Wireless Communications

EENG 5820

Lecture 8

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Today

- FDMA
- TDMA
- CDMA

9.1 Introduction

- **Duplexing**
  - A two-family house
  - To talk and listen simultaneously
  - Simplex, half-duplex, and full duplex

- **FDD**
  - Each user has two distinct bands of frequencies
  - Uplink/Downlink, forward/reverse channel
- **TDD**
  - Each user are allowed to access the channel in assigned *time slots*
  - Each duplex channel has both forward and reverse time slot

9.1 Introduction

- **Duplexing (cont.)**

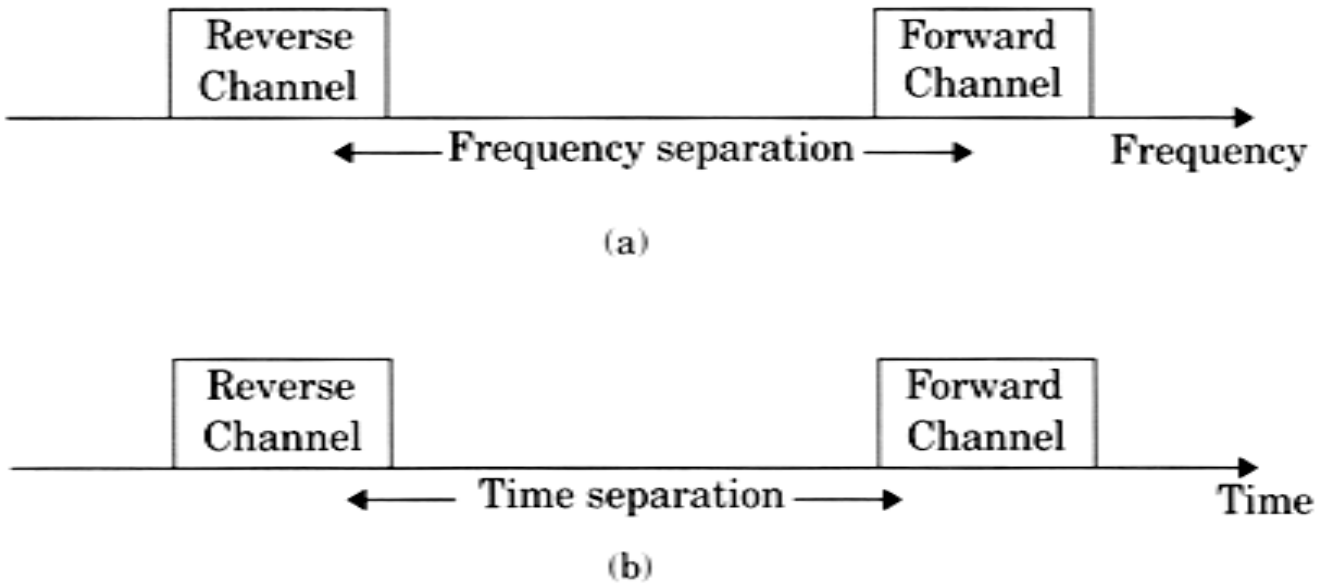


Figure 9.1 (a) FDD provides two simplex channels at the same time; (b) TDD provides two simplex time slots on the same frequency.

9.1 Introduction

Tradeoff between FDD and TDD

- **FDD**
  - Each transceiver simultaneously transmits and receives radio signals which can vary by more than 100 dB (GSM: TX 100 mW, RX -100dBw)
  - Inexpensive RF and oscillator technologies: frequency separation design
- **TDD**
  - Time latency
  - Cordless phone or short range applications
  - More effective for fixed wireless access where propagation delays do not vary in time

9.1 Introduction

9.1.1 Introduction to Multiple Access

- **FDMA, TDMA, and CDMA**
- **Narrowband systems**
  - Transmission bandwidth of a single channel is *less* than the coherence bandwidth of the channel
  - FDMA/FDD, TDMA/FDD, TDMA/TDD
- **Wideband systems**
  - Transmission bandwidth of a single channels is much *larger* than the coherence bandwidth of the channel
  - TDMA and CDMA with FDD or TDD
- **Packet Radio (PR) and Space Division Multiple Access (SDMA)**

Small-scale fading

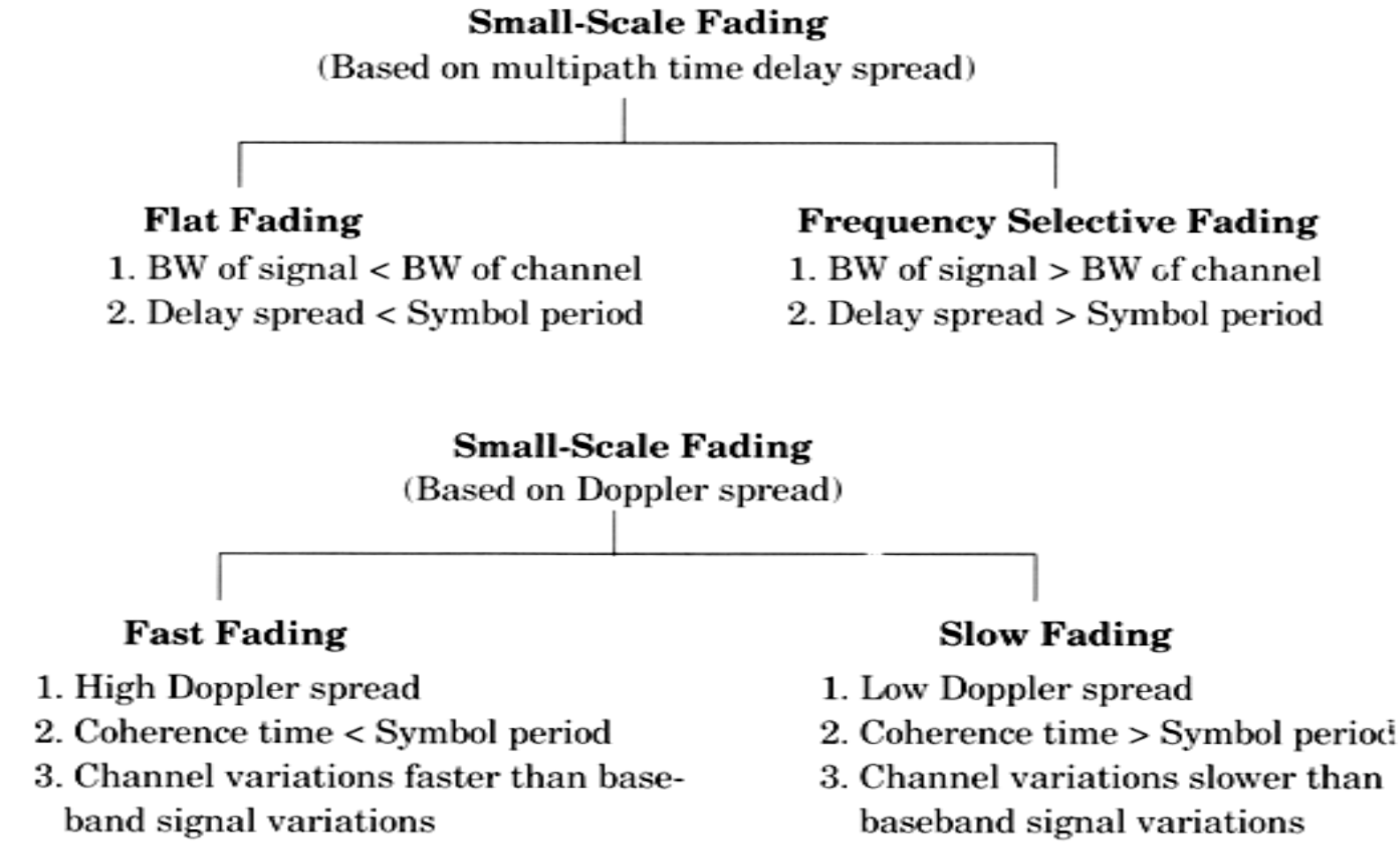


Figure 5.11 Types of small-scale fading.

9.1 Introduction to Multiple Access

Table 9.1 Multiple Access Techniques Used in Different Wireless Communication Systems

Cellular System	Multiple Access Technique
Advanced Mobile Phone System (AMPS)	FDMA/FDD
Global System for Mobile (GSM)	TDMA/FDD
US Digital Cellular (USDC)	TDMA/FDD
Pacific Digital Cellular (PDC)	TDMA/FDD
CT2 (Cordless Telephone)	FDMA/TDD
Digital European Cordless Telephone (DECT)	FDMA/TDD
US Narrowband Spread Spectrum (IS-95)	CDMA/FDD
W-CDMA (3GPP)	CDMA/FDD CDMA/TDD
cdma2000 (3GPP2)	CDMA/FDD CDMA/TDD

9.2 FDMA

- Each user is allocated a unique frequency band or channel

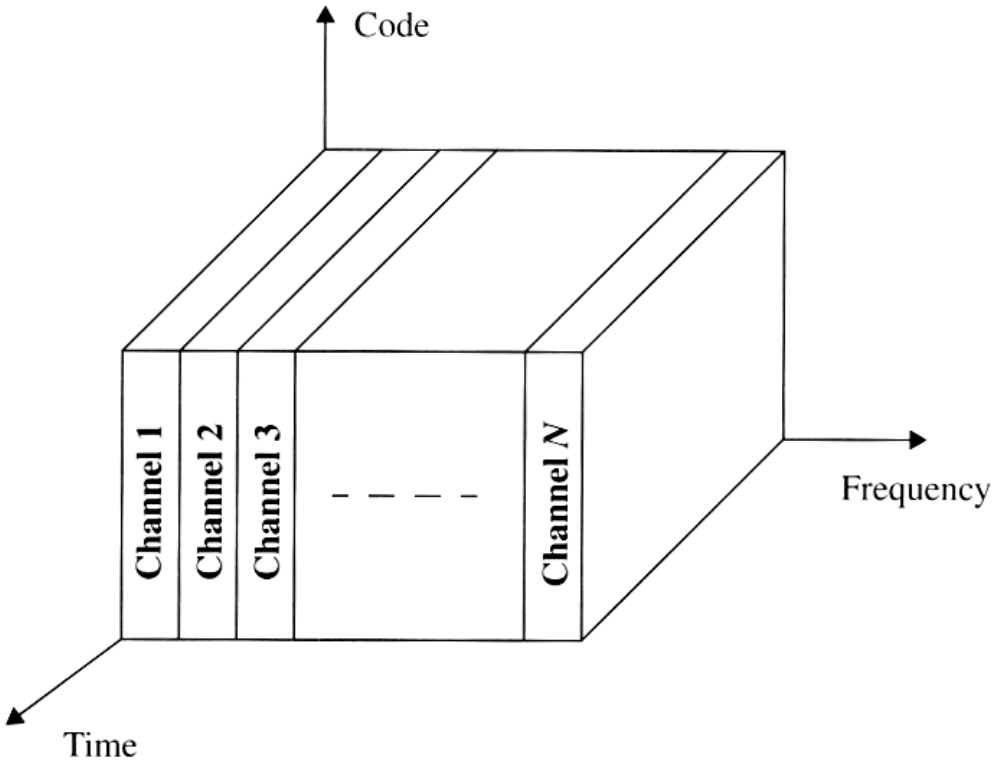


Figure 9.2 FDMA where different channels are assigned different frequency bands.

Features of FDMA

- If an FDMA channel is not in use, then it sits idle and cannot be used by other uses
- Narrow bandwidth (30 kHz in AMPS)
- Complexity of FDMA is lower compared TDMA
- Fewer bits are needed for overhead (synchronization and framing bits)
- Higher cell site system costs, bandpass filters to eliminate spurious radiation at the base station
- Nonlinear effects: signal spreading in frequency domain and generate *inter-modulation* frequencies

9.2 FDMA

- **Number of channels supported by FDMA**

$$N = \frac{B_t - 2B_{guard}}{B_c}$$

$B_t \rightarrow$ Total spectrum allocation

$B_{guard} \rightarrow$ Guard band

$B_c \rightarrow$ Channel bandwidth

Example

In US AMPS, each cellular operator is allocated 416 channels

$$B_t = 12.5\text{MHz}$$

$$B_{guard} = 10\text{kHz}$$

$$B_c = 30\text{kHz}$$

$$N = \frac{12.5\times10^3 - 2\times10}{30} = 416$$

9.3 TDMA

- Divide the radio spectrum into time slots, and in each slot only one user is allowed to either transmit or receive

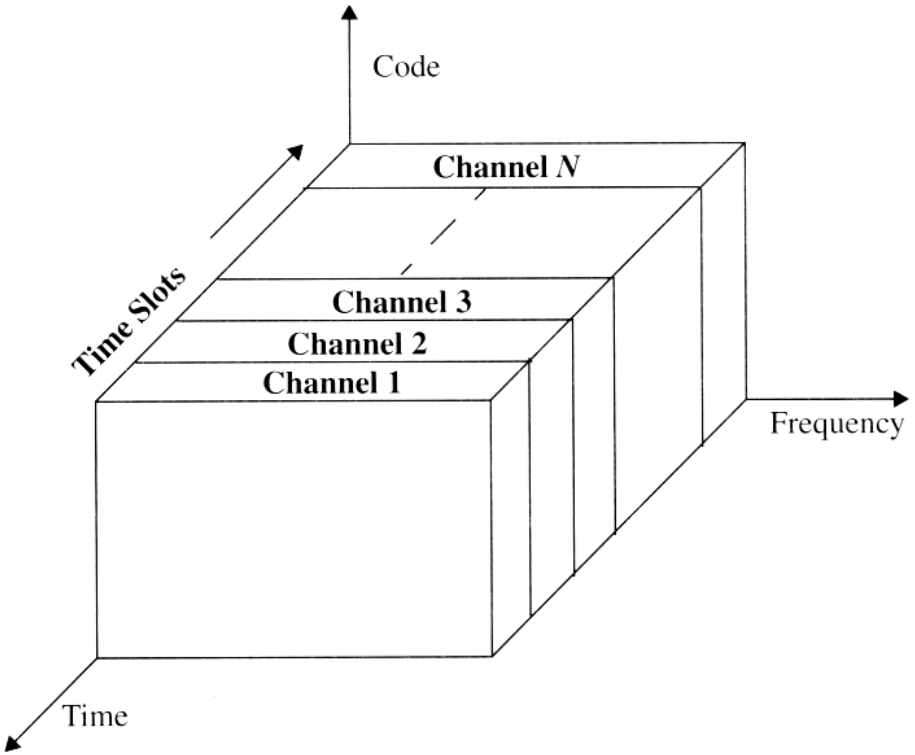


Figure 9.3 TDMA scheme where each channel occupies a cyclically repeating time slot.

9.3 TDMA

- Each user occupies a cyclically repeating time slot

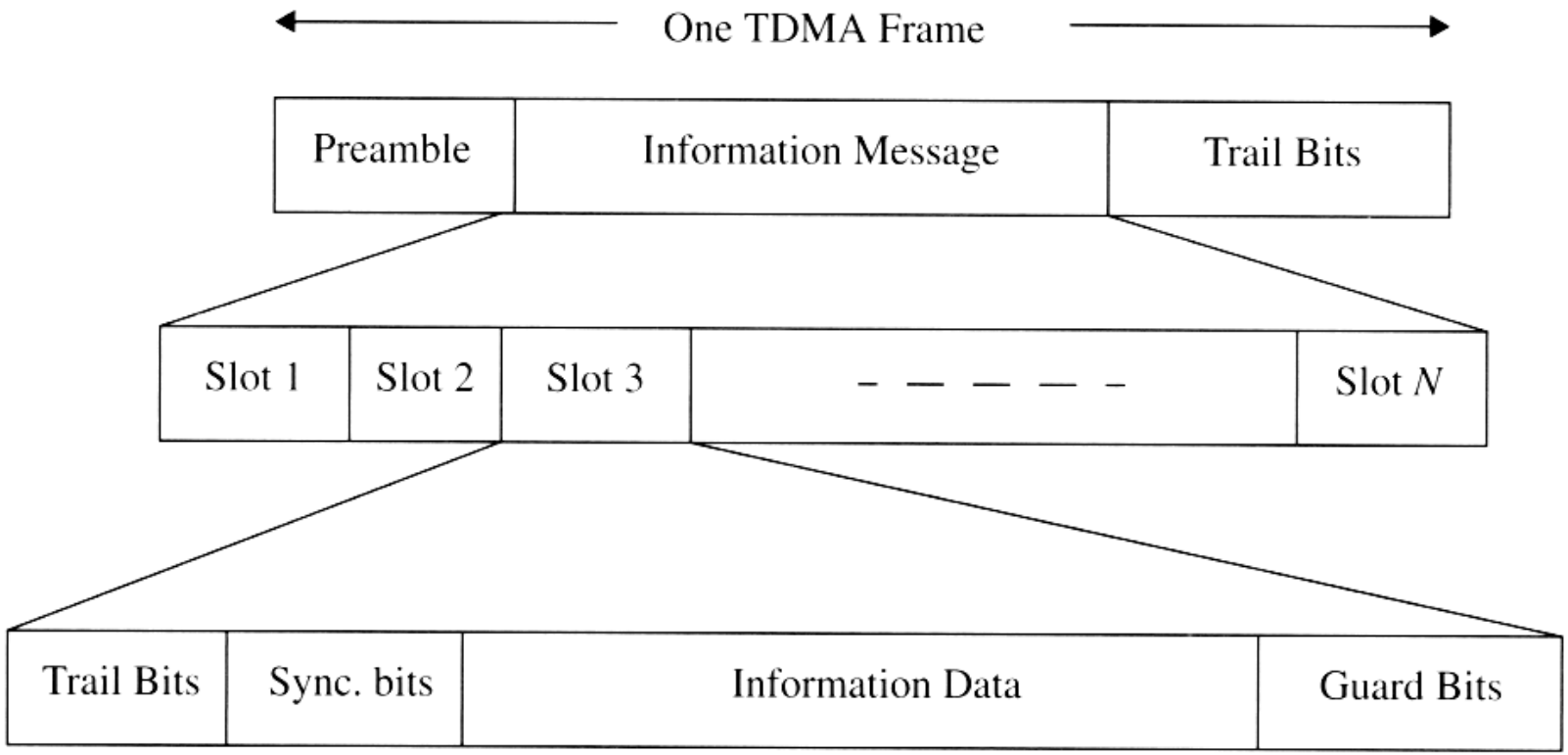


Figure 9.4 TDMA frame structure. The frame is cyclically repeated over time.

9.3 TDMA

Features

- Data transmission occurs in bursts, not continuous, which results in lower power consumption
- Simpler handoff since handset can listen on an idle slot (mobile assisted hand off MAHO)
- Adaptive equalization is needed since the data rate is high
- High synchronization overhead is required
- Bandwidth can be a supplied on demand to different users by concatenating or reassigning time slots based on priority

Efficiency of TDMA

$$b_{OH} = N_r b_r + N_t b_p + N_t b_g + N_r b_g$$

$N_r \rightarrow$ # of reference bursts per frame

$N_t \rightarrow$ # of traffice bursts per frame

$b_r \rightarrow$ # of overhead bits per reference burst

$b_p \rightarrow$ # of overhead bits per preamble in each slot

$b_g \rightarrow$ # of equivalent bits in each guard time interval

$$b_T = T_f R$$

$T_f \rightarrow$ Frame duration

$R \rightarrow$ channel bit rate

$$\eta_f = (1 - \frac{b_{OH}}{b_T}) \times 100\%$$

9.3 TDMA

Number of Channels in TDMA system

$$N = \frac{m(B_{tot} - B_{guard})}{B_c}$$

$m \rightarrow$ maximum number of TDMA users on each radio channel

$B_{tot} \rightarrow$ Total spectrum allocated

$B_{guard} \rightarrow$ Guard band allocated

$B_c \rightarrow$ Channel bandwidth

9.3 TDMA

Example

A GSM system has eight time slots per frame, each time slot has 156.25 bits, and data is transmitted at 270.833kbps, find

a) the time duration of a bit

b) The time duration of a slot

c) The time duration of a frame

d) How long must a user occupying a single time slot wait between two successive transmissions

$$\text{a) } T_b = \frac{1}{270.833\text{kbps}} = 3.692\mu\text{s}$$

$$\text{b) } T_{slot} = 156.25 \times T_b = 0.577\text{ms}$$

$$\text{c) } T_f = 8 \times T_{slot} = 4.615\text{ms}$$

$$\text{d) } 4.615\text{ms}$$

9.4 Spread Spectrum Multiple Access

- SSMA uses signals which have a transmission bandwidth that is several orders of magnitude greater than the minimum required RF bandwidth (IS95, 1.25MHz)
- Frequency Hopped Multiple Access (FH)
- Direct Sequence Multiple Access (DS), also called Coded Division Multiple Access (CDMA)

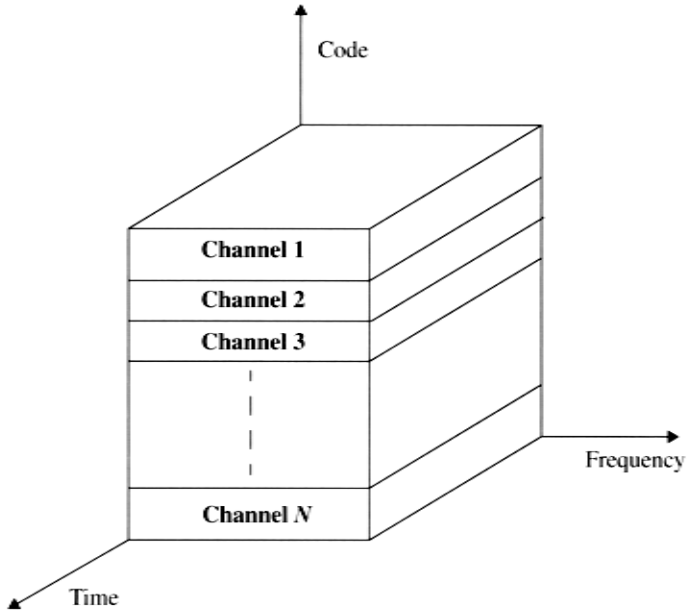


Figure 9.5 Spread spectrum multiple access in which each channel is assigned a unique PN code which is orthogonal or approximately orthogonal to PN codes used by other users.

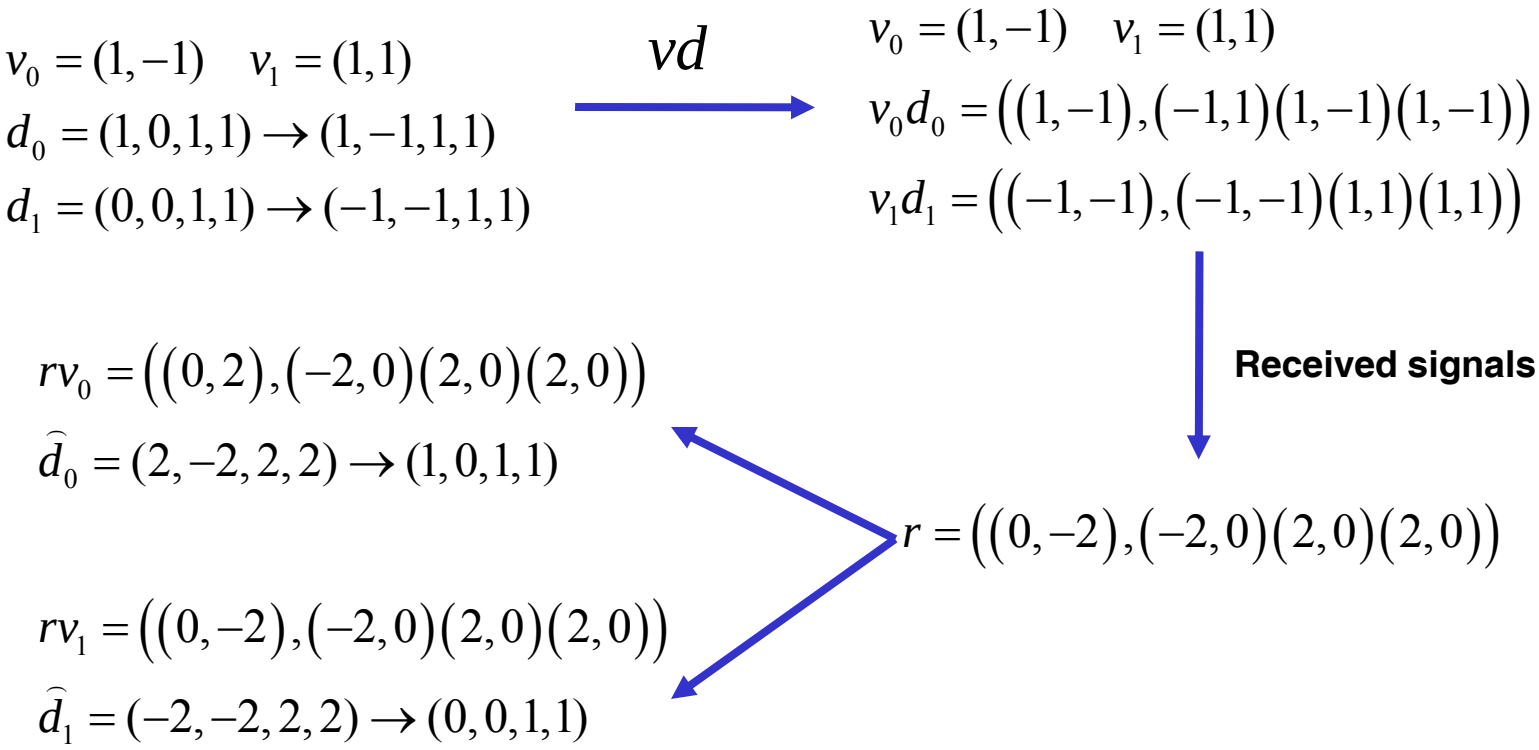
9.4 Spread Spectrum Multiple Access

9.4.1 FHMA

- **Carrier frequencies of the individual users are varied in a pseudorandom fashion within a wideband channel**
- **In the FH receiver, a locally generated PN code is used to synchronize the receiver's instantaneous frequency with that of the transmitter**
- **Fast/slow frequency hopping: rate of change of the carrier frequency v.s. symbol rate**

9.4 Spread Spectrum Multiple Access

- **CDMA: Each user has its own pseudorandom codeword which is approximately orthogonal to all other codewords**



9.4 Spread Spectrum Multiple Access

Features

- Soft capacity limit. Increasing the # of users raises the noise floor
- Multipath fading may be substantially reduced because the signal is spread over a large spectrum
- Channel data rates are very high, multipath is delayed by more than a chip (noise), RAKE reciever
- Soft handoff since CDMA uses co-channel cells, MSC choose the best version of the signals
- Near-far problem, power control

9.5 Space Division Multiple Access

- SDMA controls the radiated energy for each user in space
- Reverse link presents the most difficulty in cellular systems

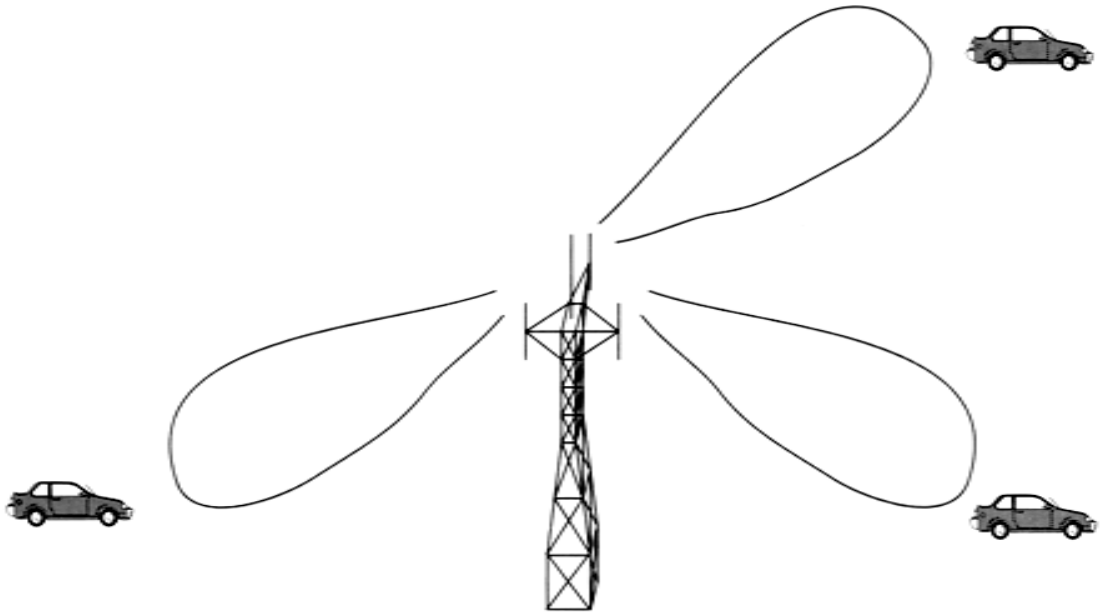


Figure 9.8 A spatially filtered base station antenna serving different users by using spot beams.

Homework

- 9.4(a, b), 9.7, 9.10, 9.12, 9.13