Chapter 5 :

Small scale multipath propagation

قسم هندسة تقنيات الحاسوب
د.مصدق ماهر عبد الزهرة

Chapter 5

5.1 Small-scale fading

Small-scale fading: is used to describe the rapid fluctuations of the amplitude of a radio signal over a short period of time or travel distance.

- Fading is caused by interference between ***two or more versions of the transmitted signal*** which arrive at the receiver at slightly different times.
- These waves are called ***multipath waves***, combine at the receiver antenna to give a resultant signal which can vary widely in amplitude and phase, depending on the distribution of the intensity and relative propagation time of waves and the bandwidth of the transmitted signal.

5.2 Small-scale fading effects:

1. Rapid changes in signal strength over a small travel distance or time interval.
2. Random frequency modulation due to varying Doppler shifts on different multipath signals.
3. Time dispersion caused by multipath propagation delays.

5.3 Factors influencing (causes of) small-scale fading:

- **Multipath propagation:** reflecting objects and scatters create a changing environment that affects the signal in amplitude, phase and time.
- **Speed of the mobile:** the relative motion between the mobile and the BS causes Doppler shifts, on each of the multipath components.
- **Speed of surrounding objects:** moving objects cause time-varying Doppler shifts.
- **Transmission bandwidth of the signal:** if the transmitted signal bandwidth is greater than the bandwidth of the channel, the signal will be distorted.

Coherent bandwidth of the channel is a measure of the frequency difference for which the signal is not distorted in amplitude (the channel does not distort the signal).

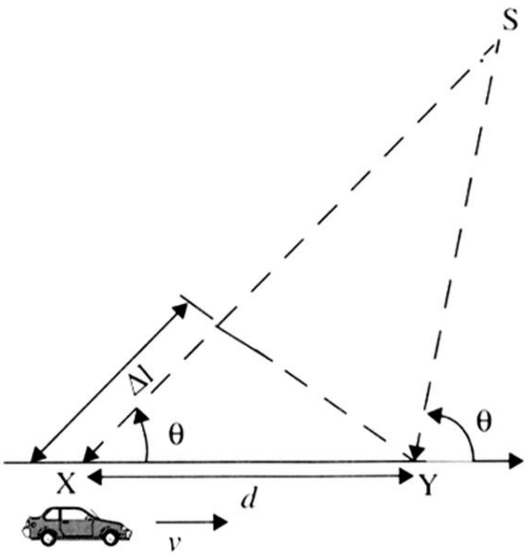
5.4 Doppler shift

- Consider a mobile terminal moving at a constant velocity *v*, along a path segment having length *d* between points *X* and *Y*, while it receives signal from a remote source *S*.

  The path length difference between S and points *X* and *Y*:

  $$\Delta l = d\cos\theta = v\Delta t\cos\theta$$

  where Δt is the time required for the mobile to travel from *X* to *Y*.



- The phase change in the received signal

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

- The Doppler shift can be calculated using

$$f_D = \frac{1}{2\pi}\frac{\Delta\emptyset}{\Delta t} = \frac{v}{\lambda}\cos\theta$$

- **The Doppler shift depends on:**

  1. Mobile velocity
  2. Carrier frequency
  3. Angle between the direction of motion and the direction of arrival of the wave

- Doppler shift is ***positive*** if the mobile is moving ***towards*** the source.
- Doppler shift is ***negative*** if the mobile is moving ***away*** from the source.

Example:

Consider a transmitter which radiates a sinusoidal carrier frequency of 1850 *MHz*. For a vehicle moving at 96.6 *km/h*, compute the received carrier frequency if the mobile is moving

a) Directly towards the transmitter,
b) Directly away from the transmitter,
c) In a direction which is perpendicular to the direction of arrival of the transmitted signal.

Solution:

Given:

$f = 1850\ MHz$,

$v = 96.6\ km/h = 96.6 \times (1000 / 3600) = 26.82\ m/s$

$\lambda = c / f = 3\times10^8 / 1850\times10^6 = 0.162m$

(a)

The vehicle is moving directly towards the transmitter, meaning that $\theta = 0^o$.

The Doppler shift in this case is positive.

Doppler frequency $f_D = \frac{v}{\lambda}\cos\theta = \frac{26.82}{0.162}\cos(0) = 165\,Hz$

The received frequency $= f + f_D = 1850\times10^6 + 165 = 1850.000165\ MHz$

(b)

The vehicle is moving directly away from the transmitter, meaning that $\theta = 180^o$.

The Doppler shift in this case is negative.

Doppler frequency $f_D = \frac{v}{\lambda}\cos\theta = \frac{26.82}{0.162}\cos(180) = -165\,Hz$

The received frequency $= f + f_D = 1850\times10^6 - 165 = 1849.999834\ MHz$

(c)

The vehicle is moving perpendicular to the angle of arrival of the transmitted signal, meaning that θ = 90°.

Doppler frequency $f_D = \frac{v}{\lambda}\cos\theta = \frac{26.82}{0.162}\cos(90) = 0\,Hz$

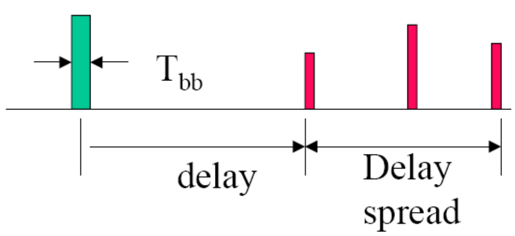
There is no Doppler shift.

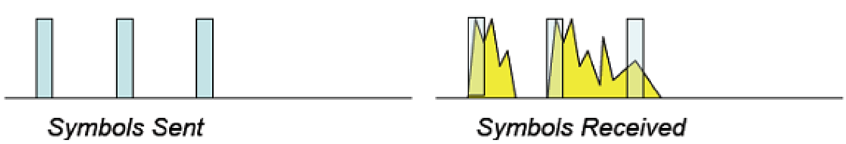
The received signal frequency is the same as the transmitted frequency (f = 1850 MHz).

5.5 Determining the impulse response of a channel

- Transmit a narrowband pulse into the channel

- Measure replicas of the pulse that traverse different paths between transmitter and receiver





- A mobile radio channel may be modeled as a linear filter with a time-varying impulse response
- The time variation is due to receiver motion in space
- The filtering is caused by the summation of amplitudes and delays of multiple arriving waves, due to multipath