Chapter 7
Multiple Division Techniques for Traffic Channels (7.1~7.2)

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Outline

- 7.1 Introduction
- 7.2 Concepts and Models for Multiple Divisions
  - Frequency Division Multiple Access (FDMA)
  - Time Division Multiple Access (TDMA)
  - Code Division Multiple Access (CDMA)
  - Orthogonal Frequency Division Multiplexing (OFDM)
  - Space Division Multiple Access (SDMA)

7.1 Introduction

- To support many users in a wireless system, many traffic channels need to be available.
- Three basic ways to have many channels within an allocated bandwidth
  - FDMA (Freq. Division Multiple Access)
  - TDMA (Time Division Multiple Access)
  - CDMA (Code Division Multiple Access)
- Two other variants
  - OFDMA (Orthogonal Freq. Division Multiple Access)
  - SDMA (Space Division Multiple Access)

Basic Concepts

- Multiple access techniques are based on orthogonalization of signals
- A radio signal is a function of frequency, time and code as;

$$s(f,t,c) = s(f,t)c(t)$$

where $s(f,t)$ is the function of frequency and time and
$c(t)$ is the function of code.

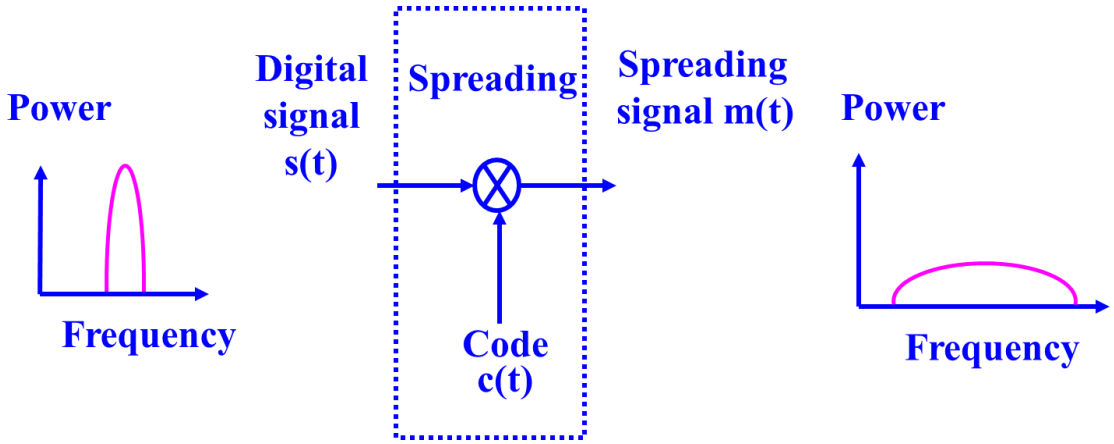
  - Use of different frequencies to transmit a signal: FDMA
  - Distinct time slot: TDMA
  - Different codes: CDMA

7.2.3 CDMA: Spread Spectrum

- Spread Spectrum:

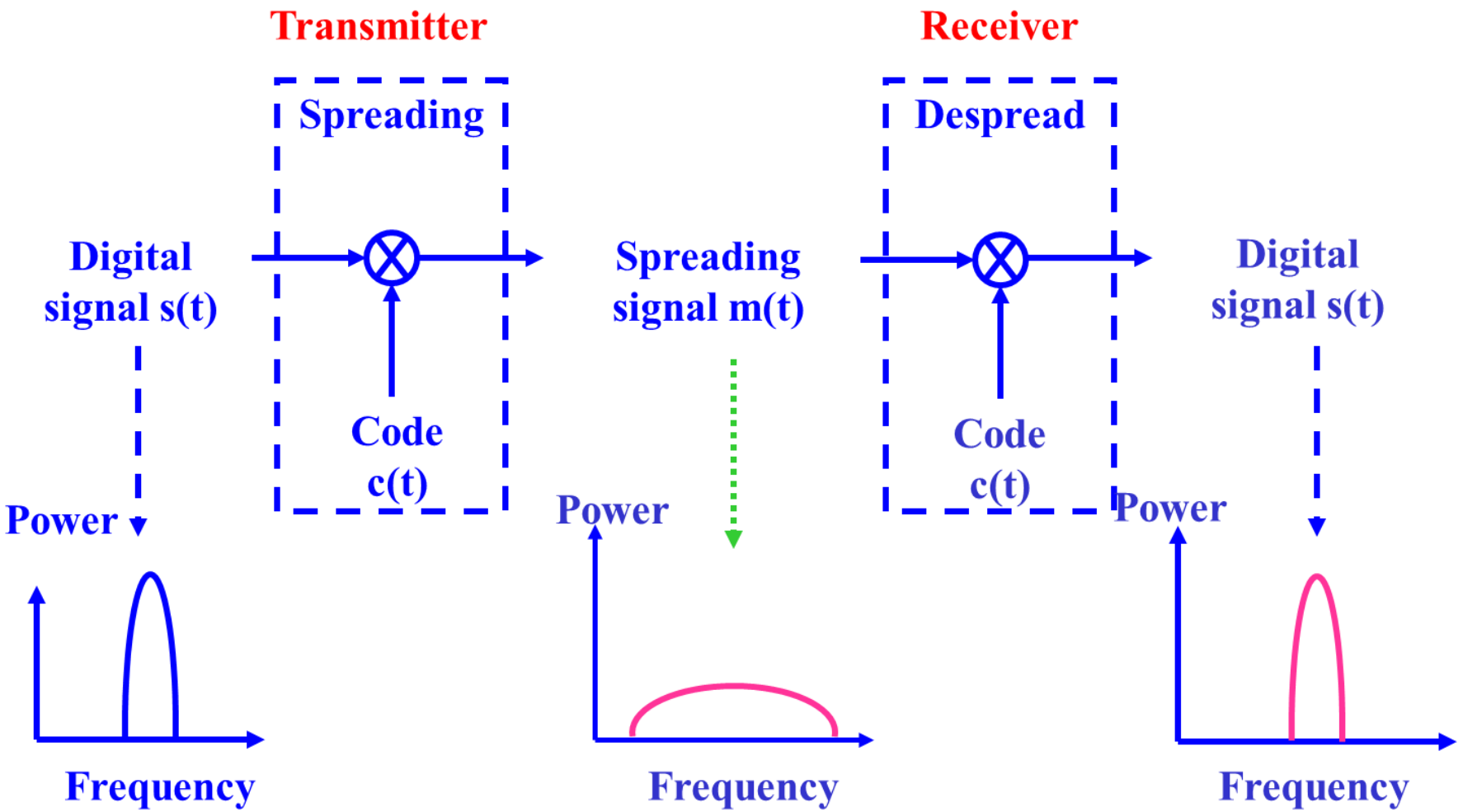
  A transmission technique wherein <u>data occupy a larger bandwidth than necessary</u>

$$m(t) = s(t) \otimes c(t)$$



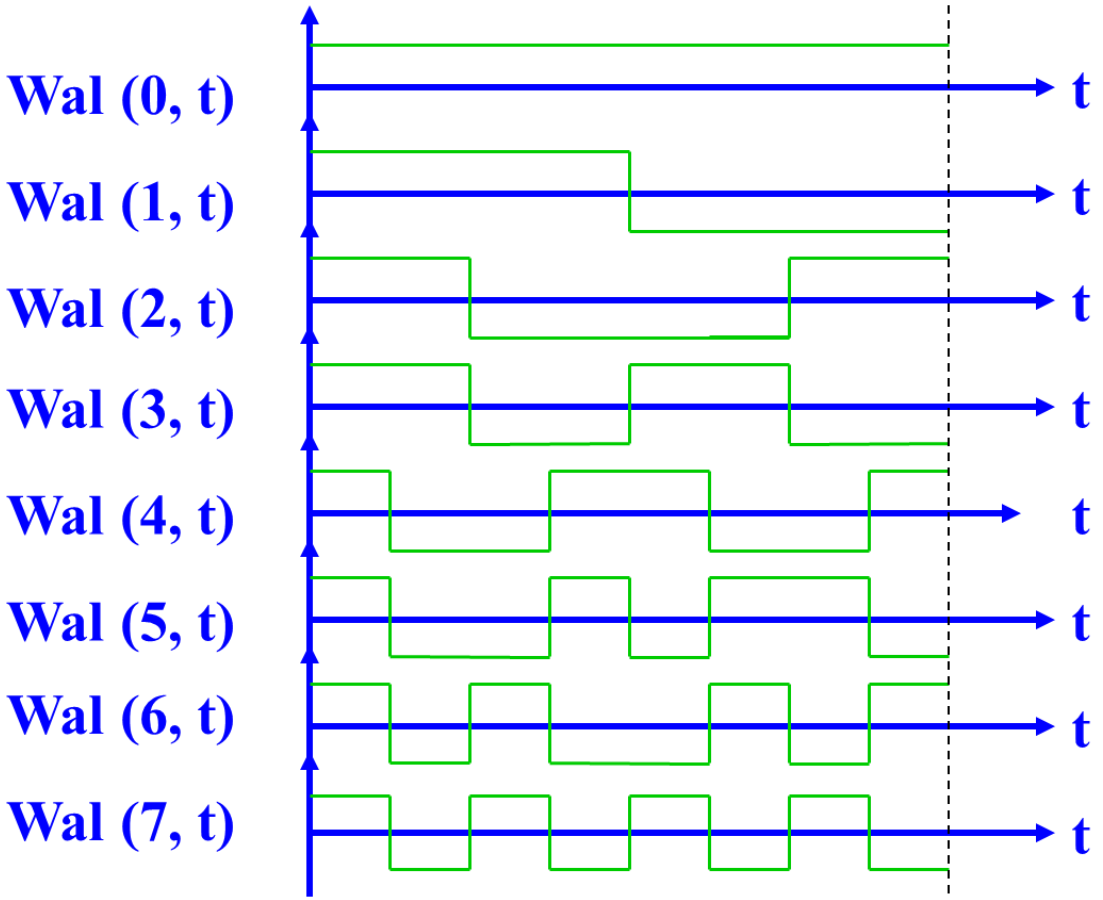
- Two types of spread spectrum systems
  - DSSS (Direct Sequence Spread Spectrum)
  - FHSS (Freq. Hopping Spread Spectrum)

Direct Seq. Spread Spectrum (DSSS)



Direct Seq. Spread Spectrum (DSSS)

- Orthogonal Codes (Walsh Codes)



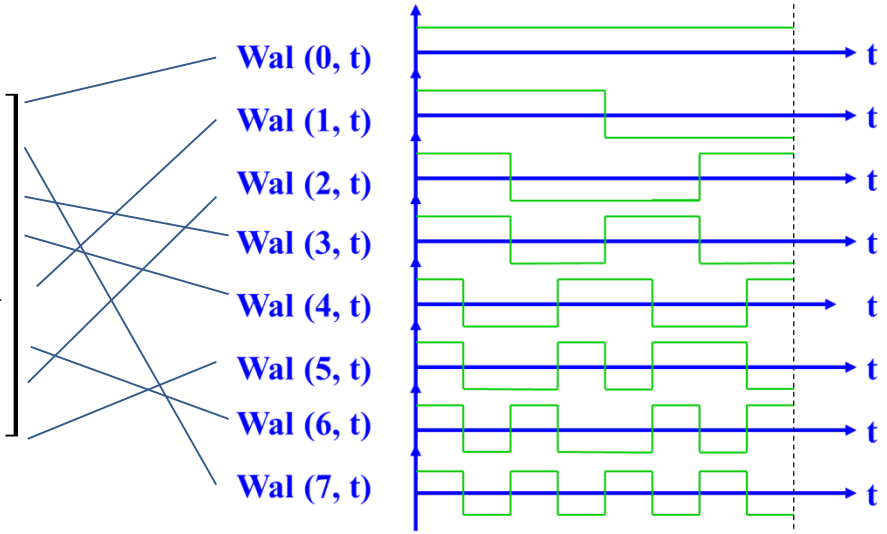
Direct Seq. Spread Spectrum (DSSS)

- Hadamard Matrix: H
  - $HH^T = nI_n$, ($I_n : n \times n$ identity matrix)
- Example
  - $H_1 = [1]$
  - $H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$
  - $H_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$
  - $H_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$

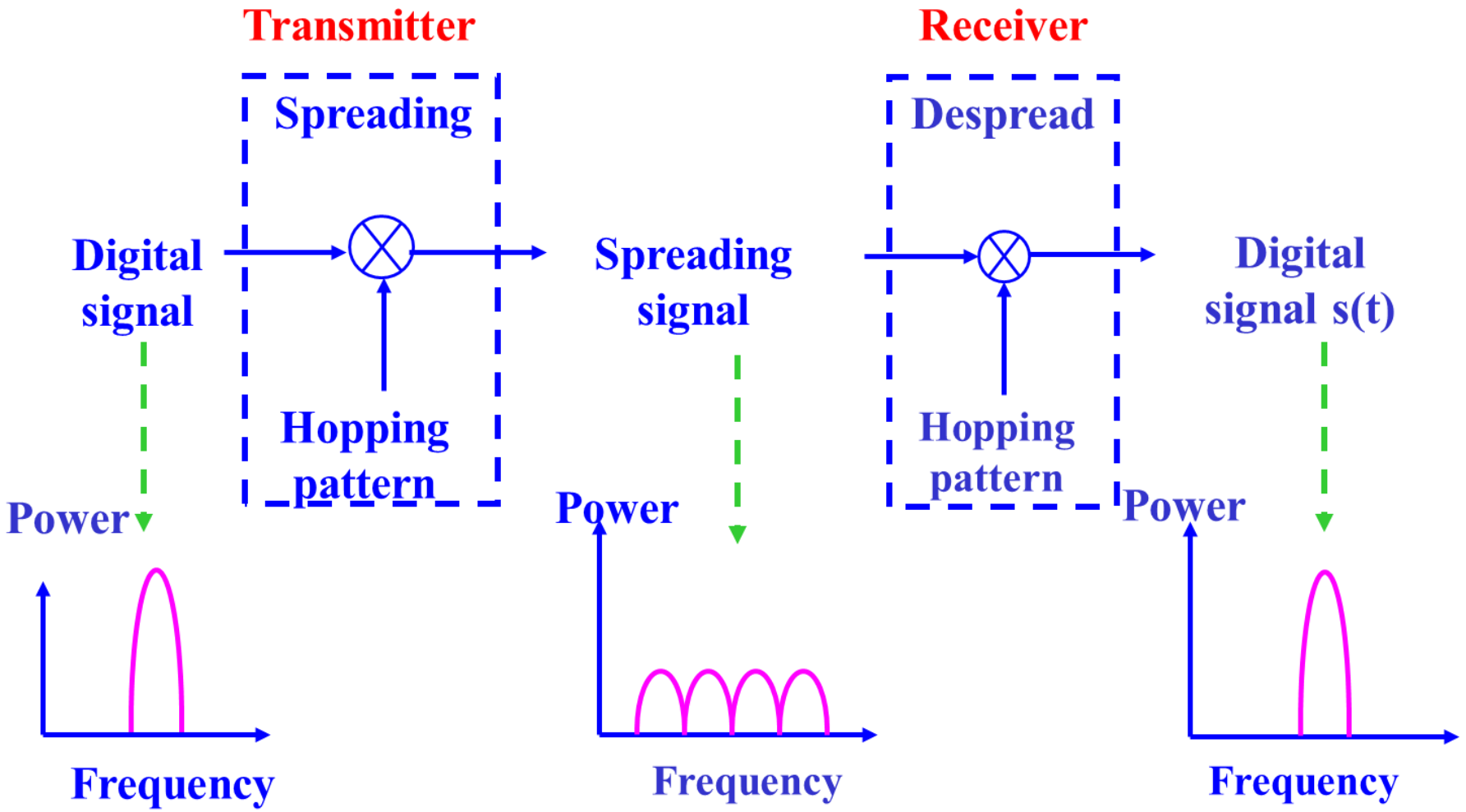
$$H_{2^k} = \begin{bmatrix} H_{2^{k-1}} & H_{2^{k-1}} \\ H_{2^{k-1}} & -H_{2^{k-1}} \end{bmatrix}$$

Direct Seq. Spread Spectrum (DSSS)

- $H_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$

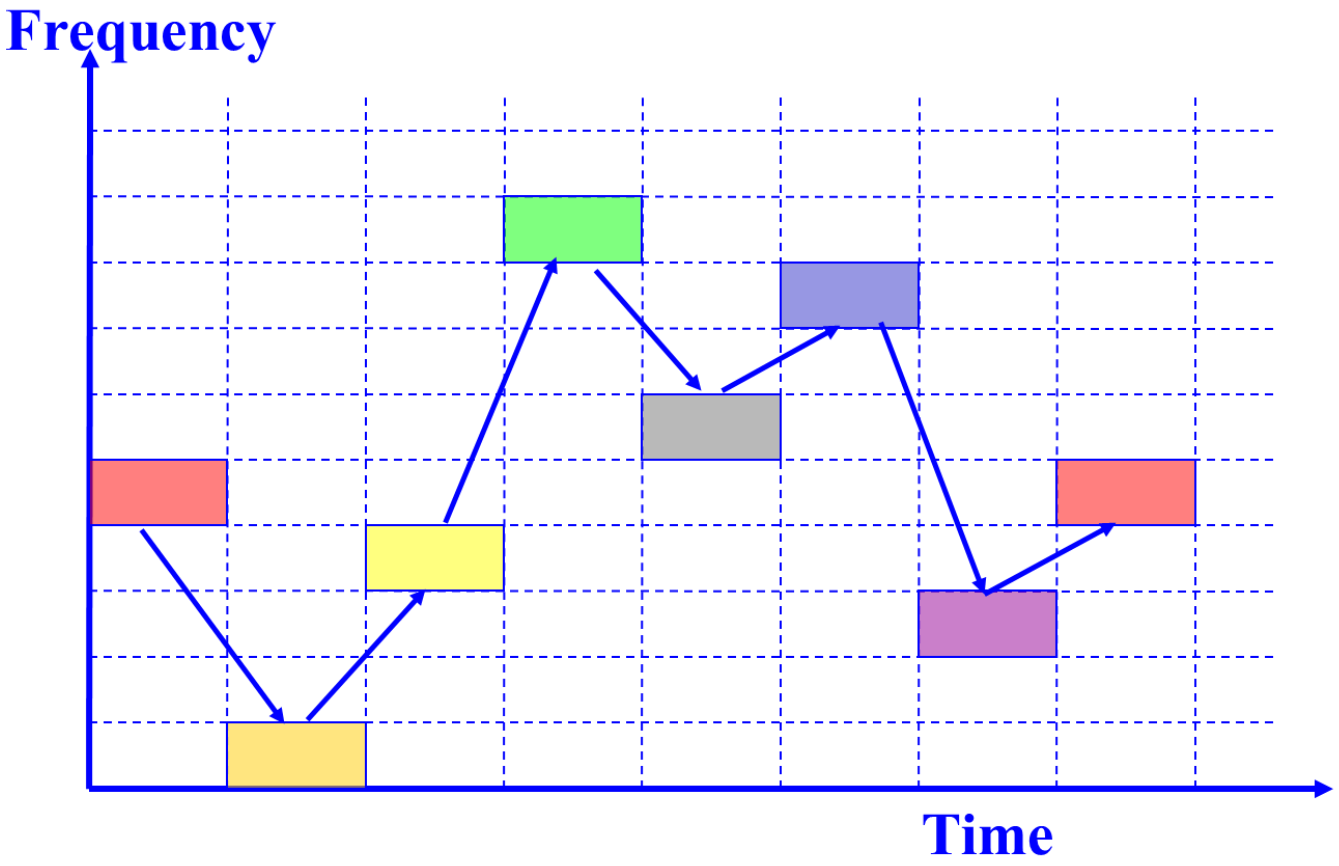


Freq. Hopping Spread Spectrum (FHSS)



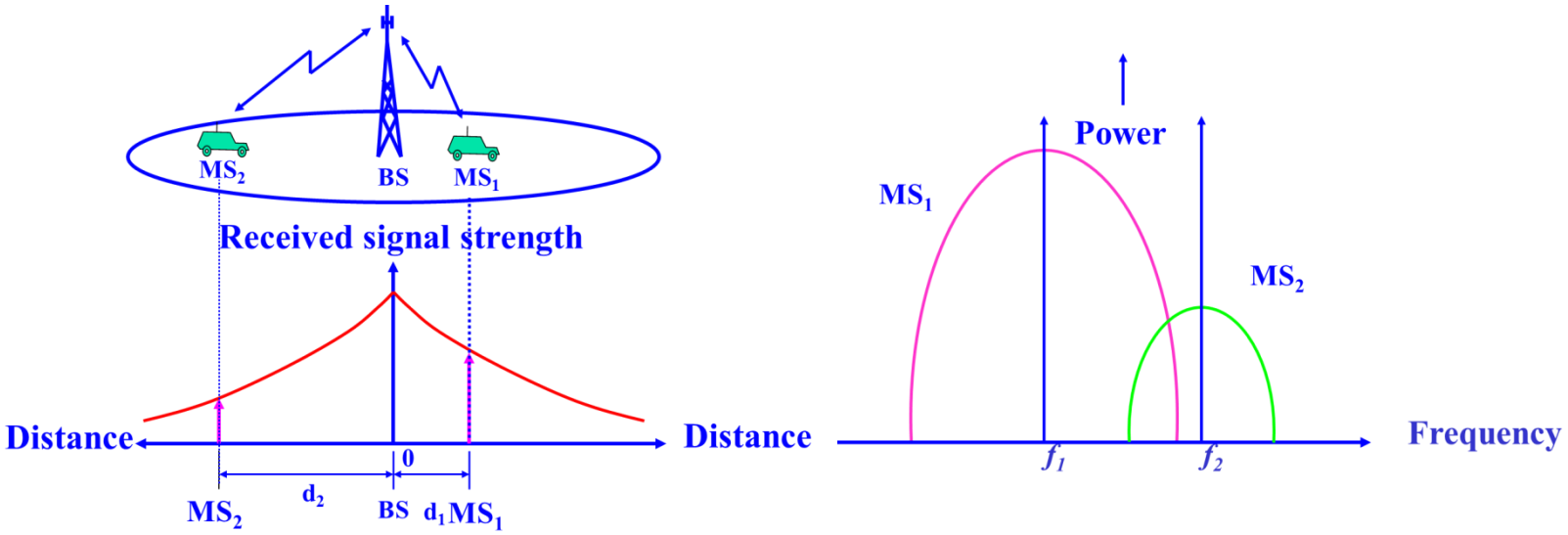
Freq. Hopping Spread Spectrum (FHSS)

- Frequency Hopping Pattern



Near-Far Problem

- Assumption: Tx. power of each MS to be the same.
- Rx signal level at the BS from the MS1 and MS2 are quite different due to the difference in the path lengths.
  - Out-of-band radiation of the signal from the MS1 interferes with the signal from the MS2 in the adjacent channel.
  - **Adjacent channel interference** becomes serious when the difference in the Rx signal strength is high.

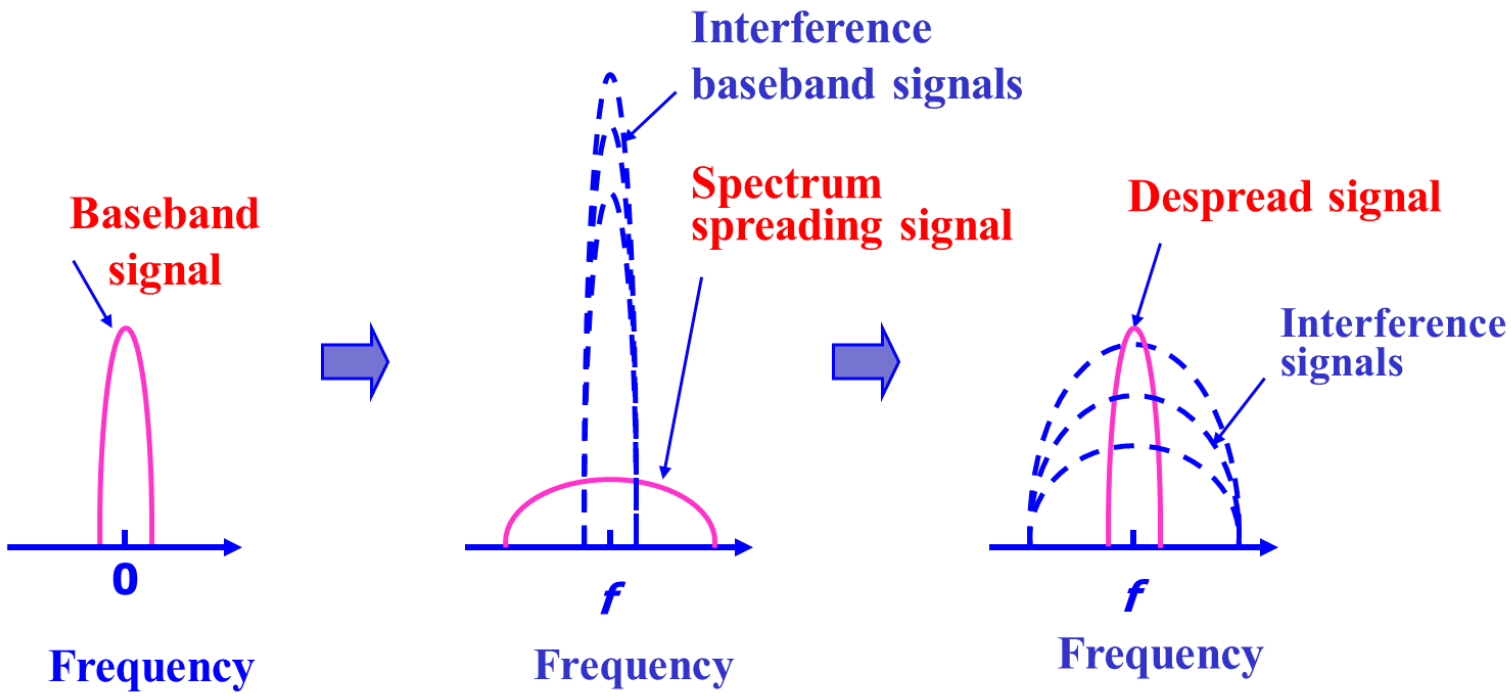


Near-Far Problem

- **For CDMA systems** where the spread spectrum signals are multiplexed on the same frequency using low crosscorrelation codes.

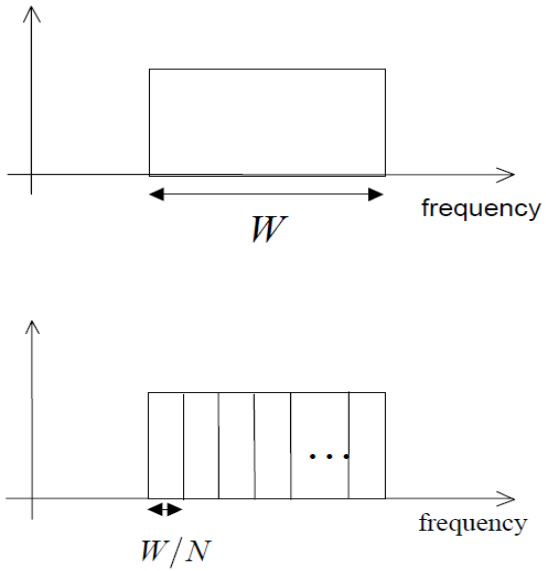
  ⇒ **The near-far problem becomes more important.**

- One simple solution ⇒ **"Power Control"**



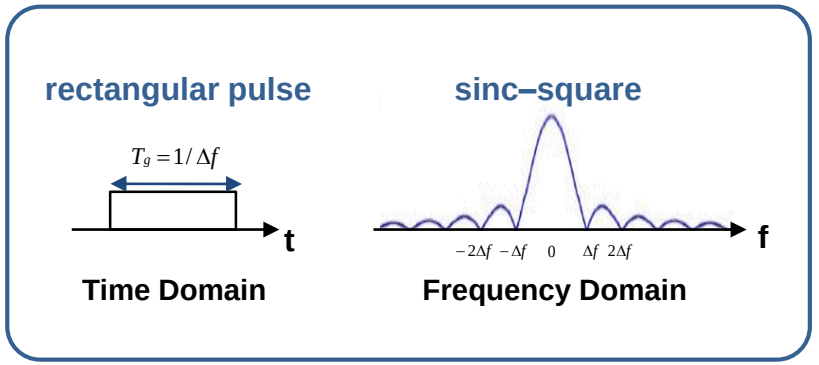
OFDMA (Orthogonal FDMA)

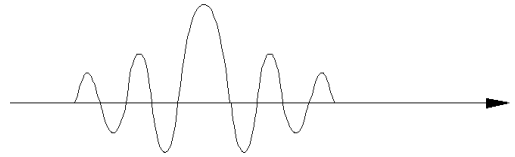
- OFDMA (Orthogonal Freq. Division Multiple Access)
  - Multiple access scheme based on OFDM (Orthogonal Freq. Division Multiplexing)
  - OFDM: a transmission scheme using multiple carriers (multi-carrier system)
- Single Carrier vs. Multicarrier
  - Single carrier system:
    - Signal representing each bit uses all of the available spectrum
  - Multicarrier system:
    - Available spectrum divided into many narrow bands
    - Data is divided into parallel data streams each transmitted on a separate band

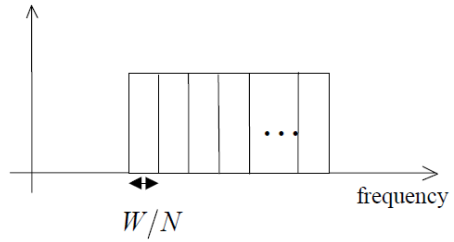


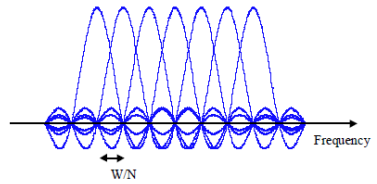
OFDMA (Orthogonal FDMA)

- OFDM is a multicarrier system
  - $\sin(x)/x$ spectra for subcarriers.
  - Available bandwidth is divided into very many narrow bands, called **subcarriers**.
    - About 2000-8000 for digital TV
    - 1000~2000 for wireless systems
  - Data is transmitted in parallel on these bands (or subcarriers) which are orthogonal with each other.
- Narrow band in freq. domain
  ⇒ Longer symbol duration in time domain.
  ⇒ less ISI(Inter-Symbol Interference) in multipath fading channels.



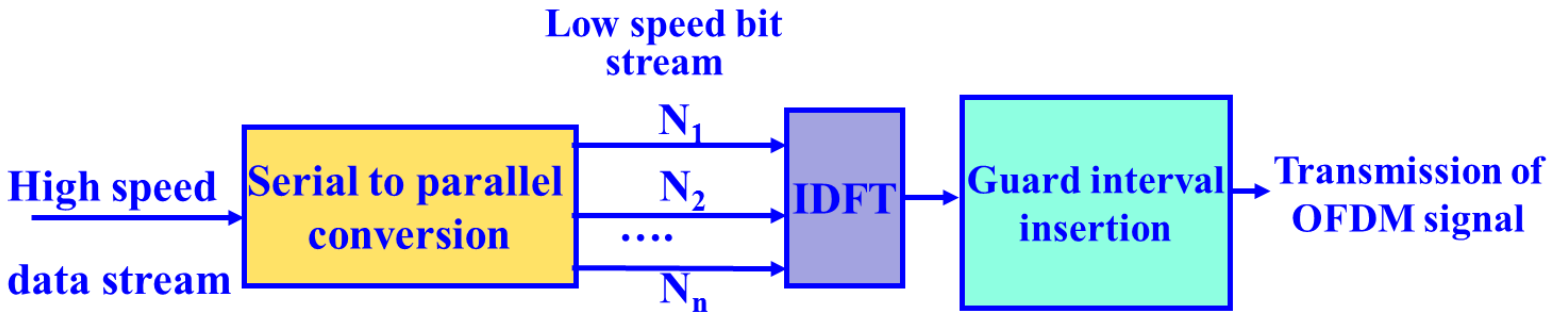




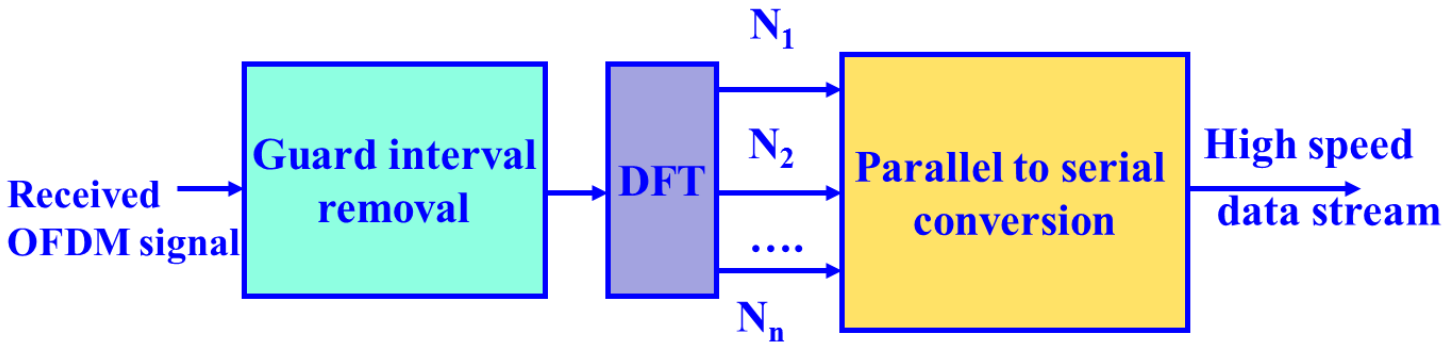


OFDMA (Orthogonal FDMA)

- Modulation and Demodulation in OFDM



Modulation operation at the OFDM transmitter



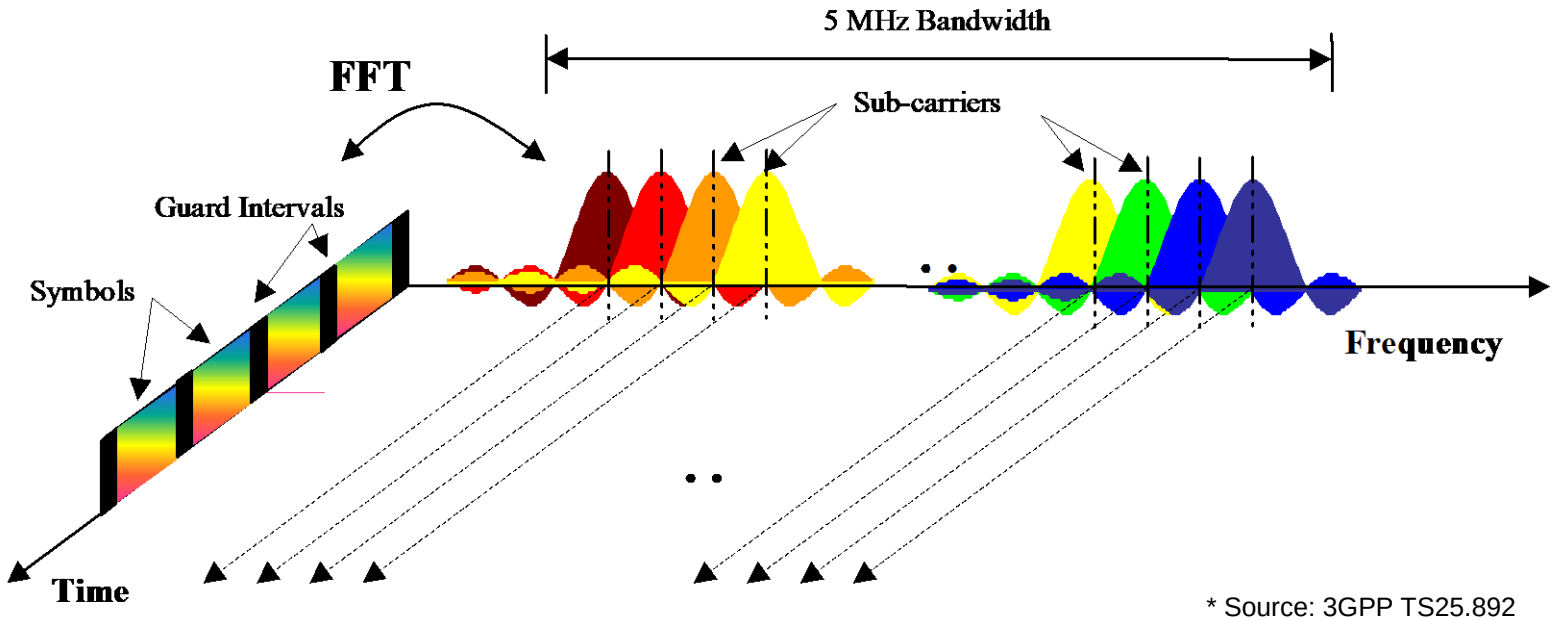
Demodulation steps at the OFDM receiver

OFDMA (Orthogonal FDMA)

- Using OFDM in wireless systems ⇒ Recent
  - Due to low cost for digital signal processing
- ETSI considered adopting OFDM for GSM in 1980's
  - Too expensive to implement OFDM (by using FFT)
- 3GPP seriously considered OFDM for 3G UMTS in 1998
  - Still expensive
  - Chose CDMA based technology consequently
- OFDM & OFDAM are used for recent & next generation wireless systems
  - Mobile WiMAX, LTE, LTE-Advanced
  - IMT-Advanced

OFDMA (Orthogonal FDMA)

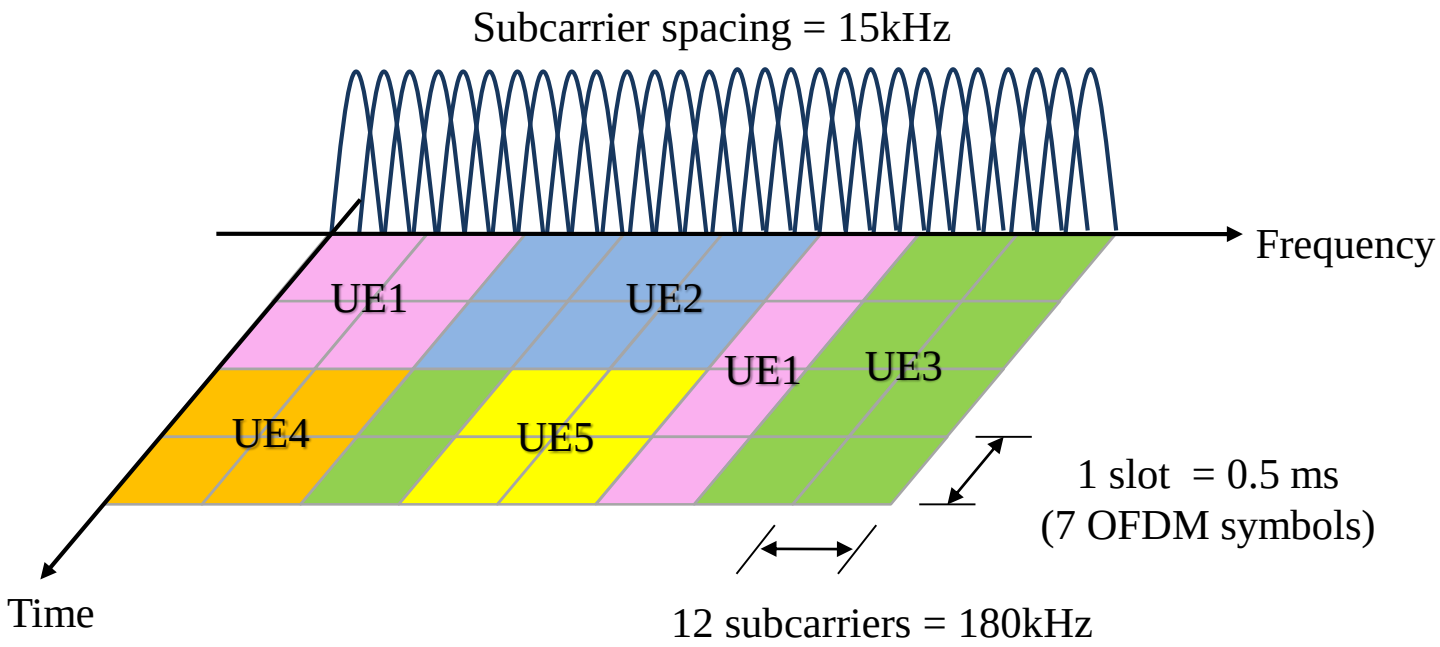
- OFDMA (Orthogonal Frequency Division Multiple Access)
  - Applied OFDM for multiple access to wireless systems
  - Using 2-dimensional resource (time & frequency)
  - Scheduling considering each user's channel condition and QoS (Quality of Service)



* Source: 3GPP TS25.892

OFDMA (Orthogonal FDMA)

- OFDMA in LTE
  - Resource Block (RB) : the minimum unit of resource allocation
    - 0.5 ms x 180 kHz (12 subcarriers)
    - Uses RB pair (1 ms) for real scheduling

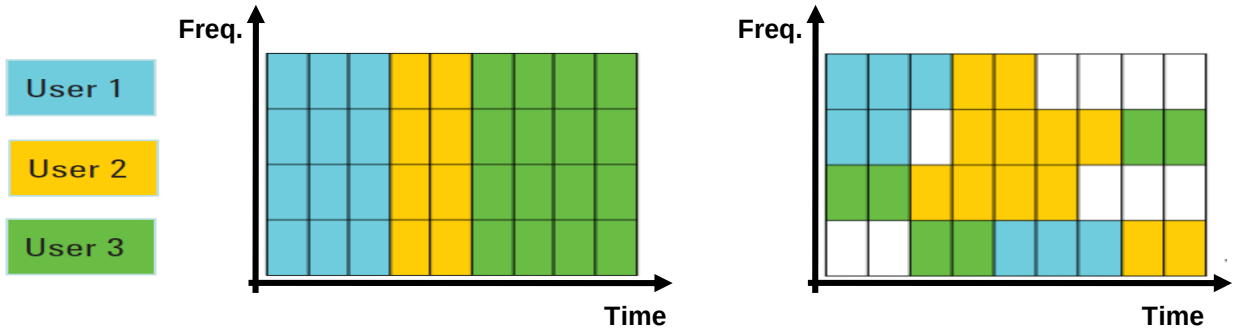


OFDMA (Orthogonal FDMA)

- CDMA vs. OFDMA

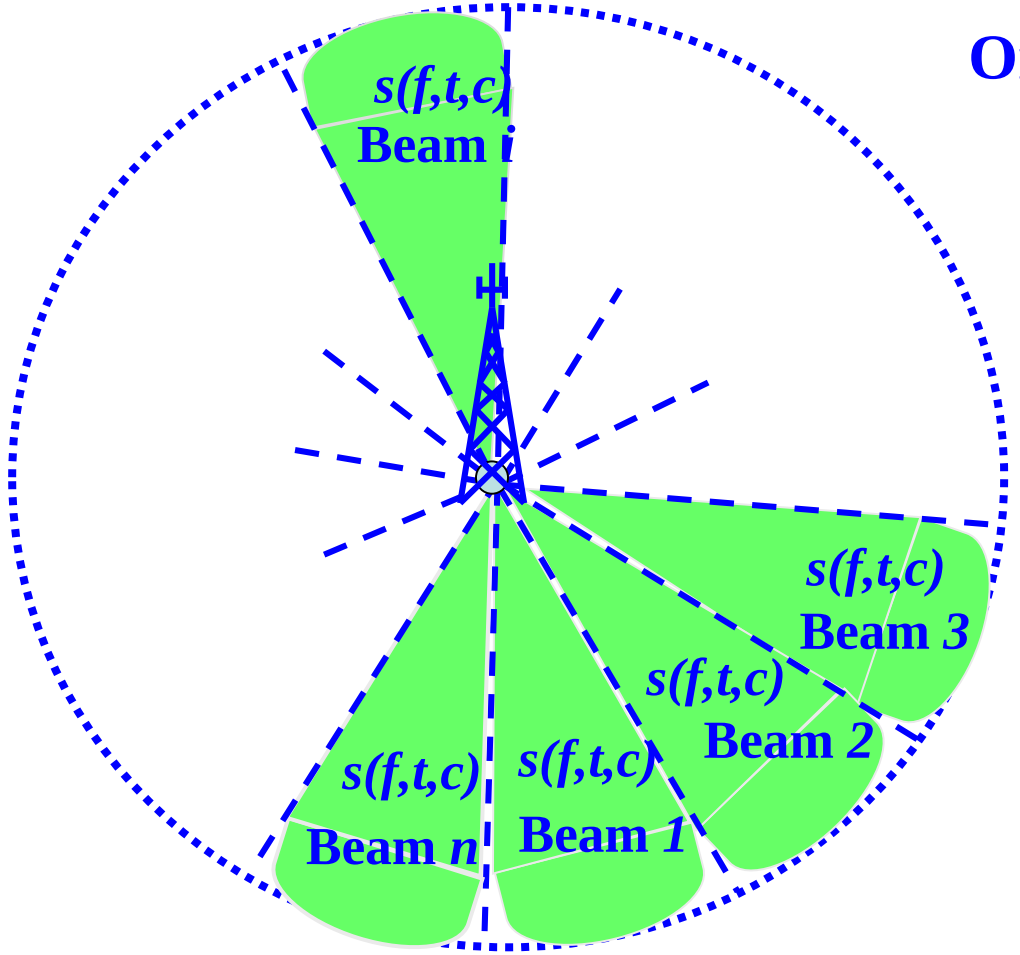
항 목	CDMA	OFDMA
Transmission bandwidth	Full system bandwidth	Variable up to full system bandwidth
Symbol period	Very short : inverse of the system bandwidth	Very long : Defined by subcarrier spacing and independent of system bandwidth
Separation of users	Orthogonal spreading codes	Frequency and time

- OFDM vs. OFDMA



7.2.5 SDMA (Spatial Division Multiple Access)

Space divided into spatially separate sectors

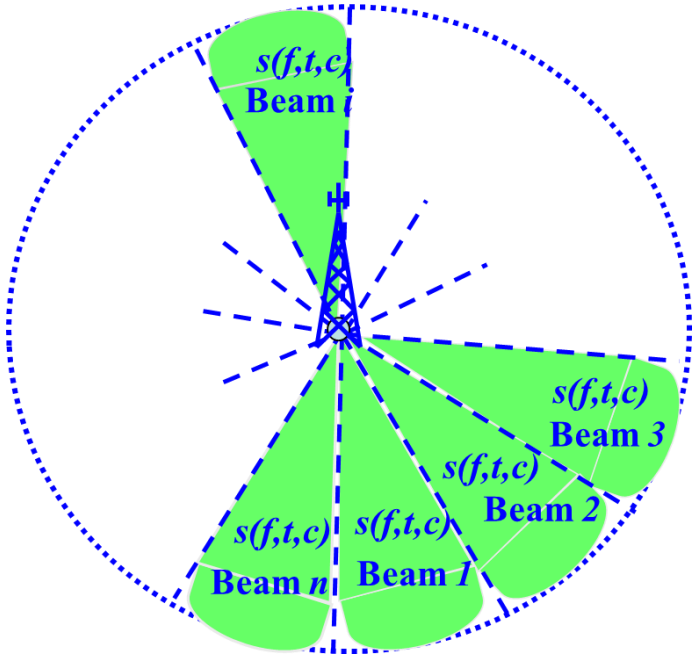


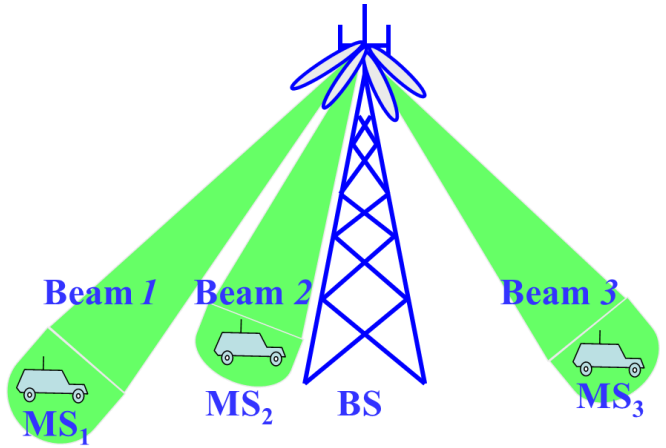
Omni-directional transmission

The concept of SDMA

7.2.5 SDMA (Spatial Division Multiple Access)

- SDMA
  - Focused transmission reduces the interference from undesired directions by placing minimum radiation patterns in the direction of interferers.
  - Reduces interference to other users in a cell
  - Enhances the quality of comm. link significantly ⇒ higher capacity.





The basic structure of a SDMA system.

Thank You !