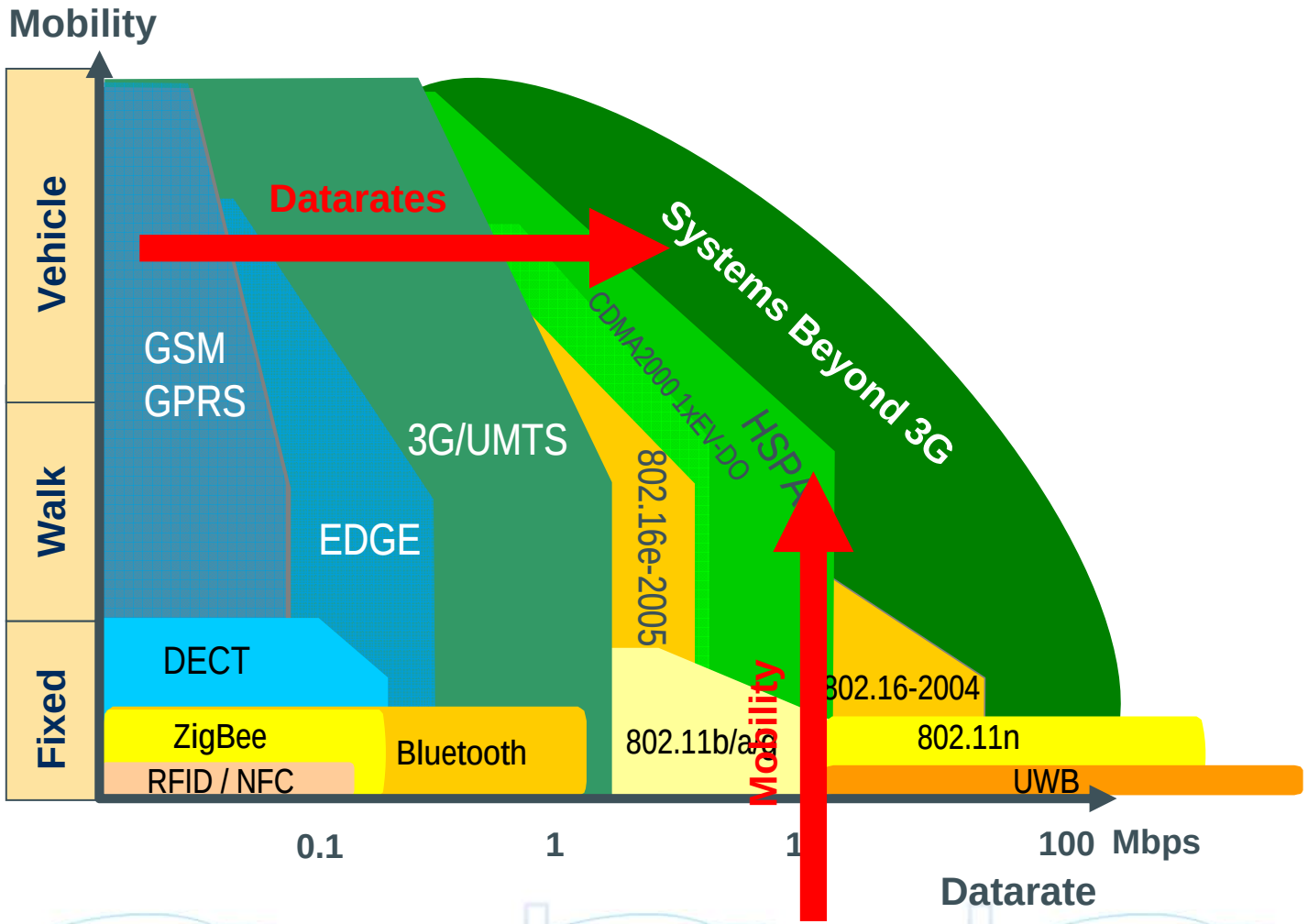
WiMAX Experiences and Visions

Dr. Wolfgang Wendler
wolfgang.wendler@rsd.rohde-schwarz.com

Introduction to the Market

Wireless Landscape

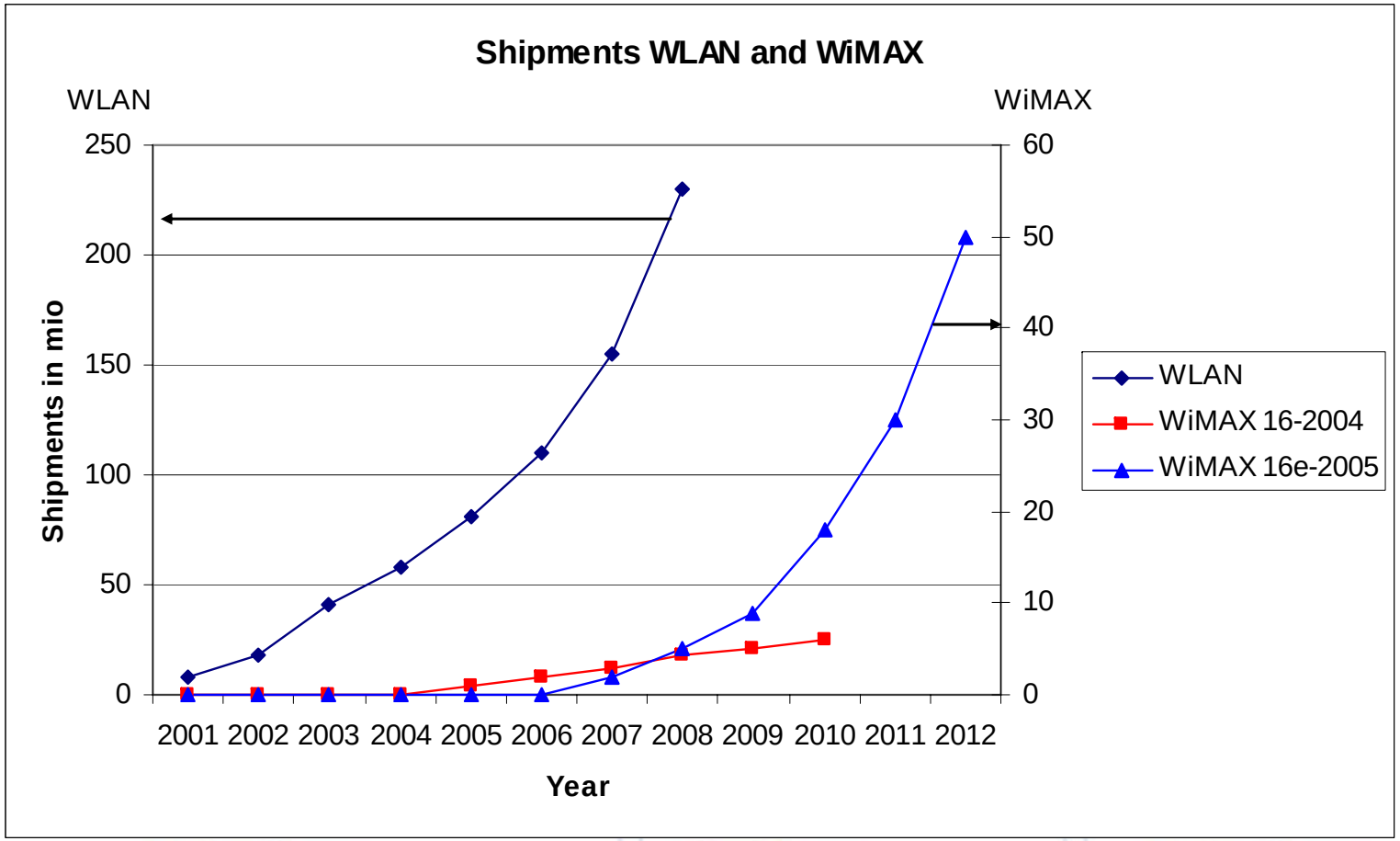


ROHDE&SCHWARZ

Applications

- WLL, FWA, Last Mile, Internet at Home (802.16-2004)
- Backhaul for WiMAX / WLAN Access Points, Microwave Link (802.16-2004)
- BWA, Mobile Internet, mobile Data services (802.16e-2005)
- WiMAX is technically a „4G System“

WiMAX Shipments vs. WLAN



ROHDE&SCHWARZ

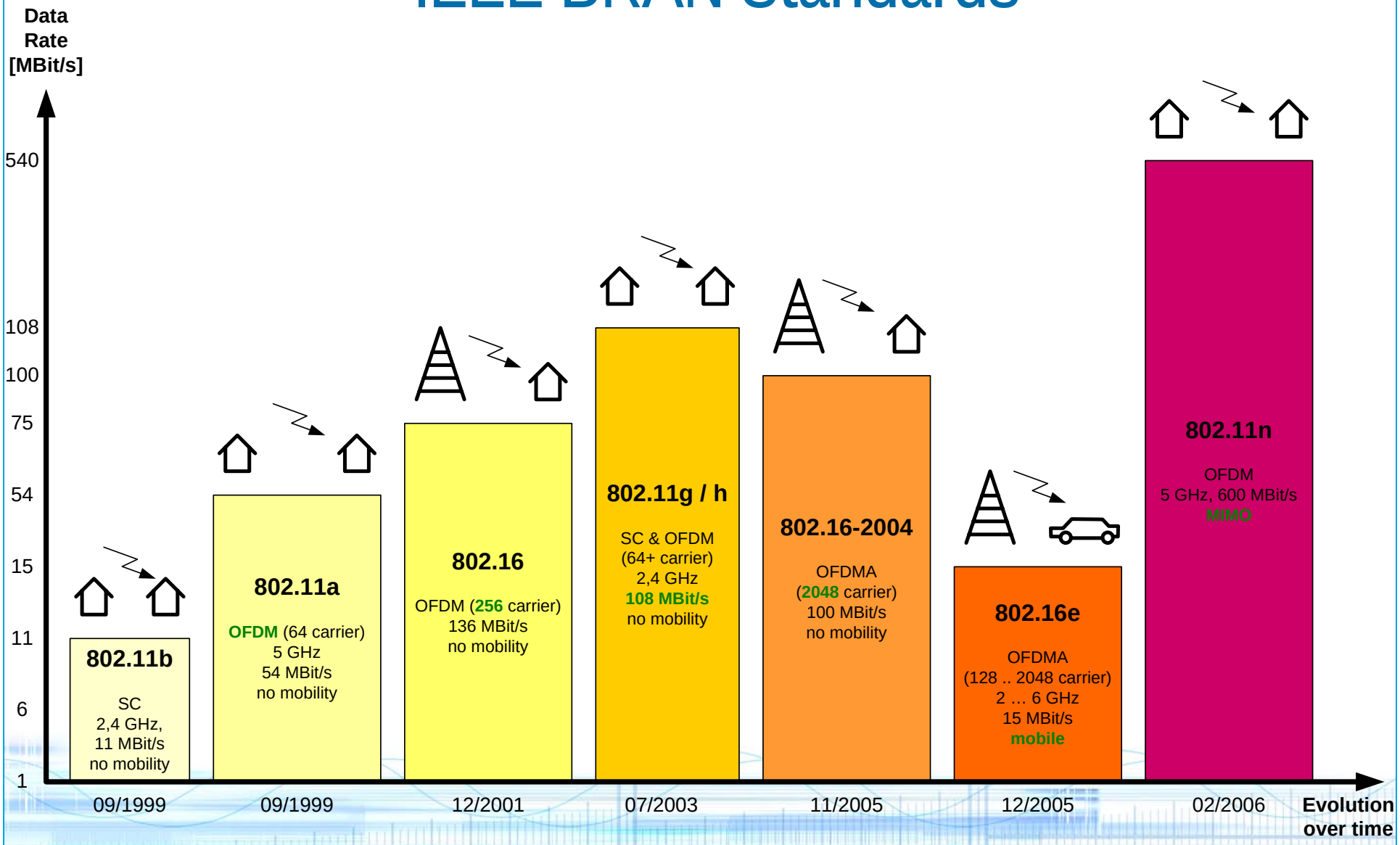
WiMAX Overview

IEEE standards for BRAN*

- IEEE 802.11™ (WiFi)
  - Short-range: ~100 m
  - Wireless Local Area Networks (WLAN)
  - Referred to as “Wi-Fi” for “Wi-Fi Alliance”
  - “**private**” character, no network operator necessary (No Handover, No QoS, PtP)
- IEEE 802.16 ™ WIMAX
  - Worldwide Interoperability of Microwave Access
  - Long-range: ~3 - 50 km
  - Wireless Metropolitan Area Networks (WMAN)
  - Korean (Samsung) approach: “WiBro” for “Wireless Broadband”
  - “**public**” character, i.e. network operator involved (Handover, QoS, PMP)

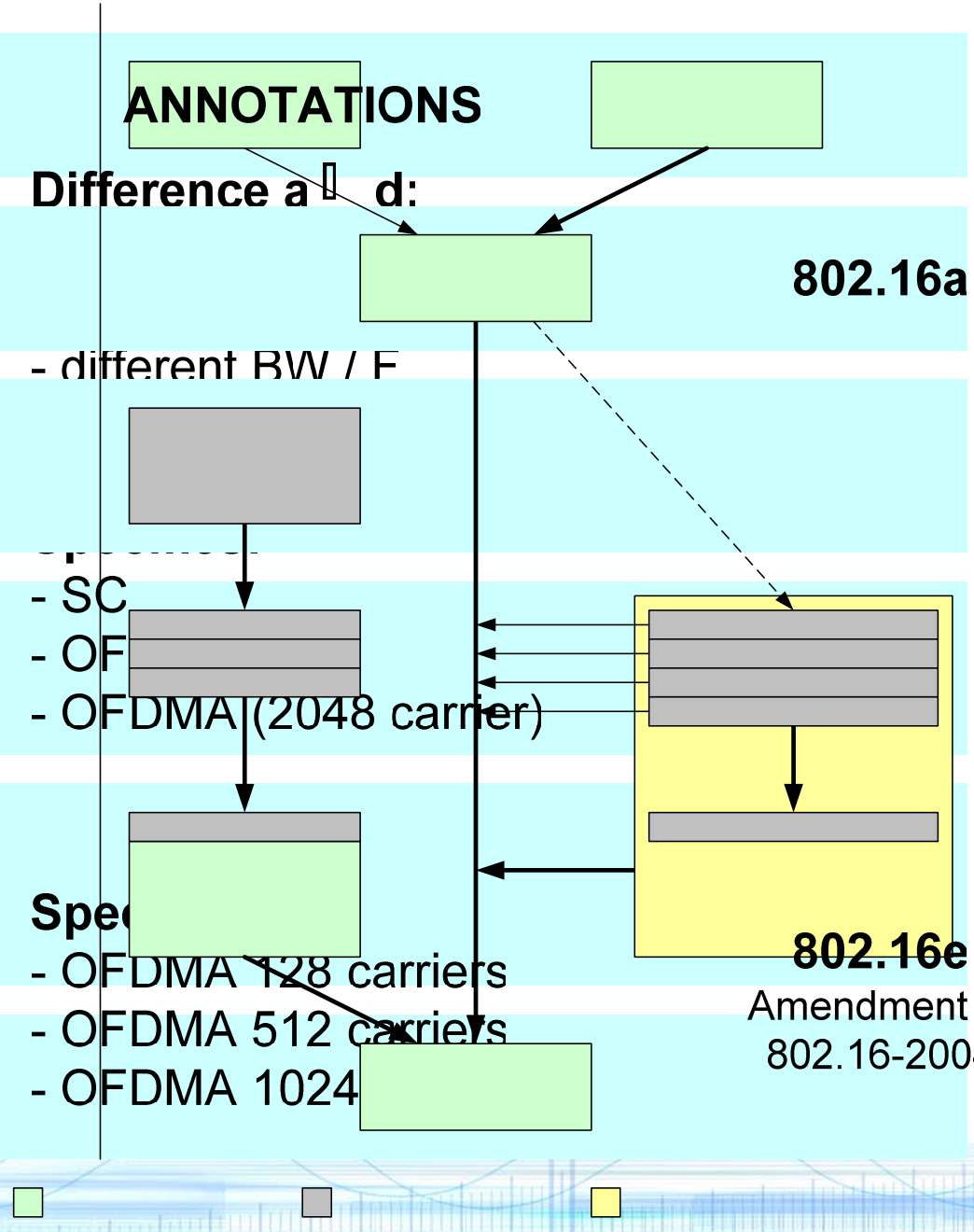
*Broadband Radio Access Network
PMP = Point to Multipoint
PtP = Point to Point

IEEE BRAN Standards



ROHDE&SCHWARZ

The WiMAX IEEE 802.16 Evolution



ROHDE&SCHWARZ

Non-IEEE BRAN approaches

- ETSI (European Telecom Standards Institute)
  - Over 50 liaisons between 802.16 and ETSI
  - ETSI HIPERMAN
    - Below 11 GHz
    - IEEE began first (802.16a)
    - Harmonized with 802.16 OFDM
  - Cooperation on conformance tests
- Korea: WIBro (Wireless Broadband)
  - Several liaisons with TTA (Telecommunication Technology Association)
  - WiBro “must comply with IEEE 802.16-2004 and IEEE 802.16e-2005 or later versions.”

Conformance Specifications IEEE 802.16-2004

802.16/Conf01
>10 GHz PICS
Aug '03

802.16/Conf02
> 10 GHz TSS&TP
Sep '03

802.16/Conf03
> 10 GHz RCT
Jun '04

Rohde & Schwarz has been selected as WiMAX RCT vendor by the WiMAX Forum

Conformance Specifications IEEE 802.16e-2005

P802.16/Cor1
<11 GHz PICS
Start May '04

PICT = Product Implementation Conformance Statement
TSS&TP = Test Suite Structure & Test Purpose
RCT = Radio Conformance Test

The fixed WiMAX IEEE 802.16-2004

- OFDM (WirelessMAN-OFDM)
  - 256-point FFT (ETSI HiperMAN)
- OFDMA (WirelessMAN-OFDMA)
  - 2048-point FFT
- Single-Carrier (WirelessMAN-SCa)
  - NLOS application

PHY

- More efficient IP and small packet transport
- Support for more users per channel
- Flexible QoS
- ARQ for link reliability
- Adaptive Antenna System (AAS) support
- Dynamic Frequency Selection (DFS) for unlicensed bands
- Support of Mesh Operation

MAC

mobile WiMAX IEEE 802.16e-2005 amendments

- Kept the Fixed PHYs but added “Scalable OFDMA”
  - 128, 512, 1024 and 2048 FFT
  - Automatic FFT size / bandwidth detection by SS
- Expanded MIMO Support

- H-ARQ (Hybrid Automatic Repeat Request)
- Handover Support
  - Make-Before-Break, Break-Before-Make
  - Macro-Diversity Handover
- Sleep Mode
- Scanning for neighbors
- Advertisement of neighborhood (Broadcasting of the neighbor cells)
- Efficient network re-entry process

WIMAX Operation Frequency Bands

- MDS (Multipoint Distribution System)
  - 2.15 – 2.16 GHz
- WCS (Wireless Communication Service)
  - 2.305 – 2.32 and 2.345 – 2.36 GHz (BW = 2.5 – 15 MHz , F_s = 2.88 – 17.28 MHz)
- MMDS (Multichannel Multipoint Distribution Service)
  - 2.500 – 2.686 GHz (BW = 1.5 – 24 MHz , F_s = 1.72 – 27.52 MHz)
- ETSI (European Telecommunications Standards Institute)
  - 3.41 – 4.2 and 10 – 10.680 GHz (BW = 1.75 – 28 MHz, F_s = 2 – 32 MHz)
- U-NII (Unlicensed National Information Infrastructure)
  - 5.150 – 5.350 and 5.750 – 5.825 GHz (BW 10 – 20 MHz , F_s = 11.52 – 23.04 MHz)

3G to 4G capabilities

	Rates per cell	Rates per subscriber	Latency	Deployment expected	Application
3G	10 Mbps (5 MHz BW)	0.5 Mbps	> 100 ms	2006	Basic Multimedia
16e	75 Mbps (20 MHz BW)	5-10 Mbps	< 100 ms	2007	Broadband Multimedia „quadruple play“
LTE	100 Mbps (20 MHz BW)	10 Mbps	10 ms	2008	Broadband Multimedia „quadruple play“
4G	1 Gbps (100 MHz BW)	100 Mbps	< 10 ms	2012	Full broadband High quality Multimedia

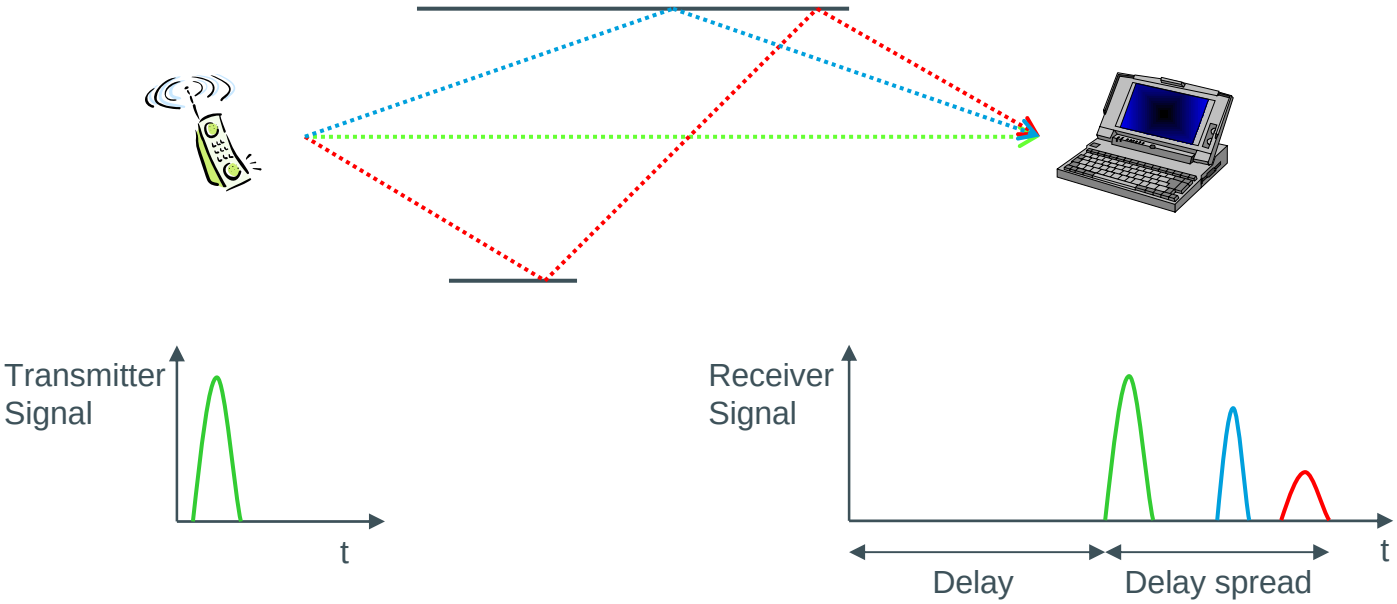
Quadruple play = Telephony, Internet, Video, Mobility
LTE = Long Term Evolution = E-UTRAN (in LTE 3GPP moves to OFDM)
Latency = Round Trip Time (Time from a Request for a Package to RNC to received Package)

Physical Layer in Detail

OFDM

Why Orthogonal Frequency Division Multiplexing ?

Problem of multi-path interference with one carrier:

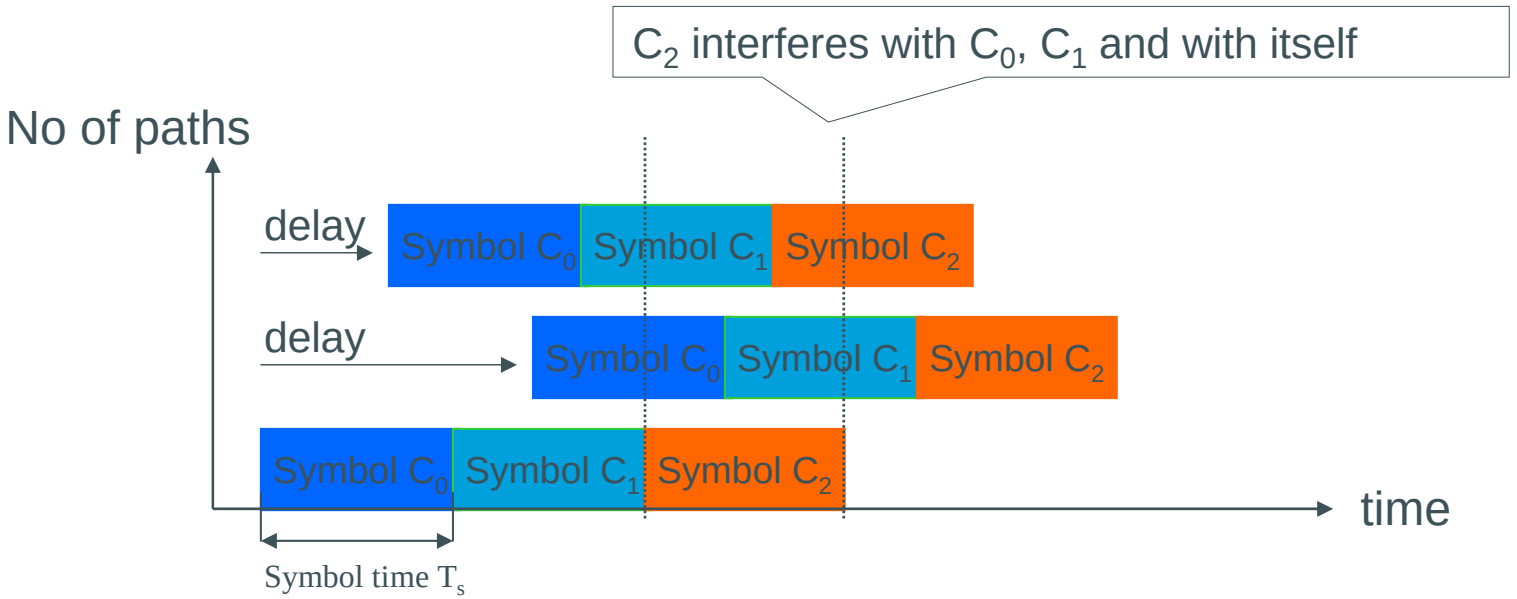


Multi-path interference when symbol duration shorter than delay spread

OFDM

Inter-symbol interference

Multipath interference in a high rate single-carrier system

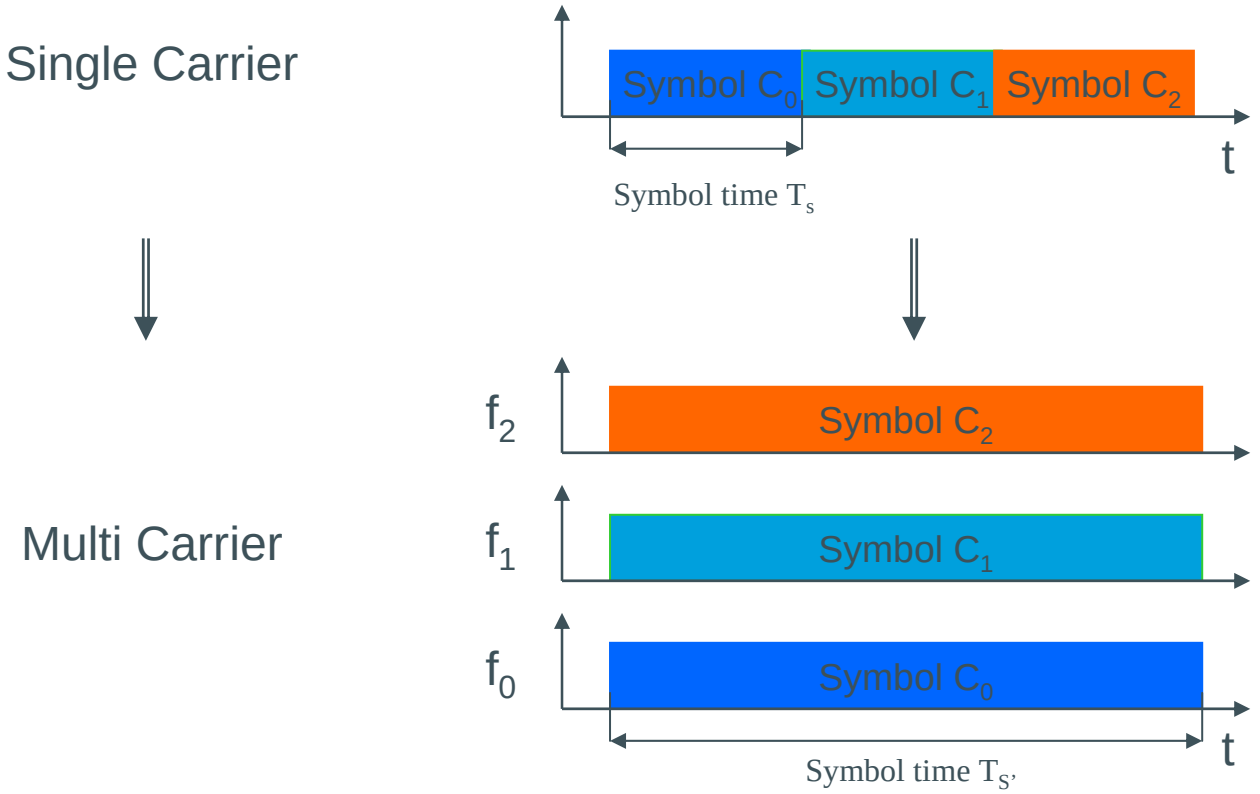


Delay in the different paths causes interference

ROHDE&SCHWARZ

OFDM

Solution to this problem of inter-symbol interference

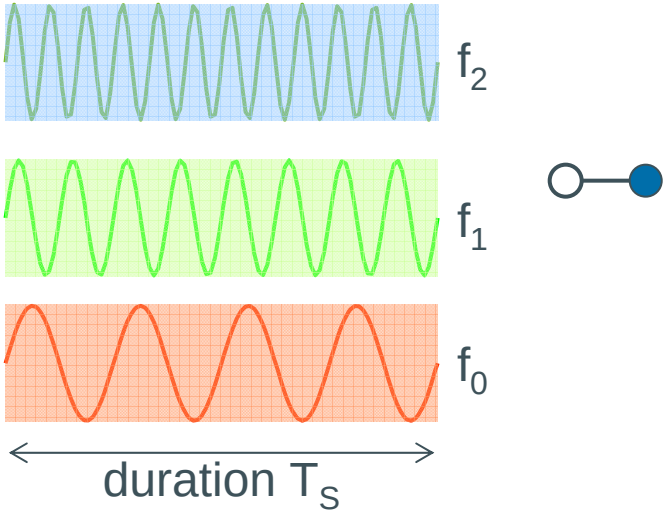


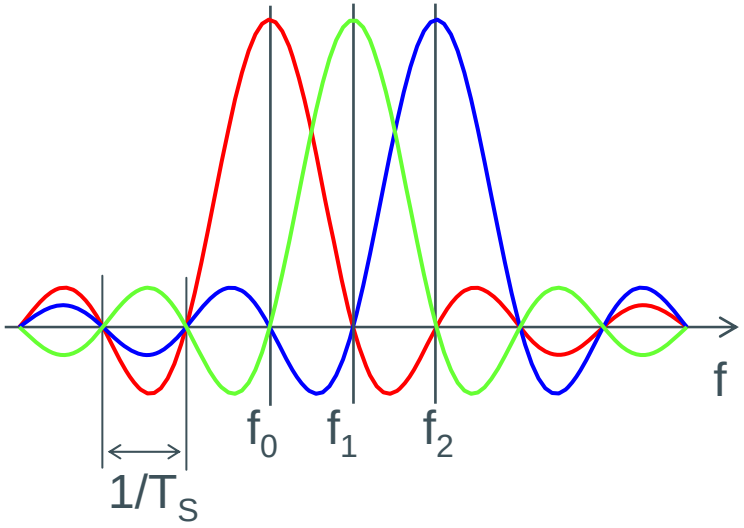
Due to the longer transmission time $T_{S'}$ multi-path interference is reduced

ROHDE&SCHWARZ

OFDM

Principle of orthogonality of frequency





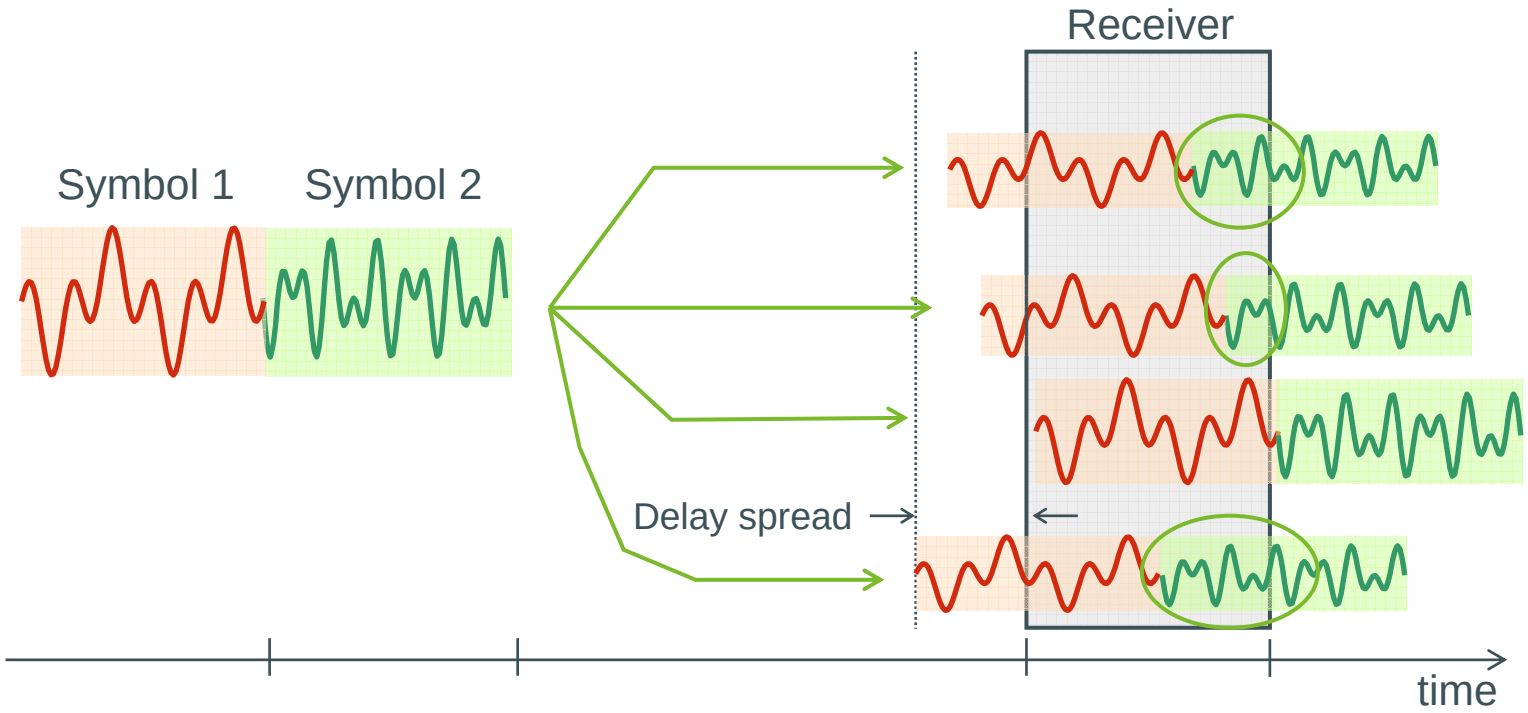
Characteristics of orthogonal waveforms:

- $f_{Carrier} = f_0 + n/T_S$ where n is an integer
- The maximum of one carrier is at the zero crossings of all others
- The cross correlation of sine waves is zero, if they are sampled at the correct location
- This is obtained by the following setting

$\Delta f = 1/T_S$, therefore: $f_n = n \times \Delta f$

OFDM

Suppressing multipath interference

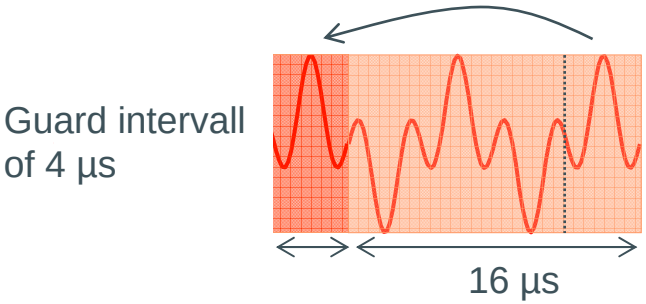


Problem:

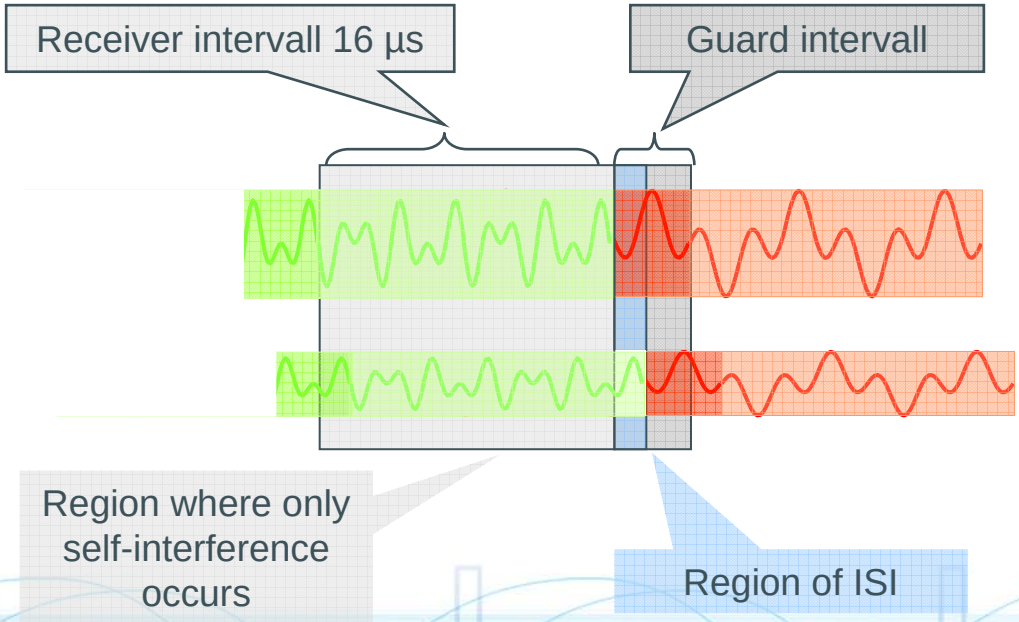
Due to different paths to the receiver, the different OFDM symbols **would** interfere with themselves or each other

OFDM

Suppressing multipath interference



By inserting a guard period (cyclic extension) the multi-path interference can be reduced



WiMAX 802.16-2004 OFDM and WLAN 802.11a/g OFDM

Parameter	WiMAX	WLAN
FFT length	256	64
Number of carriers used	200	52
Number of pilot carriers	8	4
Duplex	FDD/TDD	TDD
Bandwidth	Scalable from 1.25 MHz up to 28 MHz	Fixed 20 MHz Turbo mode 40 MHz

WiMAX 802.16-2004 OFDM and WLAN 802.11a/g OFDM

Parameter	WiMAX	WLAN
Modulation formats	BPSK, QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM
Guard period	¼, 1/8, 1/16, 1/32	Fixed
MiMo Adaptive antenna systems	Yes	No scheduled for 802.11n
Sub channalization	Yes	No

802.16-2004 Rev. d: OFDM Mode

OFDM parameter:

- FFT Size: 256
- Used Carriers: 200
- Pilots: 8
- Guard Carriers: 28 left, 27 right
- Channel BW: 1.25 – 28 MHz

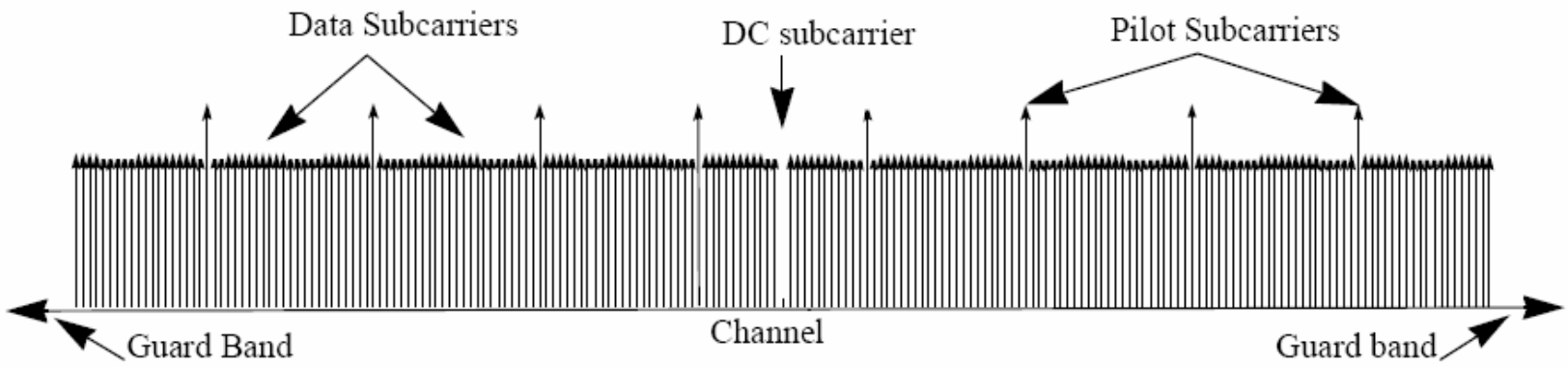
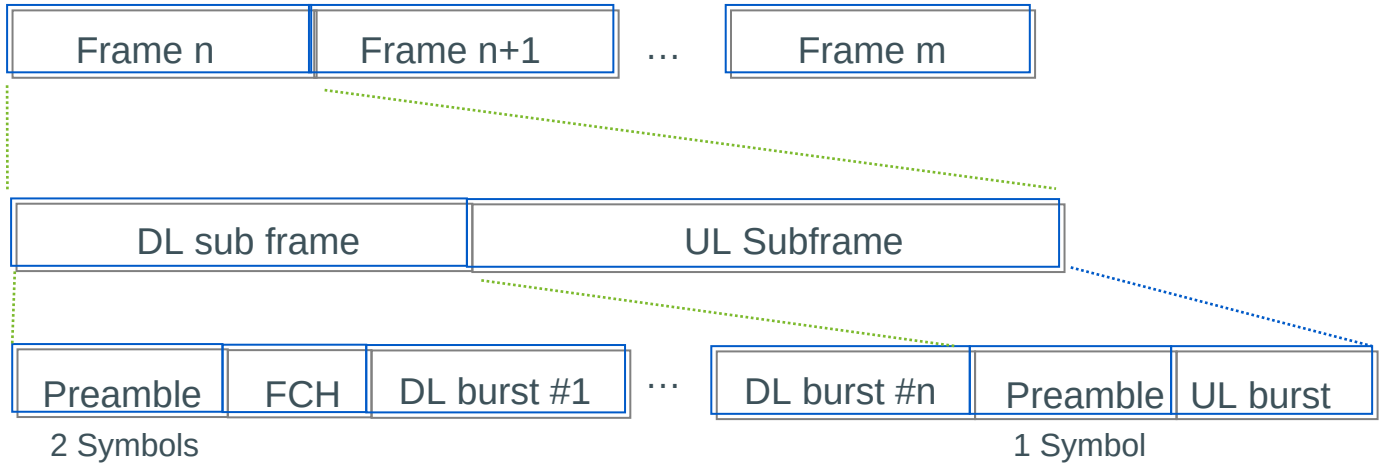
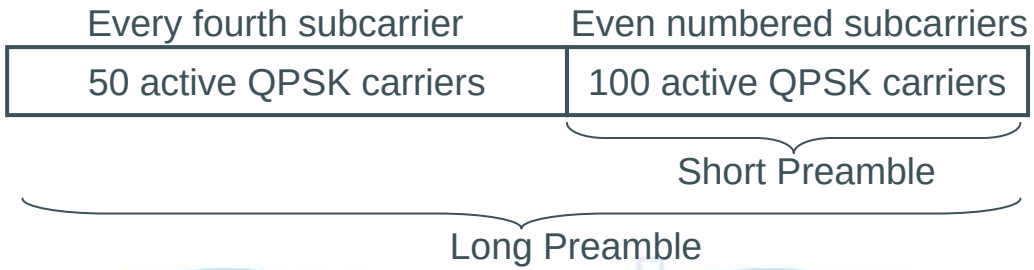


Figure 196—OFDM frequency description

Frame Structure of WiMAX 802.16-2004 OFDM



Preamble definition



WiMAX 802.16-2004 OFDMA

Parameter:

- FFT Size: 2048
- Used Carriers: variable 1681- 1728
- Pilots: diff. sets (const. + variable) ~ 192
- Guard Carriers: variable 159-184 left, 160-183 right
- Channel BW: 1.25 – 28 MHz

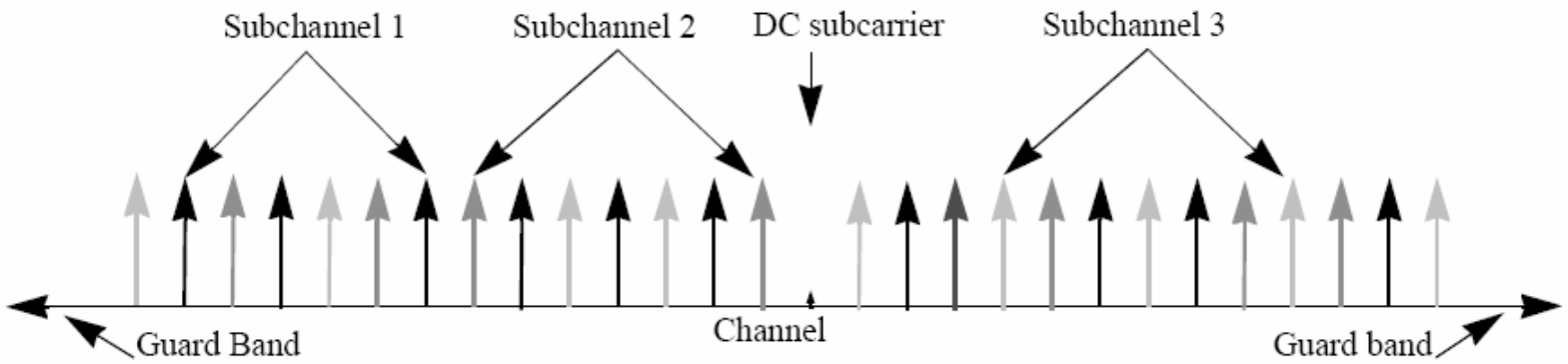
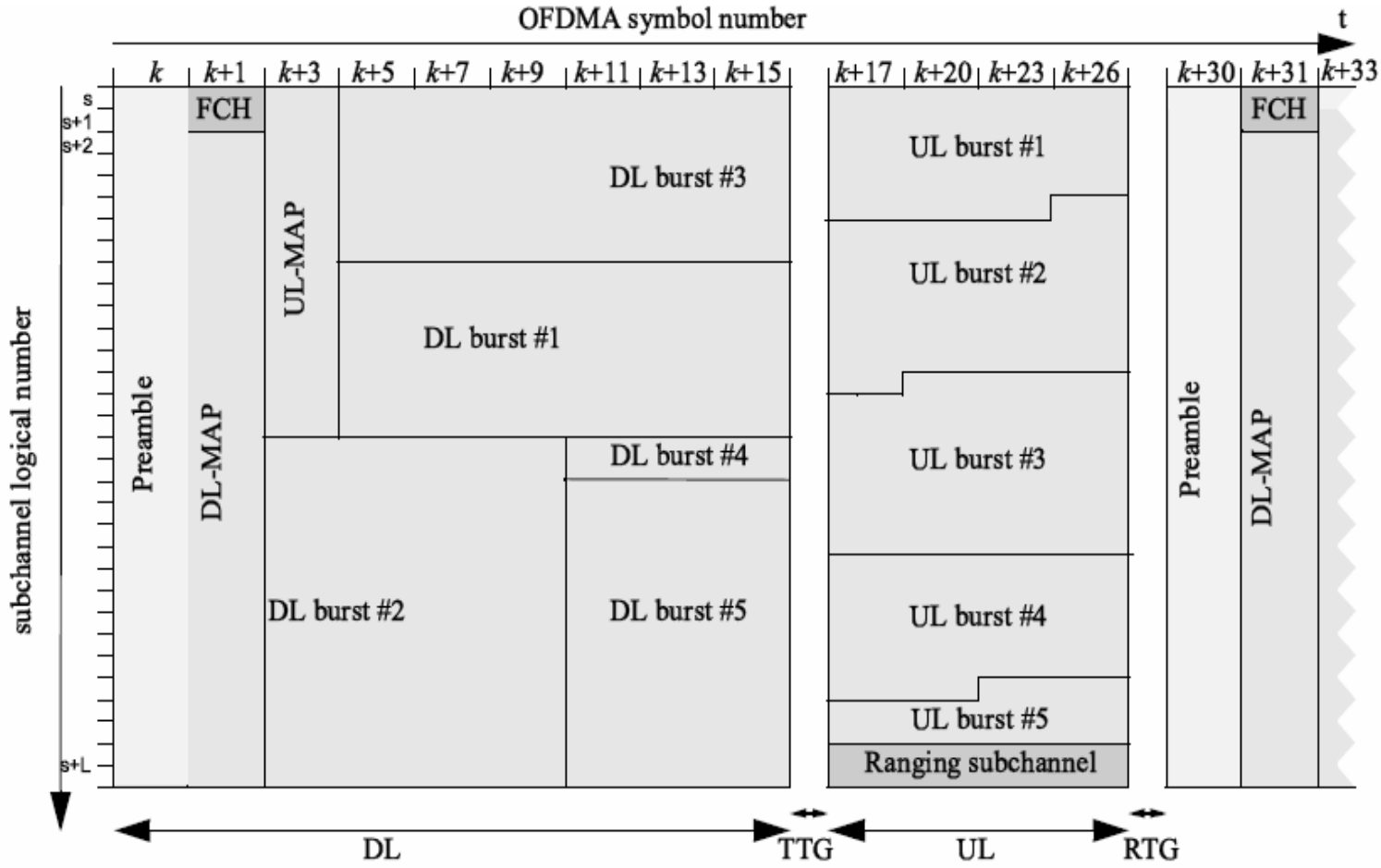


Figure 214—OFDMA frequency description (3 channel schematic example)

WiMAX 802.16-2004 OFDMA



ROHDE&SCHWARZ

MIMO Standardisation in WiMAX

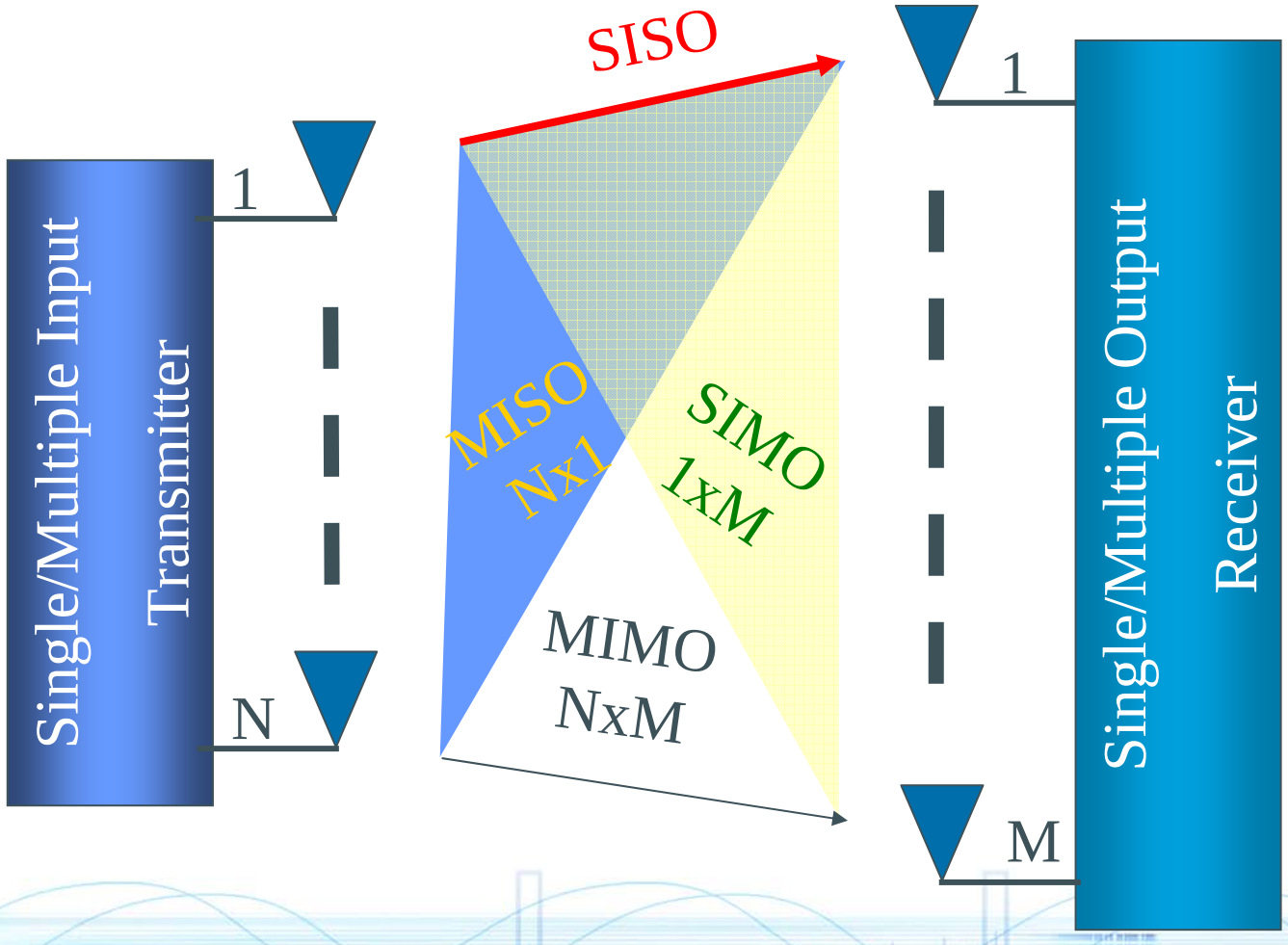
802.16-2004

- WirelessMAN-SC
- WirelessMAN-SCa
- Wireless-MAN-OFDM MISO
- Wireless-MAN-OFDMA MIMO
- Wireless-HUMAN

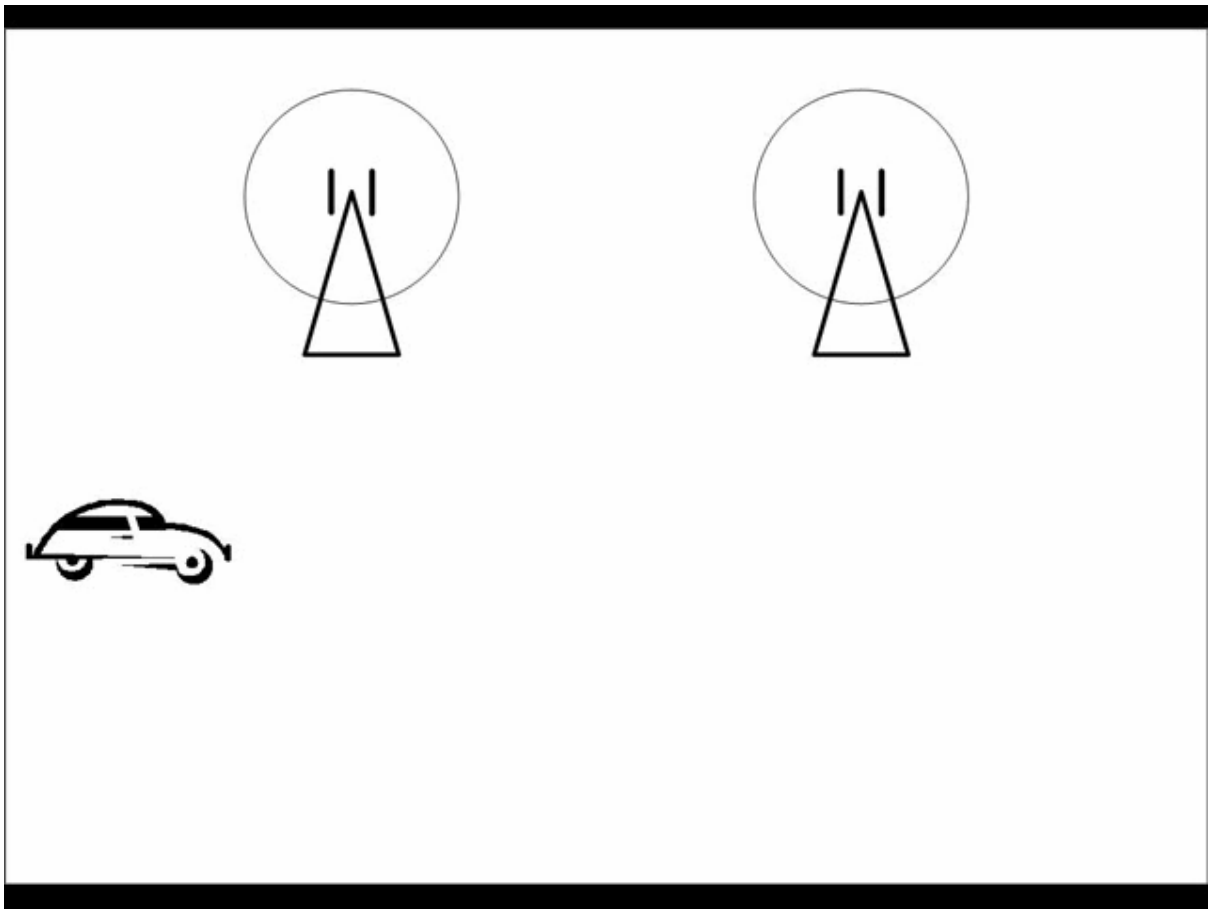
802.16e-2005

- WirelessMAN-SCa
- Wireless-MAN-OFDM
- Wireless-MAN-OFDMA MIMO

What is MIMO?

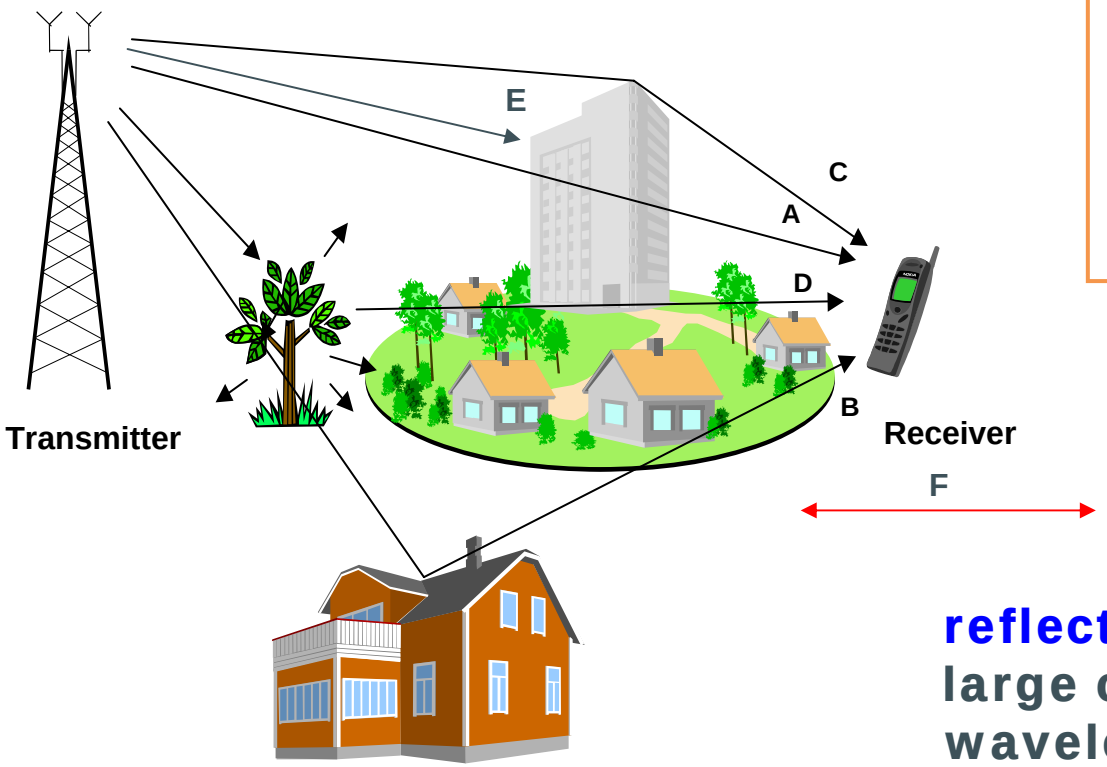

SISO
1
Single/Multiple Input
Transmitter
N
MISO
Nx1
SIMO
1xM
MIMO
NxM
1
M
Single/Multiple Output
Receiver

Beamforming



ROHDE&SCHWARZ

Fading



A: free space
B: reflection
C: diffraction
D: scattering
E: shadowing (birth death)
F: doppler

reflection: object is large compared to wavelength

scattering: object is small or its surface irregular

Solutions of Rohde & Schwarz

Signal Generation

The SMx Family of Vector Signal Generators:

SMU 200A

SMJ 100A

SMATE 200A

covered by **Option –K49**

IEEE 802.16-2004 Rev. d
OFDM/OFDMA
IEEE 802.16e-2005
OFDM/OFDMA

SMU200A - Configuration

SMU200A
1141.2005.02
Vector Signal Generator

- **SMU-B102** 1141.8503.02 — 100 kHz to 2.2 GHz
- **SMU-B103** 1141.8603.02 — 100 kHz to 3 GHz
- **SMU-B104** 1141.8703.02 — 100 kHz to 4 GHz
- **SMU-B106** 1141.8803.02 — 100 kHz to 6 GHz

SMU-B13 2x
1141.8003.02
Baseband Main Module

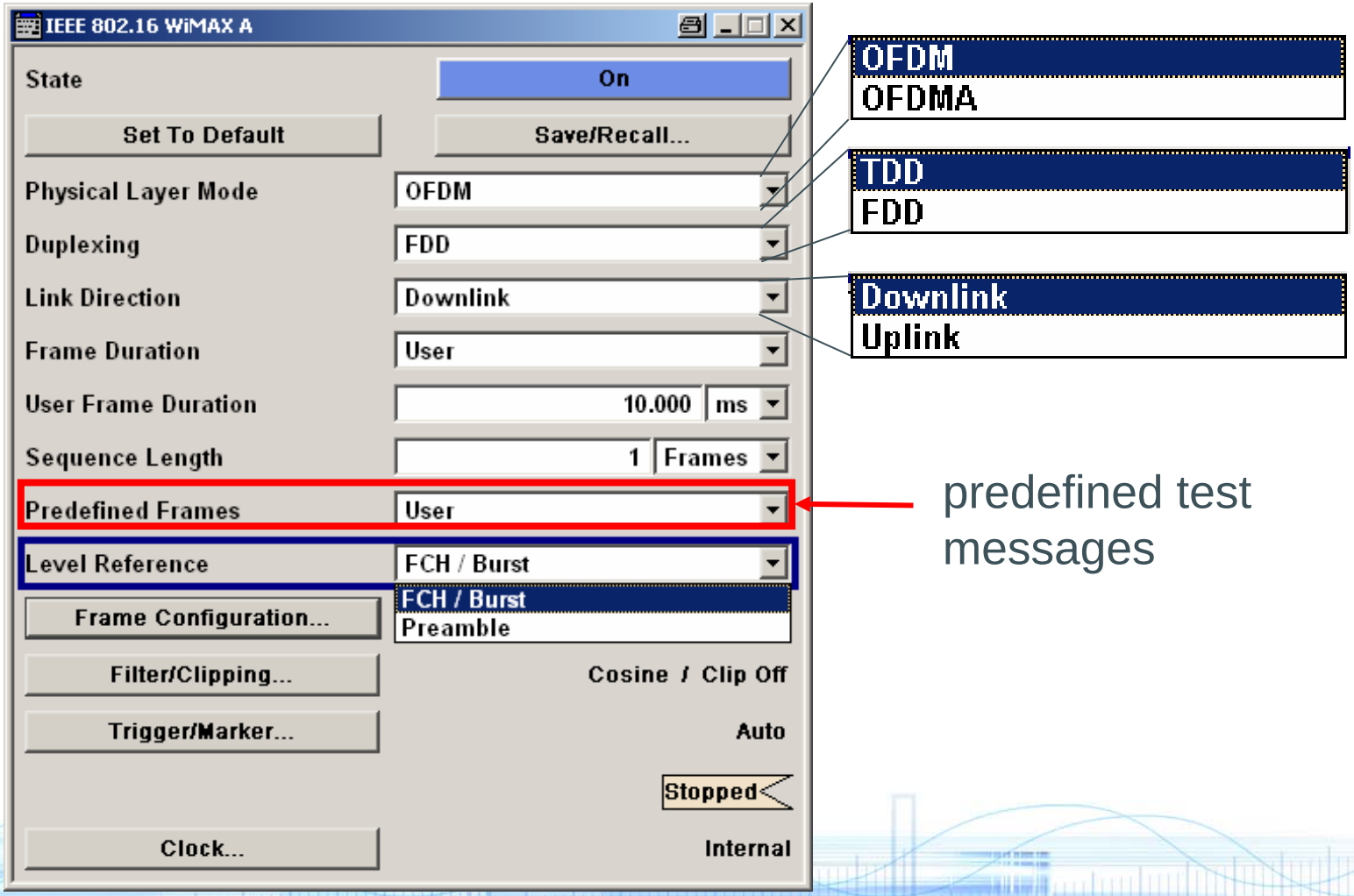
- **SMU-B10** 2x — 1141.7007.02 — Baseband Gen. with ARB (64 MSamples) and Digital Mod.
- **SMU-B11** 2x — 1141.7007.02 — Baseband Gen. with ARB (16 MSamples) and Digital Mod.
- **SMU-B14** 1160.1800.02 — Fading Simulator
  - **SMU-B15** 1160.2288.02 — Fading Simulator Extension
  - **SMU-K71** 1160.9201.02 — Dynamic Fading and Enhanced Resolution
  - **SMU-K71** 1160.9201.02 — Dynamic Fading and Enhanced Resolution

SMU-K49 2x
1161.0366.02
Digital Standard IEEE 802.16

802.16 -2004 OFDM Receiver Tests

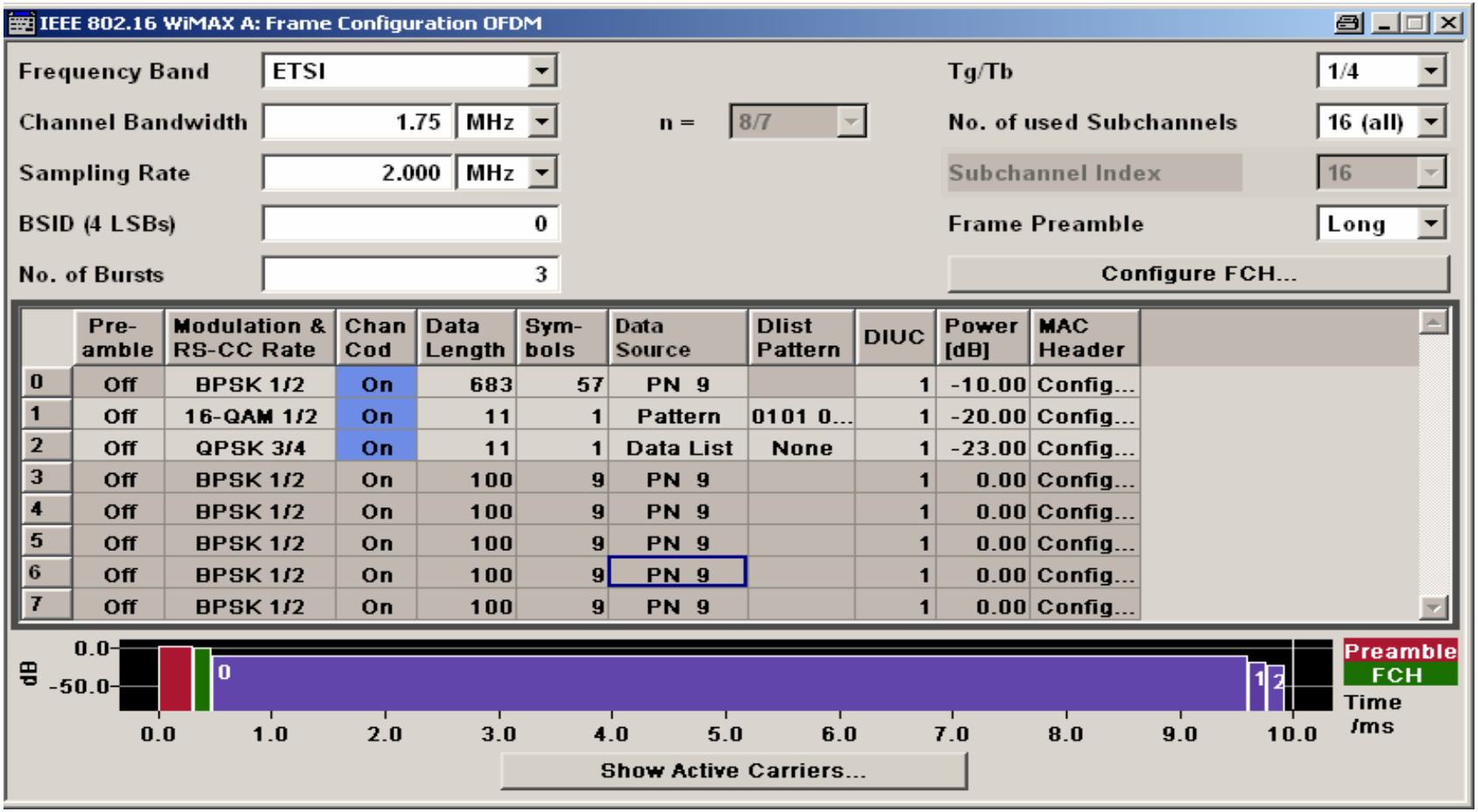
- 8.3.11.1 Receiver sensitivity
- 8.3.11.2 Receiver adjacent and alternate channel rejection
- 8.3.11.3 Receiver maximum input signal
- 8.3.11.4 Receiver maximum tolerable signal
- 8.3.11.5 Receiver image rejection
- 8.3.12 Frequency and Timing

WiMAX in the SMU Family Configuration Panel (FDD, DL)



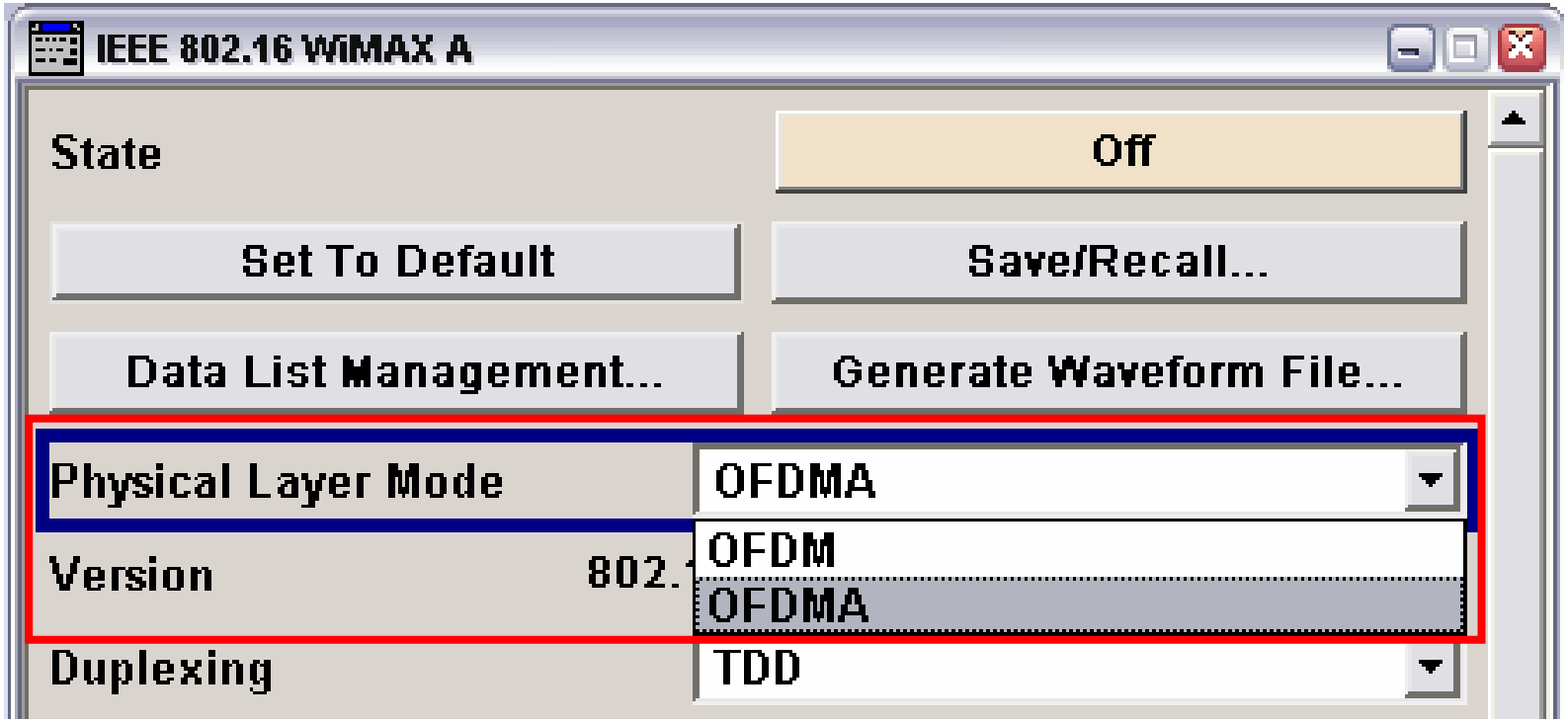
ROHDE&SCHWARZ

OFDM - Frame Configuration



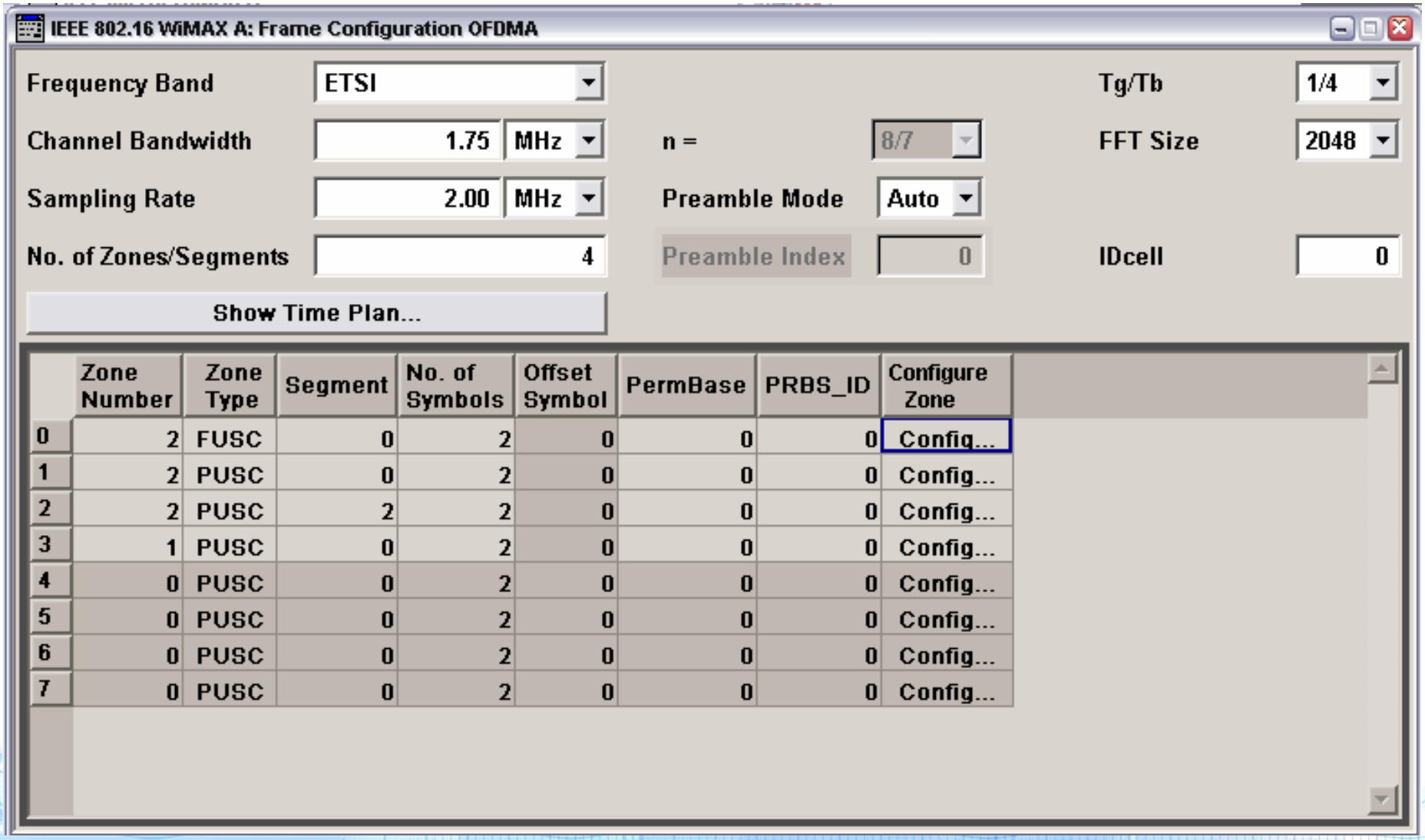
ROHDE&SCHWARZ

Setting OFDM or OFDMA



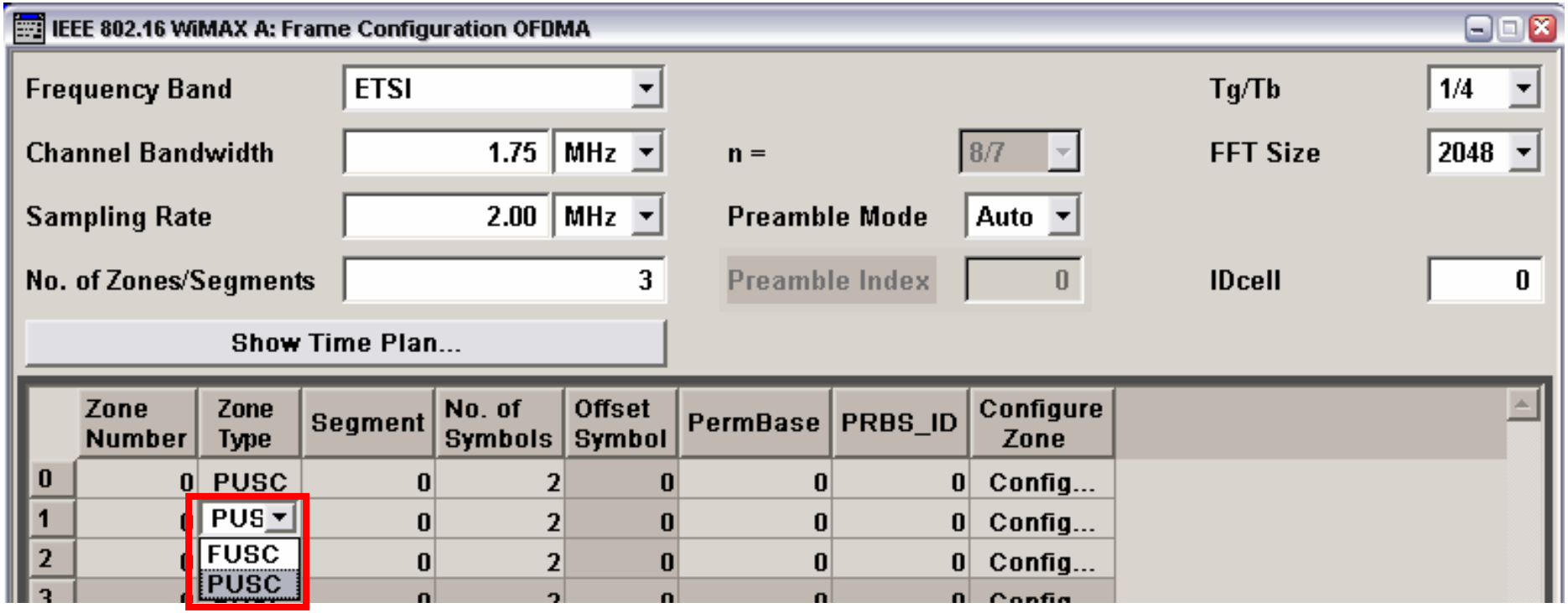
ROHDE&SCHWARZ

OFDMA – Frame Configuration



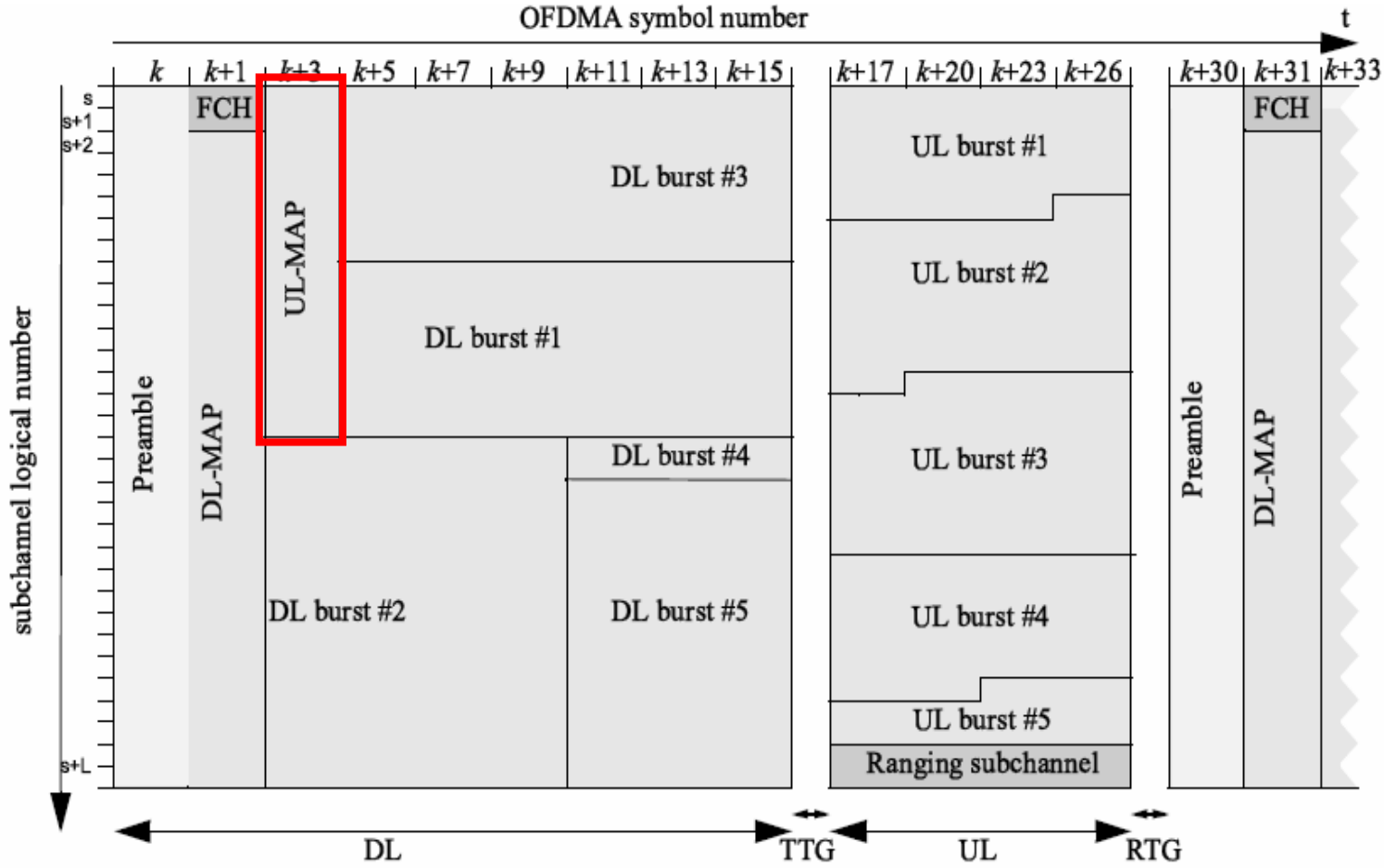
	Zone Number	Zone Type	Segment	No. of Symbols	Offset Symbol	PermBase	PRBS_ID	Configure Zone
0	2	FUSC	0	2	0	0	0	Config...
1	2	PUSC	0	2	0	0	0	Config...
2	2	PUSC	2	2	0	0	0	Config...
3	1	PUSC	0	2	0	0	0	Config...
4	0	PUSC	0	2	0	0	0	Config...
5	0	PUSC	0	2	0	0	0	Config...
6	0	PUSC	0	2	0	0	0	Config...
7	0	PUSC	0	2	0	0	0	Config...

PUSC and FUSC



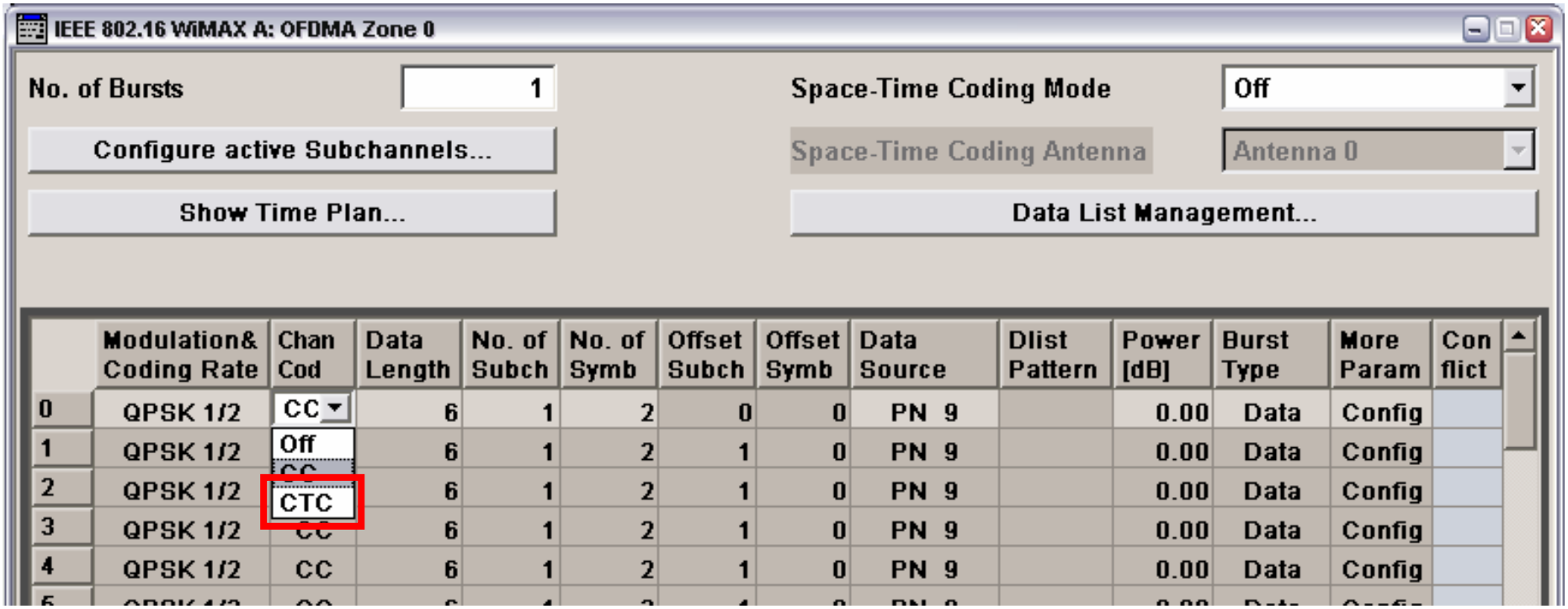
- FUSC = Fully Utilized Subchannel Allocation
  - all subchannels are used for transmission
- PUSC = Partially Utilized Subchannel Allocation
  - only a part of the subchannels are used for transmission

Automatic UL Map generation



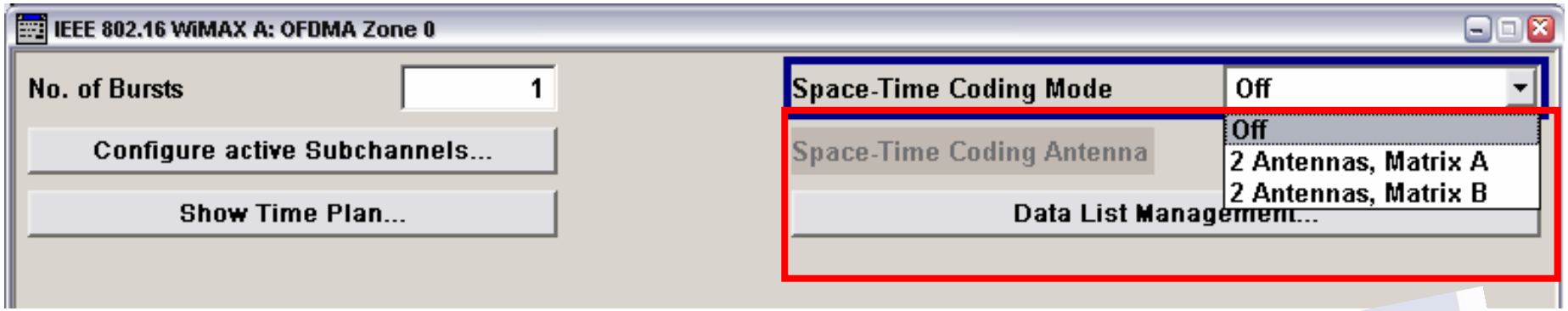
- For generating the Downlink signal you need to know the Uplink map

Convolution Turbo Coding

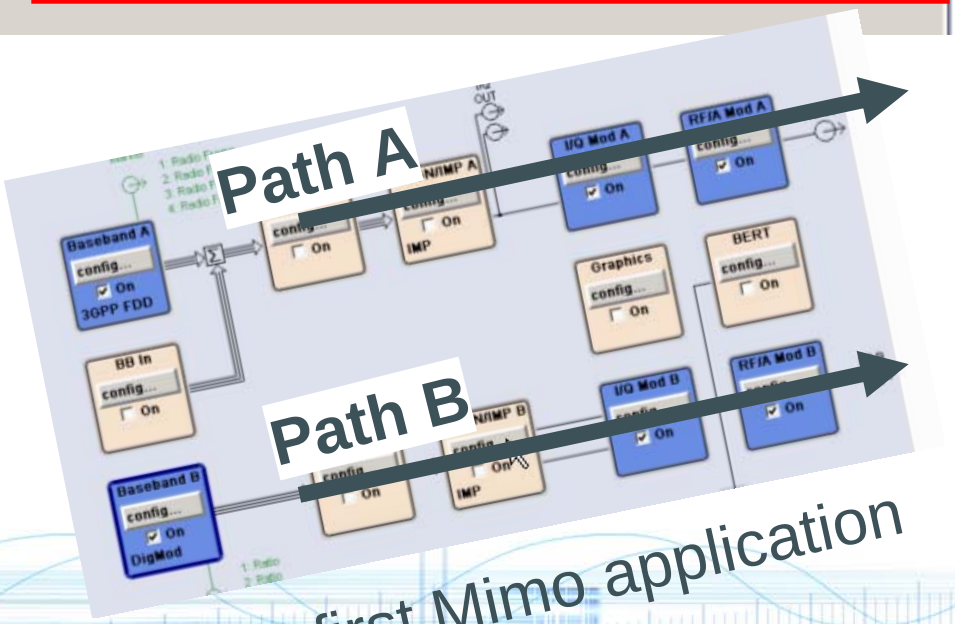


- CTC: error correction coding, just like CC

Space time coding



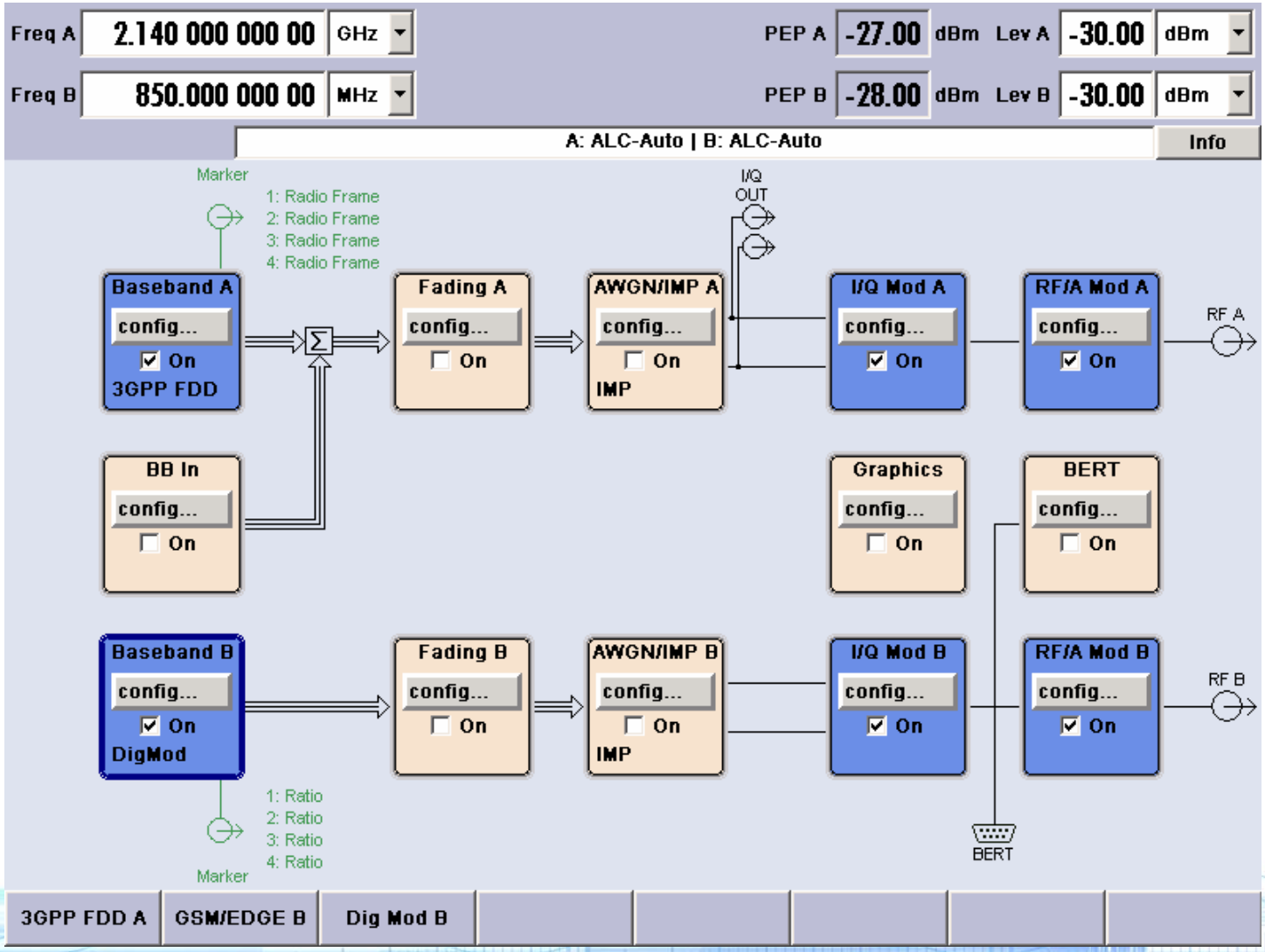
- Transmit Dicersity



first Mimo application

ROHDE&SCHWARZ

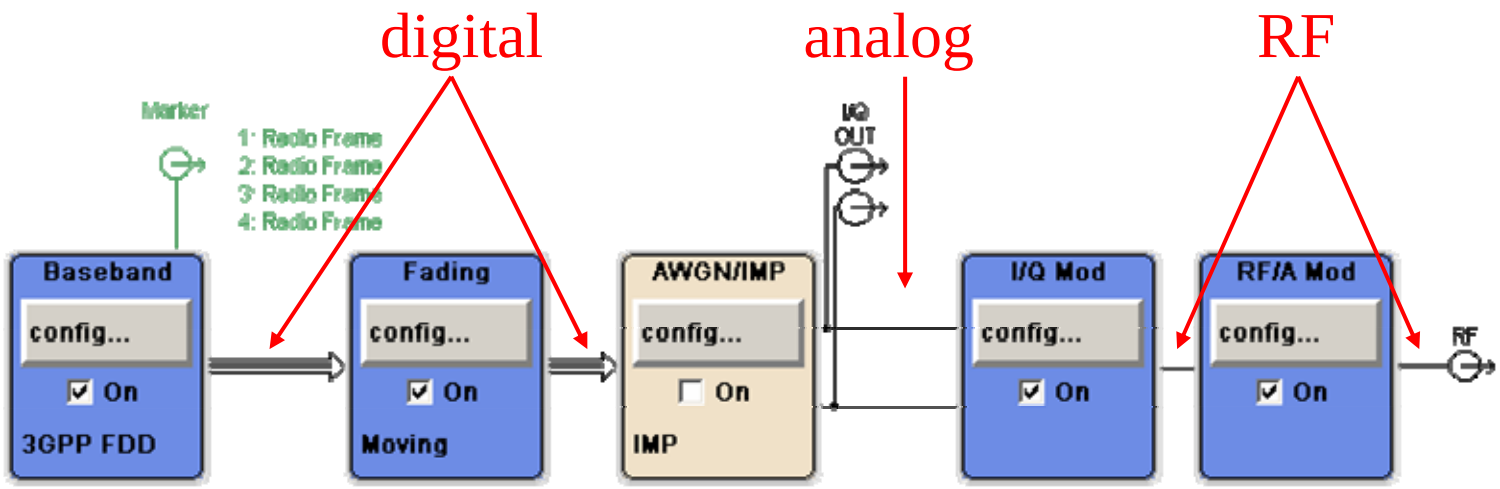
Fading with R&S SMU200A



ROHDE&SCHWARZ

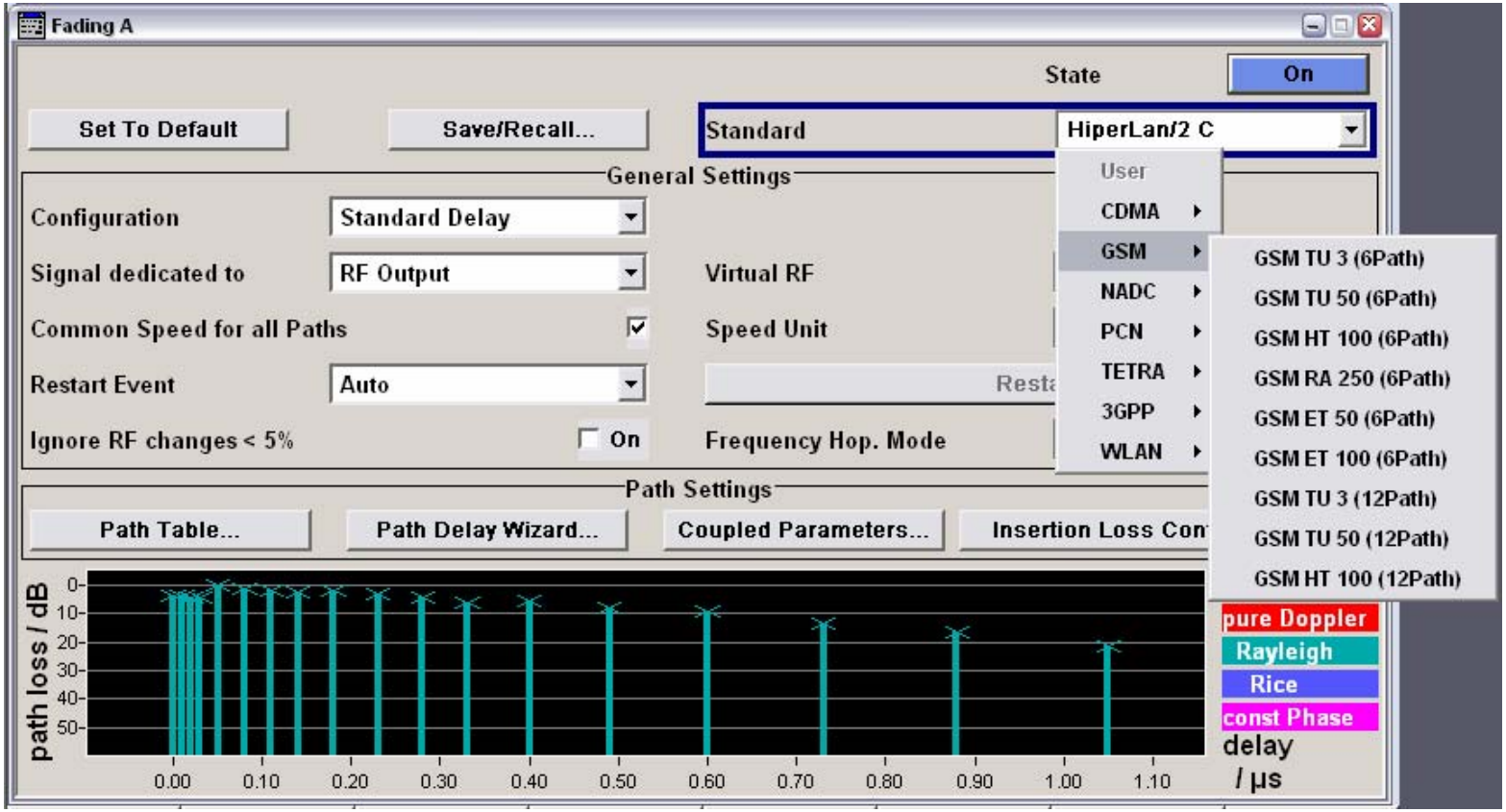
Fading Concept

Modern Baseband Fader – Example SMU200A



- Low price
- Broad frequency band
- No conversion loss (pure digital 18 bit)
- Small size (one box solution, even for dual channel fading)

Fading for WiMAX



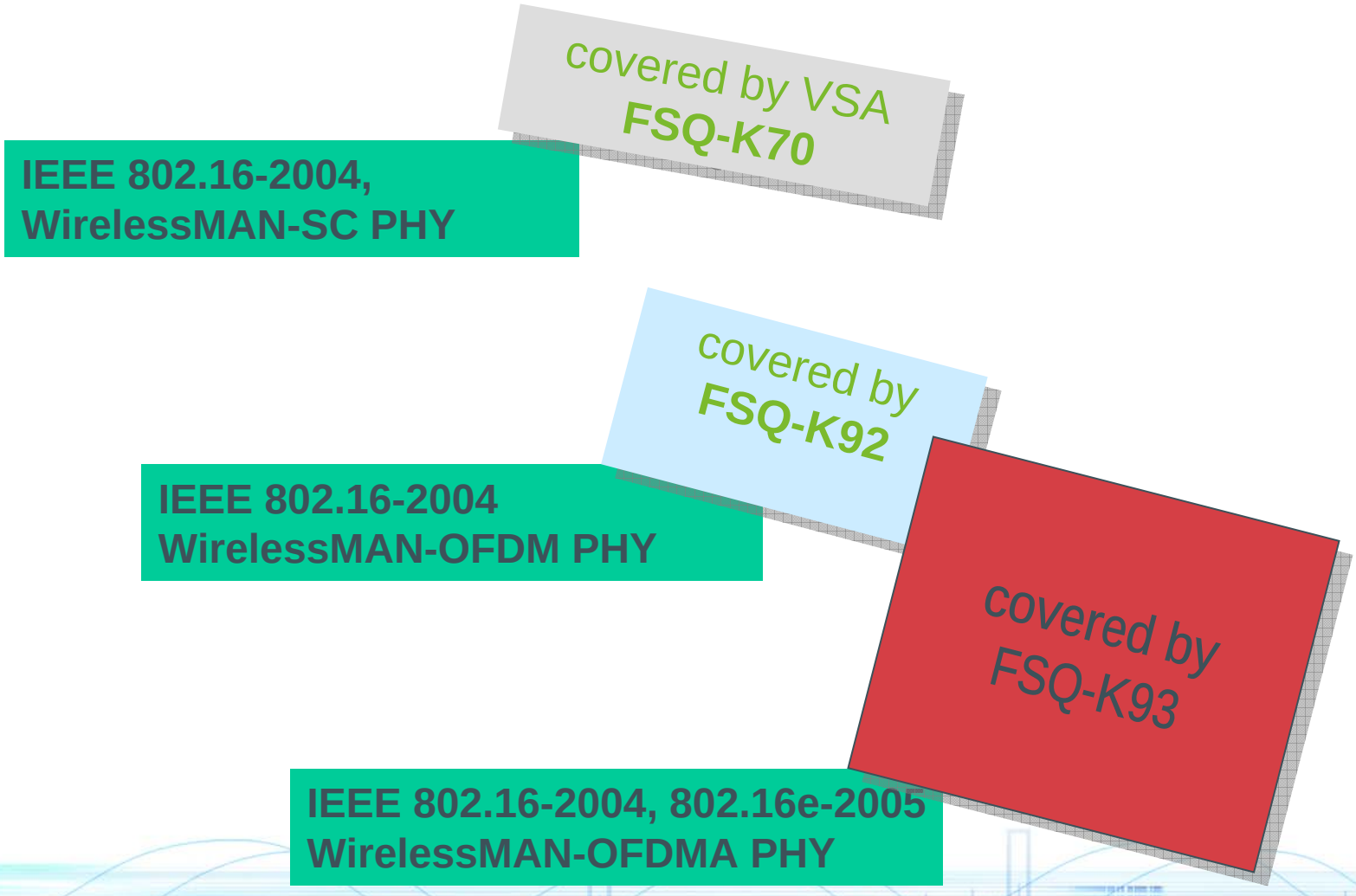
- Besides others GSM and 3GPP scenarios are available.

ROHDE&SCHWARZ

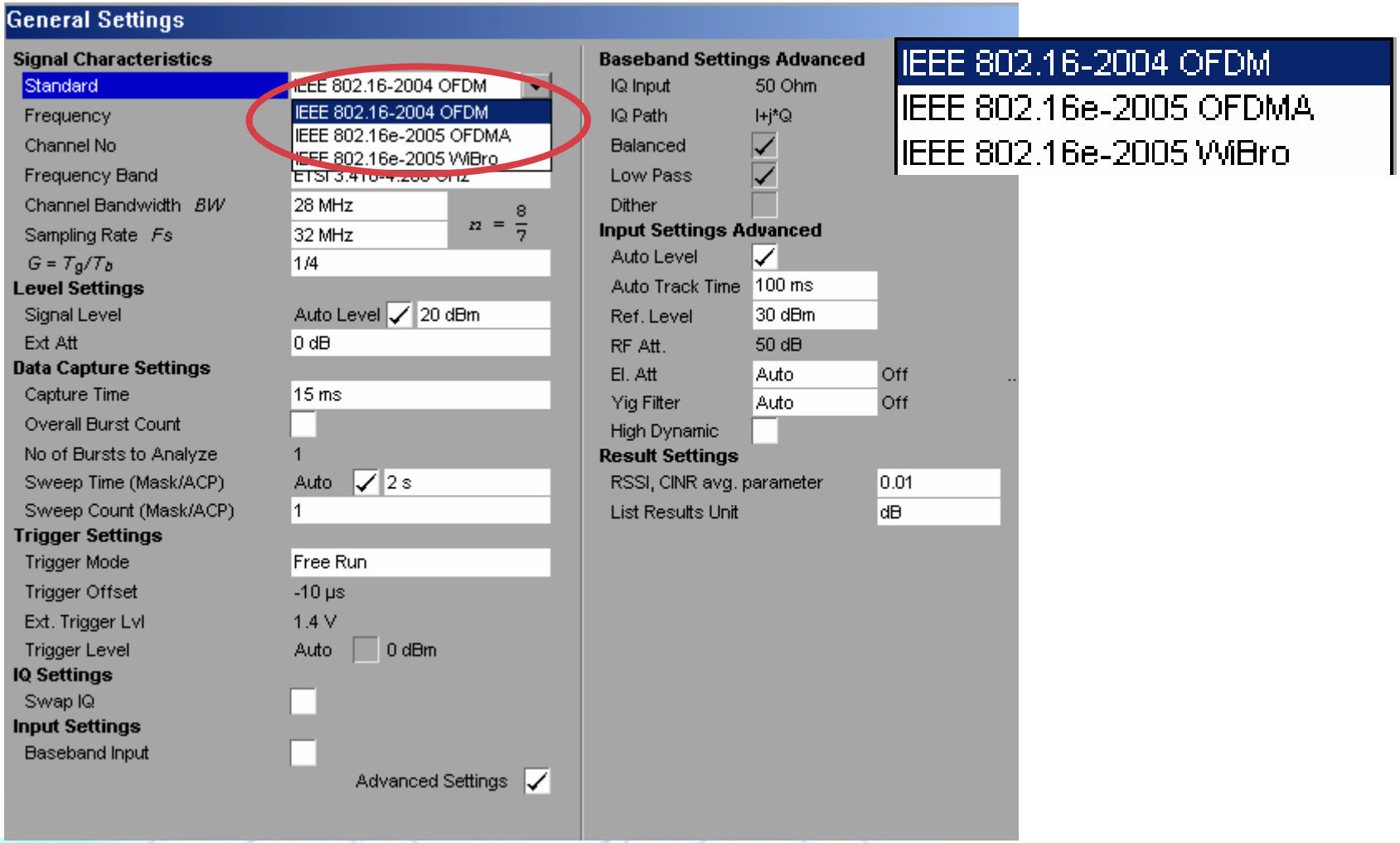
802.16 -2004 OFDM Transmitter Tests

- 8.3.9 Channel quality measurements (e.g. CINR)
- 8.3.10.1 Transmit power level
- 8.3.10.1.1 Transmitter spectral flatness
- 8.3.10.1.2 Transmitter constellation error
- 8.3.10.2 Transmitter channel bandwidth and RF carrier frequency
- 8.3.12 Frequency and Timing

Signal Analysis of WIMAX Signals



Signal Analysis FSQ-K92/K93 Settings



ROHDE&SCHWARZ

Application Firmware FSQ-K92/K93

Scalar Results:

- EVM Measurements
  - EVM all Carriers
  - EVM Data Carriers only
  - EVM Pilot Carriers
- IQ constellation
  - IQ Offset
  - Gain Imbalance
  - Quadrature Offset
- Power Measurement
  - Power Burst
  - Crest Factor
- Symbol Clock Error
- CINR Measurement

Scalar Results

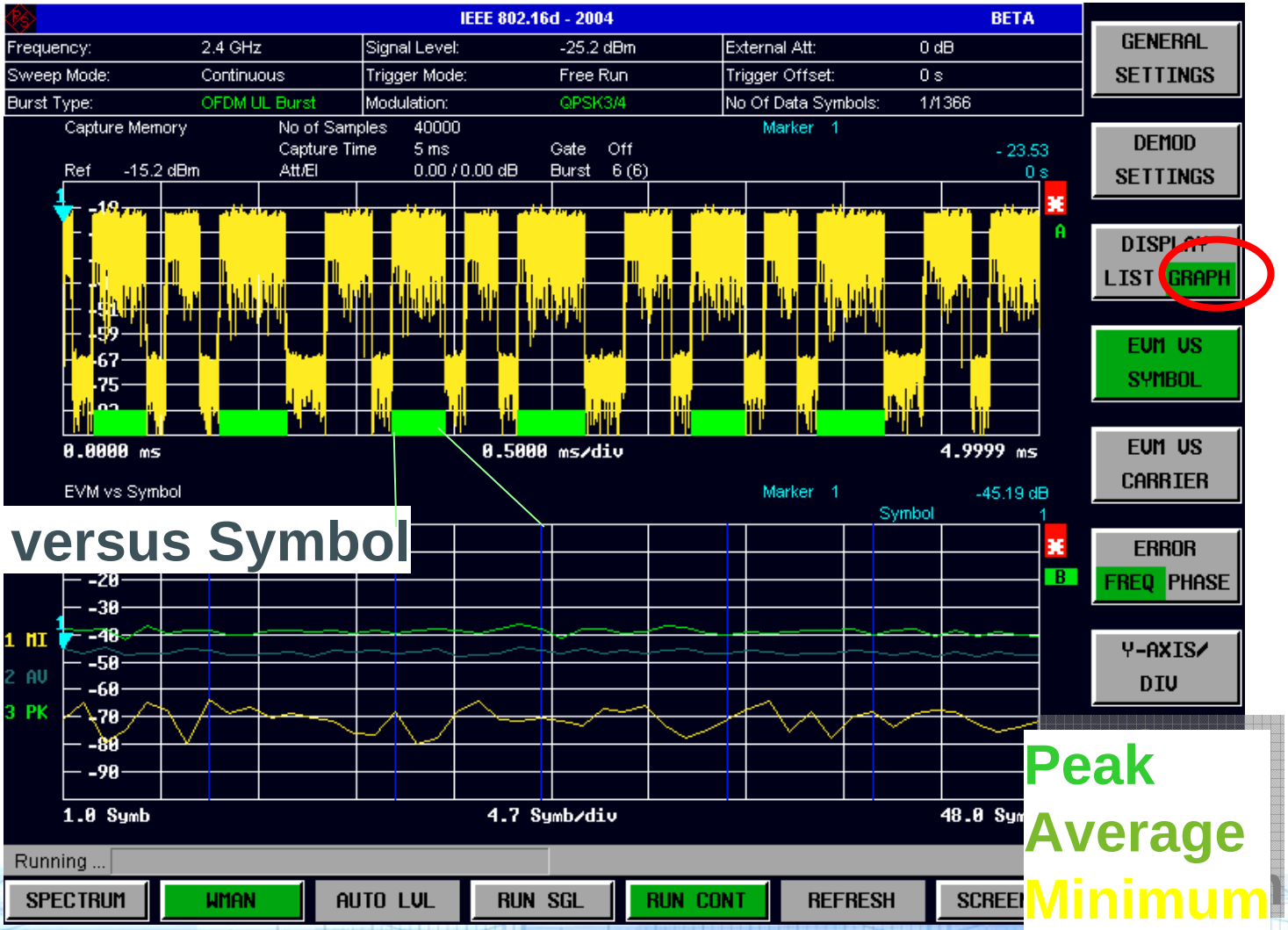
ROHDE&SCHWARZ

Application Firmware FSQ-K92/K93

Graphical Results:

- EVM Measurements
  - EVM vs. Symbol
  - EVM vs. Carrier
- Phase/Frequency Error vs. Preamble
- Spectrum Flatness (Difference)
- Group Delay
- Constellation Diagram
- Bit Stream
- Spectrum Emission Mask (IEEE,ETSI)
- Adjacent Channel Power (absolute and relative)
- CCDF measurement

Graphical Results

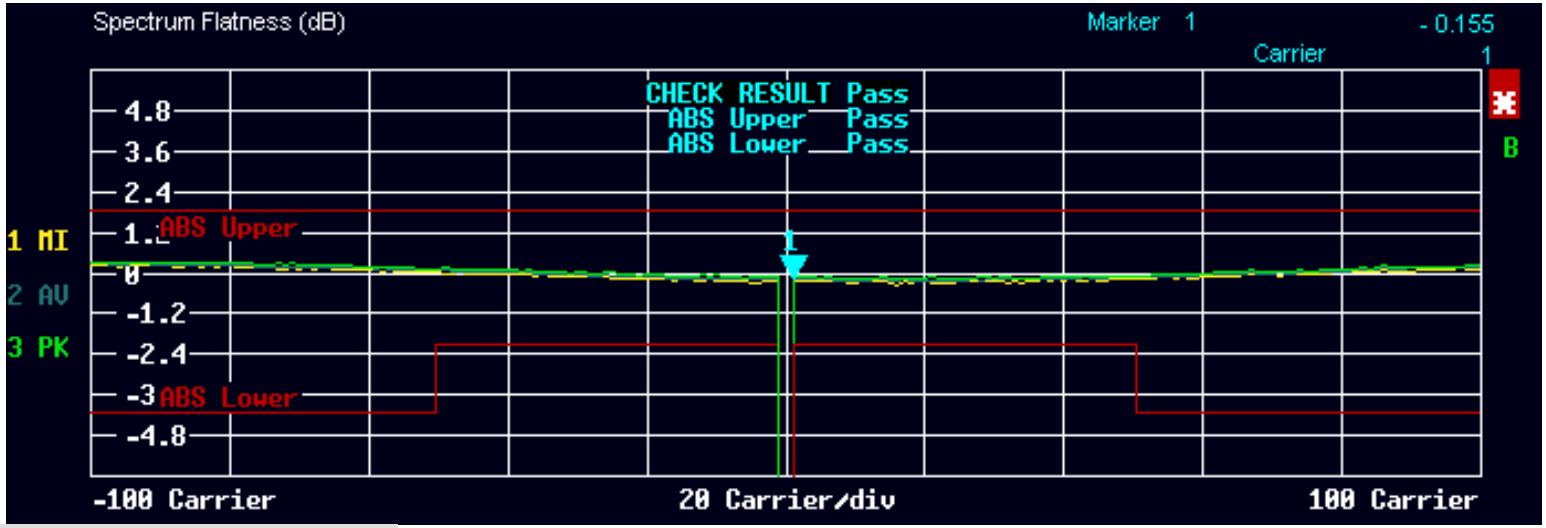


EVM versus Symbol

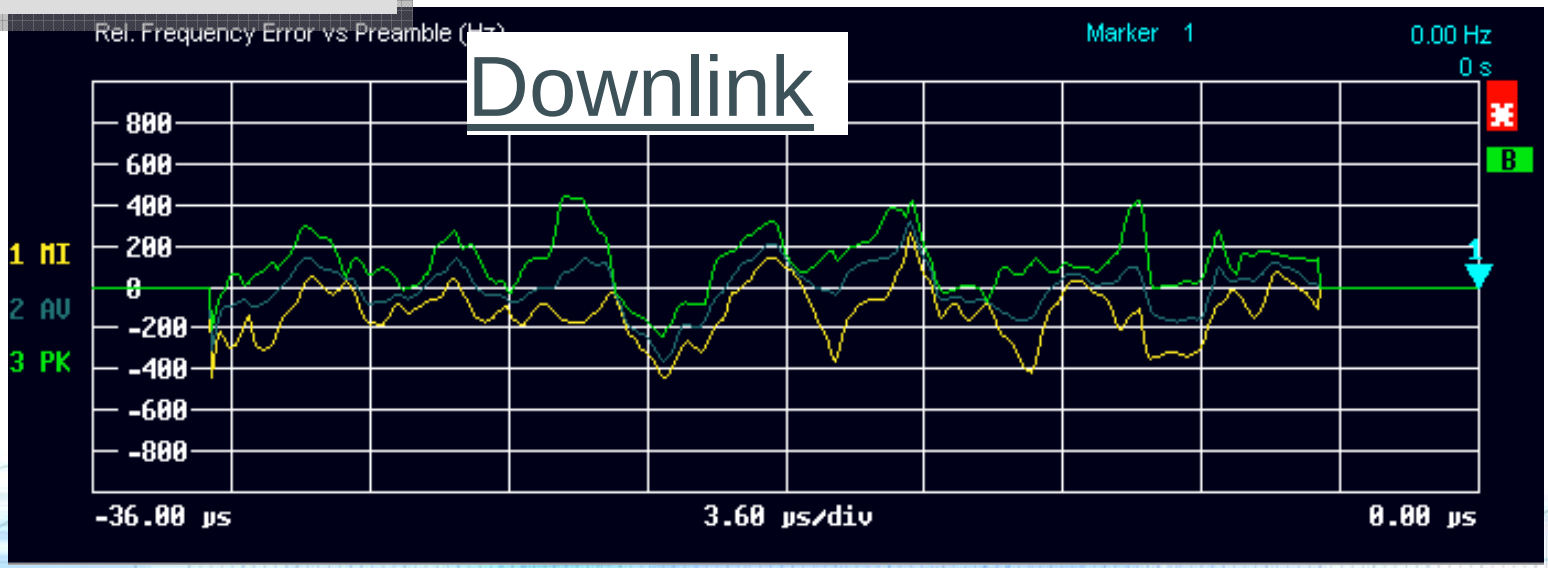
Peak
Average
Minimum

ROHDE&SCHWARZ

Spectrum Flatness and Spectrum Flatness Difference



Frequency Error vs. Preamble

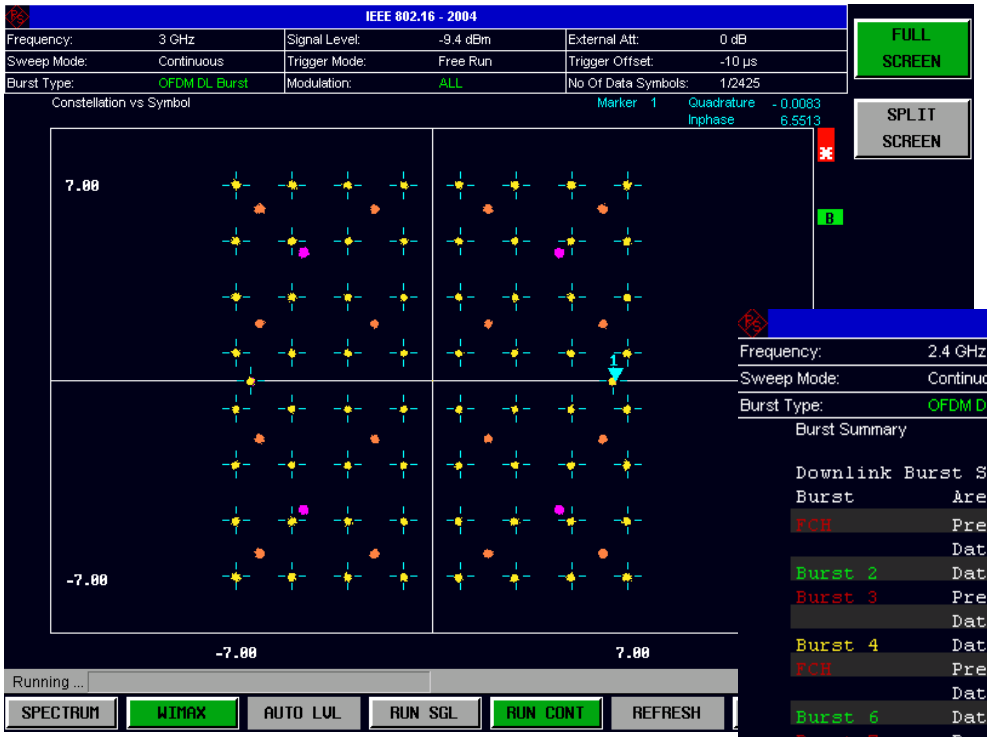


Downlink

ROHDE&SCHWARZ

All Mode

All bursts of a frame can be analysed – the results for EVM and power are displayed in a table and a composite constellation diagram can be displayed



IEEE 802.16 - 2004 BETA V3.81 February 6th 2006

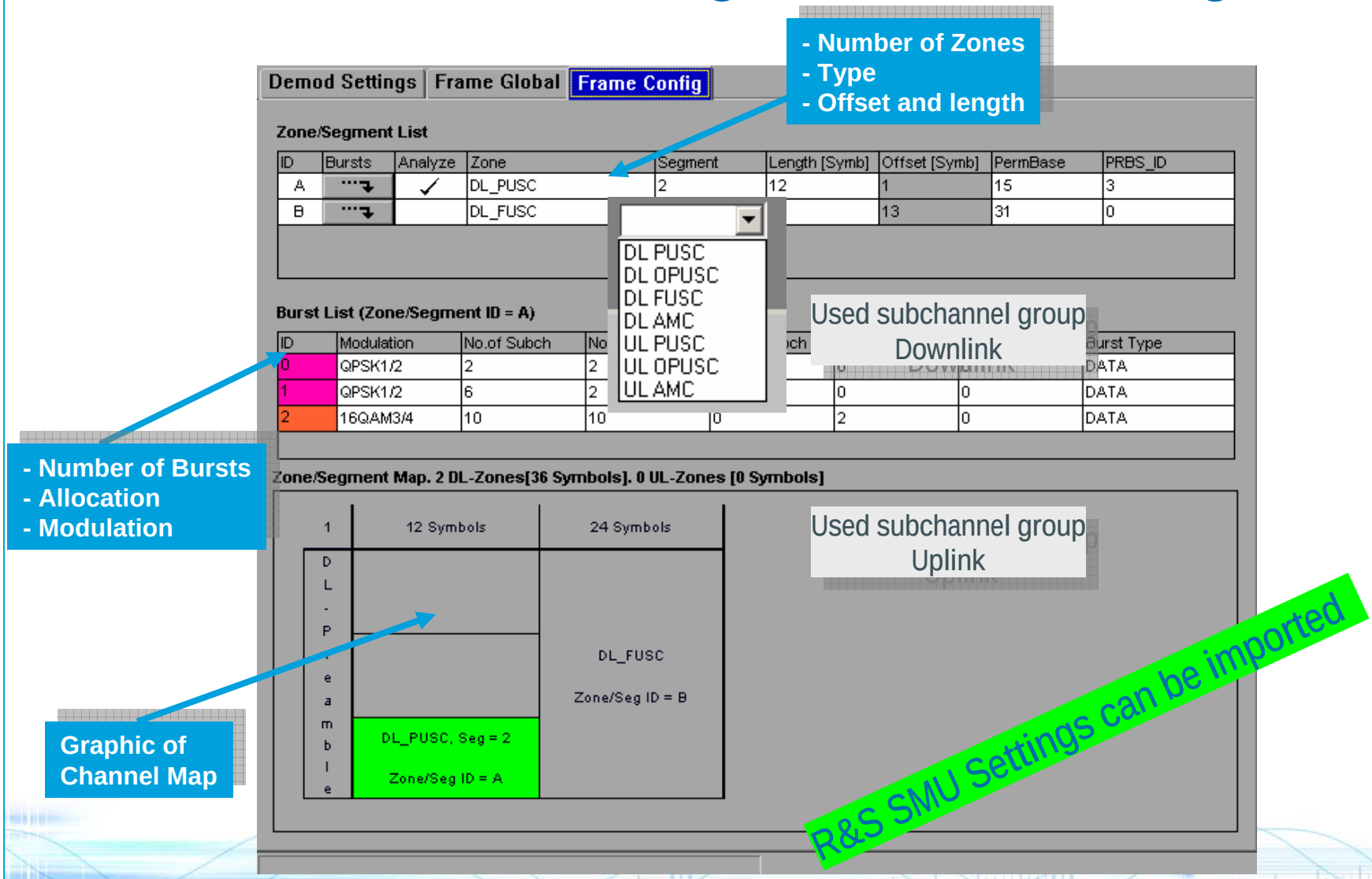
Frequency:	2.4 GHz	Signal Level:	1.8 dBm	External Att:	0 dB
Sweep Mode:	Continuous	Trigger Mode:	Free Run	Trigger Offset:	-10 µs
Burst Type:	OFDM DL Burst	Modulation:	64QAM3/4	No Of Data Symbols:	1/2425

Burst Summary

Downlink Burst Summary List

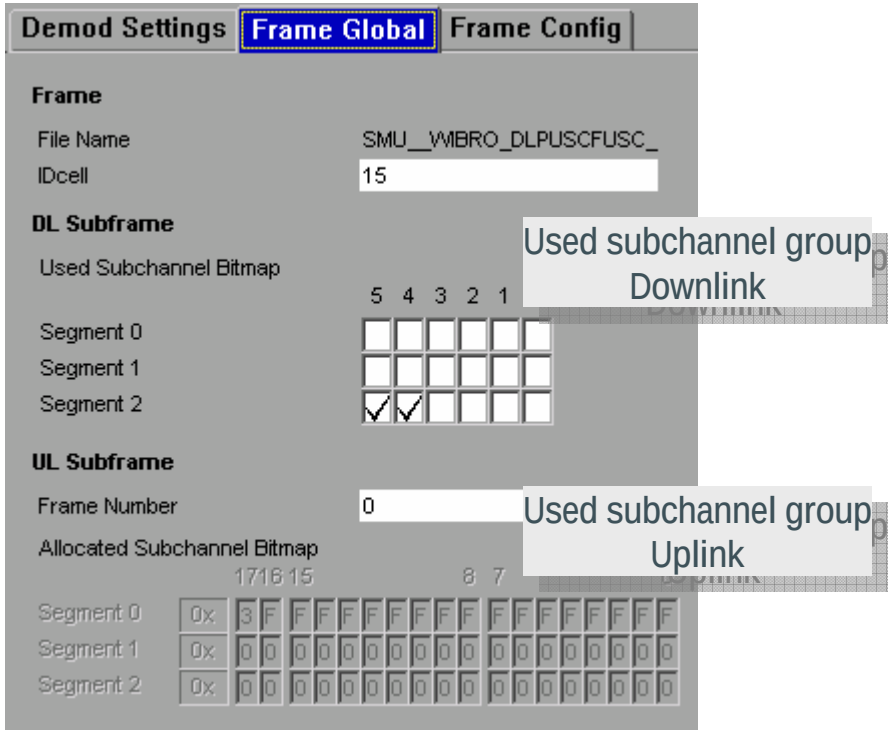
Burst	Area	Modulation	Length[sym]	Power[dBm]	EVM[dB]
FCH	Preamble	BPSK	2	1.56	-50.49
	Data	BPSK	1	-1.33	-54.48
Burst 2	Data	QPSK	1	-1.33	-52.05
Burst 3	Preamble	BPSK	2	1.52	-56.96
	Data	16QAM	118	-1.33	-53.86
Burst 4	Data	64QAM	105	-1.35	-53.51
FCH	Preamble	BPSK	2	1.55	-43.90
	Data	BPSK	1	-1.34	-53.80
Burst 6	Data	QPSK	1	-1.34	-53.15
Burst 7	Preamble	BPSK	2	1.60	-55.67
	Data	16QAM	118	-1.34	-53.90
Burst 8	Data	64QAM	105	-1.36	-53.59
FCH	Preamble	BPSK	2	1.61	-49.63
	Data	BPSK	1	-1.34	-53.56
Burst 10	Data	QPSK	1	-1.34	-49.70
Burst 11	Preamble	BPSK	2	1.51	-56.27
	Data	16QAM	118	-1.34	-53.48
Overall			582	-0.08	-51.40

Demodulation Settings for OFDMA Signal



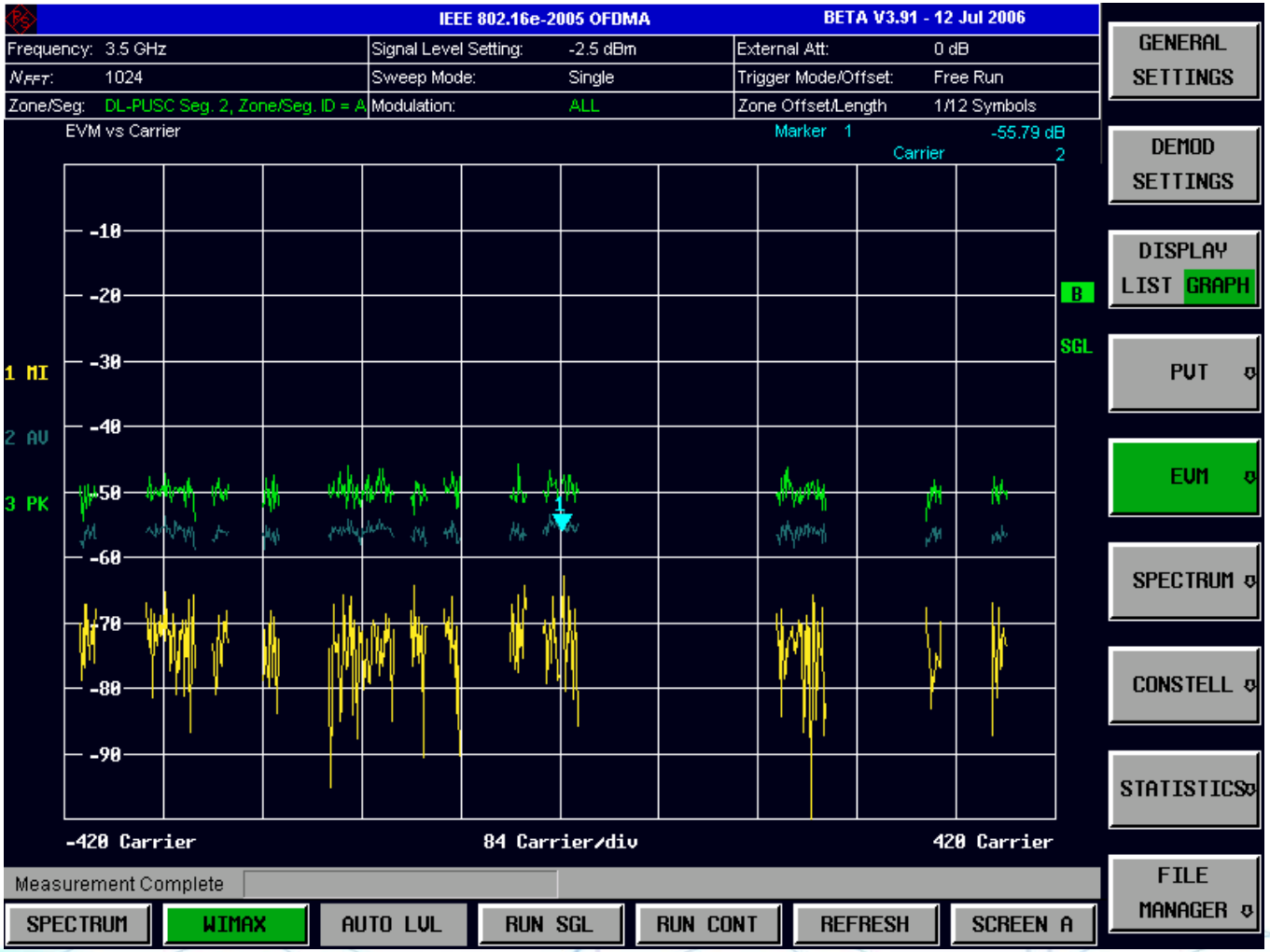
ROHDE&SCHWARZ

Demodulation Settings for OFDMA Signal



ROHDE&SCHWARZ

EVM v s. Carrier (PUSC zone)



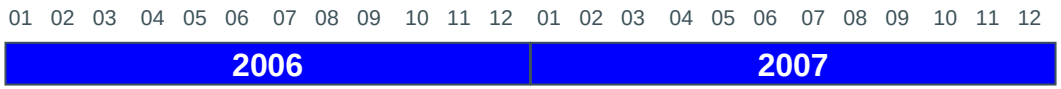
ROHDE&SCHWARZ

Roadmap

Generator Solutions Roadmap

AMC
Sounding
HARQ & Fast Feedback Channels
WiMAX SUI Fading Models

SMU, SMJ, SMATE RF Generators
With WiMAX Option –K4
WinIQSim2 Simulation Software



Analyzer Solutions Roadmap

-K93
DL- and UL- AMC
Channel decoding
DL- OFUSC and UL- OPUSC
Dedicated pilots

FSL-K93 internal solution

FSQ-K93
Group delay measurement
Decode and display FCH field
Auto demodulation according to DL- and UL- map
DL- and UL- PUSC using all subchannels
Amplitude tracking
(DL- and UL- AMC)

OFDMA FSQ-K93 solution internal
Analysis of 1 out of N zones
Analysis 1 of 3 segments
Transfer SMU settings to FSQ via LAN
Measurement of TTG, RTG

FSQ and FSL Signal Analysis
With WiMAX OFDM Option -K92 (internal)
With WiMAX OFDMA Option -K93 (external) -K93 includes -K92

01 02 03 04 05 06 07 08 09 10 11 12 01 02 03 04 05 06 07 08 09 10 11 12

2006 | **2007**

ROHDE&SCHWARZ

R&S WiMAX RCT Test System

R&S SMU
Signal Generation

R&S SMU
BB Fading/ Interferer

WiMAX BSSE

R&S RF SSCU

R&S Controller

R&S FSQ
Signal Analysis

R&S Power Sensor

Other Rohde & Schwarz T&M solutions

- Rohde & Schwarz delivers also other T&M solutions, which can be helpful for your WiMAX development and production testing like:
- Power Meters
- Spectrum Analysis FSH 3/6
- Arbitrary Waveform Generator AFQ100A
- Have a look under www.wimax.rohde-schwarz.com