Mobile and Sensor Systems

Lecture 1: Introduction to Wireless Systems

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About Me

- Reader in Mobile Systems
  - NetOS Research Group
- Research on Mobile, Social and Sensor Systems
- More specifically,
  - Human Mobility and Social Network modelling
  - Opportunistic Mobile Networks
  - Mobile Sensor Systems and Networks

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In This Course

- General understanding and applications of, challenges and solutions for various types of:
  - Mobile Systems and Networks
  - Sensor Systems and Networks

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List of Lectures

- Lecture 1: *Wireless Systems.*
- Lecture 2: *Mobile Mac Layer and Telecommunication Systems.*
- Lecture 3: *Wireless LAN, Bluetooth, Ad Hoc Networks.*
- Lecture 4*: Ad Hoc and Delay Tolerant Routing.*
- Lecture 5: *Sensor Systems and MAC Layer Protocols.*
- Lecture 6: *Sensor Networking Routing Protocols.*
- Lecture 7: *Sensor Systems Reprogramming and Mobile Sensing.*
- Lecture 8*: Mobile Phone Sensing.*

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What is a Mobile System?

Mobile vs Wireless

- Two aspects of mobility:
  - user mobility: users communicate (wireless) “anytime, anywhere, with anyone”
  - device portability: devices can be connected anytime, anywhere to the network
- Wireless vs. mobile Examples

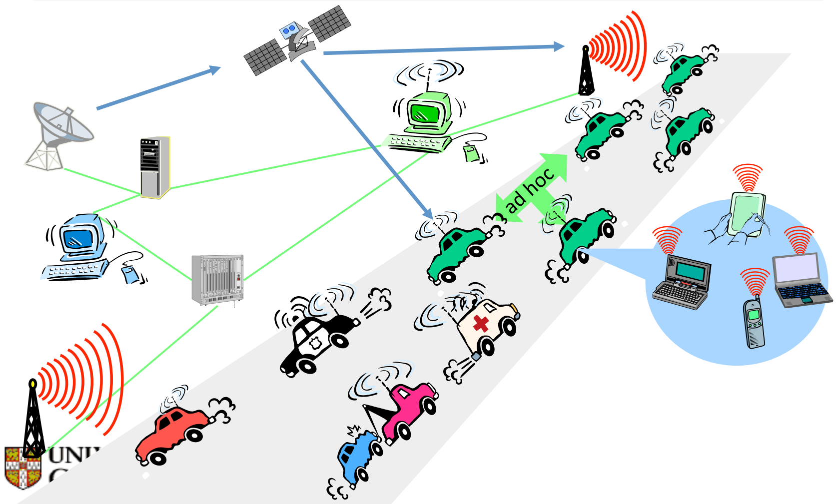
Wireless	Mobile	Examples
×	×	stationary computer
×	✓	notebook [connected via Ethernet in various places]
✓	×	wireless LANs in historic buildings
✓	✓	mobile phone/laptop (with 3G/WIFI)

- The demand for mobile communication creates the need for integration of wireless networks into existing fixed networks

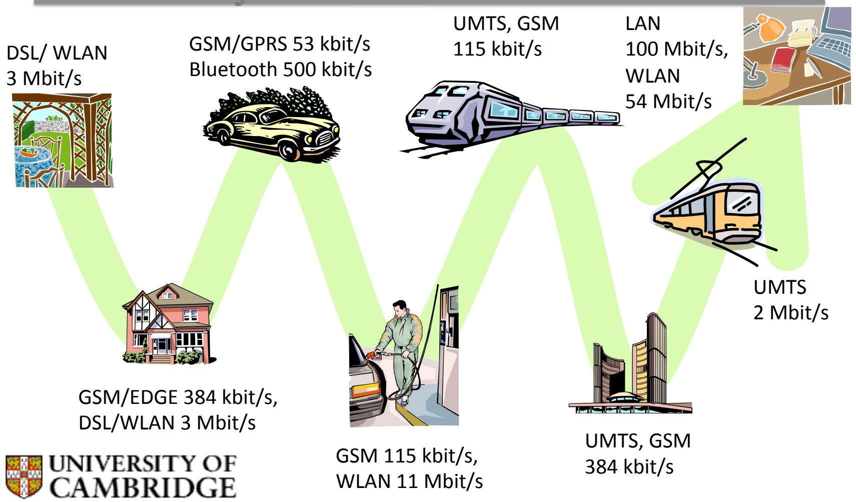
Applications

- Vehicles/Phones
  - transmission of news, road condition, weather, music
  - personal communication using GSM/UMTS
  - position via GPS
  - local ad-hoc network with vehicles close-by to prevent accidents, guidance system, redundancy
  - Traffic and route data (e.g., from busses, high-speed trains) can be transmitted in advance for maintenance
- Emergencies
  - early transmission of patient data to the hospital, current status, first diagnosis
  - replacement of a fixed infrastructure in case of earthquakes, hurricanes, fire etc.

Typical application: road traffic



Mobile and wireless services – Always Best Connected



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Location dependent services

- Location aware services
  - what services, e.g., printer, fax, phone, server etc. exist in the local environment
- Follow-on services
  - automatic call-forwarding, transmission of the actual workspace to the current location
- Information services
  - "push": e.g., current special offers in the supermarket
  - "pull": e.g., where is "Pizza Hut"?
- Support services
  - caches, intermediate results, state information etc. "follow" the mobile device through the fixed network
- Privacy
  - who should gain knowledge about the location?

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Effects of device portability

- Power consumption
  - limited computing power, limited transmission, trading off with quality displays
- Loss of data
- Limited user interfaces
  - compromise between size of fingers and portability
  - integration of character/voice recognition
- Limited memory
  - flash-memory as alternative

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Wireless networks vs fixed networks

- Higher loss-rates due to interference
  - Other networks, car emissions
- Restrictive regulations of frequencies
  - frequencies have to be coordinated, useful frequencies are almost all occupied
- Low transmission rates
  - local some Mbit/s, regional currently, e.g., 53kbit/s with GSM/GPRS
- Higher delays, higher jitter
  - connection setup time with GSM is several seconds, several hundred milliseconds for other wireless systems
- Lower security, simpler active attacking
  - radio interface accessible for everyone, base station can be simulated, thus attracting calls from mobile phones
- Always shared medium
  - secure access mechanisms important

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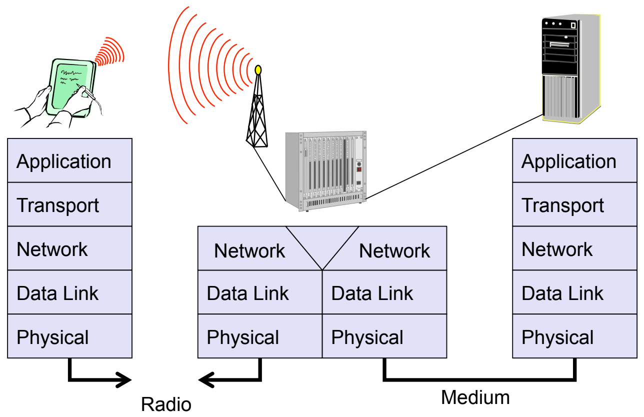
Simple reference model



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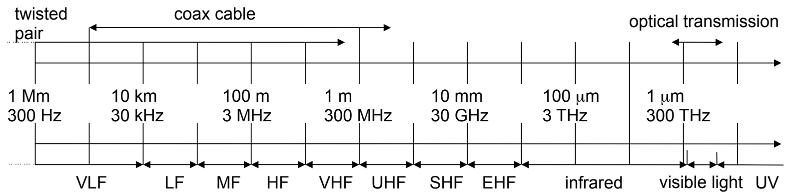
Frequencies for communication

- VLF = Very Low Frequency
- LF = Low Frequency
- MF = Medium Frequency
- HF = High Frequency
- VHF = Very High Frequency

UHF = Ultra High Frequency
SHF = Super High Frequency
EHF = Extra High Frequency
UV = Ultraviolet Light

- Frequency and wave length
  - $\lambda = c/f$
  - wave length λ, speed of light $c \cong 3\text{x}10^8$m/s, frequency f



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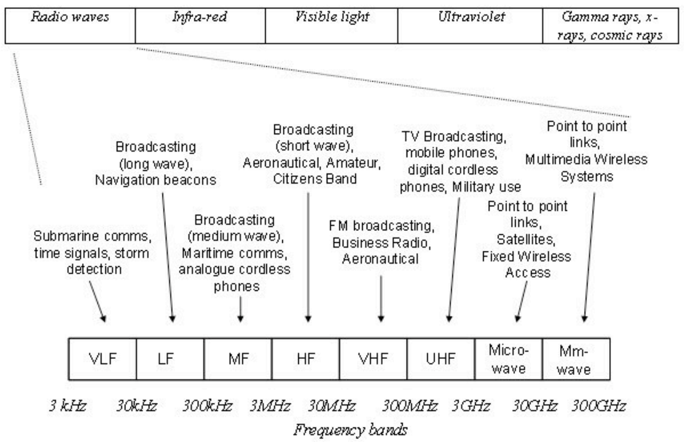
Spectrum Bands



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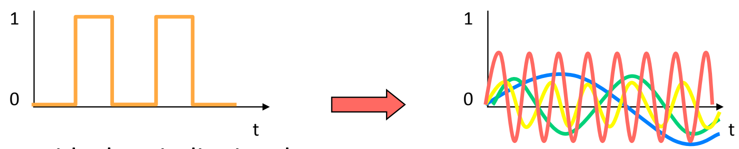
Mobile systems based on radio communication

- Characterized by radio propagation
- Signal does not travel on a wire but in the air
- Recap:

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$



ideal periodic signal

real composition (based on harmonics)

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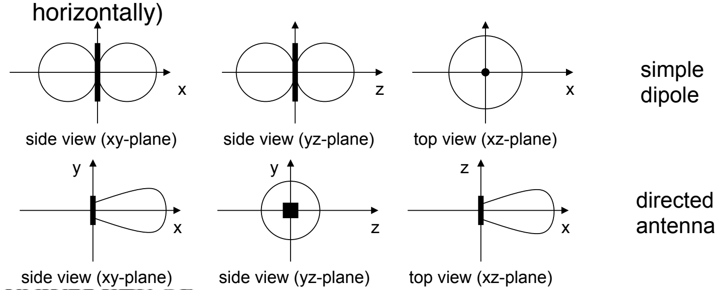
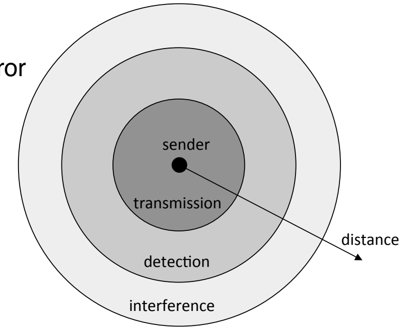
Antennas

- Radiation and reception of electromagnetic waves, coupling of wires to space for radio transmission
- Isotropic radiator: equal radiation in all directions (three dimensional) - only a theoretical reference antenna
- Real antennas always have directive effects (vertically and/or horizontally)



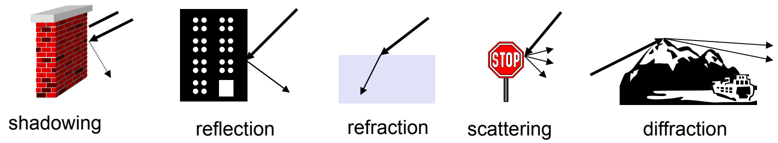
Signal propagation ranges (in theory!)

- •Transmission range
  - – communication possible, low error rate
- Detection range
  - detection of the signal possible, no communication possible
- Interference range
  - signal may not be detected and adds to the background noise

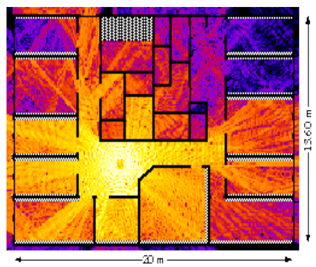


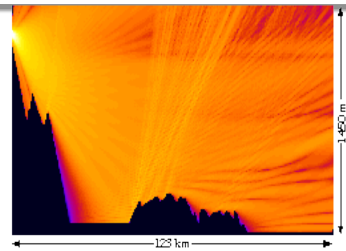
Signal propagation

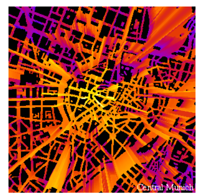
- Propagation in free space always like light (straight line)
- Receiving power proportional to $1/d^2$ in vacuum – much more in real environments (d = distance between sender and receiver)
- Receiving power additionally influenced by
- fading (frequency dependent)
- shadowing
- reflection at large obstacles
- refraction depending on the density of a medium
- scattering at small obstacles
- diffraction at edges



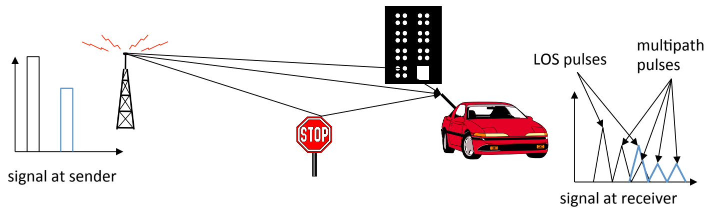
Real world example







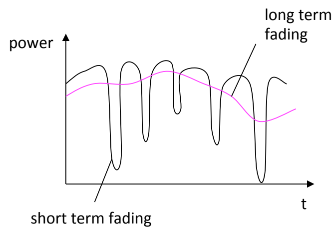
Multipath propagation



- Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction
- The signal reaches a receiver directly and phase shifted
- Distorted signal depending on the phases of the different parts

Effects of mobility

- Channel characteristics change over time and location
  - signal paths change
  - different delay variations of different signal parts
  - different phases of signal parts
- Quick changes in the power received (short term fading)
- Additional changes in
  - distance to sender
  - obstacles further away
- Slow changes in the average power received (long term fading)

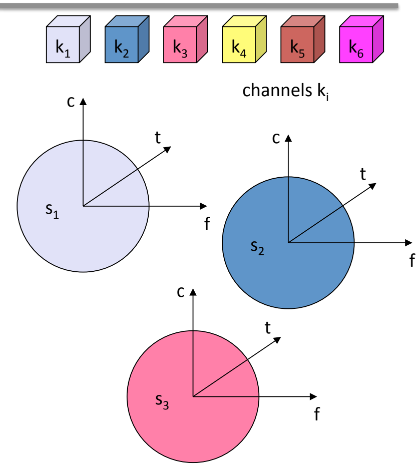


Shared Medium

- How is the medium within a certain spectrum band shared about various competing entities who want to communicate?

Multiplexing

- Multiplexing in 4 dimensions
  - space (s_i)
  - time (t)
  - frequency (f)
  - code (c)
- Goal: multiple use of a shared medium
- Important: guard spaces needed!

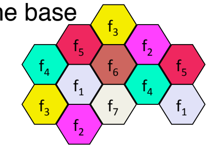


Example of multiplexing: Cell structure

- Implements **space division multiplex**: base station covers a certain transmission area (cell)
- Mobile stations communicate only via the base station
- Advantages of cell structures:
  - higher capacity, higher number of users, less transmission power needed, more robust, decentralized, base station deals with interference, transmission area etc. locally
- Problems: fixed network needed for the base stations, handover (changing from one cell to another) necessary, interference with other cells
- Cell sizes from some 100 m in cities to, e.g., 35 km on the country side (GSM) - even less for higher frequencies

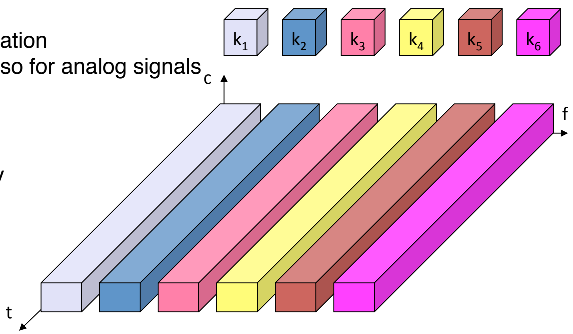
Frequency planning I

- Frequency reuse only with a certain distance between the base stations
- Standard model using 7 frequencies:
- Fixed frequency assignment:
  - certain frequencies are assigned to a certain cell
  - problem: different traffic load in different cells
- Dynamic frequency assignment:
  - base station chooses frequencies depending on the frequencies already used in neighbour cells
  - more capacity in cells with more traffic
  - assignment can also be based on interference measurements



Frequency multiplex

- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- Advantages:
  - no dynamic coordination necessary, works also for analog signals
- Disadvantages:
  - waste of bandwidth if the traffic is distributed unevenly
  - inflexible
  - guard spaces

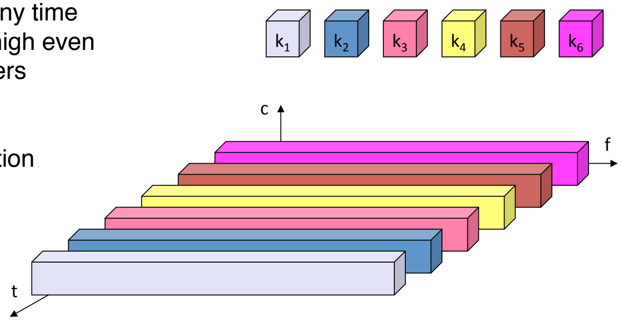


GSM

- GSM uses FDM
- A duplex channel for each mobile station and base station couple:
- Uplink channels use a frequency band and downlink channel another one.
- Each MS is associated to a pair of uplink/downlink channel

Time multiplex

- A channel gets the whole spectrum for a certain amount of time
- Advantages:
  - only one carrier in the medium at any time
  - throughput high even for many users
- Disadvantages:
  - precise synchronization necessary



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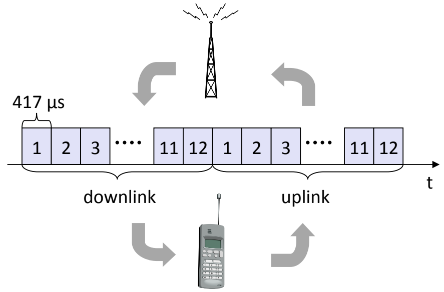
TDD/TDMA - general scheme



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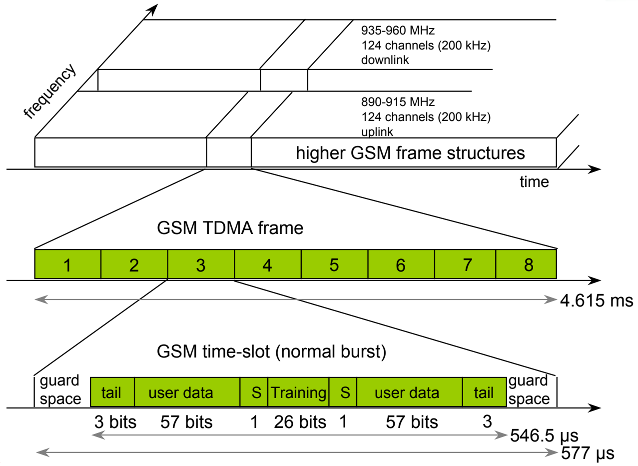
FDM and TDM in GSM



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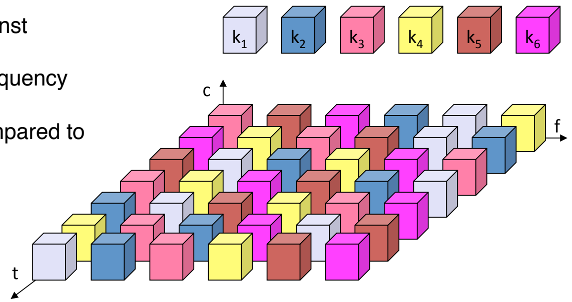
Time and frequency multiplex

- A channel gets a certain frequency band for a certain amount of time
  Example: GSM
- Advantages:
  - better protection against tapping
  - protection against frequency selective interference
  - higher data rates compared to code multiplex
- but: precise coordination required



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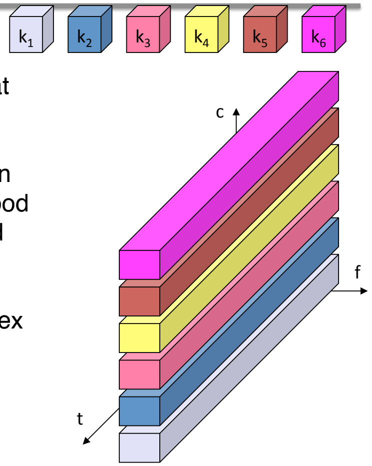
Code multiplex

- Each channel has a unique code
- All channels use the same spectrum at the same time
- Advantages:
  - bandwidth efficient, no coordination and synchronization necessary, good protection against interference and tapping
- Disadvantages:
  - lower user data rates, more complex signal regeneration, Implemented using spread spectrum technology



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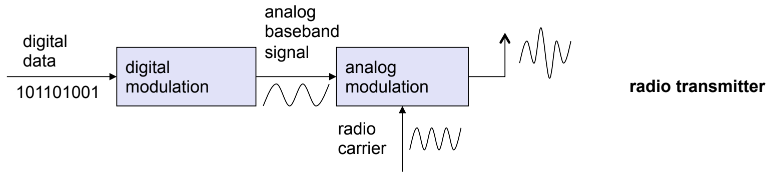
Modulation

- When a digital signal needs to be transmitted over wireless it needs to be translated into analog.



- Basic methods:
  - Amplitude shift keying
  - Frequency shift keying
  - Phase shift keying

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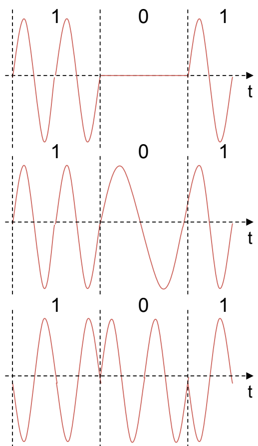
Digital modulation

- Modulation of digital signals known as Shift Keying
- Amplitude Shift Keying (ASK):
  - very simple
  - low bandwidth requirements
  - very susceptible to interference
- Frequency Shift Keying (FSK):
  - Frequency 1 to 1 and frequency 2 to 0
  - needs larger bandwidth
- Phase Shift Keying (PSK):
  - Signal phase is shifted
  - more complex
  - robust against interference



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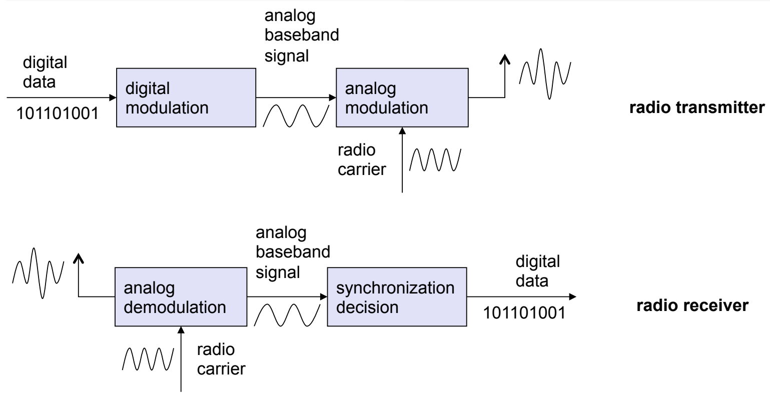
Modulation and demodulation



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Summary

- In this lecture we have discussed the issues imposed by the propagation of signal in wireless networks and indicated some solutions

- **Main Reference for Mobile Part:**
  J. Schiller. Mobile Communications. Addison Wesley. 2000.

Acknowledgement: some slides have been taken from supporting material associated with the above book.

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