Ubiquitous Computing (CS60055)

Wireless Transmission

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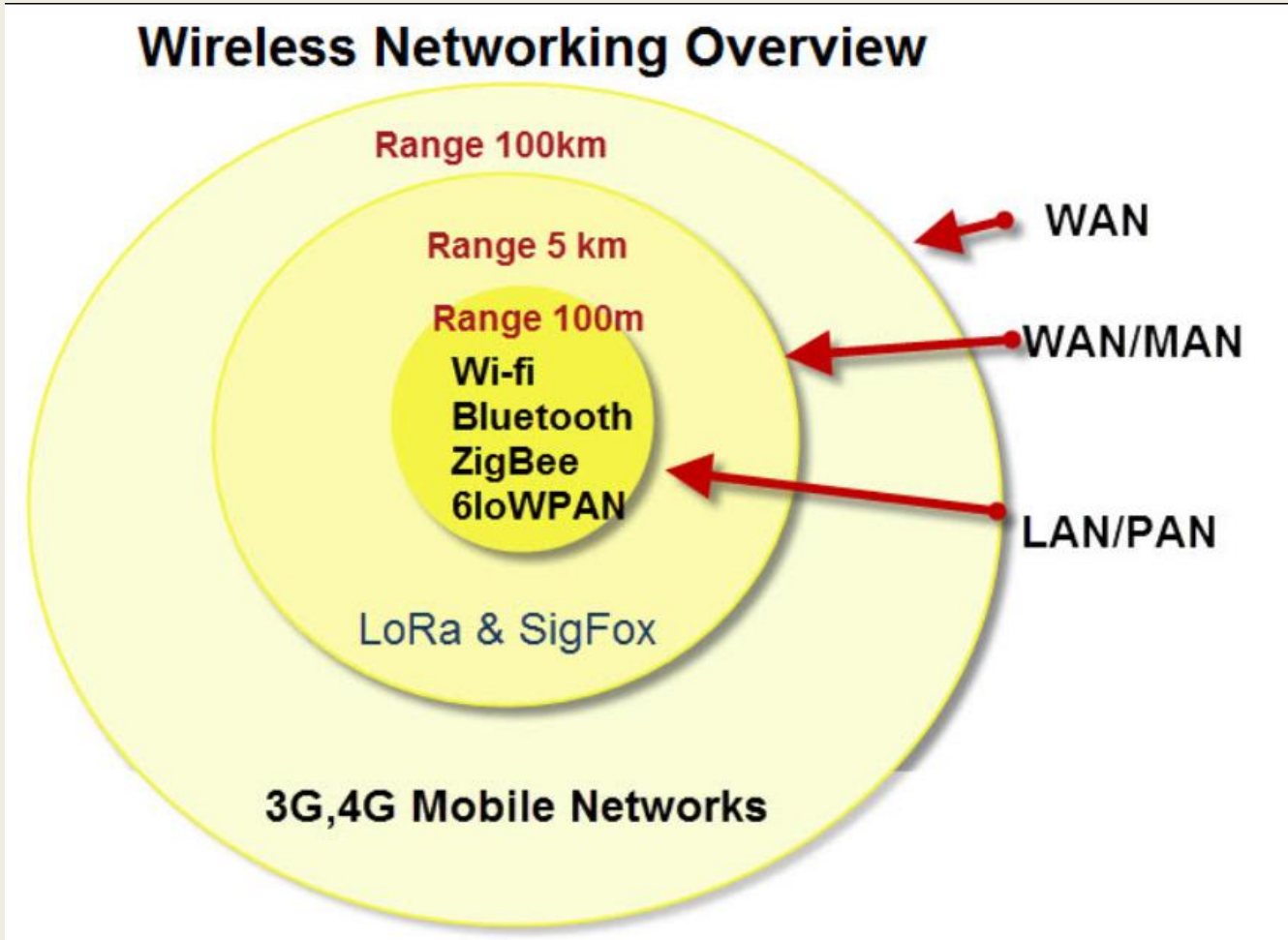
Wireless Technologies

- Wireless technology refers to technology that allows us to communicate without using cables or wires.



http://www.steves-internet-guide.com/iot-wireless-technologies/?hcb=1

Advantages of Wireless Technologies for Ubiquitous Computing

- **Anywhere:**
  - In contrast to wired networks which can only be accessed at a fixed number of network junctions, wireless networks give users the freedom to access them anywhere where they are still in range of a wireless transmitter or hub that they have access permission for.

- **Mobility:**
  - Wireless communication networks can be accessed while moving. The cost of installing wireless transmitters and receivers typically is much cheaper than a wired network.

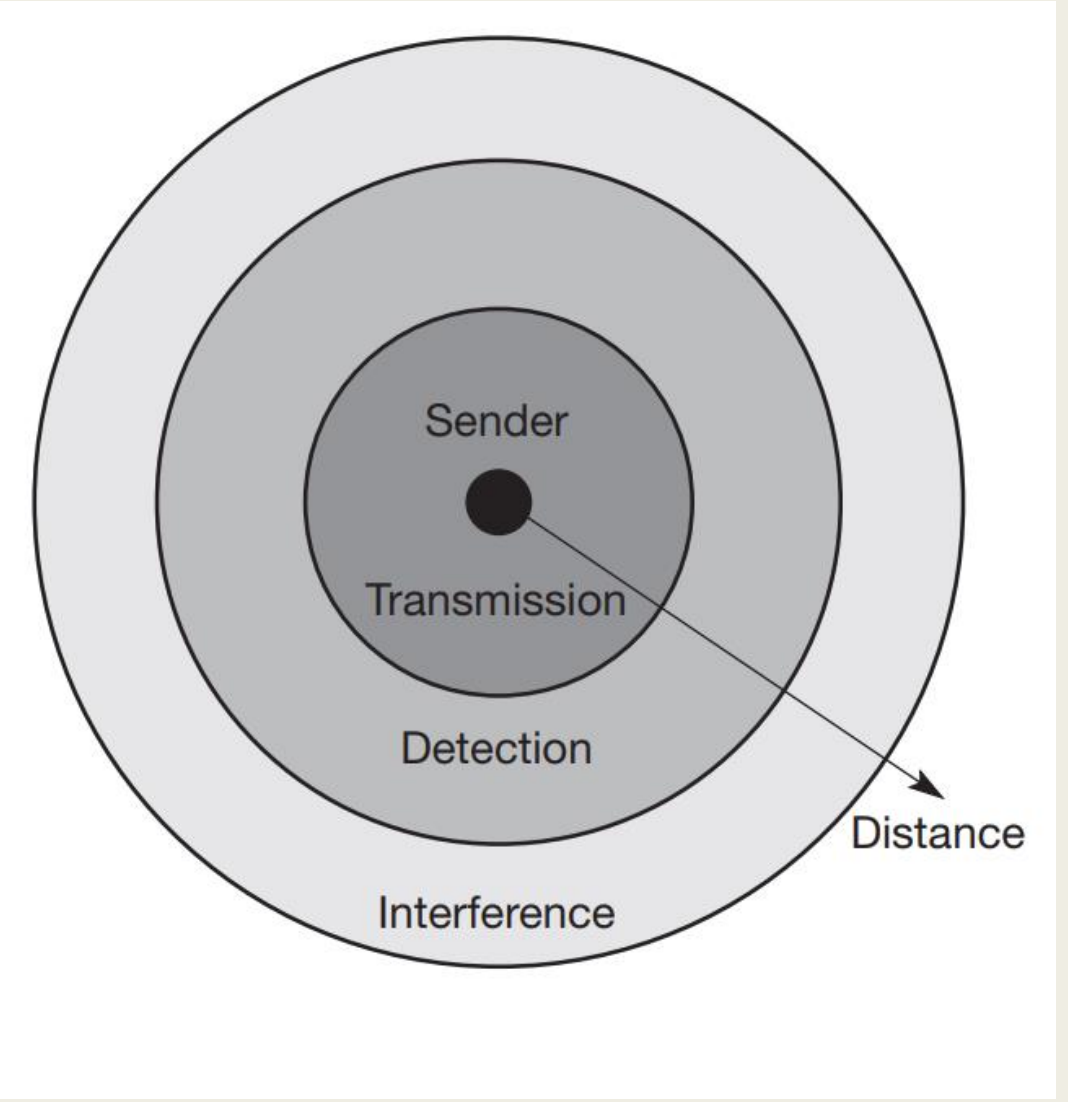
Cont...

- **Less disruptive:**
  - Wireless networks can be used in areas where wired networks would be considered too inconvenient, disruptive or expensive to install, e.g., in old historical buildings and in emergency situations.

- **Adaptivity:**
  - Wireless networks are also considered more adaptive in terms of their ability to expand or shrink the coverage of the network and to vary the density of coverage, installing more transmitters and capacity in high populated in contrast to more rural areas.

Signal Propagation

- No wire to determine the direction of propagation .
- Received power depending on the
  length.
- Signal Strength depends upon:
  - Transmission range.
  - Detection range.
  - Interference range



Cont...

- **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 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.

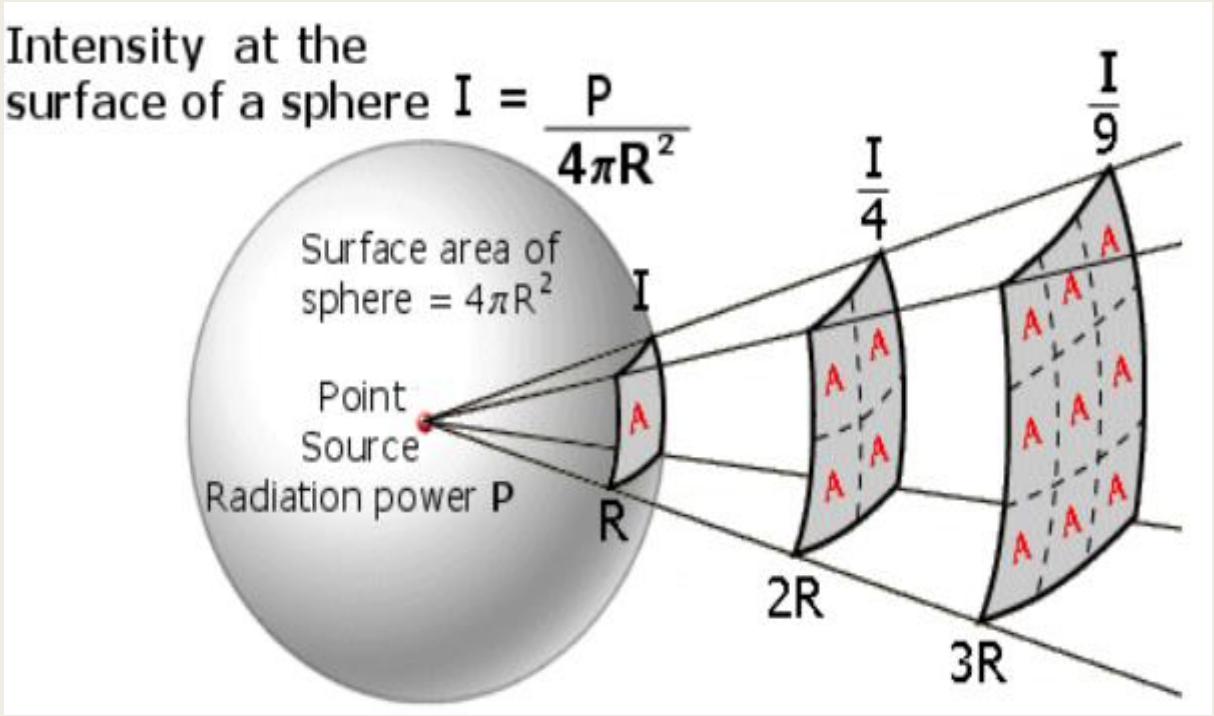
Cont...

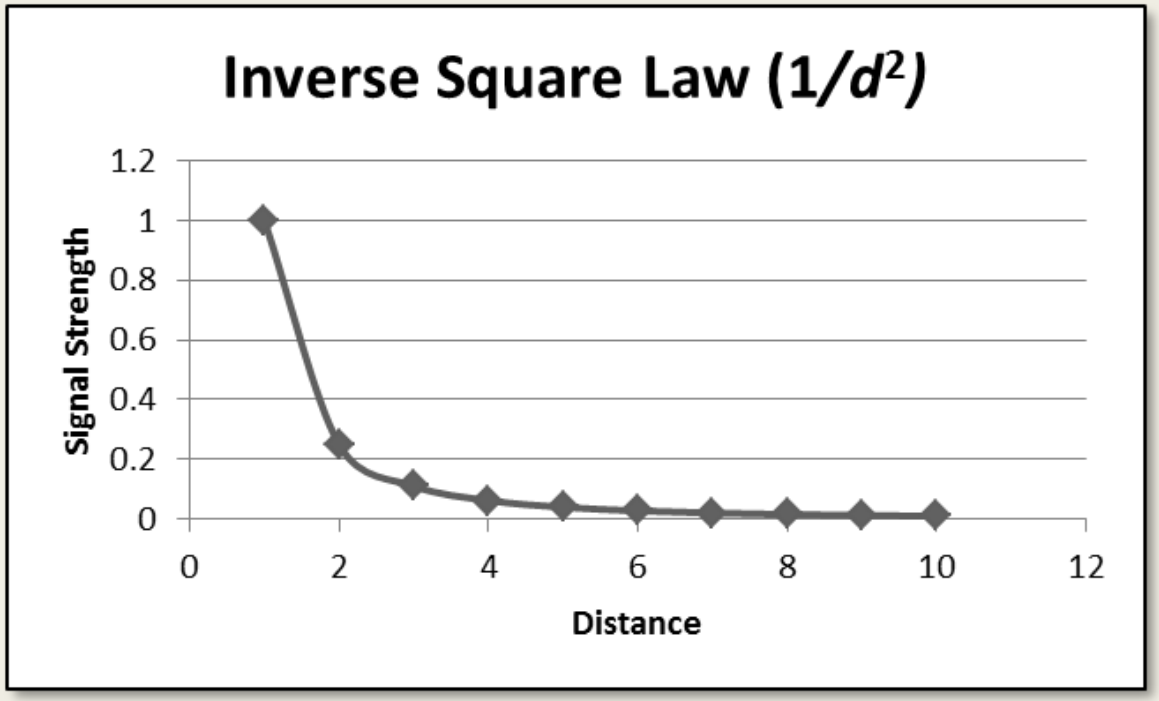
- **Interference range:**
  - Within a third even larger radius, the sender may interfere with other transmission by adding to the background noise. A receiver will not be able to detect the signals, but the signals may disturb other signals.

Path Loss of Radio Signals

- In free space radio signals follow a straight line.
- The straight line exists between a sender and a receiver it is called line-of-sight (LOS).
- The received power P is proportional to $1/d^2$ with d being the distance between sender and receiver.

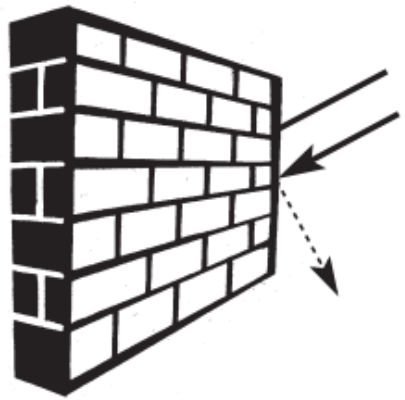
Cont...


Intensity at the surface of a sphere $I = \frac{P}{4\pi R^2}$
Surface area of sphere = $4\pi R^2$
Point Source
Radiation power P
I
R
I/4
2R
I/9
3R
A


Inverse Square Law ($1/d^2$)
Signal Strength
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
Distance

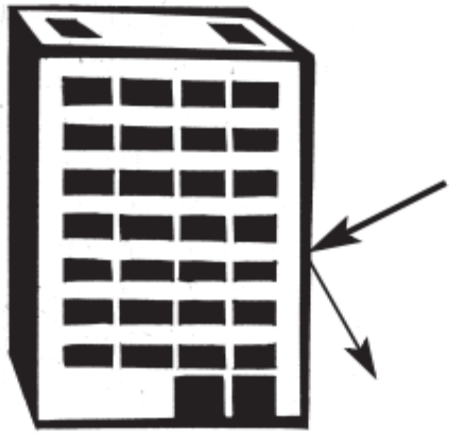
Additional signal propagation effects

Shadowing: Blocking radio signals due to large obstacles.



Shadowing

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.

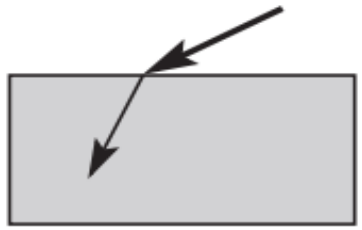


Reflection

Cont...

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.



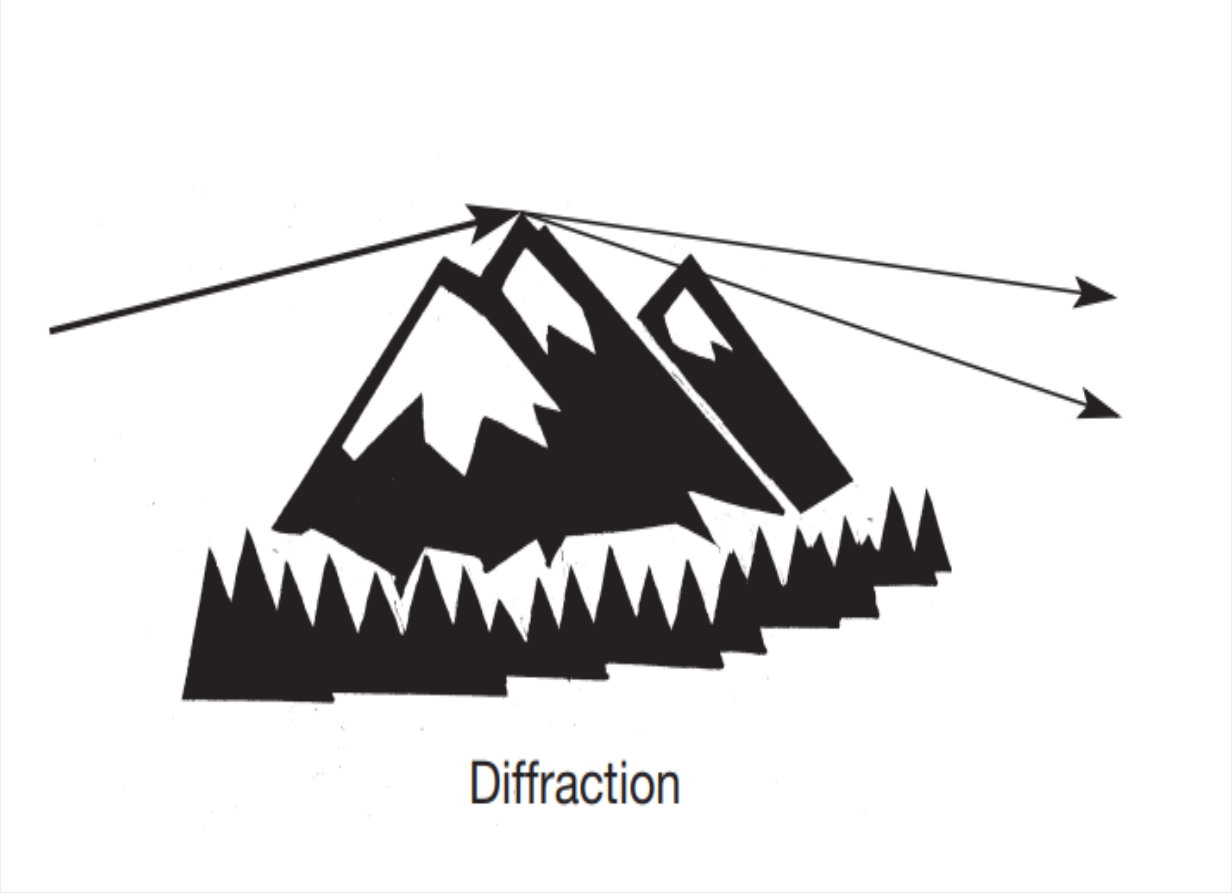
Refraction

Scattering

Cont...

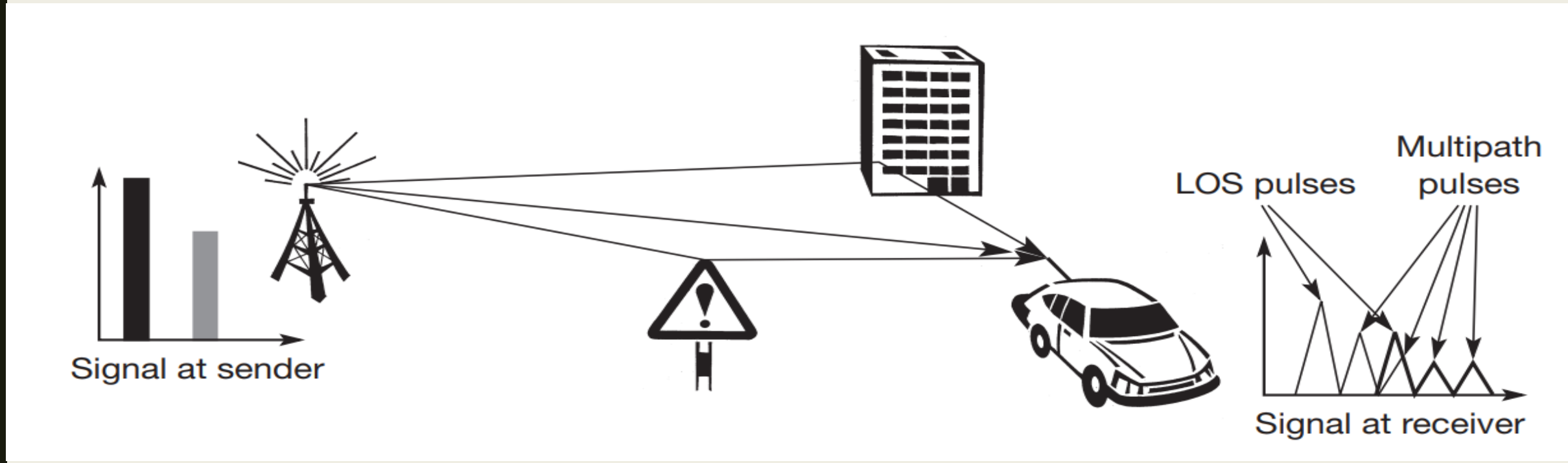
Diffraction: the bending of waves around the corners of an obstacle or through an aperture into the region of geometrical shadow of the obstacle/aperture.

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



Multipath Propagation

The transmitted signals can combine with reflected ones to corrupt the signal detected by the receiver. This is known as multipath propagation.

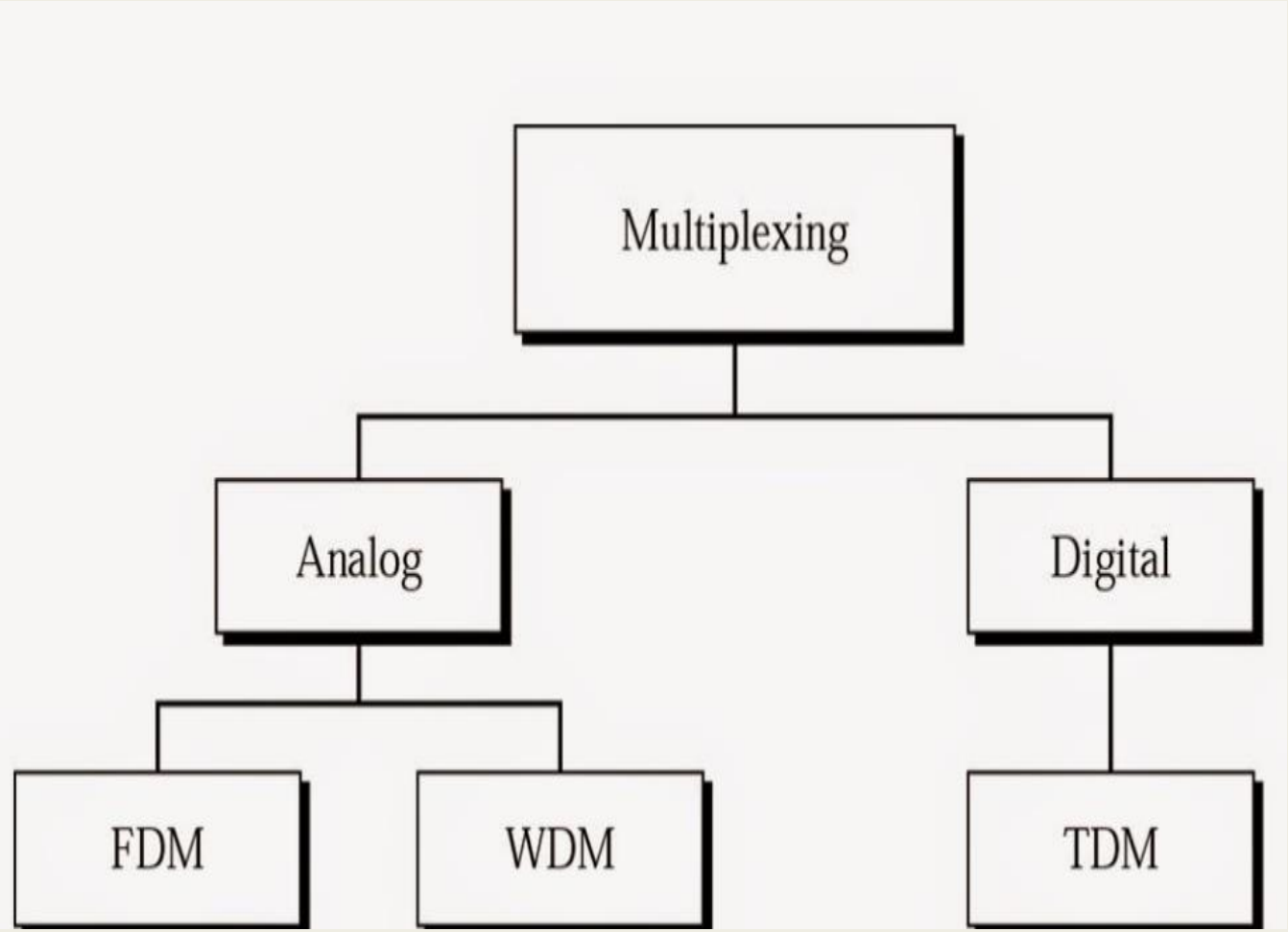


Multiplexing

- Multiplexing is the process of combining multiple signals into one signal, over a shared medium.
- It describes how several users can share a medium with minimum or no interference.
- It divides the high capacity medium into low capacity logical medium which is then shared by different streams.
- Communication is possible over the air (radio frequency), using a physical media (cable), and light (optical fiber). All mediums are capable of multiplexing.

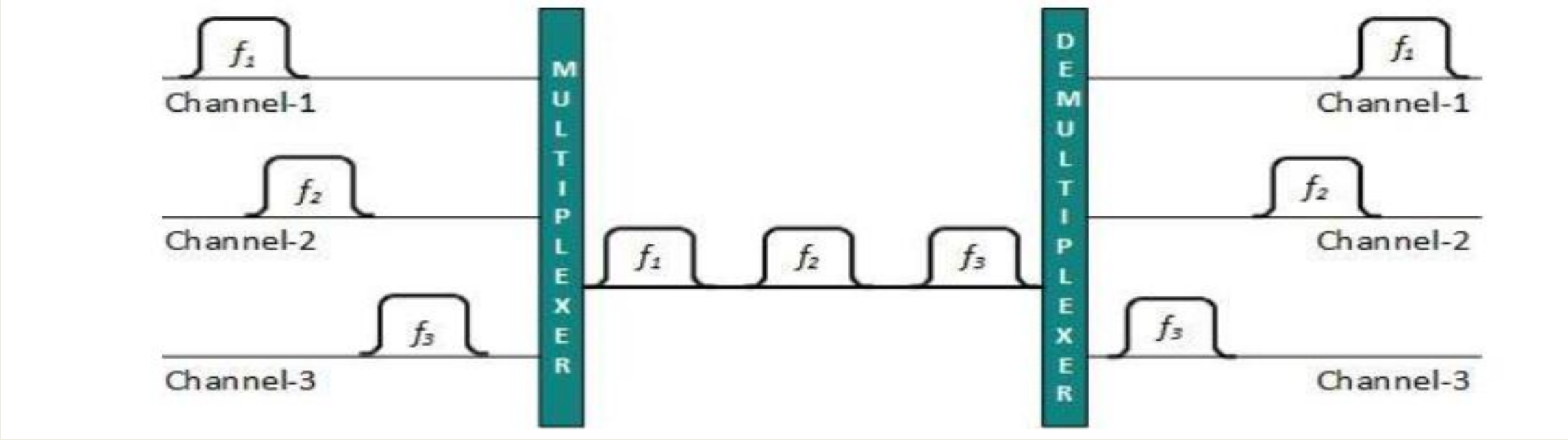
Types

- Frequency Division Multiplexing
- Time Division Multiplexing
- Space Division Multiplexing
- Code Division Multiplexing



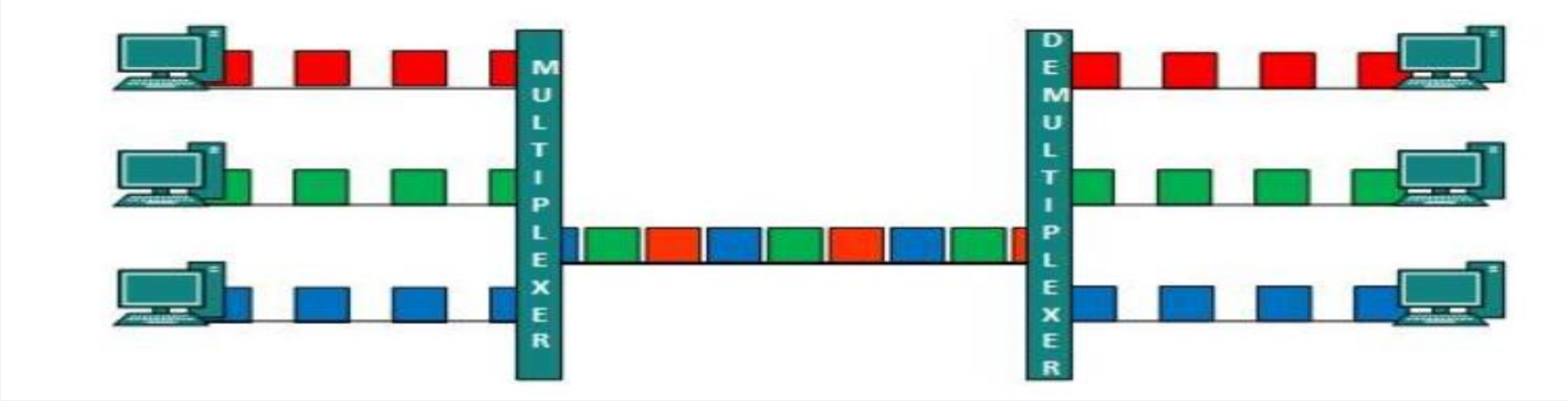
Frequency Division Multiplexing

- FDM divides the in logical channels and allocates one user to each channel.
- Each user can use the channel frequency independently.
- The channels do not overlap with each other.
- Channels are separated by guard bands.



Time Division Multiplexing

- In TDM the shared channel is divided among its user by means of time slot.
- Each user can transmit data within the provided time slot only.



Space Division Multiplexing

- SDM is a multiplexing technique in MIMO wireless communication, fiber-optic communication and other communications technologies used to transmit independent channels separated in space.

Code Division Multiplexing

- It allows its users to full bandwidth and transmit signals all the time using a unique code.
- Each station is assigned with a unique code, called chip. Signals travel with these codes independently, inside the whole bandwidth.

Modulation

- The process of superimposing a low-frequency signal on a high-frequency carrier signal.
- **Types:**
- Analog Modulation
  - Amplitude modulation (AM)
  - Frequency modulation(FM)
  - Phase modulation (PM).

- Digital Modulation
  - ASK or Amplitude shift Key
  - FSK or Frequency shift key
  - PSK or Phase shift key

Comparison

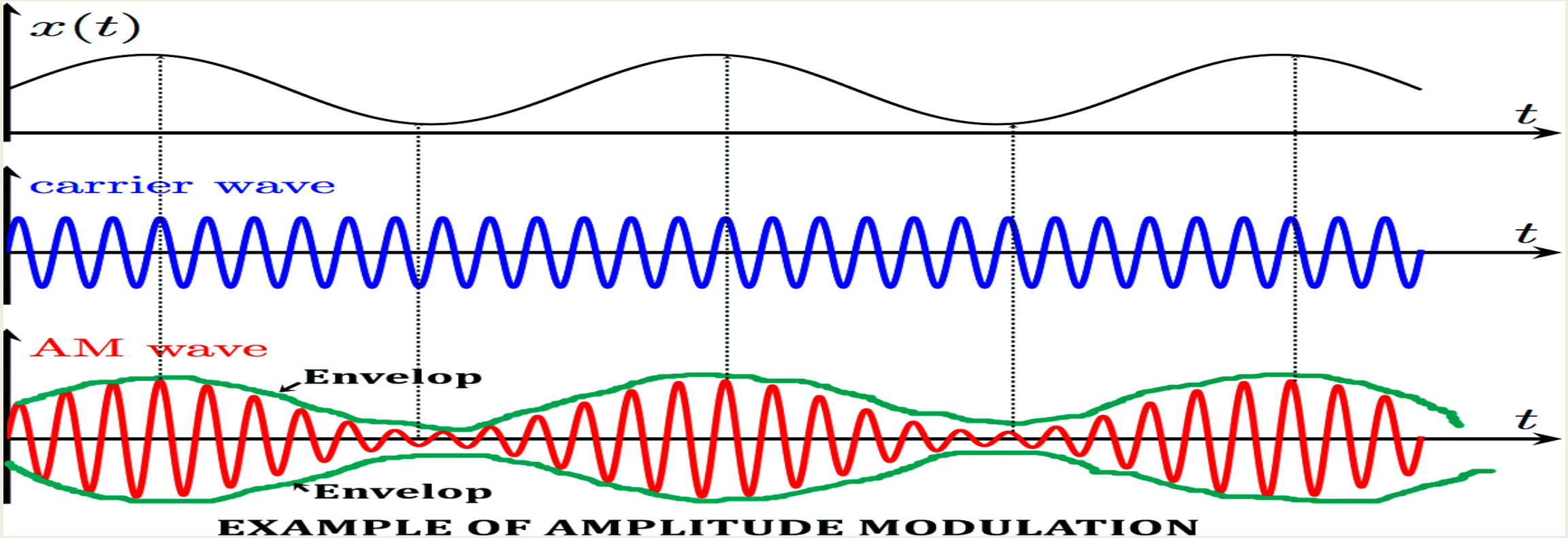
Analog Modulation	Digital Modulation
An AM signal can signify any value in a range.	A DM signal can only signify with a set of discrete values.
In analog modulation (AM), the input must be in the form of analog	In digital modulation (DM), the input must be the data in the form of digital
In AM, the value between the max & min is considered to be applicable.	In DM, only two binary numbers are considered applicable such as 1 and 0.

Cont…

Analog Modulation	Digital Modulation
It is much simpler to complete analog modulation	It requires extra phases to transmit DM.
The AM can generate a signal to carry the frequently changing data.	The DM generates a signal whose rate changes at particular time intervals.
In AM, it is not easy to disconnect the signal from noise.	In DM, the signal can simply disconnect from noise.

Amplitude Modulation

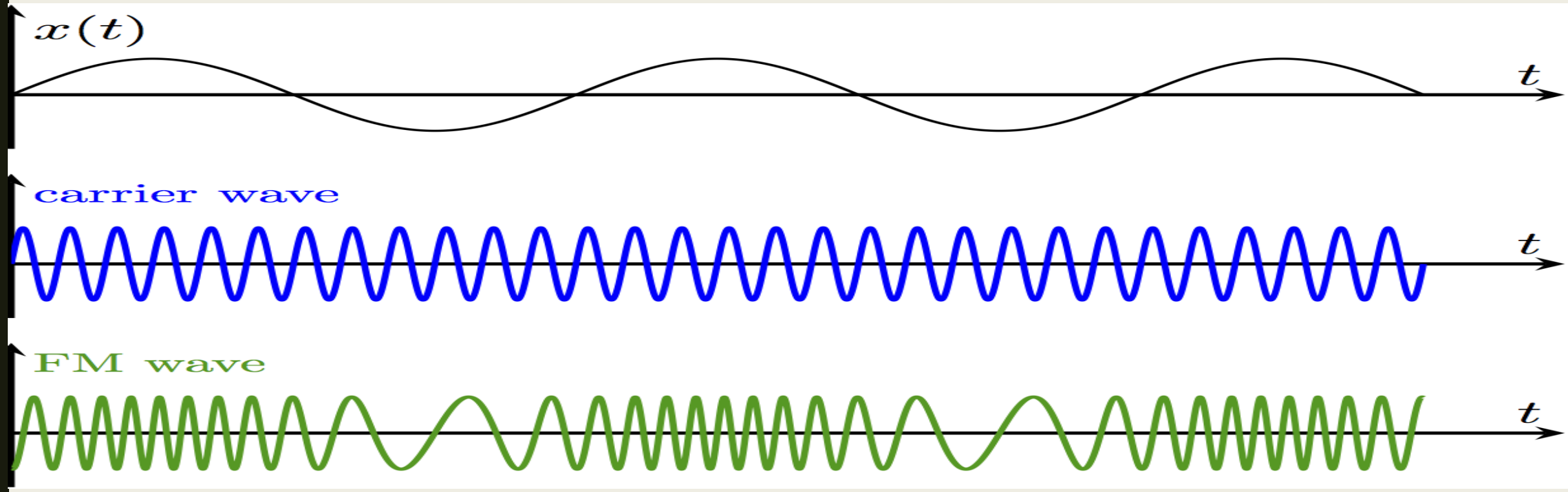
In amplitude modulation, the amplitude (signal strength) of the carrier wave is varied in proportion to that of the message signal, such as an audio signal.



EXAMPLE OF AMPLITUDE MODULATION

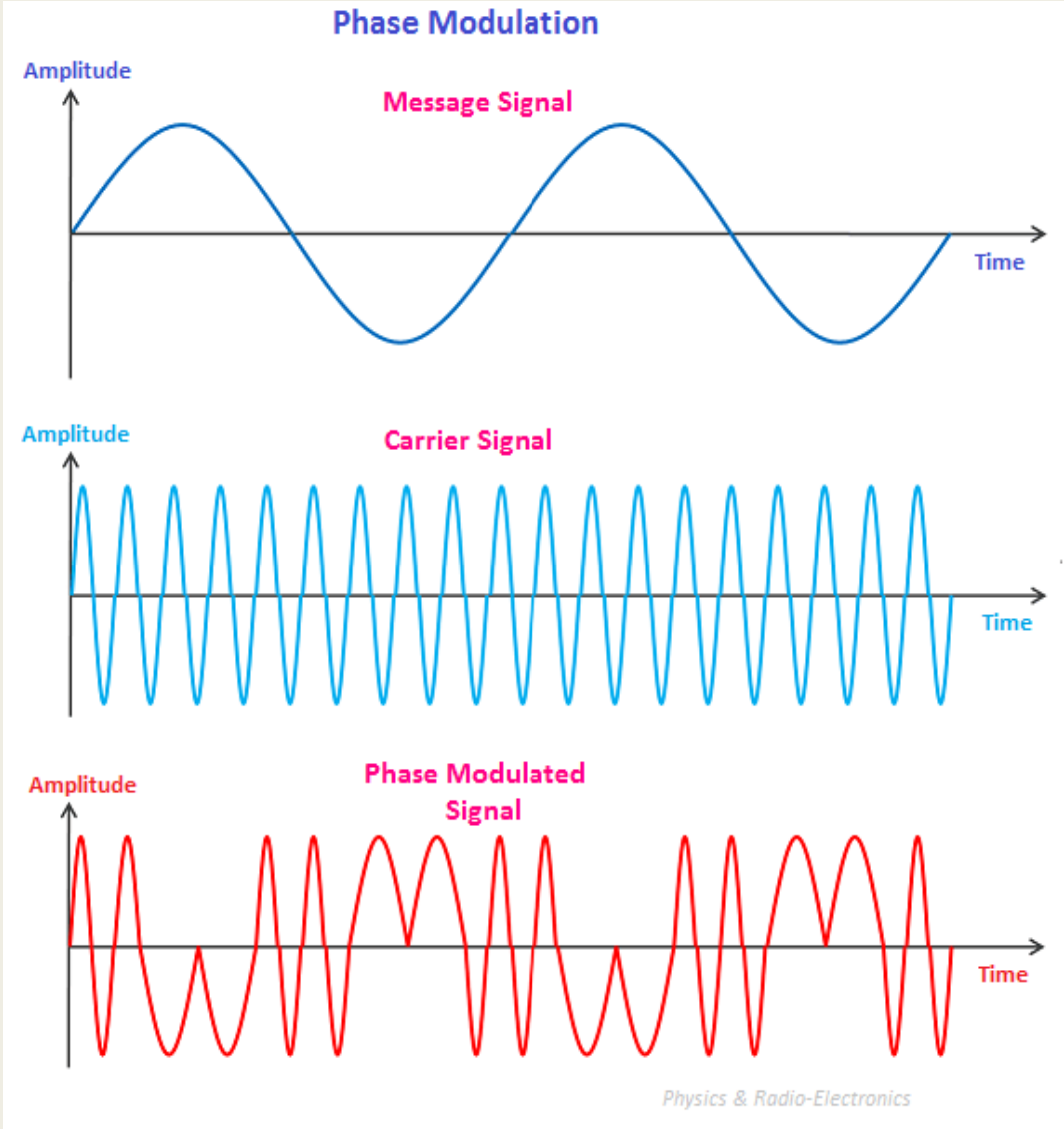
Frequency Modulation

- The frequency of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.
- The amplitude and the phase of the carrier signal remains constant whereas the frequency of the carrier changes.



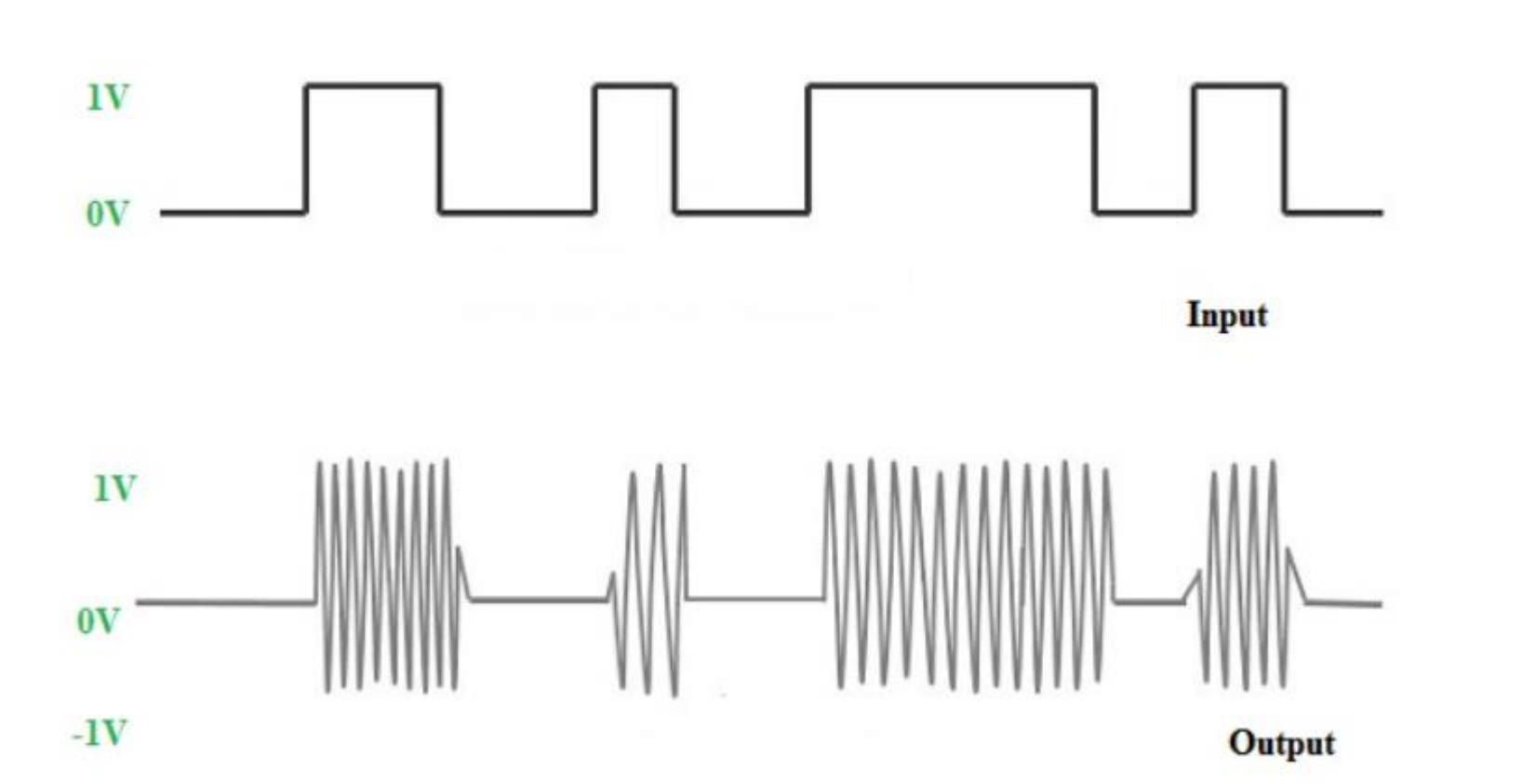
Phase Modulation

- The phase of a carrier signal is modulated to follow the changing signal level (amplitude) of the message signal.
- The peak amplitude and the frequency of the carrier signal are maintained constant, but as the amplitude of the message signal changes, the phase of the carrier changes correspondingly.



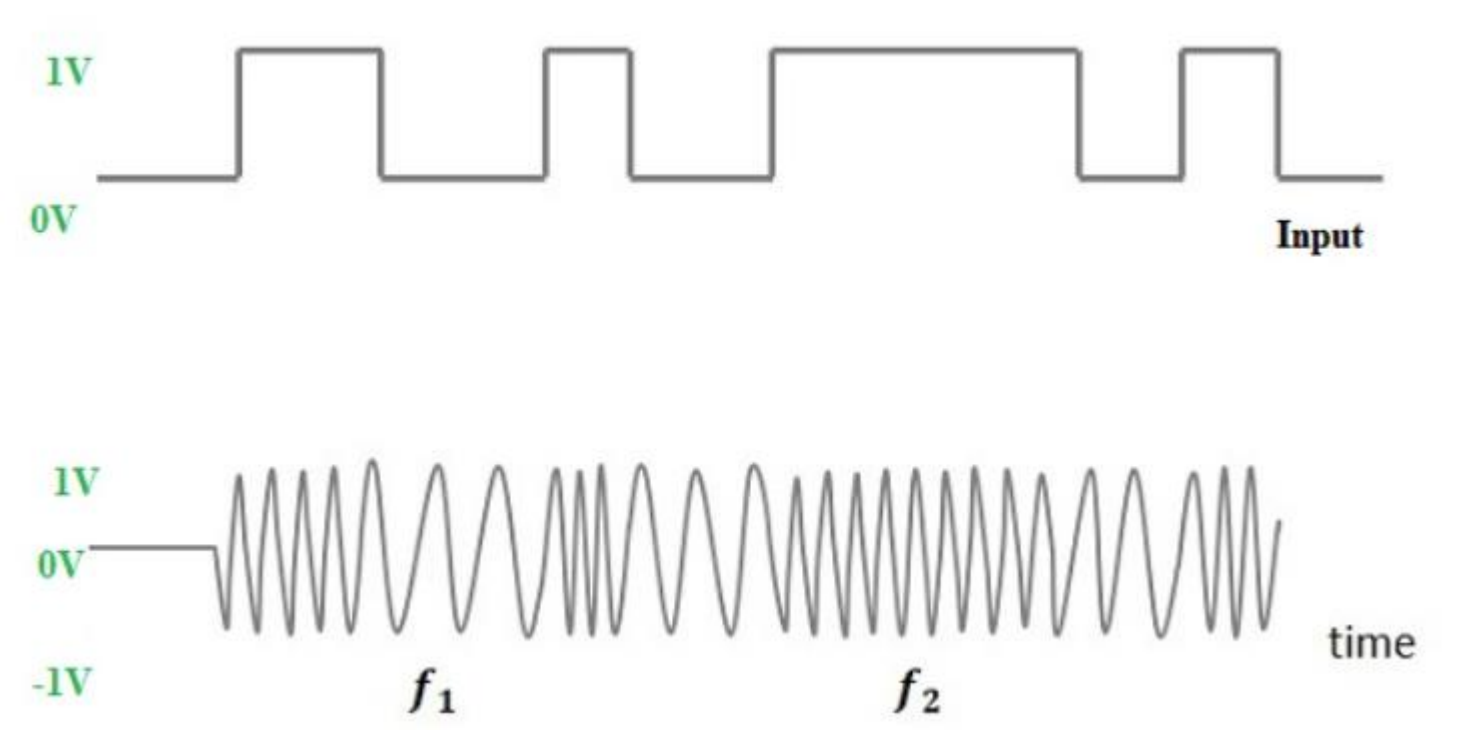
Amplitude Shift Key

- In **amplitude shift keying**, once the instant amplitude of the carrier signal is changed in quantity toward m(t) message signal.



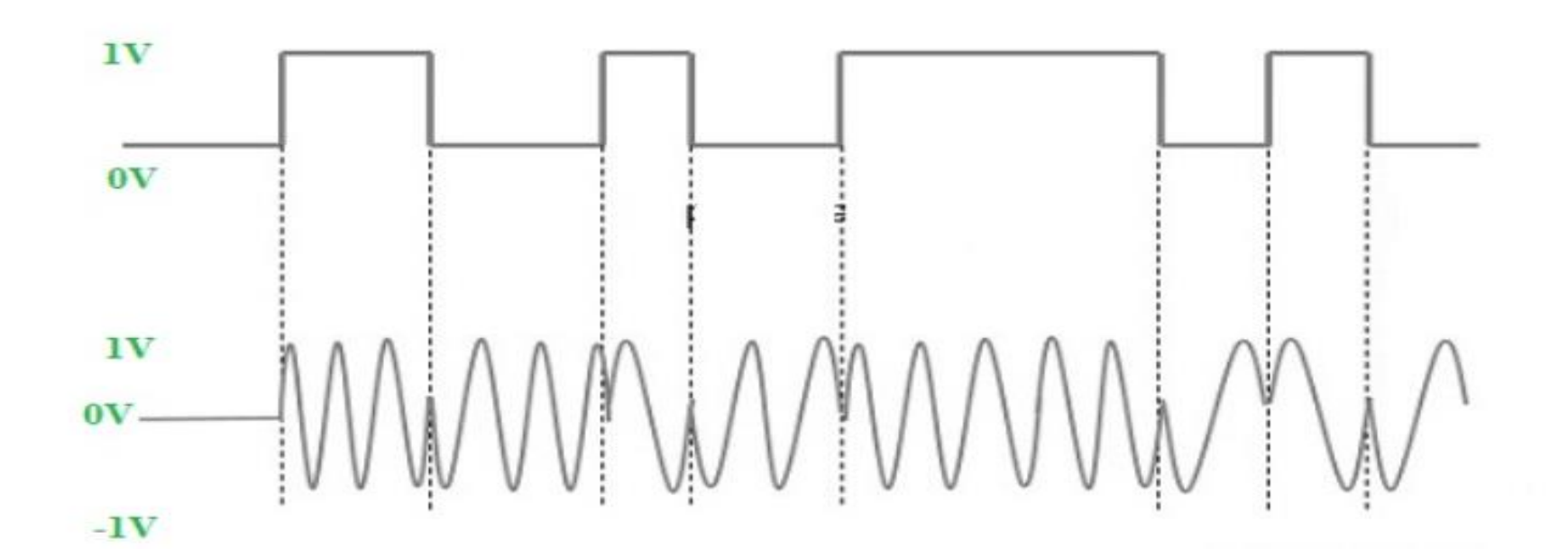
Frequency Shift Key

- In **frequency shift keying**, when the immediate frequency of the carrier signal is changed then the information will be transmitted.



Phase Shift Key

- In **phase shift keying**, the instant phase of the carrier signal is moved for this modulation. If the m(t) baseband signal is 1 then the carrier signal within phase will be transmitted. Similarly, If the baseband signal m(t)=0 then the carrier signal by out of phase is transmitted that is cos(wct+Π).

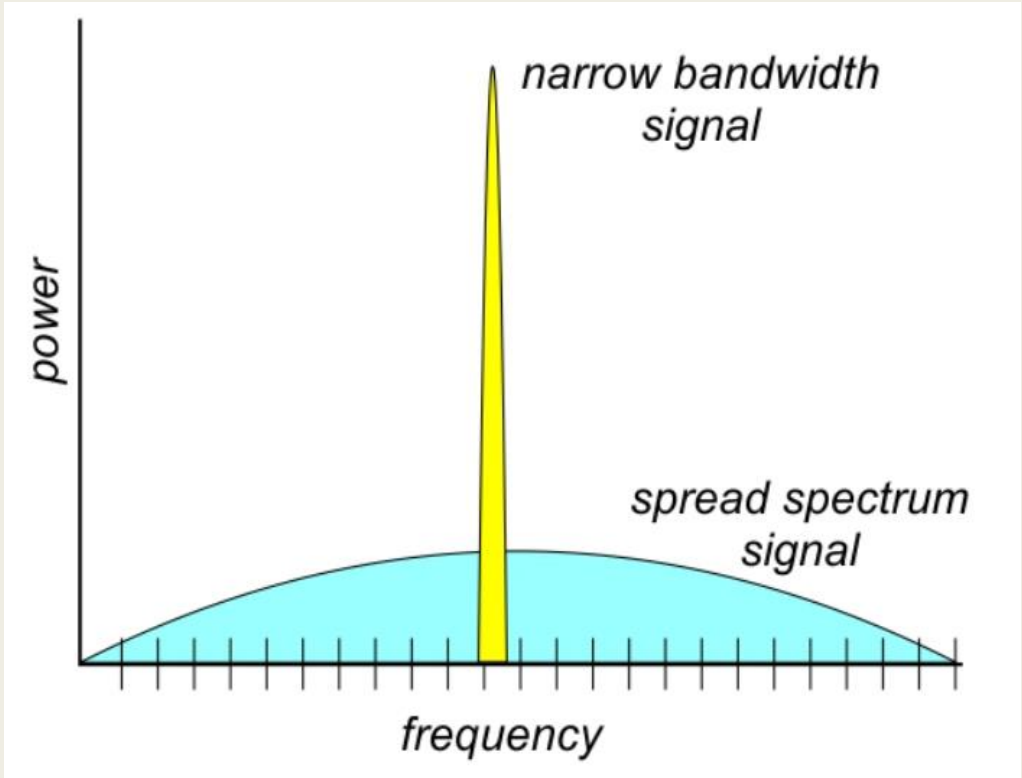


Spread Spectrum

- **Spread-Spectrum** techniques are methods by which a signal (e.g., an electrical, electromagnetic, or acoustic signal) generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth.

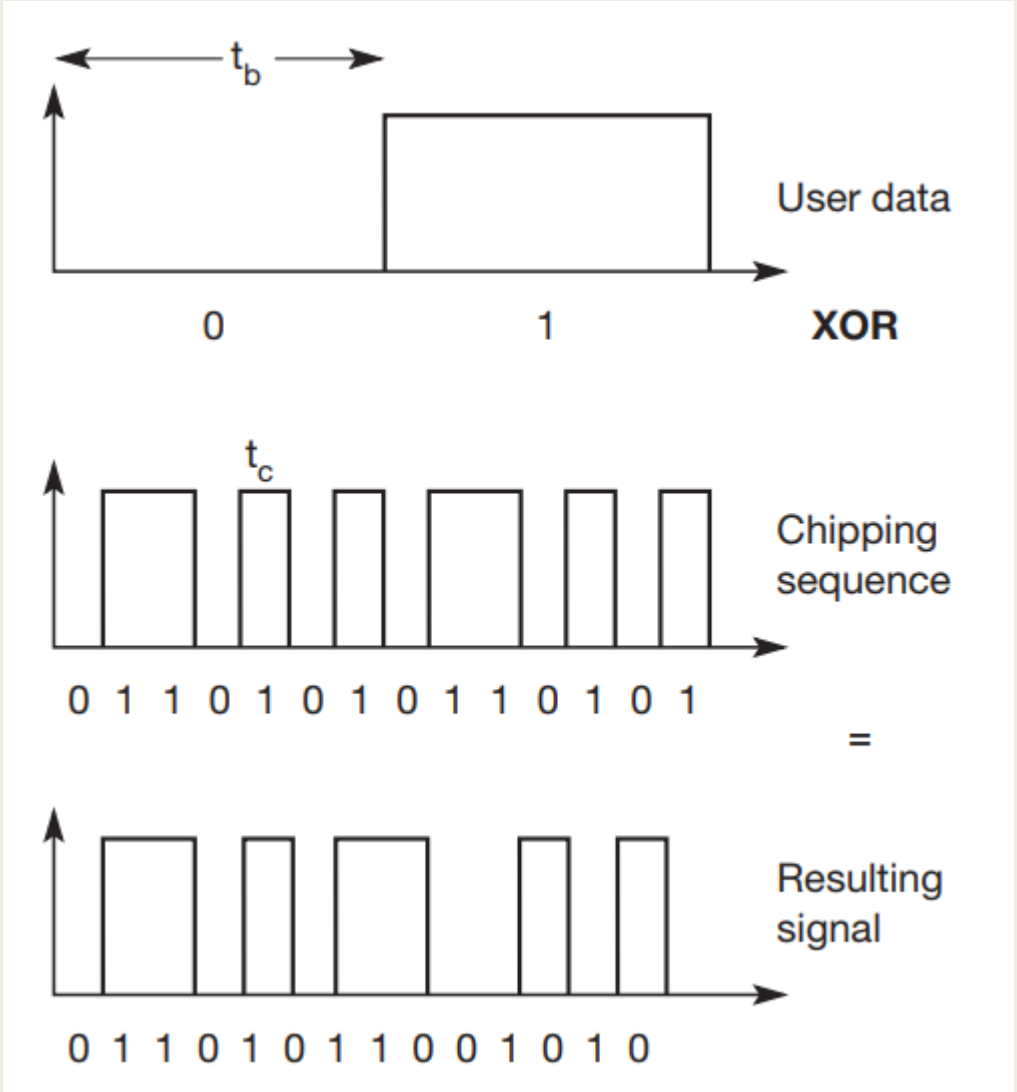
- **Techniques:**

- Direct sequence spread spectrum
- Frequency hopping spread spectrum



Direct sequence Spread Spectrum

- Direct sequence spread spectrum (DSSS) systems take a user bit stream and perform an (XOR) with a so-called chipping sequence to get the resulting signal.

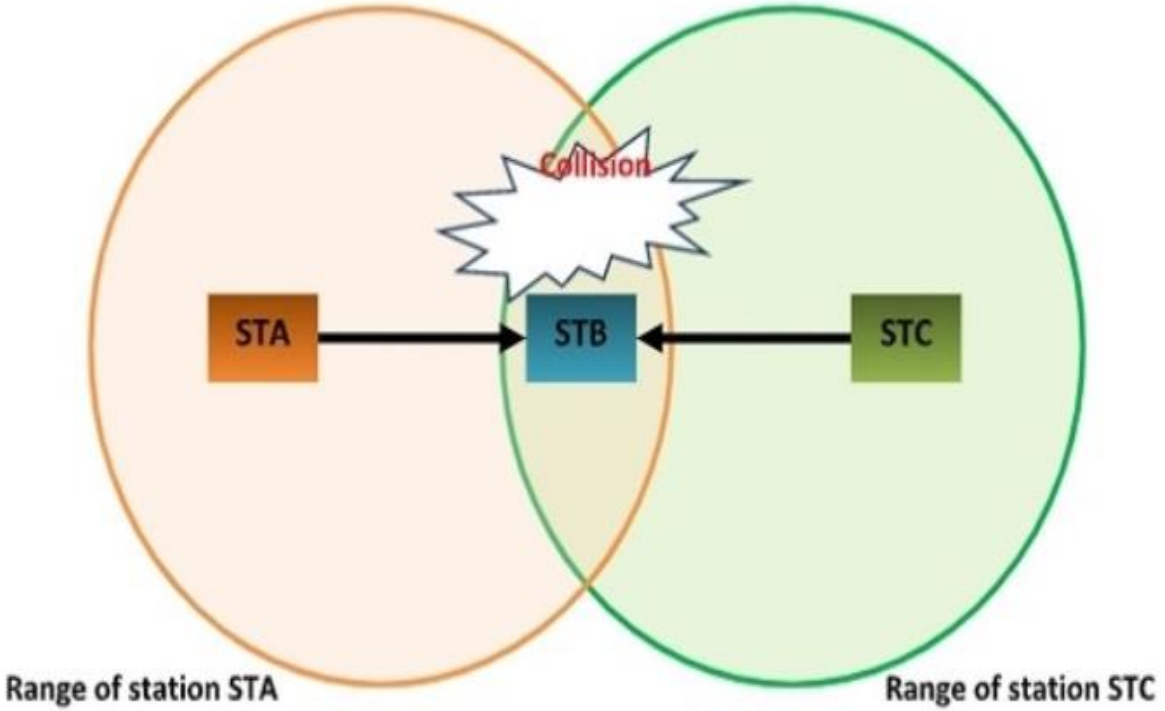


Frequency Hopping Spread Spectrum

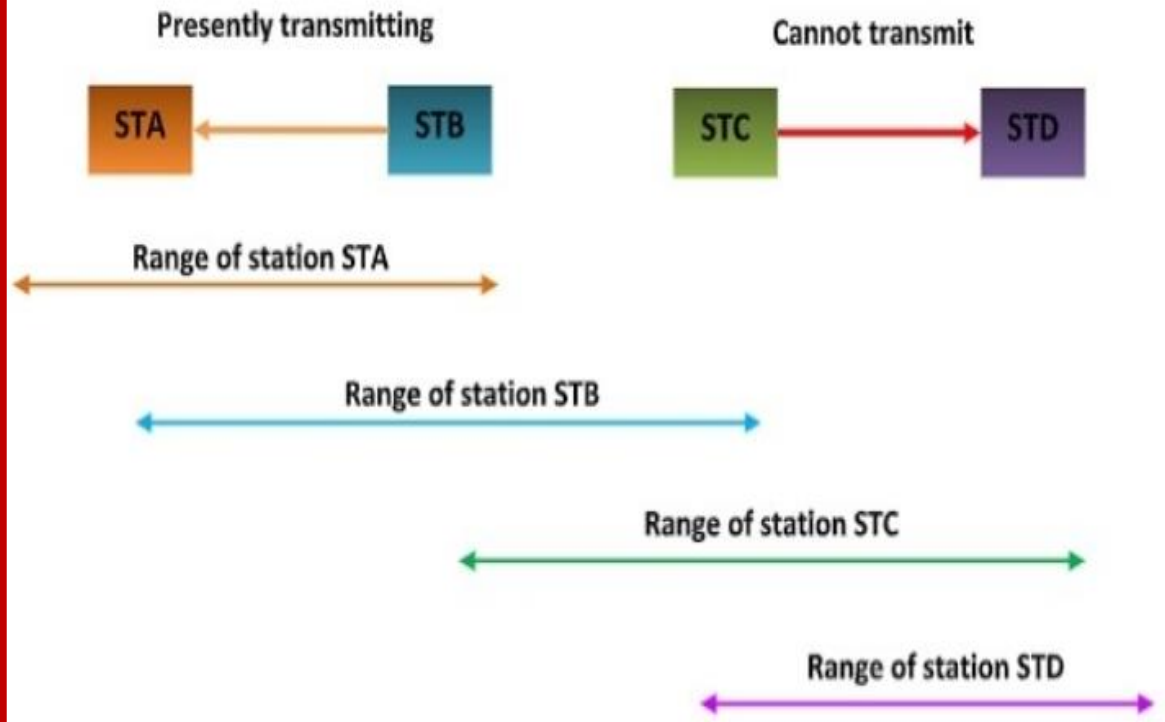
- For frequency hopping spread spectrum (FHSS) systems, the total available bandwidth is split into many channels of smaller bandwidth plus guard spaces between the channels.
- Transmitter and receiver stay on one of these channels for a certain time and then hop to another channel.

Medium Access Control

Hidden Terminal Problem



Exposed Terminal Problem



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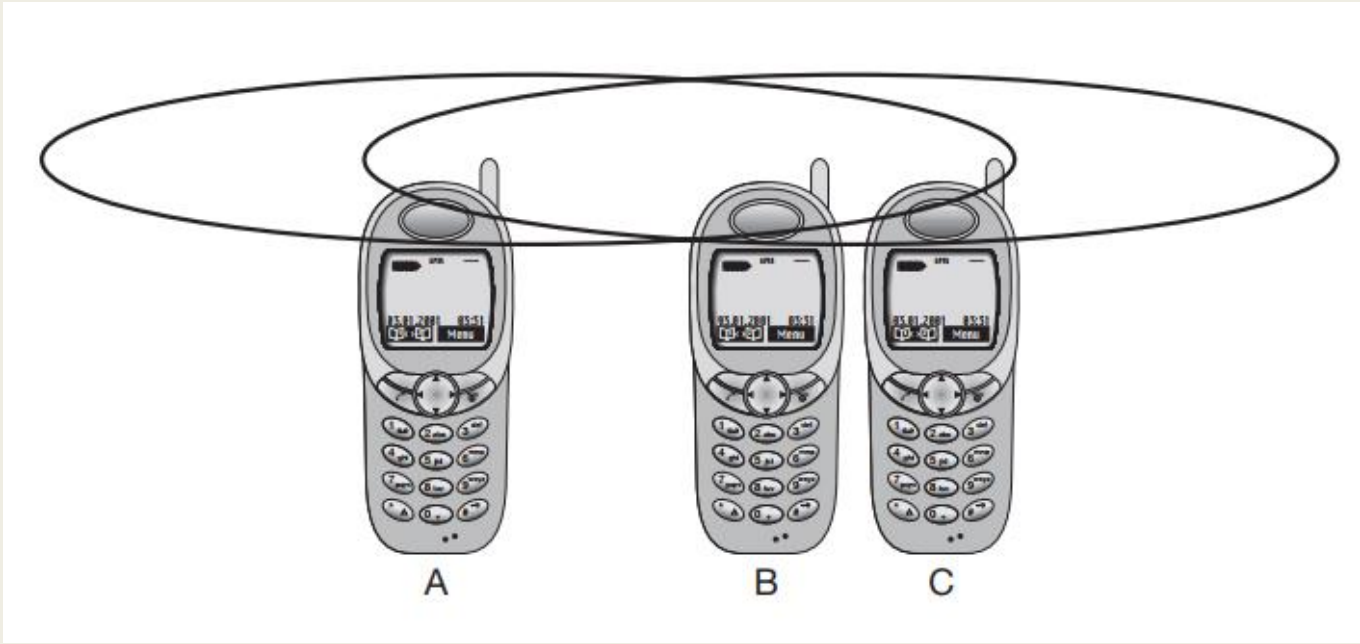
❑ Solution:

A transmitting station sends a RTS frame to the receiving station. The receiving station replies by sending a CTS frame. On receipt of CTS frame, the transmitting station begins transmission.

Any station hearing the RTS is close to the transmitting station and remains silent long enough for the CTS. Any station hearing the CTS is close to the receiving station and remains silent during the data transmission.

Near and Far Terminal

- A and B are both sending with the same transmission power.
- As the signal strength decreases proportionally to the square of the distance, B's signal drowns out A's signal.
- As a result, C cannot receive A's transmission.



SDMA: Space Division Multiple Access

- Allocates separate space to users in wireless networks.
- The basis for the SDMA algorithm is formed by cells and sectorized antennas which constitute the infrastructure implementing space division multiplexing (SDM).
- **Application:**

Assigning an optimal base station to a mobile phone user.

FDMA: Frequency Division Multiple Access

- Allocates frequencies to transmission channels according to the frequency division multiplexing (FDM).
- Can either be fixed (as for radio stations or the general planning and regulation of frequencies) or dynamic (i.e., demand driven).

- **Advantages:**
  - Reduces bit rate information, inter symbol interference and cost.
  - Easy to implement.

- **Disadvantages:**
  - The maximum flow rate per channel is fixed and small.
  - Guard bands lead to a waste of capacity.

TDMA: Time Division Multiple Access

- Facilitates many users to share the same frequency without interference.
- Divides a signal into different timeslots, and increases the data carrying capacity.

- **Advantages:**
  - Permits flexible rates.
  - No guard band and narrowband filter required for the wideband system.

- **Disadvantages:**
  - Complex signal processing is required to synchronize.
  - High data rates of broadband systems require complex equalization.

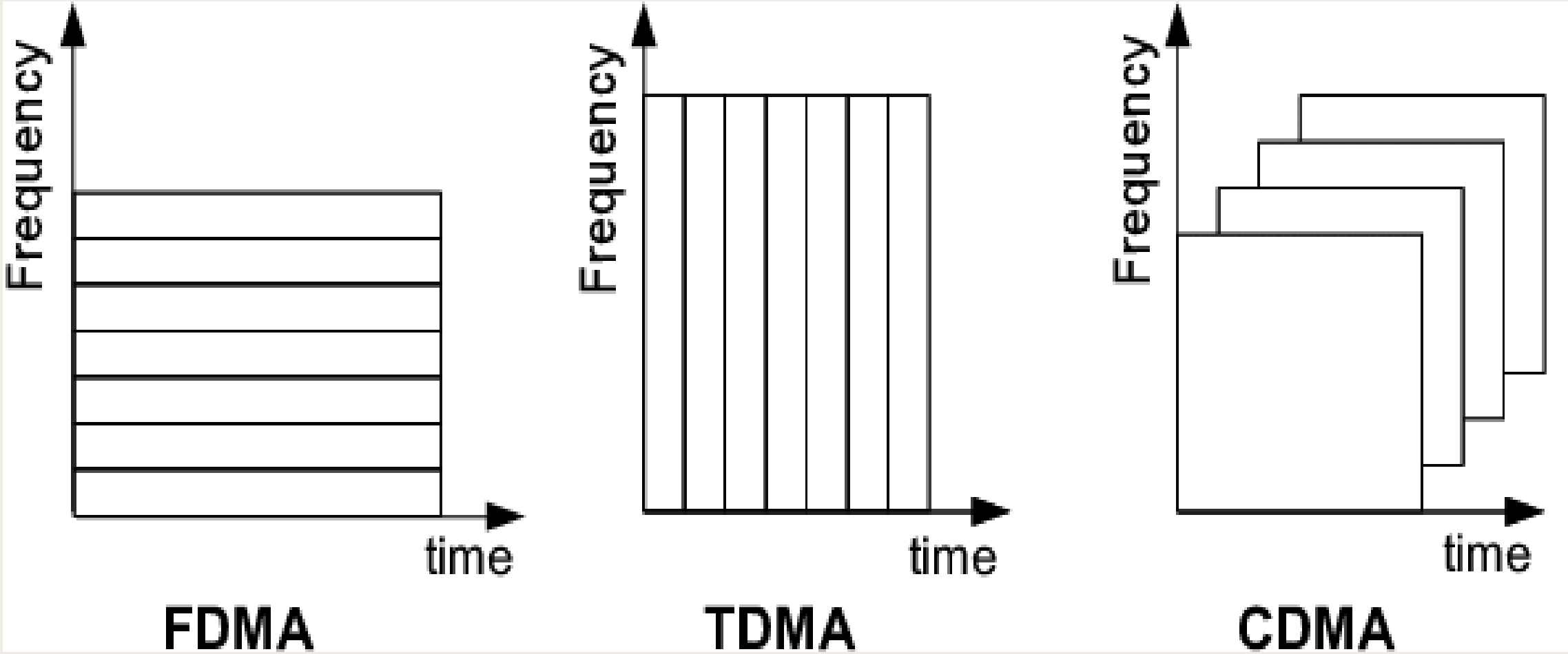
CDMA: Code Division Multiple Access

- User has access to the whole bandwidth for the entire duration.
- CDMA codes are used to distinguish among the different users.

- **Advantages:**
  - Reduces interference.
  - Flexible transfer may be used.

- **Disadvantages:**
  - A large code length can induce delay or may cause interference.
  - Time synchronization is required.

Cont...


Frequency
time
FDMA
Frequency
time
TDMA
Frequency
time
CDMA

Comparison

Approach	SDMA	TDMA	FDMA	CDMA
Idea	Segment spaced into cells or sectors.	Segments sending time into disjoint time slots demand driven.	Segment the frequency band into disjoint subbands	Spread the spectrum using orthogonal codes.
Terminals	Only one terminal can be active in one cell or one sector.	All terminals are active for short periods of time on same frequency.	Every terminal has its own frequency uninterrupted	All terminals can be active at the same place and moment uninterrupted.
Signal separation	Cell structure, directed antennas	Synchronization in time domain	Filtering in the frequency domain.	Code plus special receivers.

Cont…

Approach	SDMA	TDMA	FDMA	CDMA
Transmission scheme	Continuous	Discontinuous	Continuous	Continuous
Cell capacity	Depends on cell area	Limited	Limited	No absolute limit on channel capacity but it is an interference limited system
Advantages	Very simple, increases capacity per	Established fully digital, flexible	Simple, established, robust	Flexible, less frequency planning needed, soft handover