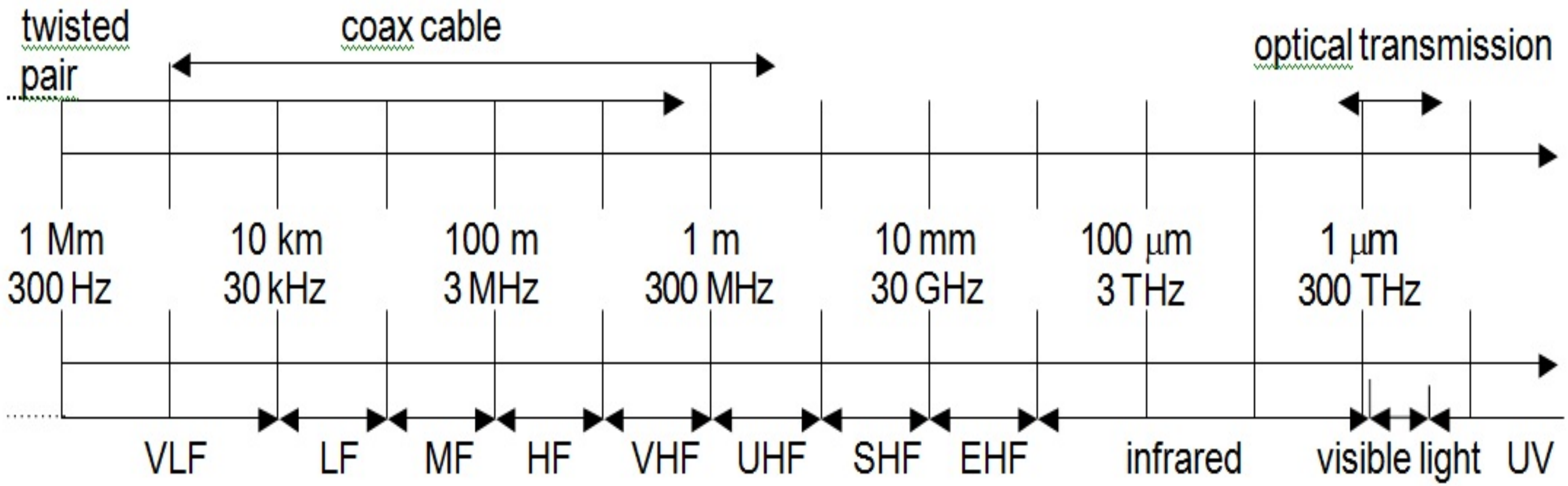
Mobile Computing – Wireless Transmission

- **Wireless Transmission**: It is based on the frequencies selected
  - Frequencies needs to be regulated
  - Modulation is needed to transmit digital data via certain frequencies.
- Frequency and wavelength:
  - $\lambda = c/f$
  - Wavelength λ, speed of light c, frequency f

Frequencies for radio transmission



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

Usage of Different Frequencies

- VLF, LF, MF, HF are not used for wireless
  - E.g used by submarines so that it can penetrate water
- VHF/UHF – ranges are used for mobile radio
  - For TV
  - Simple , small antena for cars
  - Deterministic propagation characteristics, reliable connections
- SHF and higher frequencies are used for radio links, satellite communication
  - Microwave
  - Beam forming
  - Large bandwidth
- Wireless LANs use frequencies in UHF to SHF range
  - Optical transmission e.g fibre optical links

Frequency Regulation

- **ITU** : International Telecommunication Union located at Geneva is responsible for worldwide coordination of telecommunication activities
  - It handles frequency planning, regulation and moderation
  - It takes care of periodic decision on frequency allocation for different regions

Frequency Regulation

ITU-R holds auctions for new frequencies, manages frequency bands worldwide (WRC, World Radio Conferences)

	Europe	USA	Japan
Cellular Phones	**GSM** 450-457, 479-486/460-467,489-496, 890-915/935-960, 1710-1785/1805-1880 **UMTS** (FDD) 1920-1980, 2110-2190 **UMTS** (TDD) 1900-1920, 2020-2025	**AMPS**, **TDMA**, **CDMA** 824-849, 869-894 **TDMA**, **CDMA**, **GSM** 1850-1910, 1930-1990	**PDC** 810-826, 940-956, 1429-1465, 1477-1513
Cordless Phones	**CT1+** 885-887, 930-932 **CT2** 864-868 **DECT** 1880-1900	**PACS** 1850-1910, 1930-1990 **PACS-UB** 1910-1930	**PHS** 1895-1918 **JCT** 254-380
Wireless LANs	**IEEE 802.11** 2400-2483 **HIPERLAN 2** 5150-5350, 5470-5725	902-928 **IEEE 802.11** 2400-2483 5150-5350, 5725-5825	**IEEE 802.11** 2471-2497 5150-5250
Others	**RF-Control** 27, 128, 418, 433, 868	**RF-Control** 315, 915	**RF-Control** 426, 868

Signals

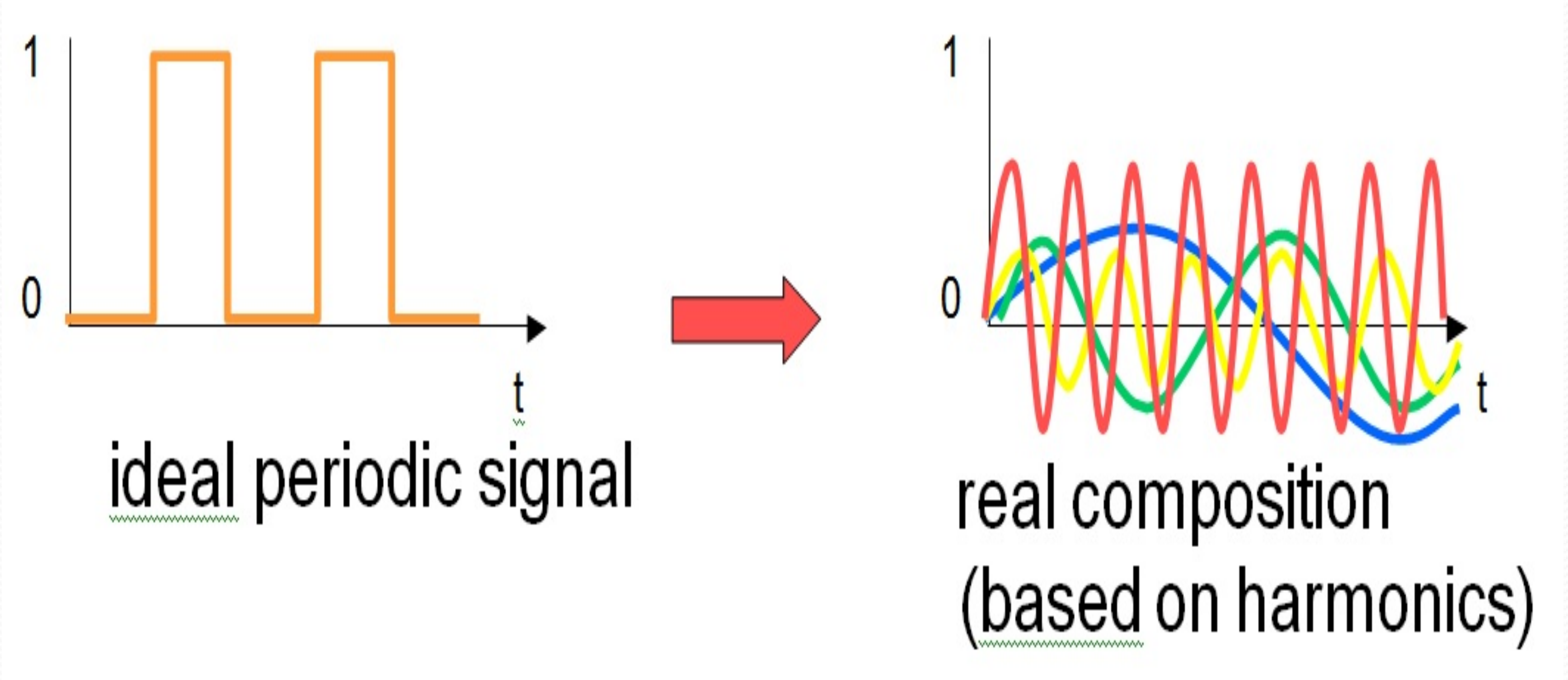
- Signal is a physical representation of data
- It acts as a function of time and location
- **Signal parameters:** parameters represent the value of data
- **Classification**
  - Continuous time/discrete time
  - Continuous values/discrete values
  - Analog signal = continuous time and continuous values
  - Digital signal = discrete time and discrete values
- Signal parameters of periodic signals:
  period T, frequency f=1/T, amplitude A, phase shift Φ

Signals (Sign Wave & Fourier Signal)

$$s(t) = A_t \sin(2\pi f_t t + \varphi_t)$$

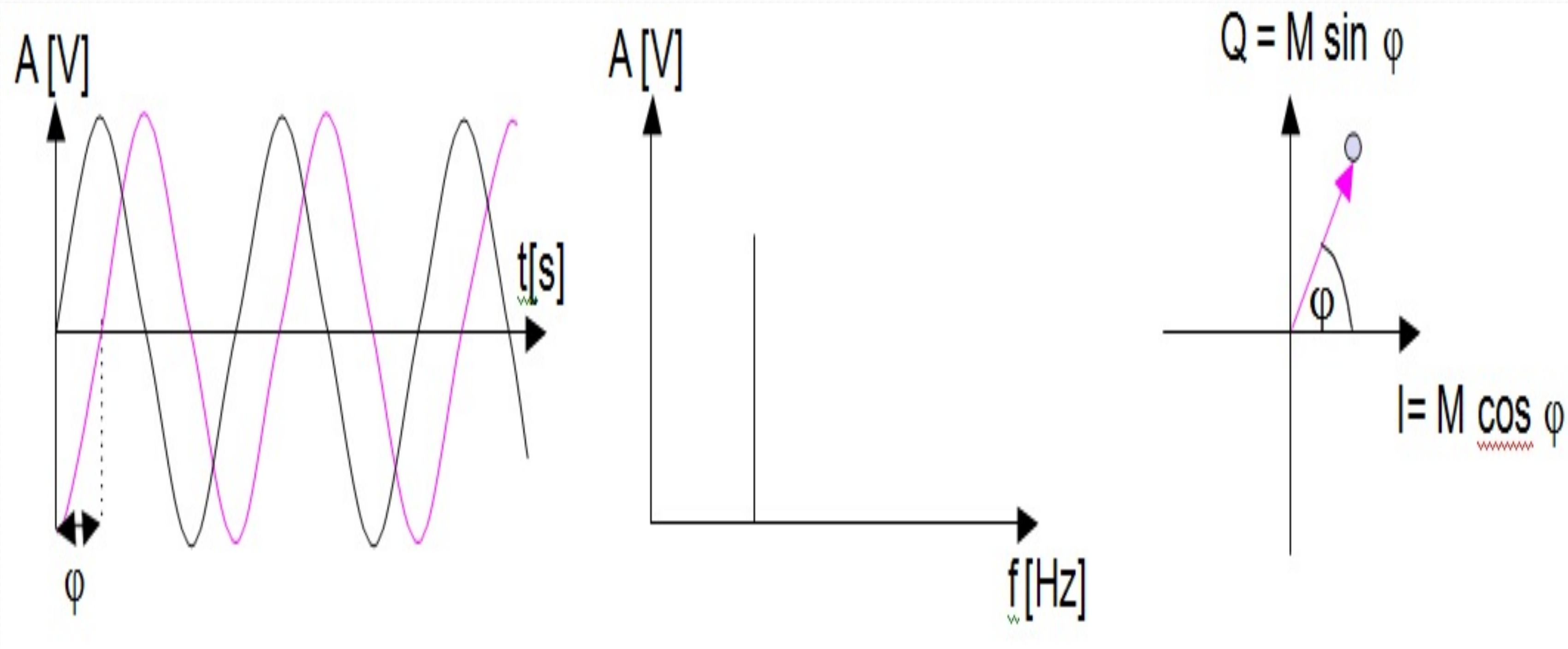
$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2pnft) + \sum_{n=1}^{\infty} b_n \cos(2pnft)$$

Signal (Analog & Digital Representation)



Different Representations of Signals

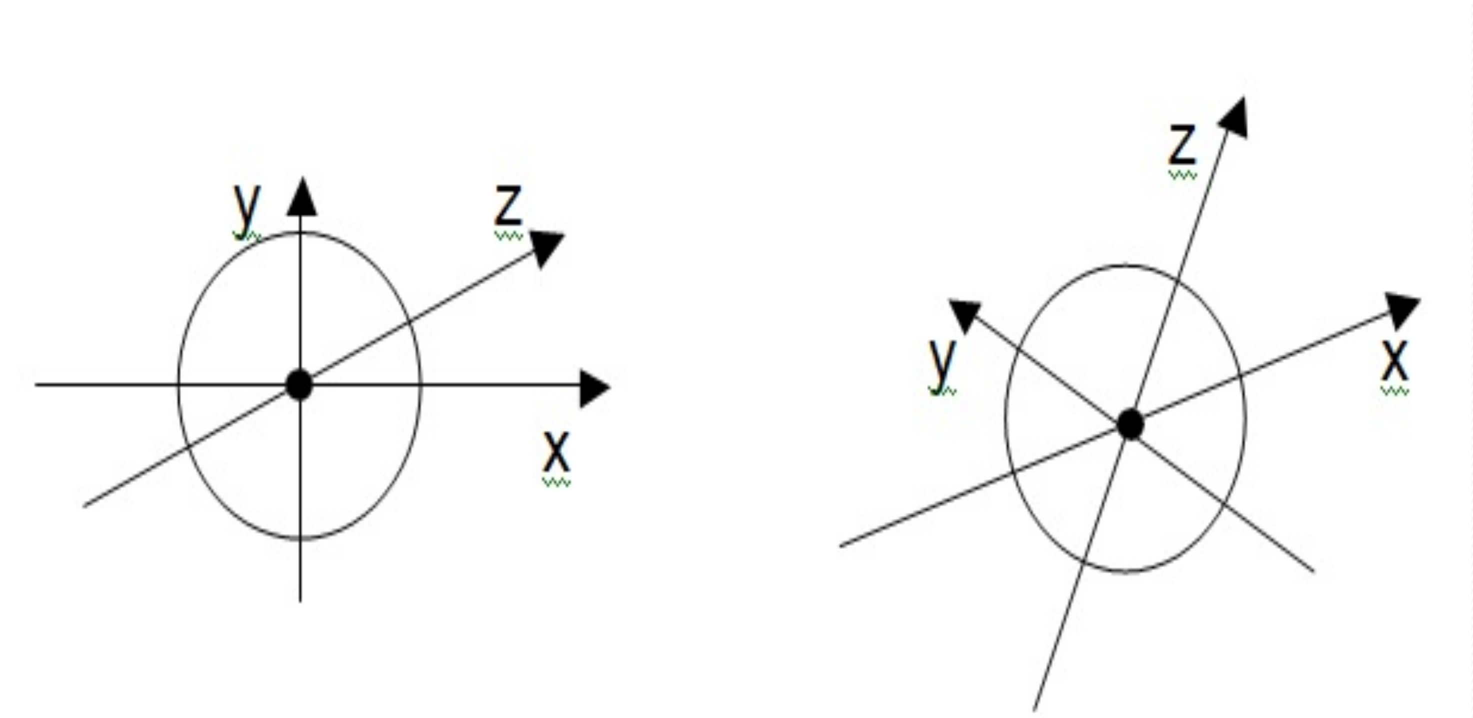
- Signal Amplitude is represented in three forms:
  - Time domain
  - Frequency domain
  - Phase domain



Antennas

- **Antenna:** It is used for the radiation and reception of electromagnetic waves, coupling of wires for radio transmission
- **Isotropic radiator:** theoretical reference antenna that radiates equal radiation in all directions (three dimensions)
- **Real antenna**: consists of directive effects (vertical and horizontal)
- **Radiation pattern:** measurement of radiation around an antenna

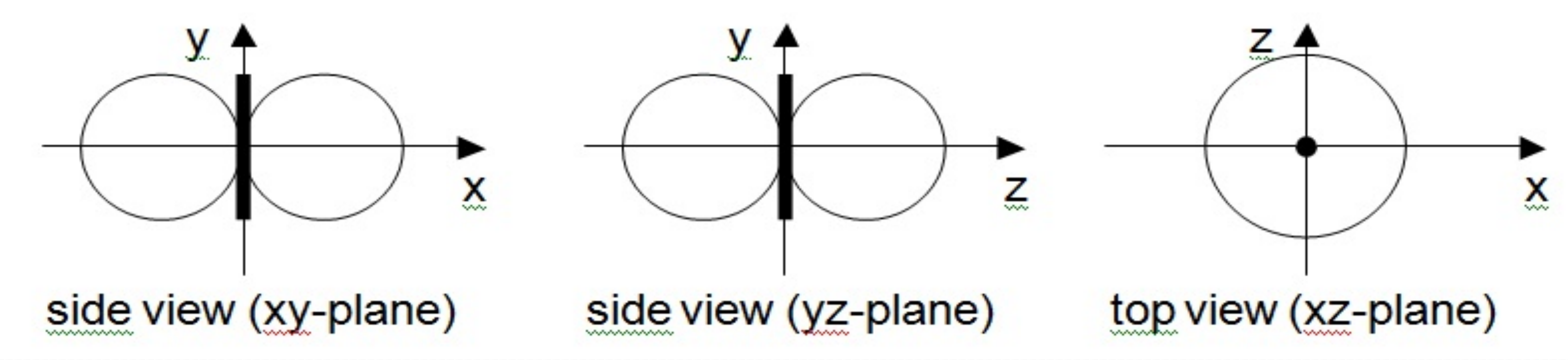
Isotropic Radiator



Antennas: simple dipoles

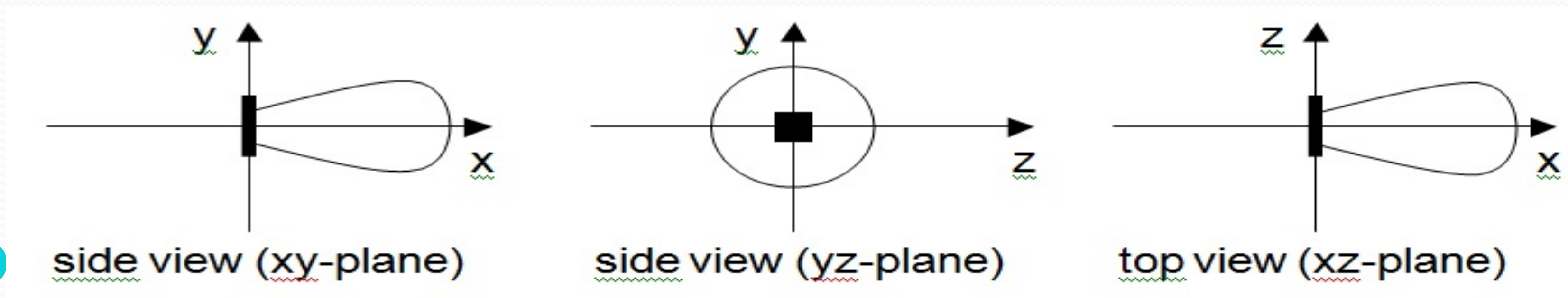
- **Real antennas**: are not isotropic radiators but dipoles with lengths λ/4 on car roofs or λ/2 as Hertzian dipole
  - Shape of antenna proportional to wavelength

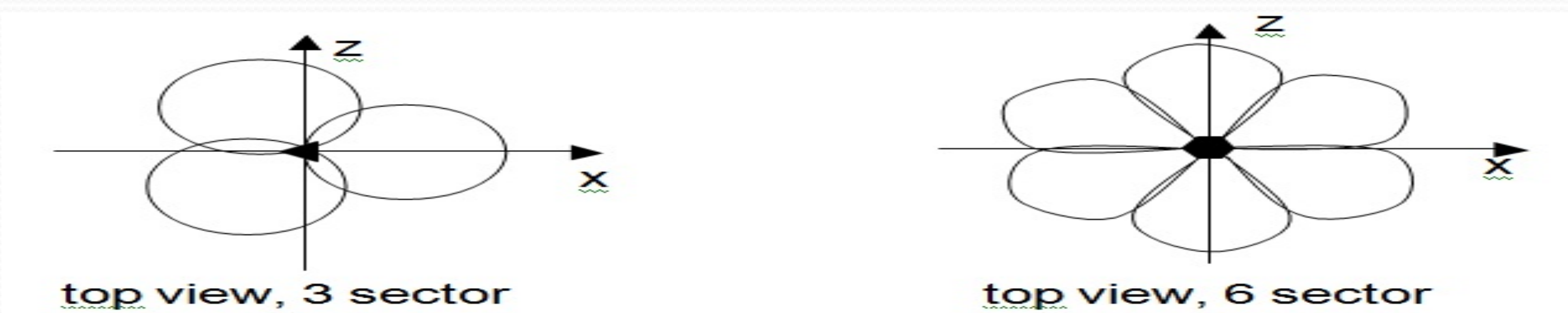
  - Example: Radiation pattern of a simple Hertzian dipole



Antennas: directed and sectorized

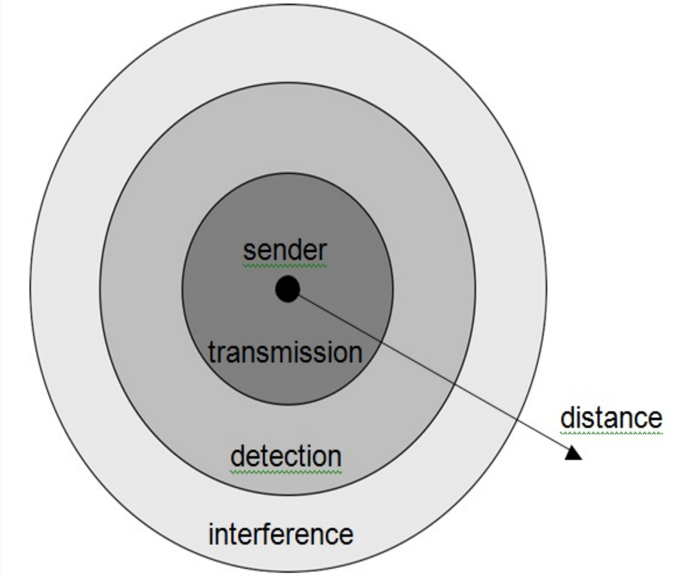
- They are used for microwave connections or base stations for mobile phones (e.g radio coverage for certain region)
- **Directed:**





Signal Propagation Ranges

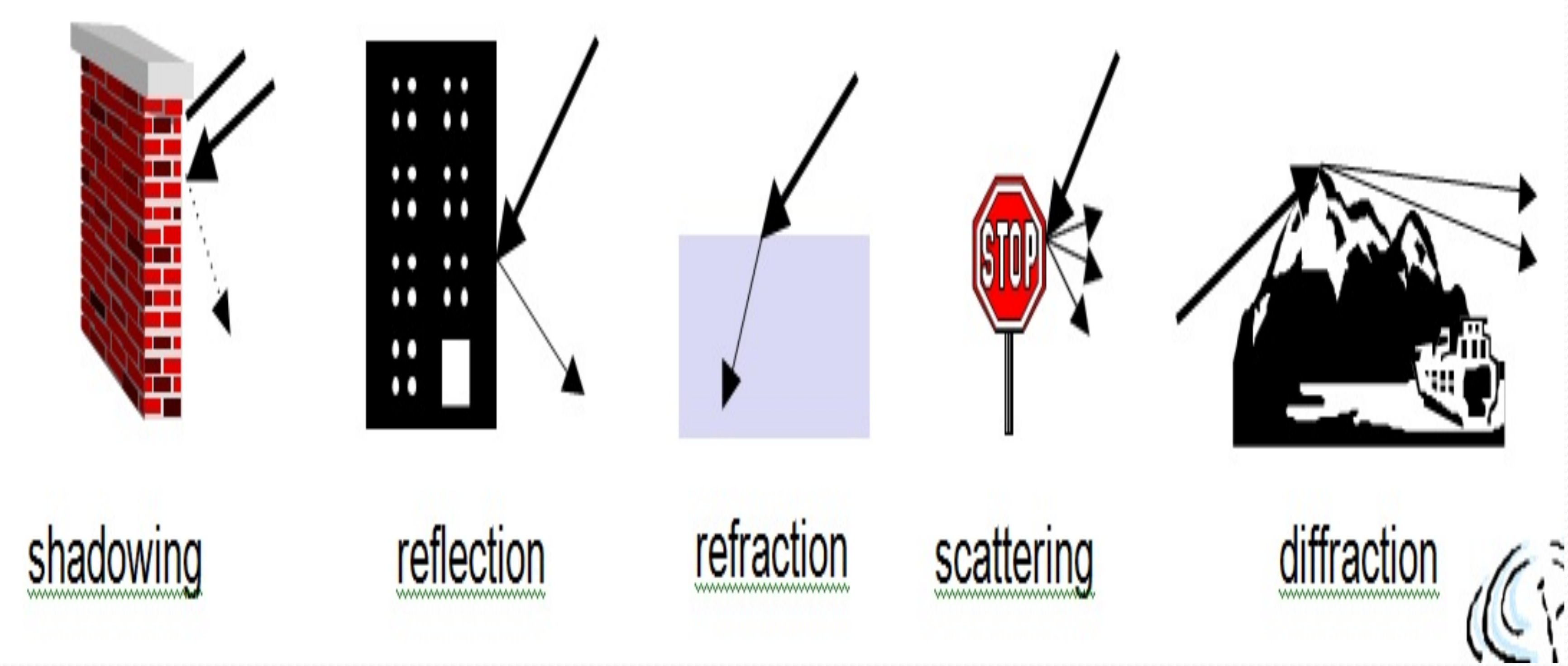
- **Transmission Range**
  - Communication possible
  - Low error rate
- **Detection Range**
  - Detection of the signal possible
  - No communication possible
- **Interference Range**
  - Signal may not be detected
  - Signal adds to the background noise



Signal Propagation Effects

- Propagation in free space always travels like light (straight line)
- Receiving power is proportional to 1/d (d – distance between sender and receiver)
- Receiving power is influenced by following:
  - Fading (frequency dependent)
  - Shadowing
  - Reflection at large obstacles
  - Refraction depending on the density of a medium
  - Scattering at small obstacles
  - Diffraction at edges

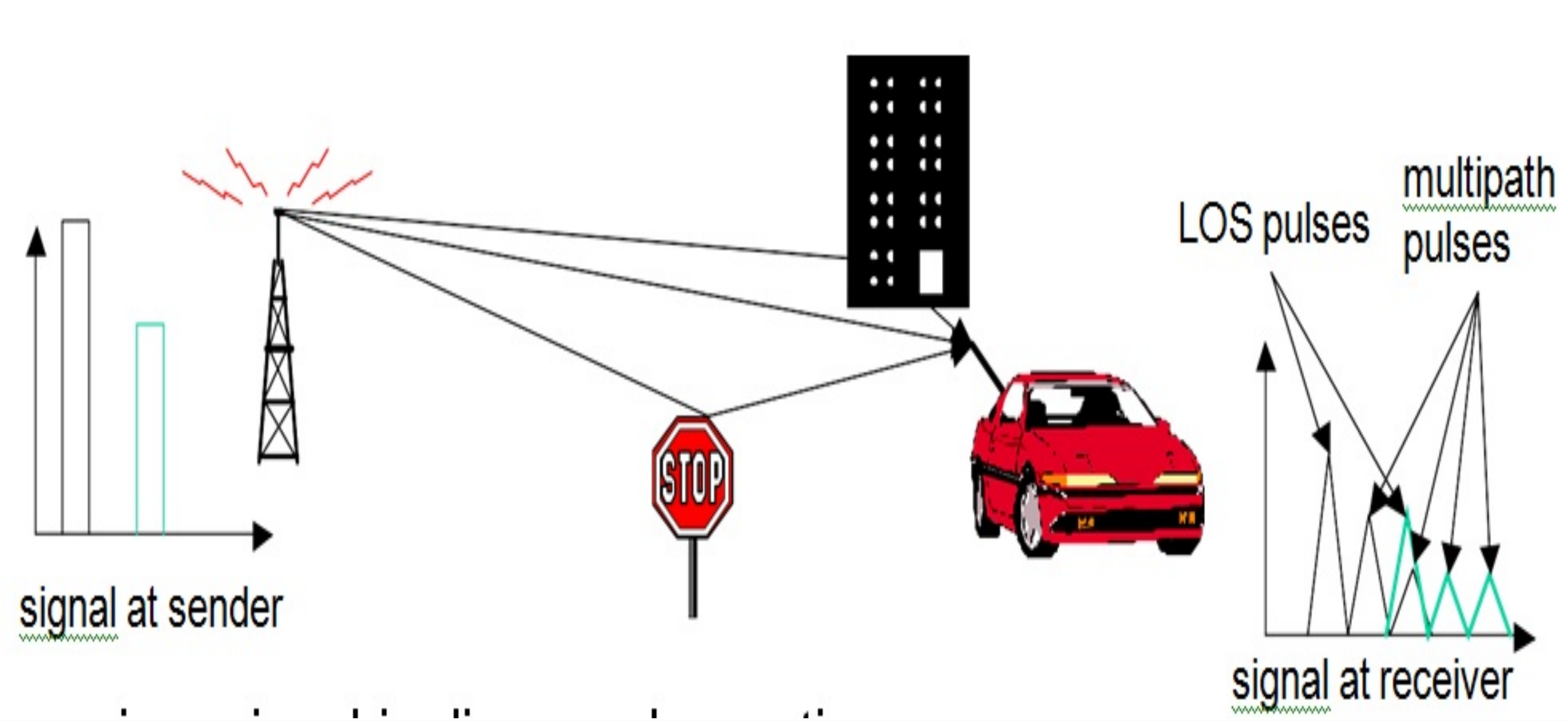
Signal Propagation Effects



Multipath Propagation

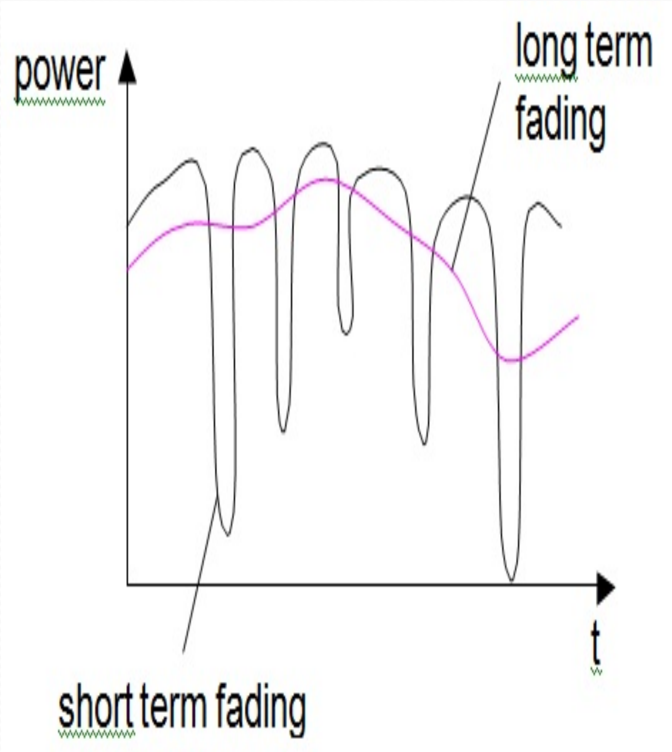
- Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction
  - **Time dispersion:**
    - Signal is dispersed over time
      - Interference with neighbour symbols, Inter Symbol Interference (ISI)
      - Signal reaches the receiver but with **phase shifted**
      - **Distorted signal** depending on the phases of different parts
- **Delay Spread:** signals travelling along different paths with different lengths arrive at the receiver at different times.

Multipath Propagation Example



Effects of Mobility

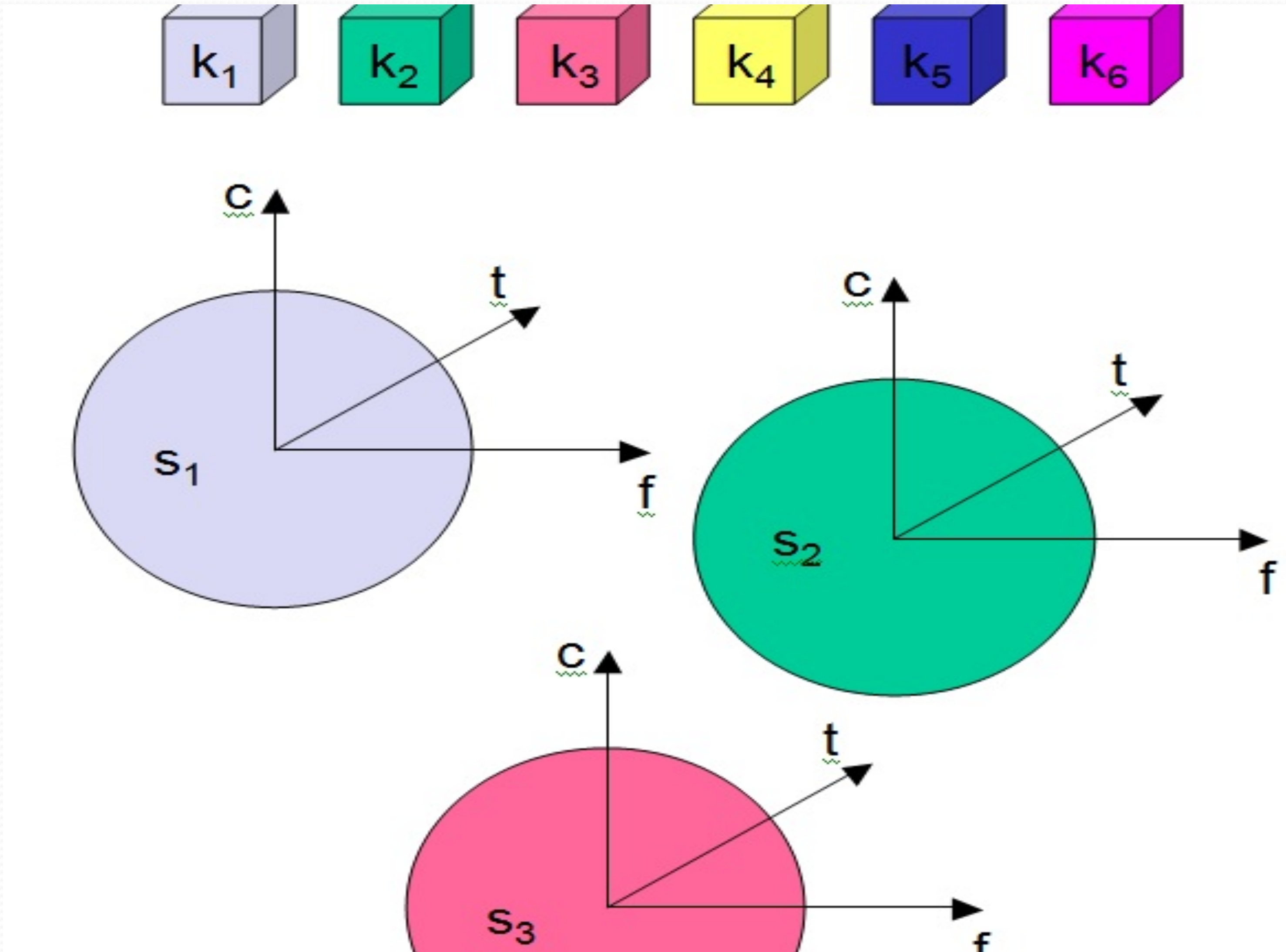
- Channel characteristics change over time and location
  - Signal path change
  - Different delay variations of different signal parts
  - Different phases of signal parts
- **Two types of fadings**
  - **Short term fading:**
    - quick changes in the power received
  - **Long term fading:**
    - slow changes in the power received



Multiplexing

- **Multiplexing**: It describes how several users can share a medium with minimum or no interference.
  - **Goal:** to make maximum use of shared medium
  - E.g highway example – highways with several lanes
    - Many users (cars) use the same medium (highways) with no interference (accidents). This is possible because of several lanes (space division multiplexing).
    - Also many users (cars) can use the same lane at different time (time division multiplexing).
- **Four ways of multiplexing**
  - Space (s)
  - Time (t)
  - Frequency (f)
  - Code (c)
- **Guard space**: space between the interference ranges.

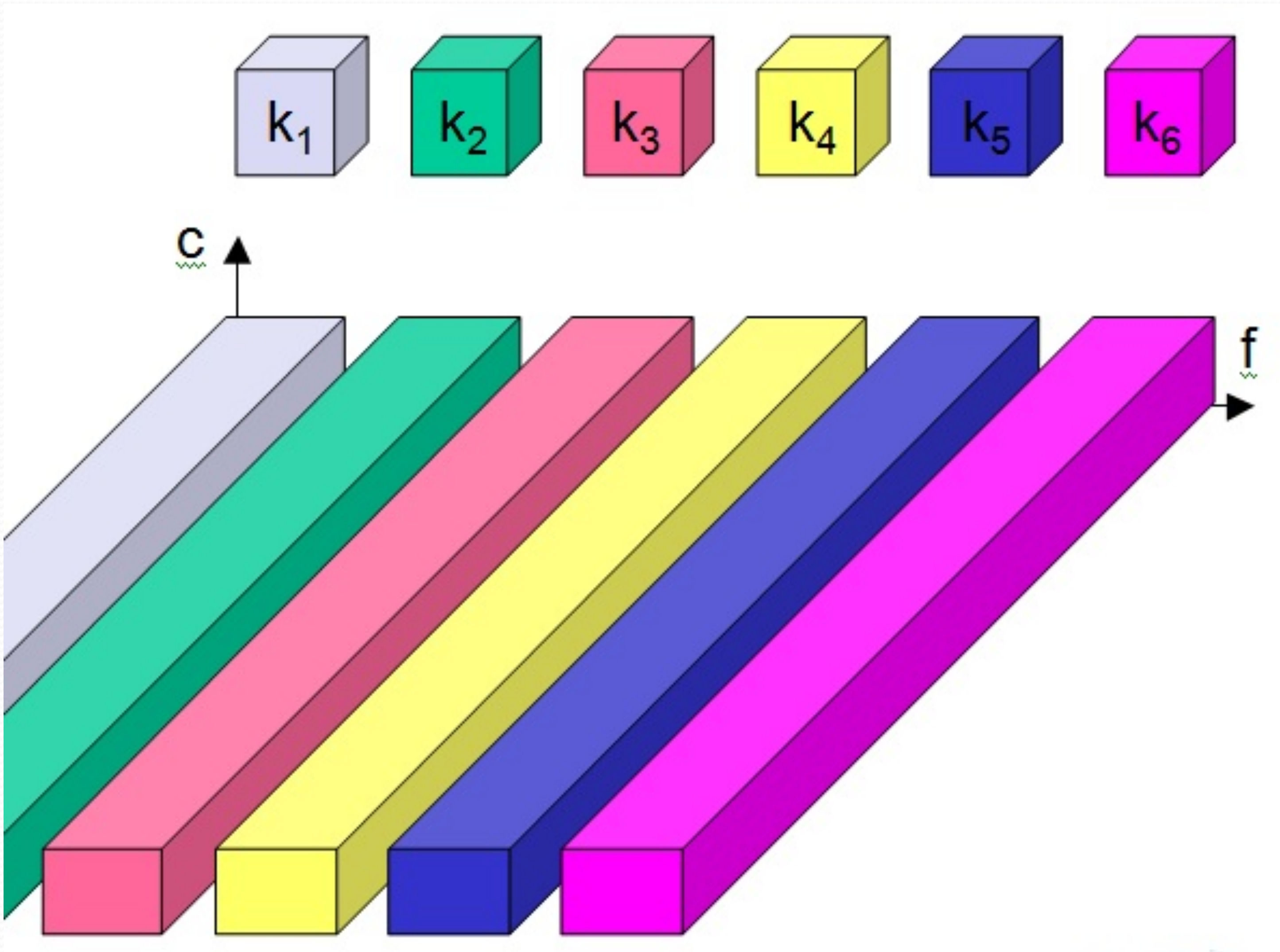
Space Division Multiplexing



Frequency Division Multiplexing

- Separation of the whole spectrum into smaller frequency bands.
  - Channel gets a certain band of the spectrum for the whole time
- **Advantages:**
  - No dynamic coordination needed
- **Disadvantages:**
  - Wastes bandwidth if the traffic is distributed unevenly
  - Inflexible

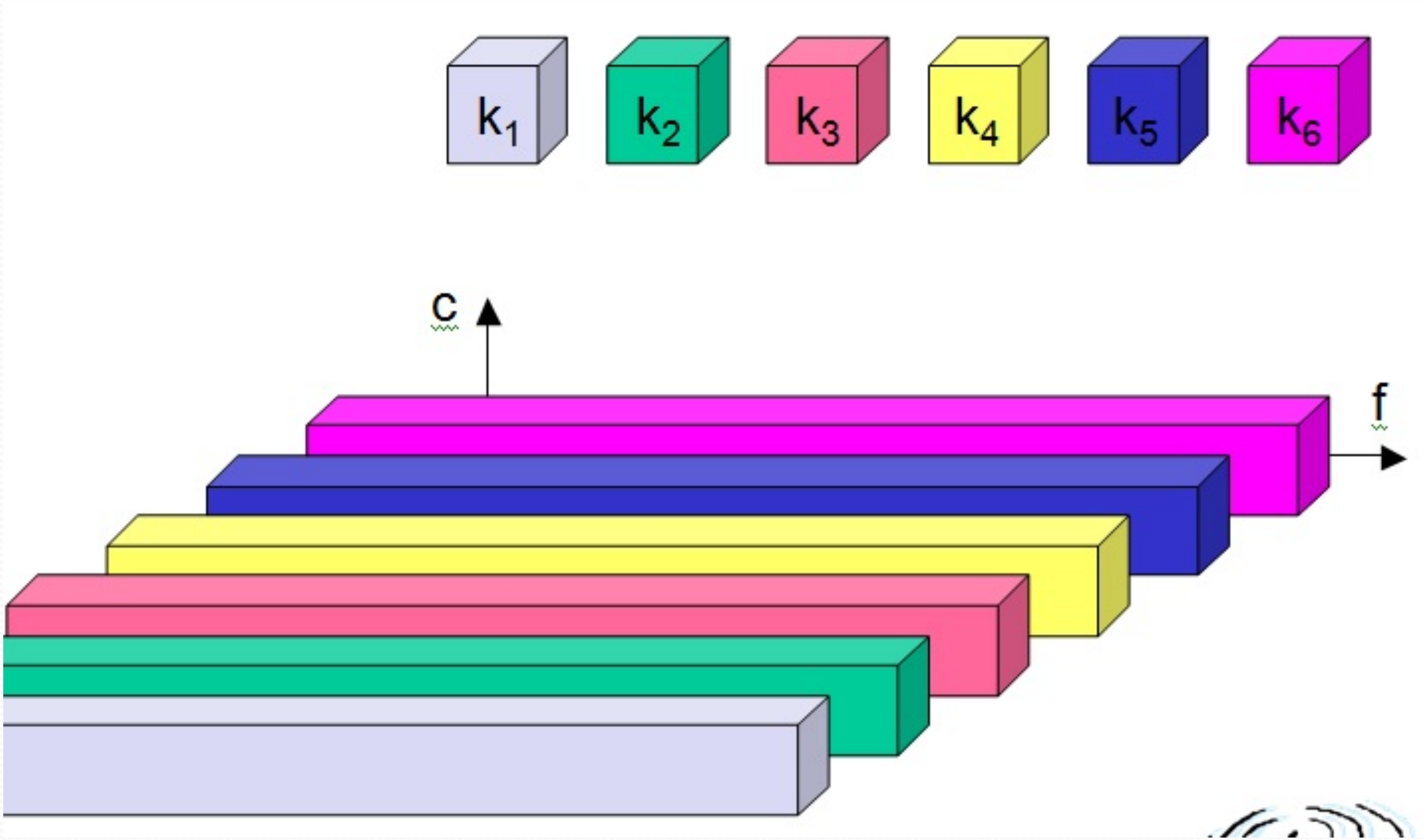
Frequency Division Multiplexing



Time Division Multiplexing

- Channel gets the whole spectrum for a certain amount of time
- **Advantages:**
  - Only one carrier in the medium at any given time
  - High throughput
- **Disadvantages:**
  - Requires precise synchronization

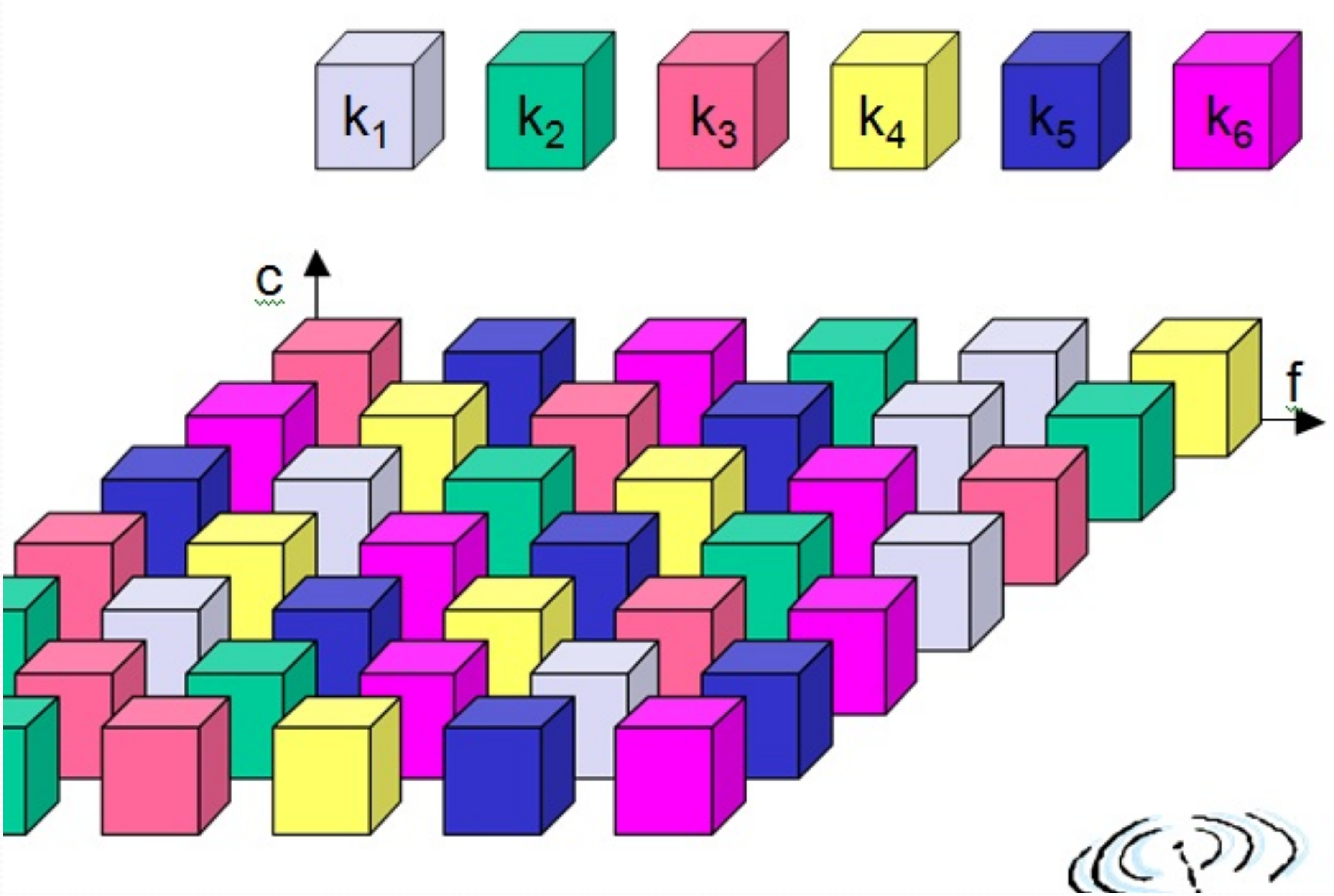
Time Division Multiplexing



Frequency & Time Division Multiplexing Combined

- Combination of both: A channel gets a certain frequency band for a certain amount of time
  - E.g GSM
- **Advantages:**
  - Better protection against tapping
  - Protection against frequency selective interference
  - Higher data rates
- **Disadvantages:**
  - Requires precise coordination

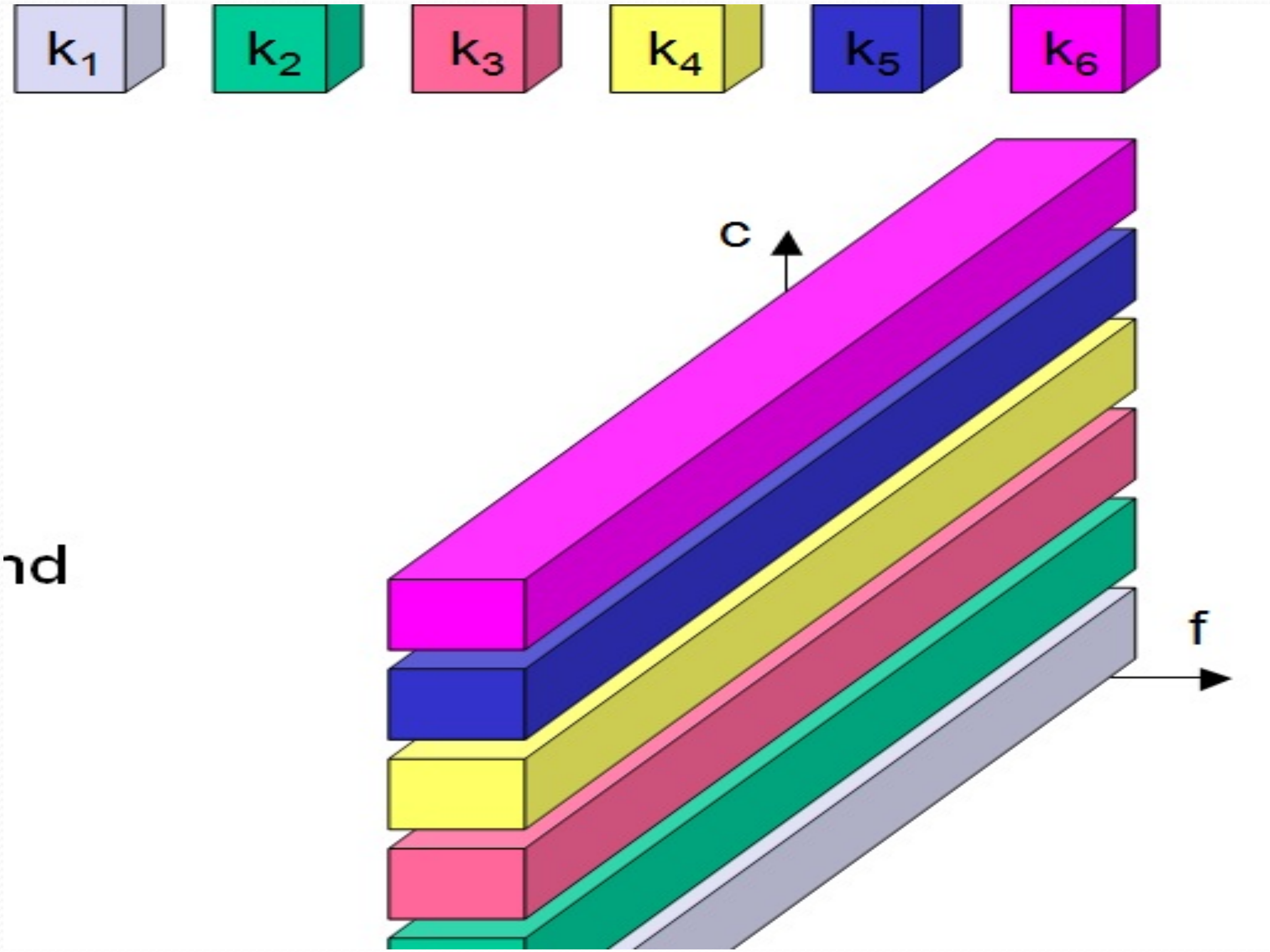
Frequency & Time Division Multiplexing



Code Division Multiplexing

- 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:**
  - More complex signal generation

Code Division Multiplexing



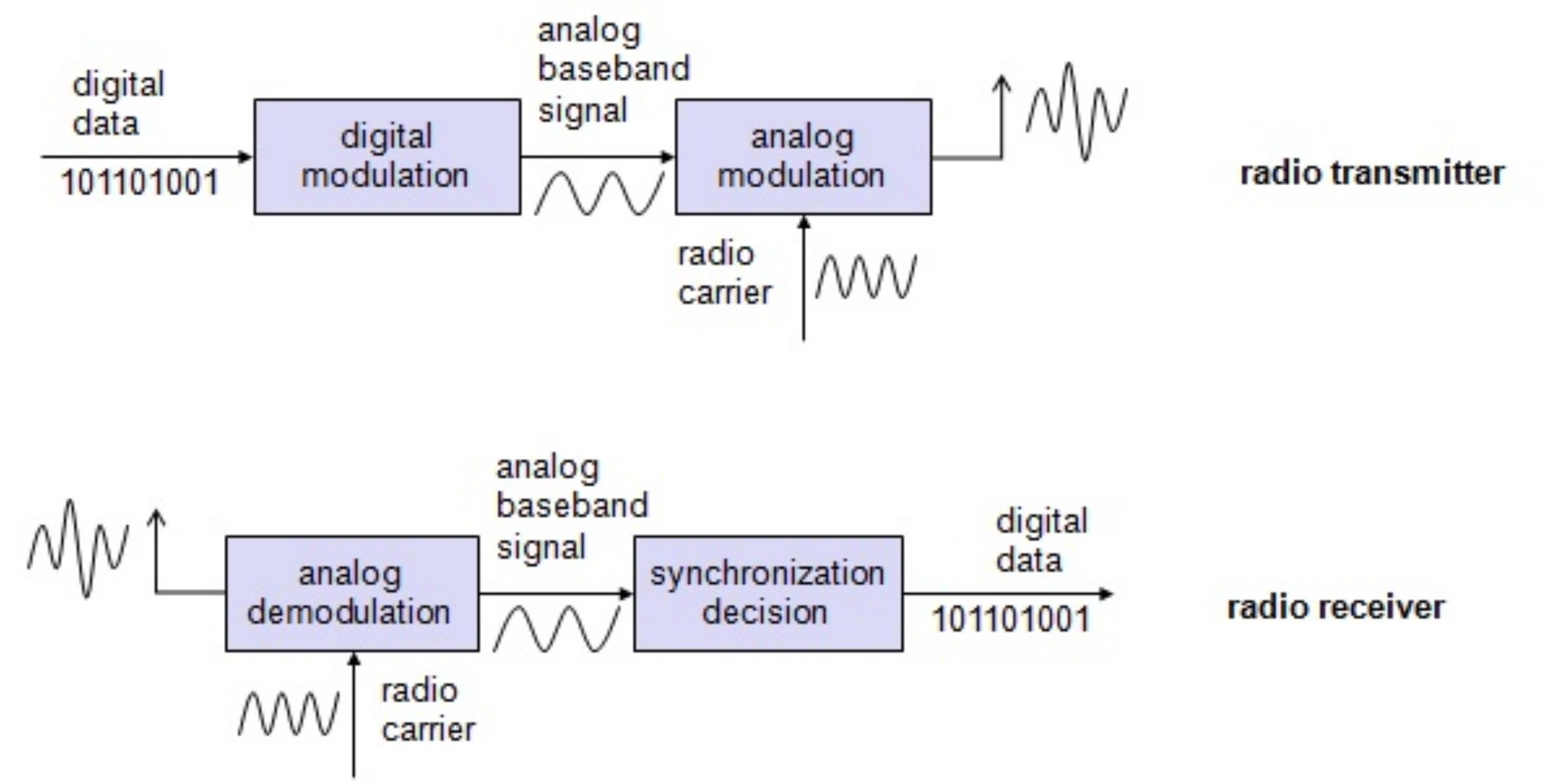
Modulation

- Digital modulation
  - digital data is translated into an analog signal (baseband)
  - Three techniques of modulation
    - Amplitude Shift Keying (ASK)
    - Frequency Shift Keying (FSK)
    - Phase Shift Keying (PSK)
  - Modulation schemes consists of differences in spectral efficiency, power efficiency, robustness
- Need for **Analog Modulation**:
  - Shifts center frequency of baseband signal upto the radio carrier
- Reasons to enhance baseband signal
  - Antennas are smaller in size
  - FDM technique shortcomings
  - Medium characteristics

Modulation Schemes

- Amplitude Modulation (AM)
  - Used in electronic communication for transmitting messages with a radio wave.
  - Amplitude (signal strength) of the carrier wave is varied in proportion to that of the message signal, such as an audio signal
- Frequency Modulation (FM)
  - It is used for the encoding of information in a carrier wave by changing the instantaneous frequency of the wave
- Phase Modulation (PM)
  - It encodes the message signal as variations in the instantaneous phases of a carrier wave.
  - The phase of a carrier signal is modulated to follow the changing signal level of the message signal.

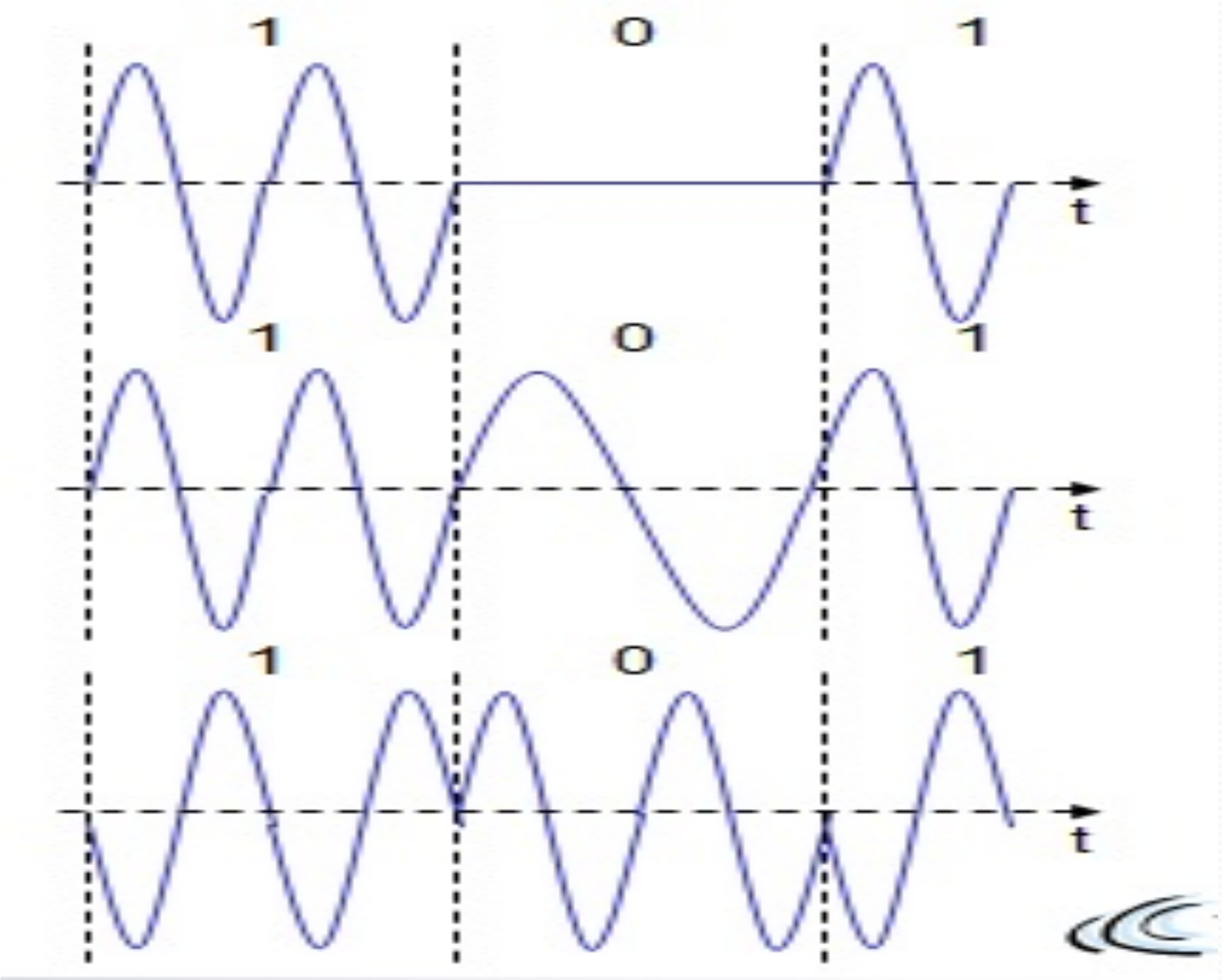
Modulation & Demodulation



Digital Modulation Techniques

- Amplitude Shift Keying (ASK)
  - One amplitude is represented by binary 0 other with 1
  - It needs smaller bandwidth
- Frequency Shift Keying (FSK)
  - Assigns one frequency f1 to the binary 1 and other f2 to binary 0
  - It is implemented by switching between two oscillators (f1 & f2)
  - It needs larger bandwidth
- Phase Shift Keying (PSK)
  - Uses shifts in the phase of a signal to represent data.

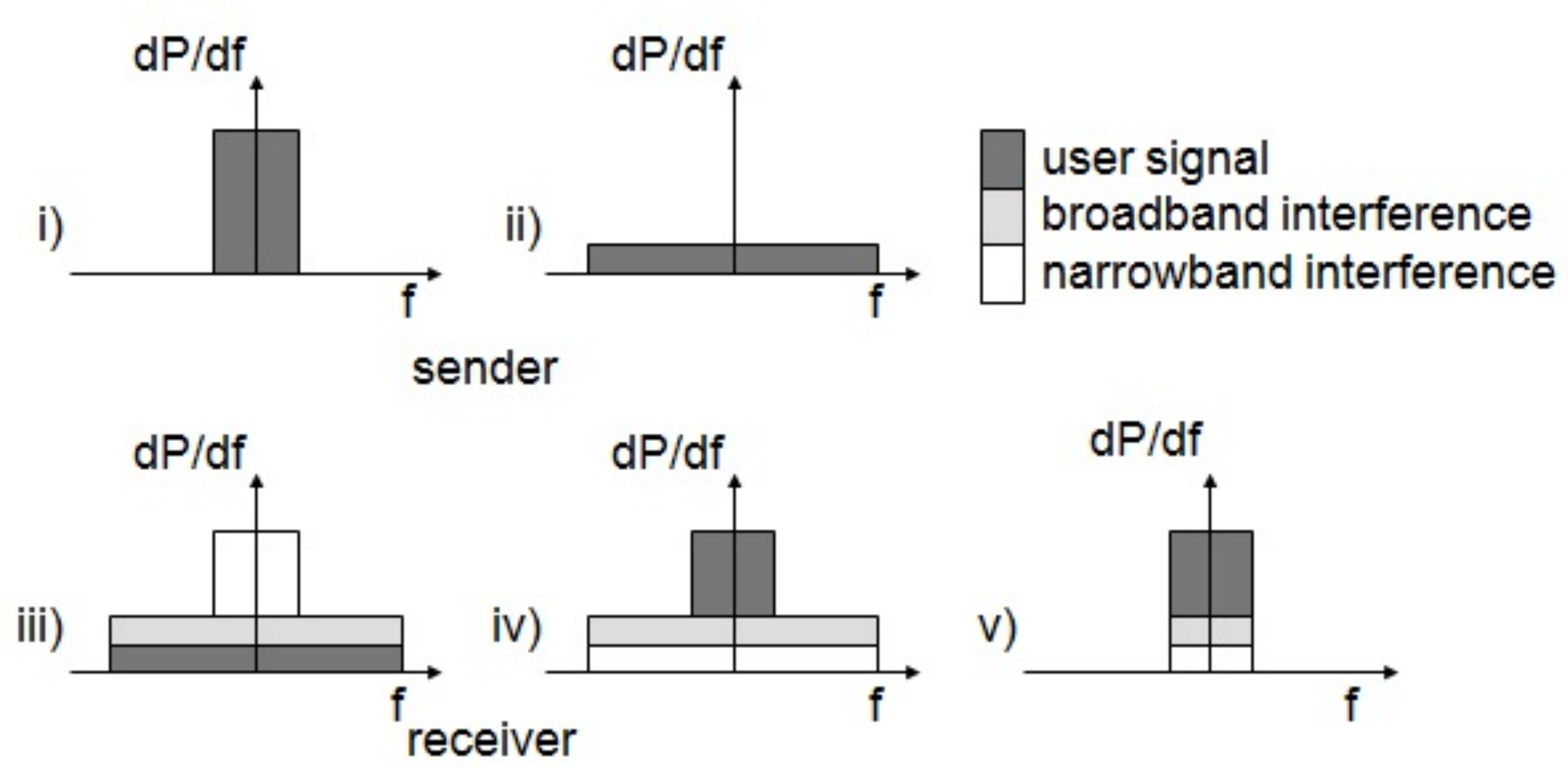
Modulation Techniques - Example



Spread Spectrum

- Spread Spectrum: Narrow band signal is spread into a broad band signal (larger frequency range)
  - **Advantage:** to provide resistance to narrowband interference.
    - **Narrow band interference**: frequency dependent fading can wipe out narrow band signals for duration of the interference.
    - Broad band signal improves the strength and quality of the signal while traversing

Effects of spreading and interference

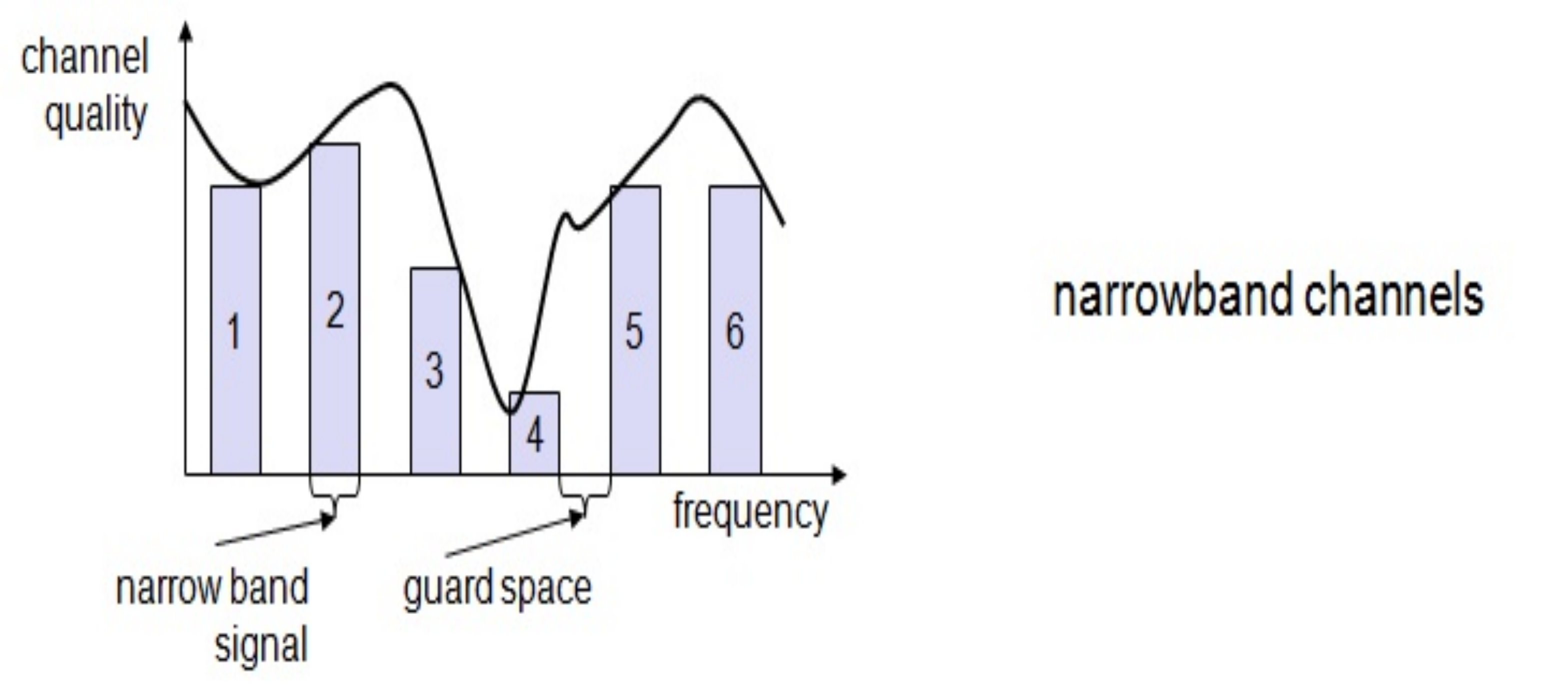


Spreading-Despreading process

- Step 1: narrowband signal from sender of user data
- Step 2: senders spreads the user signal
  - Converts narrowband signal into a broadband signal.
  - While spreading of the signal power of the signal reduces
- Step 3: during transmission, narrowband & broadband interference add to the signal
  - Sum of interference and user signal is received at the receiver end
- Step 4: receiver despreads the user signal.
  - Converts the spread user signal into narrowband signal again, while spreading the narrowband interference and leaving the broadband interference.
- Step 5: receiver applies a bandpass filter to cut off frequencies left and right of the narrowband signal.

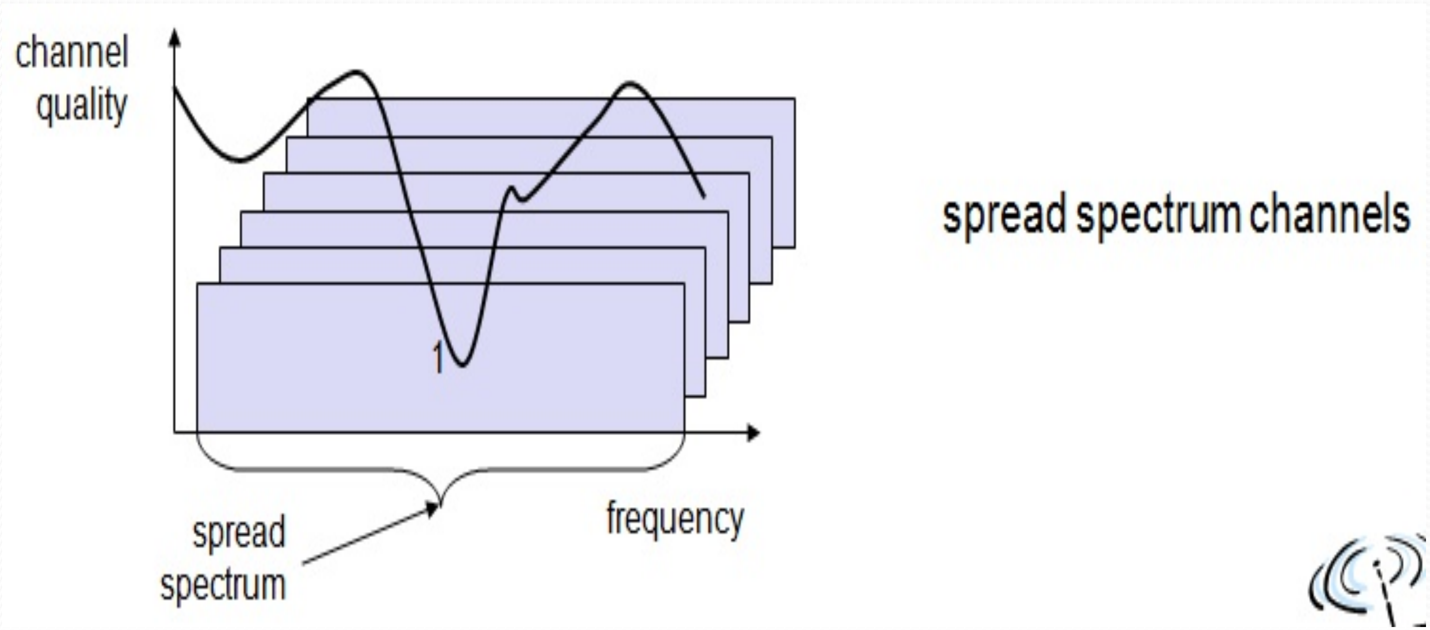
Narrowband Interference without spread spectrum

- With narrowband interference channel quality reduces.
  - Receiver cannot reconstruct the signal



Spread Spectrum to avoid Narrowband Interference

- All narrowband signals are spread into broadband signals.
  - Uses CDM technique that allows each signal to apply its own code to recover the signal.



Cellular Systems

- Cellular systems work on the concept of SDM
  - Each transmitter (base station) covers a certain area **(cell)**
  - Cell radii can vary from tens of meters in building, and hundreds of meters in cities.
  - Mobile stations communicate only via the base station
- A basic analog cellular system, consists of three subsystems: **a mobile unit, a cell site, and a mobile telephone switching office (MTSO)**
  - The cell site provides interface between the MTSO and the mobile units.
    - It has a control unit, radio cabinets, antennas, a power plant, and data terminals.

Cellular Subsystems

- Mobile Unit
  - Radio frequency – receiver/transmitter, digital signal processing, analog/digital conversion, control processor, SIM, power control & battery
- Cell Site
  - It is cell tower or cellular base station where antennas and electronic communication equipments are placed
  - Used to transmit cell phone signals to and from the mobile phone back to the receiver.
  - It includes transmitters/receivers, GPS, backup power sources, base transceiver station (BTS)
- Mobile Telephone Switching Office (MTSO)
  - It contains the switching equipment or mobile switching center for routing mobile phone calls.
  - It also contains the equipment for controlling the cell sites that are connected to the MSC (Mobile Switching Center)

Cellular Systems

- A cellular communication system consists of four major components:
  - public switched telephone network **(PSTN)**
    mobile telephone switching office **(MTSO)**
    cell sites with antenna systems
    mobile subscriber units **(MSU)**.
- Cell phones **use radio waves to communicate**.
  - Radio waves transport digitized voice or data in the form of oscillating electric and magnetic fields- electromagnetic field (**EMF**)
  - Radio waves carry the information and travel in air at the speed of light.
  - Cell phones transmit radio waves in all directions

Cellular Communication Components

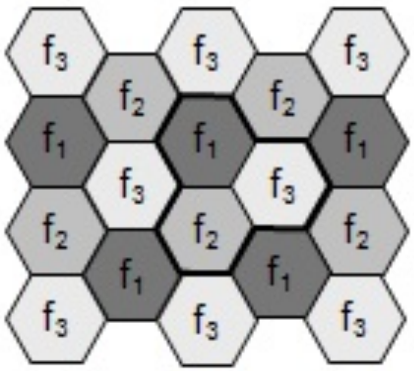
- Public Switched Telephone Network **(PSTN)**
  - It provides infrastructure and services for public telecommunication
  - It is operated by national, regional, or local telephony operators
  - It carries voice calls from phone through the network to the recipient's
- Mobile Telephone Twitching Office **(MTSO**
- Cell sites
- Mobile Subscriber Units **(MSU)**.
  - It consists of a control unit and a transceiver that transmits and receives radio transmissions to and from a cell site

Cell Structure (Advantages & Disadvantages)

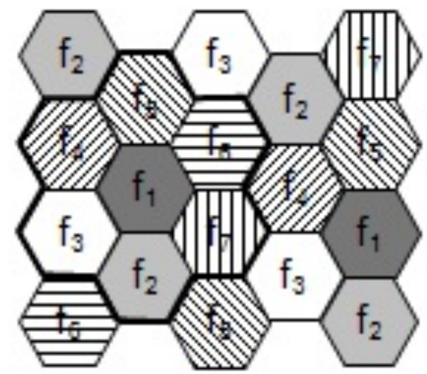
- Advantages of cell structures:
  - Higher capacity, higher number of users
  - Less transmission power needed
  - More robust decentralized
  - Base station deals with interference, transmission area locally
- Disadvantages:
  - Fixed network needed for the base stations
  - Handover (changing from one cell to another) necessary
  - Interference with other cells

Cell Cluster Pattern

- Cells are combined in **clusters**
  - E.g 3 cells or 7 cells clusters
- All cells within a cluster use disjointed sets of frequencies.



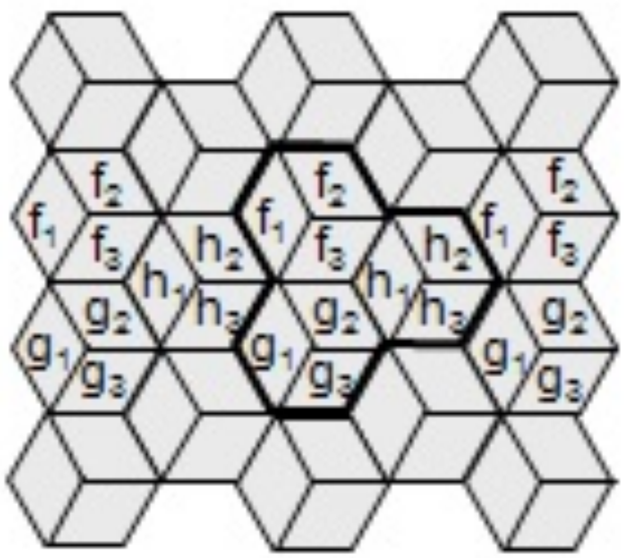
3 cell cluster



7 cell cluster

Cell Cluster Pattern – Sectorized Antenna

- **Sectorized Antenna**: - To reduce interference (under traffic conditions i.e number of users per km)
  - E.g use of three sector s per cell in a cluster with three cells.



3 cell cluster
with 3 sector antennas

Channel Allocation Strategies

- **Fixed Channel Allocation:**
  - Certain frequencies are assigned to a certain cell
  - Used in GSM system
  - **Drawback:**
    - Different traffic load in different cells
      - E.g heavy load in one cell and light load in other
- **Borrowing Channel Allocation:**
  - Cells with more traffic are dynamically allotted more frequencies.
  - Frequencies can be assigned to cells
  - Borrowed frequencies can be blocked in the surrounding cells.

Cell Breathing

- Cellular systems using **CDM** instead of **FDM**
  - Users are separated through the code
  - Cell size depends on the current load.
- **Drawback with CDM**
  - Since CDM is used as more users join, the load increases
- **CDM** cells are said to '**breath**'
  - If the load increases the cell shrinks.
  - **Reason:** higher noise if more users join the cell
    - Try to reduce the strength of the cell, that results some users out of the transmission range