^{-3}$)
- Relate to amplitude (Typical used for power in air)
  - dBuV/m *decibelmicrovolt per meter*
    - A_{ref} = 1 uV/m 20log($A/10^{-6}$)
- Relative to carrier (Typical used in wireless link calculations)
  - dBc decibels to carrier

End