無線通訊系統
(Wireless Communications Systems)

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課程要求

- Required Prior Knowledge: **Signals & Systems; Probability; Communication Systems**
- Homework: 30%
- Midterm Exam: 35%
- Final Exam: 35%
- Web Site: https://nyquist.ee.nthu.edu.tw/WCS.html
  - Password: COM5170-20260907WCSys
- Textbook: Gordon L. Stüber, Principles of Mobile Communication, **Second/Third/Fourth** Edition
- 助教時間：每週三 13:00~15:00, CL 605 室
- 助教：TWNTHUCOM5170@gmail.com

Contents

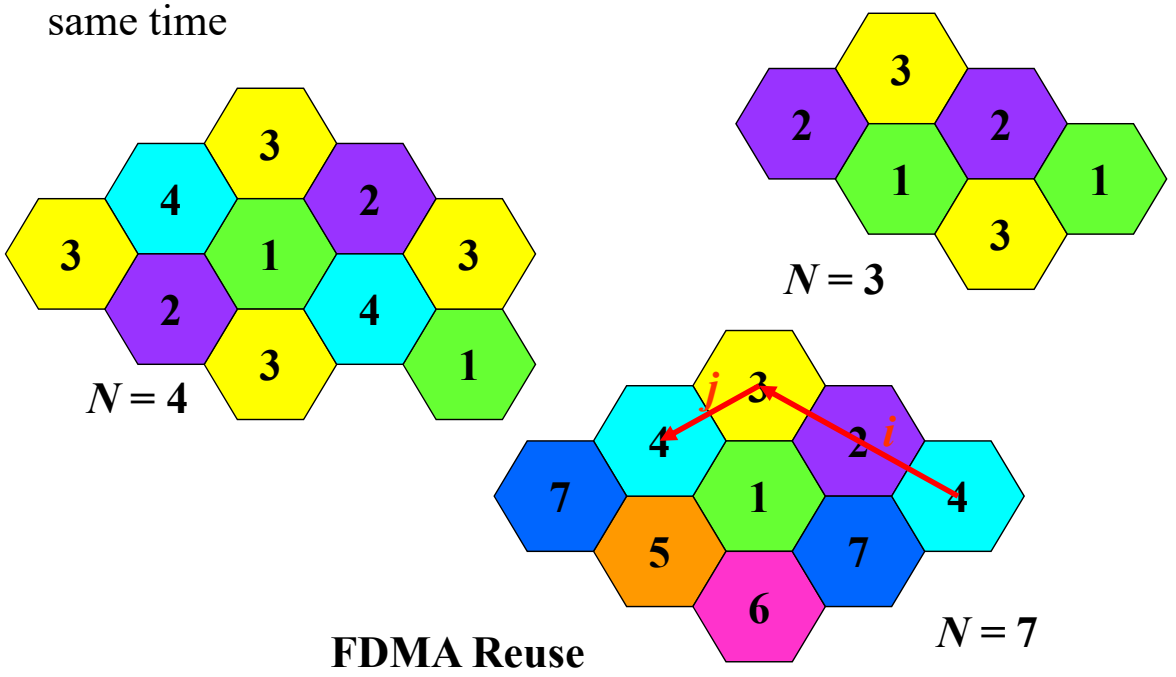
- **Chapter 1: Introduction**
- **Chapter 2: Propagation Effects**
- **Chapter 3: Physical Layer Technologies for Wireless Communication Systems**
- **Chapter 4: Radio Network Planning Technologies for Wireless Communication Systems**

Contents

- **Chapter 1: Introduction**
  - Cellular Concept & Frequency Reuse
  - Multiple Access and Duplex Methods
  - Antenna Radiation Pattern
  - Wireless Propagation
  - System Performance
  - Spectral Efficiency

Ch 1. Cellular Concept & Frequency Reuse

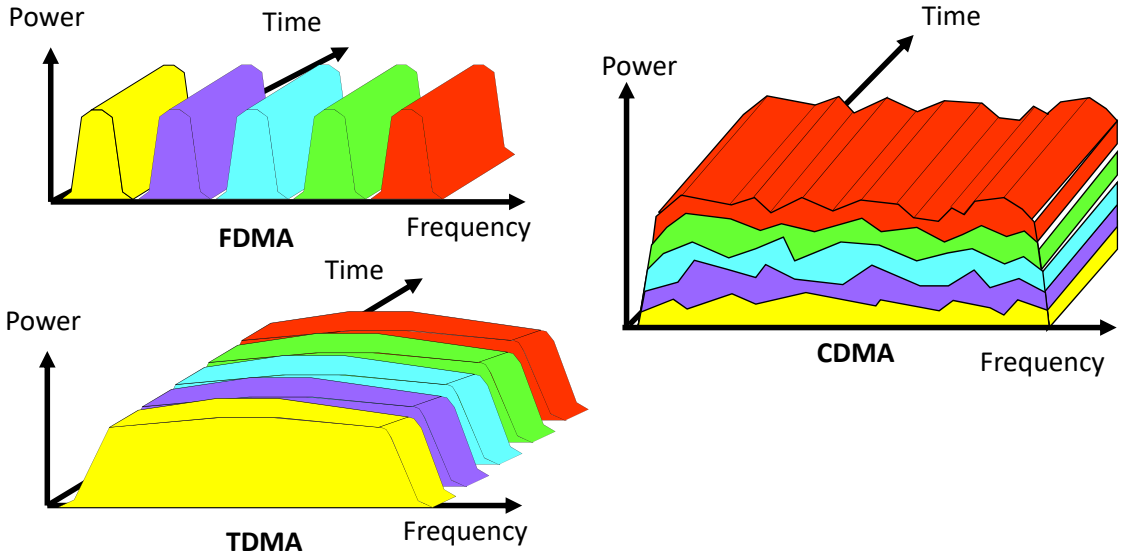
- $N = i^2 + i \times j + j^2$, $i \geq 0, j \geq 0$, i and j should not be zero at the same time



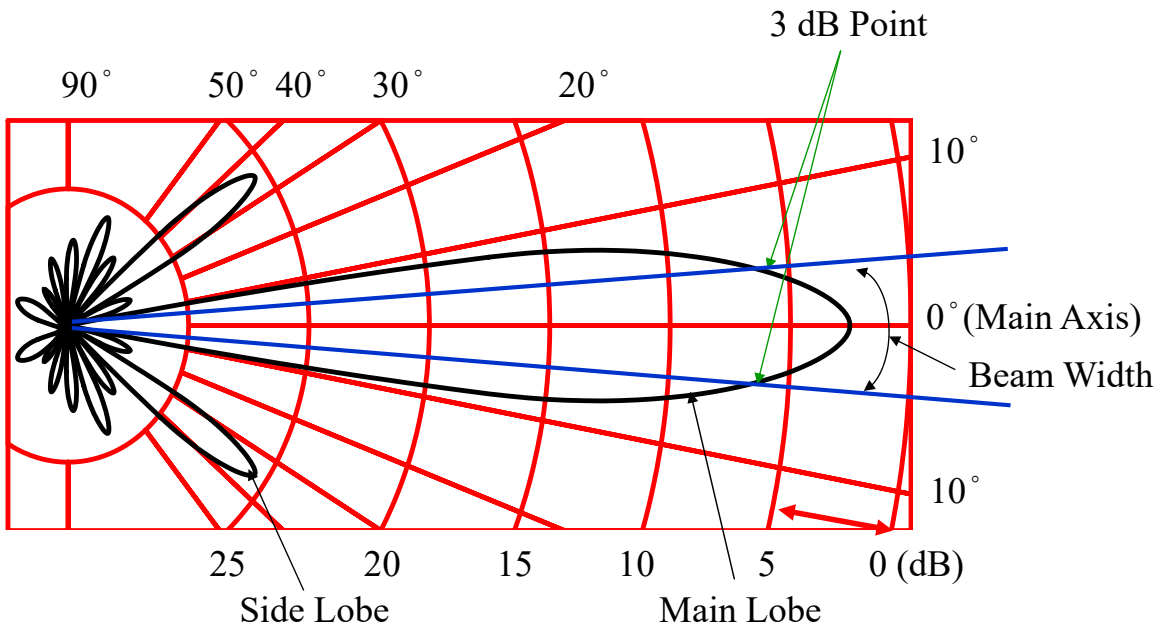
FDMA Reuse

Ch 1. Multiple Access and Duplex Methods

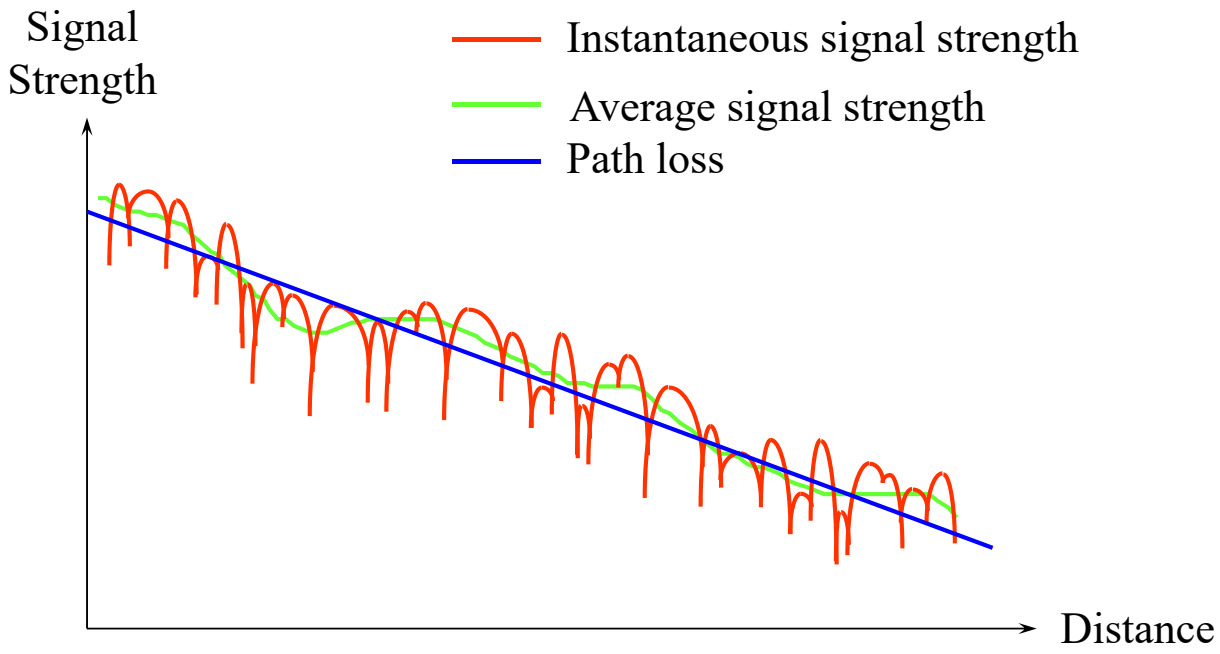
- **FDMA:** Frequency Division Multiple Access
- **TDMA:** Time Division Multiple Access
- **CDMA:** Code Division Multiple Access



Ch 1. Antenna Radiation Pattern

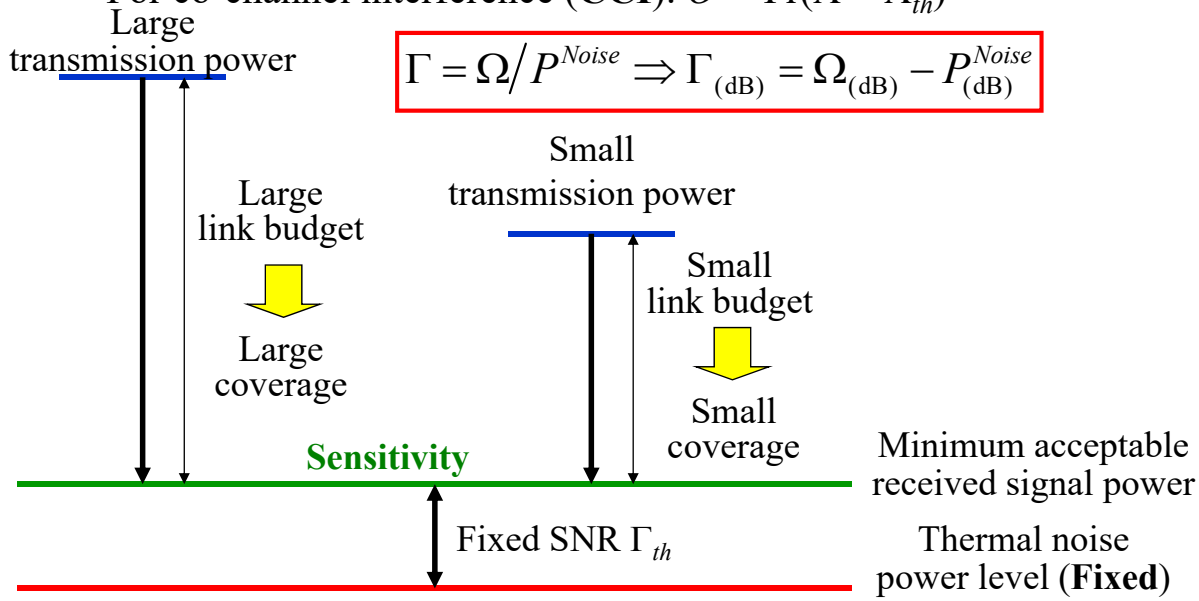


Ch 1. Wireless Propagation



Ch 1. System Performance and Outage

- Outage probability:
  - For thermal noise (**TN**): $O = \Pr(\Gamma < \Gamma_{th})$
  - For co-channel interference (**CCI**): $O = \Pr(\Lambda < \Lambda_{th})$

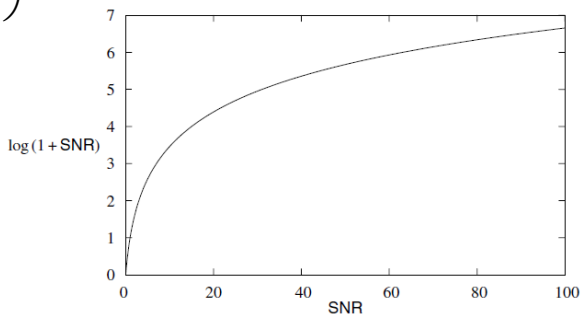


Ch 1. Spectral Efficiency

- The capacity of the AWGN channel is

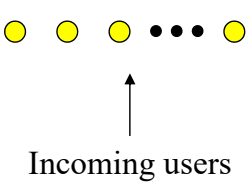
$$C_{AWGN}(P,W) = \log\left(1+\frac{P}{N_0 W}\right) = \log(1+SNR) \quad \text{bits/s/Hz}$$

  - where $SNR = P/(N_0 W)$



- η_T: **trunking efficiency**
  - Channel assignment
  - Trade-off between QoS
  - Erlang B formula

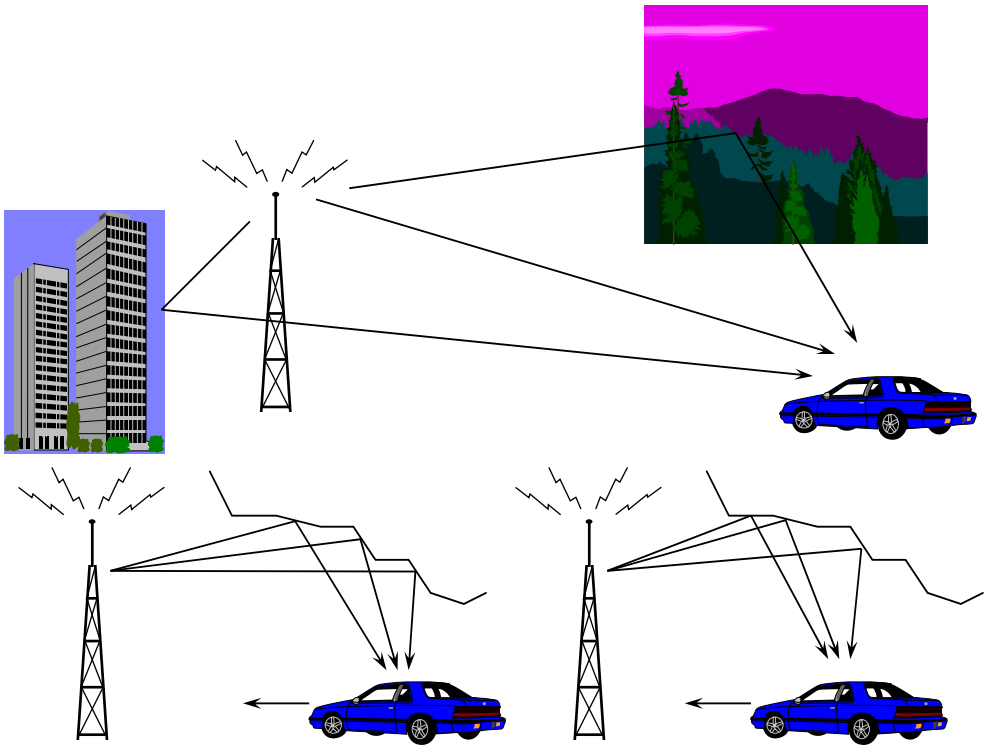
Blocking Prob. $B(\rho,m) = \dfrac{\rho^m}{m!\sum_{k=0}^{m}\dfrac{\rho^k}{k!}}$



Contents

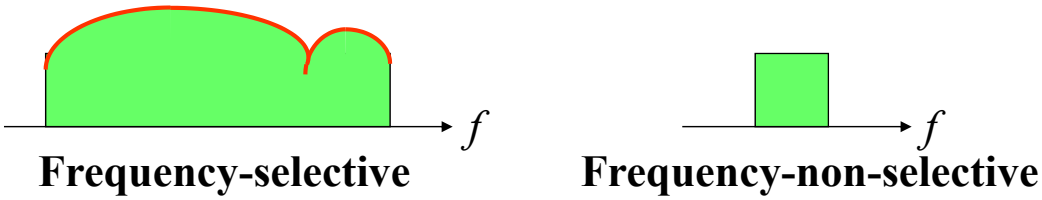
- **Chapter 2: Propagation Effects**
  - Propagation Modeling
  - Frequency-Non-Selective (Flat) Multipath Fading
  - Frequency-Selective Multipath Fading
  - Laboratory Simulation
  - Shadowing
  - Path Loss
  - MIMO Channel Model

Ch 2. Multipath Propagation



Ch 2. Freq.-Selective/Non-selective Fading

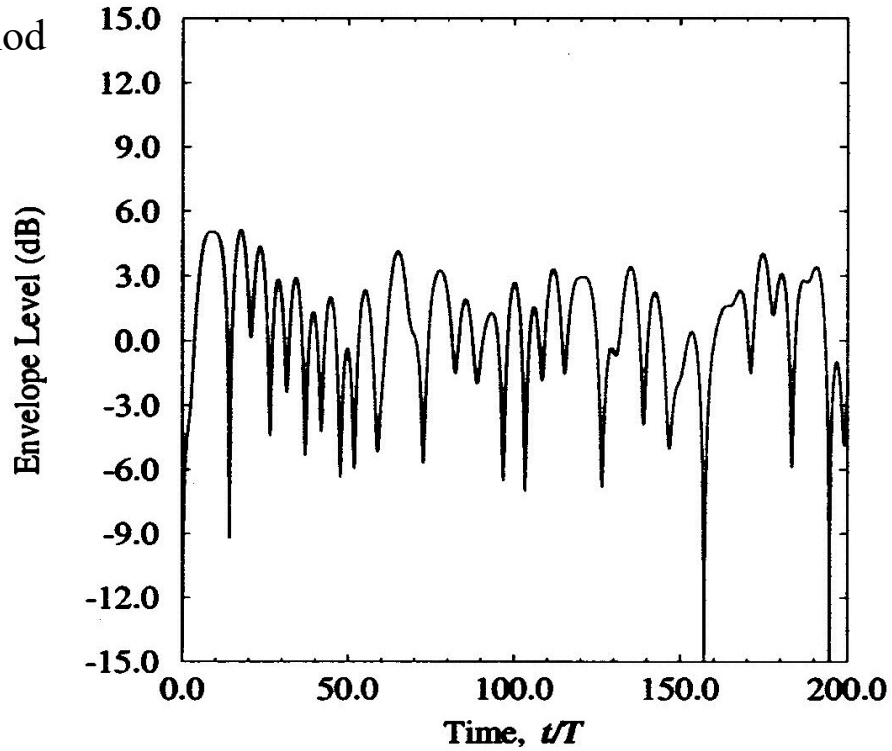
- **Frequency-selective multipath fading:**
  - The frequency components may experience **different random attenuation and phase shift**
  - Significant distortion ⇒ ISI, **equalization or RAKE is need**
- **Frequency-non-selective multipath fading:**
  - All the frequency components experience **the same attenuation and phase shift**
  - Almost no ISI



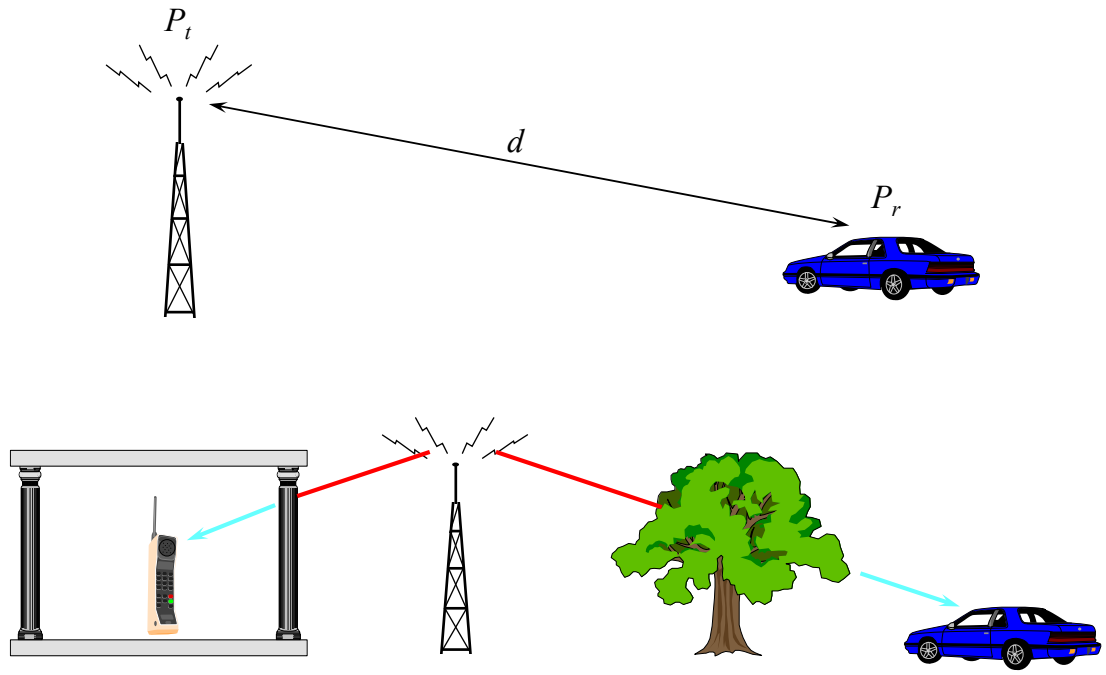
Frequency-selective **Frequency-non-selective**

Ch 2. Laboratory Simulation

- Jack's Method

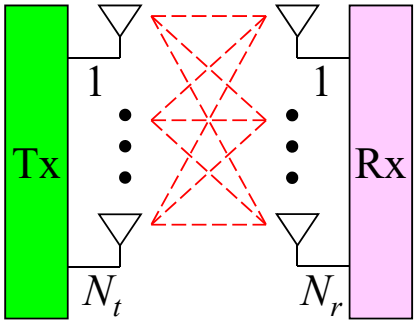


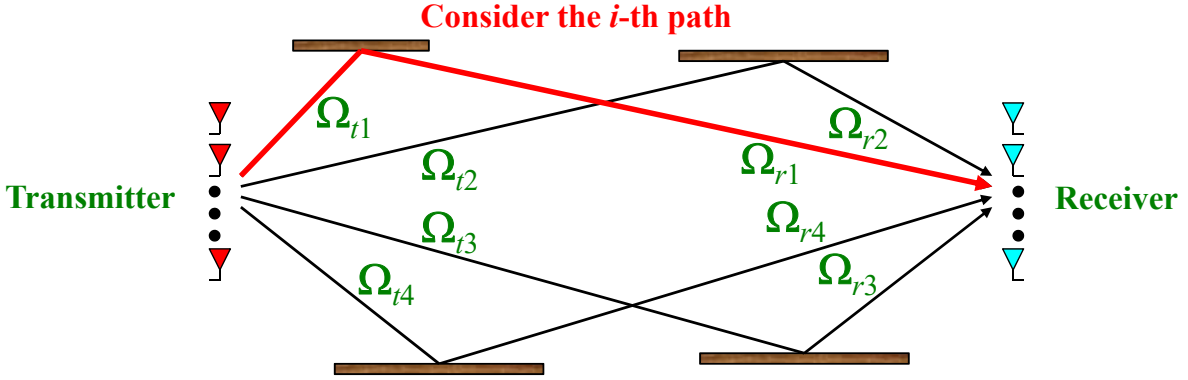
Ch 2. Path Loss and Shadowing



Ch 2. MIMO Channel Models

- A MIMO (Multiple-Input and Multiple-Output) system is one that consists of multiple transmit and receive antennas.
- For a system consisting of N_t transmit and N_r receive antennas, the channel can be described by the $N_r \times N_t$ matrix.





Contents

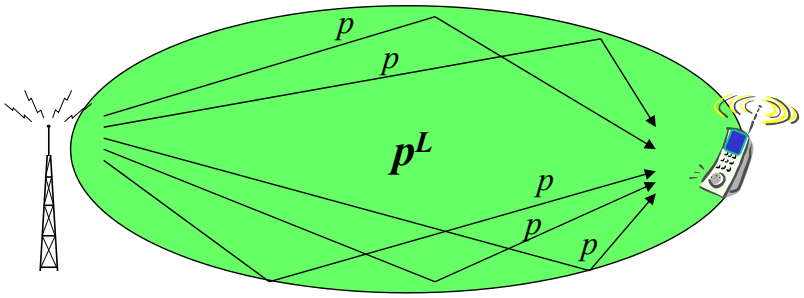
- **Chapter 3: Physical Layer Technologies for Wireless Communication Systems**
  - Data Modulation
  - Digital Signaling on Flat Fading Channels
  - Diversity Techniques
  - Transmit Diversity
  - Precoding
  - Equalization
  - Random Access Techniques

Ch 3. Modulation Signal

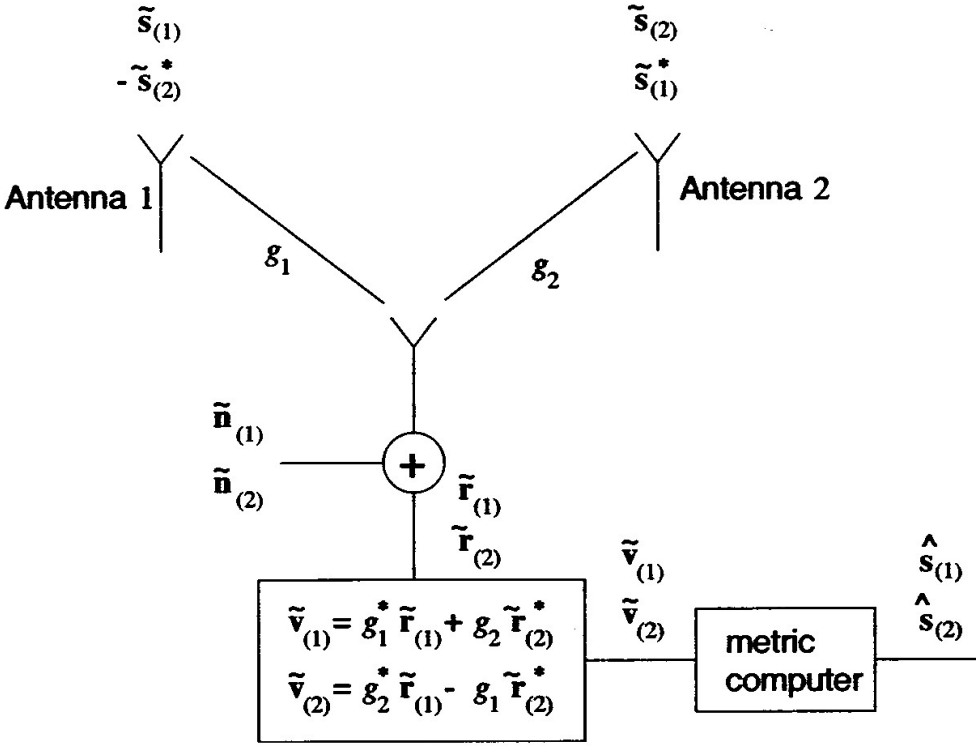
- First generation systems:
  - **FM modulation** (AMPS, TACS, NMT)
- Second generation systems:
  - **π/4-DQPSK** (IS-136, PDC, PHS)
  - **GMSK** (GSM, DCS1800, DECT)
- Third generation systems:
  - CDMA – **QPSK／Offset QPSK** (cdma2000, WCDMA)
- Fourth generation systems:
  - OFDM – **BPSK, QPSK, 16-QAM, 64-QAM** (WiMAX, LTE)
- Fifth generation systems:
  - OFDM – **…, 256-QAM, 512-QAM, 1024-QAM**

Ch 3. Diversity Techniques

- Diversity is one very effective solution for combat fading:
  - Provide the receiver with multiple faded replicas of the same information signal
  - Let p denote the probability that the instantaneous signal-to-noise ratio is below some critical threshold **on a particular diversity branch**
  - p^L is the probability that the instantaneous signal-to-noise ratio is below the same critical threshold **on L diversity branches**

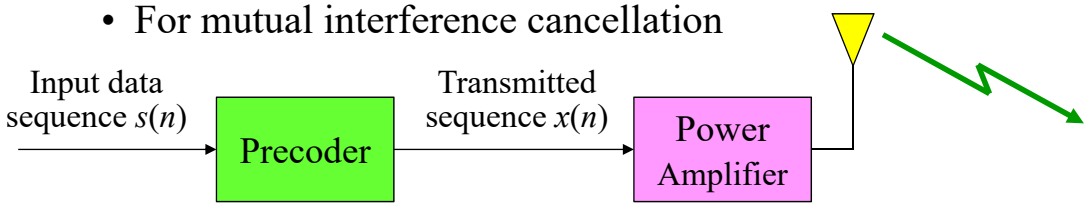


Ch 3. Space-Time Transmit Diversity



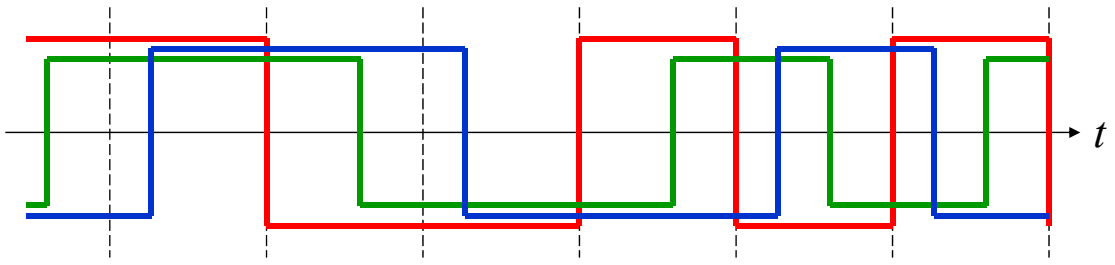
Ch 3. Precoding

- **Precoding** is a modification of a sequence of signals (symbols) before transmission to meet a specific goal/requirement.
- There are various purposes for using precoding in wireless transmissions
  - To decrease the envelope variations of the transmitted signals
  - To mitigate the inter-symbol interference induced by channels
  - To achieve radio resource mapping for different signals
    - For diversity reception
    - For multiple access
    - For mutual interference cancellation



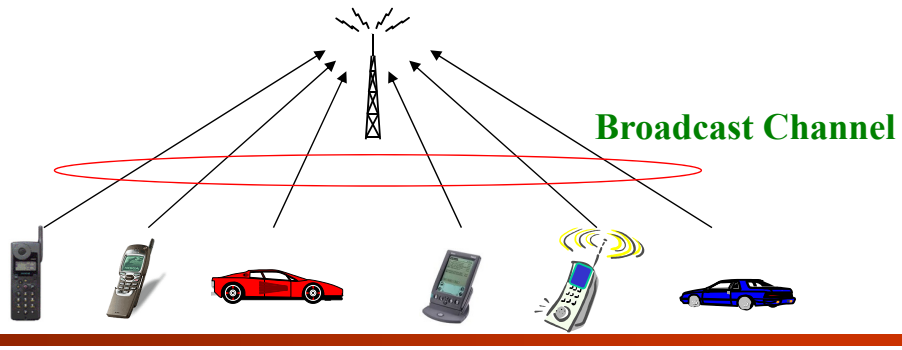
Ch 3. Equalization

- The adaptive equalization is a technique used to mitigate the combined effect of ISI and noise
- Two broad categories of equalizers:
  - Symbol-by-symbol equalizers
  - Sequence estimators



Ch 3. Random Access Techniques

- In a **broadcast channel** (such as a wireless channel), one of the key issue is to determine who gets the right of using the channel when there is **competition** for it.
- In a **synchronous** system (with a **controller**), the **multiple access techniques**, such as TDMA or CDMA, can be applied to prevent/reduce **signal collision** or **mutual interference**.
- In a **asynchronous** system, **random access techniques** should be used.

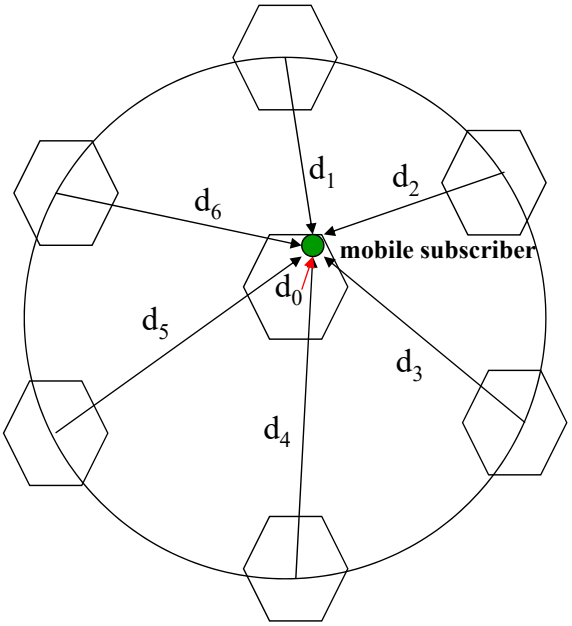


Contents

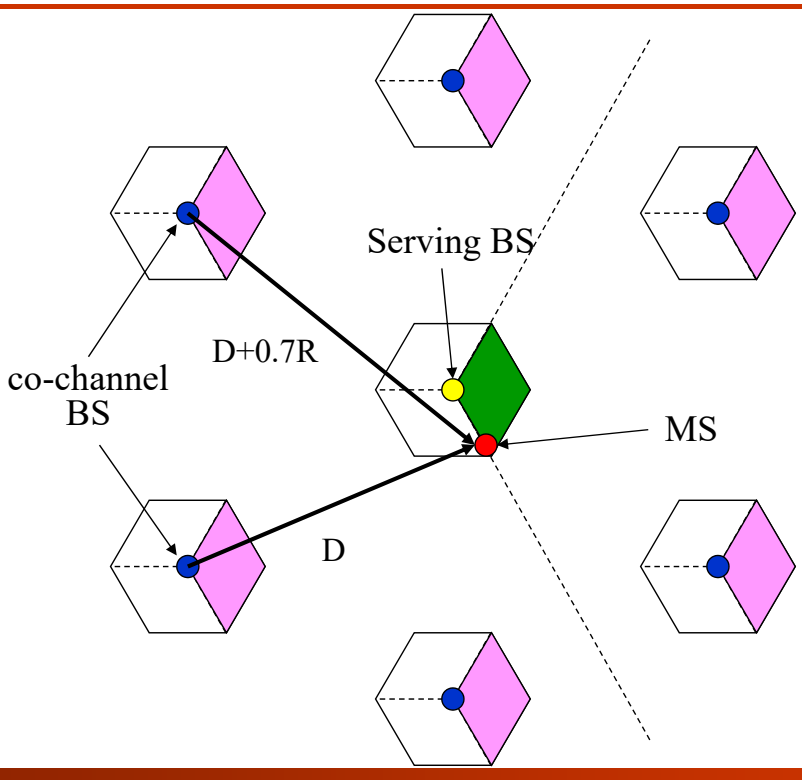
- **Chapter 4: Radio Network Planning Technologies for Wireless Communication Systems**
  - Co-channel Interference and Frequency Reuse
  - Cellular Coverage Planning
  - Link Quality and Handoff
  - Channel Assignment
  - Wireless Security

Ch 4. Co-channel Interference

- Forward channel:

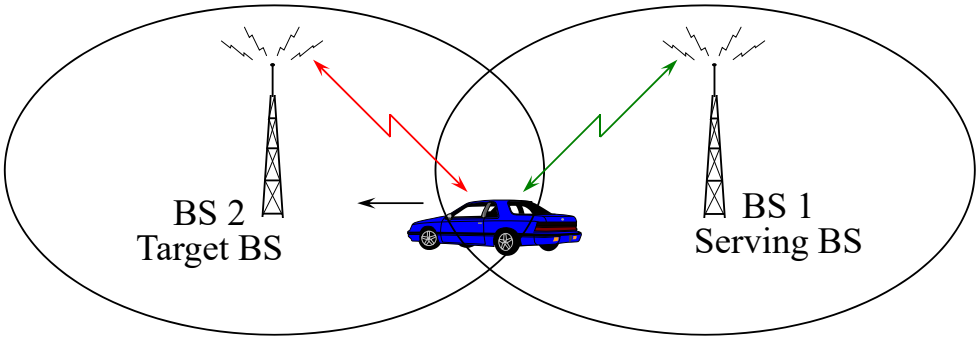


Ch 4. Cell Coverage Planning



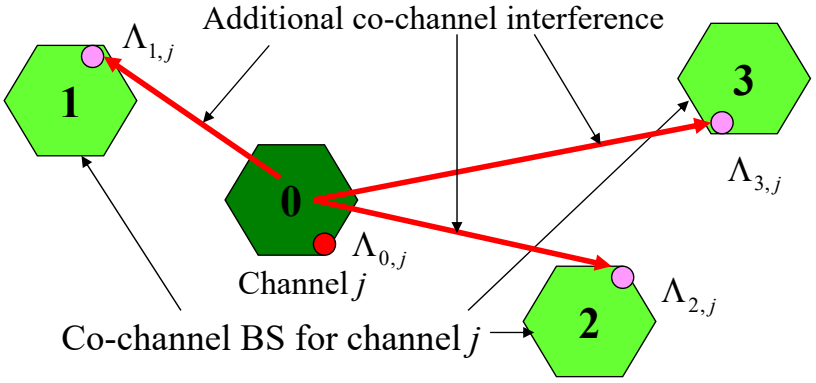
Ch 4. Handoff

- There are three types of handoff in mobile communications systems:
  - Network controlled (NCHO) (AMPS)
  - Mobile assisted (MAHO)(2nd Generation GSM and CDMA)
  - Mobile controlled (MCHO) (low-tier: PACS, DECT, PHS)

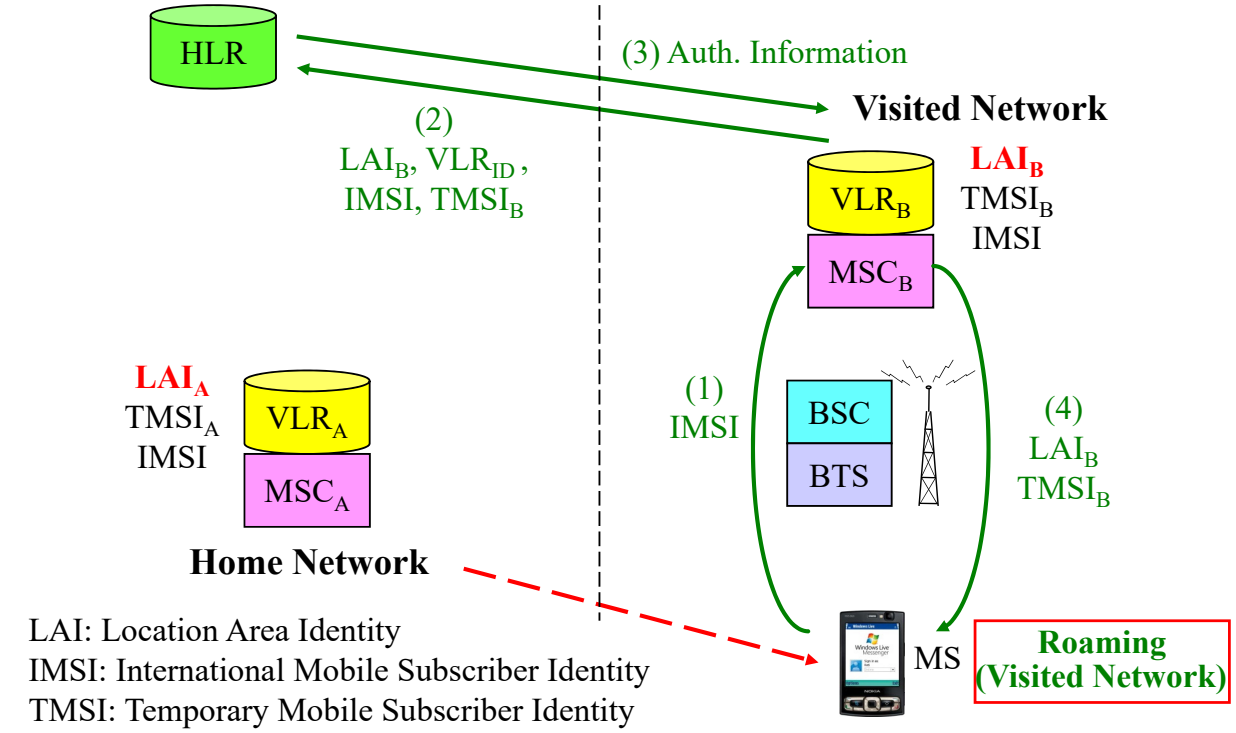


Ch 4. Channel Assignment Schemes

- Allocate the available channels to all cells in order to meet the requirements of traffic load and received signal quality for each cell
  - Maximize the offered traffic load
  - Minimize the co-channel interference



Ch 4. Authentication and Roaming



LAI: Location Area Identity
IMSI: International Mobile Subscriber Identity
TMSI: Temporary Mobile Subscriber Identity