Unit-1

I. Fading

- Fading: rapid fluctuations of received signal strength over short time intervals and/or travel distances
- Caused by interference from multiple copies of Tx signal arriving @ Rx at slightly **different** times
- Three most important effects:

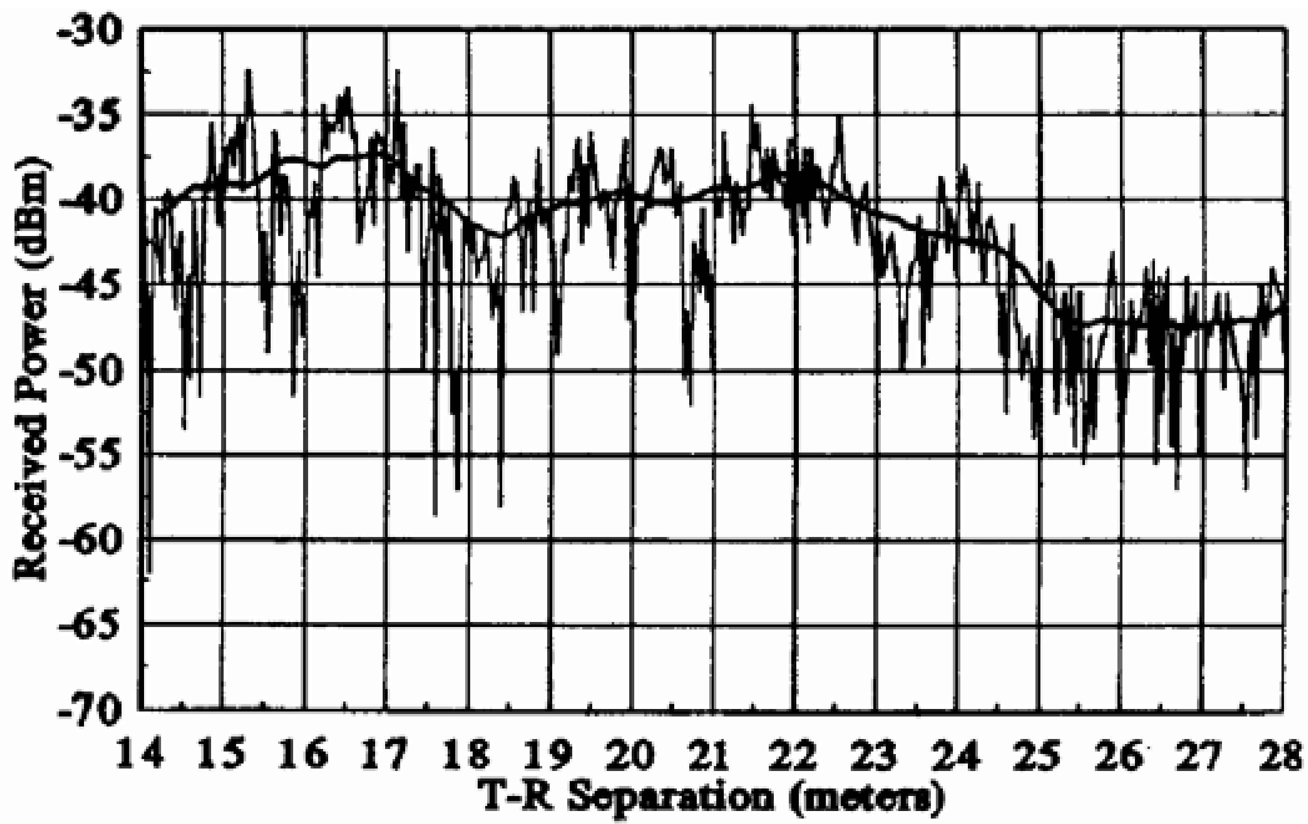
1. Rapid changes in signal strengths over small travel distances or short time periods.
2. Changes in the frequency of signals.
3. Multiple signals arriving a different times. When added together at the antenna, signals are spread out in time. This can cause a smearing of the signal and interference between bits that are received.

- *Fading* signals occur due to reflections from ground & surrounding buildings (clutter) as well as scattered signals from trees, people, towers, etc.
  - often an LOS path is not available so the **first** multipath signal arrival is probably the desired signal (the one which traveled the shortest distance)
  - allows service even when Rx is severely obstructed by surrounding clutter

- Even stationary Tx/Rx wireless links can experience fading due to the motion of objects (cars, people, trees, etc.) in surrounding environment off of which come the reflections
- Multipath signals have randomly distributed amplitudes, phases, & direction of arrival
  - vector summation of ($A \angle \theta$) @ Rx of multipath leads to constructive/destructive interference as mobile Rx moves in space with respect to time

- received signal strength can vary by *Small-scale fading* over distances of *a few meter* (about 7 cm at 1 GHz)!
  - This is a variation between, say, 1 mW and 10^{-6} mW.
  - If a user stops at a deeply faded point, the signal quality can be quite bad.
  - However, even if a user stops, others around may still be moving and can change the fading characteristics.
  - And if we have another antenna, say only 7 to 10 cm separated from the other antenna, that signal could be good.
    - This is called making use of _________ which we will study in Chapter 7.

- fading occurs around received signal strength predicted from large-scale path loss models



II. Physical Factors Influencing Fading in Mobile Radio Channel (MRC)

1) Multipath Propagation

- # and strength of multipath signals
- time delay of signal arrival
  - large path length differences → large differences in delay between signals
- urban area w/ many buildings distributed over large spatial scale
  - large # of strong multipath signals with only a few having a large time delay
- suburb with nearby office park or shopping mall
  - moderate # of strong multipath signals with small to moderate delay times
- rural → few multipath signals (LOS + ground reflection)

2) Speed of Mobile

- relative motion between base station & mobile causes random frequency modulation due to Doppler shift (f_d)
- Different multipath components may have different frequency shifts.

3) Speed of Surrounding Objects

- also influence Doppler shifts on multipath signals
- dominates small-scale fading if speed of objects > mobile speed
  - otherwise ignored

4) Tx signal bandwidth (B_s)

- The mobile radio channel (MRC) is modeled as filter w/ specific bandwidth (BW)
- The relationship between the signal BW & the MRC BW will affect fading rates and distortion, and so will determine:
  - a) if small-scale fading is significant
  - b) if time distortion of signal leads to inter-symbol interference (ISI)
- An MRC can cause distortion/ISI or small-scale fading, or both.
  - But typically one or the other.

Doppler Shift

- motion causes frequency modulation due to Doppler shift (f_d)

$$\Delta\phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi v\Delta t}{\lambda}\cos\theta$$

$$f_d = \frac{1}{2\pi}\cdot\frac{\Delta\phi}{\Delta t} = \frac{v}{\lambda}\cdot\cos\theta$$

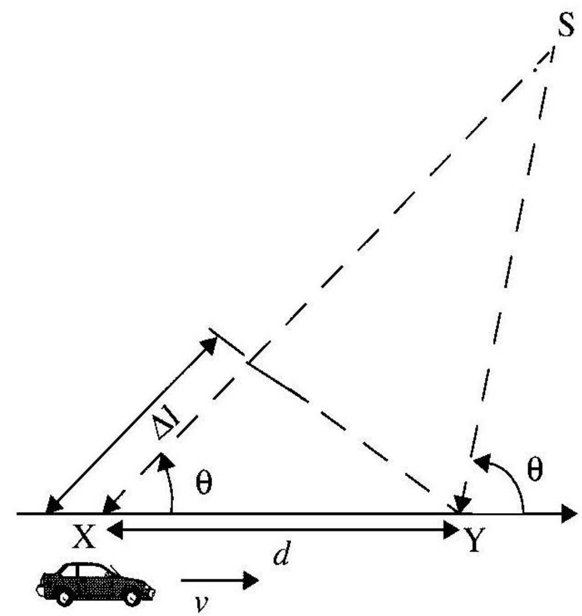


Figure 5.1 Illustration of Doppler effect.

- v : velocity (m/s)
- λ : wavelength (m)
- θ : angle between
  mobile direction
  and arrival direction of RF energy
    - » + shift → mobile moving toward S
    - » − shift → mobile moving away from S

- Two Doppler shifts to consider above
  1. The Doppler shift of the signal when it is received at the car.
  2. The Doppler shift of the signal when it bounces off the car and is received somewhere else.
- Multipath signals will have **different** f_d's for constant v because of random arrival directions!!