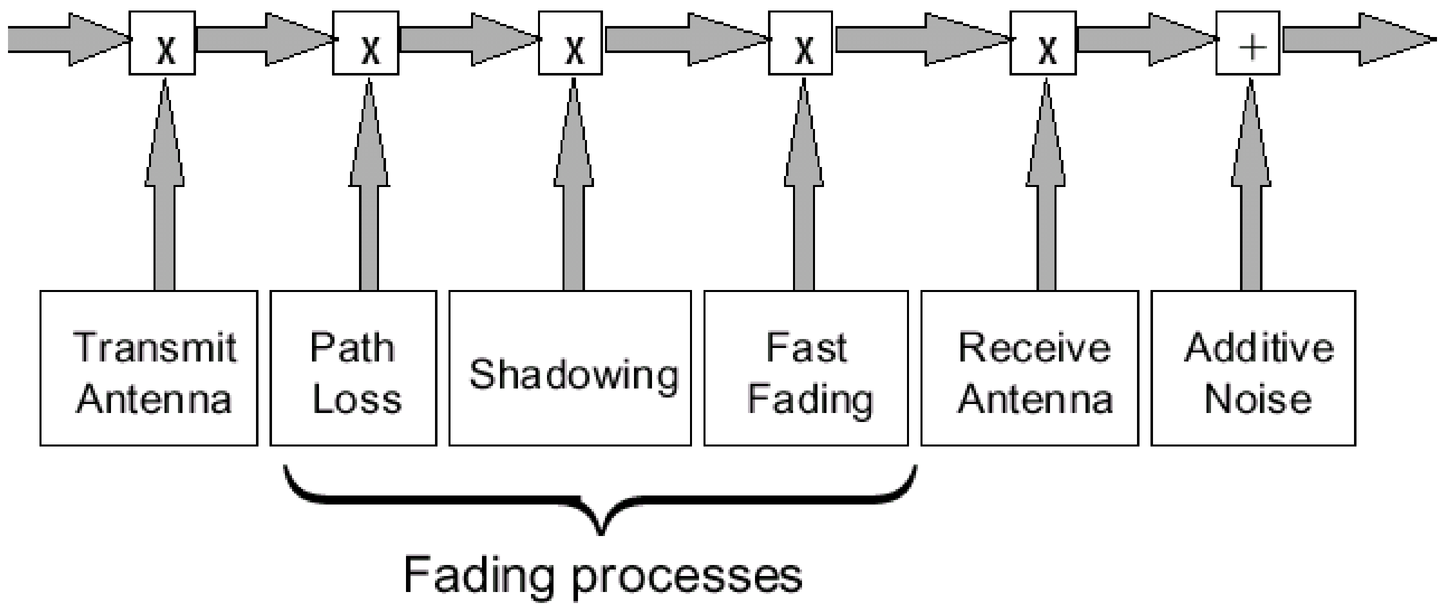
Fundamental Issues in Wireless Comm

- Radiowave propagation impairments
  - Fadings (WS: 5.4)
  - Doppler Spread (PK: 2.4)
- Error compensation schemes(WS:5.4)

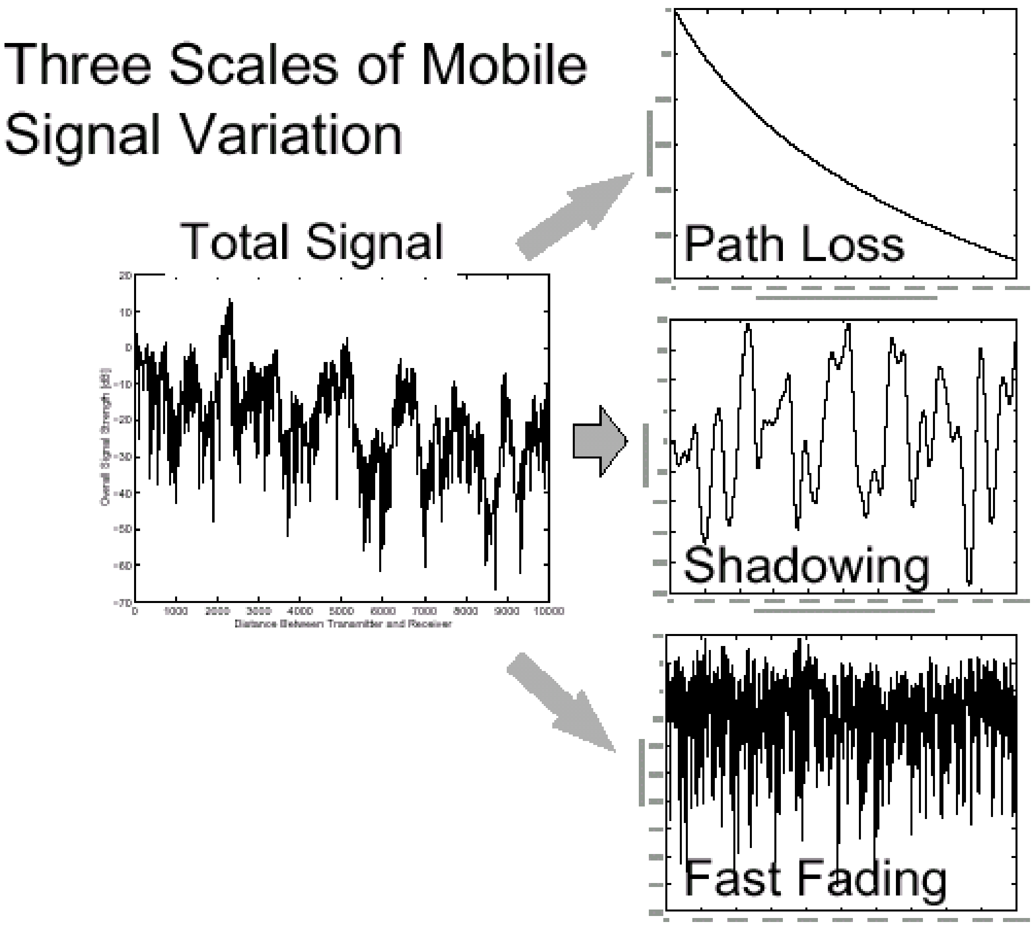
Wireless channel

The impairment in the wireless channel can be conveniently into three types fading: *path loss, shadowing (slow fading) and fast fading (or multipath fading).*



Wireless channels (2)

An example is illustrated by the signal received by a mobile receiver.



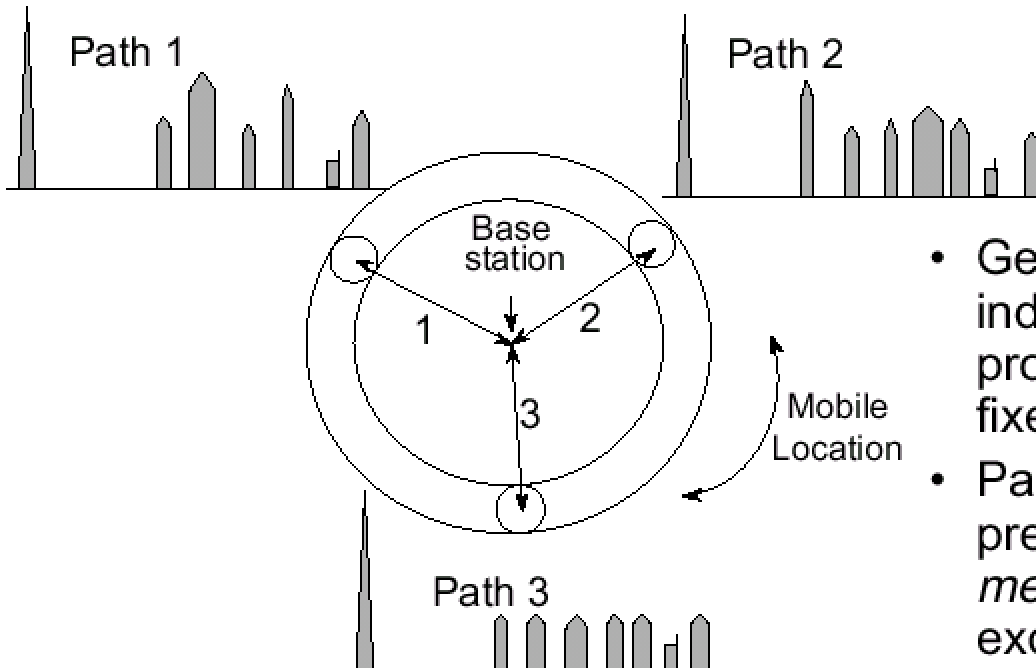
-- due to the distance, Friis' equation.

-- due to varying obstructions (tall buildings, woods, etc)

-- due to multipath interference, moving, etc.

Shadowing – Slow Fading

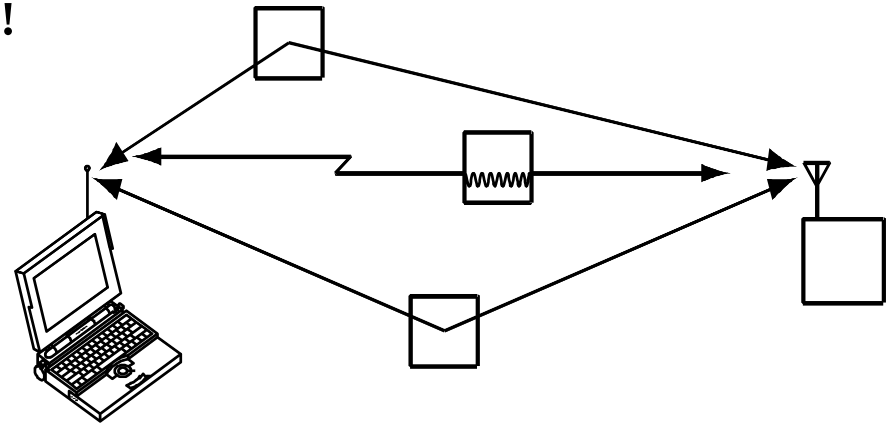
Slowing fading



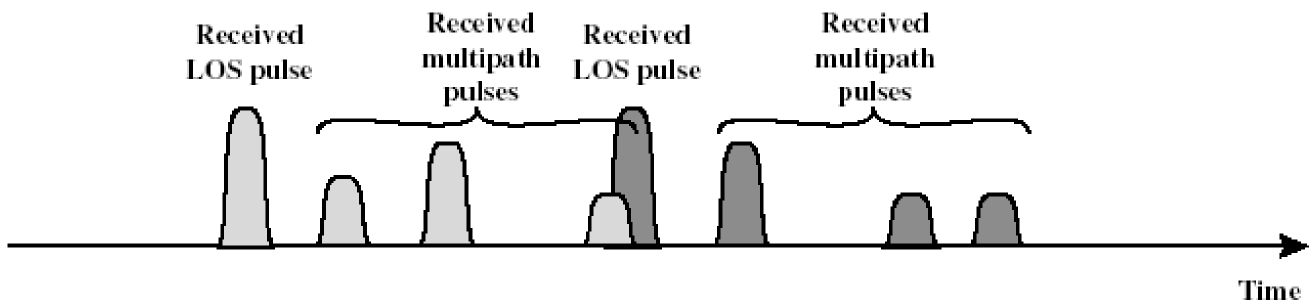
- Geometry of individual path profiles varies at fixed distance
- Path loss models predict the *median* level, exceeded at 50% of locations

The Effects of Multipath Propagation

- **Multiple copies of a signal may arrive at different phases**
  - **If phases add destructively, the signal level relative to noise declines, making detection more difficult – fast fading!**



- **Intersymbol interference (ISI)**
  - **One or more delayed copies of a pulse may arrive at the same time as the primary pulse for a subsequent bit**



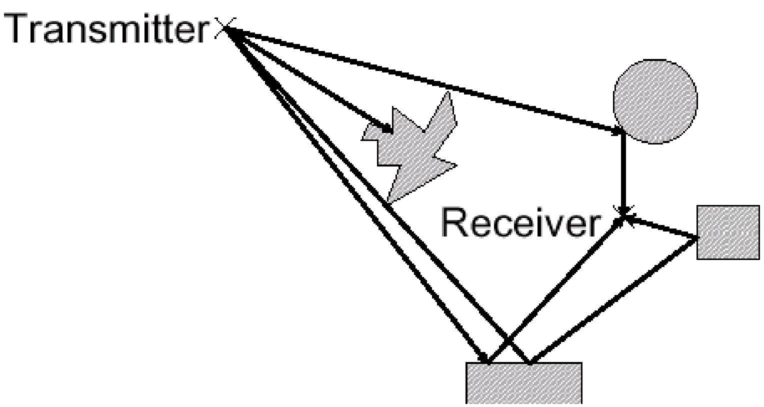
Types of Fading

- **Slow fading**
  - **Shadowing, due to obstruction.**
- **Fast fading**
      - » **The signals varies rapidly with the distance – due to multipath.**
  - **Rayleigh fading**
      - » **No LoS!**
  - **Rician fading** - **LoS**

  - **Flat fading**
      - » **The signal fluctuates in the same proportions simultaneously over the frequency band - 'narrow band signal' .**
  - **Selective fading**
      - » **Affects unequally the different spectral components.**

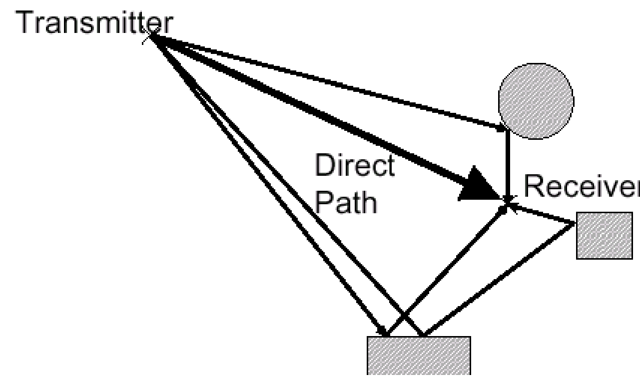
Rayleigh/Rician Fading

- All energy is scattered from scatterers near to mobile
- Direction of transmitter not necessarily perceived direction-of-arrival
- Multipaths interfere, causing cancellation and enhancement with deep and rapid variations in amplitude



Rayleigh fading (k=0)

- Strong coherent component added to random scattered component
- Signal fading less deep than NLoS case
- Distinct direction of arrival

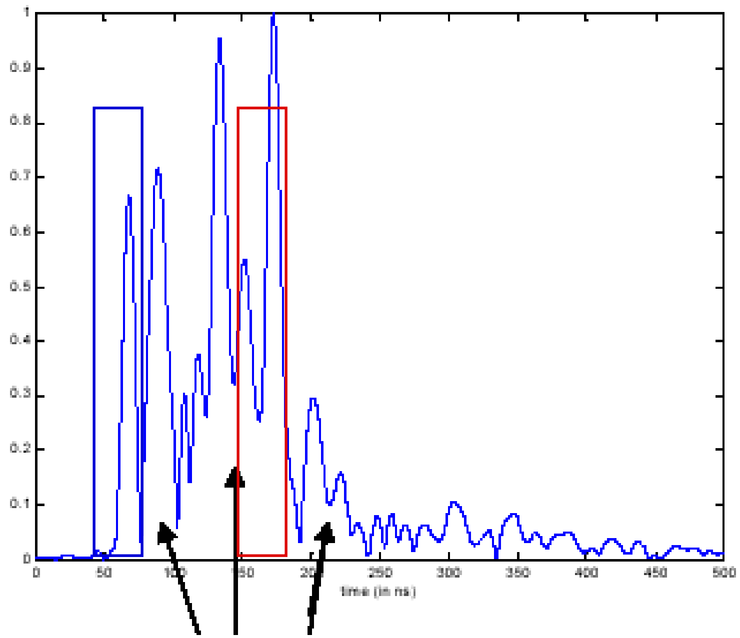


Rician fading (k >1)

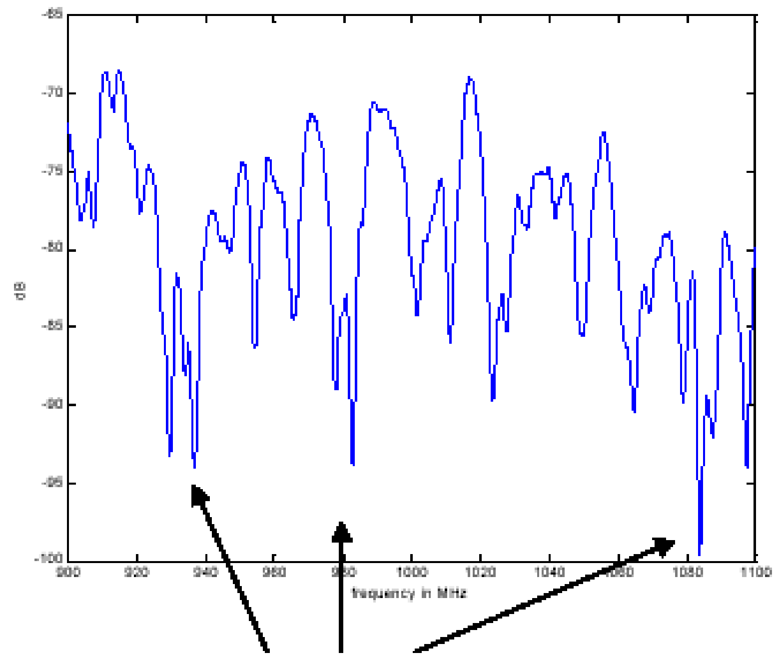
K = Power in dominant path / Power in Scattered path

Flat/Selective Fading

- **Flat fading: Narrow band case – limited signal spread, no ISI**
- **Frequency selective fading: ‘Wideband’ case – wide signal spread – causing ISI!**



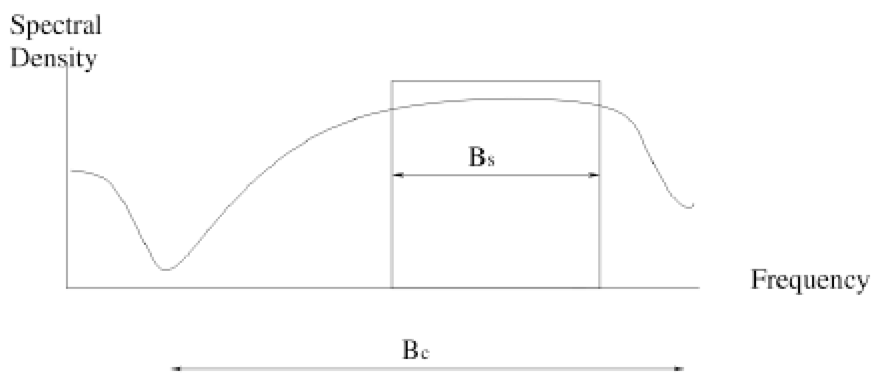
(a) Multipath arrival



(b) Frequency selective fading

Flat fading

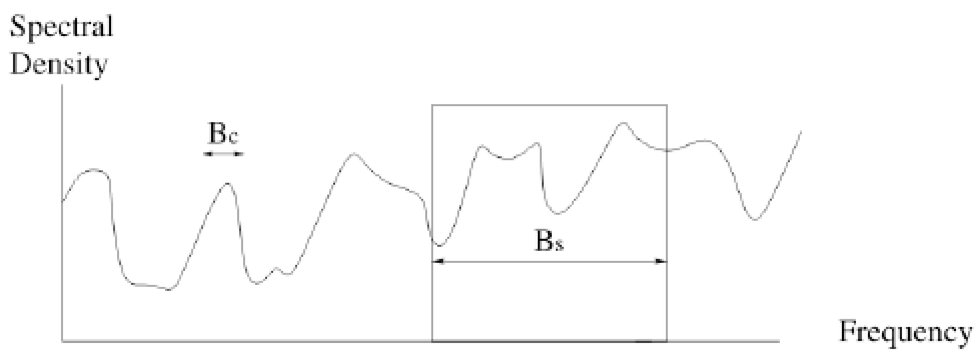
– In a flat fading channel inter-symbol interference (ISI) is absent
– The channel has a constant gain and a linear phase response over a bandwidth that is greater than the bandwidth of the transmitted signal.



– 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

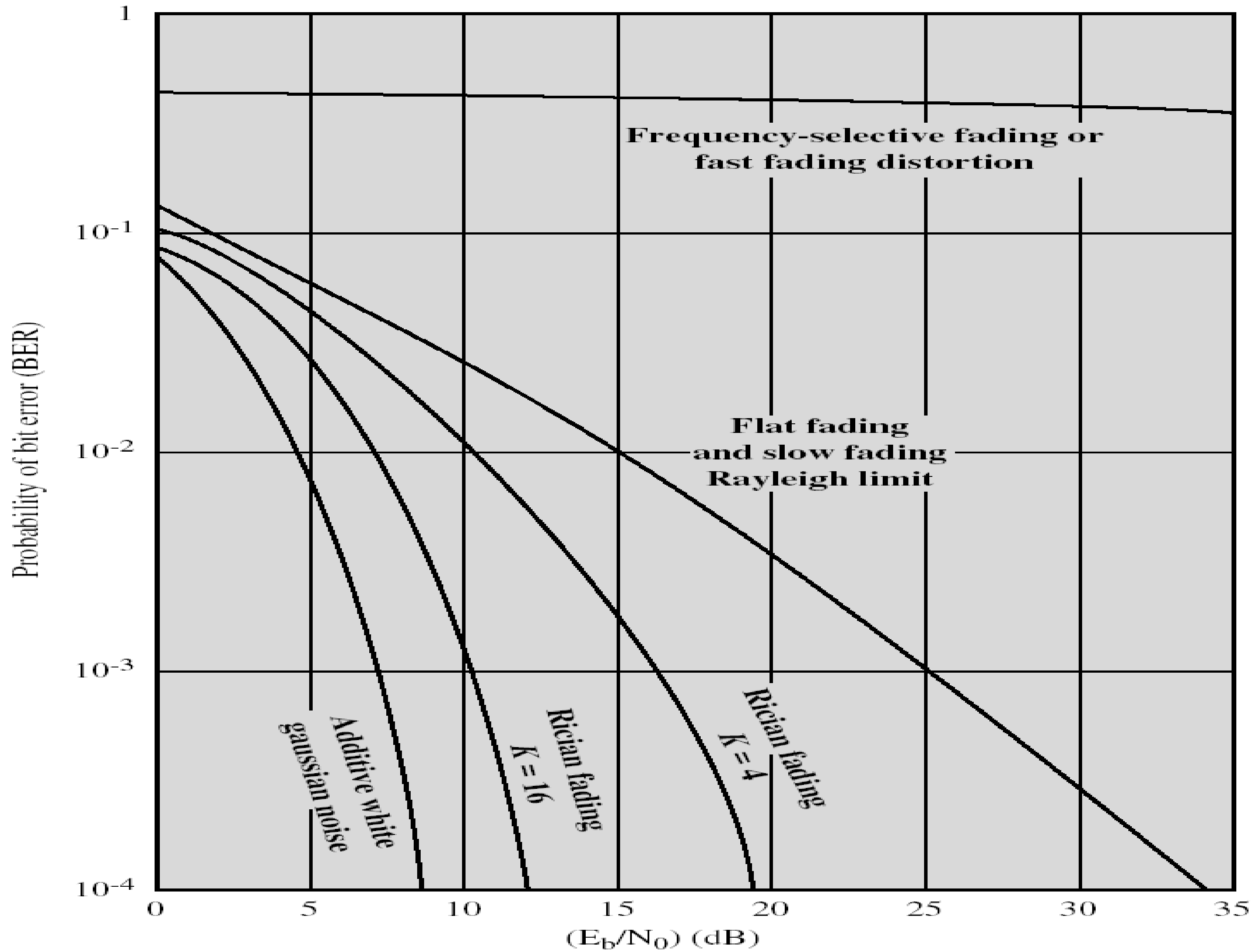
Frequency selective fading

- **Frequency selective fading**
  - 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.

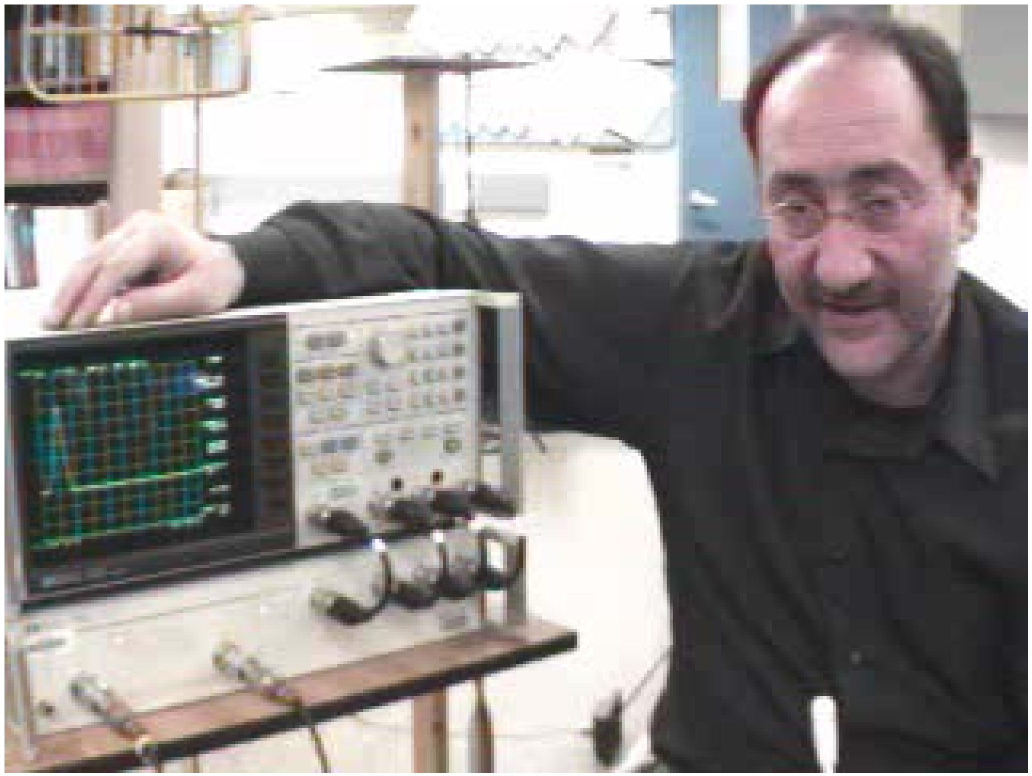


  - The spectral characteristics of the transmitted signal are not preserved at the receiver
  - Certain frequency components have larger gains than others

BER for Various Fading Conditions



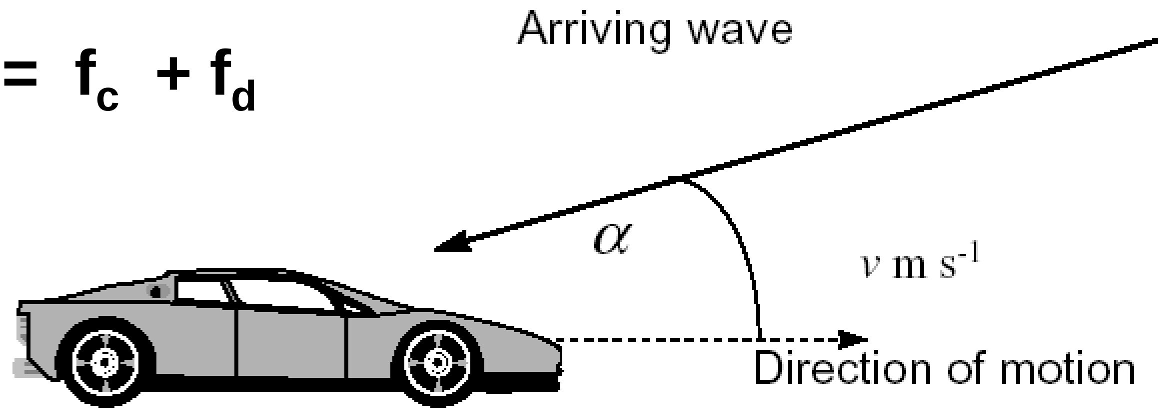
Fadings in Wireless Channels



Please watch this video clip on your own **12**

Doppler Effect

$$f_r = f_c + f_d$$



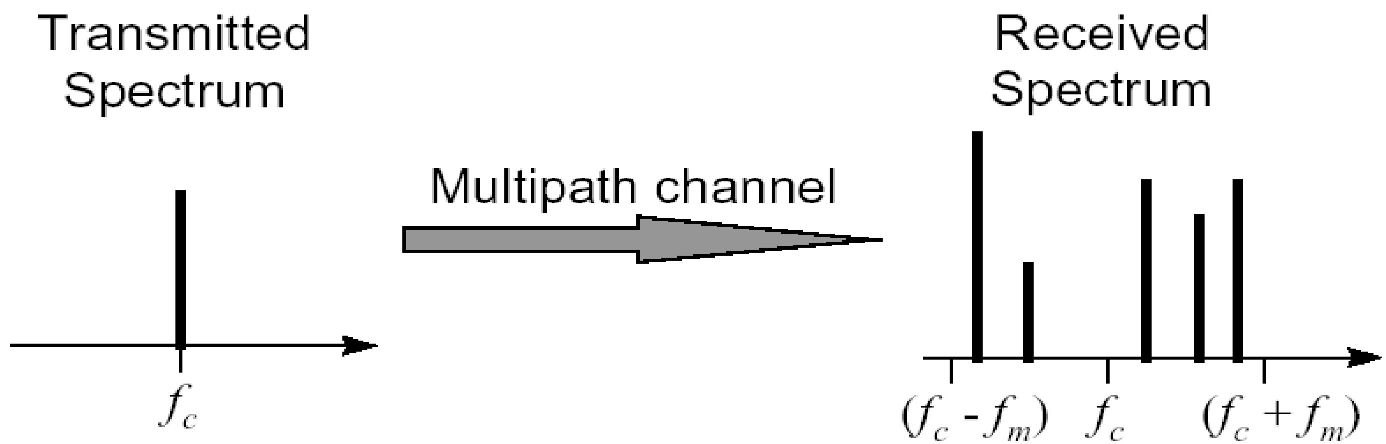
$$f_d = f_c \frac{v}{c} \cos\alpha$$

$$f_d \max = \pm f_c \frac{v}{c}$$

- Shift in apparent carrier frequency due to receiver motion relative to source (scatterer or transmitter)

Doppler Spread

- In multipath channel, have a range of α
- Leads to Doppler *spread*, not simply *shift*

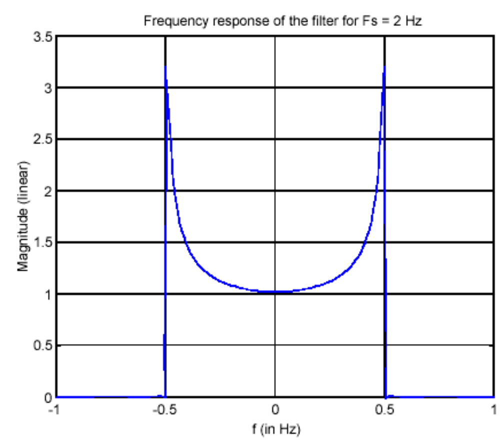


Classical Doppler spectrum:

-- Second order statistic in the fast fading

- the rate of signal changes

-- Determine the error correction capability

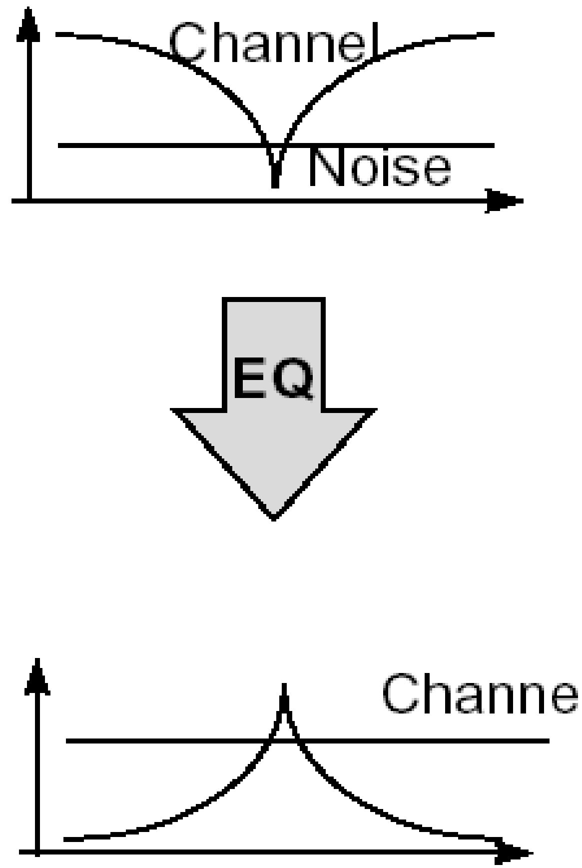


Error Compensation Mechanisms

- **Increase transmitter power**
  - counters flat fading – fading margin.
- **(Adaptive) Equalization**
  - compensates for ISI/Frequency selective fading.
- **Forward error correction (FEC)**
  - transmit redundant data bits - “coding gain” provides “fading margin”
- **Automatic Repeat Request (ARQ)**
  - retransmission protocol for blocks of data (e.g. packets) in error - stop-and-wait, go-back-N, selective-repeat etc.
- **Frequency diversity**
  - **Spread Spectrum / OFDM and etc.**
- **Space or time diversity**
  - Diversity antenna, adaptive antenna and MIMO

Adaptive Equalization

- **Used to combat intersymbol interference – in GSM.**
- **Involves gathering dispersed symbol energy back into its original time interval**
- **Has to be adaptive to account for the fast changing of the channel.**
- **The principle of the equaliser – reverse the channel effect:**



Coping with Data Transmission Errors

- **Error detection codes**
  - **Detects the presence of an error**
- **Automatic repeat request (ARQ) protocols**
  - **Block of data with error is discarded**
  - **Transmitter retransmits that block of data**
- **Error correction codes, or forward correction codes (FEC)**
  - **Designed to detect and correct errors**

Error Detection Process

- **Transmitter**
  - **For a given frame, an error-detecting code (check bits) is calculated from data bits**
  - **Check bits are appended to data bits**
- **Receiver**
  - **Separates incoming frame into data bits and check bits**
  - **Calculates check bits from received data bits**
  - **Compares calculated check bits against received check bits**
  - **Detected error occurs if mismatch**

Error Detection Process

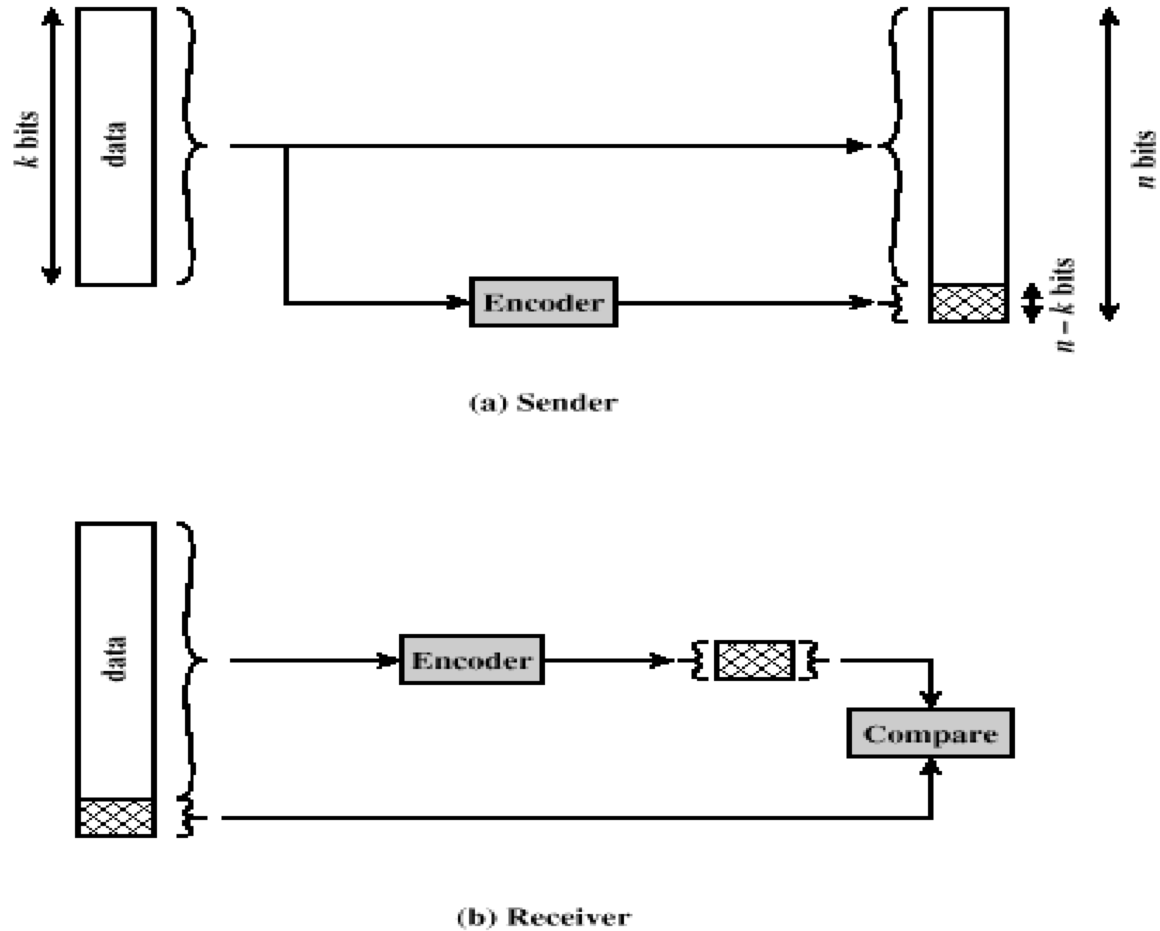


Figure 8.1 Error Detection Process

Parity Check

- **Parity bit appended to a block of data**
- **Even parity**
  - **Added bit ensures an even number of 1s**
- **Odd parity**
  - **Added   bit ensures an odd number of 1s**
- **Examples, 7-bit character [1110001]**
  - **Under Even parity: [11100010];**
  - **Under Odd parity: [11100011]**
    - » **If 10100011 received, there is an error.**
- **In Wireless Comm, Cyclic Redundancy Check using k bits!**

Wireless Transmission Errors

- **Error detection requires retransmission**
- **Detection inadequate for wireless applications**
  - **Error rate on wireless link can be high, results in a large number of retransmissions**
  - **Long propagation delay compared to transmission time**

Block Error Correction Codes

- **Transmitter**
  - **Forward error correction (FEC) encoder maps each k-bit block into an n-bit block codeword**
  - **Codeword is transmitted; analog for wireless transmission**
- **Receiver**
  - **Incoming signal is demodulated**
  - **Block passed through an FEC decoder**

- **Error Correction Code types**
  - **Block coding**
  - **Convolutional coding**

Forward Error Correction Process

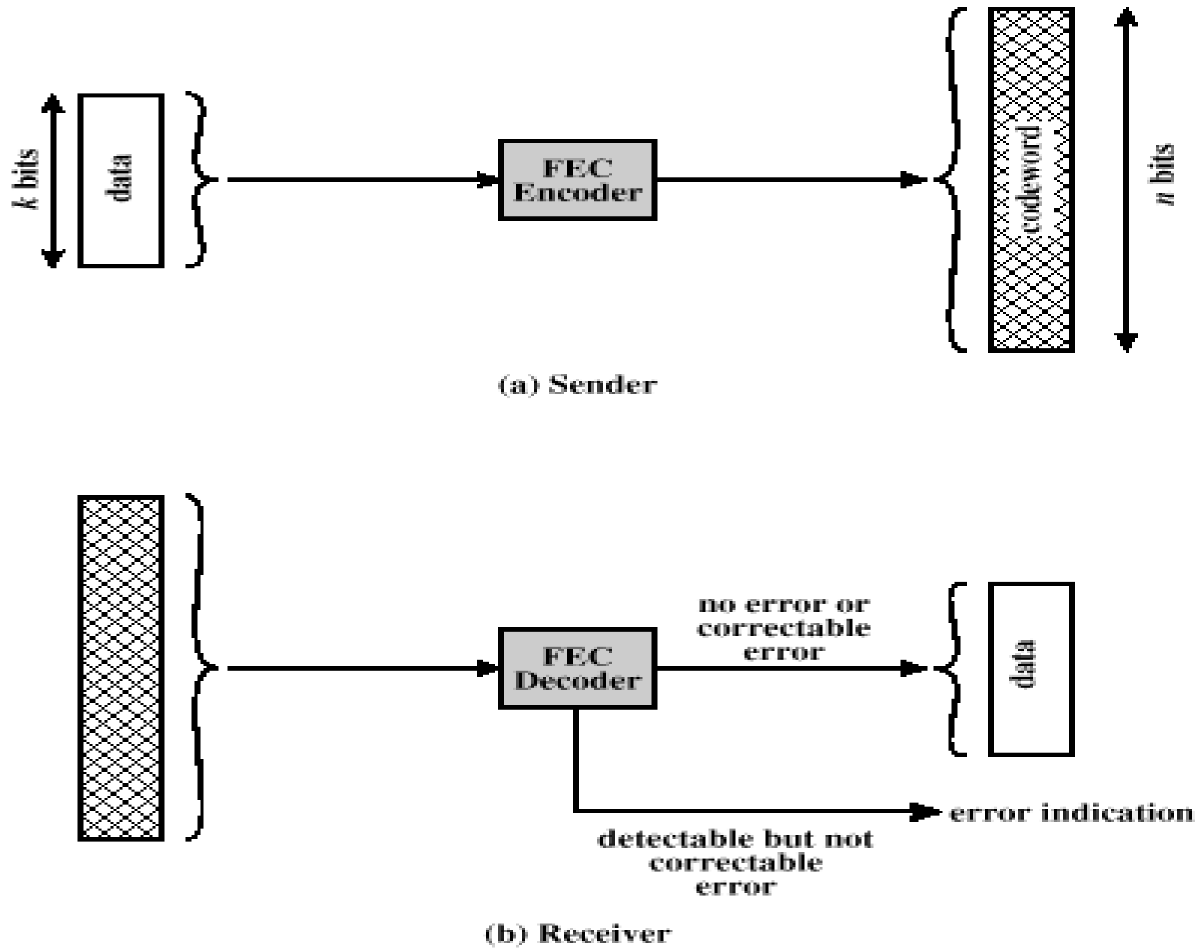


Figure 8.5 Forward Error Correction Process

Block Code Principles

- **Hamming distance – for 2 *n*-bit binary sequences, the number of different bits**
  - **E.g., v_1=011011; v_2=110001; d(v1, v_2)=3**

Example (WS:p.215):

Data block:	00	01	10	11
Codeword:	00000	00111	11001	11110

Suppose 00100 is received, which is not **a valid codeword.**

The Hamming distance:

d(00000,00100) = 1, d(00111,00100) = 2, d(11001,00100) = 4, d(11110,00100) = 3.

So the valid codeword with minimum distance is selected, i.e. 00000 → 00!

Class Quizzes

- What are: slow/fast fadings, Rayleigh/Rician fadings and flat and frequency selective fadings?
- How does Doppler Spread impact the wireless channels?
- What is the forward correction code(FEC)? Why do we need it in wireless communications?

Reading References

- References:
  - (PK): K. Pahlavan and P. Krishnamurthy, Principles of Wireless Networks: A Unified Approach, Prentice Hall, 2002 (new version coming)
  - (WS): William Stallings, Wireless Communications and Networks, 2/e , Prentice Hall, 2005
  - Antennas and Propagation in Wireless Communication Systems, S. Saunders, Wiley, 1999, ISBN: 0471986097