Lecture 2

Radio propagation characteristic

Introduction to wireless Technology

- The term *wireless communication* refers to the transfer of information using electromagnetic (EM) or acoustic waves over the atmosphere rather than using any propagation medium that employs wires. Not requiring an explicit network of wires and permitting communication while on the move
- Fortunately, EM waves travel with the speed of light in free space and inside medium (cables) – with a

delay-time =length of cable/C

EM waves can propagate in free space and inside different media

This allows very fast communication.

Understanding Radio Frequency

- *like antenna th*at use it for various types of communications. and everything, and comes in many forms. RF energy is emitted from the numerous devices television, cordless phones, WLANs, and satellite communications. RF is around everyone *Radio frequency* (RF) waves are used in a wide range of communications, including radio,
- Figure 2.1 shows some of the many ways RF is used,

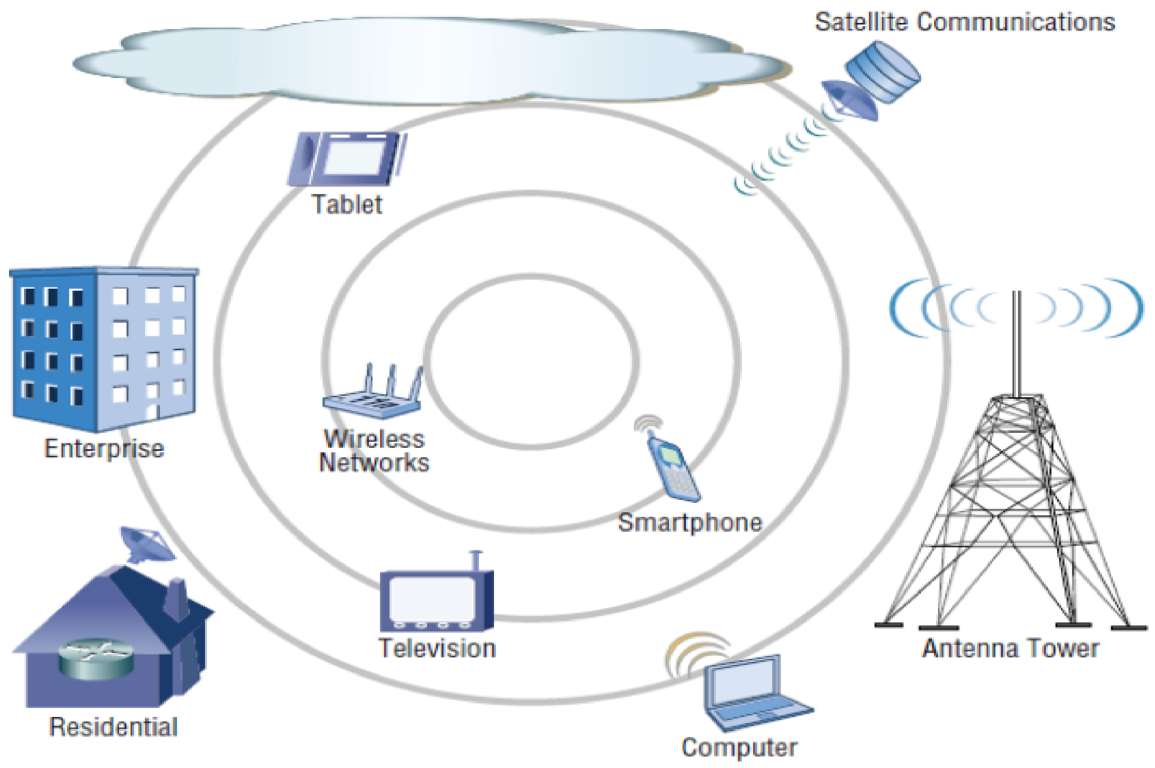
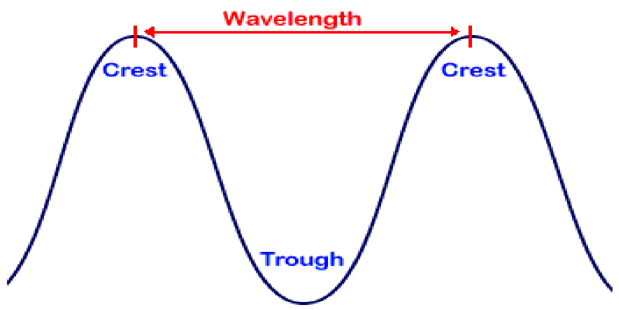


Figure 2.1. Radio frequency is used in many different devices to provide wireless communications

- RF consists of high-frequency alternating current (AC) signals passing over a copper cable connected to an antenna.
- This antenna will then transform the received signal into radio waves that propagate through the air.
- The most basic AC signal is a *sine wave*, which is the result of an electrical current varying uniformly in voltage over a period of time. This sine wave cycle will repeat a specific number of times (cycles) over a period of one second. The number of cycles per second will result in different frequencies, measured in **Hertz.**



- The distance between two consecutive maxima is called the wavelength, designated by λ. In vacuum, all electromagnetic waves travel at the speed of light: $c = 3\times10^8$ m/sec.
  In copper or fiber the speed slows down to about 2/3 of this value.
  Relation between f,λ, c: $C = \lambda f$

- Successful radio transmissions consist of a minimum of two components, a *transmitter* and *receiver* (see Figure 3.1).

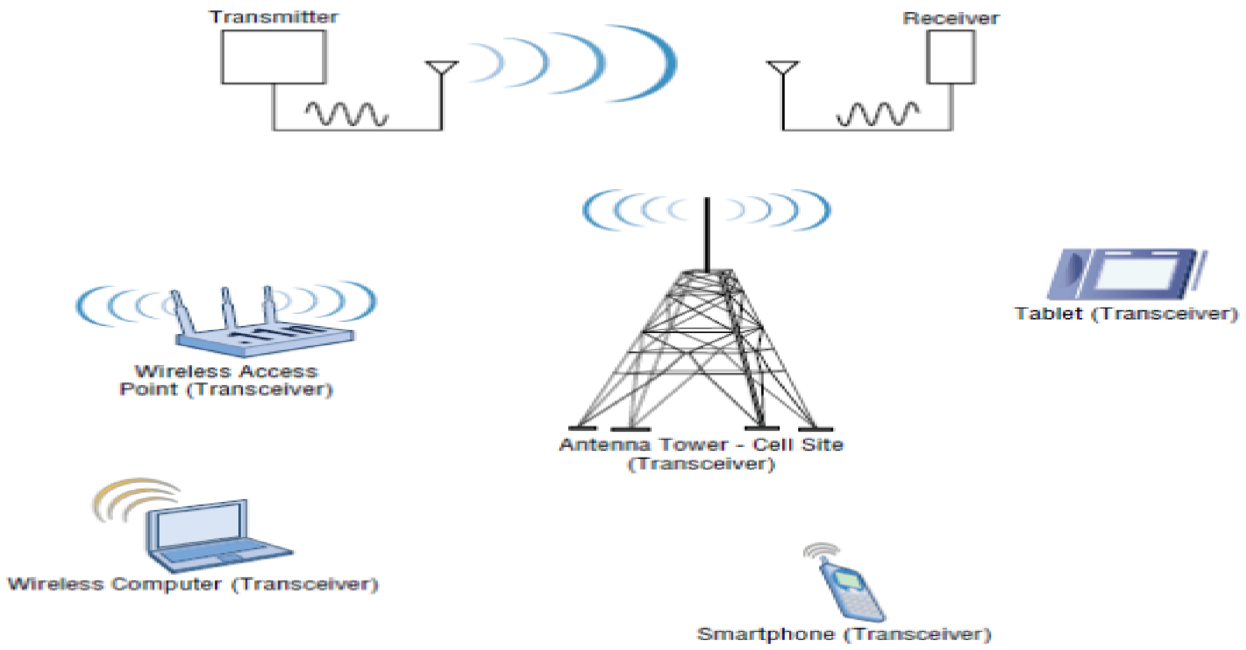


Figure 2.2 RF transmitter and receiver. In a WLAN, the transmitter and receiver could be an access point and client device, respectively.

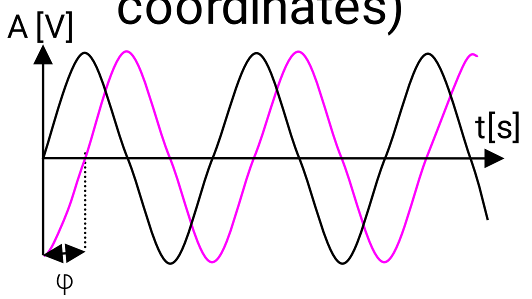
Signals

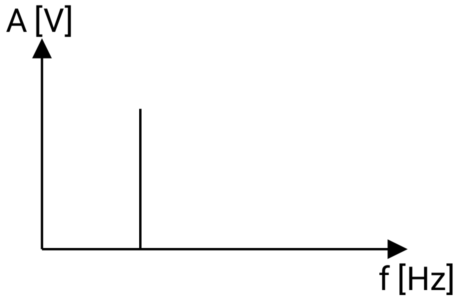
- physical representation of data
- function of time and location
- signal parameters: parameters representing the value of data
- classification
  - continuous time/discrete time
  - continuous values/discrete values
  - analog signal = continuous time and continuous values
  - digital signal = discrete time and discrete values
- signal parameters of periodic signals: period T, frequency f=1/T, amplitude A, phase shift φ
  - sine wave as special periodic signal for a carrier:

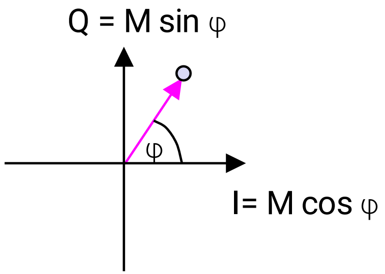
$$s(t) = A_t \sin(2 \pi f_t t + \varphi_t)$$

Signals

- Different representations of signals
  - amplitude (amplitude domain)
  - frequency spectrum (frequency domain)
  - phase state diagram (amplitude M and phase φ in polar coordinates)

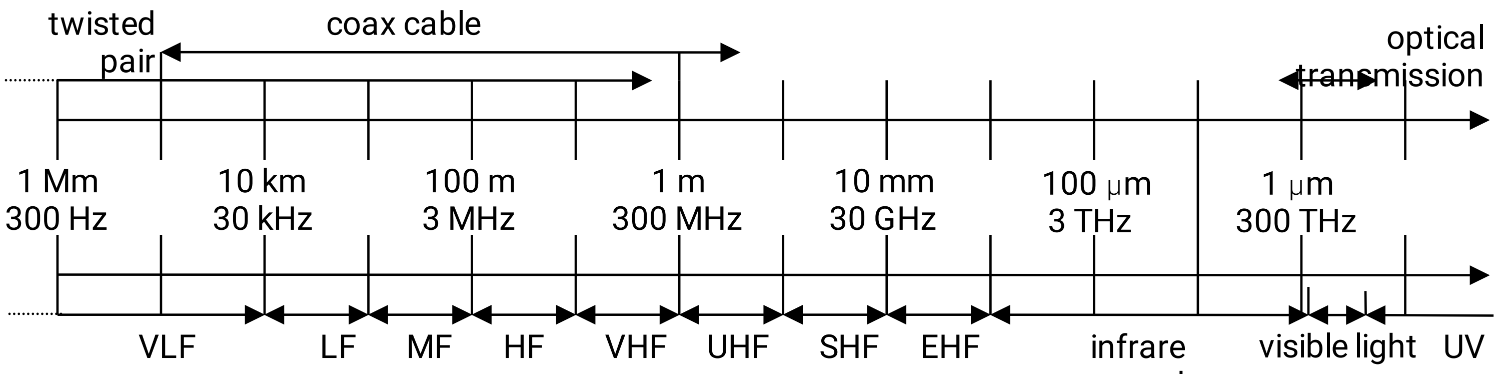






- Composed signals transferred into frequency domain using Fourier transformation
- Digital signals need
  - infinite frequencies for perfect transmission
  - modulation with a carrier frequency for transmission.

Frequencies for communication



- VLF = Very Low Frequency
- LF = Low Frequency
- MF = Medium Frequency
- HF = High Frequency
- UHF = Ultra High Frequency
- SHF = Super High Frequency
- EHF = Extra High Frequency
- UV = Ultraviolet Light
- VHF = Very High Frequency

- Frequency and wave length:
- $\lambda = c/f$
- wave length λ, speed of light $c \cong 3x10^8$ m/s, frequency f

- Wireless LANs use frequencies from UHF to SHF spectrum
  - some systems planned up to EHF
  - limitations due to absorption by water and oxygen molecules (resonance frequencies)
    - weather dependent fading, signal loss caused by heavy rainfall etc.

WIRELESS PROPAGATION

A signal radiated from an antenna travels along one of three routes:

- Ground wave.
- Sky wave.
- Line of sight (LOS).

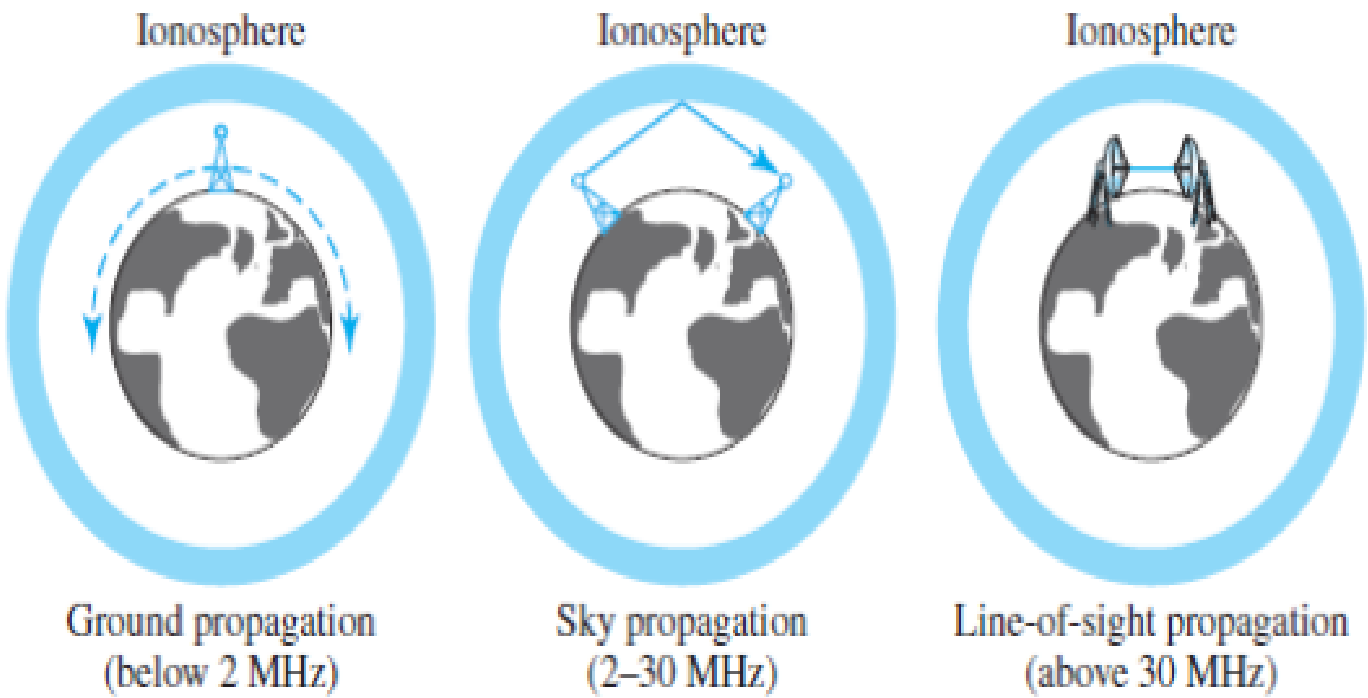


Figure 2.2 Propagation methods

Ground propagation

- In **ground propagation,** radio waves travel through the lowest portion of the atmosphere, hugging the earth.
- Radio waves (up to 2 MHz) emanate in all directions from the transmitting antenna and follow the curvature of the planet.
- Distance depends on the amount of power in the signal: The greater the power, the greater the distance.
- Radio waves with low and medium frequencies are employing , which can pass obstacles.
- Omnidirectional antenna is used, where in signals send out in all directions.

sky propagation

- In **sky propagation,** higher-frequency radio waves (2Mhz to 30Mhz) radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth.
- The ionoshere are: part of the earth's atmosphere, from about 60 kilometers to about 1,000 kilometres above the surface, in which there are many ions.
- The waves that reach ionosphere are refracted and sent back to earth.
- This type of transmission allows for greater distances with lower output power.
- Omnidirectional antenna is used.

Figure 2.3 Omnidirectional antenna

line-of-sight propagation

- Very high-frequency signals are transmitted in straight lines directly from antenna to antenna.
- Directional antennas are used.
- LOS: Line-of-Sight Communication.
- At very higher frequencies, radio waves have difficulty passing via obstacles.

Radio Frequency Channels

- RF is divided into bands. These bands can be further separated into

channels .

- A channel is a smaller allocation of a RF band.

Radio propagation characteristic

Radio Wave Basics: Propagation

LOS-Line of Sight Channel

LOS stands for Line of Sight and NLOS stands for Non Line of Sight.

LOS communication is possible when there is no obstruction between transmitter and receiver. Due to less attenuation in the LOS communication, it offers good signal strength and higher amount of throughput compare to NLOS counterpart.
Examples of LOS wireless link:

- Microwave point to point communication
- point to point connection between BS and SS.

Radio propagation characteristic

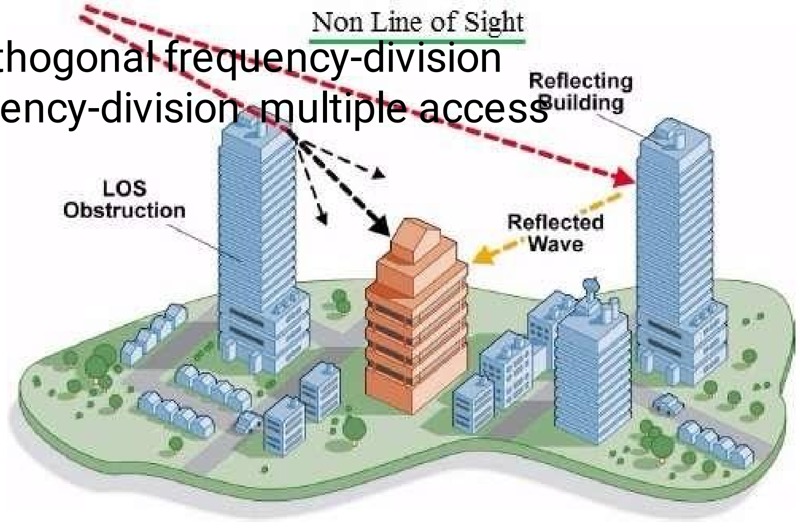
Radio Wave Basics: Propagation

NLOS-Non Line of Sight Channel

NLOS communication is possible even when there is obstruction between transmitter and receiver. The signal arrives to the receiver after going through many obstructions in between. On the path, signal goes through attenuations as well as reflection, as well as diffraction.

Due to NLOS, multiple copies of signals arrive at different times with different amplitudes.
This problem is avoided with the use of (Orthogonal frequency-division multiplexing (OFDM)) and Orthogonal frequency-division multiple access (OFDMA) techniques.
Examples of NLOS wireless link:

- WiMAX
- WLAN



Propagation Models

We are interested in propagation characteristics and models for waves between few MHz to a few GHz.

Modeling radio channel is important for:

•Determining the coverage area of a transmitter

- Determine the transmitter power requirement
- Determine the battery lifetime.

•Finding modulation schemes to improve the channel quality

- Determine the maximum channel capacity

•Transmission path between sender and receiver could be

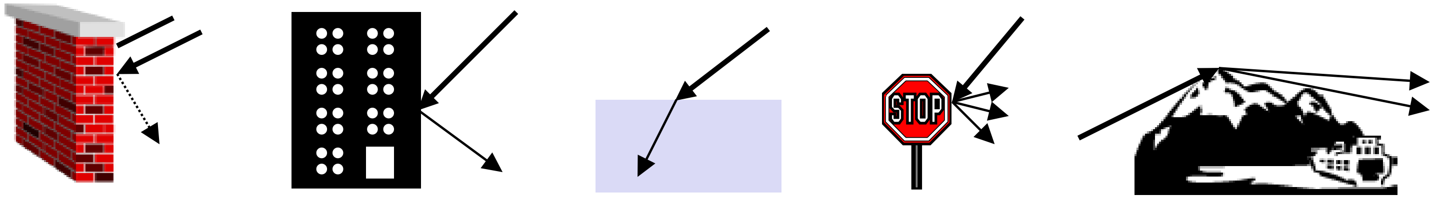
➤ Line-of-Sight (LOS)

➤ Obstructed by buildings, mountains and foliage

•Even speed of motion effects the fading characteristics of the channel

Signal propagation

- Propagation in free space always like light (straight line)
- Receiving power proportional to $1/d^2$
  (d = distance between sender and receiver)
- Receiving power additionally influenced by
  - fading (frequency dependent)
  - shadowing
  - reflection at large obstacles
  - refraction depending on the density of a medium
  - scattering at small obstacles
  - diffraction at edges



shadowin
g | reflection | refraction | scatterin
g | diffractio
n

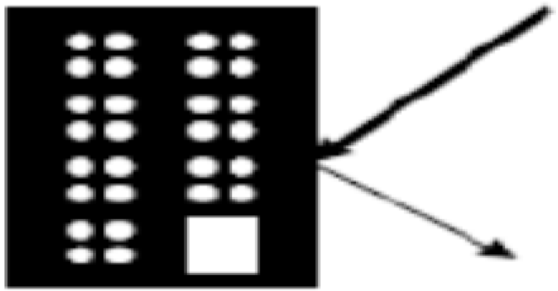
Radio Propagation Mechanisms

- The physical mechanisms that govern radio propagation are complex and diverse, but generally attributed to the following factors: Reflection, Absorption, Diffraction and Scattering.
- Reflection:-

Reflection causes the signal to bounce back on itself. The signal can interfere with itself in the air and affect the receiver's ability to discriminate between the signal and noise in the environment.

Reflection is caused by metal surfaces such as metal doors. Implementing a Wireless LAN (WLAN) across a parking lot can be tricky because of metal cars that come and go.

- Occurs when waves impinges upon an obstruction that is much larger in size compared to the wavelength of the signal.



Radio Propagation Mechanisms

• Absorption:-

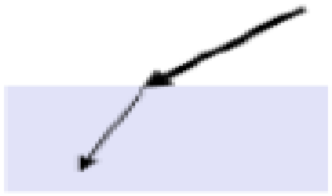
- Some of the electromagnetic energy of the signal can be absorbed by the material in objects through which it passes, resulting in a reduced signal level. Water has signif icant absorption properties, and objects such as trees or thick wooden structures can have a high water content.
- Implementing a WLAN in a coffee shop can be tricky if there are large canisters of liquid coffee.
- Coffee-shop WLAN users have also noticed that people coming and going can affect the signal level.

Material	2.4 GHz	5 GHz
Wooden Door	4 dB	7 dB
Concrete Wall	20 dB	30 dB
Plain Glass Window	3 dB	8 dB
Steel Door	20 dB	30 dB
Human body	3 dB	5 dB
Trees/Vegetation	0.5 dB/mtr	1 dB/mtr

Attenuation/Absorption Figures For Common Objects

Refraction.

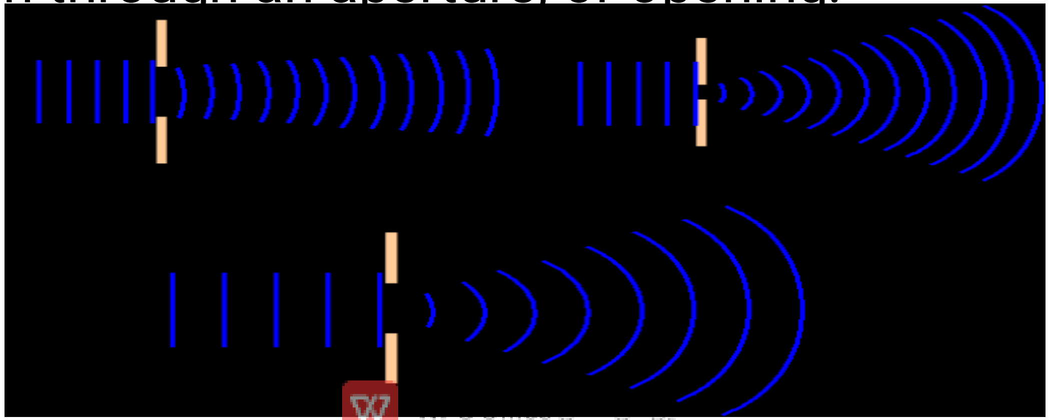
- When an RF signal passes from a medium with one density into a medium with another density, the signal can be bent, much like light passing through a prism.
- The signal changes direction and may interfere with the non-refracted signal.
- It can take a different path and encounter other, unexpected obstructions, and arrive at recipients damaged or later than expected. As an example, a water tank not only introduces absorption, but the difference in density between the atmosphere and the water can bend the RF signal.



refraction

Diffraction

- Diffraction, which is similar to refraction, results when a region through which the RF signal can pass easily is adjacent to a region in which reflective obstructions exist.
- Like refraction, the RF signal is bent around the edge of the diffractive region and can then interfere with that part of the RF signal that is not bent.
- Diffraction is the bending of waves around obstacles, or the spreading of waves by passing them through an aperture, or opening.



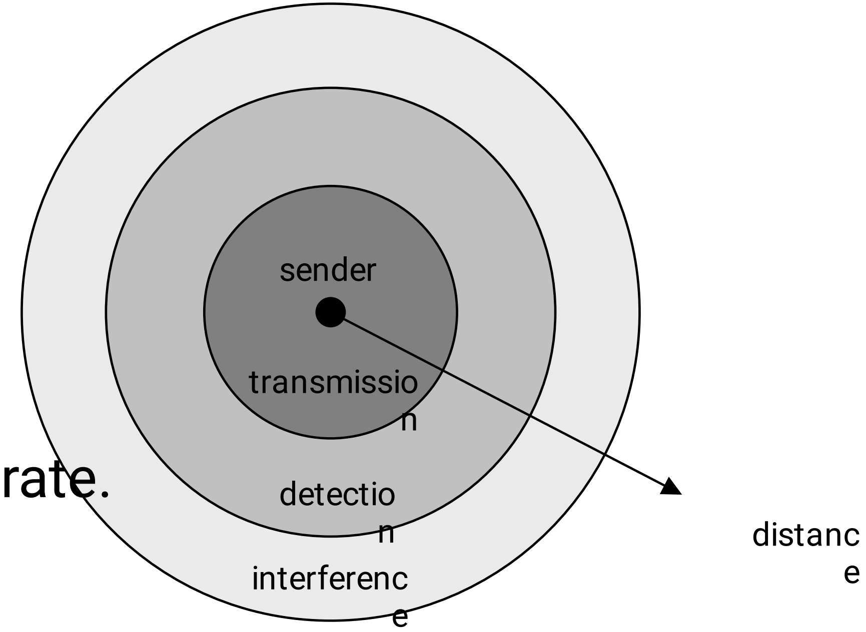
Scattering

- Scattering occurs when light bounces off an object in a variety of directions. The amount of scattering that takes place depends on the wavelength of the wave and the size and structure of the object.
- They are produced by small objects, rough surfaces and other irregularities on the channel causes the transmitter energy to be radiated in many directions Lamp posts and street signs may cause scatterin

- As a mobile moves through a coverage area, these mechanisms have an impact on the instantaneous received signal strength.
- If a mobile does have a clear line of sight path to the base-station, then the diffraction and scattering will not dominate the propagation.
- If a mobile is at a street level without LOS, then diffraction and scattering will probably dominate the propagation.

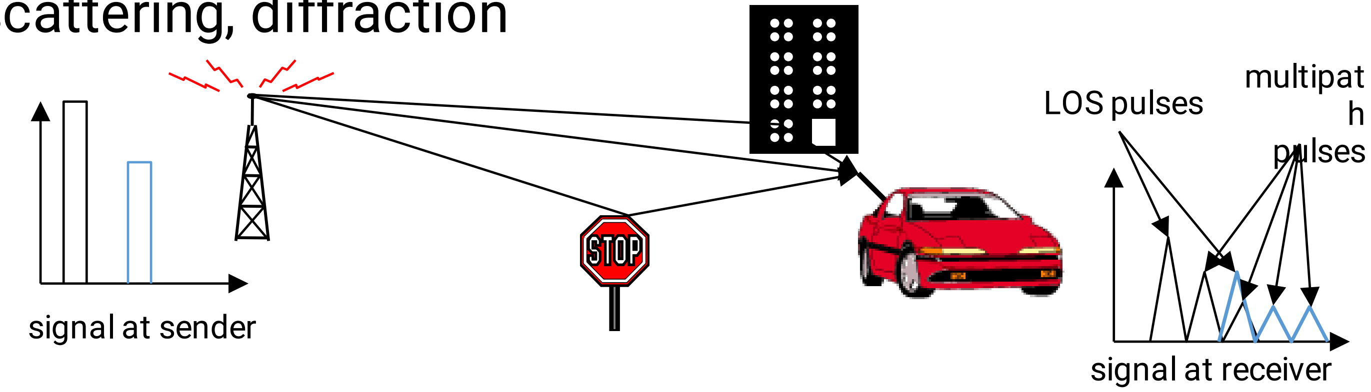
Signal propagation ranges

- Transmission range
  - communication possible
  - low error rate
- Detection range
  - detection of the signal possible
  - no communication possible , because of high error rate.
- Interference range
  - signal may not be detected
  - signal adds to the background noise



Multipath propagation

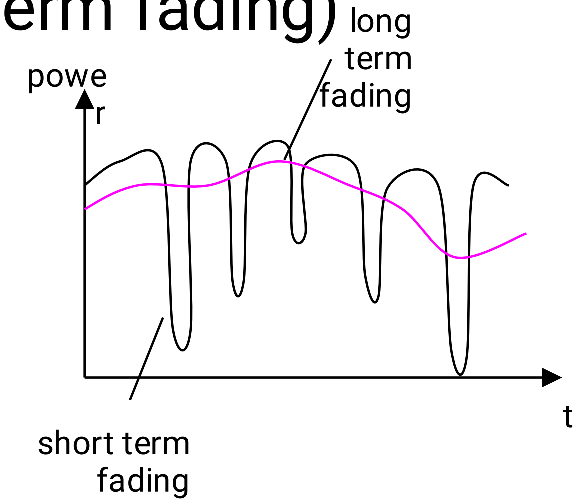
- Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction



- Time dispersion: signal is dispersed over time
- → interference with “neighbor” symbols, Inter Symbol Interference (ISI)
- The signal reaches a receiver directly and phase shifted
- → distorted signal depending on the phases of the different parts

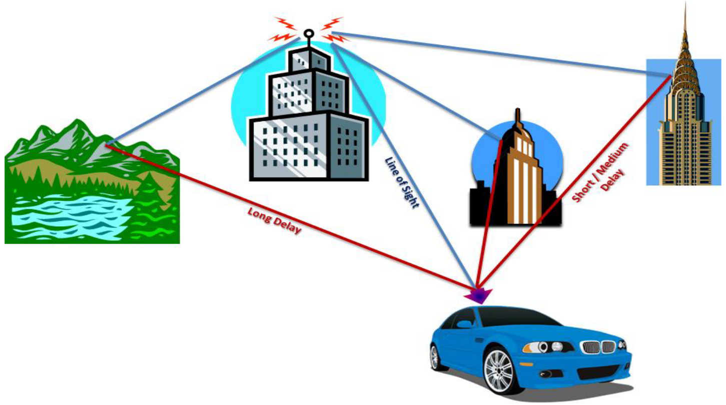
Effects of mobility

- Channel characteristics change over time and location
  - signal paths change
  - different delay variations of different signal parts
  - different phases of signal parts
- → quick changes in the power received (short term fading)

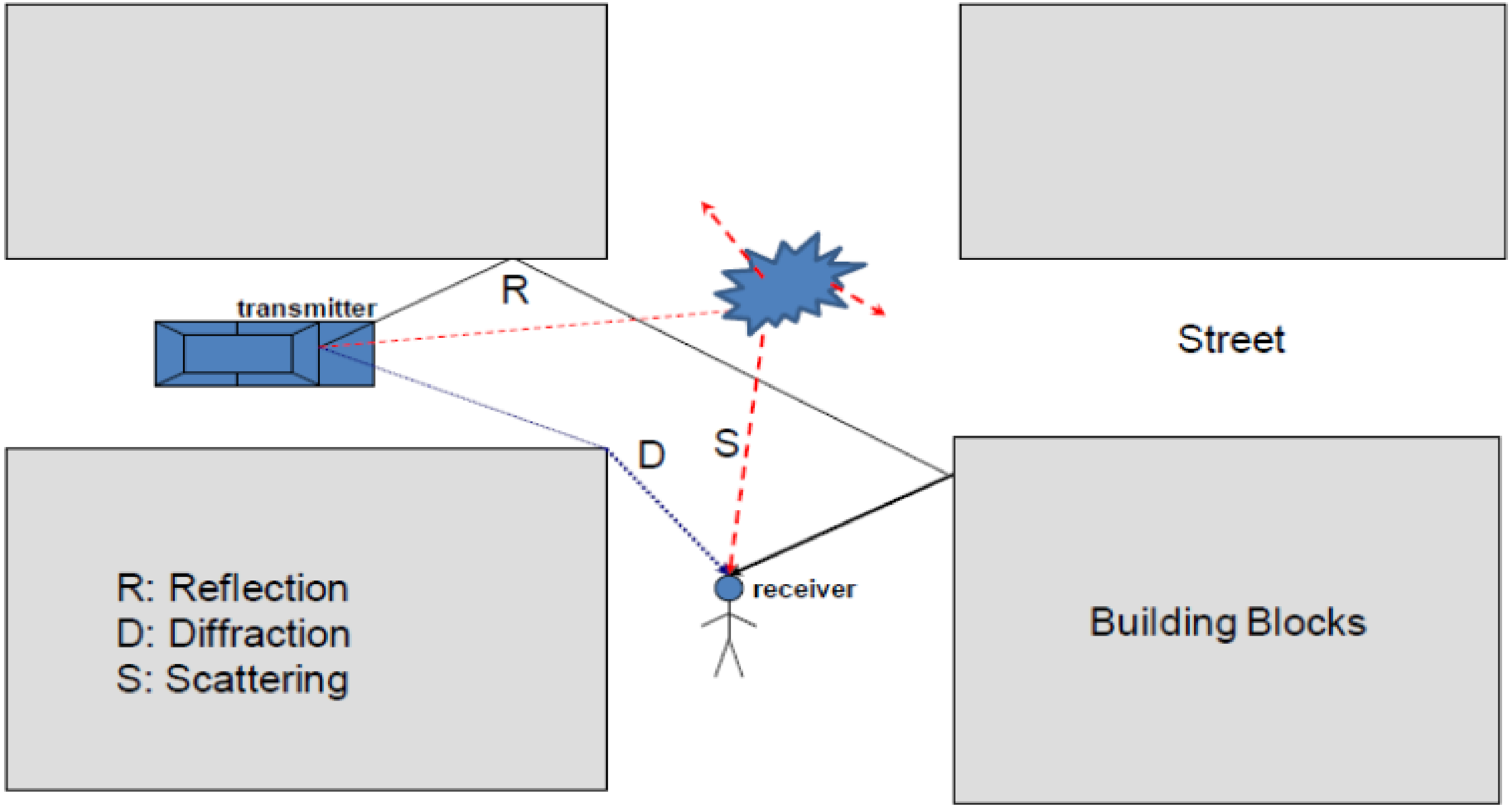


- Additional changes in
  - distance to sender
  - obstacles further away
- → slow changes in the average power received (long term fading)

Signals take multiple physical paths between transmitter and receiver can cause errors and affect the quality of communications (constructive and destructive interference, and phase shifting of the signal.)



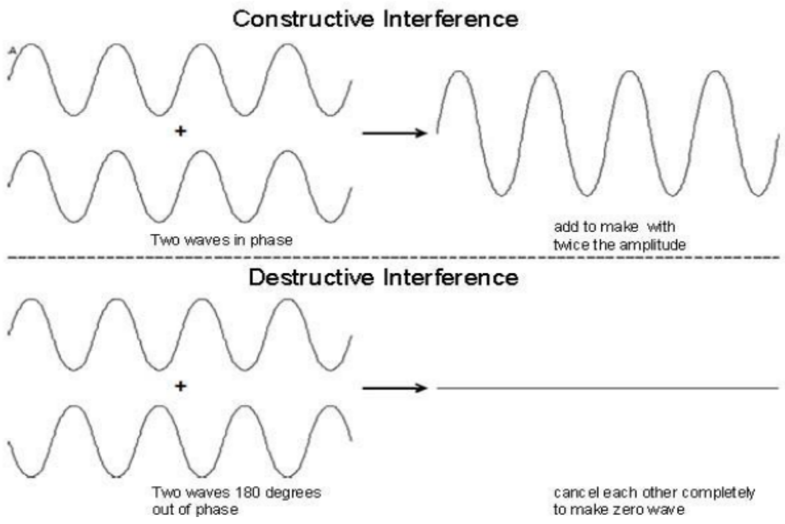
Radio Propagation Mechanisms



Signal Multipath Propagation

The effects of multipath include constructive and destructive interference, and phase shifting of the signal. In digital radio communications (such as GSM) multipath can cause errors and affect the quality of communications.

Multiple signal interfere with each other at the receiver either in constructive or deconstructive way.



Radio propagation characteristic

Decibel (dB)

What is dB (decibel):

A logarithmic unit that is used to describe a ratio between the input and output levels. Let say we have two values P1 and P2. The difference (ratio) between them can be expressed in dB and is computed as follows: **10 log (P1/P2) dB**

- For power differences, dBW is used to denote a power level with respect to 1W as the reference power level.

  Example: transmit power P1 = 100W and the received power P2 = 1 W Tx power is 100 times of received power.

  The difference is 10log(100/1W) = 20dBW.

- For power differences, dBm is used to denote a power level with respect to 1mW as the reference power level.

  Example: Tx power = 100W, Received power = 1mW Tx power is 100,000 times of received power Difference is 10log(100/1mW) = 50dBm

Example

Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that P2 is (1/2)P1. In this case, the attenuation (loss of power) can be calculated as

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{0.5 P_1}{P_1} = 10 \log_{10} 0.5 = 10(-0.3) = -3 \text{ dB}$$

A loss of 3 dB (–3 dB) is equivalent to losing one-half the power.

Exampl
e

Sometimes the decibel is used to measure signal power in milliwatts. In this case, it is referred to as dB_m and is calculated as $dB_m = 10 \log10 P_m$, where P_m is the power in milliwatts. Calculate the power of a signal with $dB_m = -30$.

Solution

We can calculate the power in the signal as

$$\text{dB}_\text{m} = 10 \log_{10} P_m = -30$$

$$\log_{10} P_m = -3 \qquad P_m = 10^{-3} \text{ mW}$$

Signal to Noise Ratio (SNR)

- To measure the quality of a system the SNR is often used. It indicates the strength of the signal w.r.t the noise power in the system.
- It is the ratio between two powers.
- It is usually given in dB and referred to as SNR_{dB}.

Example

The power of a signal is 10 mW and the power of the noise is 1 μW; what are the values of SNR and SNR_{dB} ?

Solution
The values of SNR and SNRdB can be calculated as follows:

$$SNR = \frac{10{,}000\ \mu W}{1\ \mu W} = 10{,}000$$

$$SNR_{dB} = 10 \log_{10} 10{,}000 = 10 \log_{10} 10^4 = 40$$

Example

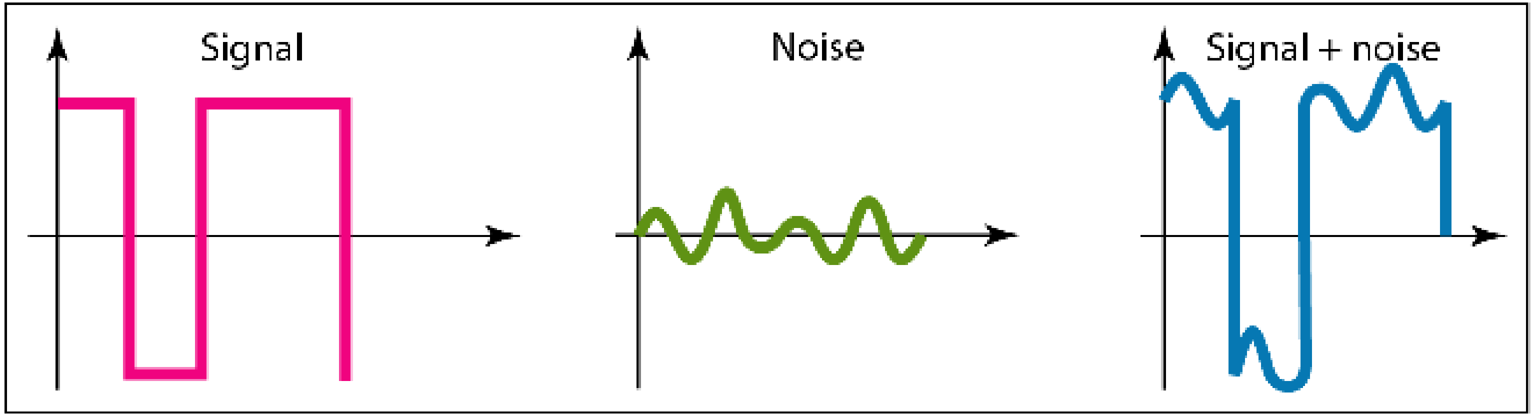
The values of SNR and SNRdB for a noiseless channel are

$$\mathrm{SNR} = \frac{\text{signal power}}{0} = \infty$$

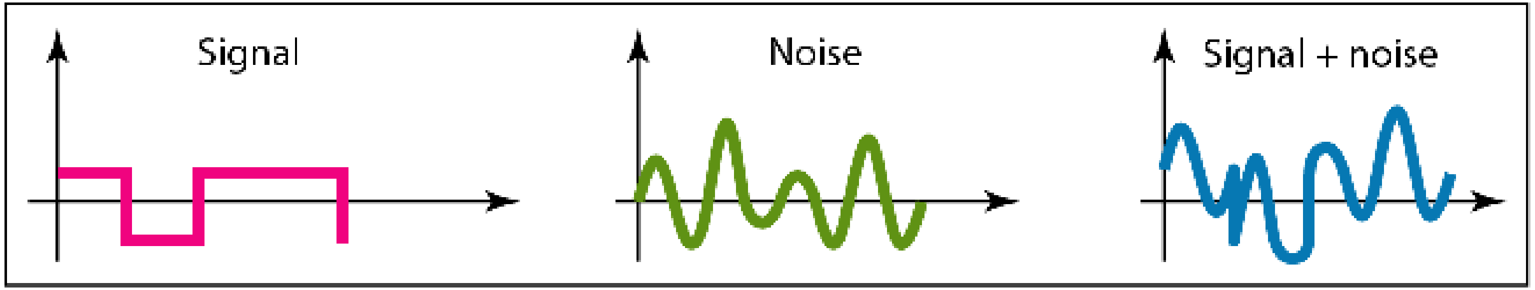
$$\mathrm{SNR_{dB}} = 10 \log_{10} \infty = \infty$$

We can never achieve this ratio in real life; it is an ideal.

Figure Two cases of SNR: a high SNR and a low SNR



a. Large SNR



b. Small SNR

Bit Error Rate

The bit error rate (BER) is the number of bit errors per unit of time. The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval.

As an example, assume this transmitted bit sequence:

1 1 0 0 0 1 0 1 1

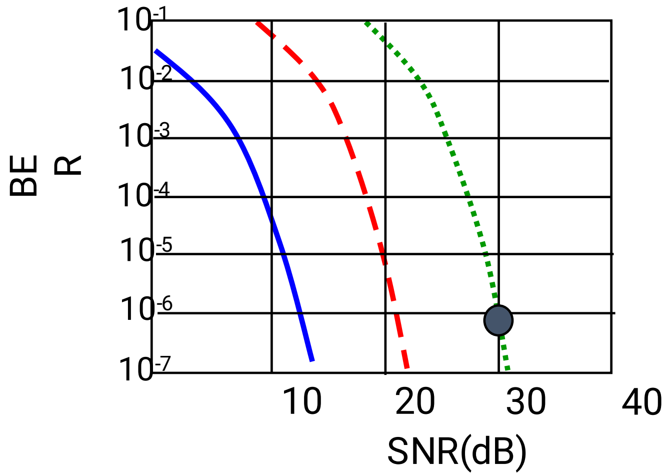
and the following received bit sequence:

0 1 0 1 0 1 0 0 1

- In this case, the number of bit errors (the underlined bits) is 3.
- The BER is 3 incorrect bits divided by 9 transferred bits, resulting in a BER of 0.333 or 33.3%.

Cont ..

- SNR decreases, BER increase and vise versa.



Modulation techniques

- QAM256 (8 Mbps)
- QAM16 (4 Mbps)
- BPSK (1 Mbps)
- operating point