Digital Communications ||

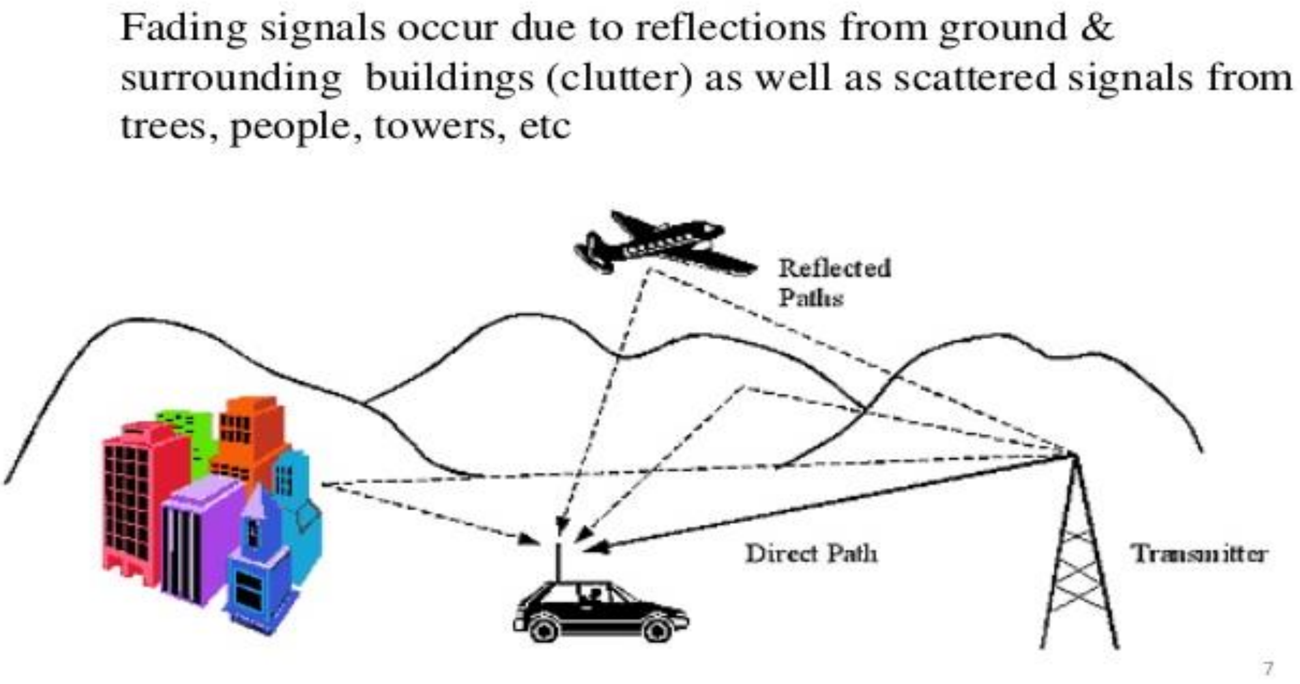
Third Year, 2^{ed} Semester

Lecture No.3

Ass. Lecturer: Yousif Allbadi
M.Sc. of Communications Engineering
Yousif_allbadi_eng@uodiyala.edu.iq
yousifallbadi@uodiyala.edu.iq

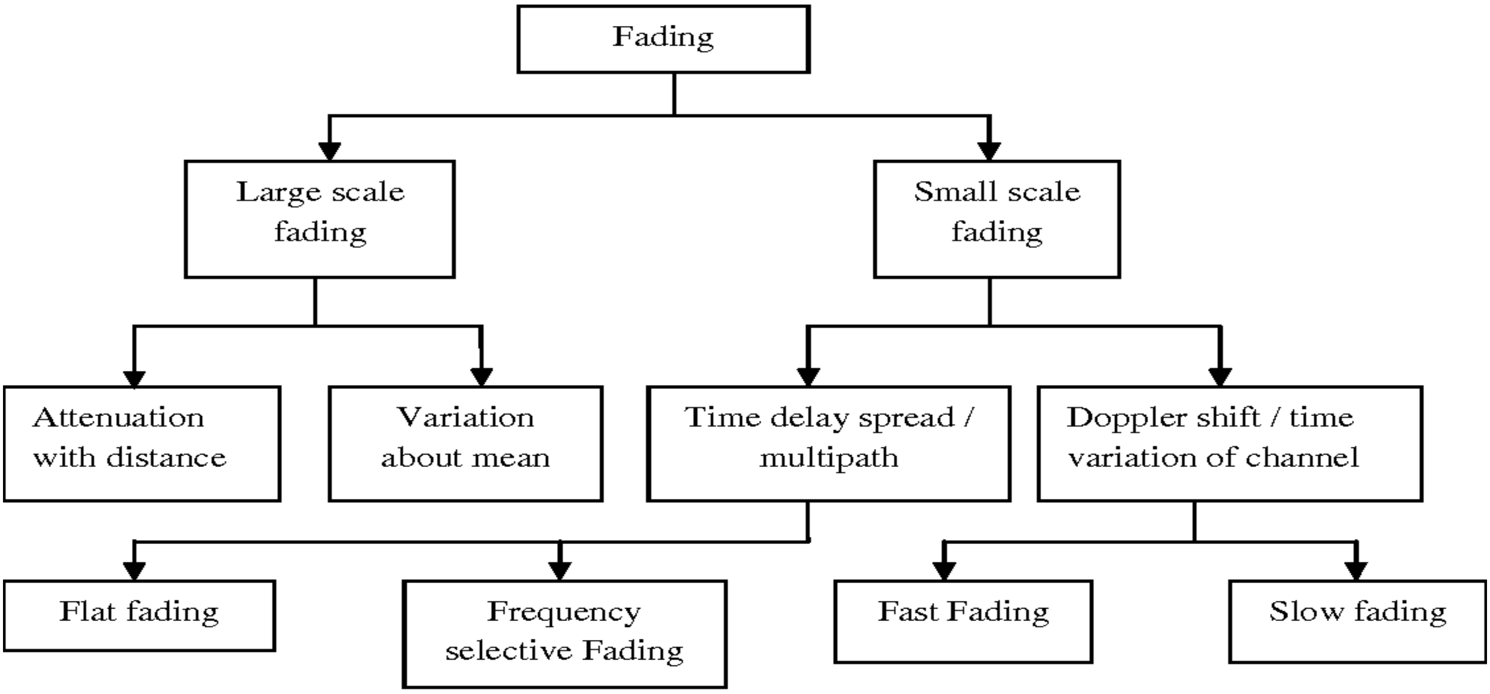
University of Diyala
College of Engineering
Department of Communications Engineering
2021-2022

Fading Channels

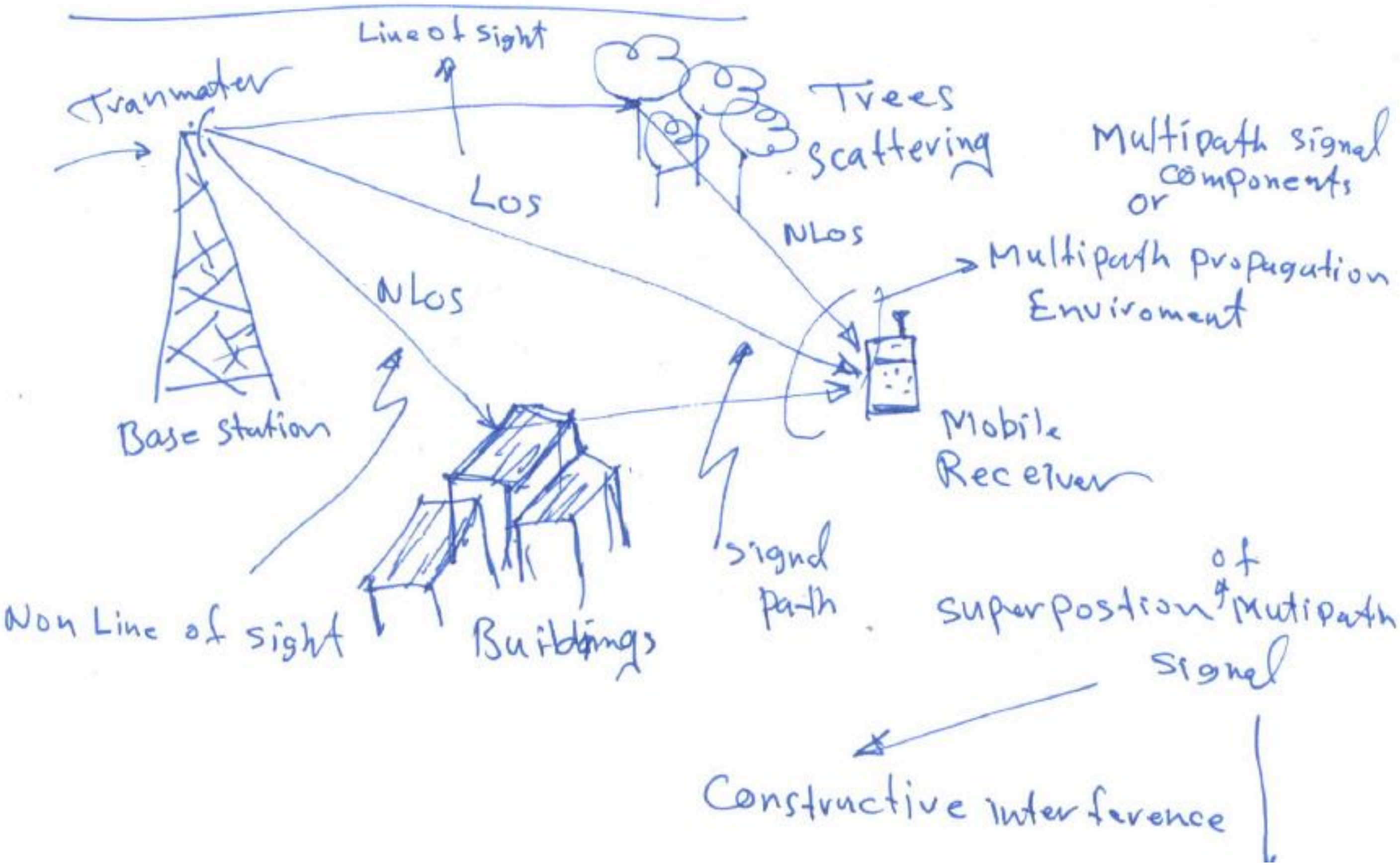


Fading signals occur due to reflections from ground & surrounding buildings (clutter) as well as scattered signals from trees, people, towers, etc

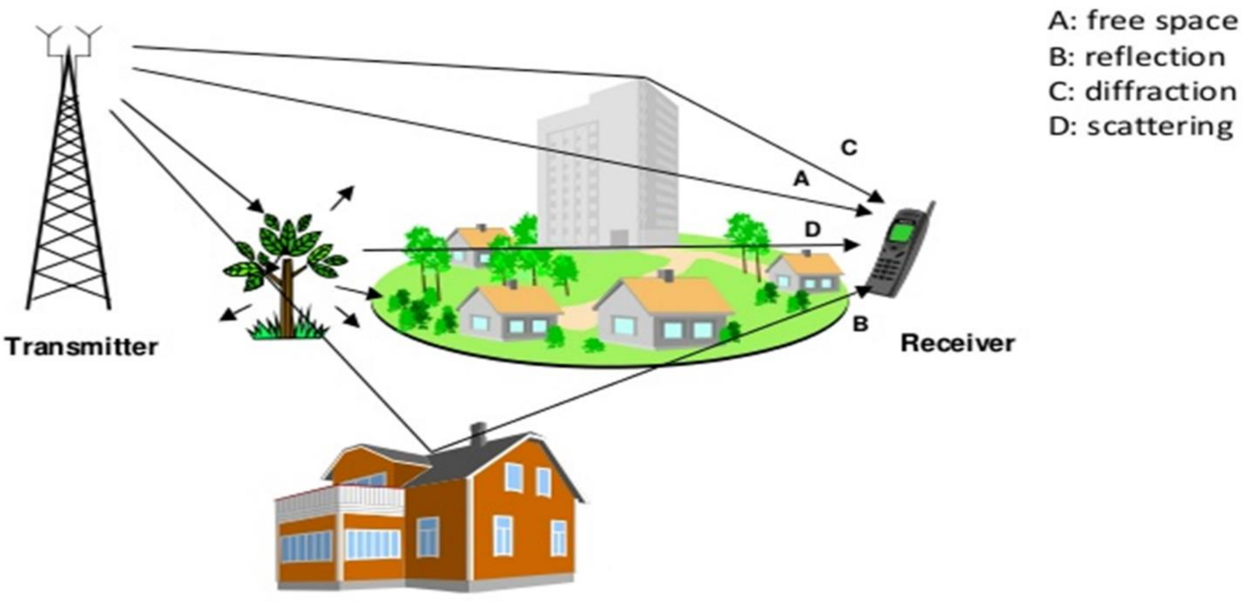
- fading is a variation of the attenuation of a signal with various variables.
- These variables include time, geographical position, and radiofrequency.
- Fading is often modeled as a random process.
- fading may either be due to multipath propagation,
- weather (particularly rain), shadowing from obstacles affecting shadow fading.



Challenge for wireless:



Multi path propagation effect

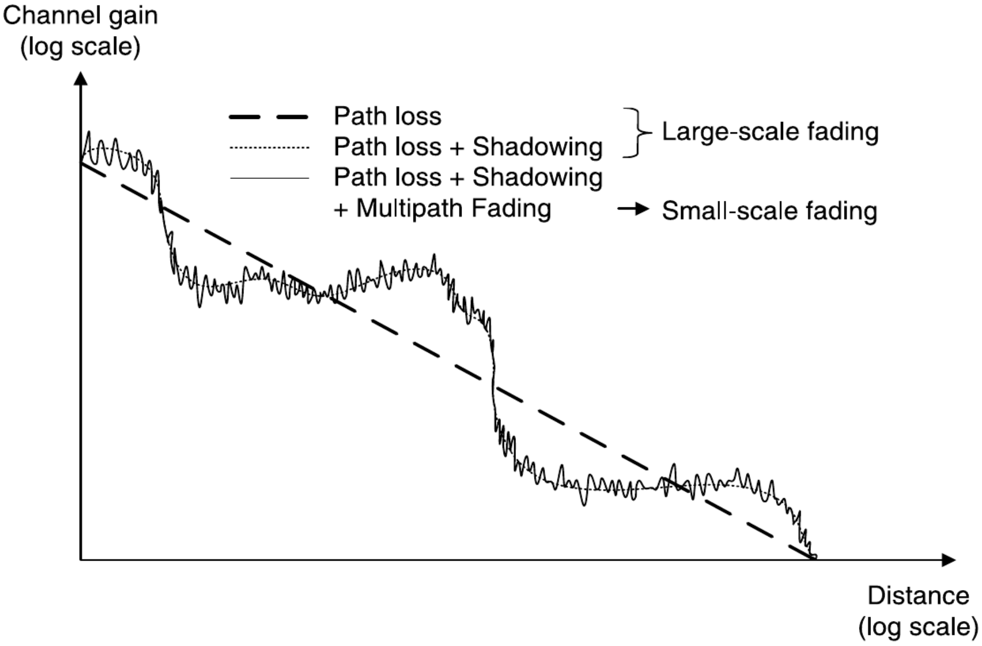


- **Large-scale fading (shadowing)**

Long term variation in the mean signal level caused by the mobile unit moving into the shadow of surrounding objects

- **Small-scale fading (multipath)**

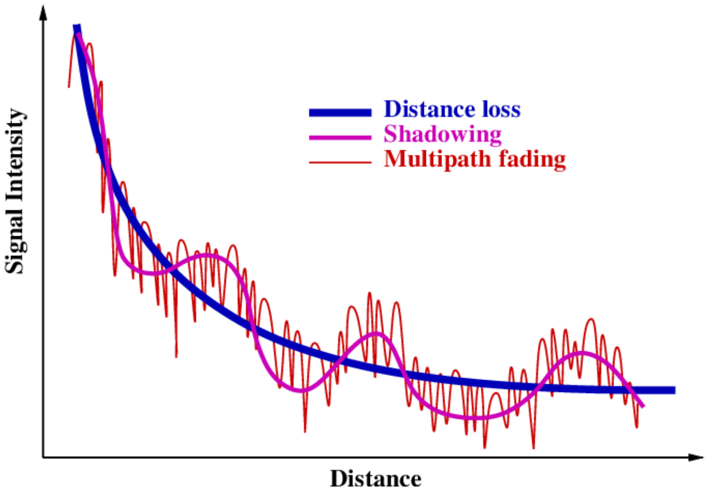
Short term fluctuation in the signal amplitude caused by the local multipath



Shadow Fading

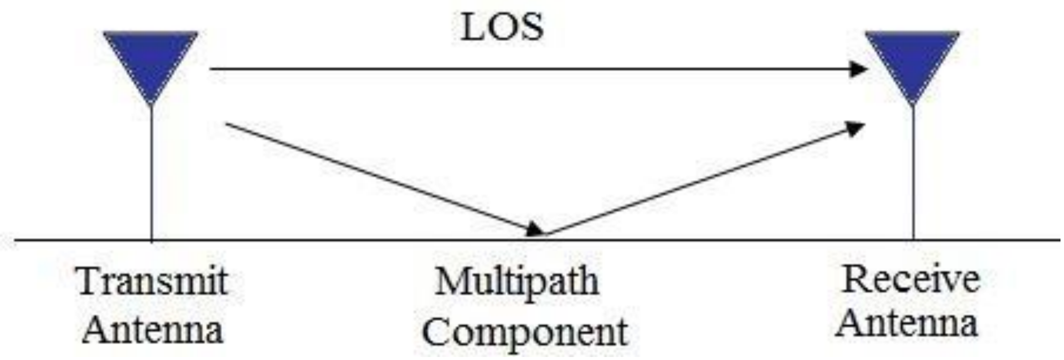
- **Shadow**
- **Long term**
- **Large Scale**
- **Log-normal**
- **Slow**

- Long-term shadow fading due to variations in radio signal power due to encounters with terrain obstructions such as hills or buildings.
- The measured signal power differs basically at different locations even though at the same radial distance from a transmitter.
- Represents the medium-scale fluctuations of the radio signal strength over distances from tens to hundreds of meters.
- Many empirical studies demonstrate that the received mean power fluctuates about the average power with a log-normal distribution.
- Can be modeled by a Gaussian random variable with standard deviation σ.



Multipath Fading

- **Multipath**
- **Short term**
- **Small Scale**
- **Fast**
- A small-scale fading that describes short-term, rapid amplitude fluctuations of the received signal during a short period.
- The actual power received over a much smaller distance varies considerably due to the destructive/constructive interference of multiple signals that follow multiple paths to the receiver.
- The direct ray is made up of many rays due to scattering multiple times by obstructions along its path, all traveling about the same distance.
- Each of these rays appearing at the receiver will differ randomly in amplitude and phase due to the scattering.



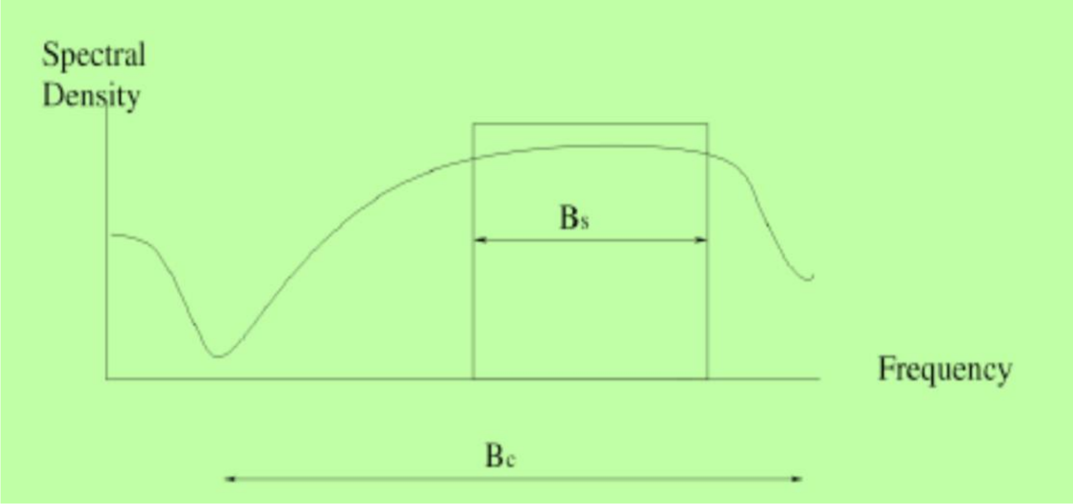
Small-scale fading can be further classified into

- Flat (or non-selective) Fading
- Frequency Selective Fading

Flat fading

- Small-scale fading is defined as being flat if the received multipath components of a symbol do not extend beyond the symbol’s time duration.

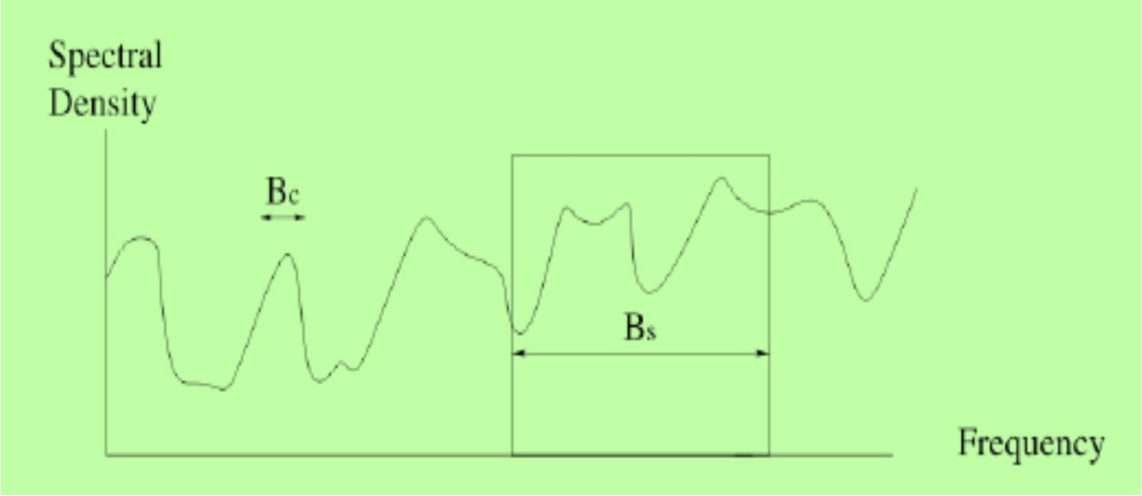
- If the delay of the multipath components concerning the main component is smaller than the symbol's duration time, a channel is said to be subject to flat fading.
- In a flat fading channel, inter-symbol interference (ISI) is absent.
- The channel has a constant gain and a linear phase response over a bandwidth that is greater than the bandwidth of the transmitted signal.



- The spectral characteristics of the transmitted signal are preserved at the receiver.
- The channel does not cause any non-linear distortion due to time dispersion.
- However, the strength of the received signal generally changes slowly in time due to fluctuations caused by multipath.
- In a flat-fading channel, the bandwidth of the transmitted signal, Bs is much less than the Coherence bandwidth, Bc of the channel.

Frequency Selective Fading

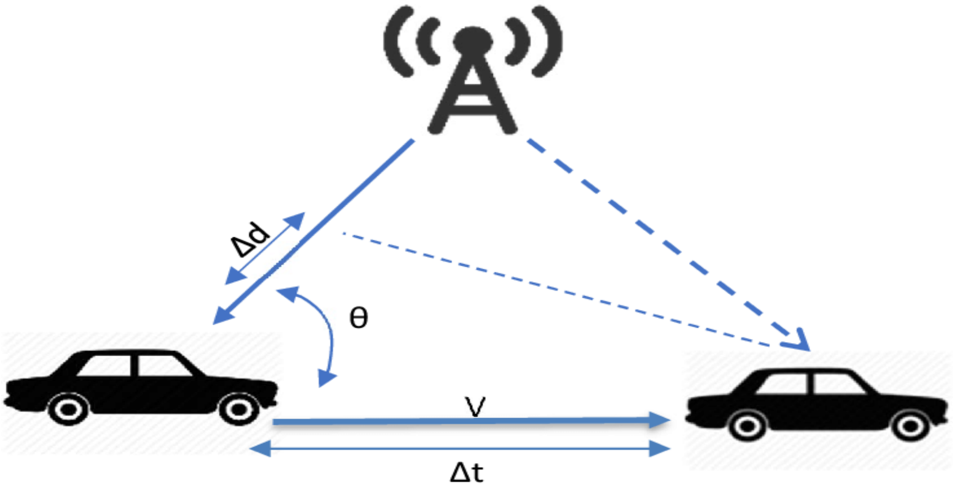
- Small-scale fading is defined as being frequency-selective if the received multipath components of a symbol extend beyond the symbol's time duration.
- The effect of multipath fading on the reception of signals depends on the signal bandwidth.
- For relatively large bandwidth, different parts of the transmitted signal spectrum are attenuated differently.
- This is manifested in the inter-symbol interference (ISI)
- If the delay of the multipath components concerning the main component is larger than the symbol's duration time, a channel is said to be subject to frequency selective fading
- The received signal includes multiple versions of the same symbol, each one attenuated (faded) and delayed.
- The received signal is distorted producing ISI.
- The channel has a constant gain and a linear phase response over a bandwidth that is much smaller than the bandwidth of the transmitted signal.



- The spectral characteristics of the transmitted signal are not preserved at the receiver.
- Certain frequency components have larger gains than others.
- The bandwidth of the transmitted signal, Bs is much greater than the coherence bandwidth of the channel Bc.

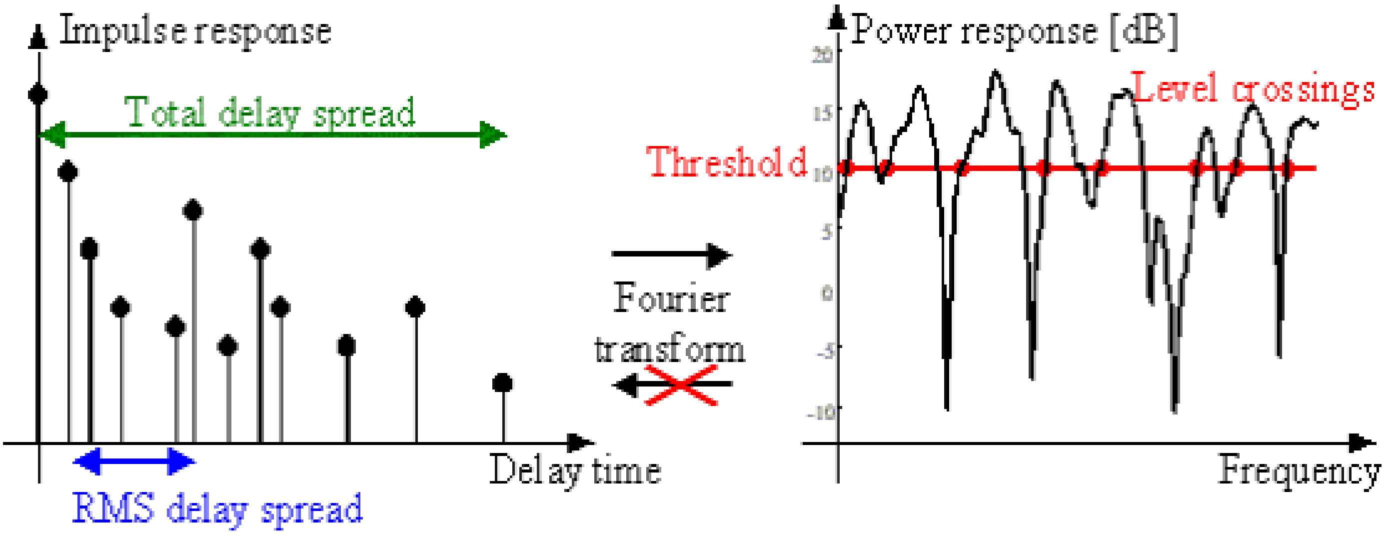
Doppler shift

- Small-scale fading due to movements: Doppler shift**.**
- How rapidly the channel fades will be affected by how fast the receiver and/or transmitter are moving.
- Motion causes a Doppler shift in the received signal components.
- It's the change in frequency of a wave for a receiver moving relative to the transmitter**.**
- When they are moving toward each other, the frequency of the received signal is higher than the source.
- When they are opposing each other, the frequency decreases.



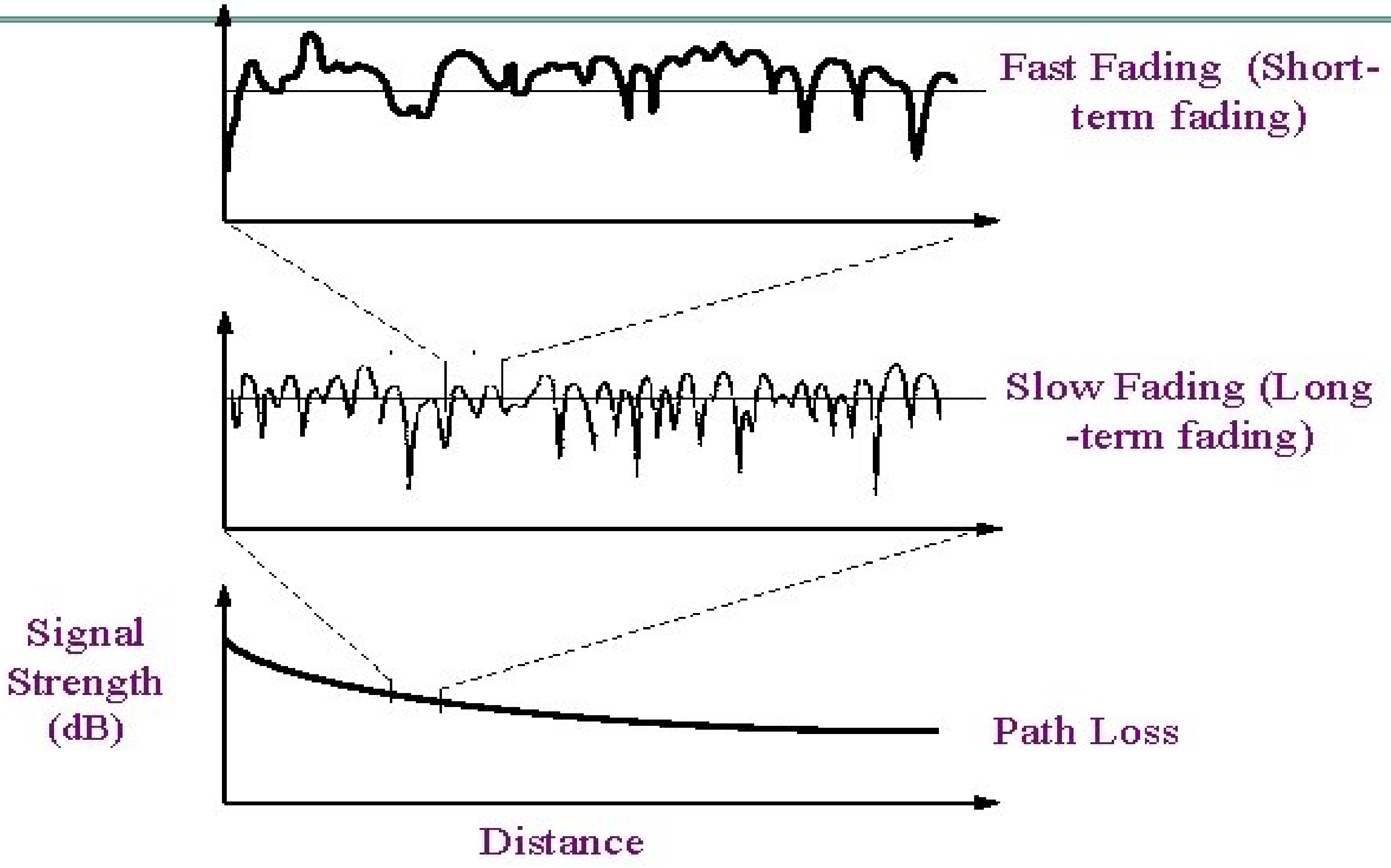
Delay Spread

- When a signal propagates from a transmitter to a receiver, the signal suffers one or more reflections.
- These forces signal to follow different paths.
- Each path has a different path length, so the time of arrival for each path is different.
- This effect that spreads out the signal is called "Delay Spread".



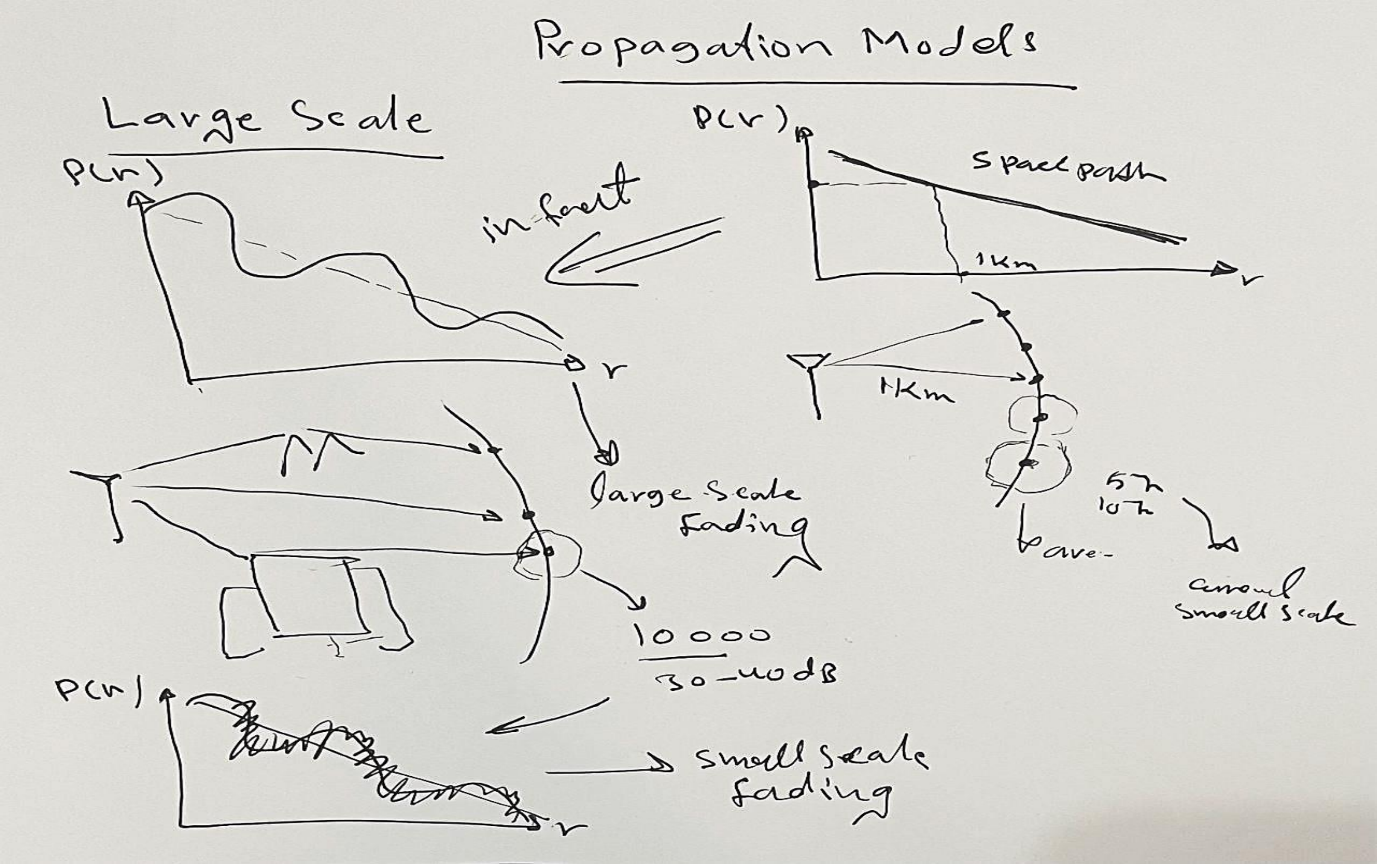
Fast and Slow Fading

- Slow or fast fading depends on the coherence time, Tc.
- Coherence time is the measure of the period over which the fading process is correlated.
- Tc is related to the delay spread, Tc=1/ds
- The fading is said to be slow if the symbol duration, Ts is smaller than Tc the coherence time (or the bandwidth of the signal is greater than the Doppler spread).



Mobile Radio Propagation

Large-Scale Path loss



$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

where P_t is the transmitted power, $P_r(d)$ is the received power which is a function of the T-R separation, G_t is the transmitter antenna gain, G_r is the receiver antenna gain, d is the T-R separation distance in meters, L is the system loss factor not related to propagation ($L \geq 1$), and λ is the wavelength in meters. The gain of an antenna is related to its effective aperture, A_e, by

$$G = \frac{4\pi A_e}{\lambda^2}$$

The effective aperture A_e is related to the physical size of the antenna, and λ is related to the carrier frequency by

$$\lambda = \frac{c}{f} = \frac{2\pi c}{\omega_c}$$

where f is the carrier frequency in Hertz, ω_c is the carrier frequency in radians per second, and c is the speed of light given in meters/s. The values for P_t and P_r must be expressed in the same units, and G_t and G_r are dimensionless quantities. The miscellaneous losses L ($L \geq 1$) are usually due to transmission line attenuation, filter losses, and antenna losses in the communication system. A value of $L = 1$ indicates no loss in the system hardware.

Example:

If a transmitter produces 50 watts of power, express the transmit power in units of (a) dBm(b) dBw. If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna. What is P, (10 km)? Assume unity gain for the receiver antenna.

Given:

Transmitter power, $P_t = 50$ W.

Carrier frequency, $f_c = 900$ MHz

Using equation (3.9),

(a) Transmitter power,

$$P_t(\text{dBm}) = 10\log\left[P_t(\text{mW})/(1\text{ mW})\right]$$
$$= 10\log\left[50 \times 10^3\right] = 47.0\text{ dBm}.$$

(b) Transmitter power,

$$P_t(\text{dBW}) = 10\log\left[P_t(\text{W})/(1\text{ W})\right]$$
$$= 10\log[50] = 17.0\text{ dBW}.$$

The received power can be determined using equation (3.1).

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} = \frac{50(1)(1)(1/3)^2}{(4\pi)^2(100)^2(1)} = 3.5 \times 10^{-6}\text{ W} = 3.5 \times 10^{-3}\text{ mW}$$

$$P_r(\text{dBm}) = 10\log P_r(\text{mW}) = 10\log\left(3.5 \times 10^{-3}\text{ mW}\right) = -24.5\text{ dBm}.$$

The received power at 10 km can be expressed in terms of dBm using equation (3.9), where $d_0 = 100$ m and $d = 10$ km

$$P_r(10\text{ km}) = P_r(100) + 20\log\left[\frac{100}{10000}\right] = -24.5\text{ dBm} - 40\text{ dB}$$
$$= -64.5\text{ dBm}.$$