MCA501: Wireless and Mobile Technology

By:

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Syllabus

1. Wireless Technology Fundamentals

Introduction to Mobile and wireless communications, Overview of radio transmission frequencies, Signal Antennas, Signal Propagation, Multiplexing – SDM,FDM, TDM,CDM, Modulation – ASK,FSK,PSK, Advanced FSK, Advanced PSK, OFDM, Spread Spectrum – DSSS,FHSS, Wireless Transmission Impairments – Free Space Loss, Fading, Multipath Propagation, Atmospheric Absorption, Error Correction – Reed Solomon, BCH, Hamming code, Convolution Code (Encoding and Decoding)

2 .Wireless Networks

Wireless network, Wireless network Architecture, Classification of wireless networks – WBAN, WPAN, WLAN, WMAN, WWAN. IEEE 802.11, IEEE 802.16, Bluetooth – Standards, Architecture and Services

3. Cellular wireless Networks

Principles of cellular networks – cellular network organization, operation of cellular systems, Handoff.

Generation of cellular networks – 1G, 2G, 2.5G, 3G and 4G.

4. Mobile communication systems

GSM – Architecture, Air Interface, Multiple Access Scheme, Channel Organization, Call Setup Procedure, Protocol Signaling, Handover, Security, GPRS – Architecture, GPRS signaling, Mobility management, GPRS roaming, network, CDMA2000- Introduction, Layering Structure, Channels, Logical Channels, Forward Link and Reverse link physical channels, W-CDMA – Physical Layers, Channels, UMTS – Network Architecture, Interfaces, Network Evolution, Release 5, FDD and TDD, Time Slots, Protocol Architecture, Bearer Model

Introduction to LTE

5 . Mobile Network Layer

Mobile IP – Dynamic Host Configuration Protocol, Mobile Ad Hoc Routing Protocols– Multicast routing

6. Mobile Transport Layer

TCP over Wireless Networks – Indirect TCP – Snooping TCP – Mobile TCP – Fast Retransmit / Fast Recovery Transmission/Timeout Freezing-Selective Retransmission – Transaction Oriented TCP , TCP over 2.5 / 3G wireless Networks

7. Application Layer

WAP Model- Mobile Location based services -WAP Gateway – WAP protocols – WAP user agent profile, Caching model-wireless bearers for WAP - WML – WMLScripts – WTA.

Module 1: Wireless Technology Fundamentals

1. Introduction to Mobile and wireless communications:

- Network
- Communication

- Waveform:
  - Changes in a recorded signal's amplitude over the duration of time.
  - Sine, square, triangle, sawtooth waveform.

- **Signals:**
  - Signals are the physical representation of data.
  - Users of a communication system can only exchange data through the transmission of signals.
- **Amplitude:**
  - Height/ Force/ Power of the wave.
- **Frequency:**
  - No. of cycles of waveforms per sec.
  - Periodicity in some event.

- **Phase:**
  - Two or more waveforms not exactly aligned together with same frequency and wavelength.
- **Wavelength:**
  - Distance travelled by an electromagnetic wave during the time of one cycle.
- **Spectrum:**
  - Representation of a signal in frequency domain.
- **Electromagnetic waves:**
  - Travel a long distance through free space.
  - Sinusoidal waves.
  - Radio Frequency waves.

- Electromagnetic Spectrum:
  - Range of frequencies over which EM waves travel for different applications.
- Bandwidth:
  - Portion of Electromagnetic Spectrum occupied by a signal.
- International Telecommunications unit (ITU).

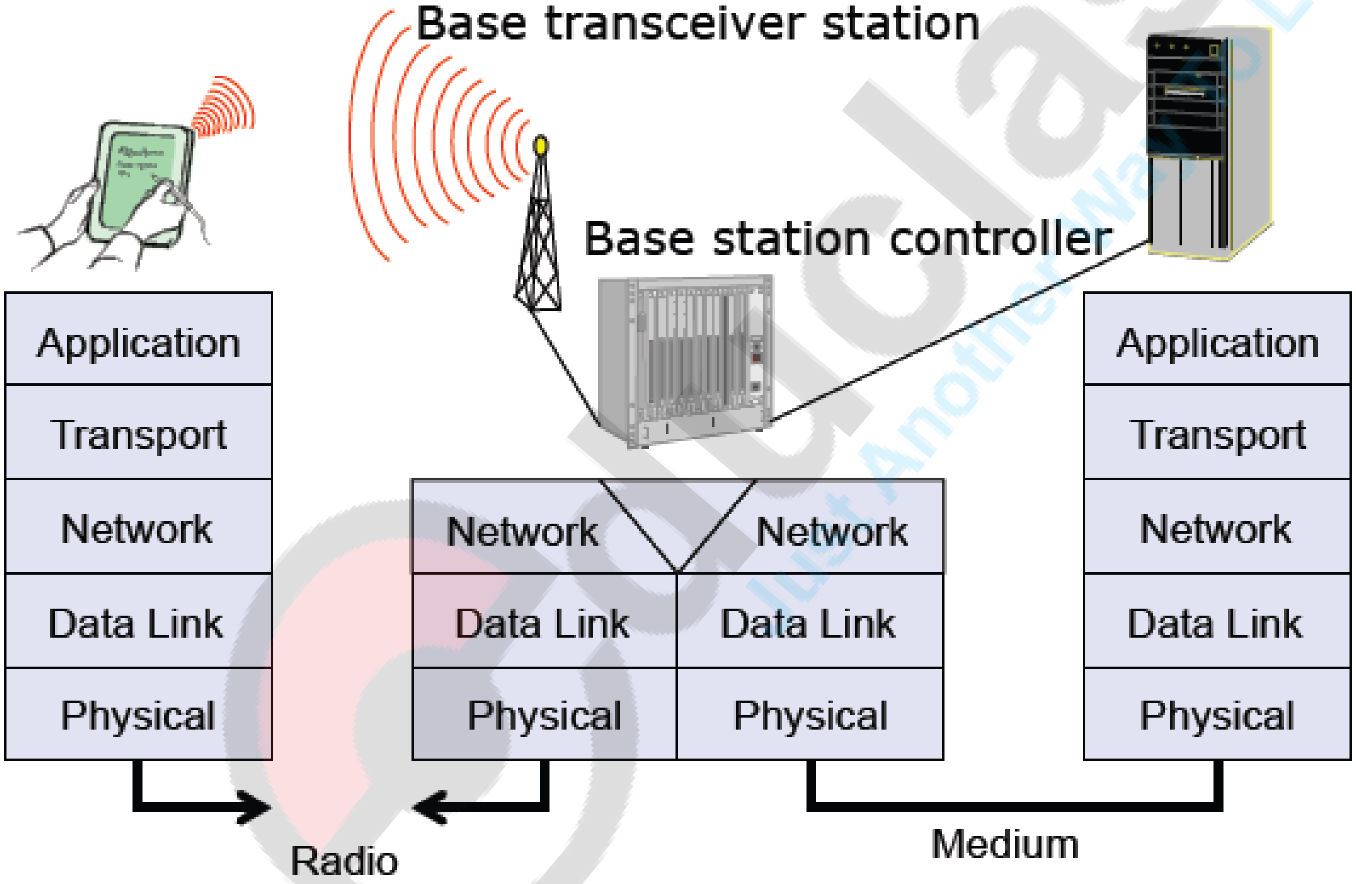
- Typical Communication System:
  - Input Signal
  - Input Transducer
  - Transmitter
  - Communication channel: Wired/ Wireless
  - Noise
  - Receiver
  - Output Transducer

- Classification of Communication Systems:
  - Simplex, Half duplex, Full duplex.
  - Analog, Digital.
  - Baseband Transmission, Transmission based on modulation.
- Modulation:
  - Modulating and carrier signal.
  - carrier signal: High frequency sinusoidal signal.
- Multiplexing:
  - Combining several message signals together and send them over the same communication channel.
  - Possible only with Modulation.

- Wireless Communication Systems:
  - Uses free space.
  - Uses EM waves.
  - Antenna: Sender and Receiver side.

  - Types:
    - Radio wave Transmission
    - Microwave Transmission
    - Mobile Cellular Networks
    - Infrared
    - Airplane to Airplane Network
    - Underwater acoustic signal transmission

Basic Reference Model



- **Physical layer:**
conversion of stream of bits into signal, carrier generation, frequency selection, signal detection, encryption

- **Data link layer:** accessing the medium – multiplexing - error correction – synchronization

- **Network layer:** routing packets – addressing - handover between networks

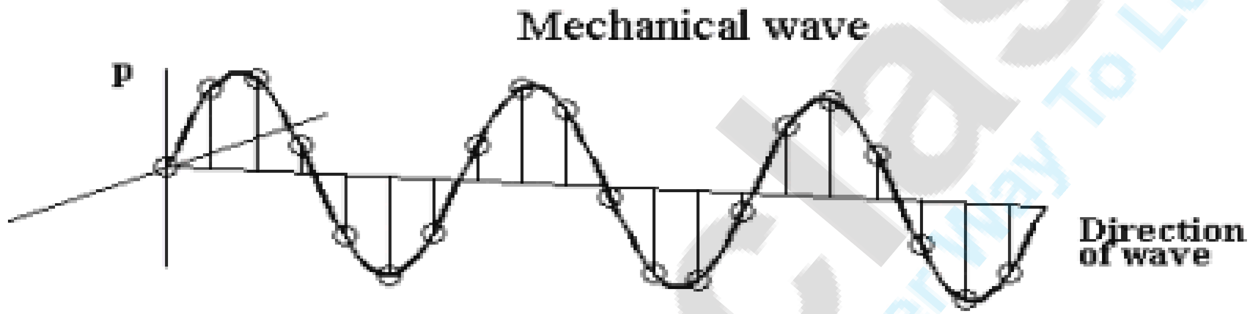
- **Transport layer:** establish an end-to-end connection – quality of service – flow and congestion control

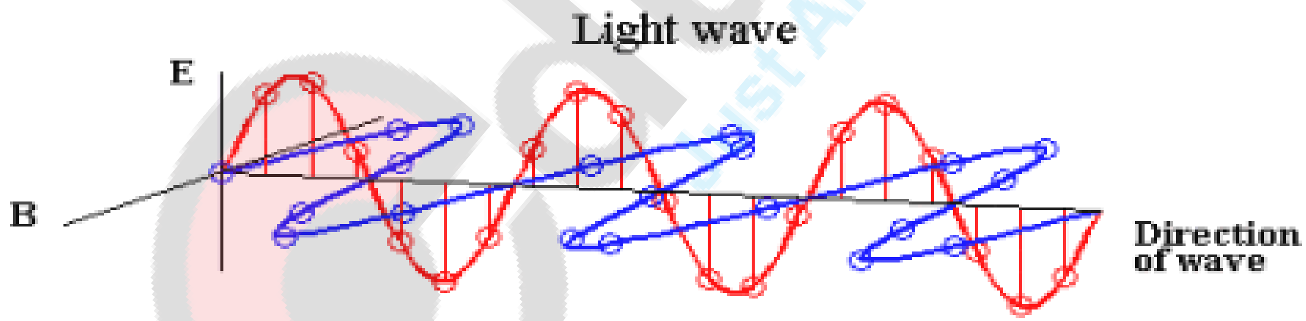
- **Application layer:** service location – support multimedia – wireless access to www

Electromagnetic Waves

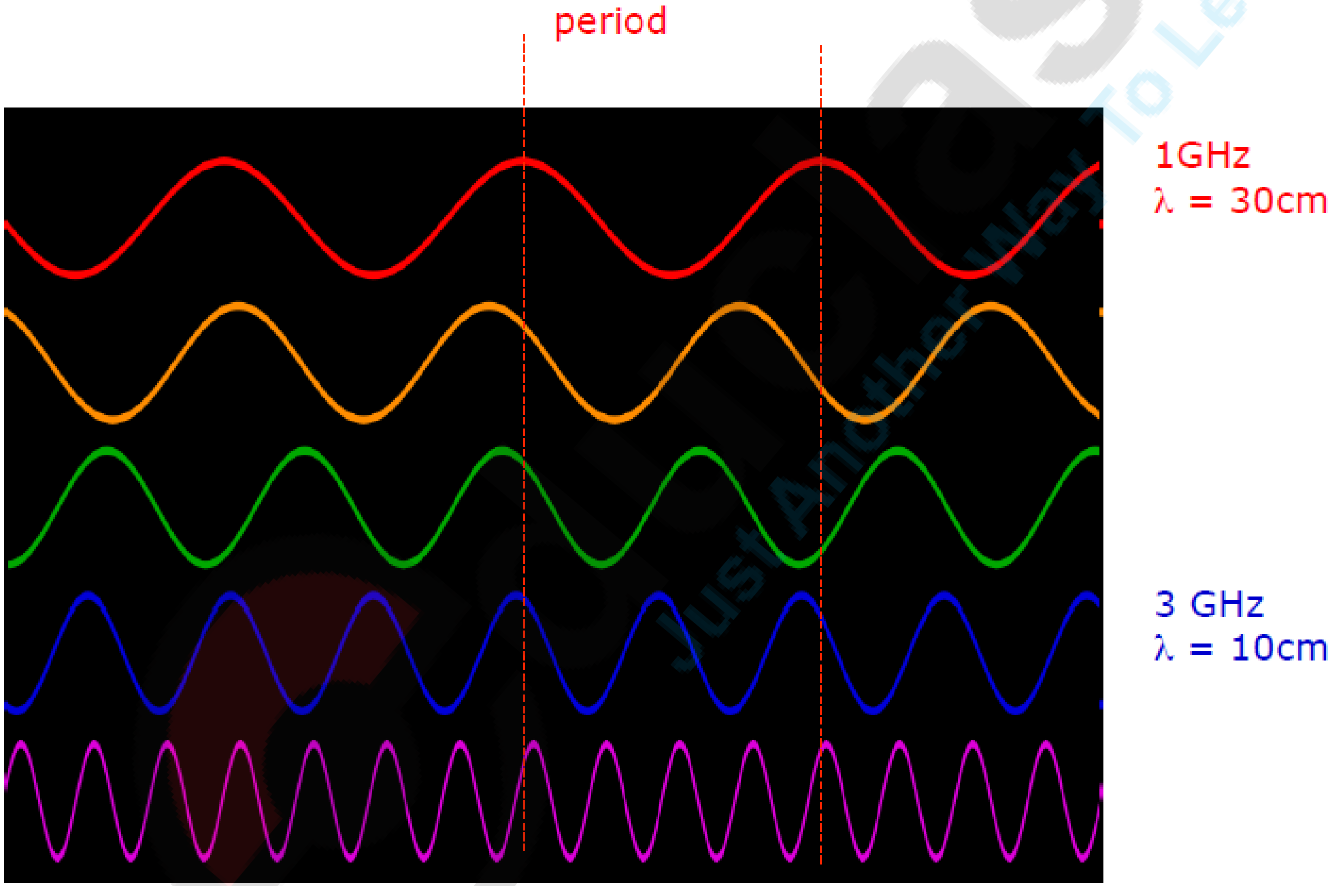
- **Electromagnetic radiation** (EMR) takes the form of self propagating waves in a vacuum or in matter.
- It consists of **electric** and **magnetic field** components which oscillate in phase perpendicular to each other and perpendicular to the direction of energy propagation.
- A **wave** is a disturbance that propagates through space and time, usually with transference of energy.
- The **wavelength** (denoted as λ) is the distance between two sequential crests.
- The **period** T is the time for one complete cycle for an oscillation of a wave.
- The **frequency** f is how many periods per unit time (for example one second) and is measured in hertz: $f=1/T$.
- The **velocity of a wave** is the velocity at which variations in the shape of the wave's amplitude propagate through space: $v = \lambda * f$.

Wave propagation

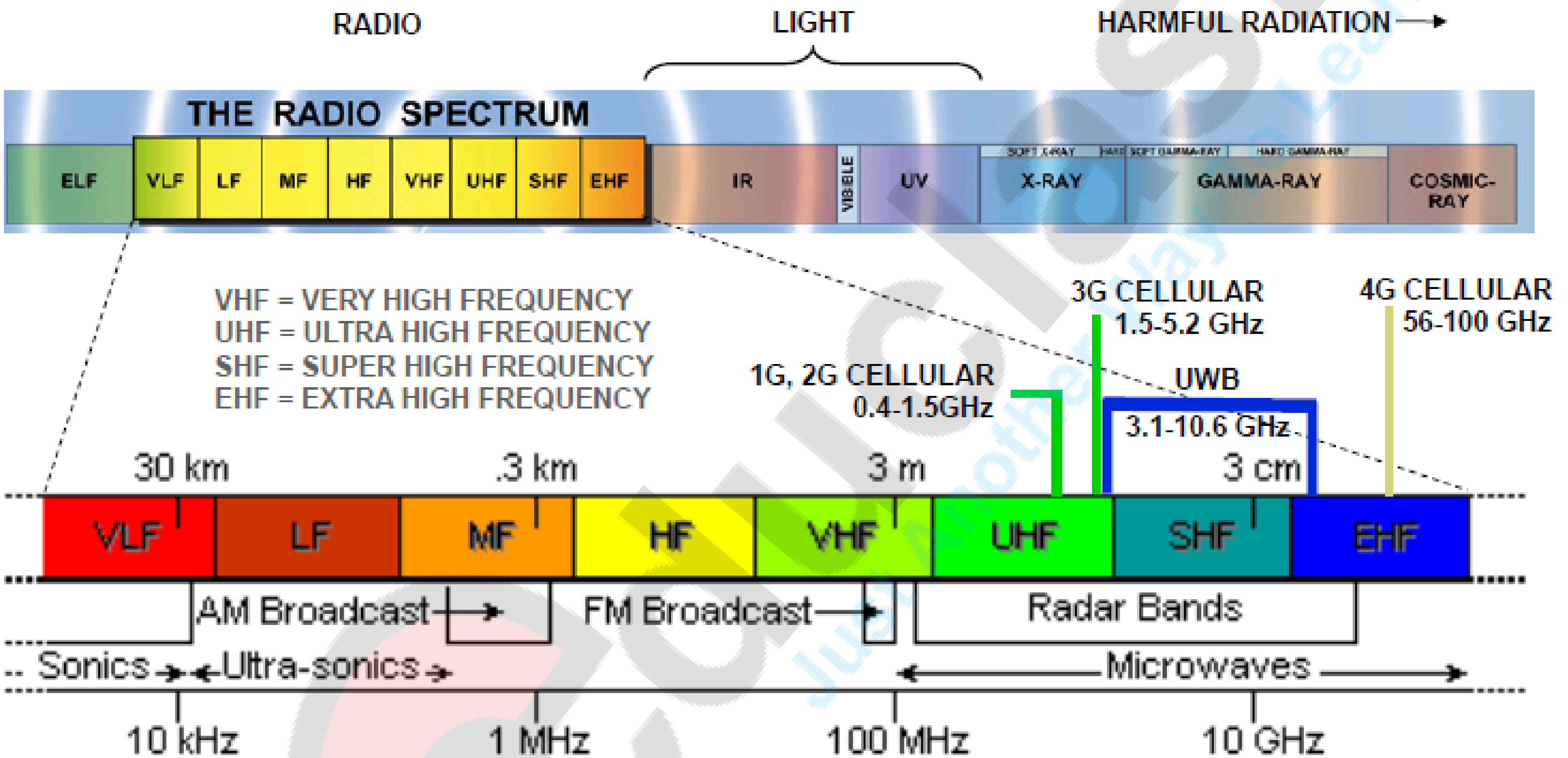




Waves with different frequencies and length



2. Frequencies for Radio Transmission



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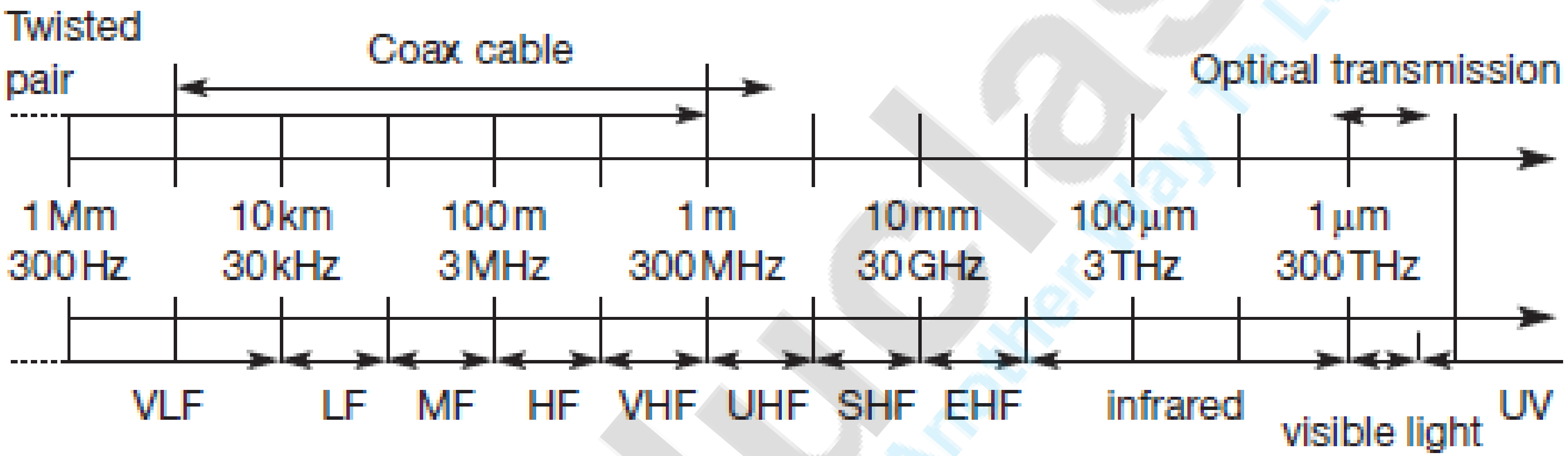
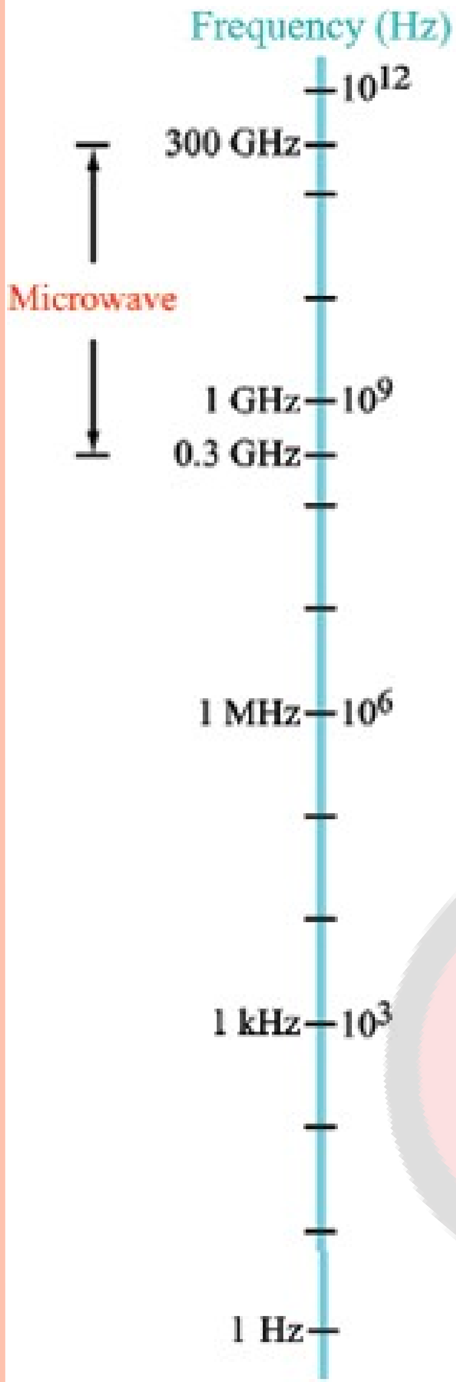
$c = \lambda * f$

$c = 299\ 792\ 458\ m/s \sim 3*10^8\ m/s$



Frequency Spectrum



Band	Applications
Extremely High Frequency (30–300 GHz)	Radar, advanced communication systems, remote sensing, radio astronomy
Super High Frequency (3–30 GHz)	Radar, satellite communication systems, aircraft navigation, radio astronomy, remote sensing
Ultra High Frequency (300 MHz – 3 GHz)	TV broadcasting, radar, radio astronomy, microwave ovens, cellular telephone
Very High Frequency (30–300 MHz)	TV and FM broadcasting, mobile radio communication, air traffic control
High Frequency (3–30 MHz)	Shortwave broadcasting
Medium Frequency (300 kHz – 3 MHz)	AM broadcasting
Low Frequency (30–300 kHz)	Radio beacons, weather broadcast stations for air navigation
Very Low Frequency (3–30 kHz)	Navigation and position location
Ultra Low Frequency (300 Hz – 3 kHz)	Audio signals on telephone
Super Low Frequency (30–300 Hz)	Ionospheric sensing, electric power distribution, submarine communication
Extremely Low Frequency (3–30 Hz)	Detection of buried metal objects
	Magnetotelluric sensing of the Earth's structure

Signals

- Signals are a function of time and location.
- Physical representation of data.
- Users can exchange data through the transmission of signals.
- The Layer 1 is responsible for conversion of data, i. e., bits, into signals and vice-versa.
- Signal parameters of periodic signals: period T, frequency f=1/T, amplitude A, phase shift ϕ.

- Sine wave as special periodic signal for a carrier:
  $s(t) = A_t \sin(2 \pi f_t t + \phi_t)$

- Sine waves are of special interest as it is possible to construct every periodic signal using only sine and cosine functions (Fourier equation).

- A typical way to represent a signal is in time domain (Amplitude A in volt versus time t in sec).
- This representation is difficult if signal consists of too many different frequencies.
- Hence need to be converted to frequency domain.

3. Signal Antennas

- An antenna is a transducer which converts electric power into electromagnetic waves.
  - Transmission - radiates electromagnetic energy into space.
  - Reception - collects electromagnetic energy from space.

- In two-way communication, the same antenna can be used for transmission and reception.

- They couple electromagnetic energy to and from space.

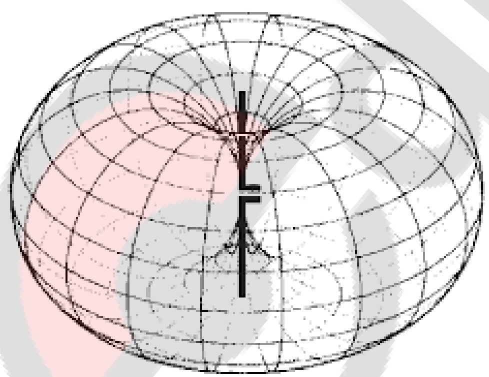
- **Radiation pattern**
  - Graphical representation of radiation properties of an antenna.
  - Depicted as two-dimensional cross section.

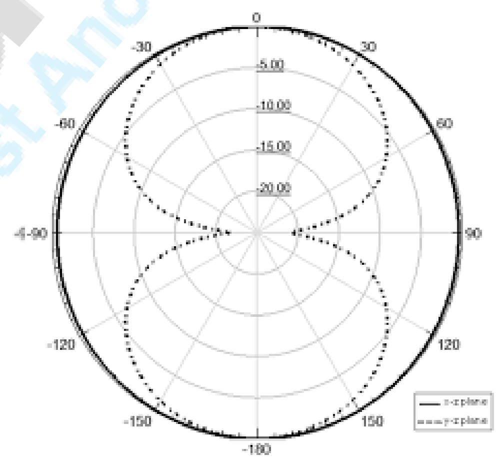
- **Beam width (or half-power beam width)**
  - Measure of directivity of antenna.
  - Beam width is the aperture angle from where most of the power is radiated.

- **Reception pattern**
  - Receiving antenna’s equivalent to radiation pattern.

Isotropic antenna

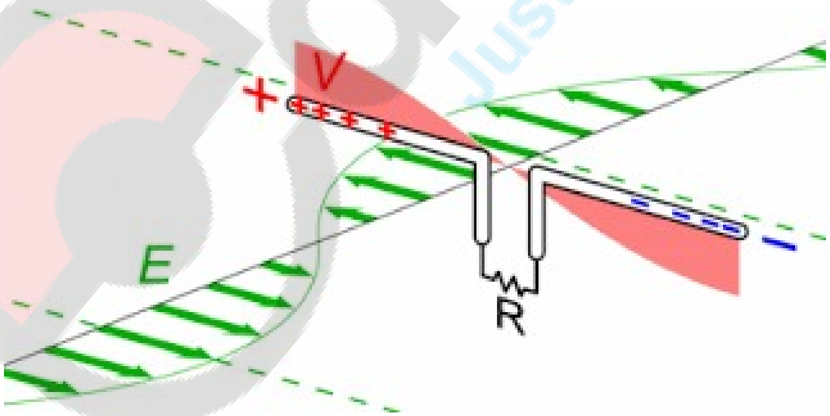
- Radiates power equally in all directions.- Omni-directional radiation pattern.
- Practically not possible.
- Every antenna will have a directive effect.- intensity of radiation is not same in all directions from the antenna.





Dipole antennas

- Simplest realistic antenna.
- Thin, center-fed dipole consisting of two collinear conductors of equal length, separated by a feeding gap.
- Omni- directional radiation pattern in one plane and figure eight pattern in other two planes.
- Half-wave dipole antenna (or Hertz antenna): If length of dipole is half the wavelength.
- Quarter-wave vertical antenna (or Marconi antenna): Length of the dipole is quarter of the wavelength.



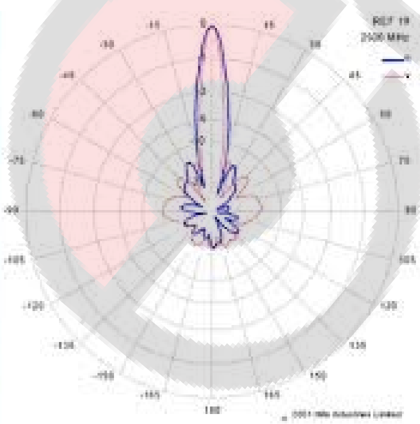
Directional antennas and sectorized antenna

Directional antennas:

- With certain fixed preferential transmission and reception directions.
- Useful when antenna is positioned in a valley or between the buildings.

Sectorized antennas:

- Several directed antennas combined together on a single pole .
- A cell can be sectorized into three or six sectors- frequency reuse.



Multi-element antenna arrays and Smart Antennas

- **Multi-element antenna arrays**:

  Two or more antennas combined together to improve reception by counteracting the negative effects of multi-path propagation.

- **Smart Antennas**:
  - Combine multiple antenna elements (antenna arrays) with signal processing to optimize radiation pattern in response to the signal environment.
  - They can adapt to changes in reception power, transmission conditions and many signal propagation effects.

Antenna gain:

Power output, in a particular direction, compared to that produced in any direction by a perfect omni- directional antenna (isotropic antenna).

Effective area:

Related to physical size and shape of antenna.

Relationship between antenna gain and effective area:

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$

Where, G = antenna gain

A_e = effective area

f = carrier frequency

c = speed of light (» 3 ´ 10^8 m/s)

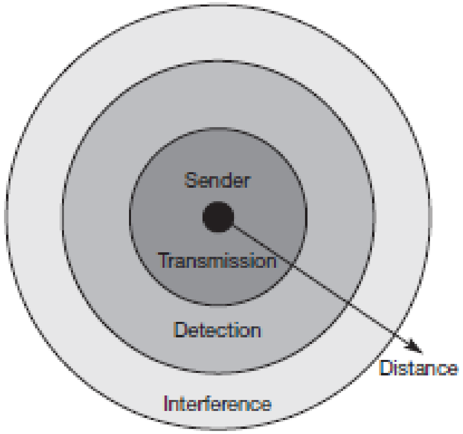
λ = carrier wavelength

4. Signal Propagation

- **Transmission range** : Within a certain radius of the sender, transmission is possible, i. e., a receiver receives the signals with an error rate low enough to be able to communicate and can also act as a sender.
- **Detection range**: Within a second radius, detection of the transmission is possible, i. e., the transmitted power is large enough to differ from background noise. However, the error rate is too high to establish communication.
- **Interference range**: Within a third even larger radius, the sender may interfere with other transmission by adding to the background noise. A receiver will not be able to detect the signals, but the signals may disturb other signals.

Propagation Modes (based on frequency):

- Ground-wave propagation
- Sky-wave propagation
- Line-of-sight propagation



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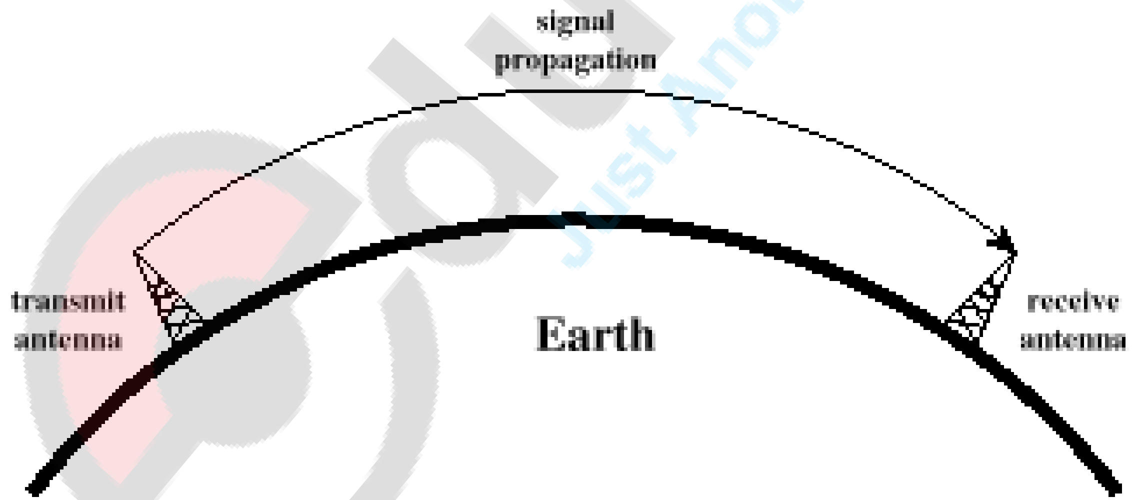
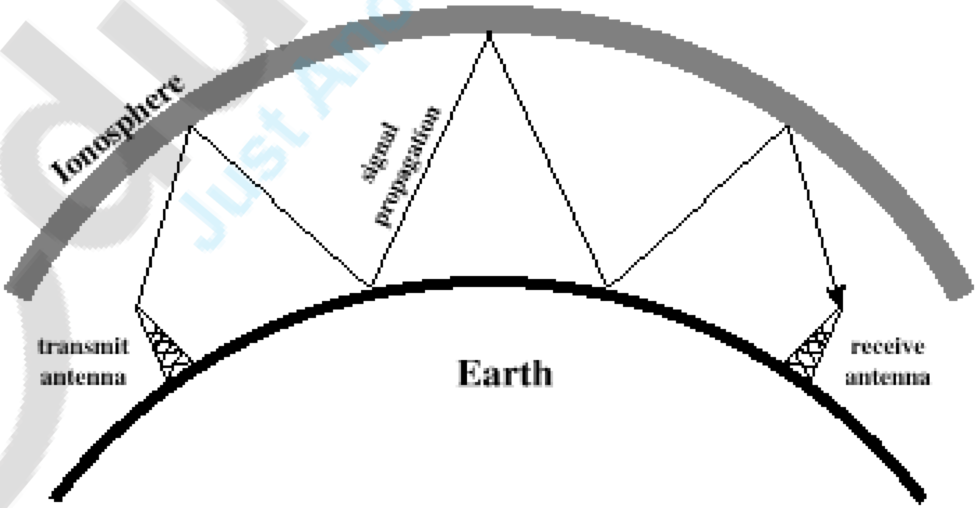
Ground Wave Propagation

- Waves with low frequencies follow the earth's surface and can propagate long distances.
- Frequencies up to 2MHz.
- These waves are used for, e. g., submarine communication or AM radio.



Sky Wave Propagation

- Signal reflected from ionized layer of atmosphere back down to earth.
- Signal can travel a number of hops, back and forth between ionosphere and earth's surface.
- Reflection effect caused by refraction.
- Frequencies between 2 MHz to 30MHz.
- Examples
    - Amateur radio
    - CB radio



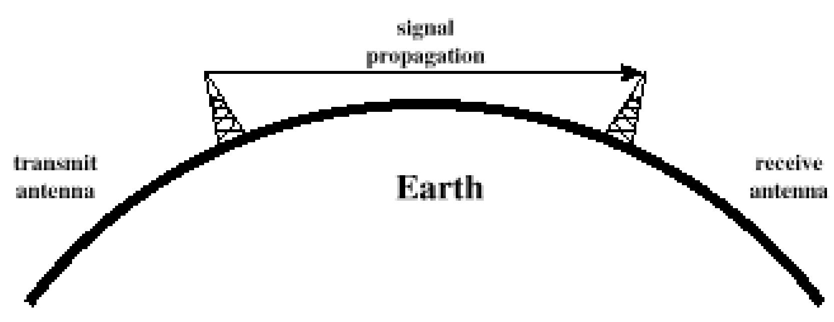
Line of Sight Propagation

Transmitting and receiving antennas must be within line of sight.

- Mobile phone systems, satellite systems, cordless telephones etc. use even higher frequencies. The emitted waves follow a (more or less) straight line of sight.
- Satellite communication – signal above 30 MHz not reflected by ionosphere.
- Ground communication – antennas within effective line of site due to refraction.

Refraction – bending of microwaves by the atmosphere

- Velocity of electromagnetic wave is a function of the density of the medium.
- When wave changes medium, speed changes.
- Wave bends at the boundary betw



Optical line of sight

$$d = 3.57\sqrt{h}$$

Effective, or radio, line of sight

$$d = 3.57\sqrt{Kh}$$

d = distance between antenna and horizon (km)

h = antenna height (m)

K = adjustment factor to account for refraction, rule of thumb K = 4/3

Maximum distance between two antennas for LOS propagation:

h_1 = height of antenna one

h_2 = height of antenna two

$$3.57\left(\sqrt{Kh_1} + \sqrt{Kh_2}\right)$$

5. Wireless Transmission Impairments

- Free Space loss
- Blocking/Shadowing
- Reflection, Refraction, Scattering, Diffraction
- Multi-path Propagation.
  - Delay spread
  - Inter-symbol Interference (ISI)
- Fading
  - Short term
  - Long term

- **Free Space loss:**

Strength of signal falls off with distance over transmission medium.

- **Attenuation factors for unguided/wireless media:**
  - Received signal must have sufficient strength so that circuitry in the receiver can interpret the signal.
  - Signal must maintain a level sufficiently higher than noise to be received without error.
  - Attenuation is greater at higher frequencies, causing distortion.

Free space loss, ideal isotropic antenna:

$$\frac{P_t}{P_r} = \frac{\left(4\pi d\right)^2}{\lambda^2} = \frac{\left(4\pi f d\right)^2}{c^2}$$

Where,

P_t = signal power at transmitting antenna

P_r = signal power at receiving antenna

$\bar{x}\lambda$ = carrier wavelength

d = propagation distance between antennas

c = speed of light (» 3 ´ 10 8 m/s)

where d and λ are in the same units (e .g., meters)

Blocking/Shadowing

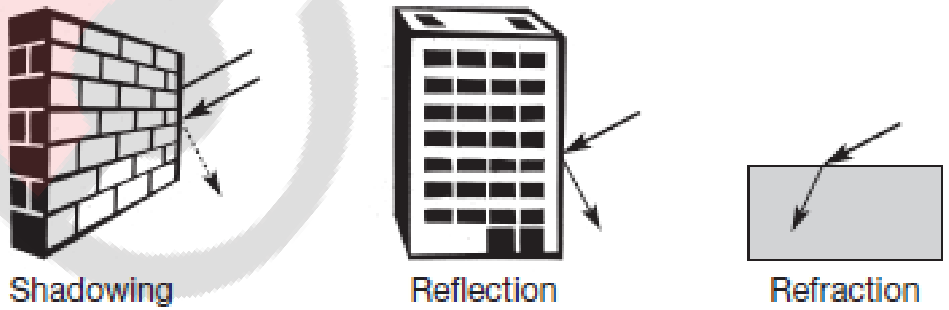
An extreme form of attenuation is **blocking** or **shadowing** of radio signals due to large obstacles.

Reflection:

If an object is large compared to the wavelength of the signal, e.g., huge buildings, mountains, or the surface of the earth, the signal is reflected. The reflected signal is not as strong as the original, as objects can absorb some of the signal's power.

Refraction:

This effect occurs because the velocity of the electromagnetic waves depends on the density of the medium through which it travels.



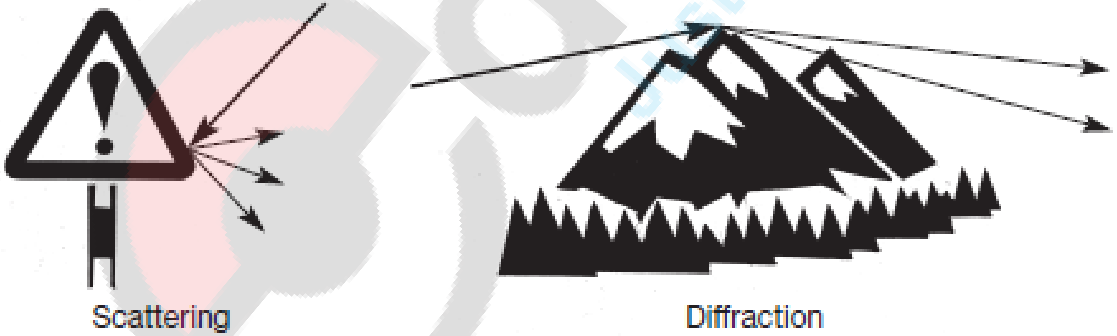
Scattering:

If the size of an obstacle is in the order of the wavelength or less, then waves can be scattered An incoming signal is scattered into several weaker outgoing signals.

Diffraction:

Radio waves will be deflected at an edge and propagate in different directions.

The result of scattering and diffraction are patterns with varying signal strengths depending on the location of the receiver.



Multi-path Propagation:

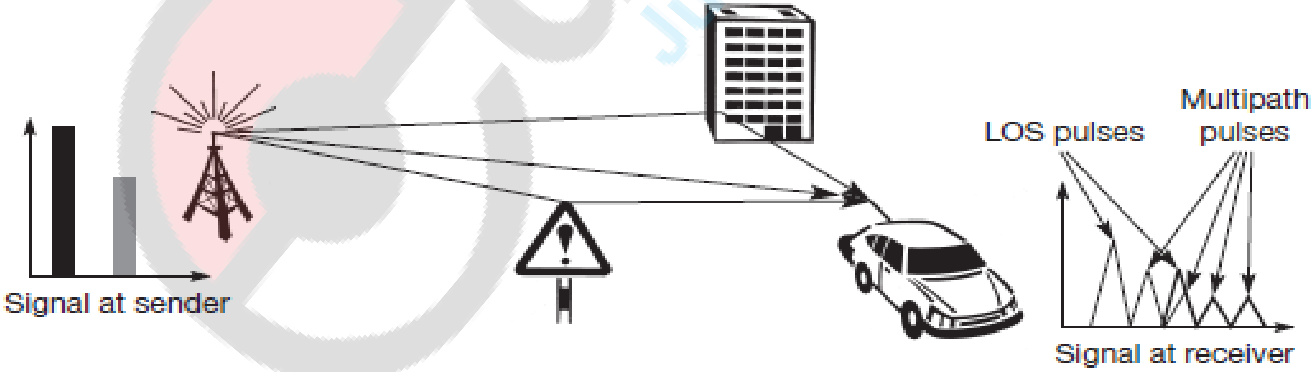
Radio waves emitted by the sender can either travel along a straight line, or they may be reflected at a large building, or scattered at smaller obstacles.

- **Delay Spread:**

Due to the finite speed of light, signals travelling along different paths with different lengths arrive at the receiver at different times.

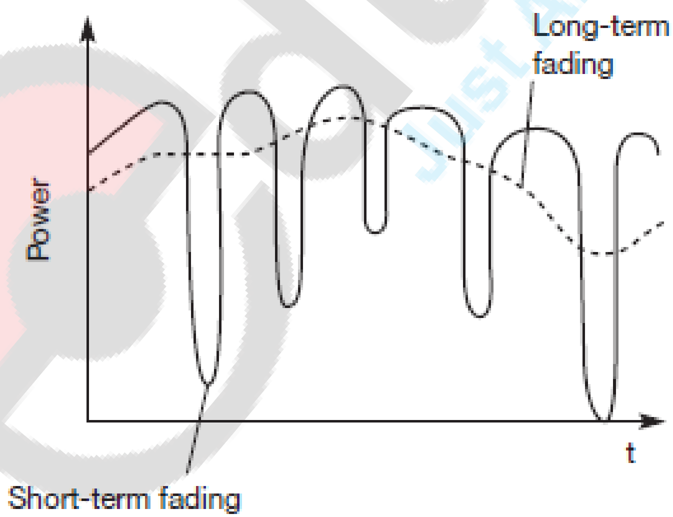
- **Inter-symbol interference (ISI):**

The energy intended for one symbol spills over to the adjacent symbol.



Fading:

- If receivers, or senders, or both, move. Then the channel characteristics change over time, and the paths a signal can travel along vary.
- The power of the received signal changes considerably over time. These quick changes in the received power are called as **short-term fading.**
- **Long term fading-** average power over time, is caused by, for example, varying distance to the sender or more remote obstacles.



6. Multiplexing

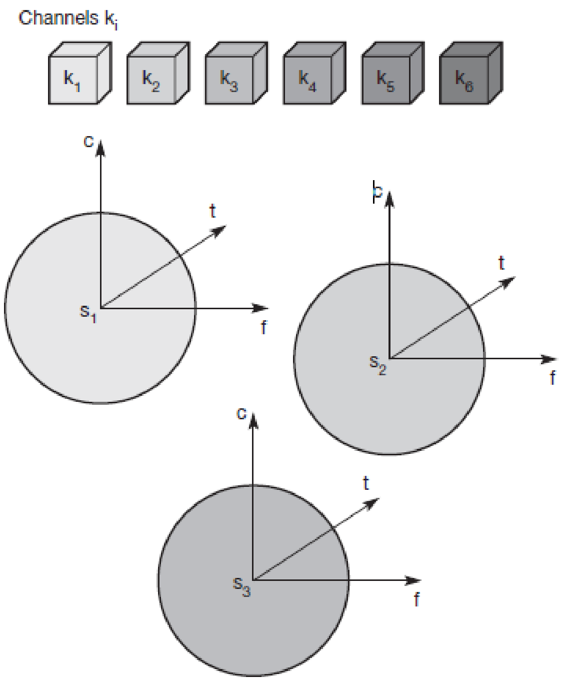
- Multiplexing describes how several users can share a medium with minimum or no interference.
- For wireless communication, multiplexing can be carried out in four dimensions: **space**, **time**, **frequency**, and **code**.
- In this field, the task of multiplexing is to assign space, time, frequency, and code to each communication channel with a minimum of interference and a maximum of medium utilization.

Types:

- Space division multiplexing (SDM)
- Frequency division multiplexing (FDM)
- Time division multiplexing (TDM)
- Code division multiplexing (CDM)

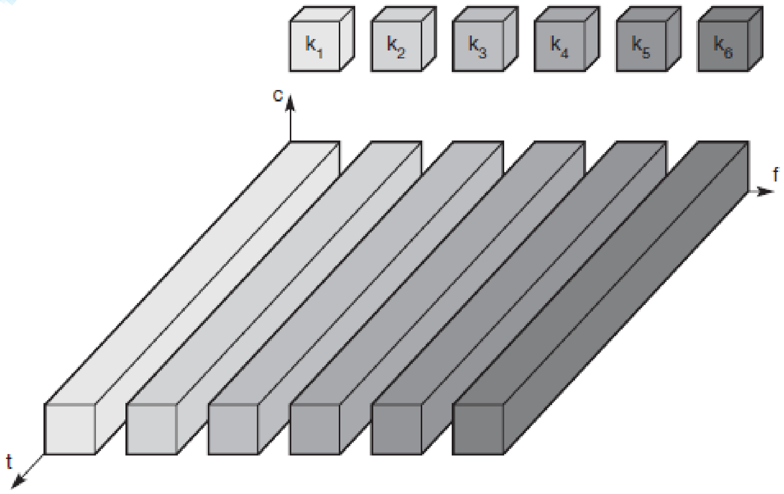
Space division multiplexing (SDM):

- Each channel has its own space with the dimensions of code c, time t and frequency f. Each channel has its interference range.
- The space between the interference ranges is sometimes called **guard space**.
- SDM implies a separate sender for each communication channel with a wide enough distance between senders.
- e.g. FM radio stations.
- Drawbacks:
  - Waste of space.
  - If two or more channels are established within the same space.



Frequency division multiplexing (FDM):

- Subdivide the frequency dimension into several non-overlapping frequency bands.
- Each channel is allotted its own frequency band.
- **Guard spaces** are needed to avoid frequency band overlapping (also called **adjacent channel interference**).
- e.g. radio stations within the same region, where each radio station has its own frequency.
- Does not need complex coordination between sender and receiver: the receiver only has to tune in to the specific sender.
- Drawbacks:
  - tremendous waste of (scarce) frequency resources.
  - very inflexible.
  - limits the number of senders.



Time division multiplexing (TDM):

- A channel is given the whole bandwidth for a certain amount of time, i.e., all senders use the same frequency but at different points in time.

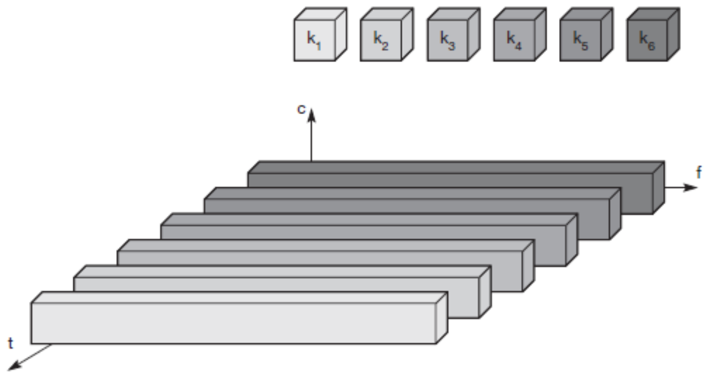
- **Guard spaces**, which represent time gaps, have to separate the different periods when the senders use the medium.

- If two transmissions overlap in time, this is called co-channel interference.

- Precise synchronization between different senders is necessary.

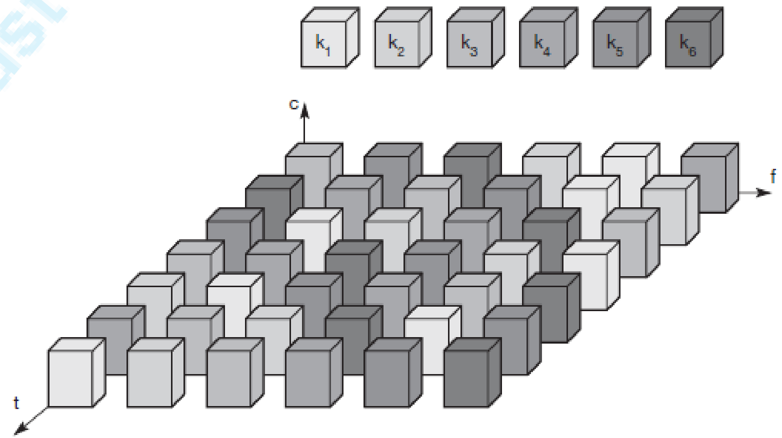
- Advantage: Scheme is quite flexible as one can assign more sending time to senders with a heavy load and less to those with a light load.

- Disadvantage: All senders need precise clocks or, alternatively, a way has to be found to distribute a synchronization signal to all senders.



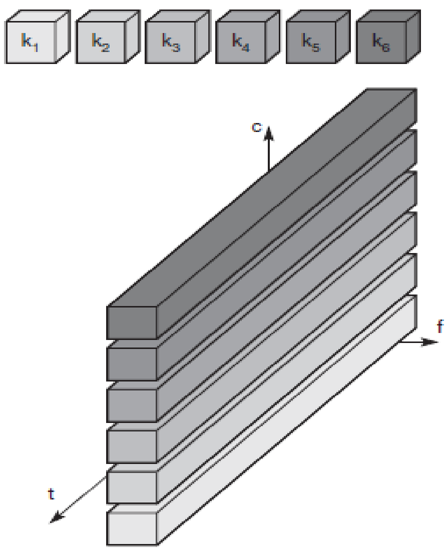
Combined Frequency and Time division multiplexing:

- A channel can use a certain frequency band for a certain amount of time.
- Guard spaces are needed both in the Time and in the Frequency Dimension.
- The mobile phone standard GSM uses this combination of frequency and time division multiplexing for transmission between a mobile phone and a base station.
- More robust against frequency selective interference, i.e., interference in a certain small frequency band.
- Provides some (weak) protection against tapping, as in this case the sequence of frequencies a sender uses has to be known to listen in to a channel.
- Drawback: necessary coordination between different senders.



Code division multiplexing (CDM):

- Channels use the same frequency at the same time for transmission.
- Separation is achieved by assigning each channel its own 'code', guard spaces are realized by using codes with the necessary 'distance' in code space, e. g., orthogonal codes.
- CDM has built-in security.
- By using a secret code a secure channel can be established in a 'hostile' environment.
- Advantages:
  - Gives good protection against interference and tapping.
- Different codes have to be assigned, but code space is huge compared to the frequency space. Assigning individual codes to each sender does not usually cause problems.
- Drawback:
  - relatively high complexity of the receiver.
  - To apply CDM, precise power control is required.



References:

Mobile Communications, Second Edition, Jochen Schiller, Pearson Education- Chapter 2.

University Questions:

1.Write a short note on Antennas.- May 16- 5M

2. Discuss the following impairments in wireless environment.- Atmospheric Absorption, Multipath Propagation, Fading.- Nov 16- 7M