Mobile Computing
Lecture 3
Modulation

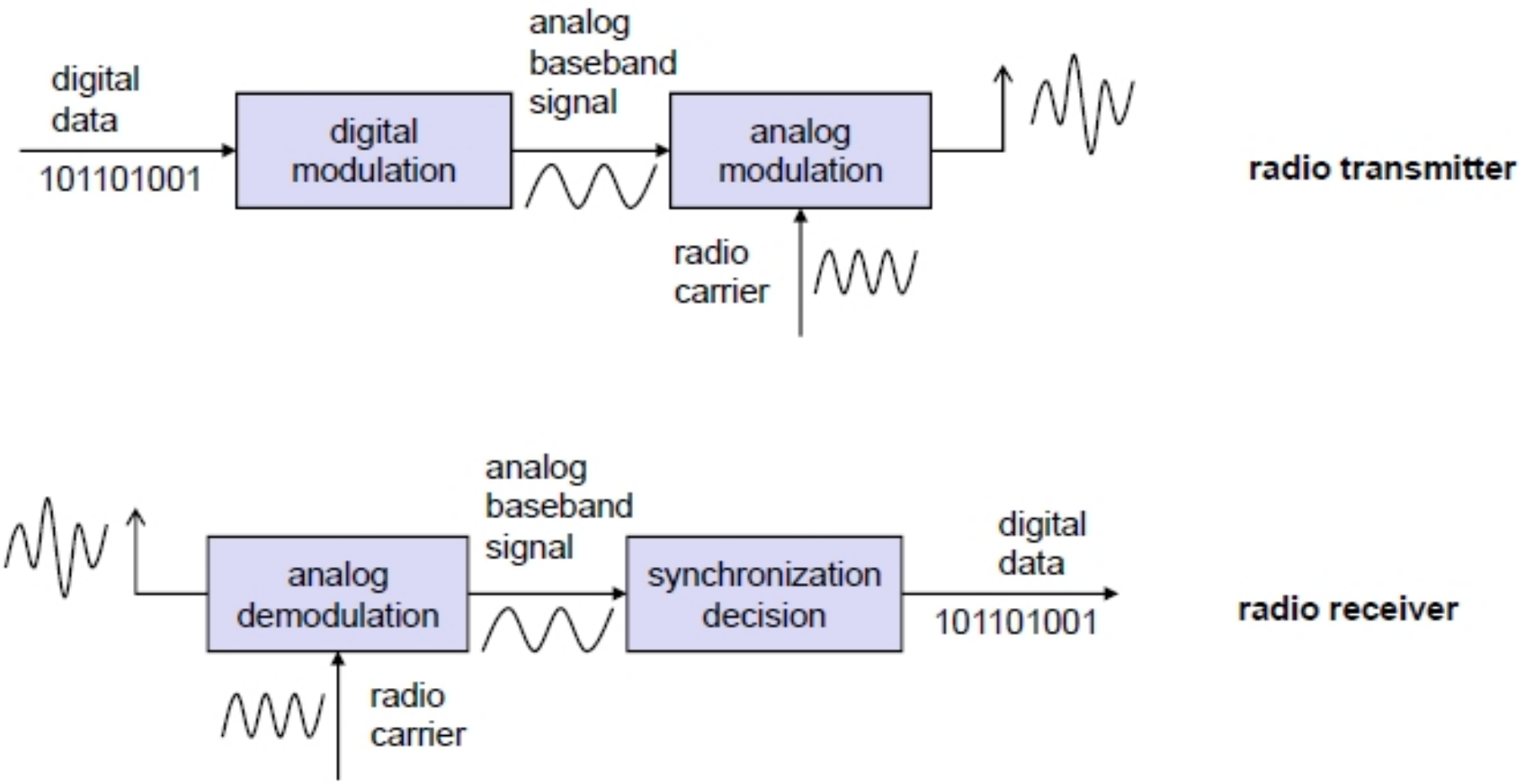
CONTENTS

- Modulation
- Demodulation
- Digital Modulation
- Use of spread spectrum
- Effects of spreading
- DSSS
- FHSS
- Cellular systems

Modulation

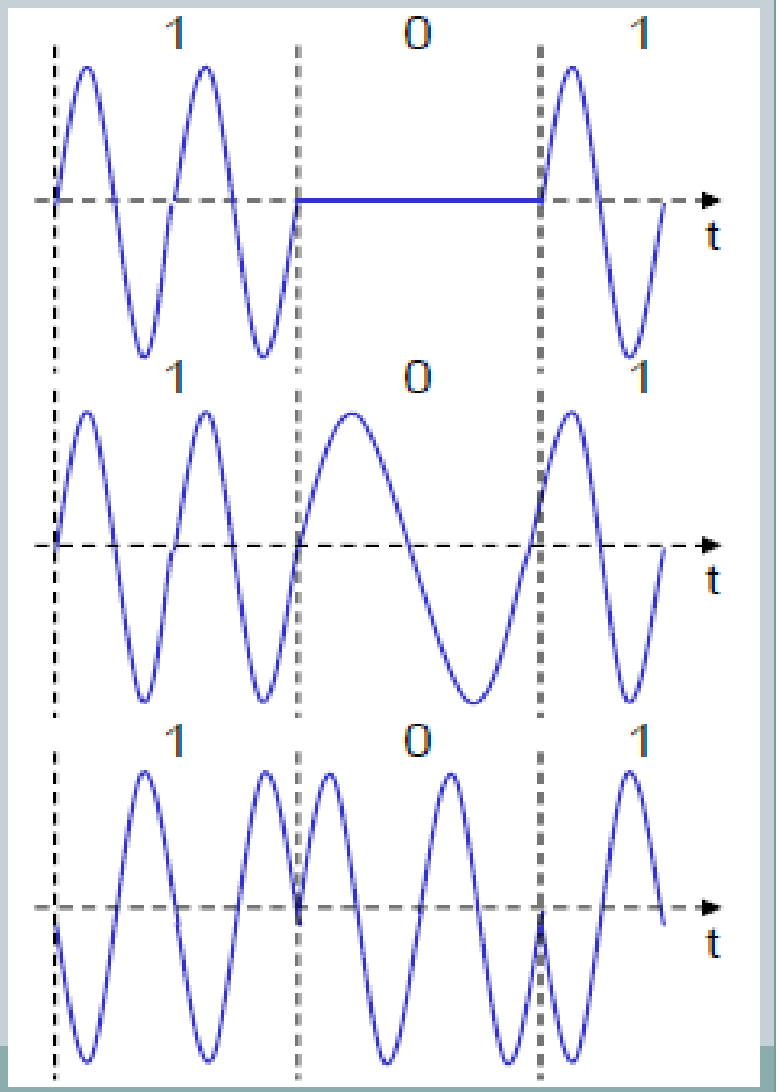
- Digital modulation
  - digital data is translated into an analog signal (baseband)
  - ASK, FSK, PSK - main focus in this chapter
  - differences in spectral efficiency, power efficiency, robustness
- Analog modulation
  - shifts center frequency of baseband signal up to the radio carrier
- Motivation
  - smaller antennas (e.g., $\lambda/4$)
  - Frequency Division Multiplexing
  - medium characteristics
- Basic schemes
  - Amplitude Modulation (AM)
  - Frequency Modulation (FM)
  - Phase Modulation (PM)

Modulation and demodulation



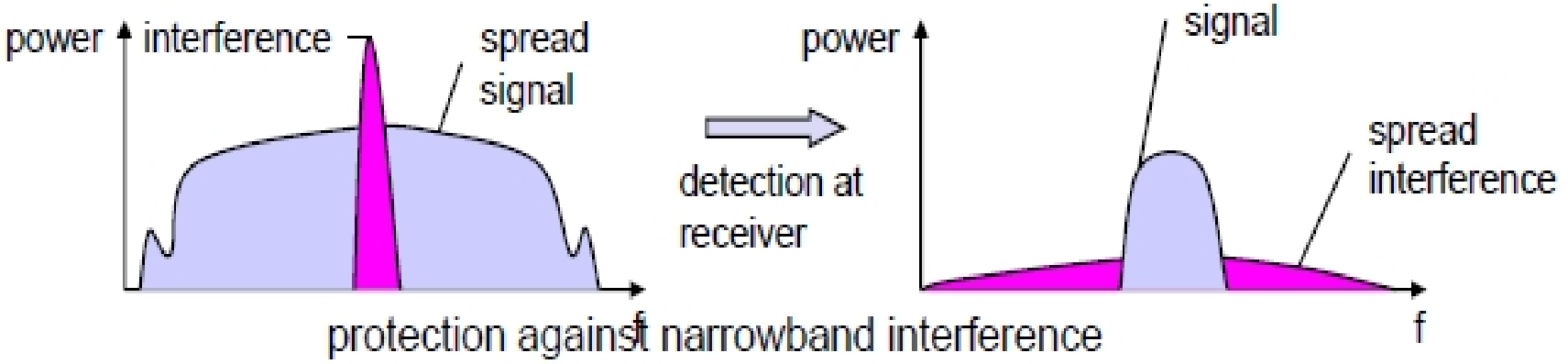
Digital modulation

- 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):
  - needs larger bandwidth
- Phase Shift Keying (PSK):
  - more complex
  - robust against interference

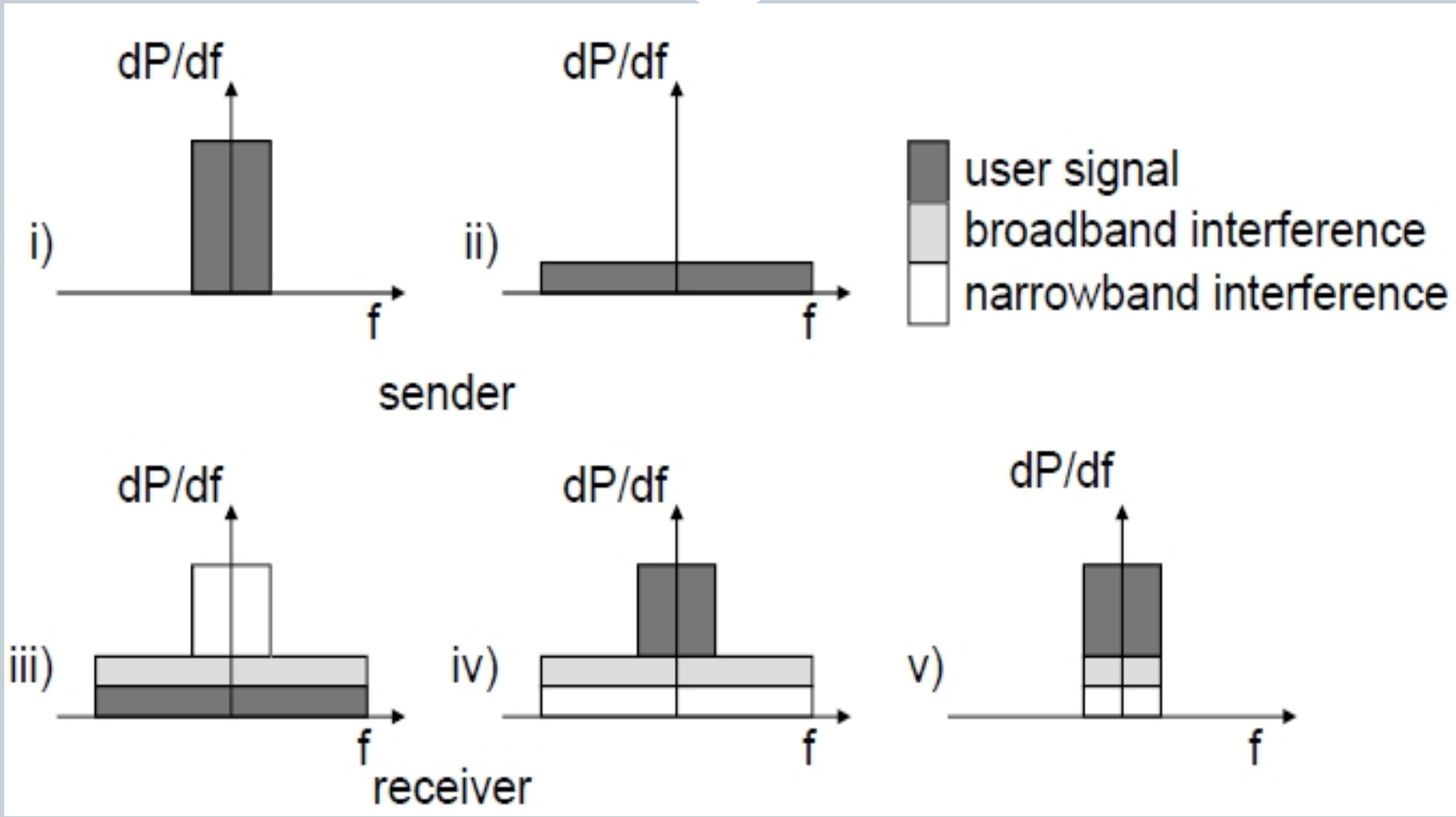


Spread spectrum technology

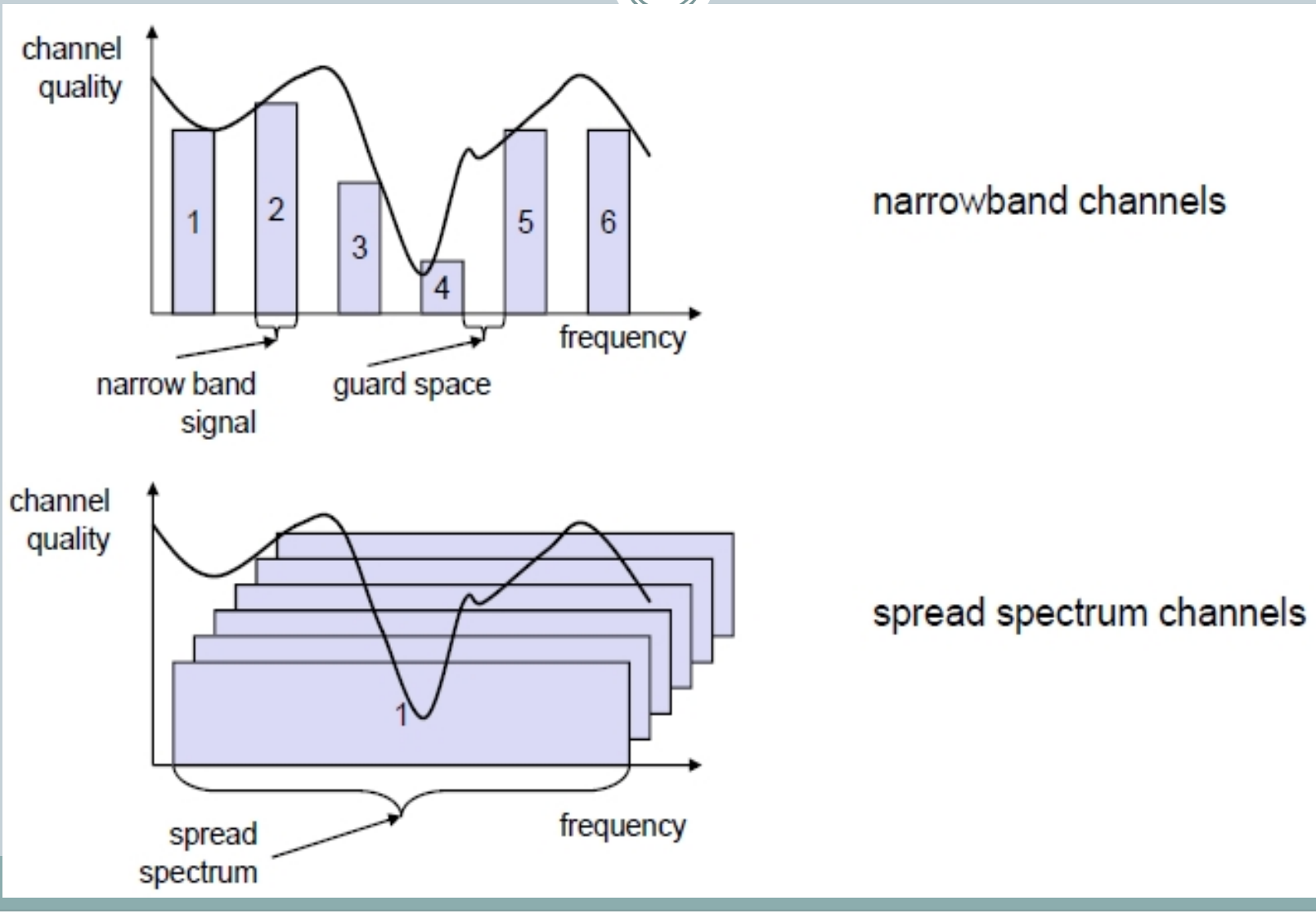
- Problem of radio transmission: frequency dependent fading can wipe out narrow band signals for duration of the interference
- Solution: spread the narrow band signal into a broad band signal using a special code
- protection against narrow band interference
- Side effects:
  - coexistence of several signals without dynamic coordination
  - tap-proof
- Alternatives: Direct Sequence, Frequency Hopping



Effects of spreading and interference

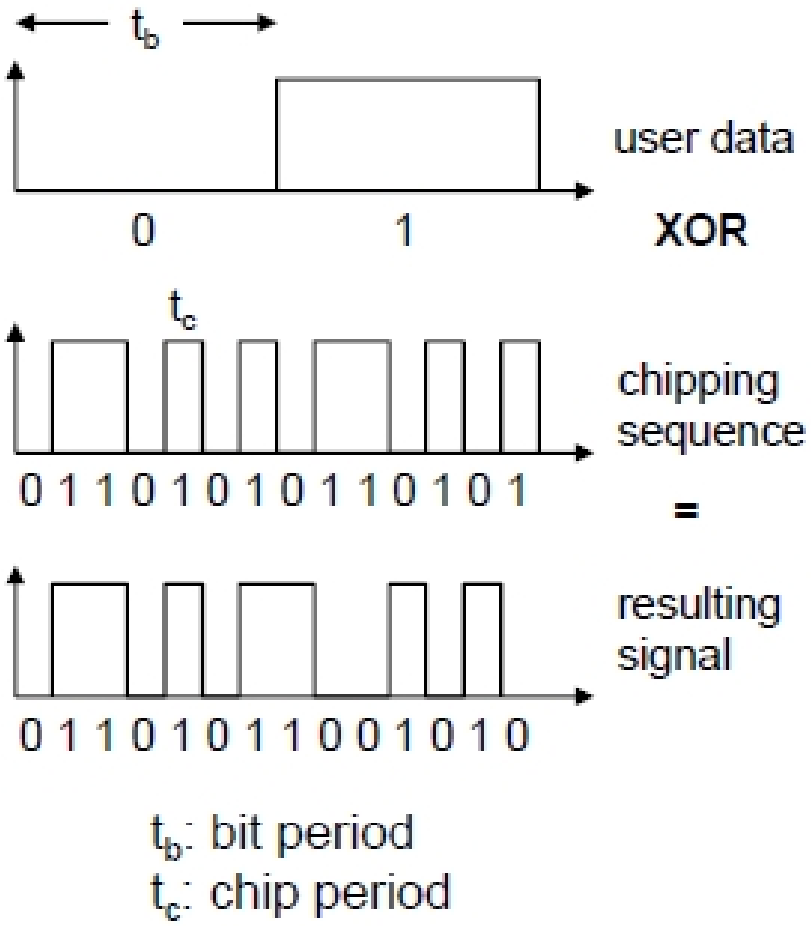


Spreading and frequency selective fading

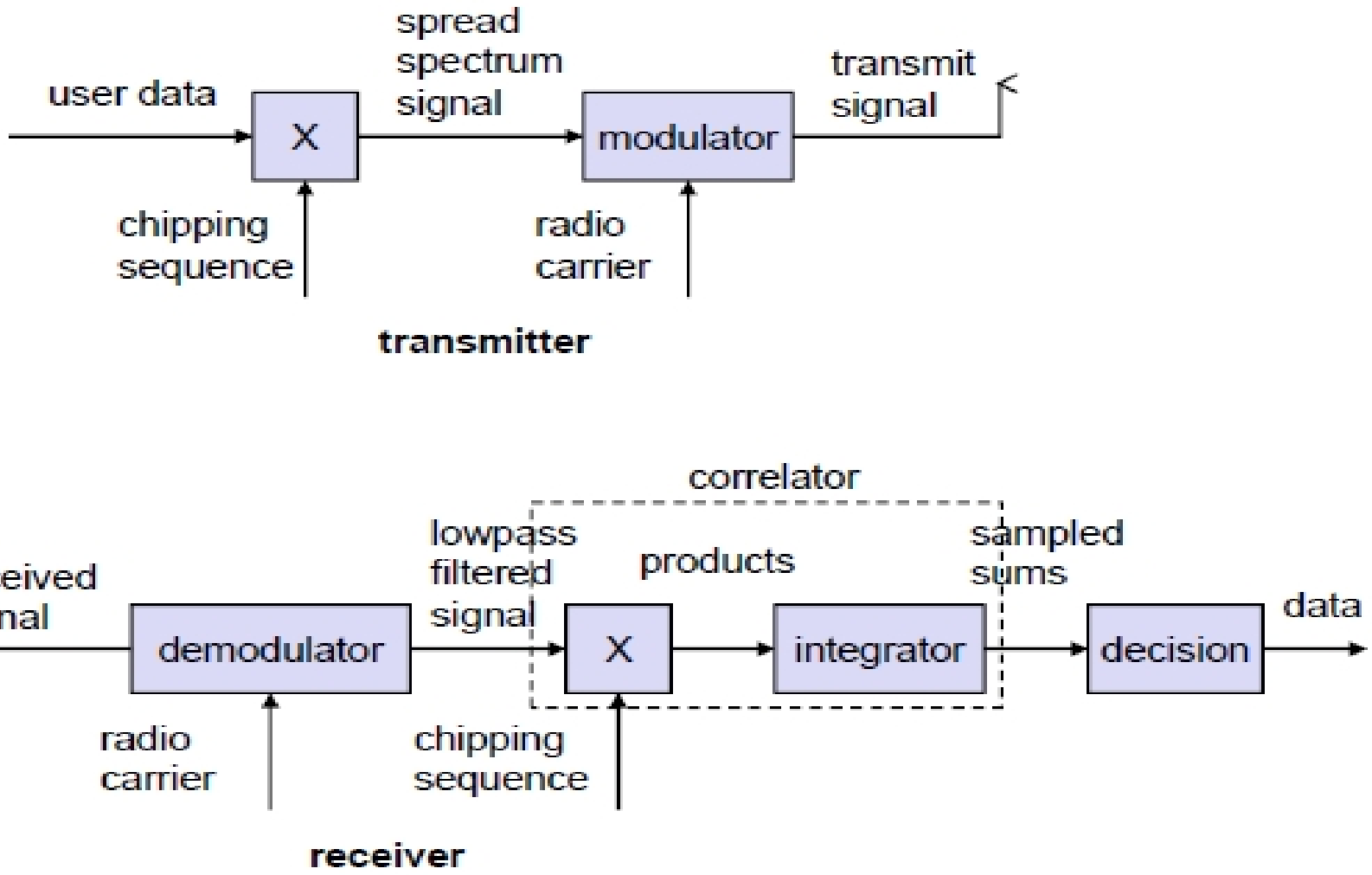


DSSS (Direct Sequence Spread Spectrum)

- XOR of the signal with pseudo-random number (chipping sequence)
  - many chips per bit (e.g., 128) result in higher bandwidth of the signal
- Advantages
  - reduces frequency selective fading
  - in cellular networks
    - base stations can use the same frequency range
    - several base stations can detect and recover the signal
    - Soft handover
- Disadvantages
  - precise power control necessary



DSSS (Direct Sequence Spread Spectrum)



FHSS (Frequency Hopping Spread Spectrum)

- Discrete changes of carrier frequency
  - sequence of frequency changes determined via pseudo random number sequence
- Two versions
  - Fast Hopping: several frequencies per user bit
  - Slow Hopping: several user bits per frequency
- Advantages
  - frequency selective fading and interference limited to short period
  - simple implementation
  - uses only small portion of spectrum at any time
- Disadvantages
  - not as robust as DSSS
  - simpler to detect

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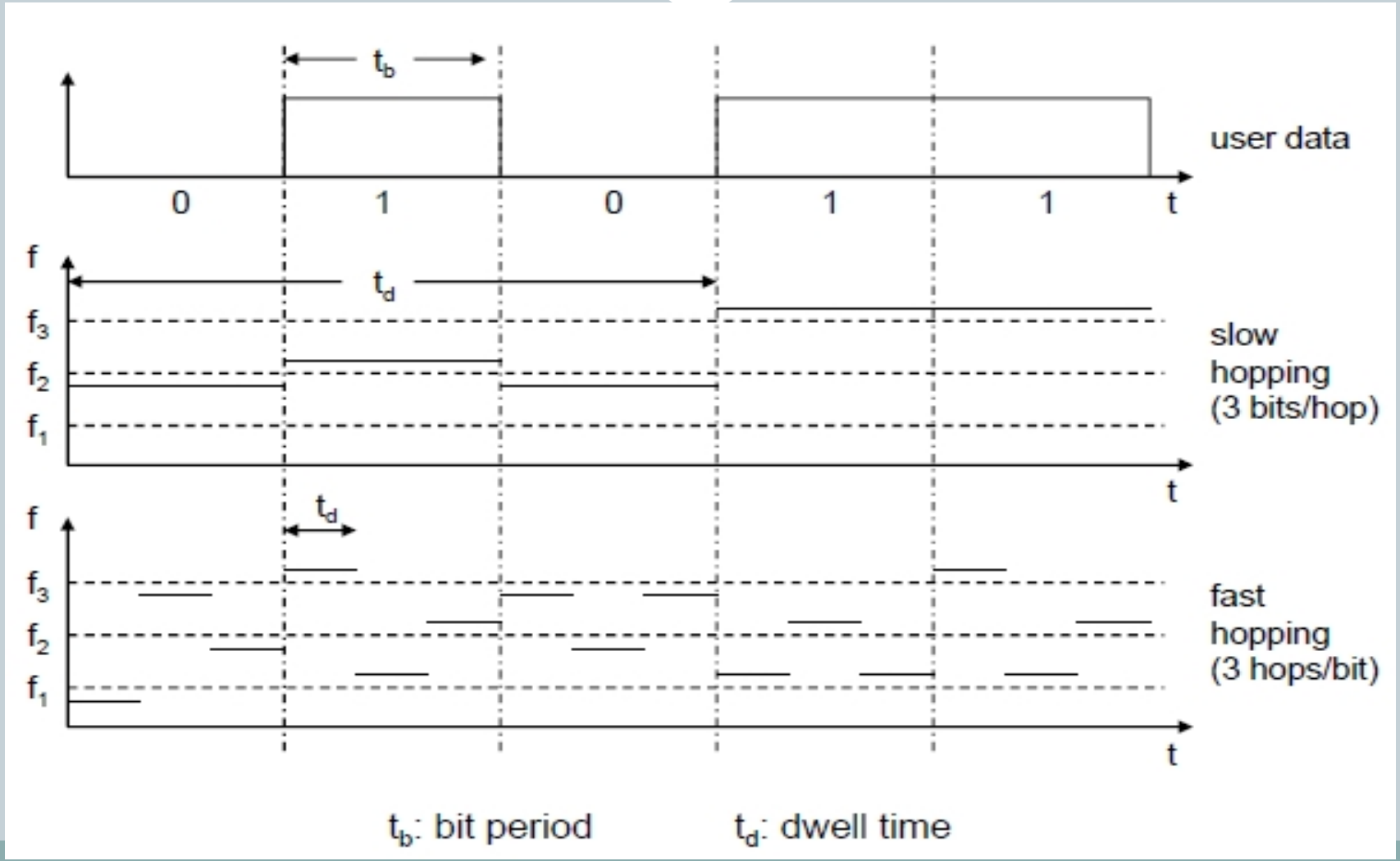
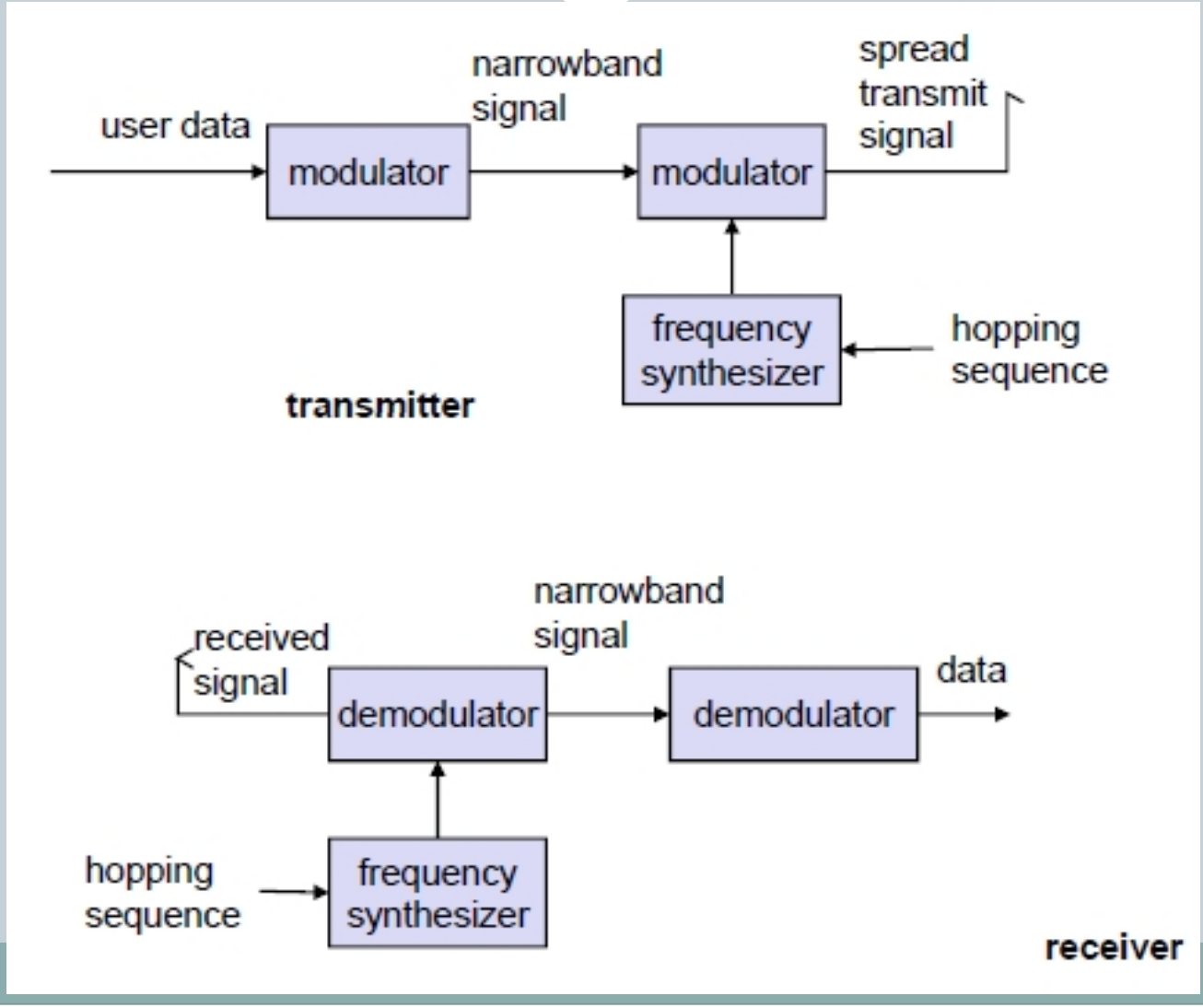

t_b
user data
0
1
0
1
1
t
f
t_d
f_3
f_2
f_1
slow
hopping
(3 bits/hop)
t
f
t_d
f_3
f_2
f_1
fast
hopping
(3 hops/bit)
t
t_b: bit period
t_d: dwell time

Cont..

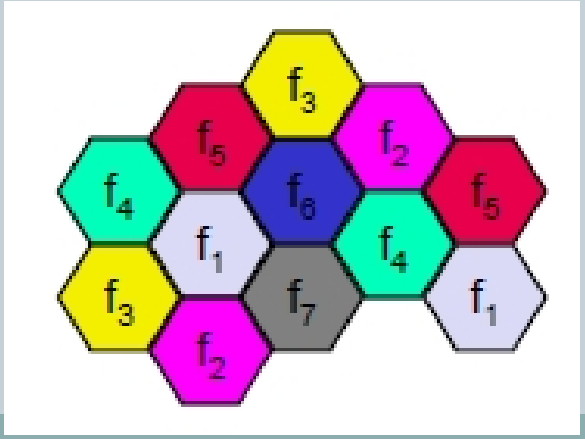

user data
modulator
narrowband signal
modulator
spread transmit signal
frequency synthesizer
hopping sequence
transmitter
received signal
demodulator
narrowband signal
demodulator
data
hopping sequence
frequency synthesizer
receiver

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

- Frequency reuse only with a certain distance between the base stations
- 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 neighbor cells
  - more capacity in cells with more traffic
  - assignment can also be based on interference measurements



Standard model using 7 frequencies

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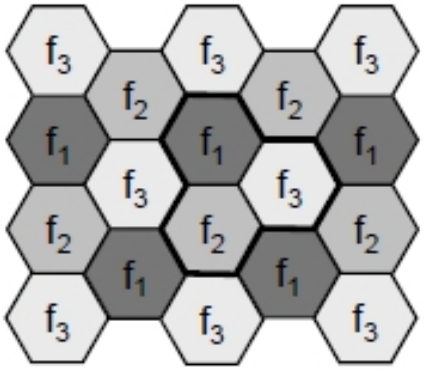
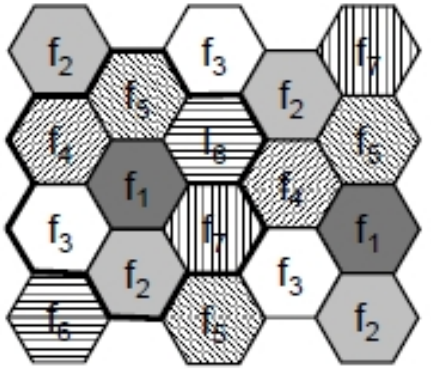
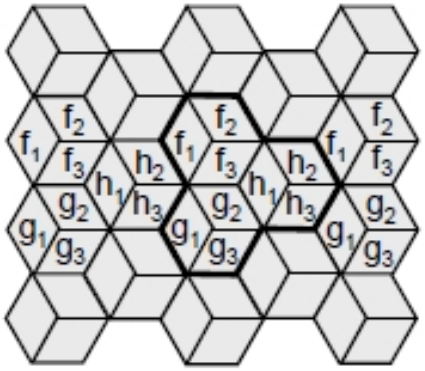


3 cell cluster



7 cell cluster



3 cell cluster
with 3 sector antennas

Cell Breathing

- CDM systems: cell size depends on current load
- Additional traffic appears as noise to other users
- If the noise level is too high users drop out of cells