Lect 3

Radio propagation characteristic

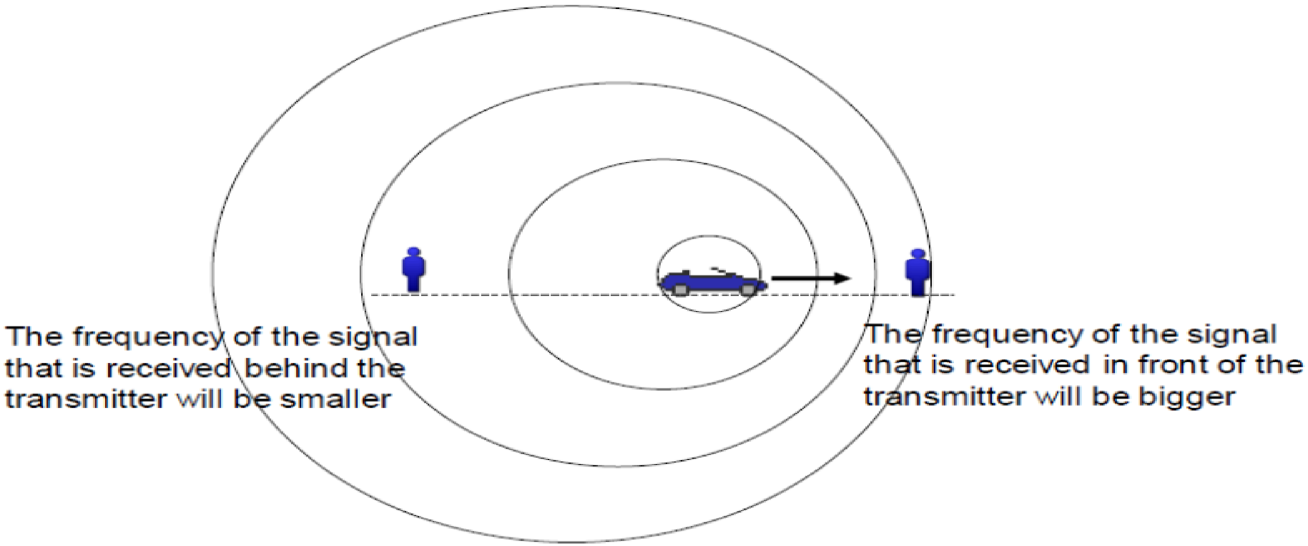
Doppler Effect

- When a transmitter or receiver is moving, the frequency of the received signal changes, i.e. İt is different than the frequency of transmission. This is called Doppler Effect. The change in frequency is called Doppler Shift.

It depends on :-

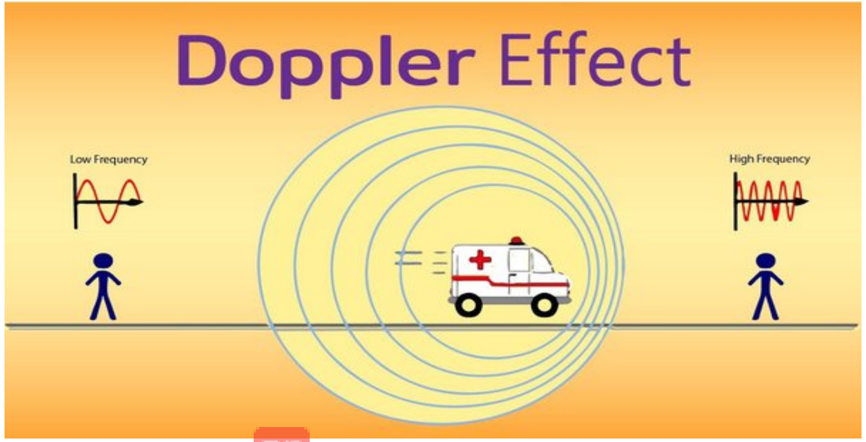
- The relative velocity of the receiver with respect to transmitter
- The frequency (or wavelenth) of transmission
- The direction of traveling with respect to the direction of the arriving signal.

Doppler Shift – Transmitter is moving



The frequency of the signal that is received behind the transmitter will be smaller

The frequency of the signal that is received in front of the transmitter will be bigger



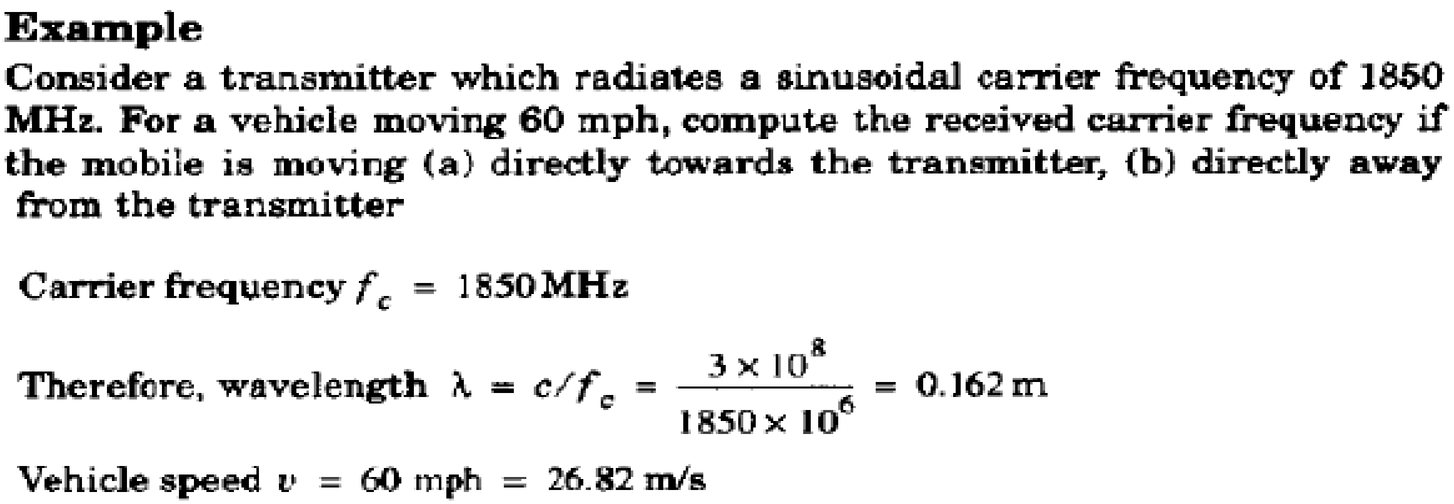
Doppler Effect

- The Doppler shift is positive

If the mobile is moving toward the direction of arrival of the wave

- The Doppler shift is negative

If the mobile is moving away from the direction of arrival of the wave



Example

Consider a transmitter which radiates a sinusoidal carrier frequency of 1850 MHz. For a vehicle moving 60 mph, compute the received carrier frequency if the mobile is moving (a) directly towards the transmitter, (b) directly away from the transmitter

Carrier frequency $f_c = 1850\,\text{MHz}$

Therefore, wavelength $\lambda = c/f_c = \dfrac{3 \times 10^8}{1850 \times 10^6} = 0.162\,\text{m}$

Vehicle speed $v = 60\,\text{mph} = 26.82\,\text{m/s}$

to convert mph into m/s, we need to multiply by 0.447.

Doppler Effect

(a) The vehicle is moving directly towards the transmitter.

The Doppler shift in this case is positive

$$f = f_c + f_d = 1850 \times 10^6 + \frac{26.82}{0.162} = 1850.00016 \text{ MHz}$$

(b) The vehicle is moving directly away from the transmitter.
The Doppler shift in this case is negative and hence the received frequency is given by

$$f = f_c - f_d = 1850 \times 10^6 - \frac{26.82}{0.162} = 1849.999834 \text{ MHz}$$

Fading

- Fading: rapid fluctuations of received signal strength over short time intervals and/or travel distances.
- Fading signals occur due to reflections from ground & surrounding buildings (clutter) as well as scattered signals from trees, people, towers, etc.

often LOS path is not available so the first multipath signal arrival is probably the desired signal (the one which traveled the shortest distance).

- Caused by interference from multiple copies of *Tx* signal arriving @ *Rx* in slightly **different** times.
- Multipath signals have randomly distributed amplitudes, phases, & direction of arrival.

- Three most important effects:

❑ Rapid changes in signal strengths over small travel distances or short time periods.

❑ Changes in the frequency of signals.

❑ Multiple signals arriving a different times.

Factors Influencing Fading

The following physical factors influence small-scale fading in the radio propagation channel:

(1) **Multipath propagation** – Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. The effects of multipath include constructive and destructive interference, and phase shifting of the signal.

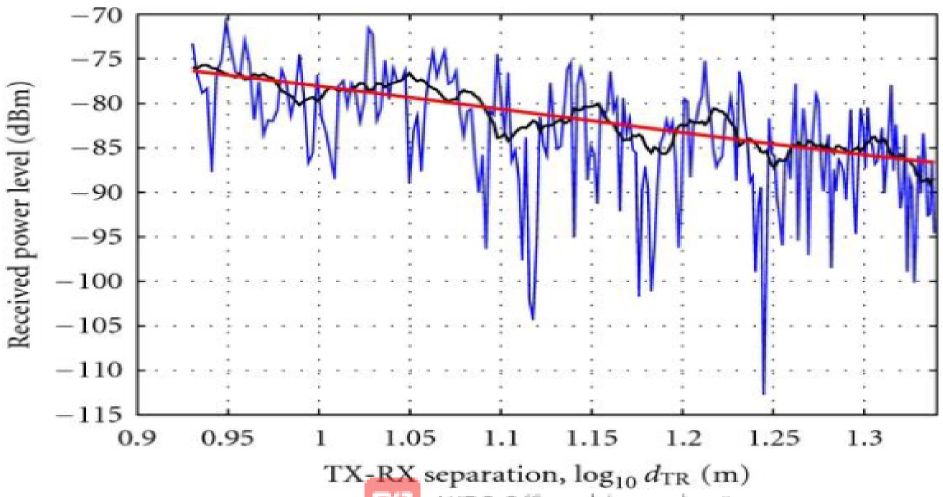
(2) **Speed of the mobile** – The relative motion between the base station and the mobile results in random frequency modulation due to different doppler shifts on each of the multipath components.

(3) **Speed of surrounding objects** – If objects in the radio channel are in motion, they induce a time varying Doppler shift on multipath components. If the surrounding objects move at a greater rate than the mobile, then this effect dominates fading.

(4) **Transmission Bandwidth of the signal** – If the transmitted radio signal bandwidth is greater than the "bandwidth" of the multipath channel (quantified by *coherence bandwidth*), the received signal will be distorted.

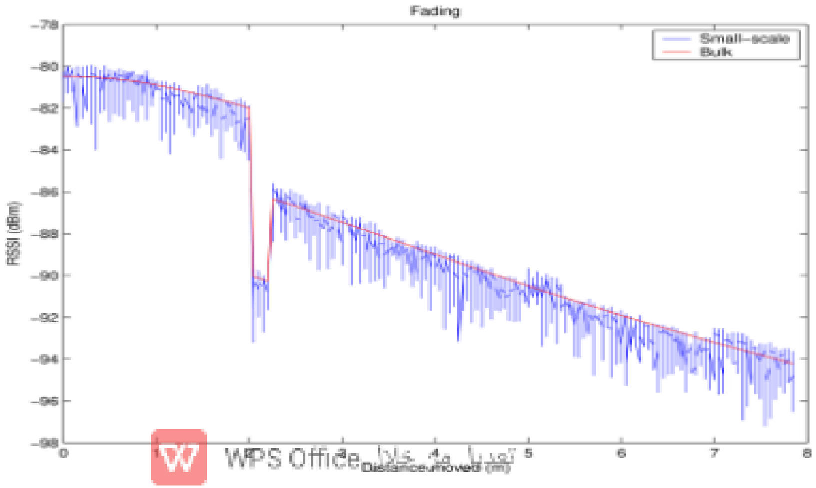
Small-scale fading

- As the mobile moves over small distances (about 7 cm at 1 GHz), the instantaneous received signal will fluctuate rapidly giving rise to small-scale fading
- The reason is that the signal is the sum of many contributors coming from different directions.
- In small scale fading, the received signal power may change, when the receiver is only moved a fraction of the wavelength.



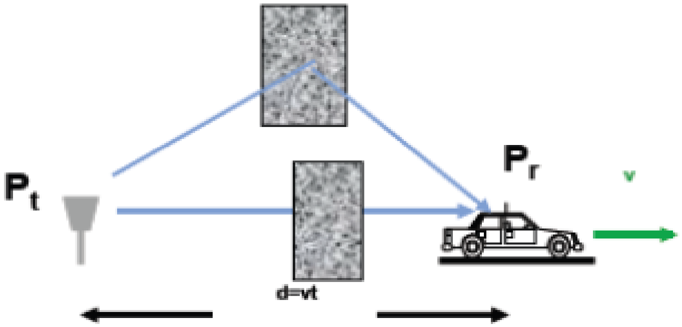
large-scale propagation models

- As the mobile moves away from the transmitter over larger distances, the local average received signal will gradually decrease. This is called large-scale path loss.
- The models that predict the mean signal strength for an arbitrary-receiver (Arbitrary: based on chance rather than being planned or based on reason: arbitrary decision-making) transmitter (T-R) separation distance are called large-scale propagation models
- Useful for estimating the coverage area of transmitters



Radio Propagation Models

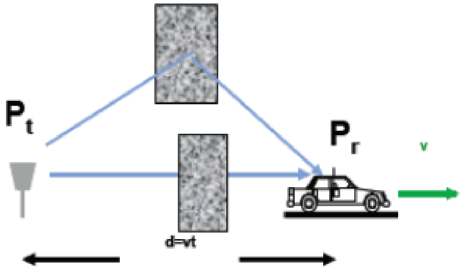
- Strengths of the waves decrease as the distance between Tx and Rx increase
- We need Propagation models that predict the signal strength at Rx from a Tx
- One of the challenging tasks due to randomness and unpredictability in the surrounding environment



- Can be categorized into two types:
  - Large-scale propagation models
  - Small-scale propagation models

- Large-scale propagation models
  - Propagation models that characterize signal strengths over Tx-Rx separation distance

- Small-scale propagation models
  - Characterize received signal strengths varying over short scale
    - **Short travel distance of the receiver**
    - **Short time duration**



Large Scale Propagation Models

Propagation models are usually required to predict the average received signal strength at a given distance from the transmitter and estimating the coverage area (averaged over meters).

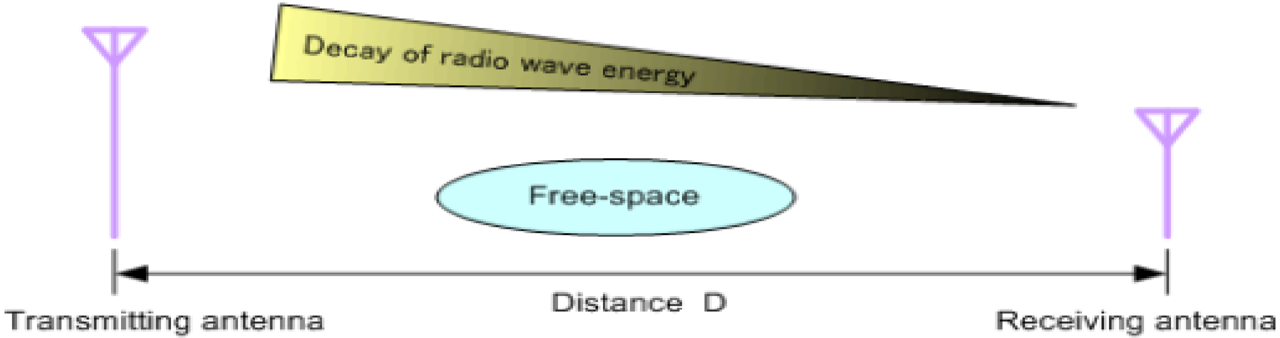
Small-Scale models (fading models)

Propagation models that characterize rapid fluctuations of the received signal strength over very short travel distances (few wavelengths) or short time duration (on the order of seconds).

Large scale propagation model

Free-Space Propagation Model

- Used to predict the received signal strength when transmitter and receiver have clear, unobstructed LOS path between them.
- The received power decays as a function of T-R separation distance raised to some power.



Attenuation of electric field intensity in free-space

- Received power Pr(d), at a distance d > d0 from a transmitter, is related to Pr• at d0, which is expressed as Pr(d0).
- Pr(d0) is the received signal strength at distance d0
  - The power received in free space at a distance greater than d0 is given by:

$$Pr(d) = Pr(d0)(d0/d)^2, \; d >= d0$$

Example: A transmitter produces 50W of power. If d0 is 100m and the received power at that distance is 0.0035mW, then find the received power level at a distance of 10km.

Solution:

- $Pr(10km) = Pr(100m)\ (100m/10km)^2$
- $Pr(10km) = 0.0035mW(10^{-4})$
- $Pr(10km) = 3.5x10^{-10}W$