Mobile Radio Propagation

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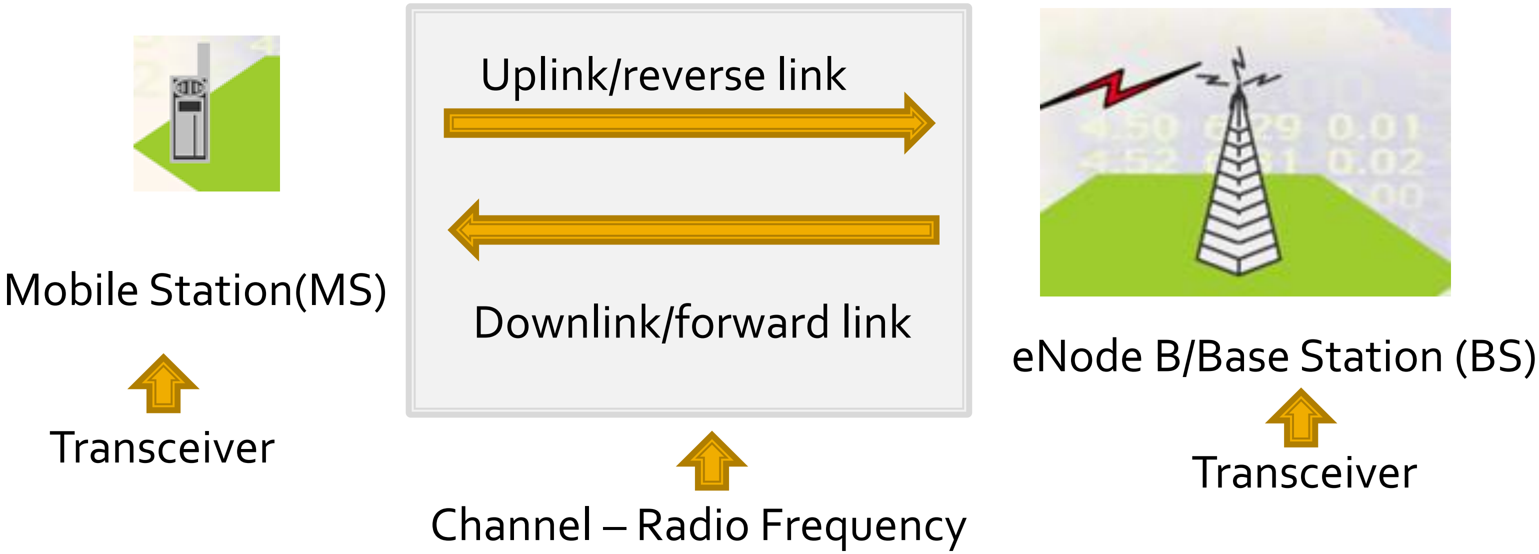
- Antenna and Sectorization

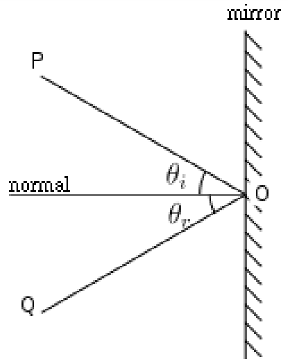
Mobile Radio Propagation



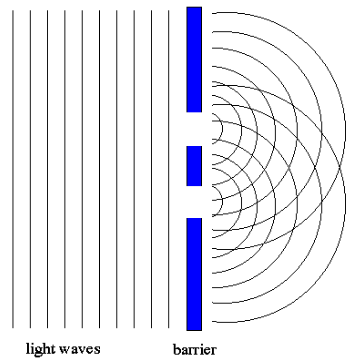
- Data is sent through Radio Frequency
- Important: To know Radio frequency characteristic, weakness to ensure high quality data transmission with low bit error rate (BER)
- We need to understand mobile radio propagation characteristic and how it influences the cellular performance.

Basic Propagation Mechanism

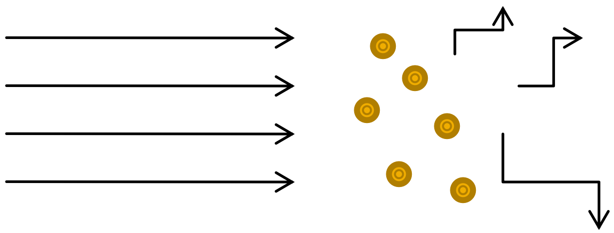
- **Reflection**: occurs when the electromagnetic wave impinges on an object which has very large dimensions as compared to the wavelength. E.g: Buildings, walls



- **Diffraction**: occurs when radio path between transmitter and receiver is obstructed by a surface that has sharp edges
  - Explains radio signals can travel urban and rural environment without LoS.



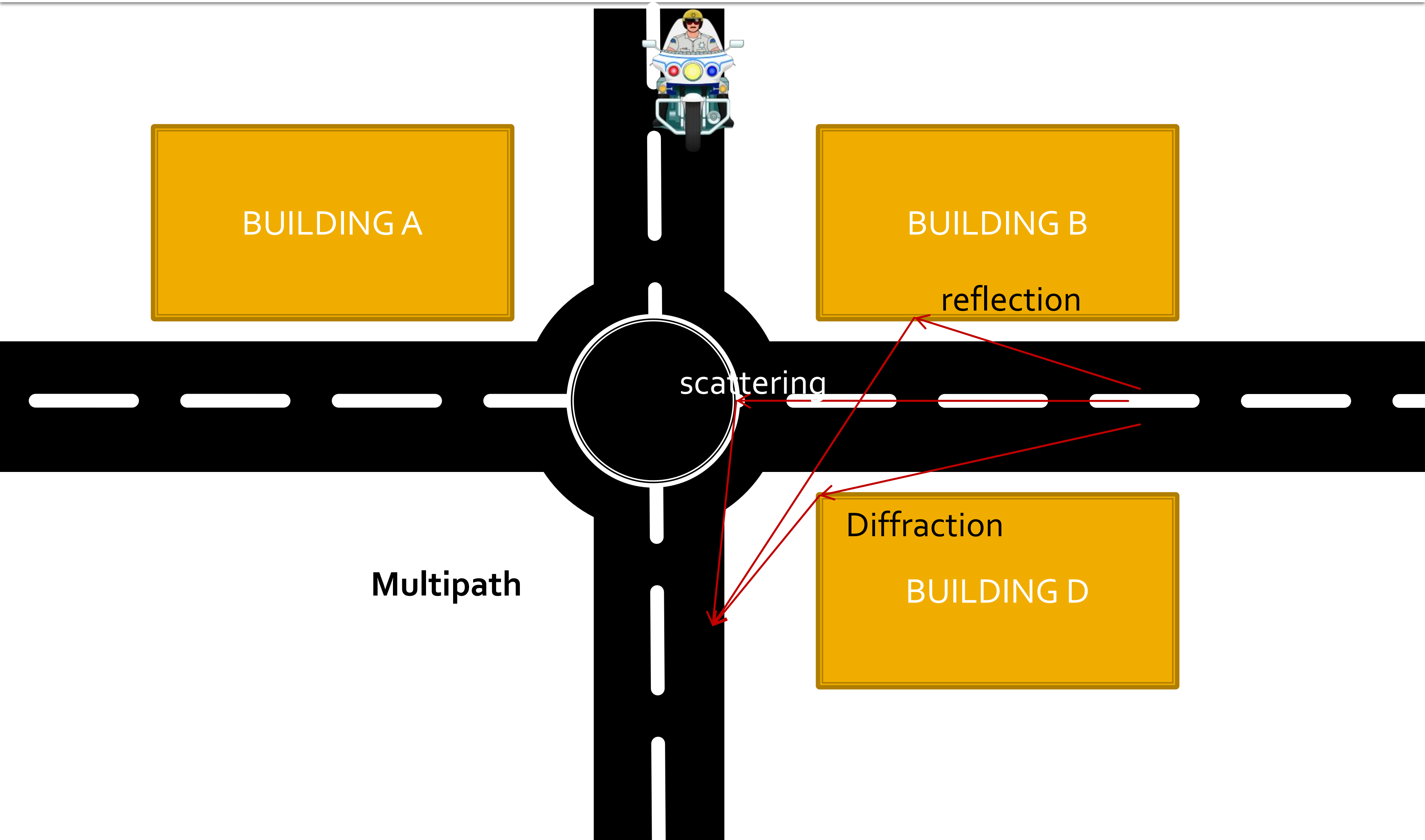
- **Scattering**: occurs when the medium has objects that are smaller or comparable to the wavelength. E.g: rain drops, rough surfaces



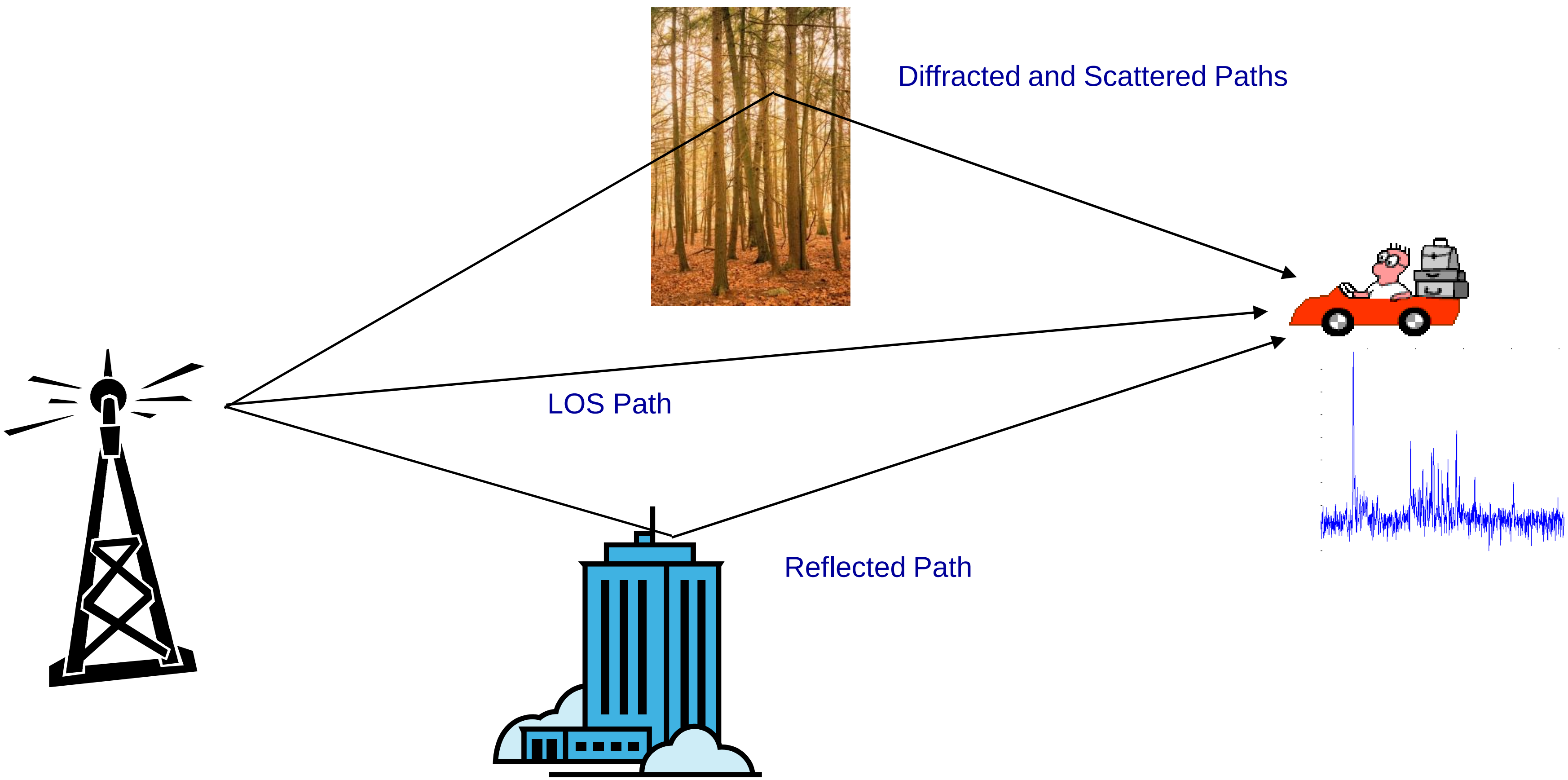
Basic Propagation Mechanism (cont.)

- As a mobile moves through a coverage area, these 3 mechanisms(reflection, refraction, scattering) have an impact on the received signal.
- If a mobile does have a Line Of Sight (LOS) to the base station, then diffraction and scattering will not dominate the propagation
- If a mobile does not have a LOS (non-LOS), diffraction and scattering will probably dominate the propagation (multipath)

Multipath Phenomena

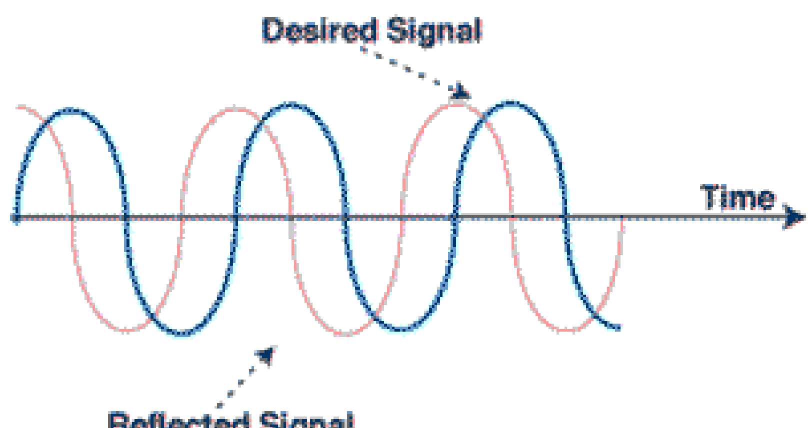


Multipath channel



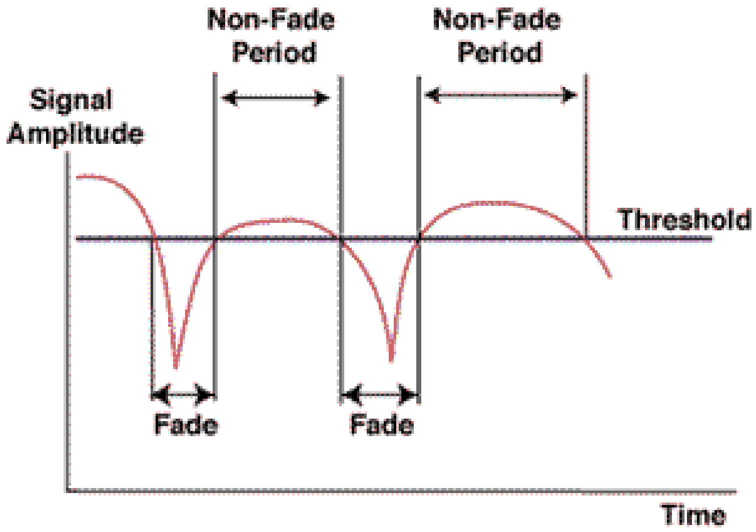
Multipath: How it Occurs

- Transmitted radio signal is reflected by physical features/structures, creating multiple signal paths between the base station and the mobile user.
- Resulting from having unwanted reflected signals.
- Often, the reflected signals do not match with the original transmitted signals.



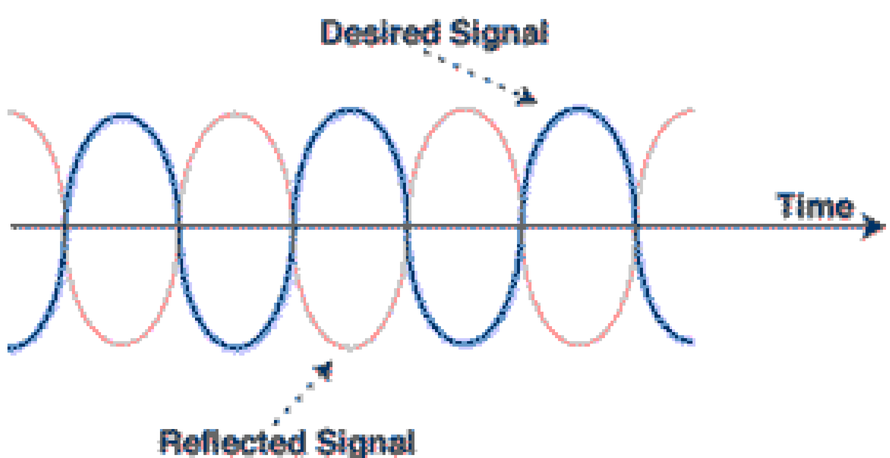
Multipath Problem: Fading

- **Fading:** the received signal strength will fluctuate downward, causing a momentary, but periodic, degradation in quality



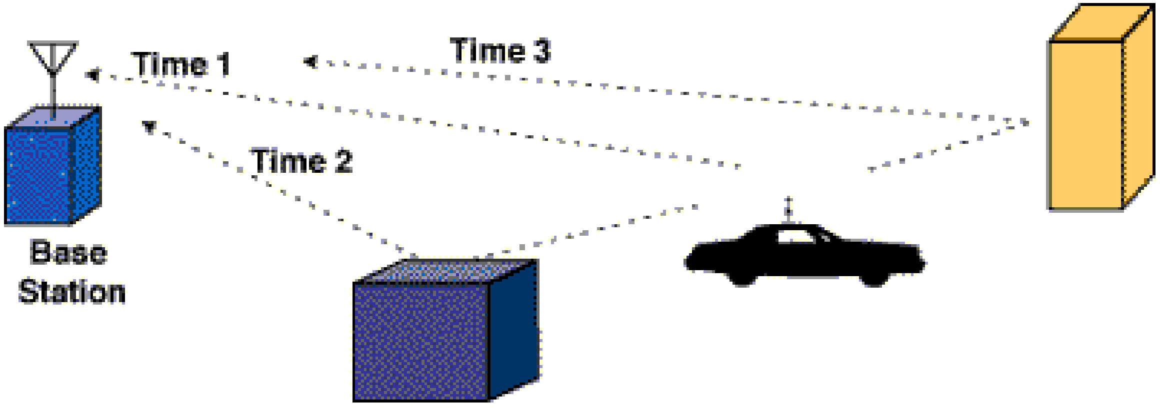
Multipath Problem: Phase Cancelation

- **Phase cancellation**: When waves of two multipath signals are rotated to exactly 180° out of phase, the signals will cancel each other.
  - The effect is of more concern when the control channel signal is canceled out, resulting in a black hole, a service area in which call set-ups will fail



Multipath Problem: Delay Spread

- **Delay spread:** multiple reflections of the same signal may arrive at the receiver at different times. This can result in intersymbol interference (or bits crashing into one another) that the receiver cannot sort out.
  - bit error rate rises and eventually causes noticeable degradation in signal quality

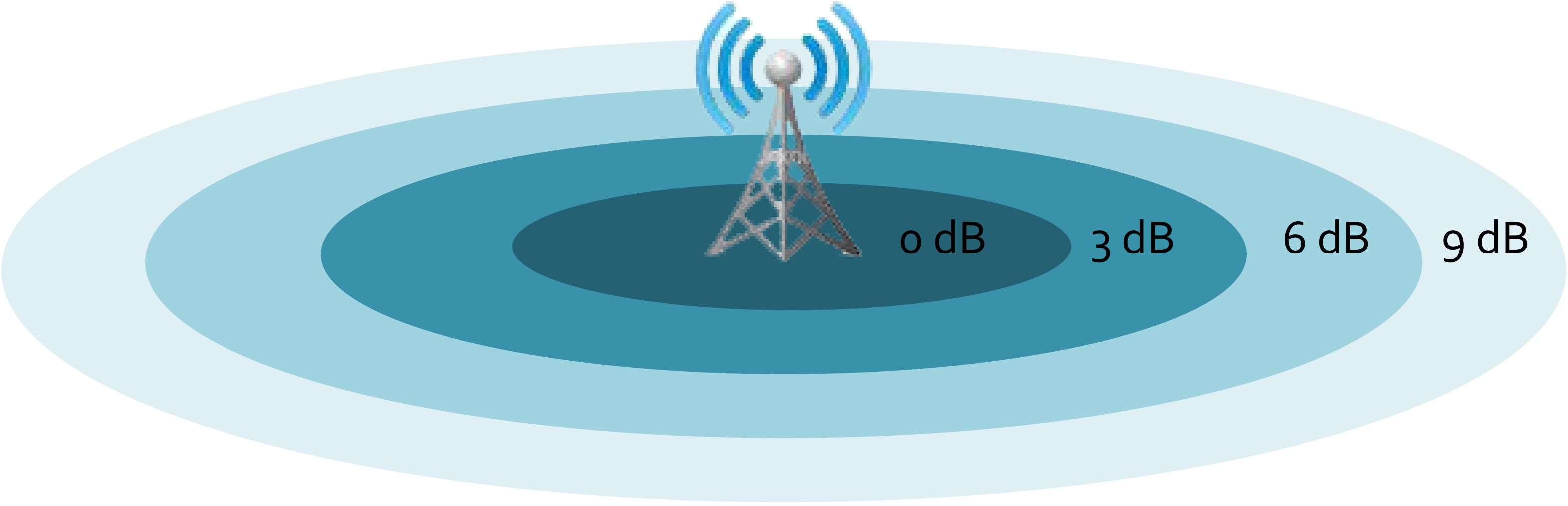


Antenna and Gain

- Antenna's function is twofold: transmit information and receive information.
- To transmit, antenna must take the radio signal that is applied to it and broadcast that signal as efficiently as possible into the intended coverage.
- **Transmitting information**: Transforms alternating electrical current into a radio signal that is propagated through space.
- **Receiving information**: Transforms a radio signal into an alternating electrical current that is decipherable to the receiving equipment.

Antenna and Gain (cont.)

- **Decibel (dB)** is used to compare one power level to another.
- **Gain** refers to how the radiation pattern emitted from an antenna. Represented by the width of a horizontal radiation pattern or how much the pattern has been electrically **compressed vertically** and **expanded horizontally**.
- The higher the stated decibel level is for a given antenna, the higher the gain capability of the antenna



Antenna Concepts

- Directionality
  - Omni (360° coverage) directional
  - Directional (limited range of coverage)
- Gain
  - Measured in dBi and dBd (0 dBd = 2.14 dBi)
  - More gain means more coverage - in certain directions
- Polarization
  - Antennas are used in the vertical polarization

Power measurement: dB,dBm, mW

dB

- Measure of relative power
- P1: 100 W, P2: 1000W (P1,P2 must be at the same unit)

$$\mathrm{dB} = 10\log_{10}\frac{P1}{P2}$$

- Can be a negative value when P2 < P1 (loss)

dBm

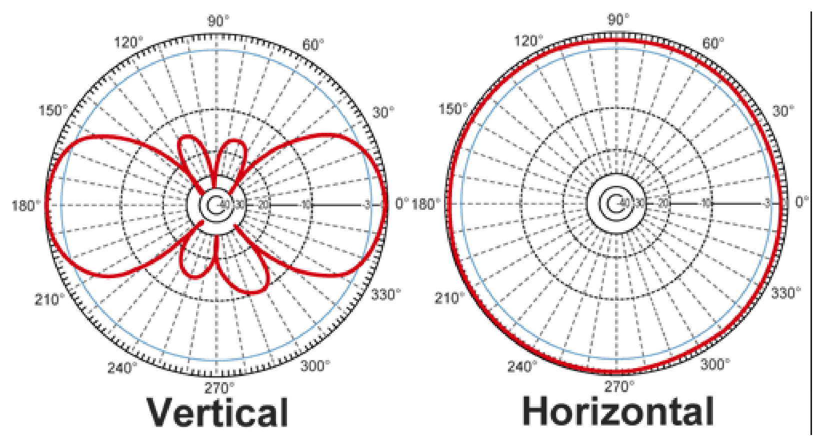
- Relative power for 0mW.
- P3: 100mW=20 dB, P4: 1mW=0 dBm, P5:0.1mW=-10dBm

$\mathrm{dBm} = 10\log_{10}\mathrm{P(mW)}$

Omni-directional Antenna

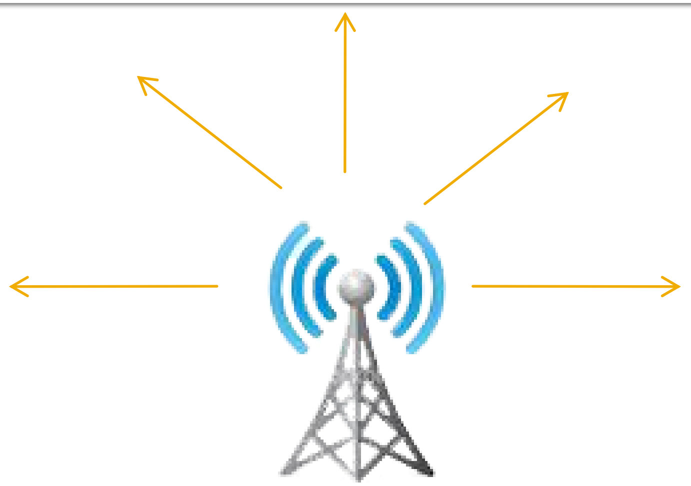
- Collinear array antenna: predominant type of omni-directional (and directional) antenna.

- Antenna elements that comprises collinear array antenna will be **longer** for antennas designed for **low frequencies** and are **shorter** for antennas that are designed for **higher frequencies** for a given power.
  - Correlates directly to the fact that lower frequency emit longer radio wavelengths. Higher frequency emit shorter wavelengths.



Directional Antenna

- Antenna that shapes and projects a beam of radio energy in a specific direction and receives radio energy only from a specific direction.
- Directional antennas are effectively omni directional antennas that use a reflecting element which directs/ focuses the RF over a specific beamwidth.
- Most popular beamwidth used is the 120⁰ beamwidth.
- Allows sectorization for effective capacity increase.
- Directional antenna produce more gain than omni-directional antenna.
  - Omni-directional antenna radiates energy 360⁰ while directional antenna radiates energy to a certain direction.

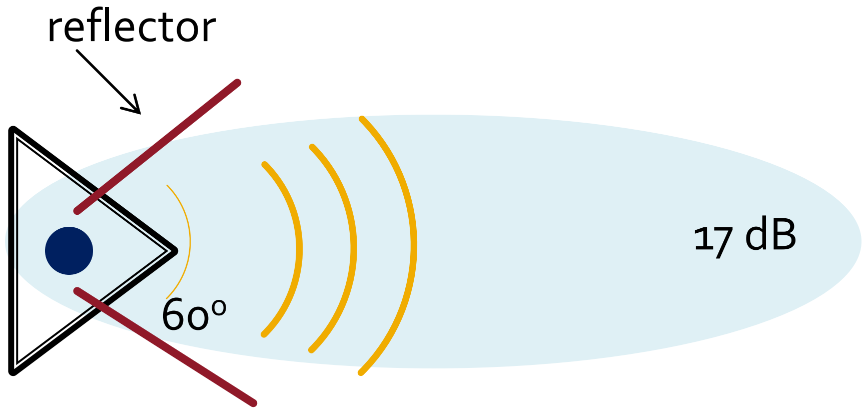


Omni-directional

Directional

Directional Antenna (cont.)

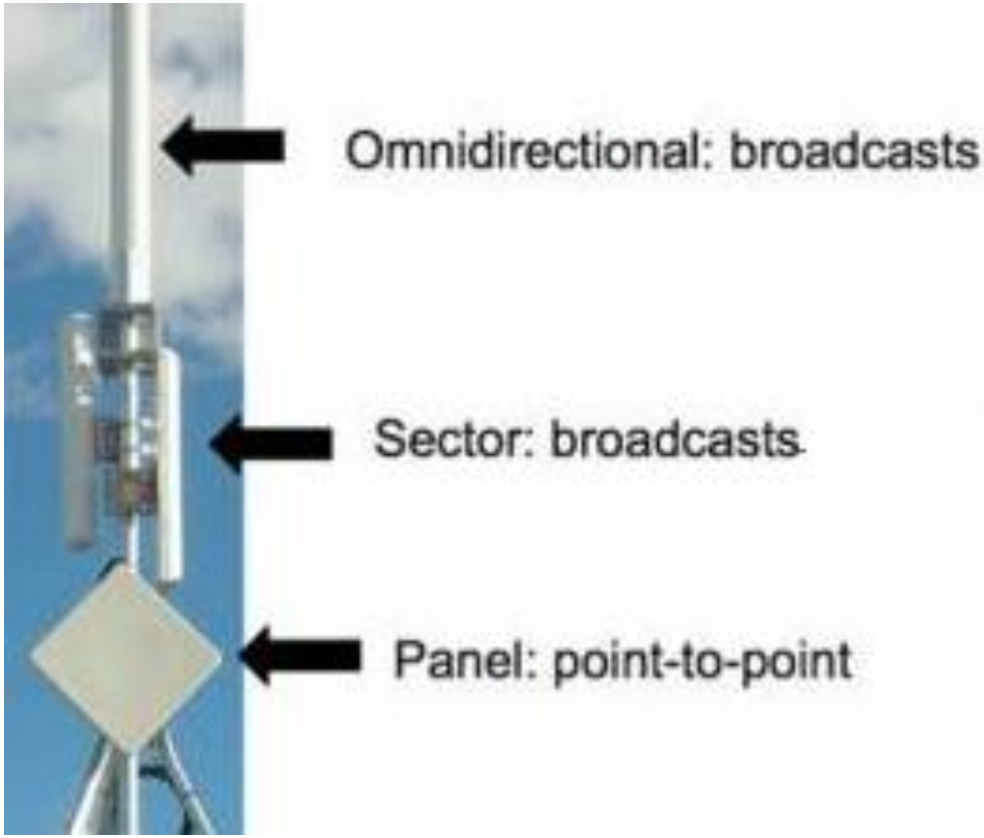
- Using directional antenna, gain is developed by inserting a **reflecting element** behind an omni-directional antenna.
- The reflector distorts and compresses the horizontal radiation pattern at the sides causing it to bulge forward and produce directional gain.
- Example: 10 dB gain antenna could be modified with a V-shaped reflector to produce 60° horizontal radiation pattern and 17 dB gain. Therefore, the directional antenna produced 7 dB more gain.



Sectorization

- Too increase system capacity without having to split cells.
- Created by subdividing omni cells into sectors that are covered using directional antennas that are mounted on the same base station.
- Operationally, each sector is treated as different cells.
- Directional antenna always produce more gain than omni-directional antenna.
- To sector a cell, a horizontal, equilateral platform that resembles a triangle is deployed on a tower.

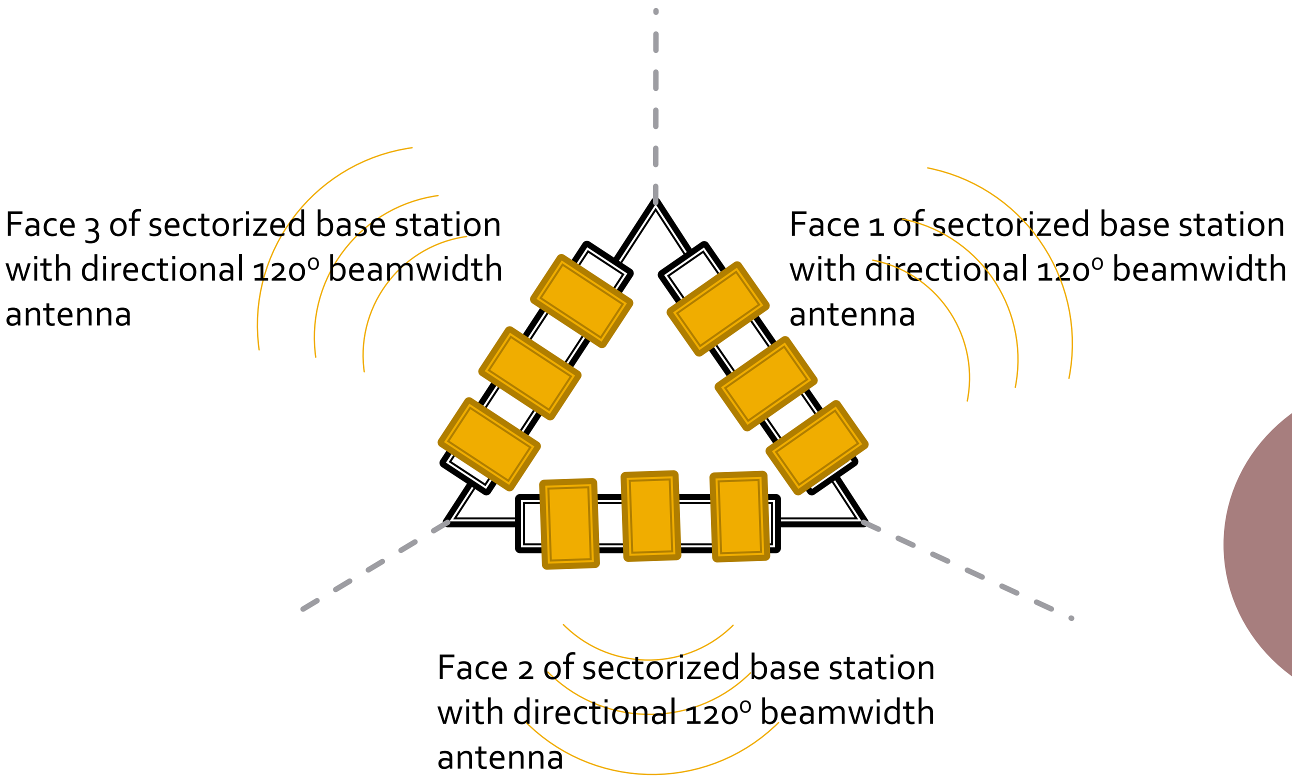
Sectorization (cont.)

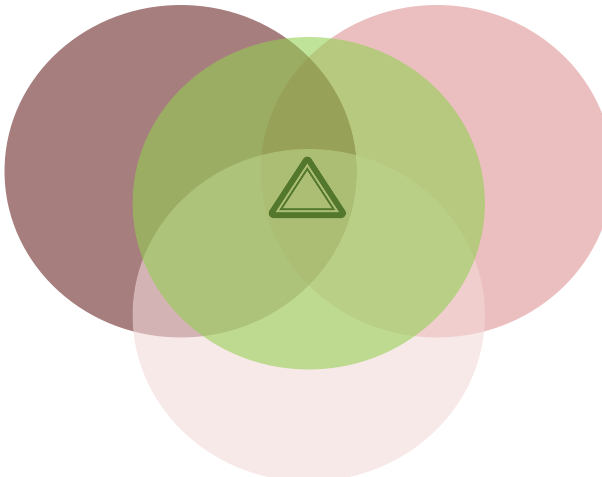


Sectorization (cont.)

- Each side of the platform is called a face and has three to four directional antennas installed.
- The directional antennas propagate the different frequency/ channels assigned within each respective face.

Sectorization (cont.)





Sectorization (cont.)

- Sectorization facilitates wireless engineering and operations:
  - Minimizes co-channel interference
  - At minimum, triples the capacity of any given coverage area compared to omni-directional antenna.
  - In case of three sectored base stations are deployed, 120^o beamwidth antenna is mounted.
  - In case of four sectored base stations are deployed, 90^o beamwidth antenna is mounted.
  - In case of six sectored base stations are deployed, 60^o beamwidth antenna is mounted.

Sectorization (cont.)

- The objective of implementing sectorization is to support higher 360° coverage from a single base station.
- Amount of sectors dictates the beamwidth of the directional antenna used for each sector.
- Each sector has its own control channels and will hand calls off to its adjacent sectors that are housed on the same tower.
- Each sector will also hand calls off to adjacent sectors when required.

Sectorization (cont.)

- When sectorizing base stations, wireless carriers/ operators must adhere a **grid angle** or **azimuth**.
- **Grid angle**: the orientation in degrees, of the face of all sectorized from true north.
- The grid angle allows each base stations' faces to be laid out symmetrically to avoid interference between co-channel sectors.

Smart Antenna System

- Flaws of standard antennas:
  - Does not eliminate co-channel interference effectively.
  - Lack of knowledge of subscribers' whereabouts.
  - Limits capacity maximization.

- Advantages of smart antennas:
  - Help wireless operators to cope with variable traffic levels.
  - Allows carriers to change gain settings to expand or contract coverage in a highly localized areas.
  - Allows carriers to modify cell's operation based on time of day/ week to accommodate an anticipated surge in call volume.

Smart Antenna System (cont.)

- Types of Smart Antenna Systems:
  - **Switched-beam**
  - **Adaptive-array**

Smart Antenna System (cont.)

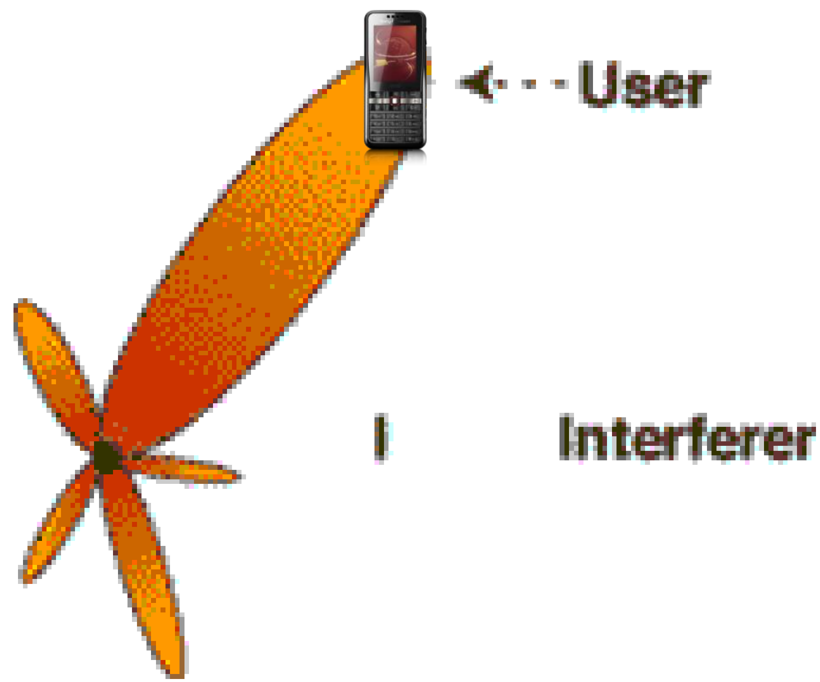
- Switched-beam Systems
  - A finite number of fixed, predefined pattern or combining sectors.
  - Detect signal strength, choose from one of several predetermined, fixed beams, and switch from one beam to another as the mobile moves throughout the sector.
  - Combines the outputs of multiple antennas in such a way as to form finely sectorized (directional) beams

Smart Antenna System (cont.)

- Adaptive-array Systems
  - An infinite number of patterns (scenario based) that are adjusted in real time.
  - The adaptive system takes advantage of its ability to effectively locate and track various types of signals to dynamically minimize interference and maximize intended signal reception

Smart Antenna System (cont.)

Switched-beam



Adaptive array

Smart Antenna System (cont.)

- Goals of smart antenna:
  - **Signal gain**—Inputs from multiple antennas are combined to optimize available power required to establish given level of coverage.
    - **better range/coverage**—Focusing the energy sent out into the cell increases base station range and coverage. Therefore, lower power requirements also enable a greater battery life and smaller/lighter handphone size.
  - **Interference rejection**—Antenna pattern can be generated toward cochannel interference sources, improving the signal-to-interference ratio of the received signals.
    - **increased capacity**—Precise control of signal nulls quality and mitigation of interference combine to frequency reuse reduce distance (or cluster size), improving capacity. Certain adaptive technologies (such as space division multiple access) support the reuse of frequencies within the same cell.

Smart Antenna System (cont.)

- Goals of smart antenna:
  - **spatial diversity**—Composite information from the array is used to minimize fading and other undesirable effects of multipath propagation.
    - **multipath rejection**—can reduce the effective delay spread of the channel, allowing higher bit rates to be supported without the use of an equalizer.
  - **power efficiency—**combines the inputs to multiple elements to optimize available processing gain in the downlink (toward the user).
    - **reduced expense**—Lower amplifier costs, power consumption, and higher reliability will result.