INTEGRATED TECHNICAL EDUCATION CLUSTER
AT ALAMEERIA

E-716-A
Mobile Communications Systems

Lecture #3
Basic Concepts of Wireless Transmission (p2)

Instructor:
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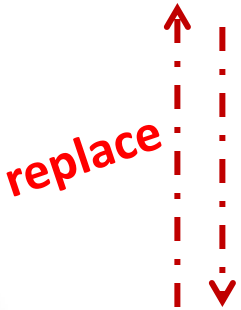
Remember !
Lectures List



Lec. 1	• *Introduction.*
Lec. 2-3	• *Concepts of Wireless Transmission.*
Lec. 4-5	• *Multiple Access Methods.*
Lec. 6	• *Wireless Channel Models.*
Lec. 7-8	• *Concepts of Cellular Networks.*
Lec. 9-13	• *Cellular Networks.*
Lec. 14-15	• *Cell Site and Mobile Antennas.*

Remember !
Lectures List

Lec. 1	• ***Introduction.***
Lec. 2-3	• ***Concepts of Wireless Transmission.***
Lec. 4-6	• ***Concepts of Cellular Networks. (OPNET)***
Lec. 7-11	• ***Types of Cellular Networks. (OPNET)***
Lec. 12-13	• ***Effects of Mobile Radio Propagation.***
Lec. 14-15	• ***Cell Site and Mobile Antennas.***

Agenda

Modulation

- ASK,PSK,FSK, QAM

Multiplexing

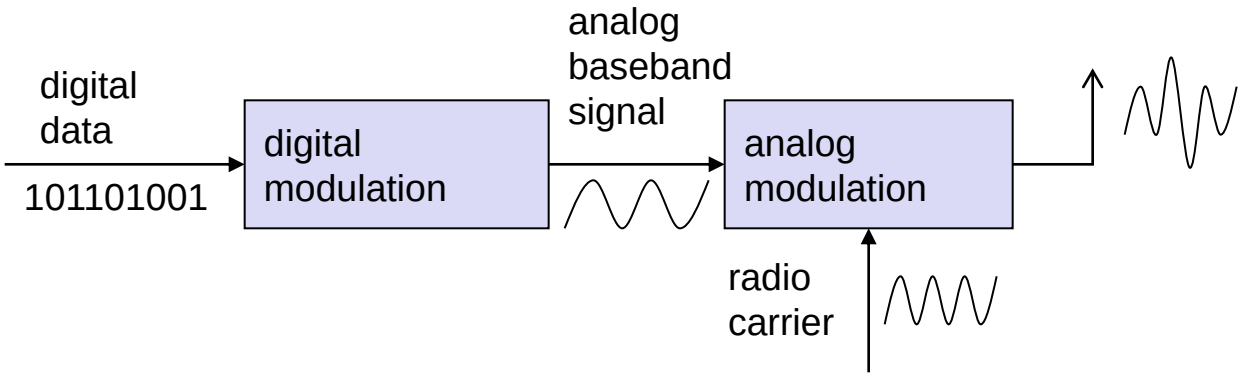
- Space/Time/Frequency/Code Multiplex

MODULATION

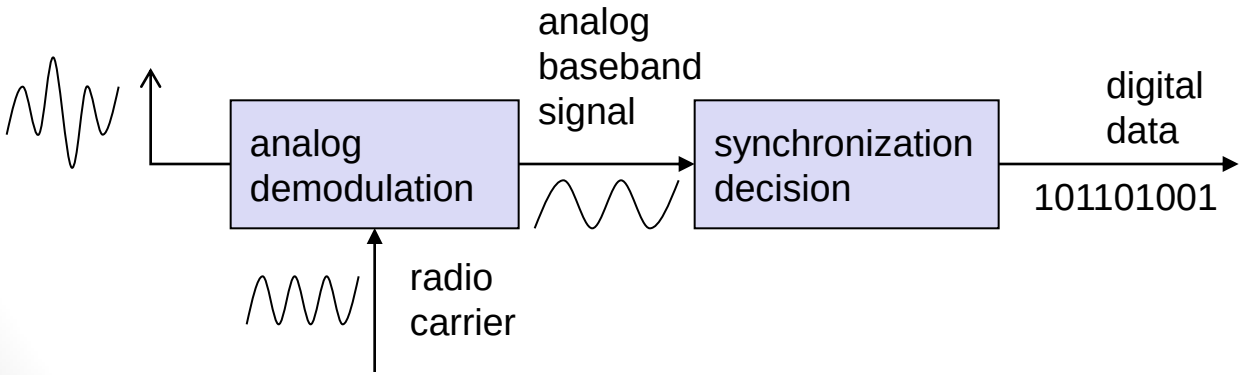
Modulation

- Digital modulation
  - digital data is translated into an analog signal (baseband)
  - ASK, FSK, PSK - main focus in this lecture
  - 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



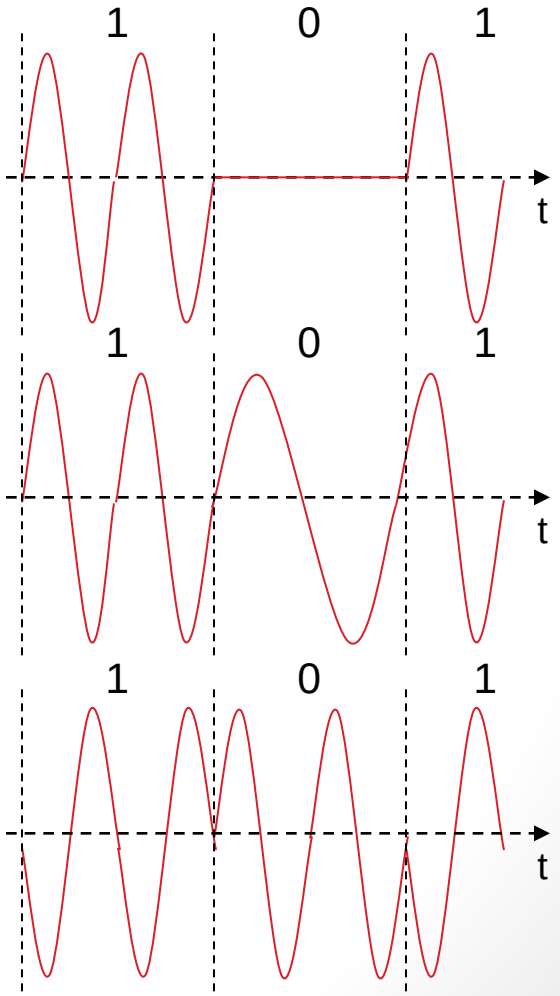
radio transmitter



radio receiver

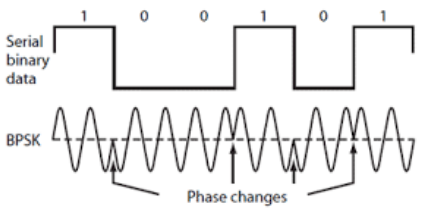
Digital Modulation

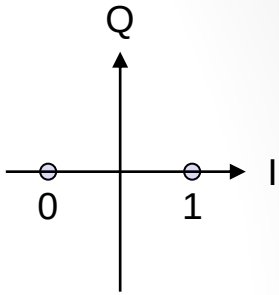
- Modulation of digital signals known as Shift Keying
- Amplitude Shift Keying (ASK):
  - very simple
  - low bandwidth requirements
  - very susceptible to interference
- Frequency Shift Keying (FSK):
  - needs larger bandwidth
- Phase Shift Keying (PSK):
  - more complex
  - robust against interference



Advanced Phase Shift Keying

- BPSK (Binary Phase Shift Keying):
  - bit value 1: sine wave
  - bit value 0: inverted sine wave
  - very simple PSK
  - low spectral efficiency
  - robust, used e.g. in satellite systems
- QPSK (Quadrature Phase Shift Keying):
  - 2 bits coded as one symbol
  - symbol determines shift of sine wave
  - needs less bandwidth compared to BPSK
  - more complex
- 8-PSK !
- DBPSK!

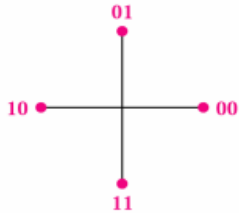




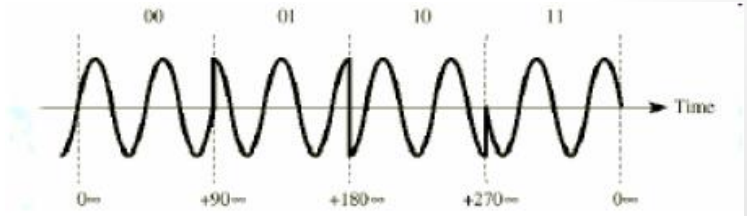
$$s(t) = \begin{cases} A\cos(2\pi f_c t), & \text{binary } 00 \\ A\cos(2\pi f_c t + \frac{\pi}{2}), & \text{binary } 01 \\ A\cos(2\pi f_c t + \pi), & \text{binary } 10 \\ A\cos(2\pi f_c t + \frac{3\pi}{2}), & \text{binary } 11 \end{cases}$$

Dibit	Phase
00	0
01	90
10	180
11	270

Dibit (2 bits)

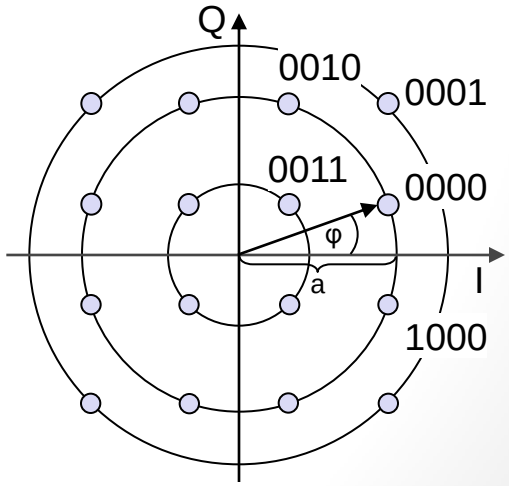


Constellation diagram



Quadrature Amplitude Modulation (QAM)

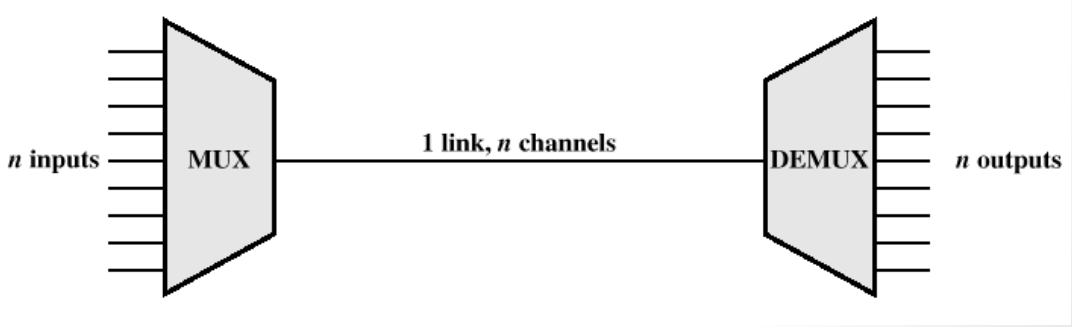
- Quadrature Amplitude Modulation (QAM)
  - combines amplitude and phase modulation
  - it is possible to code n bits using one symbol
  - 2^n discrete levels, n=2 identical to QPSK
- Bit error rate increases with n, but less errors compared to comparable PSK schemes
  - Example: 16-QAM (4 bits = 1 symbol)
  - Symbols 0011 and 0001 have the same phase ϕ, but different amplitude a. 0000 and 1000 have different phase, but same amplitude.



MULTIPLEXING

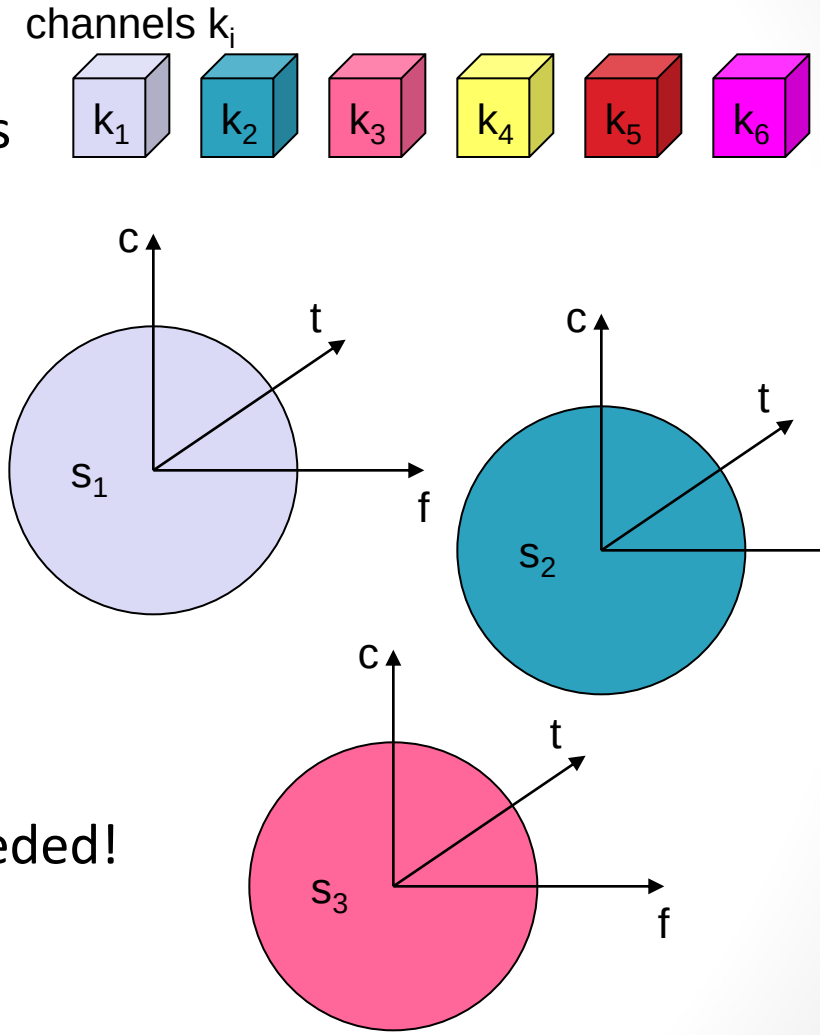
Multiplexing

- Capacity of transmission medium usually exceeds capacity required for transmission of a single signal
- Multiplexing - carrying multiple signals on a single medium
  - More efficient use of transmission medium
- Reasons:
  - Cost per kbps of transmission facility declines with an increase in the data rate
  - Cost of transmission and receiving equipment declines with increased data rate
  - Most individual data communicating devices require relatively modest data rate support



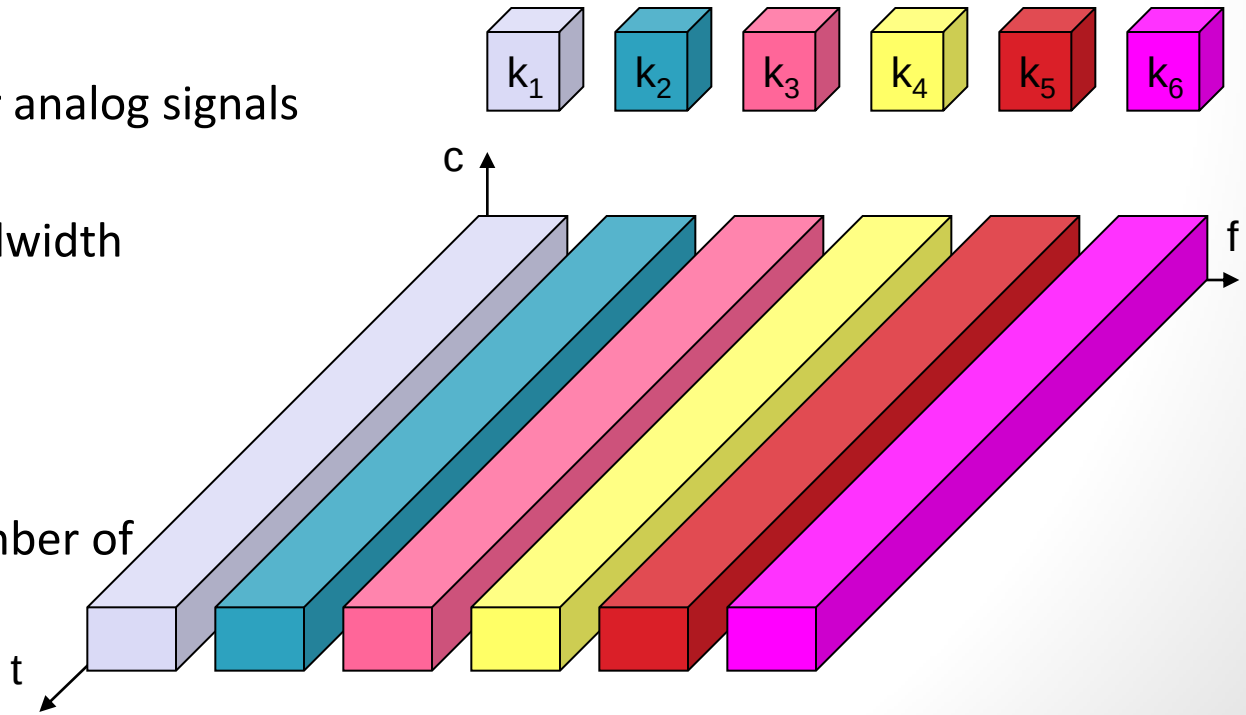
Techniques

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



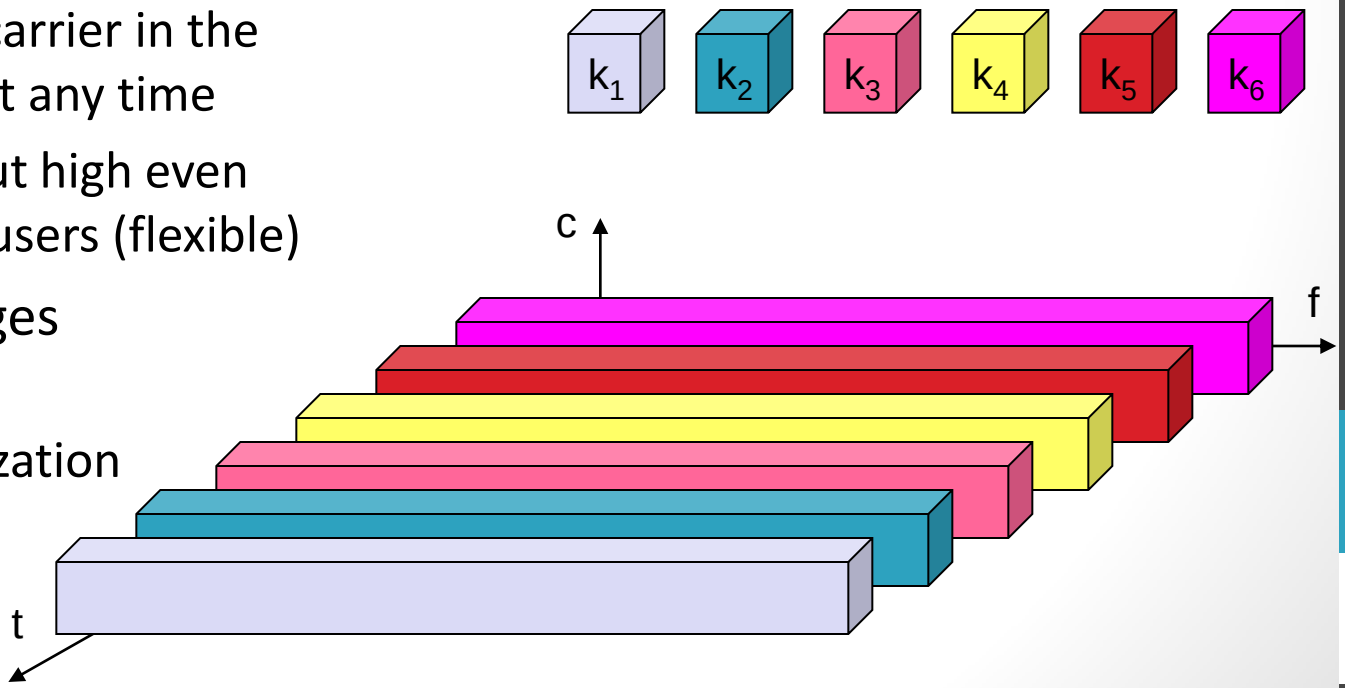
Frequency Multiplex

- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- Takes advantage of the fact that the useful bandwidth of the medium exceeds the required bandwidth of a given signal
- Advantages
  - no dynamic coordination necessary
  - works also for analog signals
- Disadvantages
  - waste of bandwidth if the traffic is distributed unevenly
  - Inflexible and limits the number of senders.



Time Multiplex

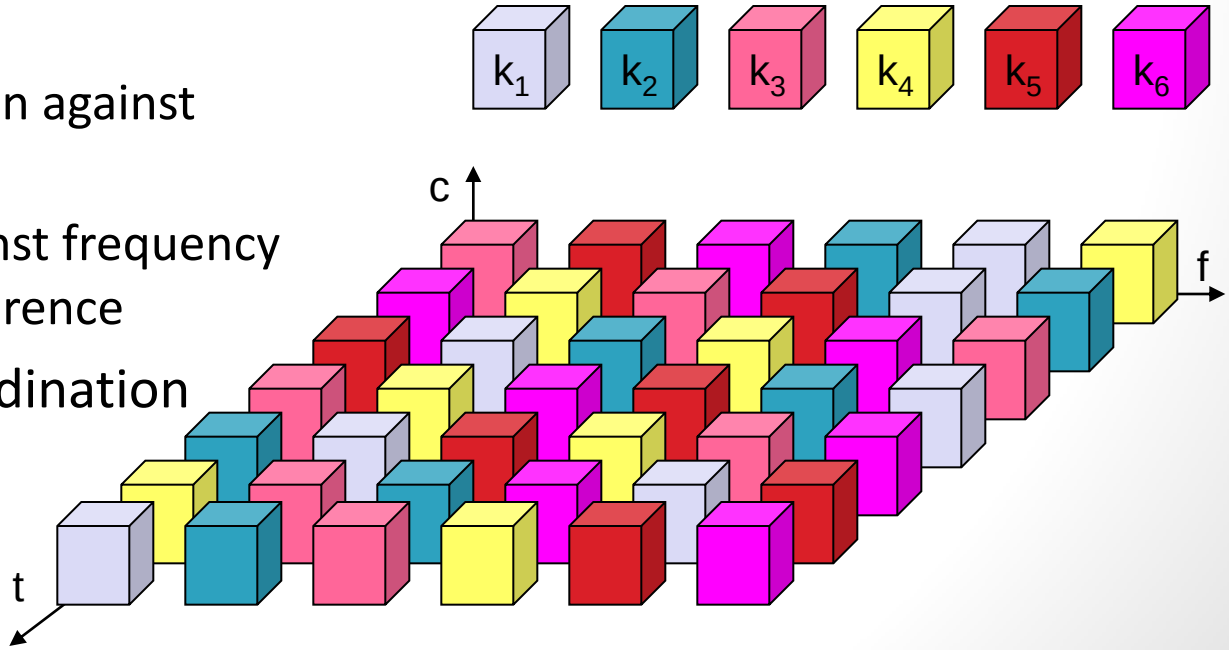
- A channel gets the whole spectrum for a certain amount of time
- Takes advantage of the fact that the achievable bit rate of the medium exceeds the required data rate of a digital signal
- Advantages
  - only one carrier in the medium at any time
  - throughput high even for many users (flexible)
- Disadvantages
  - precise synchronization necessary



Time and Frequency Multiplex

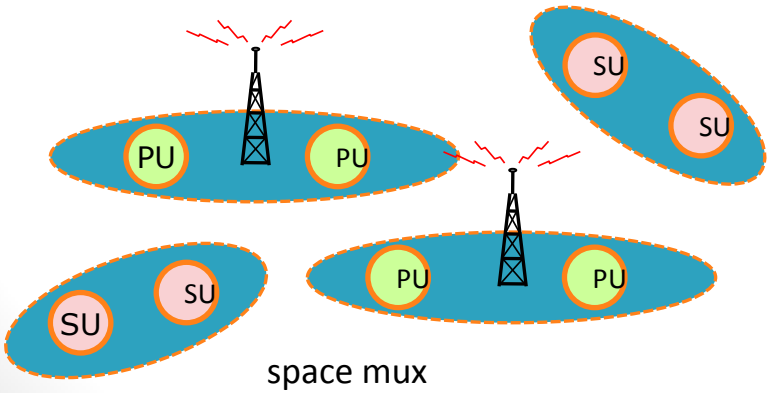
- Combination of both methods
- A channel gets a certain frequency band for a certain amount of time
- Example: GSM

- Advantages
  - better protection against tapping
  - protection against frequency selective interference
- but: precise coordination required

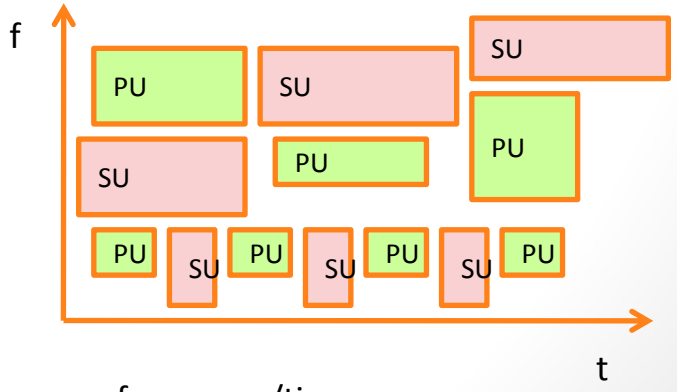


Cognitive Radio

- Typically in the form of a spectrum sensing CR
  - Detect unused spectrum and share with others avoiding interference
  - Choose automatically best available spectrum (intelligent form of time/frequency/space multiplexing)
- Distinguish
  - Primary Users (PU): users assigned to a specific spectrum by e.g. regulation
  - Secondary Users (SU): users with a CR to use unused spectrum
- Examples
  - Reuse of (regionally) unused analog TV spectrum
  - Temporary reuse of unused spectrum e.g. of pagers, amateur radio etc.

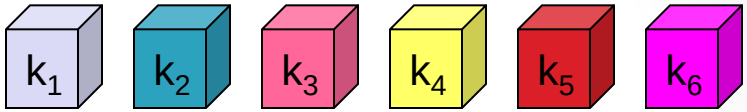


space mux

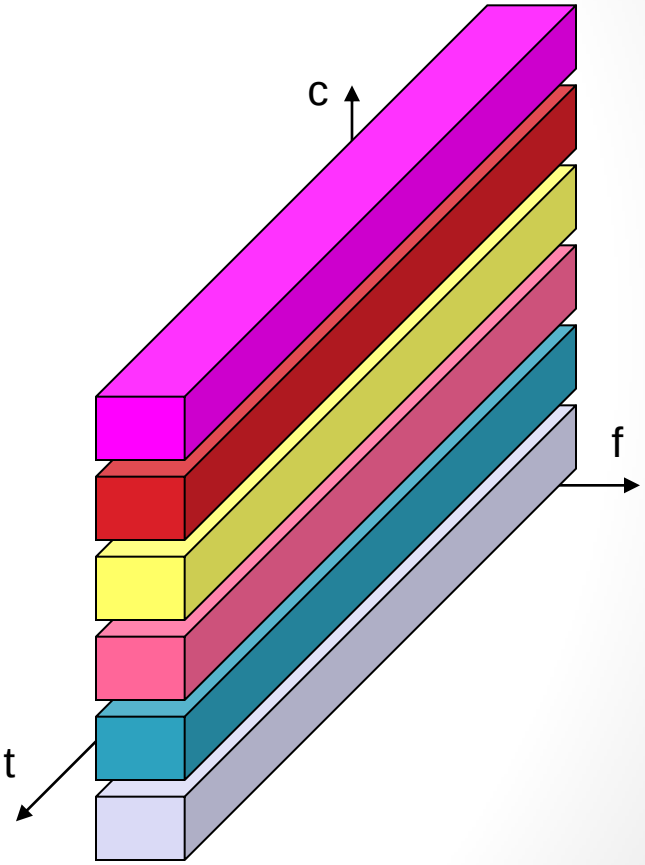


frequency/time mux

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
  - varying user data rates
  - more complex signal regeneration
- Implemented using spread spectrum technology

- For more details, refer to:
  - Chapter 2, J. Chiller, Mobile Communications, 2003.
  - Chapter 2, W. Stallings, Wireless Communications and Networks, 2005.
- The lecture is available onlin e at:
  - https://speakerdeck.com/ahmad_elbanna
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  - ahmad.elbanna@fes.bu.edu.eg