WiMAX技術及現況簡介

中山科學研究院
資訊通信研究所 精密電子組
林俊彥
2006.3.23

Contents

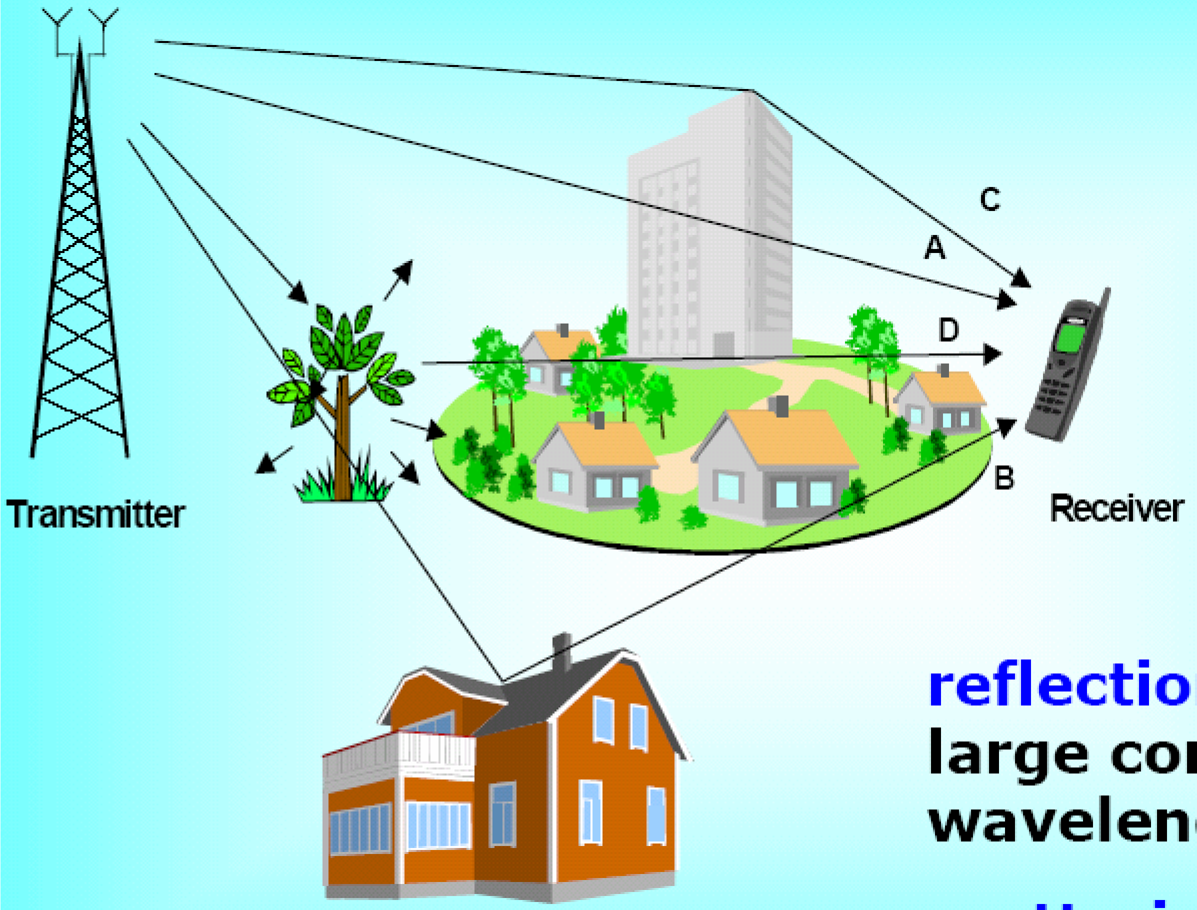
- OFDM technology
- IEEE 802.16-2004, 802.16e
- Comparison of BWA technology
- WiMAX in Taiwan
- Summary

IEEE Standards for Broadband Access Network (BRAN)

- IEEE 802.11™(WiFi)
  - Short-range:~100m
  - Wirless Local Area Networks (WLAN)
  - Referre to as “Wi-Fi” for “Wi-Fi Alliance”
  - “private” character, no network operator necessary
- IEEE 802.16™ WiMAX
  - Worldwide interoperability of Microwave Access全球微波存取互通介面標準
  - Long-range:~ 3 – 50 km
  - Wireless Metropolitan Area Networks (WMAN)
  - Korea (Samsung) approach: “WiBro” for “Wireless Broadband”
  - “public” character, i.e., network operator involoved

- OFDM technology introduction

Fading Source

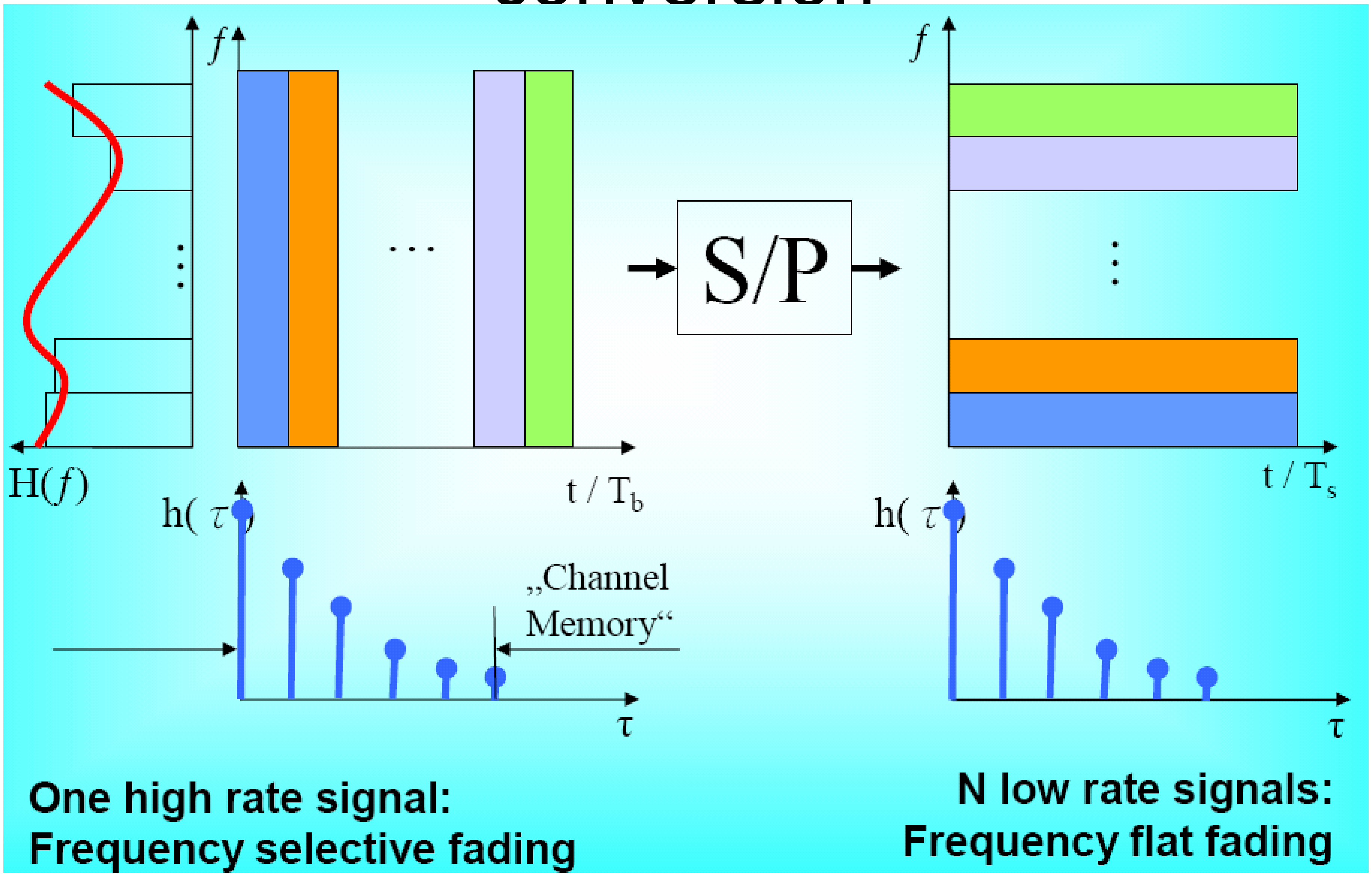


A: free space
B: reflection
C: diffraction
D: scattering

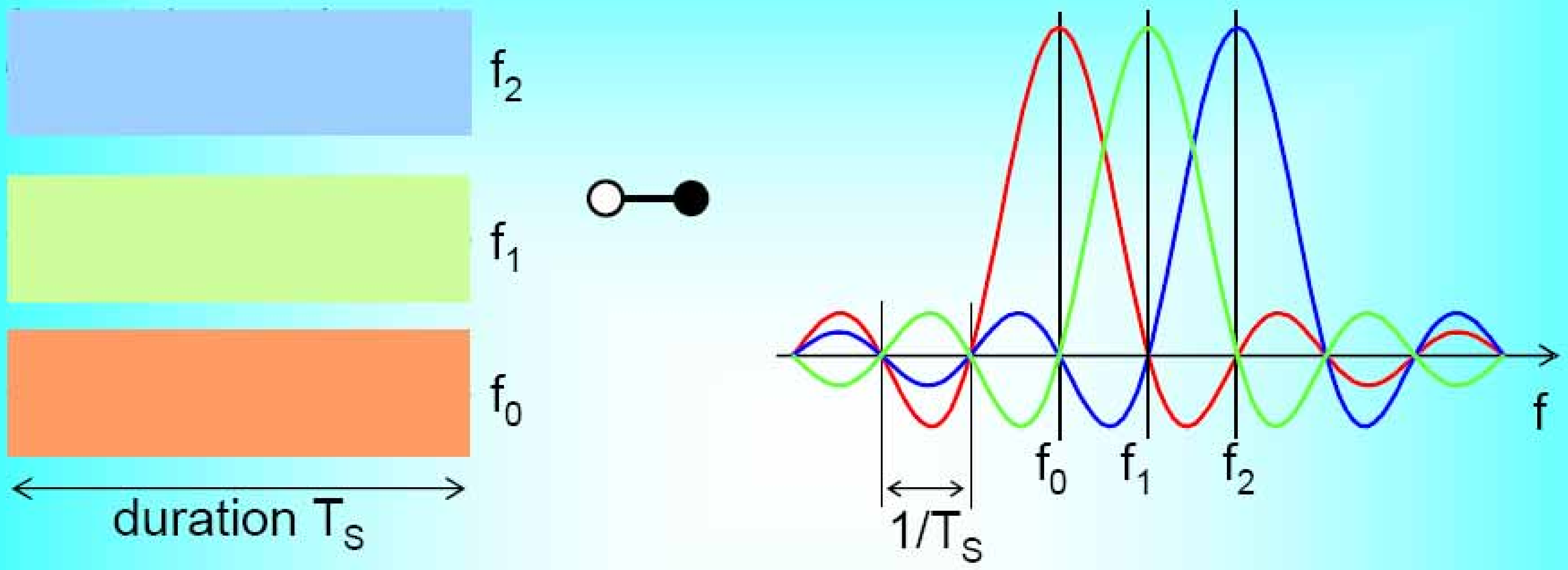
reflection: object is large compared to wavelength

scattering: object is small or its surface irregular

OFDM: Wide/Narrow band conversion

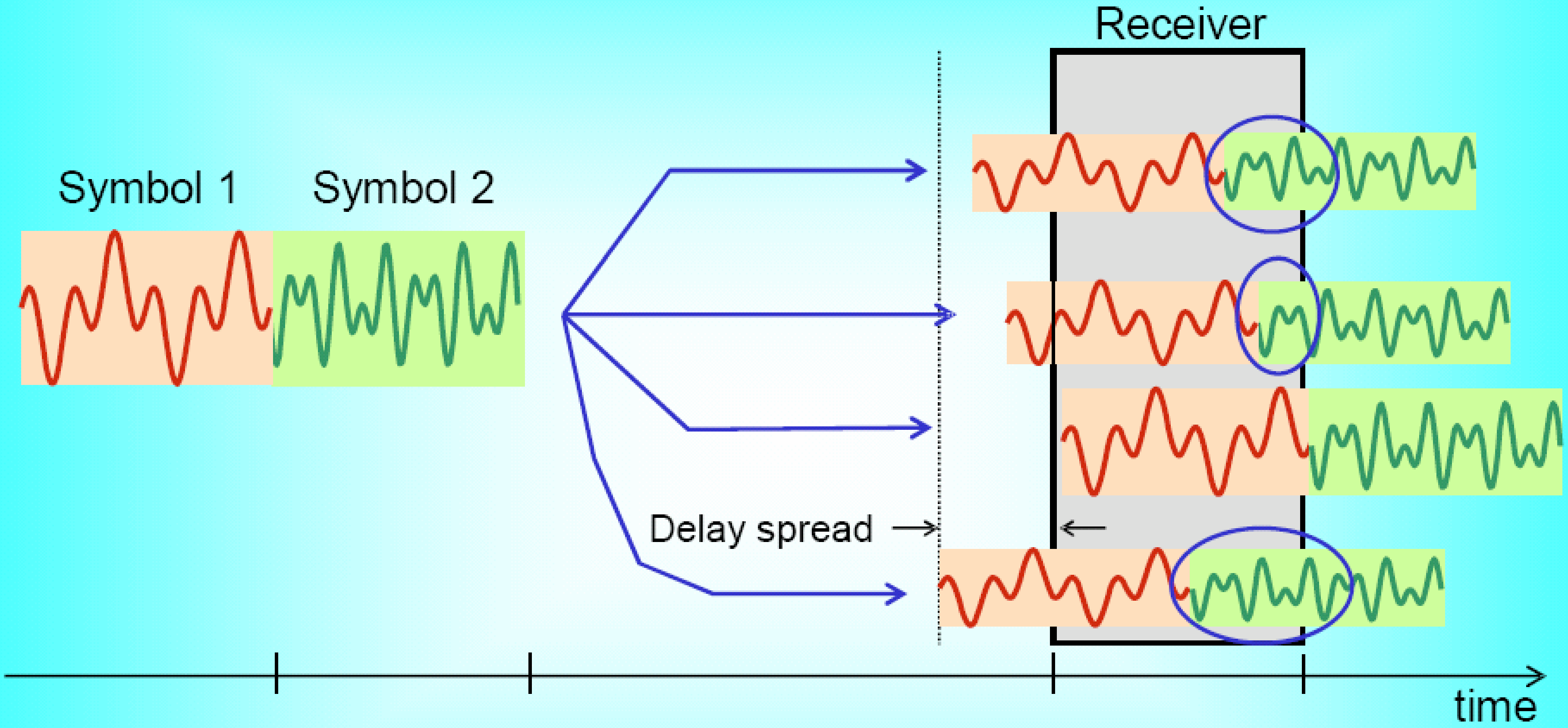


Principle of Orthogonal-FDM



- $f_{Carrier} = f_0 + n/T_s$ where n is an integer (e.g. n = -127 .. 128)
- The maximum of one carrier is at zero crossings of all others
- Cross correlation of sine waves is zero at ideal sampling points nT_s
- This is obtained by the following setting: $\Delta f = 1/T_s$, therefore: $f_n = n\Delta f$

OFDM Suppress Multi-path

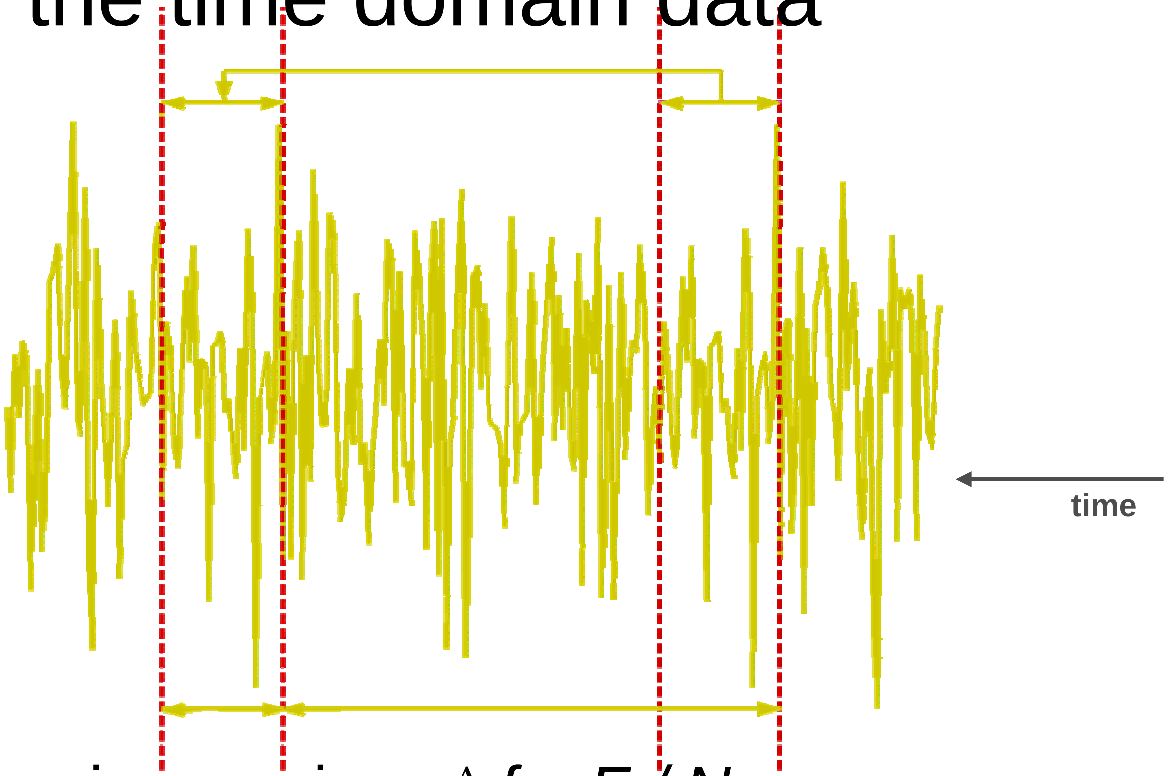


Problem:

Due to different paths to the receiver, the different OFDM symbols **would** interfere with themselves or each other

OFDM Basics: The Cyclic Prefix

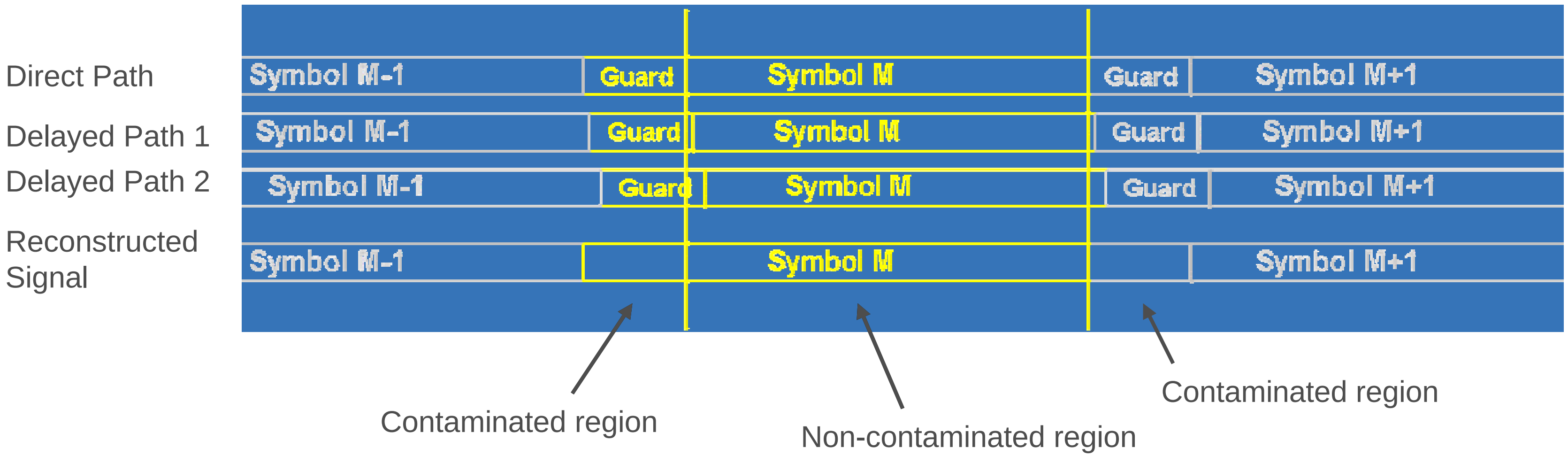
- To preserve orthogonality, one cyclically extends the time domain data



- ➢ Subcarrier spacing: $\Delta f = F_s / N_{FFT}$
- ➢ Useful symbol time: $T_b = 1/ \Delta f$
- ➢ CP time: $T_g = G^* \, T_{b,}$, G = 1/4, 1/8, 1/16 and 1/32

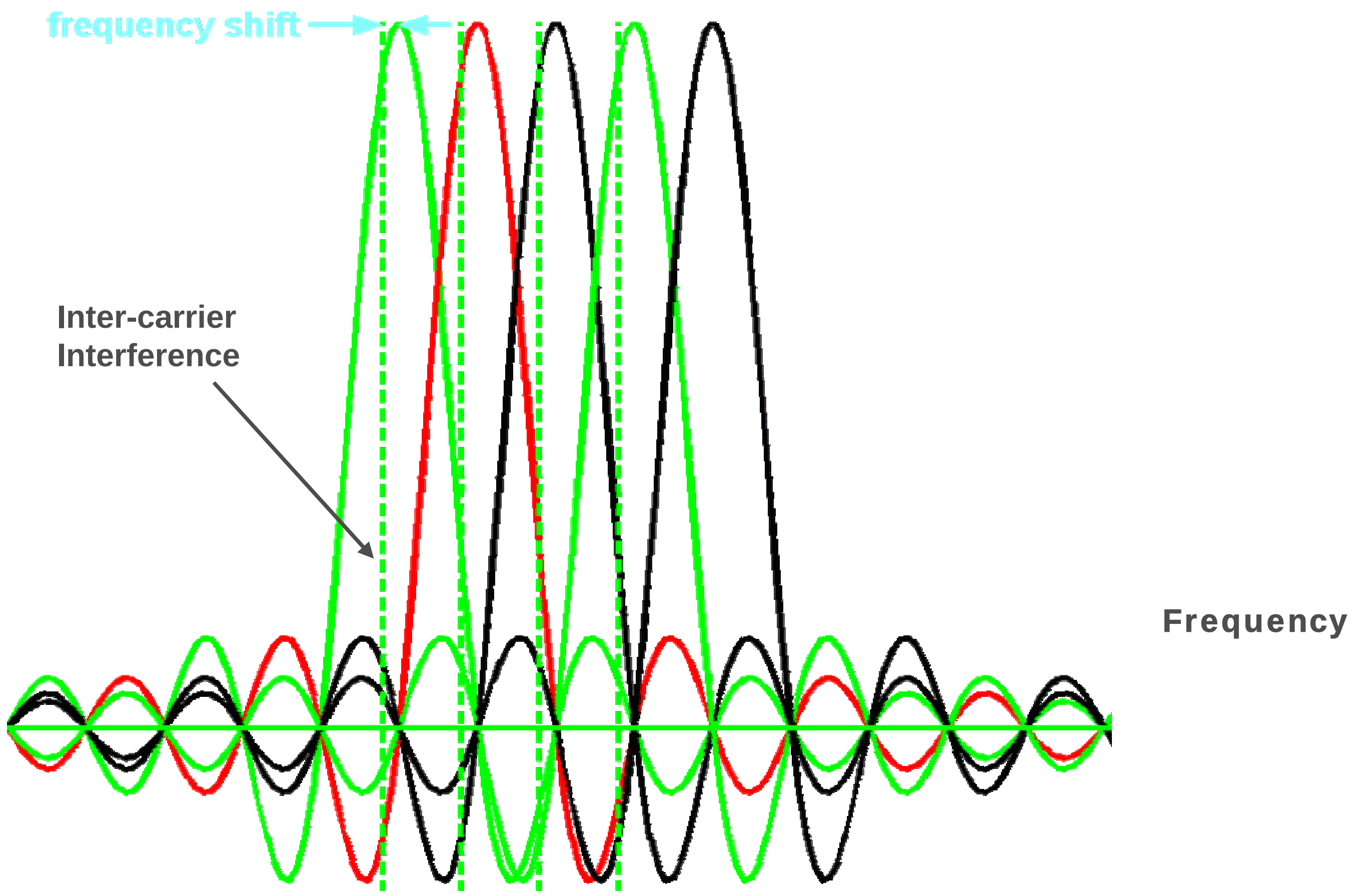
OFDM Basics: The Cyclic Prefix

- Cyclic prefix length is chosen to absorb the channel impulse response and delay spread



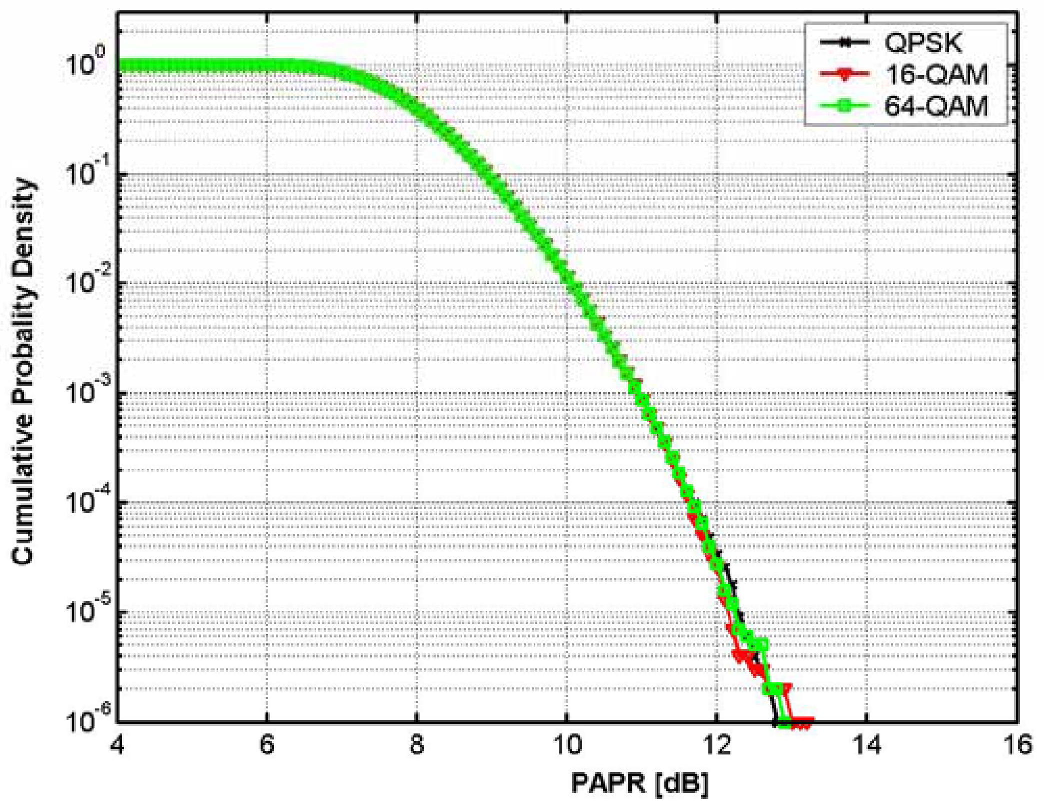
OFDM Disadvantages

- Sensitivity to Frequency Offset
  - Frequency offset breaks the orthogonality of the subcarriers $\Rightarrow$ Inter-carrier interference (ICI)

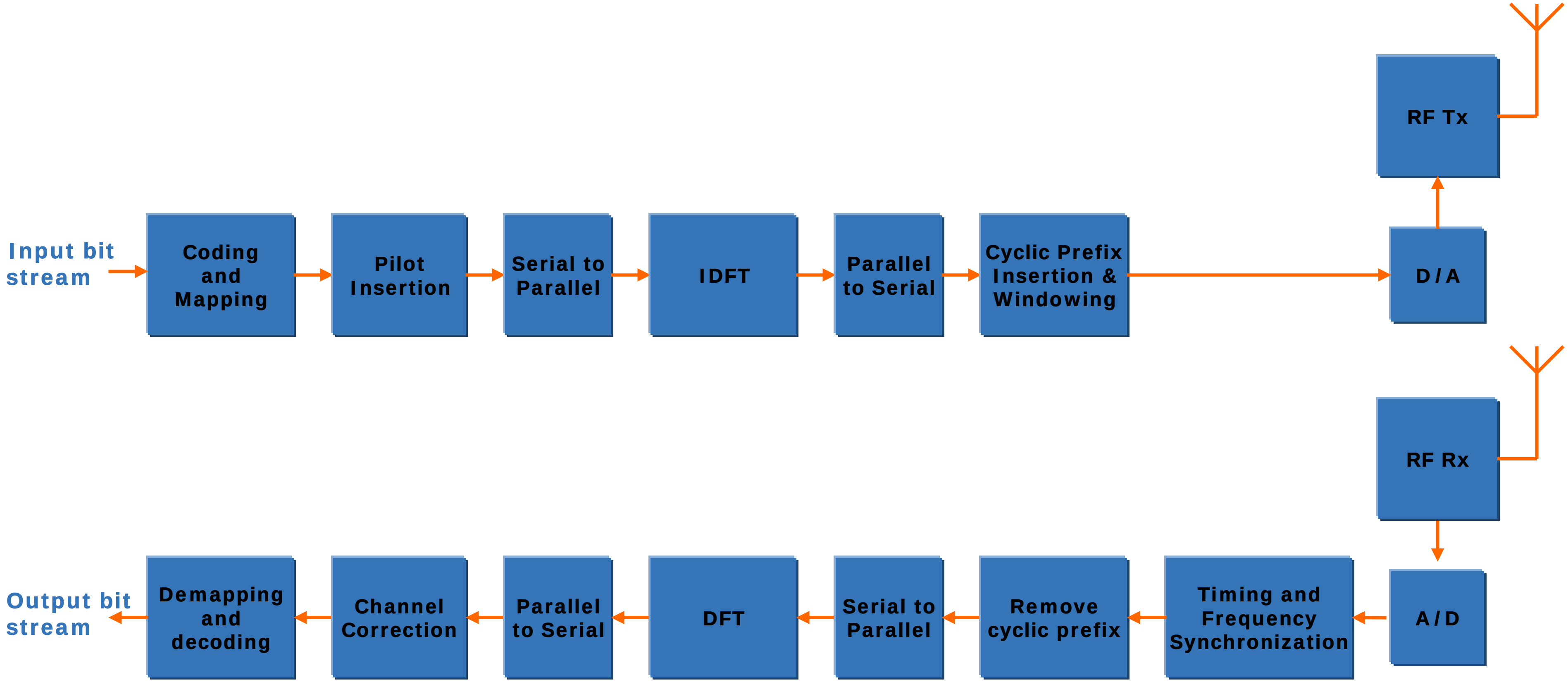


OFDM Disadvantages

- High Peak to Average Power Ratio (PAPR)
  - Cumulative distribution function for PAPR (256 point FFT):

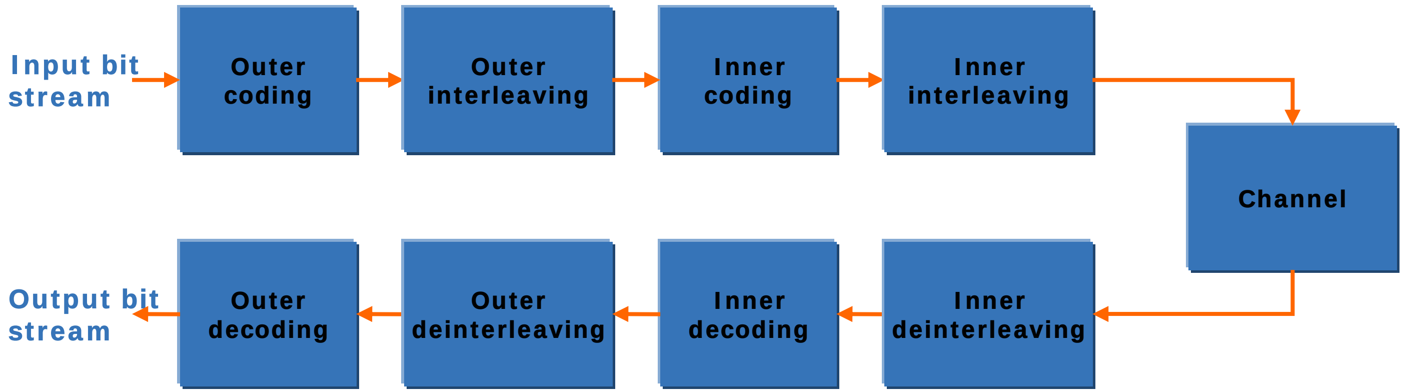


Block Diagram of an OFDM Transceiver



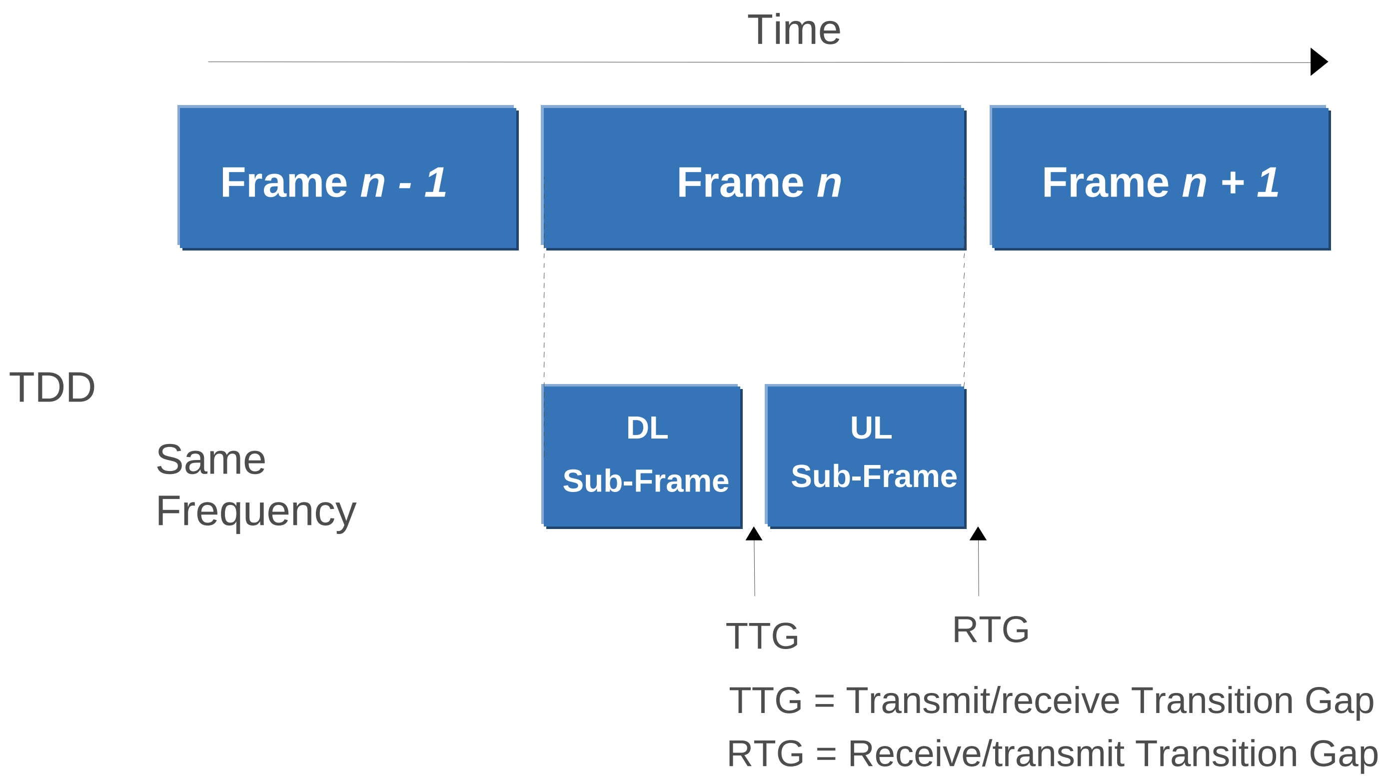
Coding: Concatenated Codes

- Concatenated codes is the combination of two codes to provide greater coding gain with less implementation complexity as a comparable single code
- Typically, inner code is a convolutional code while the outer code is a block code
- Convolutional code cleans up low-input SNR's
- Block code cleans up the remaining errors



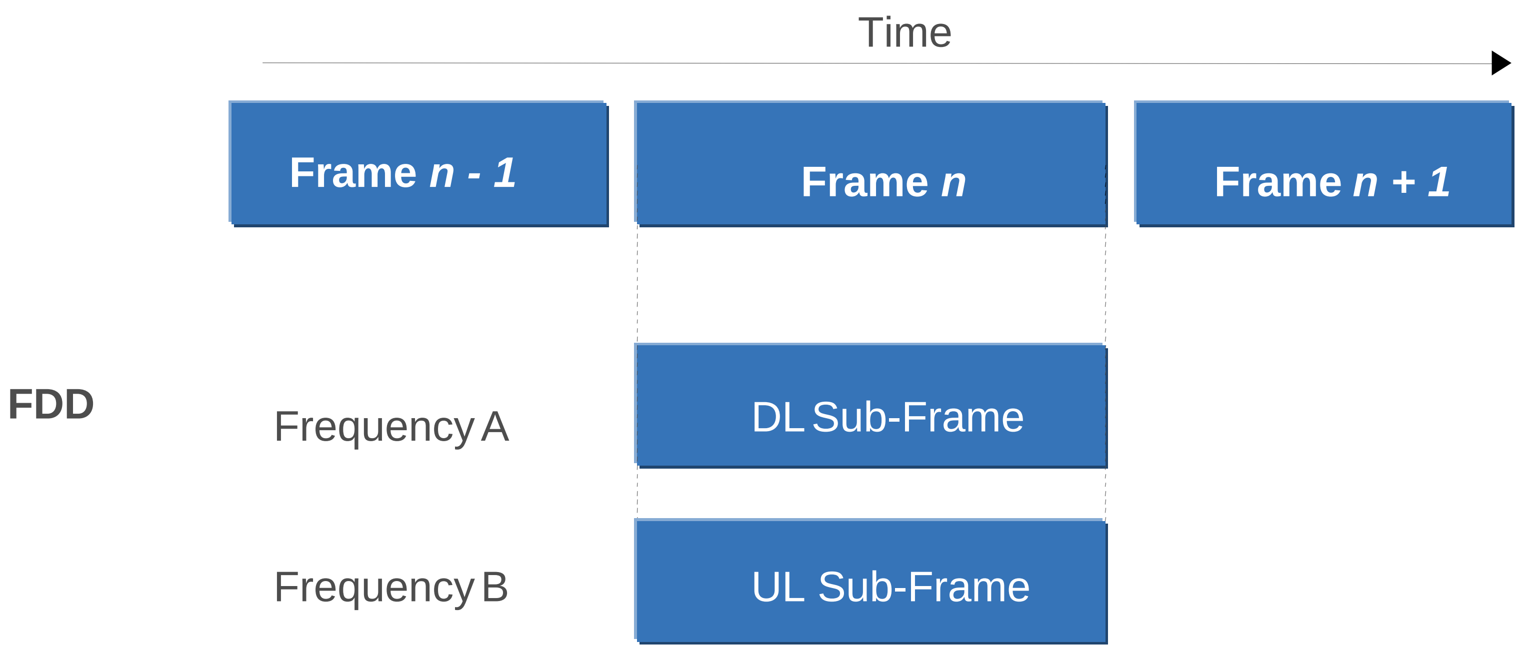
Duplexing Method

- TDD: DL sub-frame occurs first, followed by the UL sub-frame.



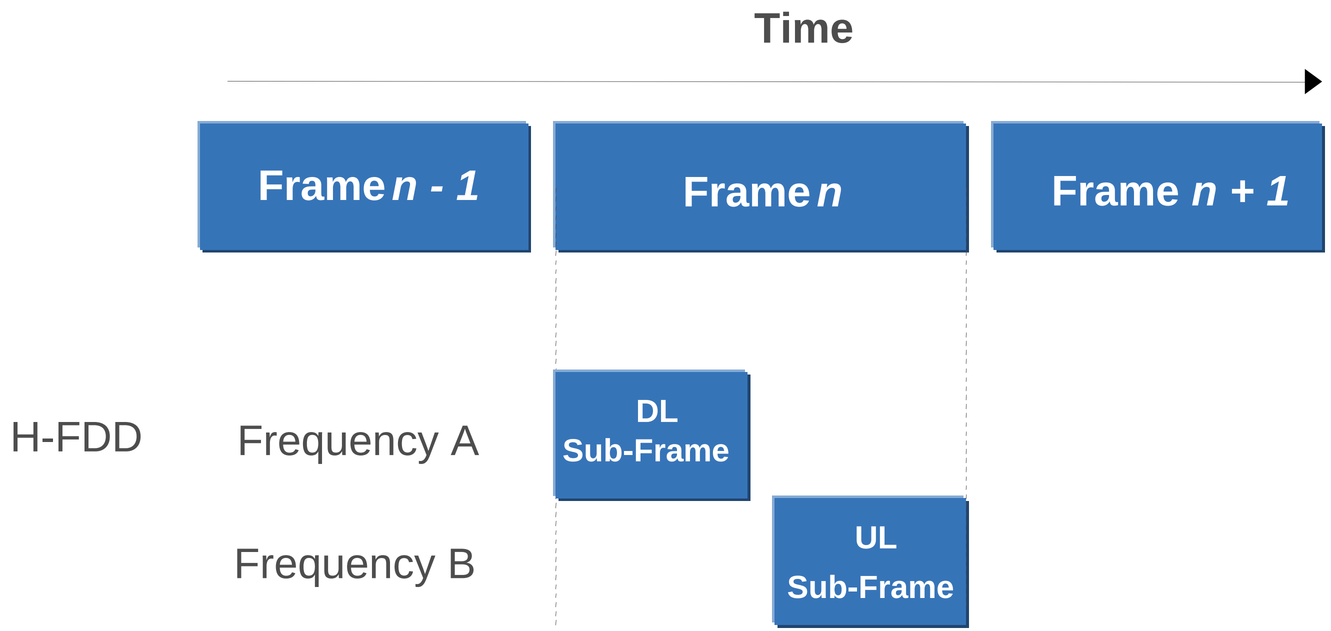
Duplexing Method

- FDD: both DL and UL transmissions occur simultaneously on different frequencies.



Duplexing Method

- **In H-FDD, the transmission occur at different times and different frequencies.**

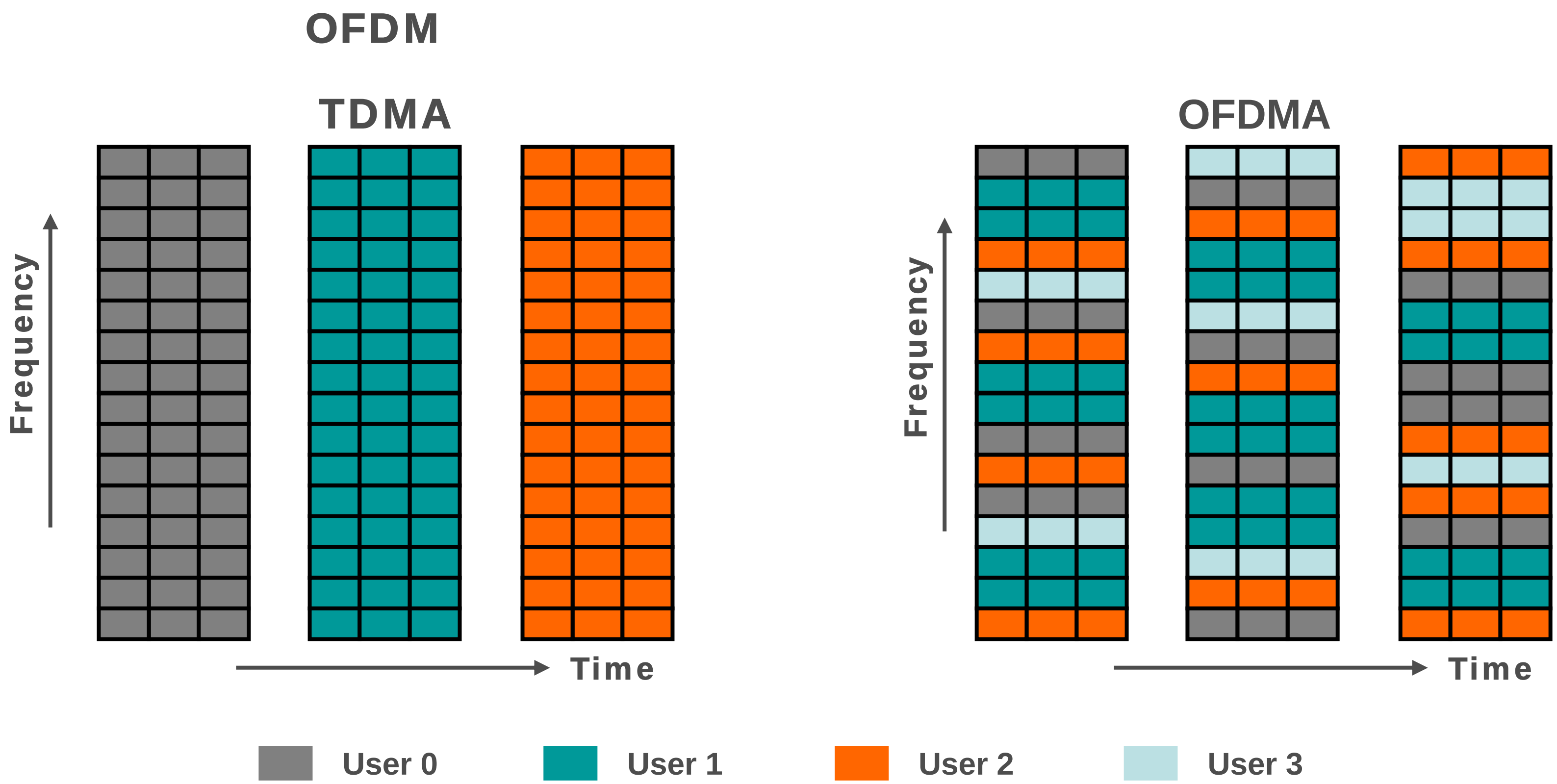


Duplexing Method

- License-exempt bands are restricted to TDD
- Licensed bands can use TDD, FDD and H-FDD

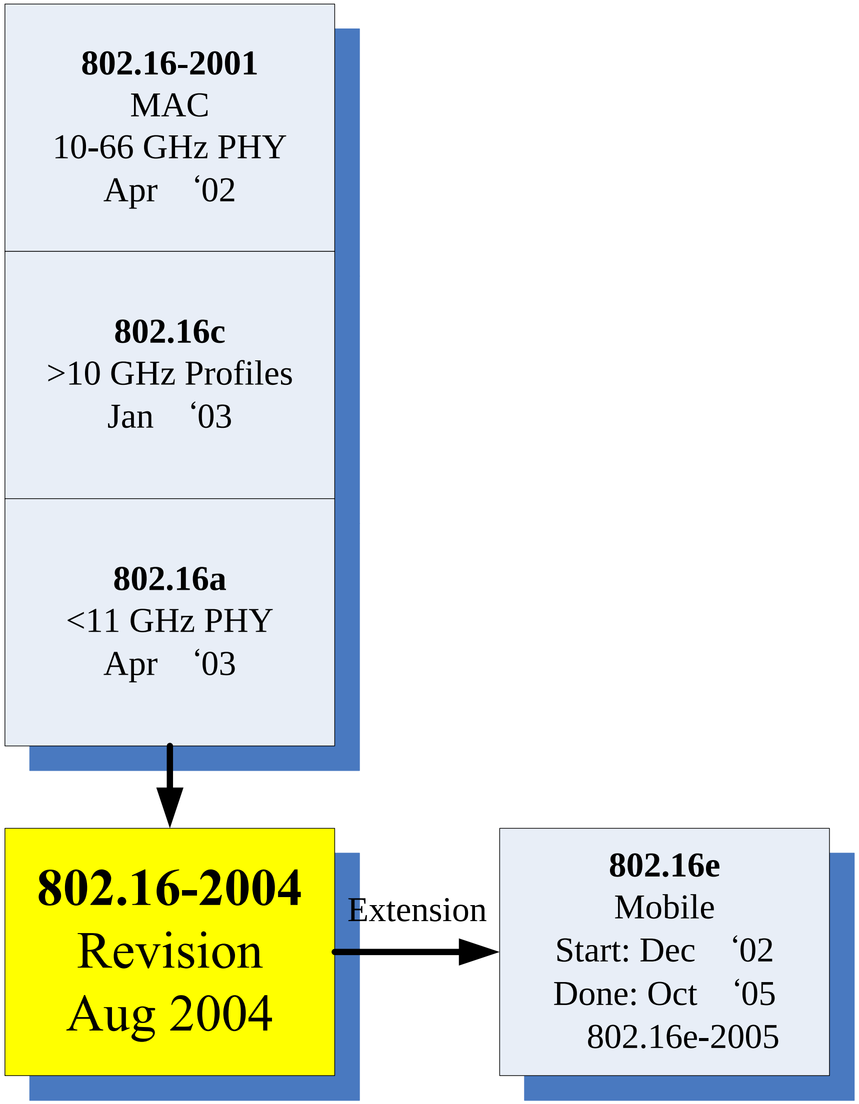
Multiple Access for OFDM

- In OFDMA, the subcarriers are divided into groups or subchannels, which are assigned to different users to accommodate BW and QoS requests.

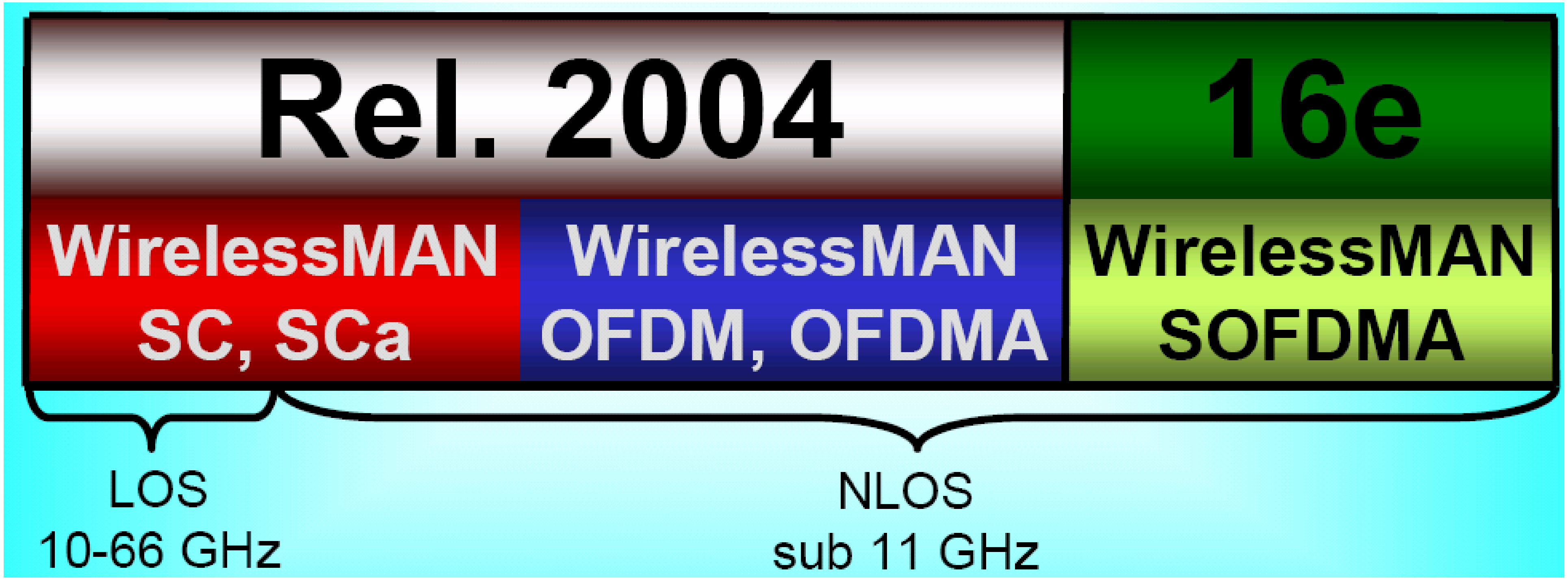


- 802.16-2004, 802.16e-2005

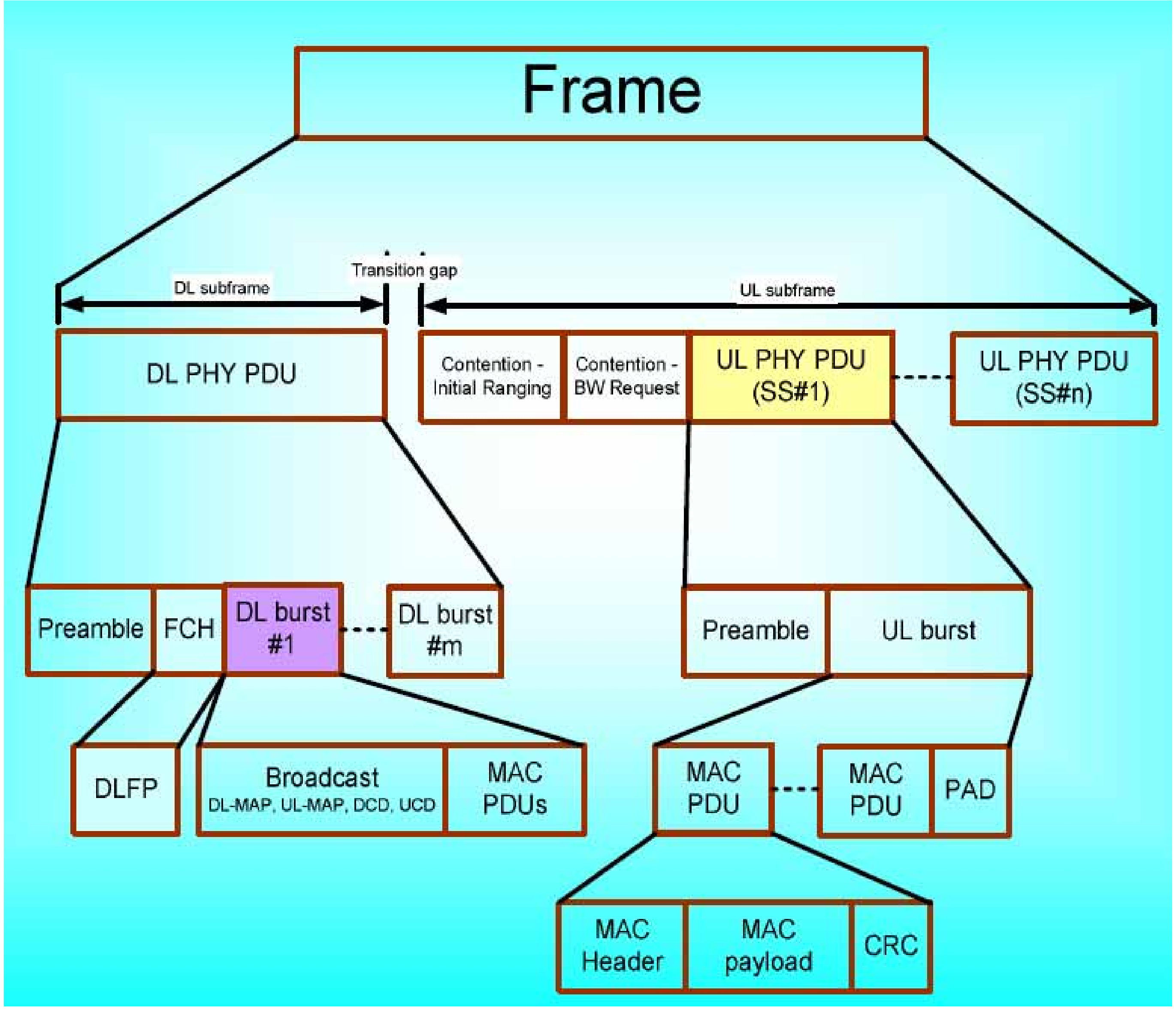
802.16 Standards



IEEE 802.16 PHY Proposals

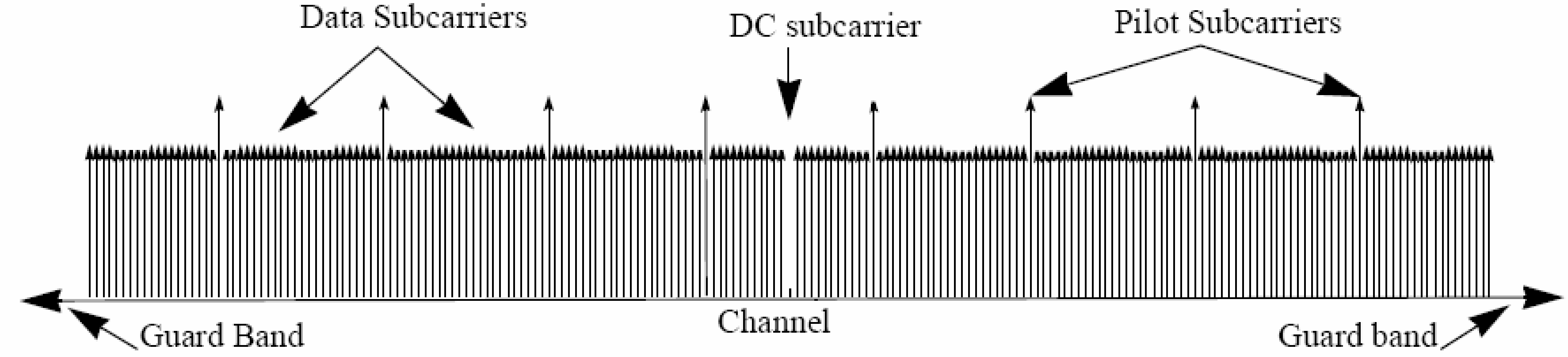


OFDM Frame Structure



802.16-2004 OFDM PHY

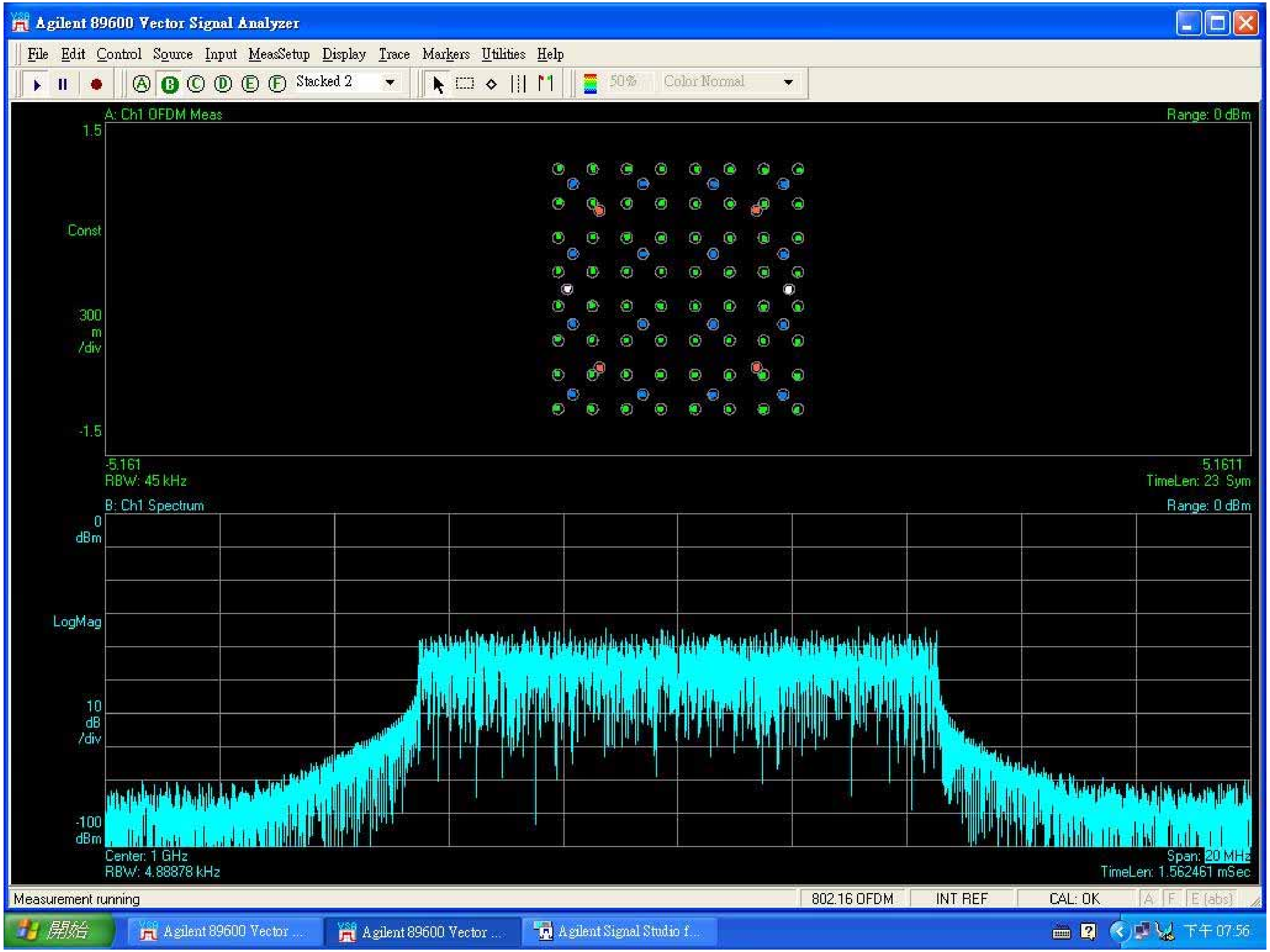
- Frequency domain
  - 256 FFT/subcarriers
  - 192 data subcarriers: for data transmission
  - 8 Pilot subcarrier: for channel estimation purposes
  - Null subcarrier: no transmission, for guard band, non-active subcarriers and DC subcarrier
  - For UL subchannelization subsets of 12,24,48 or 96 data subcarriers



28 subcarriers

27 subcarriers

OFDM Data Modulation: example



802.16-2004 Max Raw data rate

Modulation / Code Rate	QPSK 1/2	QPSK 3/4	16 QAM 1/2	16 QAM 3/4	64 QAM 2/3	64 QAM 3/4
1.75 MHz	1.04	2.18	2.91	4.36	5.94	6.55
3.5 MHz	2.08	4.37	5.82	8.73	11.88	13.09
7.0 MHz	4.15	8.73	11.64	17.45	23.75	26.18
10.0 MHz	8.31	12.47	16.63	24.94	33.25	37.40
20.0 MHz	16.62	24.94	33.25	49.87	66.49	74.81

*** MAC overhead and preamble overhead are not included in calculation**

Error Vector Magnitude Vector Magnitude Required

- 802.16-2004 Tx modulation specifications

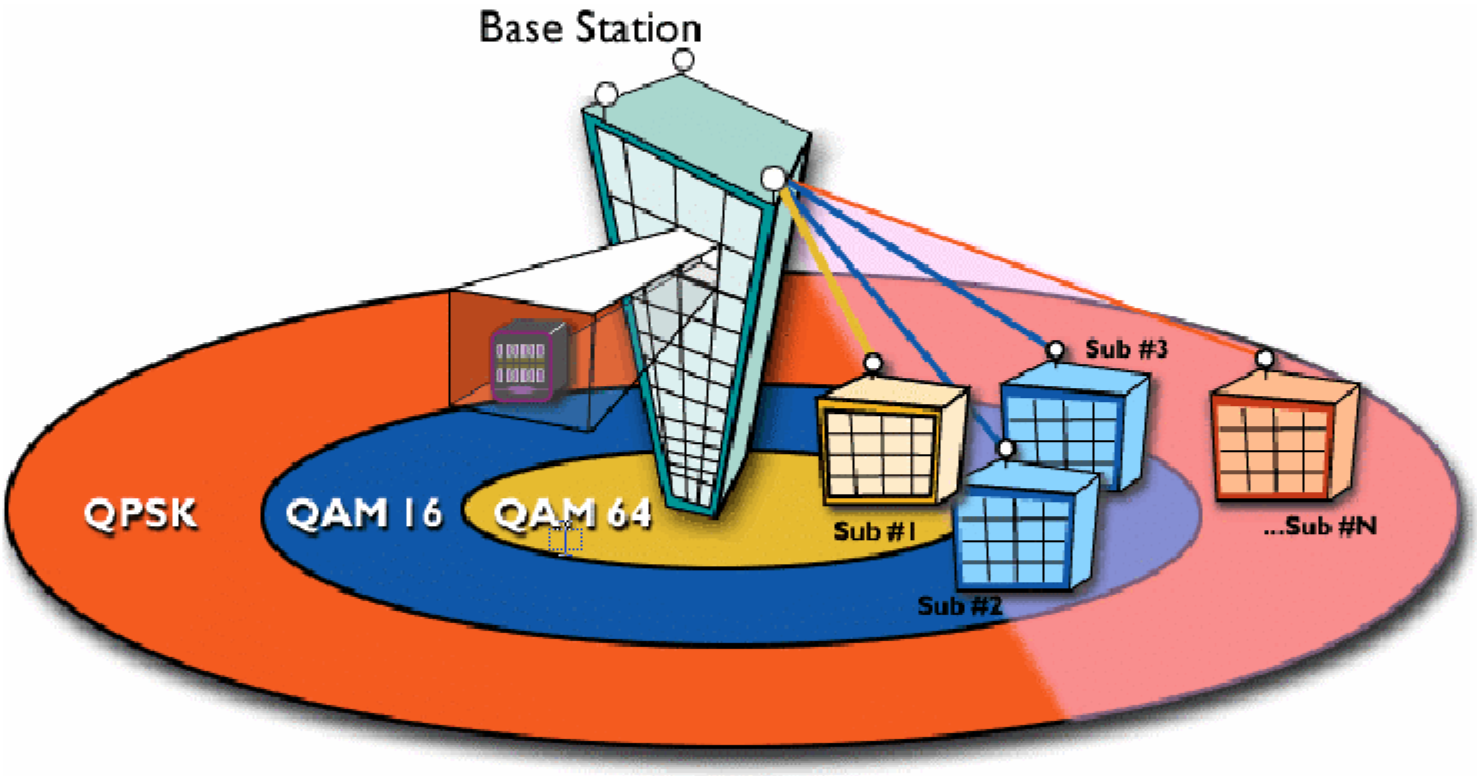
Modulation/Coding Rate	Relative Constellation Error (dB)
BPSK-1/2	–13.0 =22.4%
QPSK-1/2	–16.0 =15.8%
QPSK-3/4	–18.5 =11.9%
16-QAM-1/2	–21.5 =8.4%
16-QAM-3/4	–25.0 =5.6%
64-QAM-2/3	–28.5 =3.8%
64-QAM-3/4	–31.0 =2.8%

  – To ensure the receiver SNR does not degrade <0.5 dB

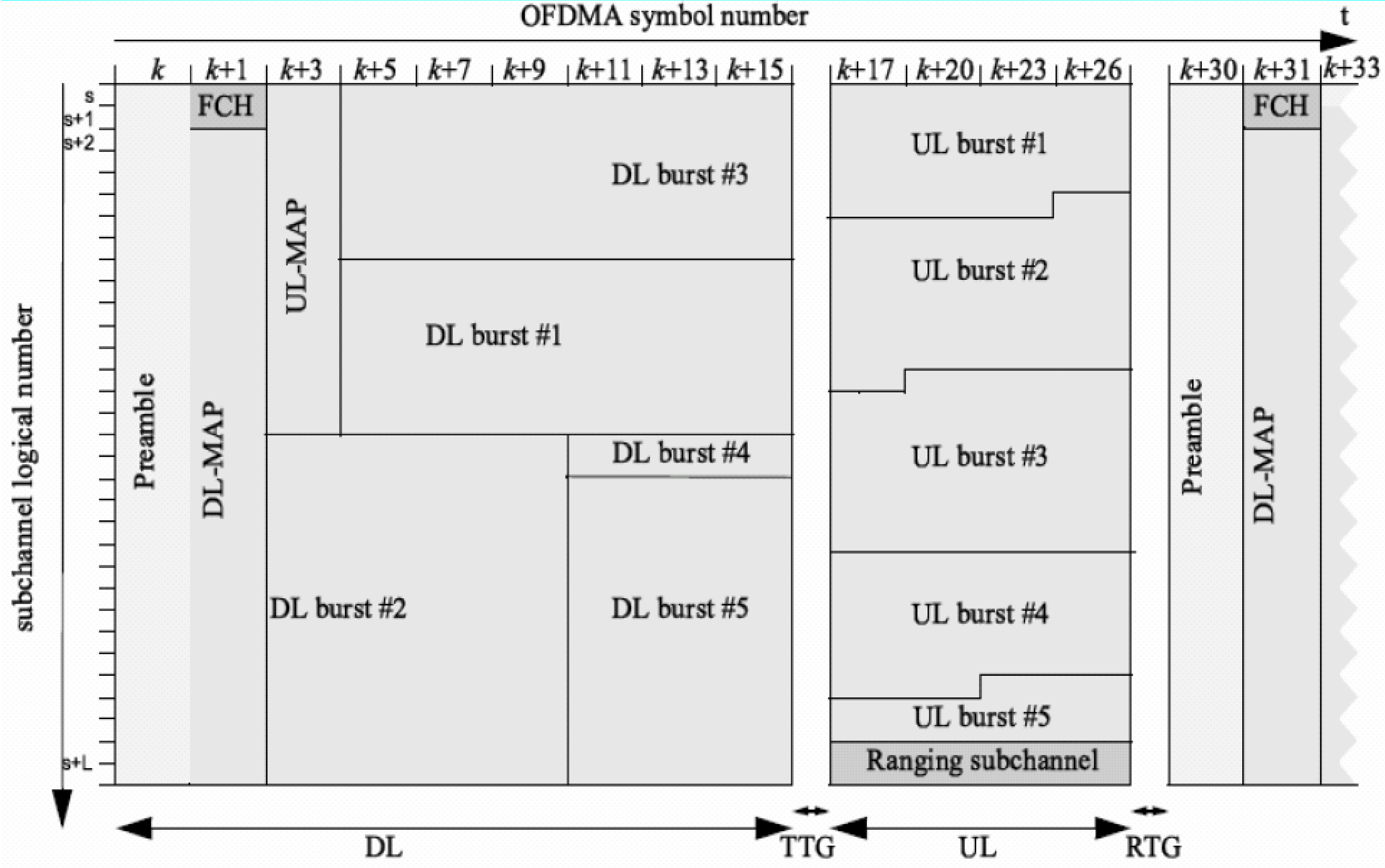
Min. SNR required in WiMAX Baseband

Modulation/coding rate	802.16-2004 SNR
BPSK-1/2	+6.4
QPSK-1/2	+9.4
QPSK-3/4	+11.2
16-QAM-1/2	+16.4
16-QAM-3/4	+18.2
64-QAM-2/3	+22.7
64-QAM-3/4	+24.4

Adaptive PHY



OFDMA Frame Structure



WiMAX key parameters comparison

Parameter	OFDM-2004	OFDMA-2004	SOFDMA-16e	WIBRO
FFT size	256	2048	128,512,1024	1024
System bandwidth	1.25 – 28 MHz	1.25 – 28 MHz	1.25 – 20 MHz	8.75 MHz
Pilots	Fixed (8)	Fixed & Variable	Fixed & Variable	Fixed
Preamble	Long Preamble on DL Short Preamble on UL	DL preamble only	DL preamble only	DL only
Subchannelisation	UL only	FUSC & PUSC	FUSC & PUSC	OFUSC & PUSC
CP ratio	¼, 1/8, 1/16, 1/32	¼, 1/8, 1/16, 1/32	¼, 1/8, 1/16, 1/32	1/8
Frame length	2.5, 4, 5, 8, 10, 12.5, 20 ms	2, 2.5, 4, 5, 8, 10, 12.5, 20 ms	2, 2.5, 4, 5, 8, 10, 12.5, 20 ms	5 ms

- Comparison of BWA technology

Comparison of Standards Using OFDM

- IEEE 802.16
  - To provide Wireless Metropolitan Area Network services
  - Originally to compete against cable and DSL markets
  - Standardizing all licensed bands below 11 GHz (e.g. MMDS, 3.5 GHz)
  - Official standard: IEEE std 802.16-2004 for fixed access with three possible PHY's--SCM, OFDM-256, OFDMA-2048
    - WiMAX has chosen the OFDM-256 PHY
  - 802.16e--project to amend standard for mobility; ➔802.16-2005

Comparison of WiMAX & xDSL

.	WiMAX	xDSL	
	IEEE 802.16-2004	ADSL/ADSL2+	VDSL/VDSL2
DL Data rate	75 Mbps	8M/16~25M bps	55.2M/7~100M bps
UL Data rate	75 Mbps	2Mbps	19.2Mbps
Distance.	LOS:30~50km NLOS: 4~9km	4km/0.6-2km	0.3km-2km/0.4km-2km

資料來源：工研院 IEK(2005/08)

Comparison of Standards Using OFDM

- IEEE 802.11a (g)
  - To provide Wireless Local Area Network services
  - Standardized in 1999 (2003)
  - BPSK, QPSK, 16-QAM, and 64-QAM modulation
  - Convolutional code (171, 133 octal) w/puncturing-- 1/2, 2/3, 3/4
  - Coherent detection w/ training symbols and fixed pilots
  - Provides up to 54 Mbits/s

Comparison of WiMAX & WiFi

Tech.	WiMAX	WiFi	
Standard	IEEE 802.16-2004	802.11b	802.11a/g
Data rate	75Mbps@BW=20MHz	11 Mbps	54Mbps
Distance	30~50kM(LOS)/ 4~9km(NLOS)	100m(indoor)/300m/(outdoor	100m(indoor)/300m/(outdoor)
RF freq.	2~66GHz	2.4GHz ISM	5GH U-N11,2.4GHz ISM(g)
BW	1.25~20MHz	22MHz	20 MHz
PHY Mod.	OFDM/OFDMA	DSSS	OFDM
QoS	Yes	No	No
Mobility	Low	High	High

資料來源：工研院 IEK(2005/08)

Comparison of WiMAX & 3G

Tech	WiMAX	3G	
Standard	IEEE 802.16e	CDMA-2000	WCDMA
Data rate	30Mbps@BW=10MHz	2.4~3.1Mbps	2Mbps/10Mbps(HSDPA)
Distance	2~5km	2~5km	2~5km
RF freq.	2~6GHz	400,800,700,900,1800,2100MHz	900,1800,2100
BW	1.25~20MHz	1.25MHz	5MHz
PHY Mod.	OFDM	CDMA	CDMA
Duplex	TDD	FDD	FDD
Mobility	Low	High	High

資料來源：工研院 IEK(2005/08)

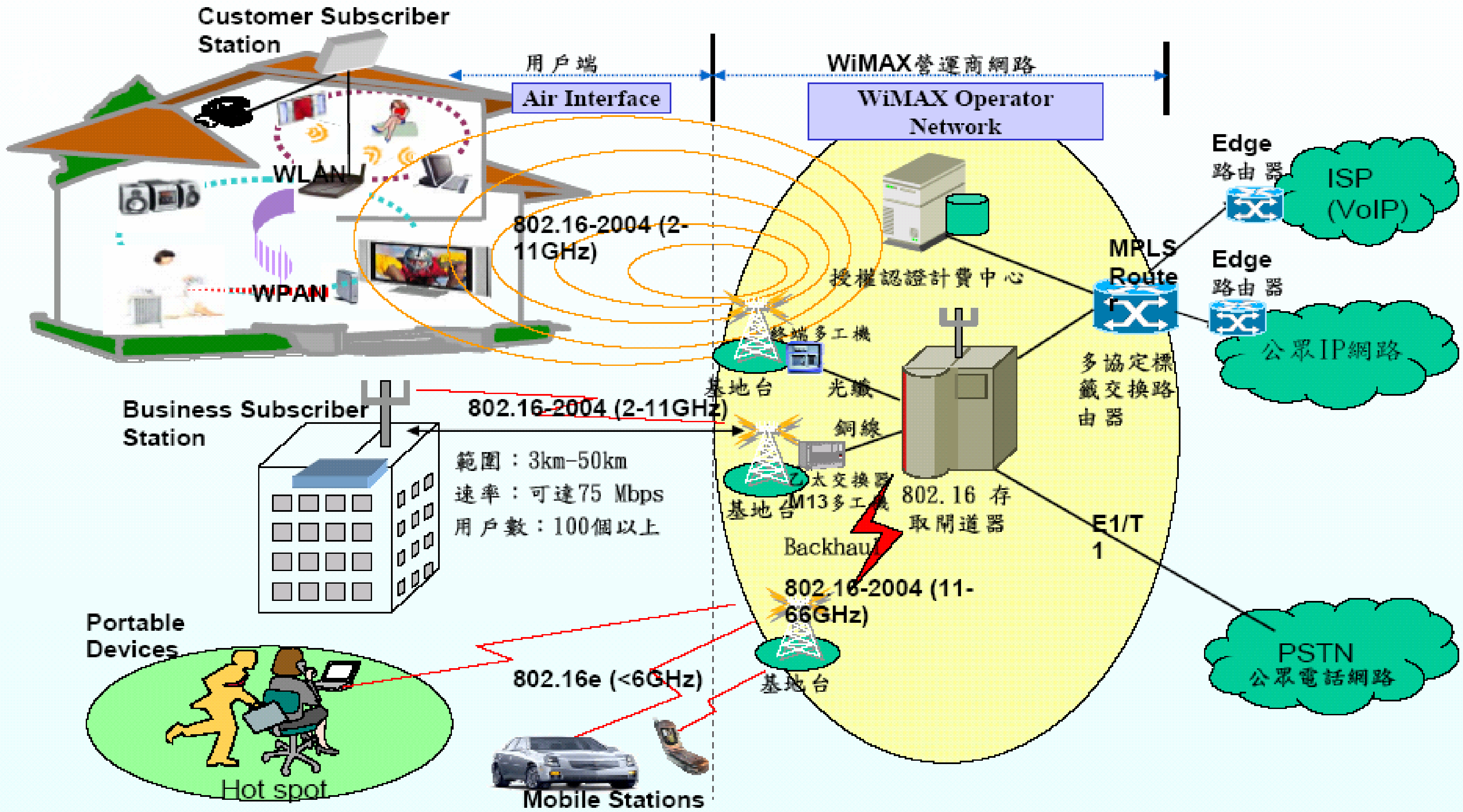
Comparison BWA Technology

	HSPA	I-HSPA	WiMAX 802.16e	Flash-OFDM	UMTS-TDD	CDMA 1xEV-DO
Channel bandwidth	5 MHz	5 MHz	1.75-20 MHz	1.25 MHz	1.25 MHz- 20 MHz	1.25 MHz
Mobility	global, high-speed	global, high-speed	up to 120 km/h	>200 km/h	Full mobility >100 km/h	global, high-speed
Average downlink user data rate	1 - 2 Mbit/s	1 - 2 Mbit/s	6 Mbps (1:3 UL/DL)	1 - 1.5 Mbit/s	1-2 Mbps (@ 5MHz)	500 kbit/s
Average uplink user data rate	800 kbit/s	800 kbit/s	2 Mbps (1:3 UL/DL)	300 - 500 kbit/s	384 kbit/s (@5MHz)	150 kbit/s
Typical cell radius	2 - 10 km	2 - 10 km	1-5 km	5 - 20 km *	2 - 20 km *	5 - 20 km *
TCP roundtrip time	50 ms	50 ms	20-50 ms	35 ms	70-110 ms	300 ms
VoIP support	yes	yes	yes	yes	yes	no (too high latency)

Source: Strategy Analytics, Nokia evaluation

- WiMAX in Taiwan

我國理想WiMAX網路系統架構圖



TW-WiMAX發展藍圖初稿

總　則(一)

1. WiMAX技術（Worldwide Interoperability for Microwave Access）為全球最重要之新興無線技術之一。我國WiMAX發展涉及頻譜規劃，M-Taiwan行動應用之網路架構選擇，電信國家型計畫/晶片系統國家型計畫技術研發時程，故行政院科技顧問組召集成立『台灣WiMAX發展藍圖工作小組』，進行跨部會跨計畫之整體規畫，以力求取得全球領先優勢。
2. 該工作小組自6月13日開始運作，至今已召開九次工作會議，目前已完成發展時程及工作項目初步規畫。
3. 電信總局已規劃以3.4-3.7GHz及2.5G-2.69GHz為主要頻段：
   (1) 3.4-3.7GHz已有既設電台及固定衛星服務（FSS）下鏈使用，唯經協調可和諧共用部分亦可提供固網業者作為無線寬頻接取Last mile或Backhaul。
   (2) 2.5G-2.69GHz則先規劃30MHz供實驗用，並擬在2006年底前完成騰讓及未來發照準備。

經濟部推廣**WiMAX**，加速**M-Taiwan**計畫

- 經濟部與美商英特爾(Intel)公司於2005年十月中簽訂合作協議，將聯手在台灣佈建及推廣WiMAX無線寬頻技術和應用，加速實現「行動台灣(M-Taiwan)應用推動計畫」，打造無線寬頻通訊環境。
- 在規劃有新台幣370億元經費的M-Taiwan計畫下，WiMAX是在城市各角落進行無線寬頻全面佈建與應用的工作中，最重要的技術選項。行政院希望台灣未來能成爲世界規模最大的WiMAX產業發展基地，並取得WiMAX產業發展領先全球的優勢；因此，政府在兩年內將補助11億元，協助建立WiMAX平台技術和關鍵零組件，提升台灣相關資訊廠商的晶片製造、內容、服務、技術能力，並獎勵國內營運商採用台灣設計代工的WiMAX產品，以促進後者成長，在資訊產業上、中、下游共同推動WiMAX的相關應用，加速WiMAX的普及。
- 爲此經濟部長立意，未來5年要建立800萬個無線上網用戶，並且最快將於2007年建置10個行動城市、15個WiMAX無線應用示範區，最終目標是協助國內網通及電信業者進軍全球。

總　　則(二)

4. 本藍圖並提出以下關鍵系統產品做為投入研發之方向：

   (1)WiMAX晶片開發

   (2) WiMAX關鍵系統；

   - 含基地台, WiFi – WiMAX Gateway, 固定式中繼台, WiMAX家用/商用終端系統。

   (3)WiMax應用平台；

   - 含網路電話(VoIP)，網路電視(IP TV Broadcast), 無線線上遊戲(Pervasive On-Line Gaming), 行動照護(e–Health)等。

5. 本藍圖確定WiMAX 為M-Taiwan計畫重要技術選項。

6. 本藍圖對未來WiMAX架構提出規劃與建議，供各部會及產業界投入相關發展之參考，本藍圖並建議各計畫間宜深度扣合。

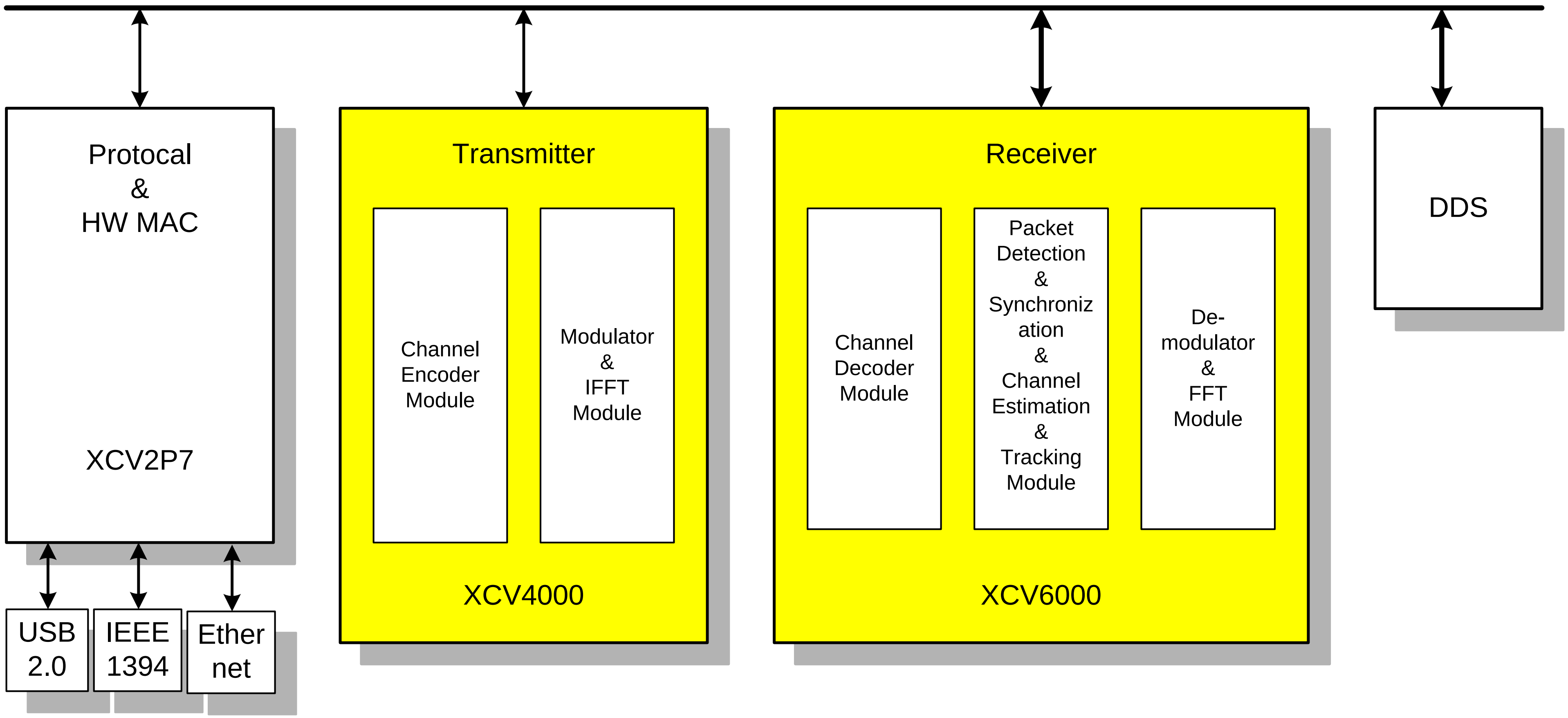
7. 本藍圖小組工作成員包括行政院科技顧問組、交通部電信總局、經濟部工業局、技術處、通推小組、工研院、資策會、中科院、電信國家型計畫及學者代表。

- 有關頻譜配置，林逢慶表示，爲藍圖工作小組成員之一的電信總局已成立「無線寬頻接取應用管理小組」，規劃初期開放兩段頻率供WiMAX之用。首先，2.5G-2.69GHz先規劃30MHz立即供實驗使用。由於該頻段未來仍將作商業用途，電信總局擬在2006年底前完成騰讓及未來發照準備，開放方式原則上將與國際接軌，比照美、加、星等國家的做法，傾向以拍賣方式爲主。其次，3.4-3.7GHz則可立即提供固網業者納爲「基地台後端接取使用（Backhaul）」或無線寬頻接取，建設最後一哩的無線用戶迴路，將採申請制，不用拍賣。
- 此外，林逢慶指出，由於部份WiMAX應用將有使用608-710MHz現有類比電視頻段（2008年開始回收）的需求，將請電信總局完成所需實驗頻段的整理，以滿足測試所需。至於大家關心的「M-Taiwan計畫」，經濟部工業局已將WiMAX列爲重要技術選項，並規劃從今年（2005）下半年起展開測試。另外，我國不但計劃在2006年建立WiMAX試驗場測，未來更將爭取WiMAX Forum的同意，在2007年之前建立WiMAX測試認證實驗室，以提供優質技術環境，促進相關產業發展。

資料來源: 行政院國家資訊通信發展推動(NICI)小組, 交通部電信總局

WiMAX Baseband processor & MAC Board of CSIST

- Block Diagram



What CSIST have done!

- CSIST's WiMAX Baseband processor is implemented O.K. in FPGA and is testing according to the main requirements of 802.16-2004 RCT
- CSIST's WiMAX MAC is implemented O.K. in imbedded OS system and compliant with the basic requirements of 802.16-2004
- Non-signaling Test setup for the radio performance of 802.16-2004 has been setup in CSIST
- RF and Baseband processor can be independently or integrally tested

Summary

- 手機PDA化,PDA手機化

敬　請　指　教　！