Multicarrier Communication and Cognitive Radio

SDR Course seminar

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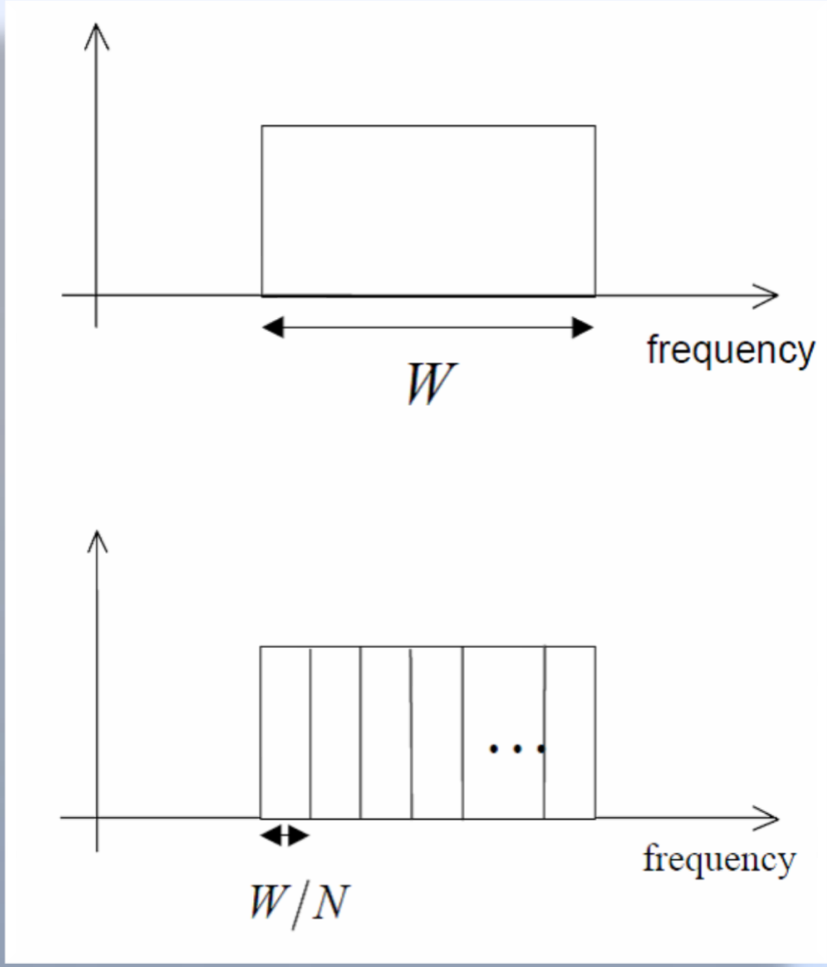
What Will We See?

- Introduction about mc and OFDM
- A Basic OFDM System Model
- OFDM-Based Cognitive Radio
- Merits
- Challenges
- Multi-band OFDM

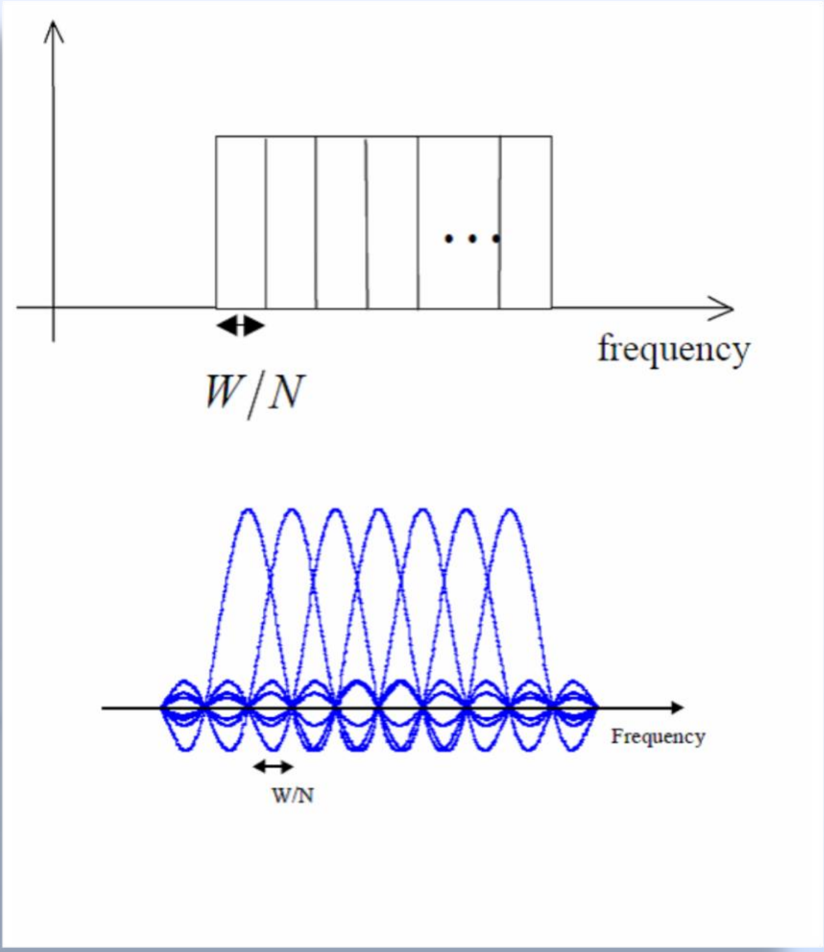
Multi-Carrier System

- 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



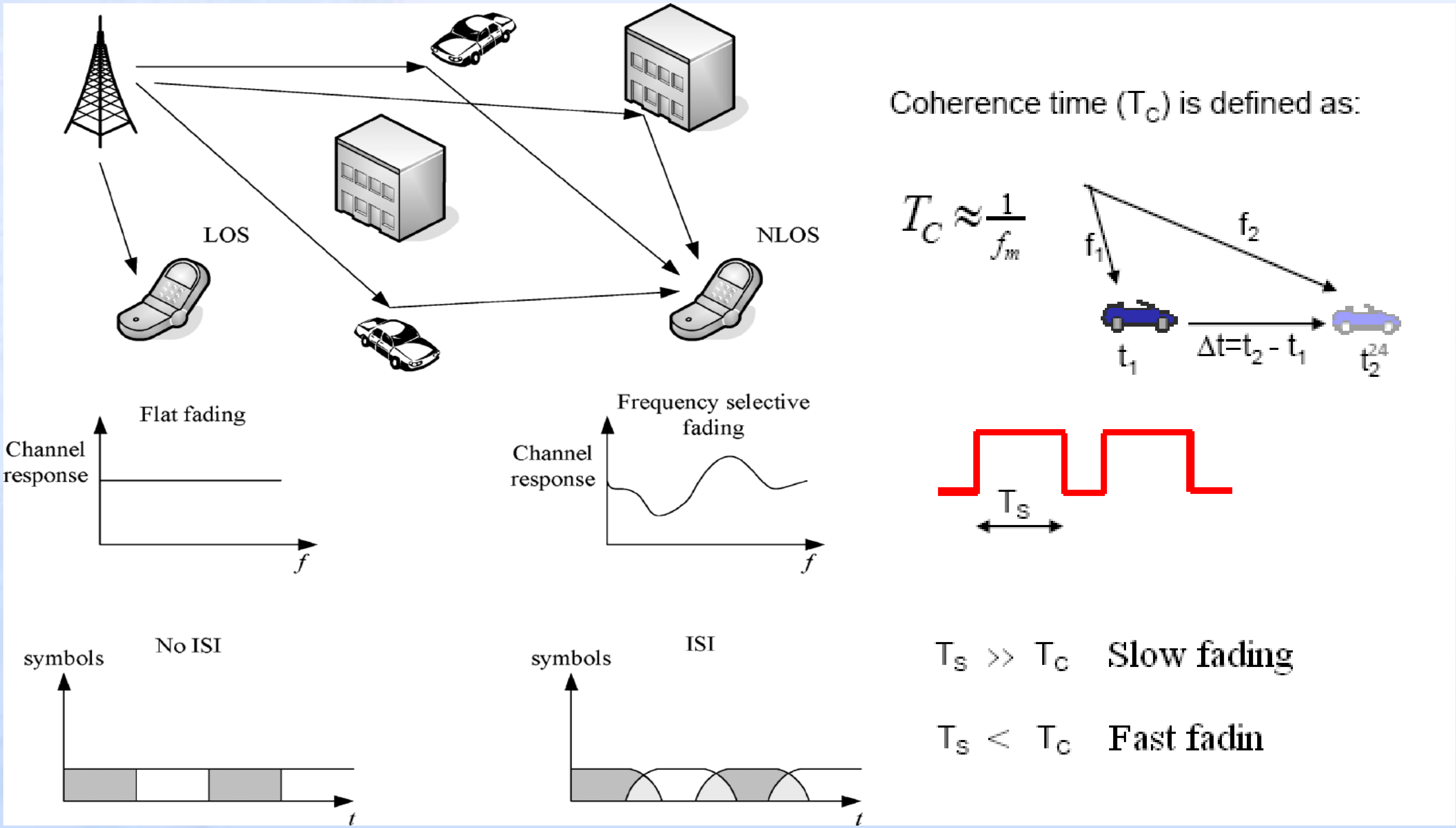
OFDM

- OFDM is a multicarrier system
  - uses discrete Fourier
  - Transform/Fast Fourier
  - Transform (DFT/FFT)
  - sin(x)/x spectra for subcarriers
- Available bandwidth is divided into very many narrow bands
- Data is transmitted in parallel on these bands



Small scale Fading

Multi-path fading | Doppler shift

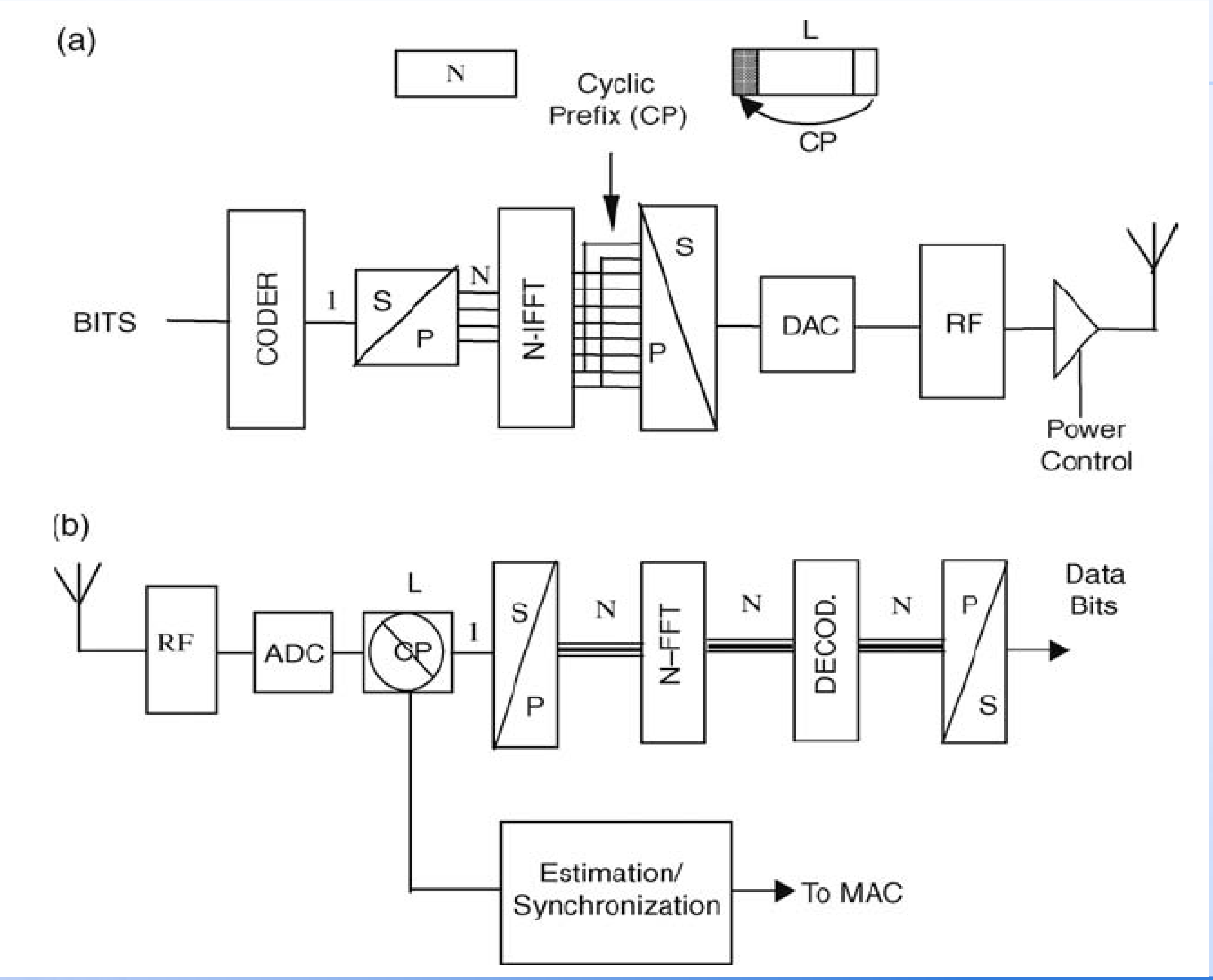


Solving the fading

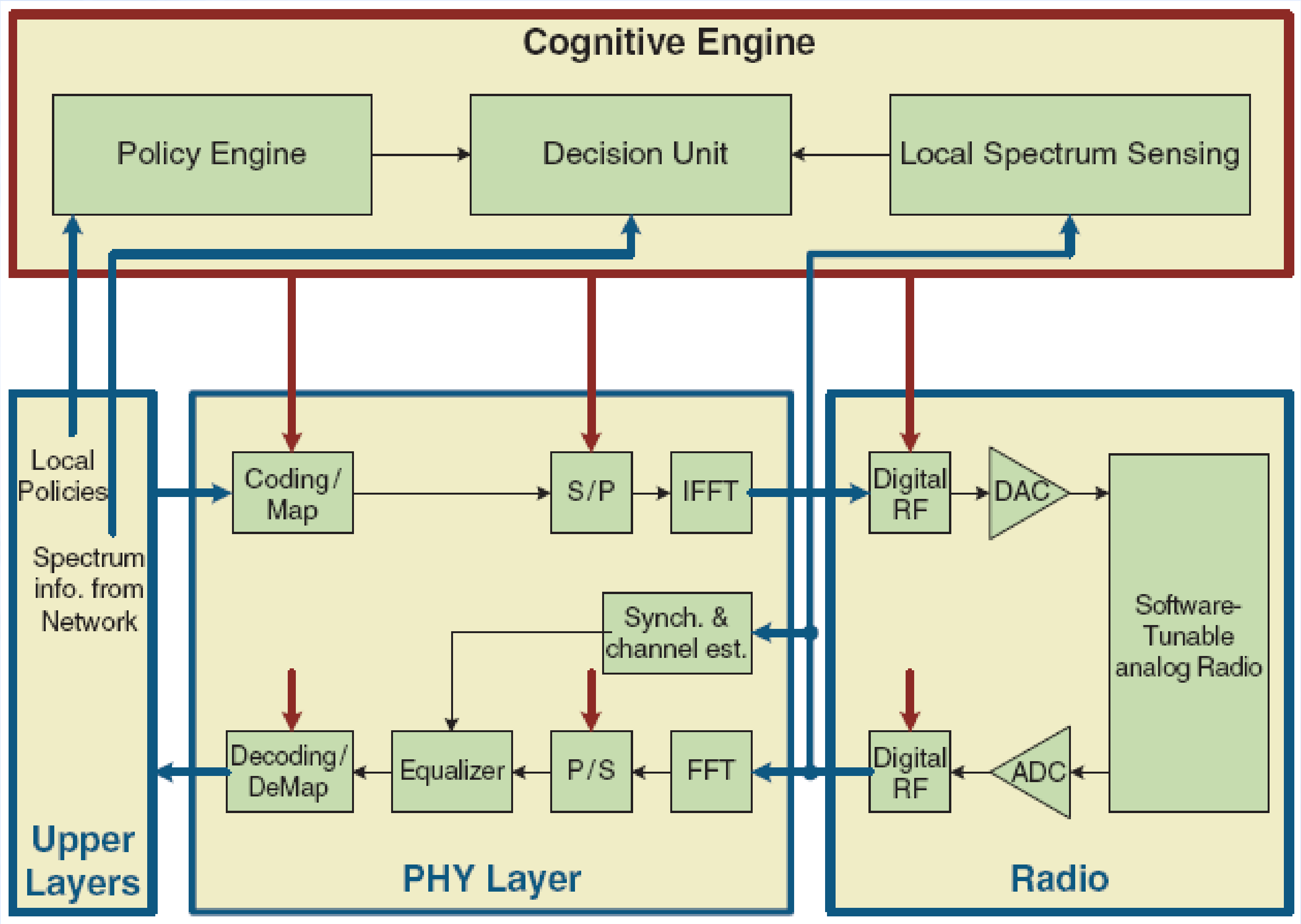
- Shorter than subcarrier bandwith from bandwith coherence (solving frequency selective fading)
- Longer than symbol period from time coherence (deal with fast fading)
- There exists an optimum value of these parameters that should be used to improve the system performance
- Interleaving (for burst error)

- Cyclic prefix
  - Trick to avoid residual ISI

A Basic OFDM System Model



OFDM-based Cognitive radio system block diagram



Why OFDM is a Good Fit for Cognitive Radio

- The underlying sensing and spectrum shaping capabilities together with flexibility and adaptiveness make OFDM probably the best candidate for cognitive radio systems.
- we present some of the requirements.

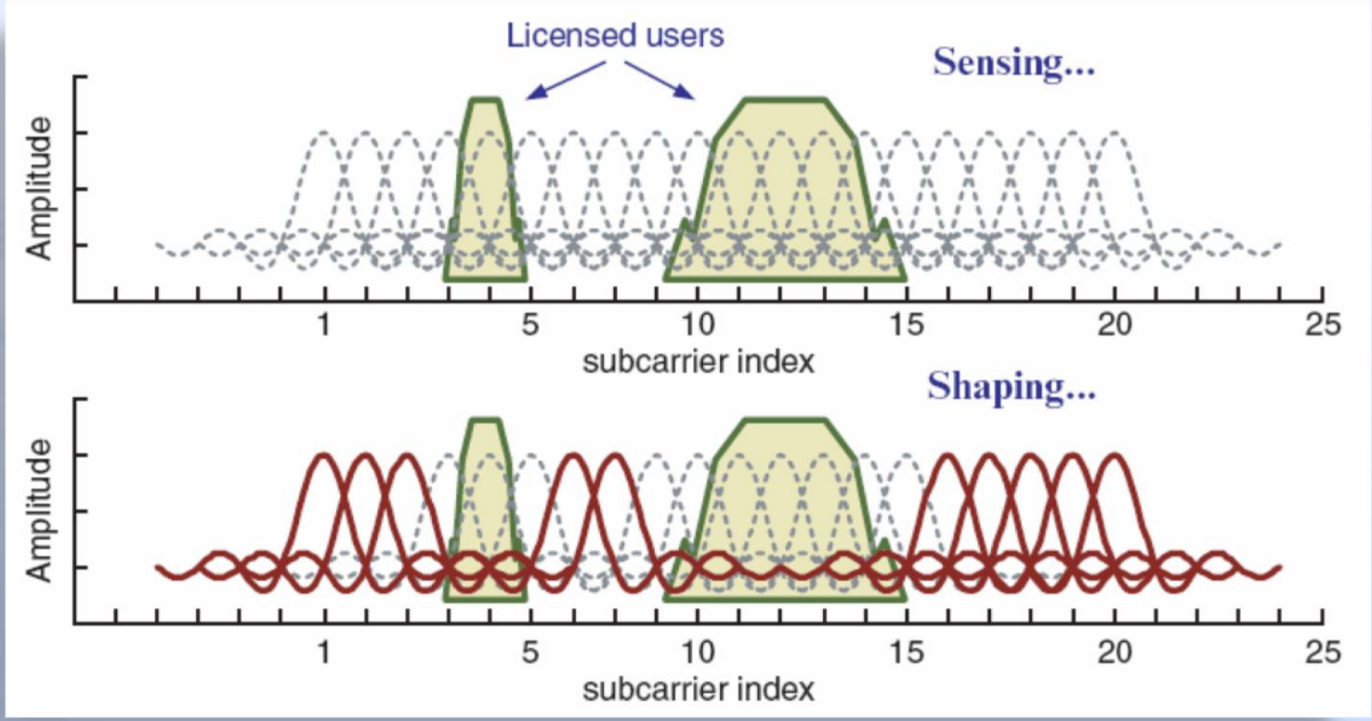
Merits

- **Spectrum Sensing and Awareness**
- Cognitive radio should be able:
- Scan the spectrum measure power availability, interference, and noise
- System should be able to identify different users, licensed or rental users

- The processing time is very important
- Inherent FFT operation of OFDM eases spectrum sensing in frequency domain
- conversion from time domain to frequency domain is achieved inherently by using DFT

Merits (2)

- **Spectrum Shaping**
- By disabling a set of subcarriers, the spectrum of OFDM signals can be adaptively shaped to fit into the required spectrum mask.



Merits (3)

- **Advanced Antenna Techniques**
  - Diversity combining, and space-time equalization is easy in smart antenna
  - Increases the capacity of MIMO–OFDM

Merits (4)

- **Multiple Accessing and Spectra Allocation**
- OFDM supports the well-known multiple accessing techniques (TDMA, FDMA, CSMA, MC–CDMA)
- In OFDMA, subcarriers are grouped into sets each of which is assigned to a different user
- assignment schemes:

randomized, or clustered

Merits (5)

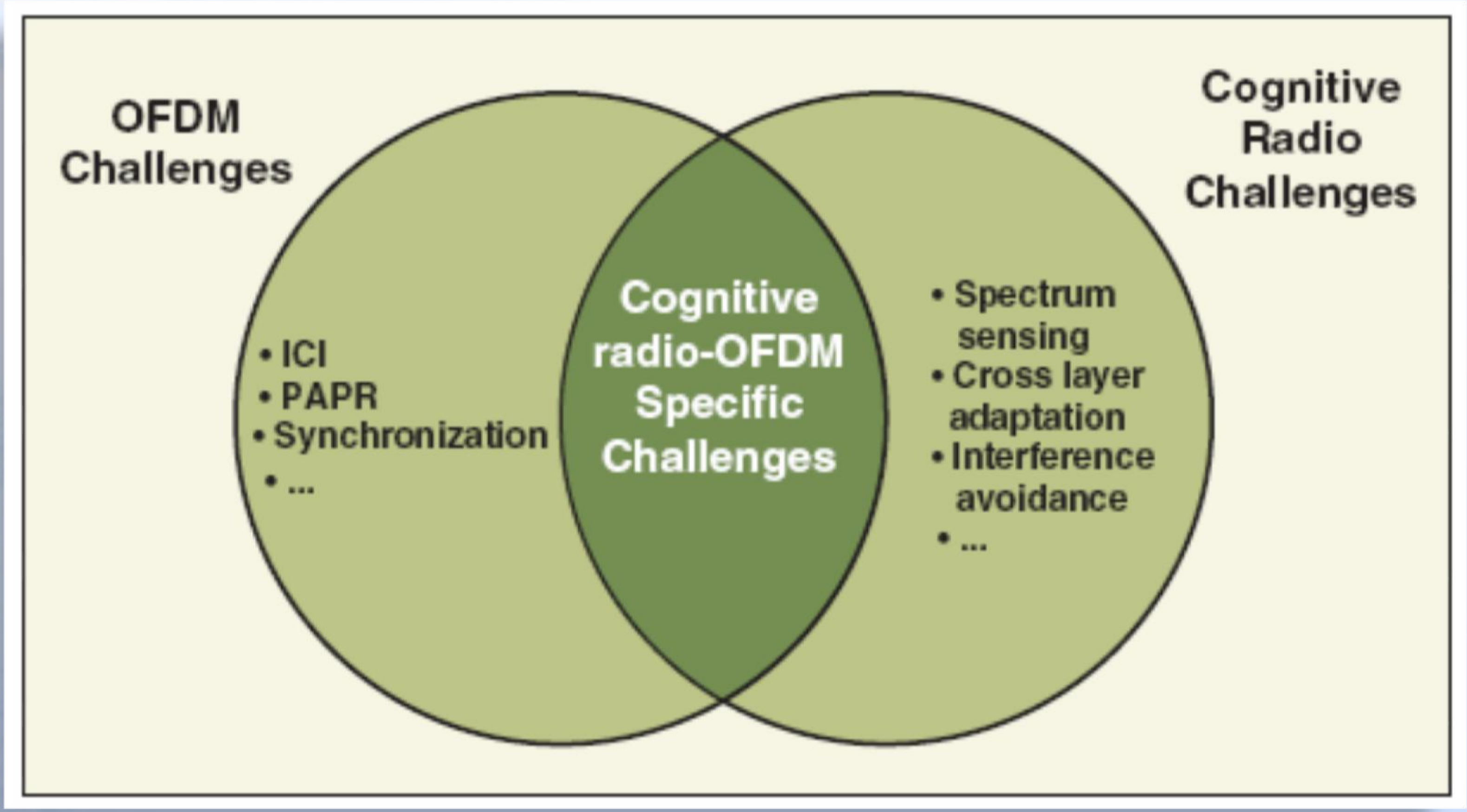
- **Interoperability**
- ability of two or more systems or components to exchange information and to use the information that has been exchanged

Table 11.1. OFDM-based wireless standards.

Standard	IEEE 802.11(a/g)	IEEE 802.16(d/e)	IEEE 802.22	DVB-T
FFT size	64	128, 256, 512, 1024, 2048	1024, 2048, 4096	2048, 8192
CP size	1/4	1/4, 1/8, 1/16, 1/32	Variable	1/4, 1/8, 1/16, 1/32
Bit per symbol	1, 2, 4, 6	1, 2, 4, 6	2, 4, 6	2, 4, 6
Pilots	4	Variable	96, 192, 384	62, 245
Bandwidth (MHz)	20	1.75 to 20	6, 7, 8	8
Multiple accessing	CSMA	OFDMA /TDMA	OFDMA /TDMA	N/A

- 802.15.1 & 802.11.b
  FHSS 2.4 GHz
- 80.2.15.2 coexistence

Challenges to Cognitive OFDM Systems



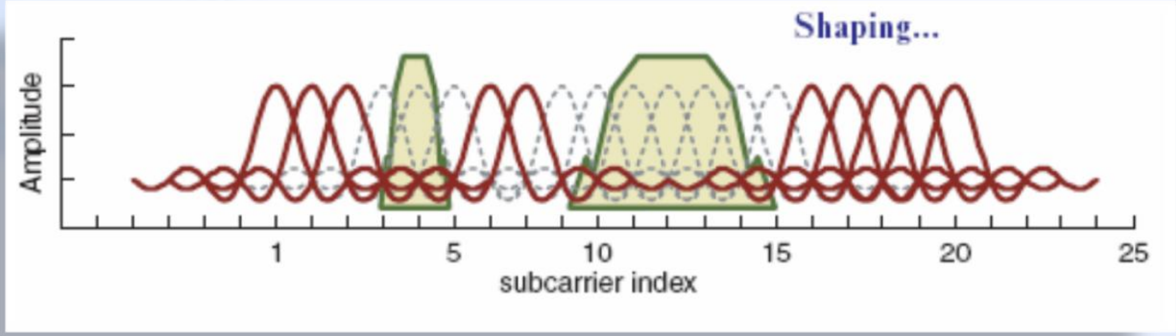
Challenges to Cognitive OFDM Systems(2)

- **Spectrum Shaping**
  - determining the subcarriers to be used by the OFDM system while keeping the interference to and from primary users at a negligible level

- **Effective Pruning Algorithm Design**
  - Pruning means that eliminate the subcarriers is deactivated
  - efficiency of FFT algorithms can be increased and / or execution time can be decreased
  - Designing effective pruning algorithms is important for cognitive OFDM systems for achieving higher performance.

Challenges to Cognitive OFDM Systems(3)

- **Signaling the Transmission Parameters**



- The receiver, should be informed about subcarriers that are deactivated and that are to be used. Signaling of this information should be performed carefully.
- A. M. Wyglinski (2006). The activation/deactivation of subcarriers is performed over a block of subcarriers instead of each individual subcarrier. Hence, the signaling overhead can be reduced by a factor of each block's size.
- FFT size, CP size, etc. can be changed and this information should also be conveyed to the receiver.

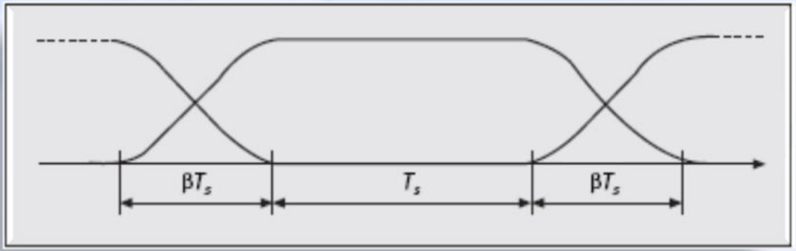
Challenges to Cognitive OFDM Systems(4)

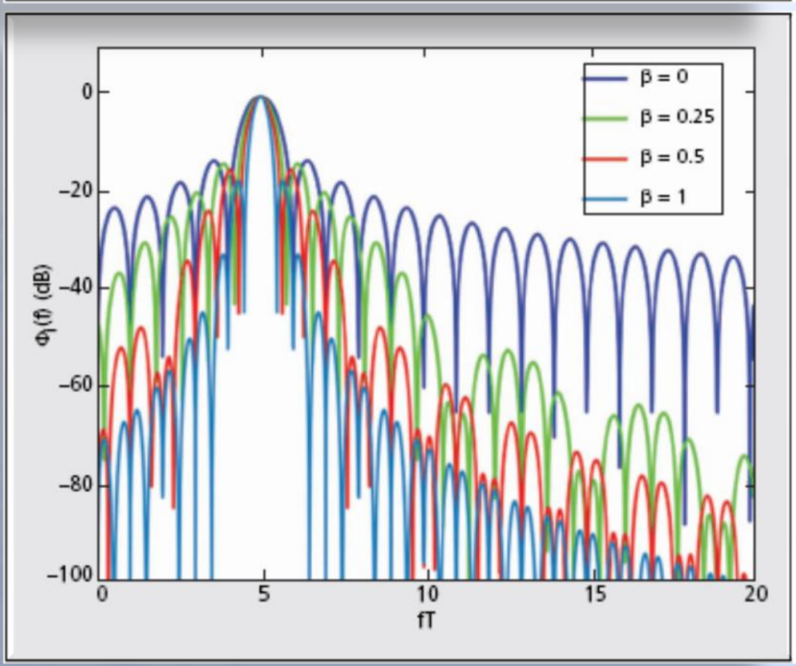
- **Synchronization**
  - To keep the orthogonality between subcarriers and avoid interference, all users should be synchronized to the receiver.
  - The NBI, which can interfere with the preamble.
  - Pilots might fall into unused subcarriers if used
  - Longer preambles are needed in CR-OFDM systems as compared to conventional systems.

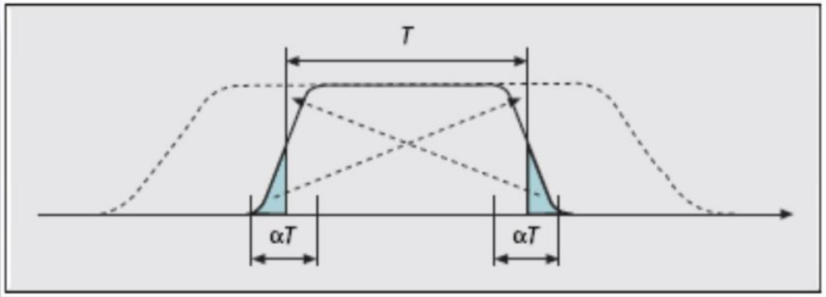
Challenges to Cognitive OFDM Systems(5)

- **Mutual Interference**

1- Raised cosine windowing in transmitter







2- windowing in receiver

(1+α)N sample are chosen

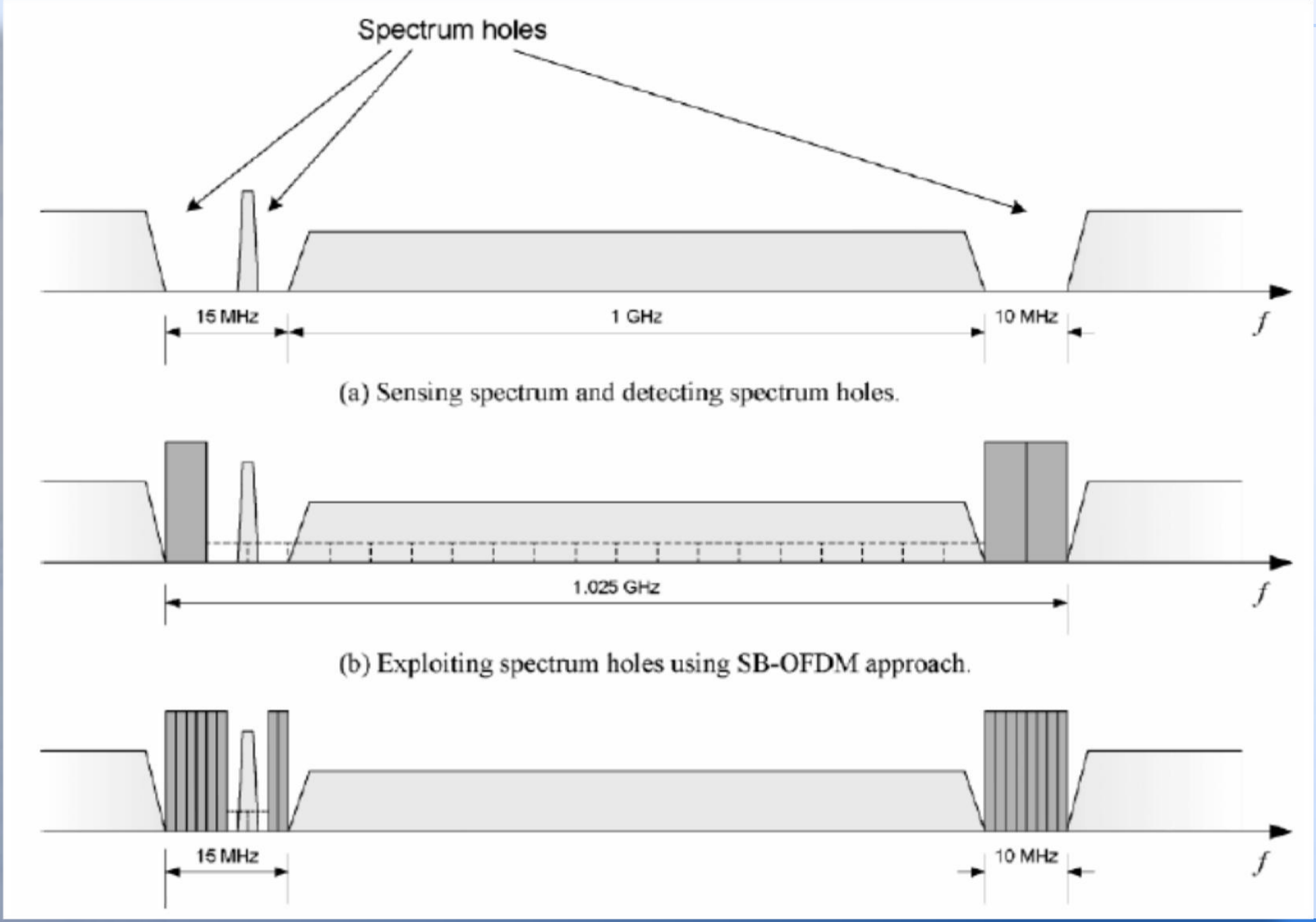
3- Subcarrier weighting

Multi-band OFDM

- While using a single band simplifies the system design
- Processing a wide band signal requires building highly complex RF circuitry for signal transmission/reception
- High speed ADCs are required
- Higher complexity channel equalizers]

- System hardware as smaller portions of the spectrum are processed at a time
- Dividing the spectrum into smaller bands allows for better spectrum allocation
- The system can drop some of the available bands to achieve other goals

A scenario for compare SB-OFDM & MB-OFDM system



Cognitive-OFDM: Standards and Technologies

- WiMAX – IEEE 802.16d
- IEEE 802.22
- IEEE 802.11k

- **Conclusion**
- OFDM technique is used in many wireless systems and proven as a reliable and effective transmission method.
- By employing OFDM transmission in cognitive radio systems; adaptive, aware and flexible systems that can interoperate with current technologies can be realized.

Thanks