ViSU TechDays

Introduction to Wi-Fi7 and UWB

Jörg Köpp
GF-MW – Wireless Market Segment Management

ROHDE&SCHWARZ
Make ideas real

Modern phones need a couple of wireless technologies to meet customer & application needs

WI-FI IS NOW

- Wi-Fi6E and Wi-Fi7 will drive investments in new test equipment
- Wi-Fi resource management introduced with Wi-Fi6 (OFDMA) drives need for signaling testing
- Wi-Fi player try to enter new markets (IIoT)

The HISTORY and FUTURE of Wi-Fi

Learn more about IEEE 802.11 testing:
www.rohde-schwarz.com/wlan

HOME AND OFFICE NETWORKS | M2M AND IoT NETWORKS | ROOM AND DESK AREA NETWORKS | VEHICLE NETWORKS

WaveLAN, the starting point for Wi-Fi development, was used for wirelessly connecting cashing machines.

802.11 b
Higher speed physical layer extension in the 2.4 GHz band
Spatial streams: 1x1 SISO | Modulation type: CCK
Channel bandwidth: 22 MHz | Bands: 2.4 GHz
Transmission/access method: CSMA/DSSS

802.11 a
High speed physical layer in the 5 GHz band
Spatial streams: 1x1 SISO | Modulation type: 64QAM
Channel bandwidth: 20 MHz | Bands: 5 GHz
Transmission/access method: CSMA/OFDM

Need for faster speed and better distance coverage.

802.11 g
Further higher data rate extension
Spatial streams: 1x1 SISO | Modulation type: 64QAM
Channel bandwidth: 20 MHz | Bands: 2.4 GHz
Transmission/access method: CSMA/OFDM

The ability to connect to the internet via mobile devices and the rising number of smartphones on the market required the introduction of features like MIMO.

802.11 n
Enhancements for higher throughput (HT)
Spatial streams: 4x4 SU-MIMO | Modulation type: 64QAM
Channel bandwidth: 40 MHz | Bands: 2.4, 5 GHz
Transmission/access method: CSMA/OFDM

More and more people wanted Wi-Fi at home and at work. High speed Wi-Fi was therefore required in the 5 GHz spectrum to relieve the over-crowded 2.4 GHz spectrum.

802.11 ac
Enhancements for very high throughput (VHT)
Spatial streams: 8x8 DL MU-MIMO | Modulation type: 256QAM
Channel bandwidth: 160 MHz | Bands: 5 GHz
Transmission/access method: CSMA/OFDM

The heavy use of Wi-Fi meant that a new approach was required. OFDMA allows multiple devices to communicate simultaneously.

802.11 ad
Directional multi-gigabit (DMG) in the 60 GHz band
Spatial streams: 1x1 SISO | Modulation type: 64QAM
Channel bandwidth: 2.16 MHz | Bands: 60 GHz
Transmission/access method: CSMA/SC

Designed for in-room/desk network applications requiring very high data rates such as for HD video streaming.

Achieves up to 20 Gbit/s throughput and enables extended distances for enlarged application space.

802.11 ay
Enhanced DMG (EDMG) in bands above 45 GHz
Spatial streams: 8x8 MU-MIMO | Modulation type: 64QAM
Channel bandwidth: 8.64 MHz | Bands: >45 GHz
Transmission/access method: CSMA/OFDM

Enables use of the sub GHz spectrum for IoT and remote internet applications.

802.11 af
Television very high throughput (TVHT)
Spatial streams: 4x4 DL MU-MIMO | Modulation type: 256QAM
Channel bandwidth: 6, 7, 8 MHz | Bands: sub GHz
Transmission/access method: CSMA/OFDM

802.11 ah
Sub 1 GHz License exempt
Spatial streams: 4x4 DL MU-MIMO | Modulation type: 256QAM
Channel bandwidth: 1, 2, 4, 8, 16 MHz | Bands: sub GHz
Transmission/access method: CSMA/OFDM

802.11 p
Wireless access in vehicular environments
Spatial streams: 1x1 SISO | Modulation type: 64QAM
Channel bandwidth: 10 MHz | Bands: 5.9 GHz
Transmission/access method: CSMA/OFDM

Provide Wi-Fi based car-to-car communications to enable emerging intelligent traffic services.

Meet today's and tomorrow's rising demands on V2X communications on the way to fully autonomous vehicles.

802.11 ax
Enhancement for high efficiency (HE) Wi-Fi
Spatial streams: 8x8 MU-MIMO | Modulation type: 1024QAM
Channel bandwidth: 160 MHz | Bands: 2.4, 5, 6 GHz
Transmission/access method: CSMA/OFDM/OFDMA

802.11 bd
Enhancements for next generation vehicular (NGV)
Spatial streams: 2x2 SU-MIMO | Modulation type: 256QAM
Channel bandwidth: 10, 20 MHz | Bands: 5.9, 60 GHz
Transmission/access method: CSMA/OFDM

802.11 be
Enhancements for extreme high throughput (EHT)
Spatial streams: 16x16 MU-MIMO | Modulation type: 4096QAM
Channel bandwidth: 320 MHz | Bands: 2.4, 5, 6 GHz
Transmission/access method: CSMA/OFDM/OFDMA

The advent of home office and schooling as well as industrial applications require improved data throughput, reduced latency and efficiency.

Multi-antenna transceiver methods

The evolution from SISO to single-user and multi-user MIMO was essential to meet data throughput demands.

Single input single output (SISO)
Use of a single antenna on access points and devices for sequential communications of the access point with connected devices, applying a carrier sense multiple access (CSMA) scheme to control spectrum access.

Single-user multiple input multiple output (SU-MIMO)
Use of multiple antennas to improve data throughput, applying a carrier sense multiple access (CSMA) scheme to control spectrum access.

Multi-user MIMO
Based on OFDMA, MU-MIMO allows simultaneous communications of stations in parallel. Beamforming enables multiple users to apply individual MIMO schemes at the same time to ensure efficient communications.

Test and measurement solutions from Rohde & Schwarz

R&S®CMW270 wireless connectivity tester
The non-cellular expert designed for testing Wi-Fi access points (AP) and stations (STA) in signaling and non-signaling mode.

R&S®CMW100 communications manufacturing test set
Ultra-compact, non-signaling tester optimized for production line testing including 4G, 5G and Wi-Fi 6 wireless technologies.

R&S®SMV200A vector signal generator
The fine art of signal generation – supports Wi-Fi modulation at full bandwidth and enables MIMO testing with real-time fading.

R&S®SMBV100B vector signal generator
The new benchmark in its class with up to 500 MHz modulation bandwidth and perfect accuracy even at high output power levels.

R&S®FSW signal and spectrum analyzer
Setting standards in innovation and usability for testing Wi-Fi devices with 800 MHz real-time analysis bandwidth.

R&S®FSVA3000 signal and spectrum analyzer
The right choice for Wi-Fi RF spectrum and signal analysis in R&D. Supports 480 MHz analysis bandwidth.

R&S®TS8997 regulatory test system for wireless devices
Testing of wireless devices operating in the ISM bands in line with ETSI and FCC standards.

R&S®DST200 RF diagnostic chamber
Ideal environment for RF analysis during development. Supports a wide range of radiated test applications for Wi-Fi devices.

Wi-Fi® is a registered trademark of Wi-Fi Alliance®

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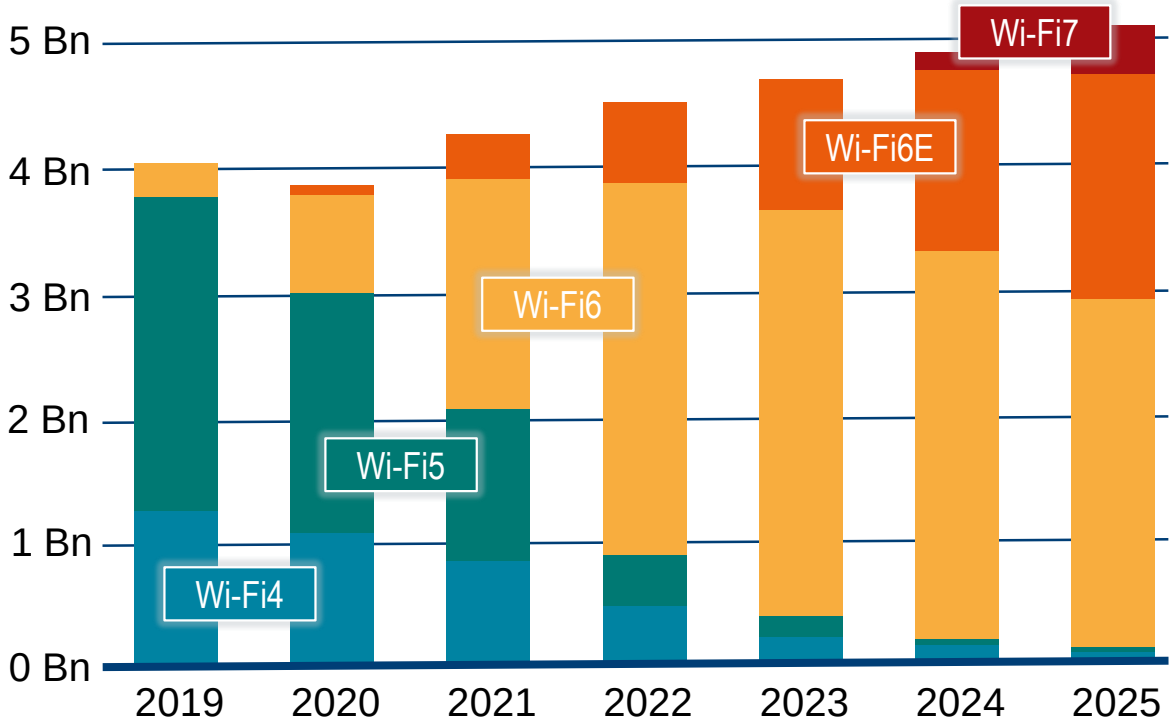
https://www.rohde-schwarz.com/solutions/test-and-measurement/wireless-communication/wireless-connectivity/wlan-wifi/poster-the-history-and-future-of-wi-fi_254536.html

Wi-Fi outlook

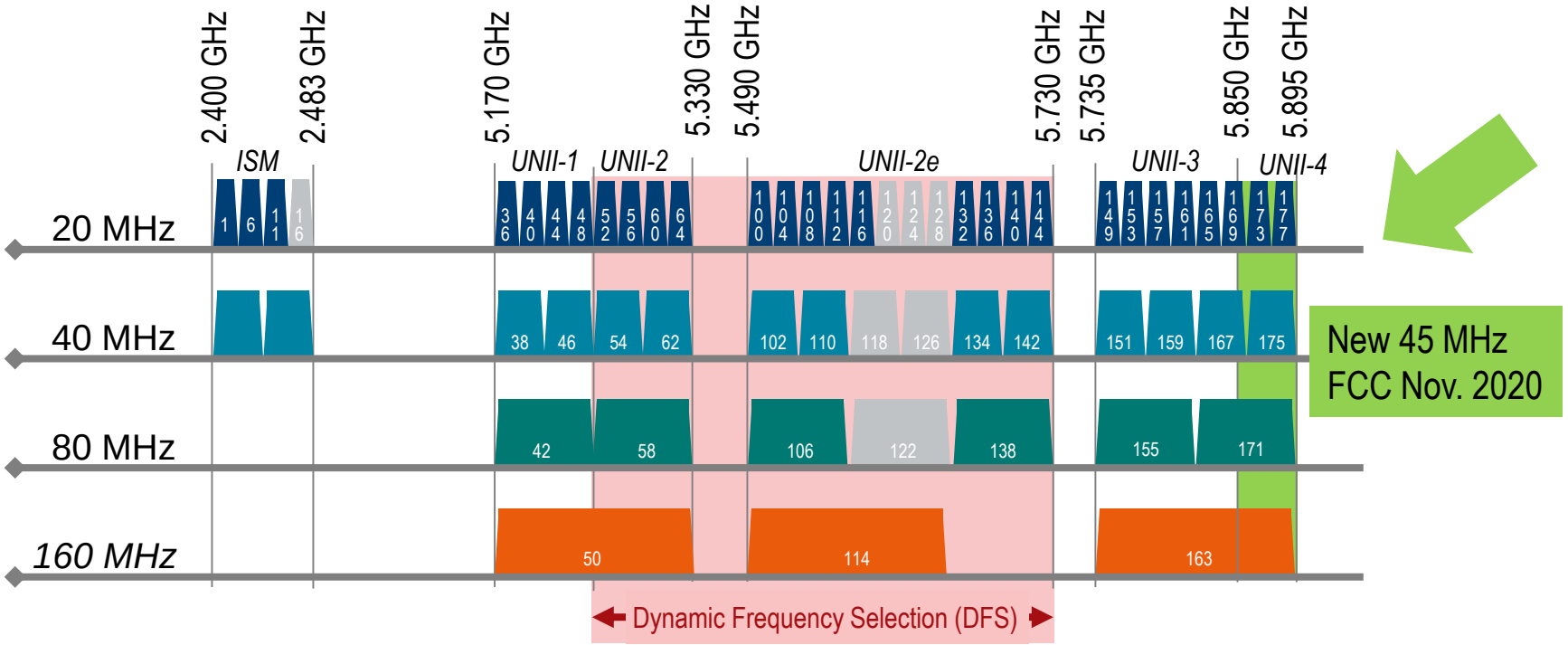
- Rapid shift to Wi-Fi6 in the next two years
- Continously increasing share of Wi-Fi6E
- **Wi-Fi7 shipments will start in 2024**

Shipment of Wi-Fi enabled products/devices/systems



Source: IDC presentation at MWJ panel discussion (Feb. 2021)

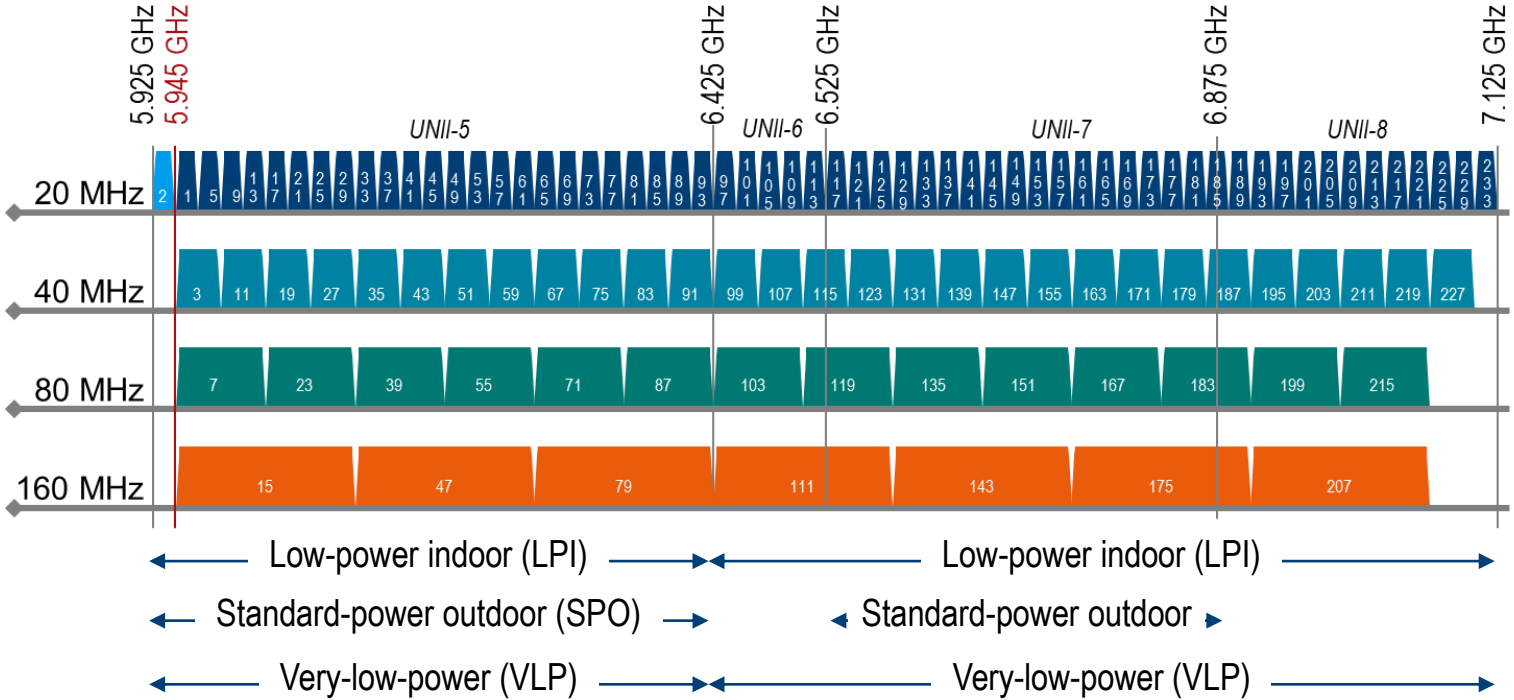
Some additional spectrum at 5.9 GHz



! Regionally different rules for indoor/outdoor use, power limitations , DFS and TPC (transmit power control) !

More spectrum for Wi-Fi at home … Wi-Fi6E

Still in early stage with regulation in progress



Device classes FCC Part 15 Subpart E for 6 GHz UNII

Phase 1

Indoor (5.9-7.1 GHz; ≤320 MHz)

Phase 2

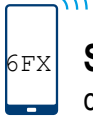
Outdoor (5.9-6.4GHz & 6.5-6.9 GHz ≤320 MHz)

Low-power indoor AP*
Fixed, wired power, integrated ant.
Prohibited on cars, trains, etc.
EIRP of 30 dBm

Subordinate*
fixed, integrated ant.,
controlled by AP, no Internet
EIRP of 30 dBm

Indoor client
controlled by AP,
no direct client connection
EIRP of 24 dBm

Dual client



Standard client
controlled by AP,
no direct client connection.
EIRP of 30 dBm
(6 dBm lower than AP)

Standard power AP
Geolocation detection
Managed by an AFC
Antenna pointing angle
EIRP of 36 dBm

Fixed client
Geolocation detection
Managed by an AFC via AP
Antenna pointing angle
EIRP of 36 dBm

* prohibited on oil platforms, cars, trains, boats, and aircraft, except large aircraft while flying above 10,000 feet

Regulatory effort to make more spectrum available for Wi-Fi

	Low-power indoor (LPI)	Very-low-power (VLP)	Standard-power	Reference
FCC	5.9-7.1 GHz AP EIRP: 30 dBm	na	5.9-6.4 & 6.5-6.9 GHz EIRP: 36 dBm (AFC)	Part 15 E U-NII 6 GHz
EU	5.9-6.4 GHz AP EIRP: 200 mW	5.9-6.4 GHz EIRP 20 mW	na	CEPT report 75
UK	5.9-6.4 GHz AP EIRP: 250 mW	5.9-6.4 GHz EIRP 25 mW	na	OFCOM for Wi-FI
UAE	5.9-6.4 GHz AP EIRP: 250 mW	na	na	Press release
Brazil	5.9-7.1 GHz AP EIRP: 30 dBm	5.9-7.1 GHz AP EIRP: 14 dBm	na	Press release
Korea	5.9-7.1 GHz AP EIRP: 250 mW	5.9-7.1 GHz EIRP: 25 mW	na	Press release
Chile	5.9-7.1 GHz AP EIRP: 30 dBm	na	na	Press release

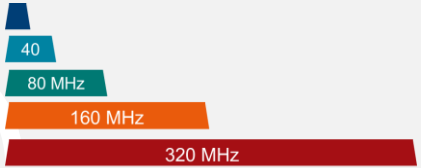
next: Mexico (5.9-7.1), Argentina (5.9-6.4 GHz), Peru, Colombia

Extreme High Throughput

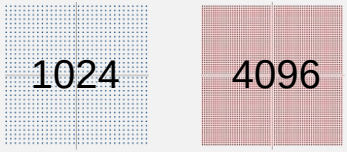
with EEE 802.11be (Wi-Fi7)

Wi-Fi7 – IEEE 802.11be some topics of interest

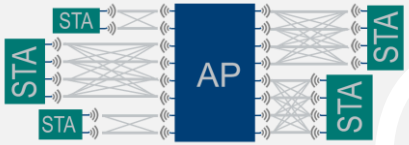
320 MHz channel bandwidth



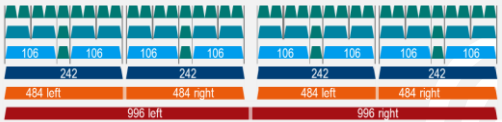
4096 QAM



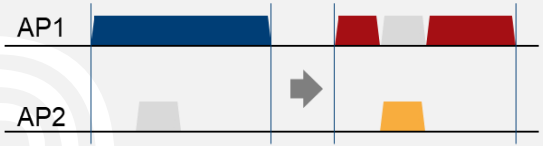
16 Spatial streams



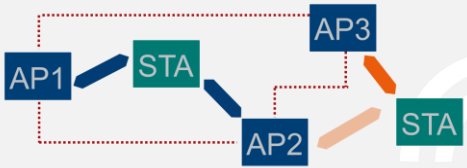
Channelization and tone plan



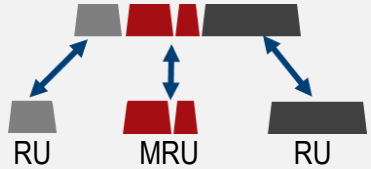
(Preamble puncturing)



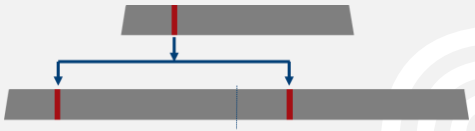
Multi AP Coordination



Multi-RU per user

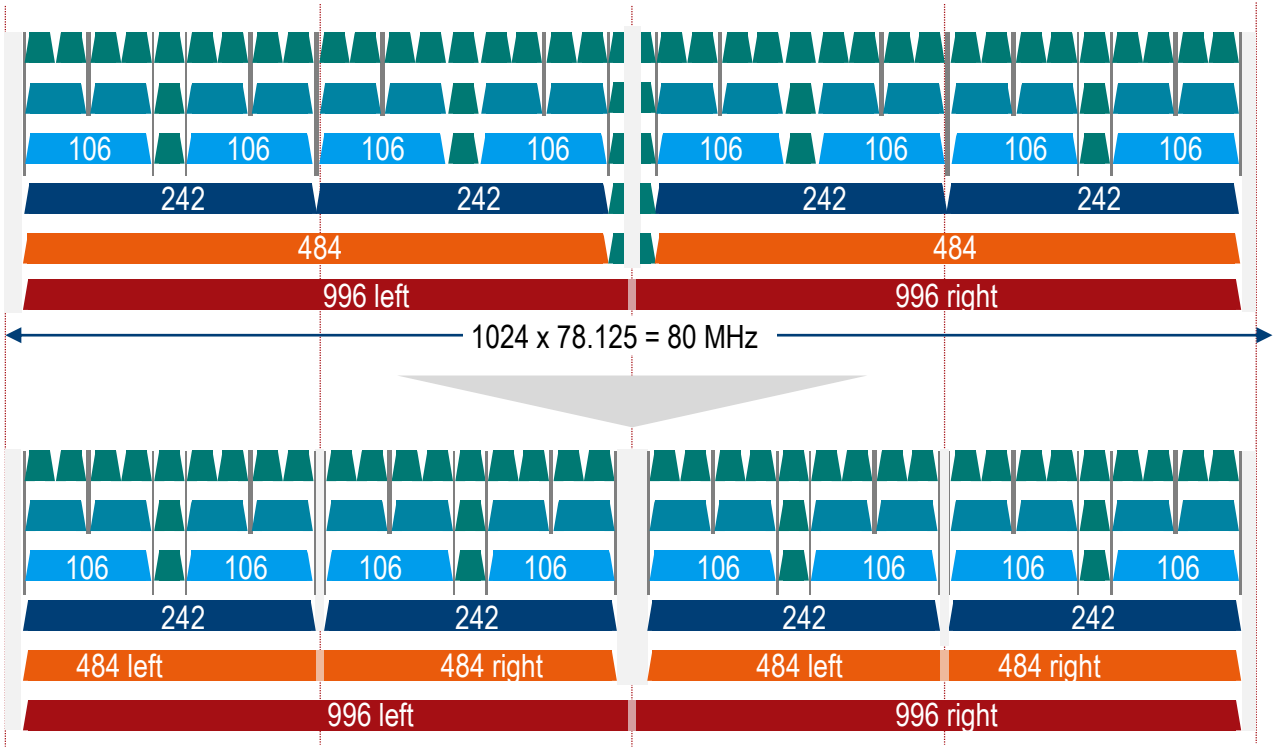


(DCM + DUP)



Multi-Link Operation

Modified tone-plan ≥ 80 MHz



- 802.11be tone plan is based on 20/40 MHz PPDU 11ax tone plan
- 802.11be modifies the HE80 MHz OFDMA tone plan to fix the problems with regulation and puncturing (20 MHz boundery)
- The 80MHz OFDMA design applies to any RU < 996 for all modes of transmission, SU, DL MU, TB PPDU, with and without puncturing.

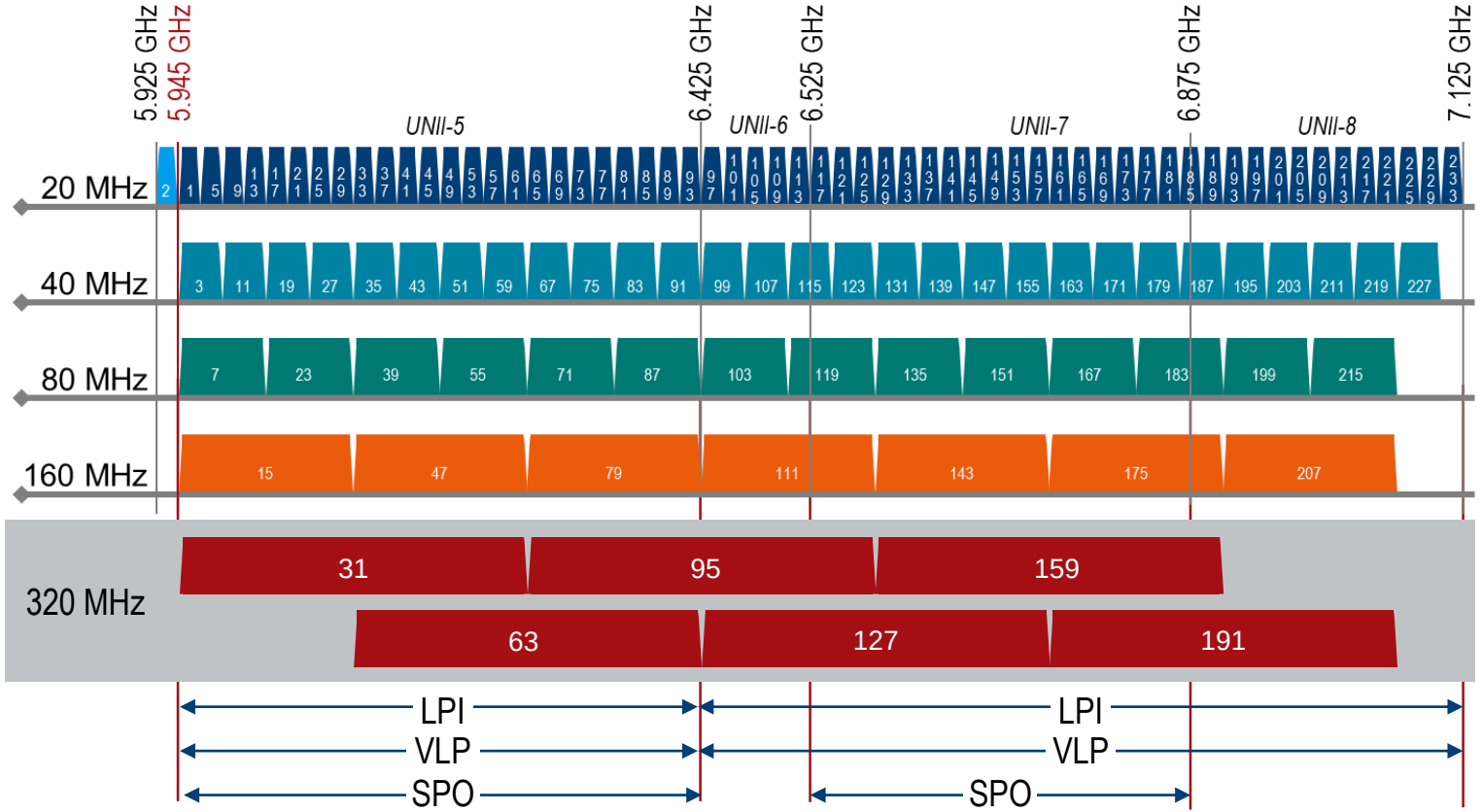
EVM Requirements for ETH MU (AP) and ETH TB (STA)

MCS	Modulation	Coding	EVM of EHT MU PDDU	EVM of EHT TB PDDU[1)]	EVM of EHT TB PDDU[2)]
0	BPSK	1/2	- 5 dB	-13 dB	- 27 dB
1	QPSK	1/2	- 10 dB	-13 dB	-27 dB
2		3/4	-13 dB	-13 dB	-27 dB
3	16-QAM	1/2	-16 dB	-16 dB	-27 dB
4		3/4	-19 dB	-19 dB	-27 dB
5	64-QAM	2/3	-22 dB	-22 dB	-27 dB
6		3/4	-25 dB	-25 dB	-27 dB
7		5/6	-27 dB	-27 dB	-27 dB
8	256-QAM	3/4	-30 dB	-30 dB	-30 dB
9		5/6	-32 dB	-32 dB	-32 dB
10	1024-QAM	3/4	-35 dB	-35 dB	-35 dB
11		5/6	-35 dB	-35 dB	-35 dB
12	**4096-QAM**	3/4	**-38 dB**	**-38 dB**	**-38 dB**
13		5/6	**-38 dB**	**-38 dB**	**-38 dB**
	BPSK-DCM	1/2	-5 dB	-13 dB	-27 dB
	BPSK-DCM-DUP	1/2	-5 dB	N/A	N/A

[1)] TX power > max power of EHT-MCS 7 (dB)

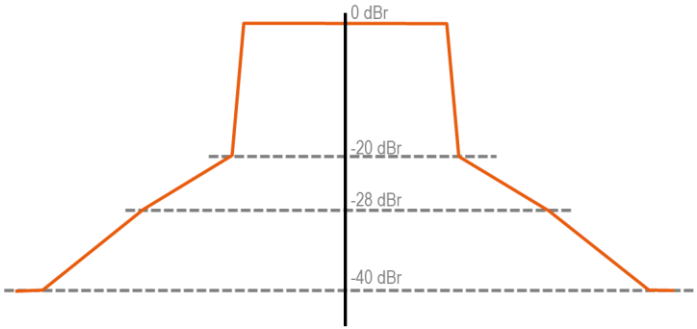
[2)] TX power ≤ max power of EHT-MCS 7 (dB)

A very limited number of available 320 MHz channels

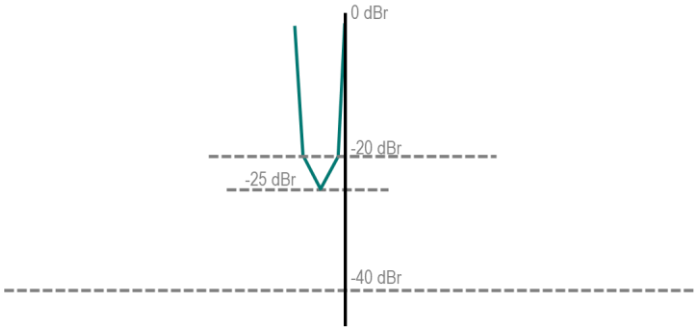


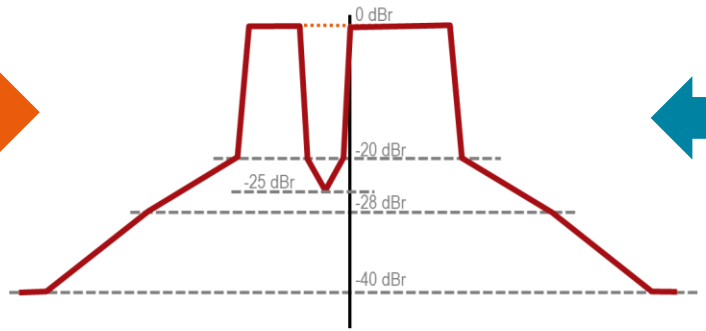
Construction of PSD mask for 80 MHz EHT PPDU with the second lowest 20 MHz subchannel punctured

80MHz Spectral mask



Preamble puncture mask (20 MHz middle)

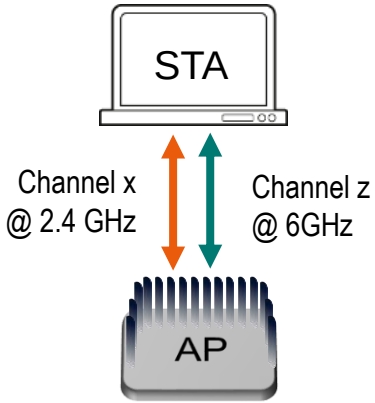




There are some more features for efficiency, throughput & low latency

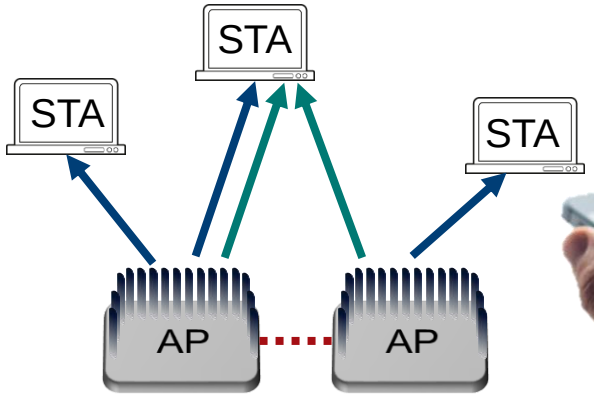
Multi-link operation (MLO)

Link aggregation on MAC layer between multi-link devices (MLD) to provide higher throughput, lower latency and better reliability



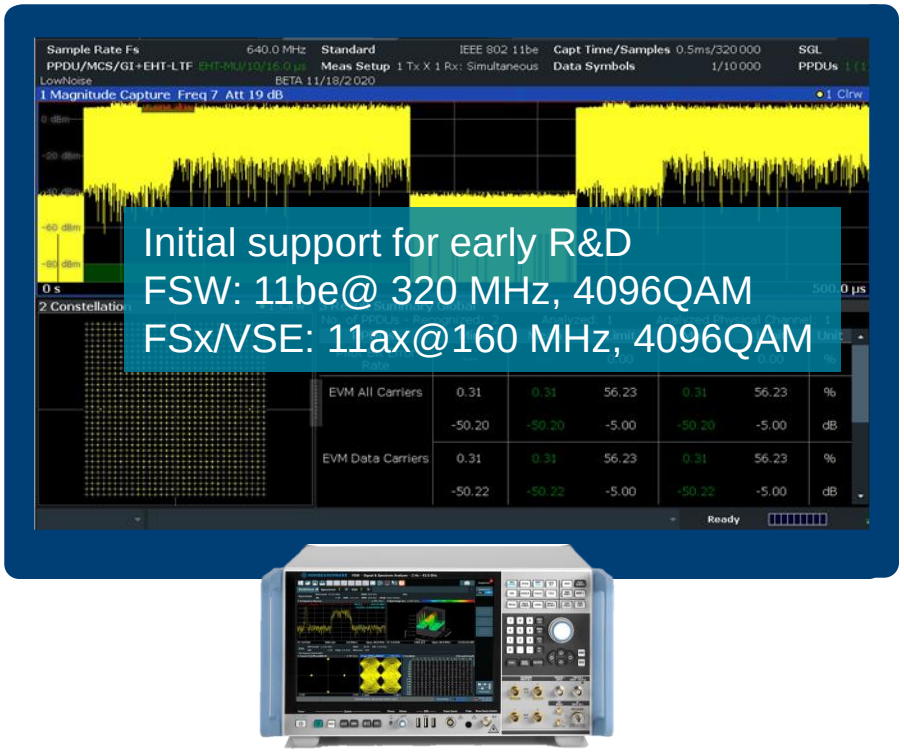
Multi-AP operation

Close coordination between APs to allow different schemes of coordinated transmission
(e.g. coordinated OFDMA, beamforming, processing)

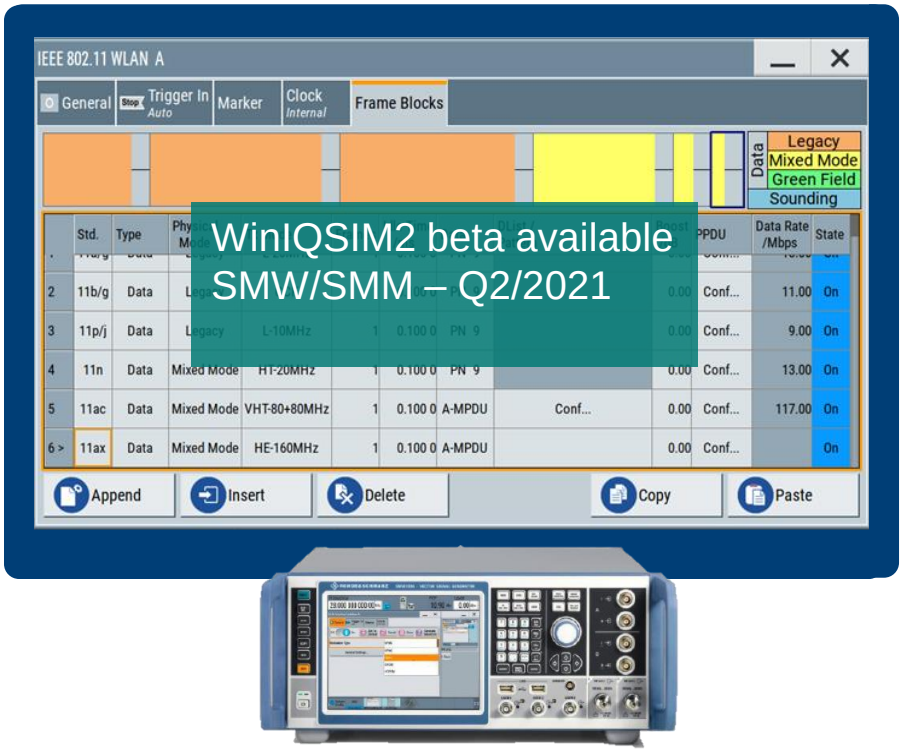


More about TSN, sensing, low power, etc.

Early 802.11be (Wi-Fi7) support by 1E/1G



Please contact Werner Dürport for details



Please contact Michael Kaltenbach for details

We start with Wi-Fi7 promotion now!

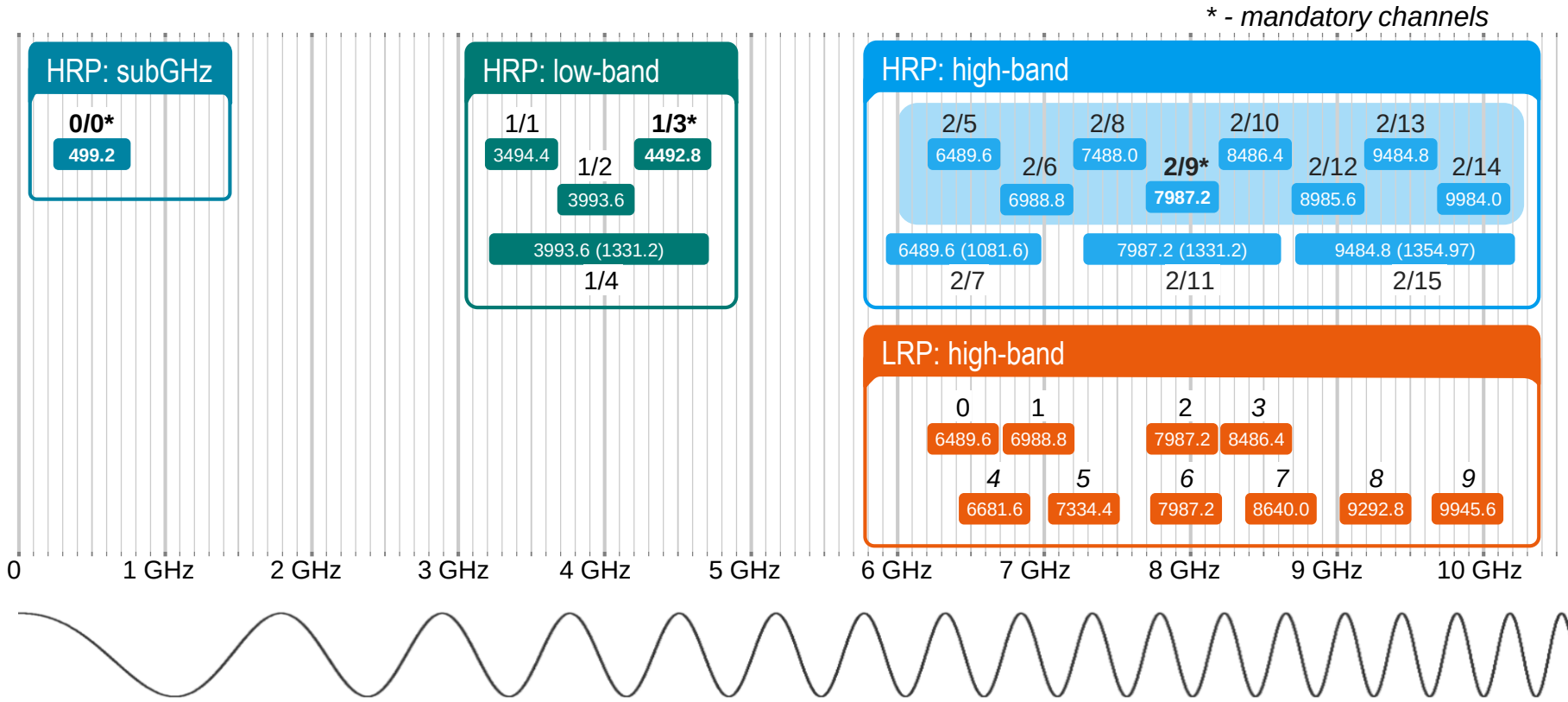
WLAN IEEE 802.11be testing
Rohde & Schwarz test solutions are designed to help test engineers to work already today on the 7Th generation of Wi-Fi, which is promising extreme high data throughput.

R&S Webinar
Are you ready for testing of Wi-Fi6E/7? We are!
Summer 2021
presented by Hagen Heggenberger and Joerg Koepp

UWB ON EVERY PHONE

- More and more UWB applications around phones
- Very high interest on our solutions in production and R&D
- Next: FiRa certification

UWB channel allocation based on 802.15.4z



Impulse radio ultra-wideband (UWB) standardization: IEEE 802.15.4 (groups a, f, z)

HRP UWB PHY High Rate Pulse repetition frequency			LRP UWB PHY Low Rate Pulse repetition frequency					
RDEV	ERDEV		RDEV			ERDEV		
base	BPRF	HPRF	base	extend	long-range	DF	enh. DF	DF w/ EPC
Modulation BPM-BPSK **Pulse Rate:** 3.9 MHz 15.6 MHz 62.4 MHz	**Modulation** BPM-BPSK **Pulse Rate:** 62.4 MHz	**Modulation** BPSK **Pulse Rate:** 124.8 MHz 249.6 MHz	**Modulation** OOK **Pulse Rate:** 1 MHz	**Modulation** OOK **Pulse Rate:** 1 MHz	**Modulation** PPM **Pulse Rate:** 2 MHz	**Modulation** PBFSK **Pulse Rate:** 1 MHz 2 MHz 4 MHz	**Modulation** PBFSK **Pulse Rate:** 1 MHz 2 MHz 4 MHz	**Modulation** PBFSK-PPM **Pulse Rate:** 1 MHz 2 MHz
802.15.4a/z	802.15.4z		802.15.4f/z			802.15.4z		

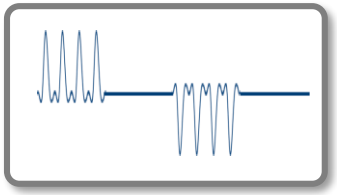
RDEV: Ranging device
ERDEV – Enhanced Ranging Device
BPM - burst position modulation

BPRF – Base pulse repetition frequency
HPRF – High pulse repetition frequency
PBFSK – Pulsed binary frequency shift keying

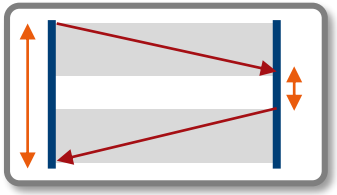
PPM – Pulse Positioning Modulation
EPC – enhanced Payload capacity
BPSK - binary phase shift keying

DF – Dual frequency
OOK: On-Off Keying

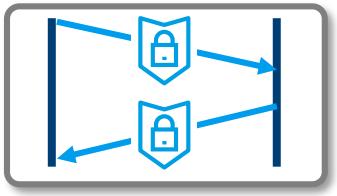
802.15.4z: Ensure interoperability for secure fine ranging applications with lower power consumption at higher range



Higher pulse repetition rates improve power consumption and allow reliable communication to ranges of up to 100 m

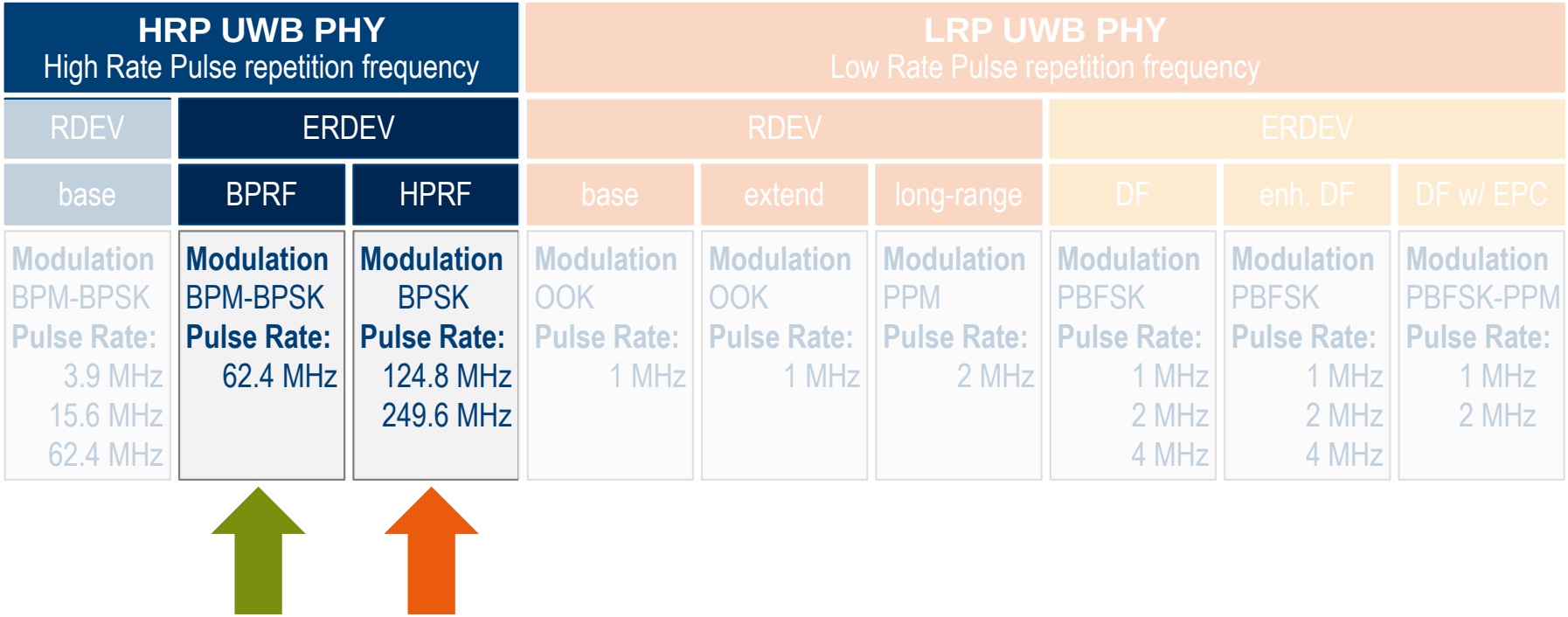


Single sided two-way ranging (SS-TWR) and **simultaneous ranging** save battery live time Ranging for **UWB-LRP** (low rate repetition)

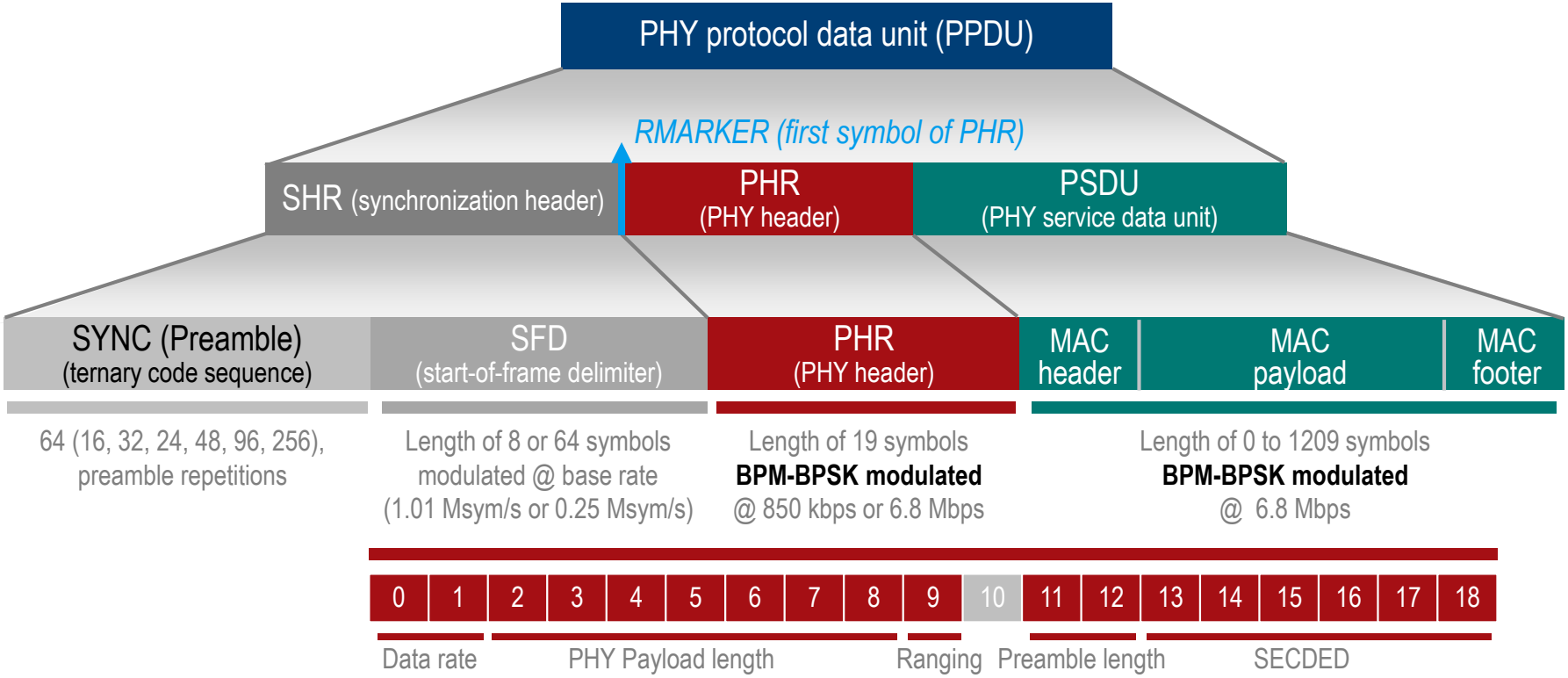


Secure ranging by cryptographic and random number generation used for scrambled timestamp sequence (STS)

HRP Enhanced Ranging DEVice (ERDEV) based on 802.15.4z

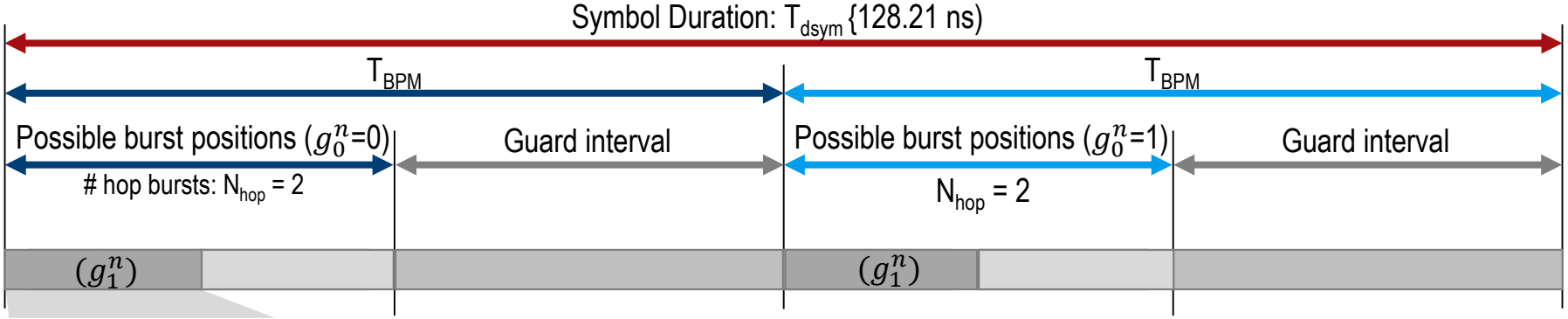


HRP-EREDV BPRF-Mode: SP0-PPDU encoding (802.15.4z)

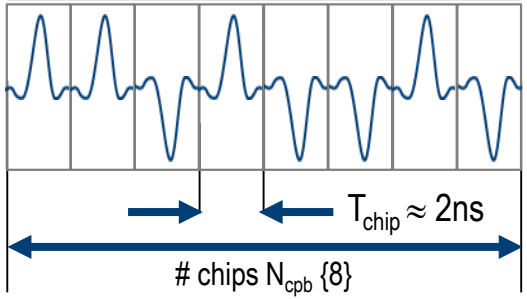


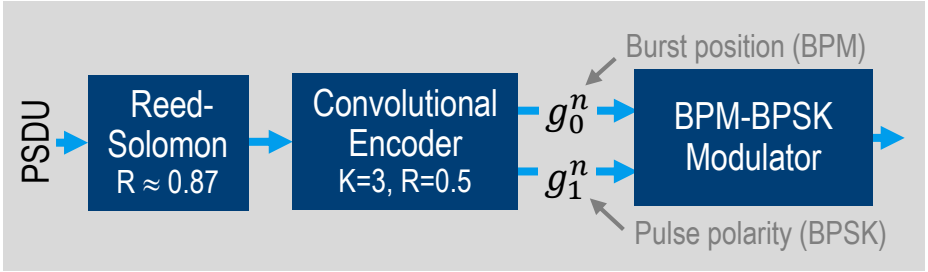
SECDED -single error correct, double error detect

HRP-ERDEV BPRF-Mode: BPM-BPSK modulation of PSDU



time hopping with polarity scrambling

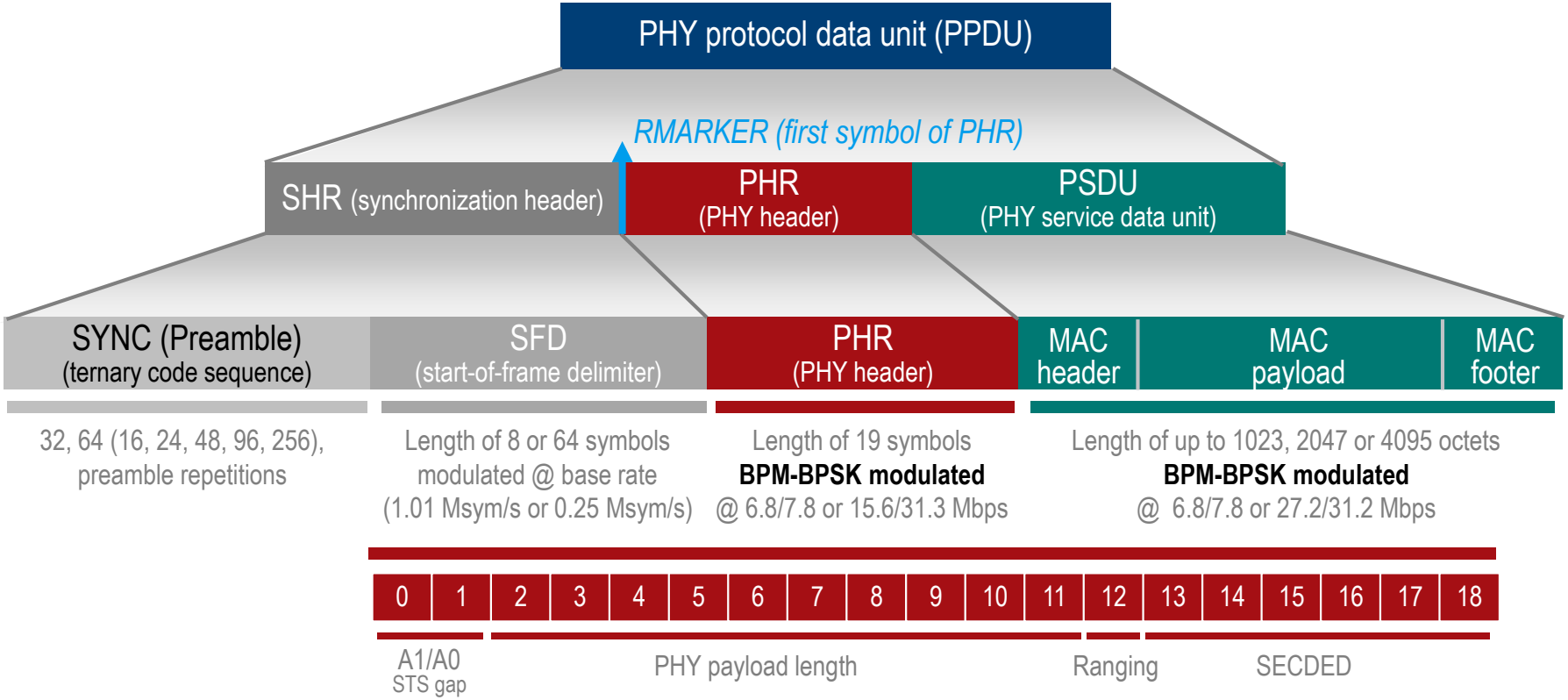




Peak PRF	Chips per symbol	Pulses per burst	FEC	Bitrate	Mean PRF
499.2 MHz	64	8	0.435	6.8 Mbps	62.4 MHz

SECDED -single error correct, double error detect

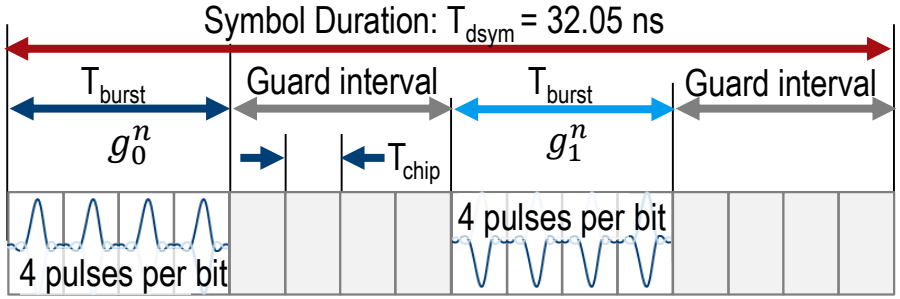
HRP-ERDEV HPRF-Mode: SP0-PPDU encoding (802.15.4z)

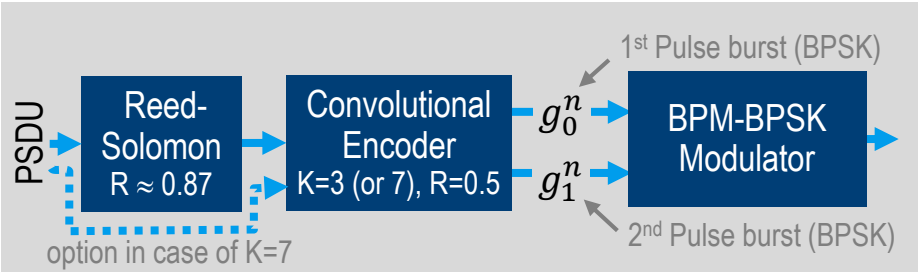


SECDED -single error correct, double error detect

HRP-EREDV HPRF-Mode: BPSK modulation (802.15.4z)

HPRF PSDU modulation @ Mean PRF of 249.6 MHz

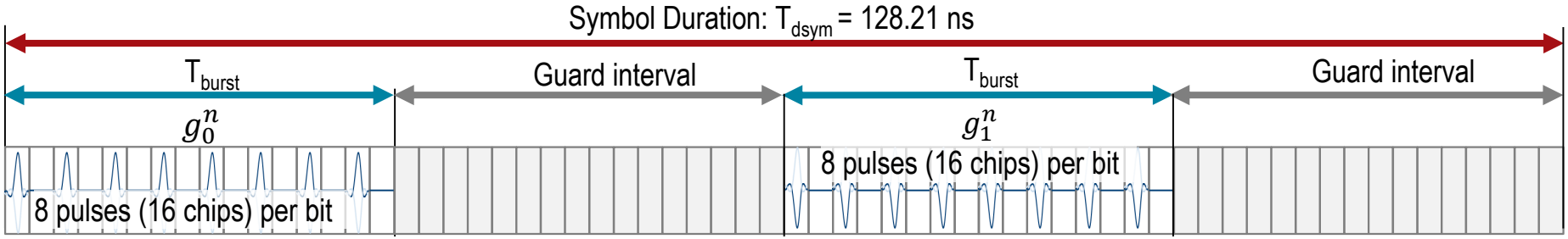


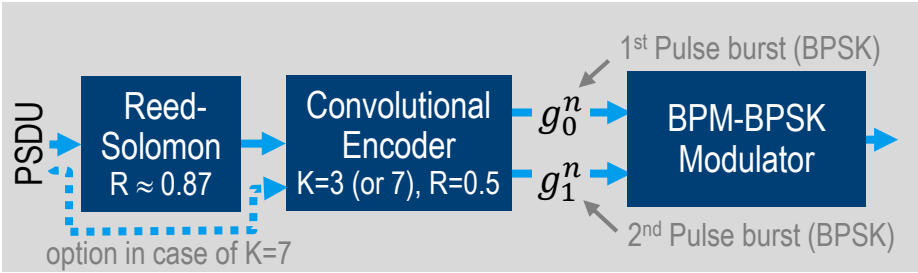


Peak PRF	Chips per symbol	Pulses per burst	FEC	Bitrate	Mean PRF
499.2 MHz	16	4	0.435	27.2 Mbps	249.6 MHz
499.2 MHz	16	4	0.500	31.2 Mbps	249.6 MHz

HRP-EREDV HPRF-Mode: BPSK modulation (802.15.4z)

HPRF PSDU modulation @ Mean PRF of 124.8 MHz





Peak PRF	Chips per symbol	Pulses per burst	FEC	Bitrate	Mean PRF
249.6 MHz	64	8	0.435	6.8 Mbps	124.8 MHz
249.6 MHz	64	8	0.500	7.8 Mbps	124.8 MHz

UWB Conformance & Certification

IEEE Standard 802.15.4

UWB Physical Layers (PHYs) and Associated Ranging Techniques – 802.14.4z

15.4 RF requirements

15.4.1 Operating frequency bands
15.4.2 Channel assignments
15.4.3 Regulatory compliance
15.4.4 Baseband impulse response
15.4.5 Transmit PSD mask
15.4.6 Chip rate clock and chip carrier alignment
14.4.7 TX-to-RX turnaround time
14.4.8 RX-to-TX turnaround time
14.4.9 Transmit center frequency tolerance
14.4.10 Receiver maximum input level of desired signal
14.4.11 Receiver energy detection (ED)
14.4.12 Link quality indicator (LQI)
14.4.13 Clear channel assessment (CCA)

Regulatory Conformance

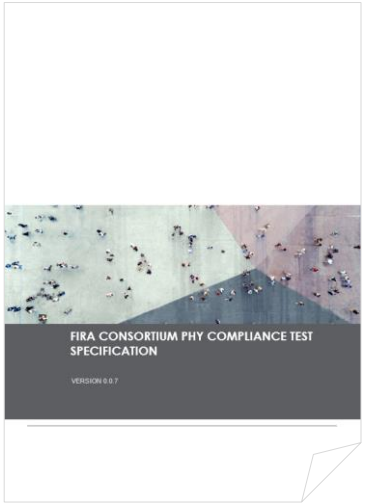
ETSI EN 303 883
Short Range Devices (SRD) and Ultra Wide Band (UWB);

ETSI EN 302 065
Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band technology (UWB)

FCC CFR 47 Part 15.250
Operation of wideband systems within the band 5925-7250 MHz

FCC CFR 47 Part 15.5xx
Technical requirements and measurement techniques ….

FiRa™ Certification test process and documents



UWB PHY Technical Requirements

UWB MAC Technical Requirements

PHY Compliance Test specification

MAC Compliance Test specification

UCI Test specification
Test mode and test Interface

Join FiRa

Prepare
(e.g. use validated test tools)

Certification testing
(by authorized test labs)

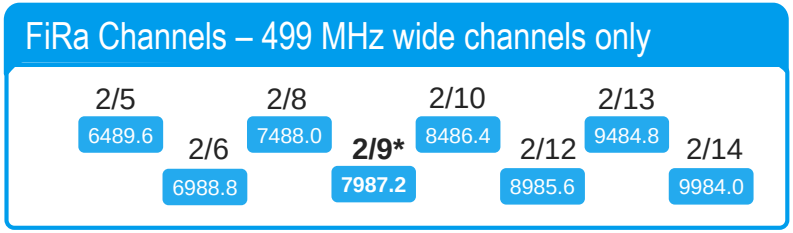
Apply

Promote

- FiRa validates **test tools to** ensure that they conform to the requirements defined in the FiRa test specifications
- FiRa authorizes **test labs** to ensure that they have the competence to conduct certification testing

FIRA PHY REQUIREMENTS

- Mandatory BPRF mode, optional HPRF mode
- PPDU formats SP0, SP1 and SP3



Some of the requirements – not complete

- The transmit carrier frequency tolerance and pulse timing shall be less than +/- 15 ppm.
- Time Domain Pulse Mask as defined in IEEE 802.15.4z-2020
- The NRMSE of all SHR and STS packets shall be less than 25%.
- The NRMSE of all PHR and PSDU packets shall be less than 30%.
- Ranging accuracy shall be ±10cm with ≥95% success rate at 0 to 10 meter separation in LOS environment.
- If the device supports AOA, AoA accuracy shall be ±5° with ≥95% success rate at 0.1 to 2 meter separation and AoA coverage of (-60°) to (+60°) in LOS environment.

Receiver Sensitivity SP0/SP1

Mode	Data Rate	RX sensitivity
BPRF	6.8 Mbps	-85 dBm
HPRF	6.8/7.8 Mbps	-85 dBm
HPRF	27.2/31.2 Mbps	- 80 dBm

Receiver Sensitivity SP3

SYNC PSR	RX sensitivity
64	-88 dBm
32	-85 dBm

FIRA CONSORTIUM UWB PHY TECHNICAL REQUIREMENTS V1.1 Jan. 2021

FIRA PHY CONFORMANCE TEST CASES

Transmitter Tests

PCT1.1.1: BPRF - Packet Format
PCT1.1.2: HPRF - Packet Format
PCT1.2.1: BPRF - Power Spectral Density Mask
PCT1.2.2: HPRF - Power Spectral Density Mask
PCT1.3.1: BPRF - Carrier Frequency Tolerance and Pulse Timing
PCT1.3.2: HPRF - Carrier Frequency Tolerance and Pulse Timing
PCT1.4.1: BPRF - Baseband Impulse Response
PCT1.4.2: HPRF - Baseband Impulse Response
PCT1.5.1: BPRF - Transmit Signal Quality (NRMSE)
PCT1.5.2: HPRF - Transmit Signal Quality (NRMSE)

Receiver Tests

PCT2.1.1: BPRF - SP0 & SP1 Packet Reception Sensitivity
PCT2.1.2: HPRF - SP0 & SP1 Packet Reception Sensitivity
PCT2.2.1: BPRF - SP3 Packet Reception Sensitivity
PCT2.2.2: HPRF - SP3 Packet Reception Sensitivity
PCT2.3.1: BPRF - SP0 & SP1 Dirty Packet Test
PCT2.3.2: HPRF - SP0 & SP1 Dirty Packet Test
PCT2.4.1: BPRF - SP3 Dirty Packet Test
PCT2.4.2: HPRF - SP3 Dirty Packet Test
PCT2.5.1: BPRF - SP3 Packet First-Path Dynamic Range
PCT2.5.2: HPRF - SP3 Packet First-Path Dynamic Range
PCT2.6.1: BPRF - Packet Format
PCT2.6.2: HPRF - Packet Format

FIRA CONSORTIUM PHY CONFORMANCE TEST SPECIFICATION V0.8 Feb. 2021

Typical PHY measurements for HRP UWB devices

Defined in IEEE 802.15.4 incl. 802.15.4z

- Regulatory requirements: Maximum allowable output power spectral density e.g. FCC/ETSI[1)] 41.3dBm/MHz
- Baseband impulse response:
  - Normalized cross-correlation (main/side lobe limits)
  - Pulse amplitude mask
- Transmit power spectral density mask
- Chip rate clock and chip carrier alignment accuracy of ± 20 × 10^{-6}
- Transmit center frequency tolerance of ± 20 × 10^{-6}

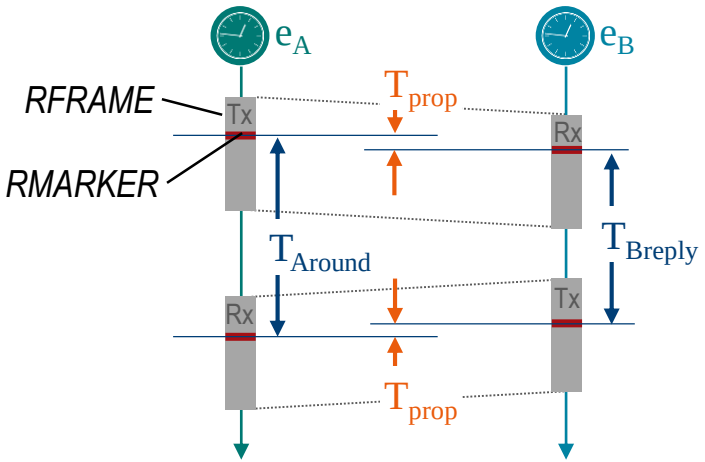
Additional measurements

- Chip/symbol clock jitter analysis
- Chip/symbol phase jitter analysis
- Main lobe width / peak
- Side lobe width / peak
- Transmit signal quality using a normalized root mean square error (NRMSE) metric
- Chip/Symbol EVM
- Preamble/data Power
- Power vs Time
- Receiver sensitivity
- …

ETSI related documents ETSI EN 302 065 and ETSI EN 303 883

Ranging estimation based on two-way ToF estimation

SS-TWR: single-sided two-way ranging



$$T_{prop} = \frac{(1+e_A) \times T_{Around} - (1+e_B) \times T_{Breply}}{2}$$

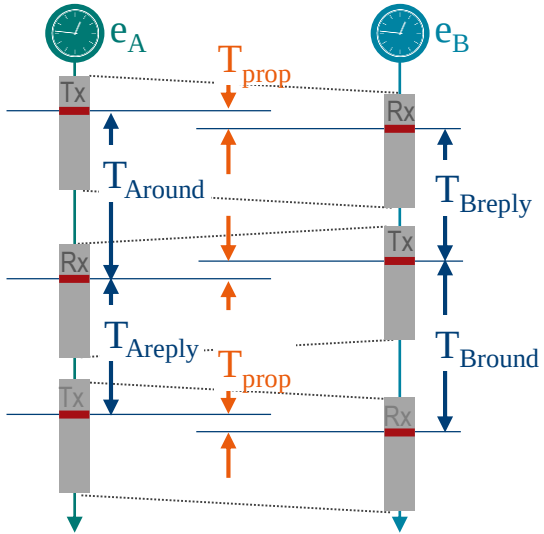
$$error = 0.5\,(e_B \times T_{Breply} - e_A \times T_{Around})$$

$e_{B;}\ e_A$ – clock offset error

$$Distance = c_{AIR} \times T_{prop}$$

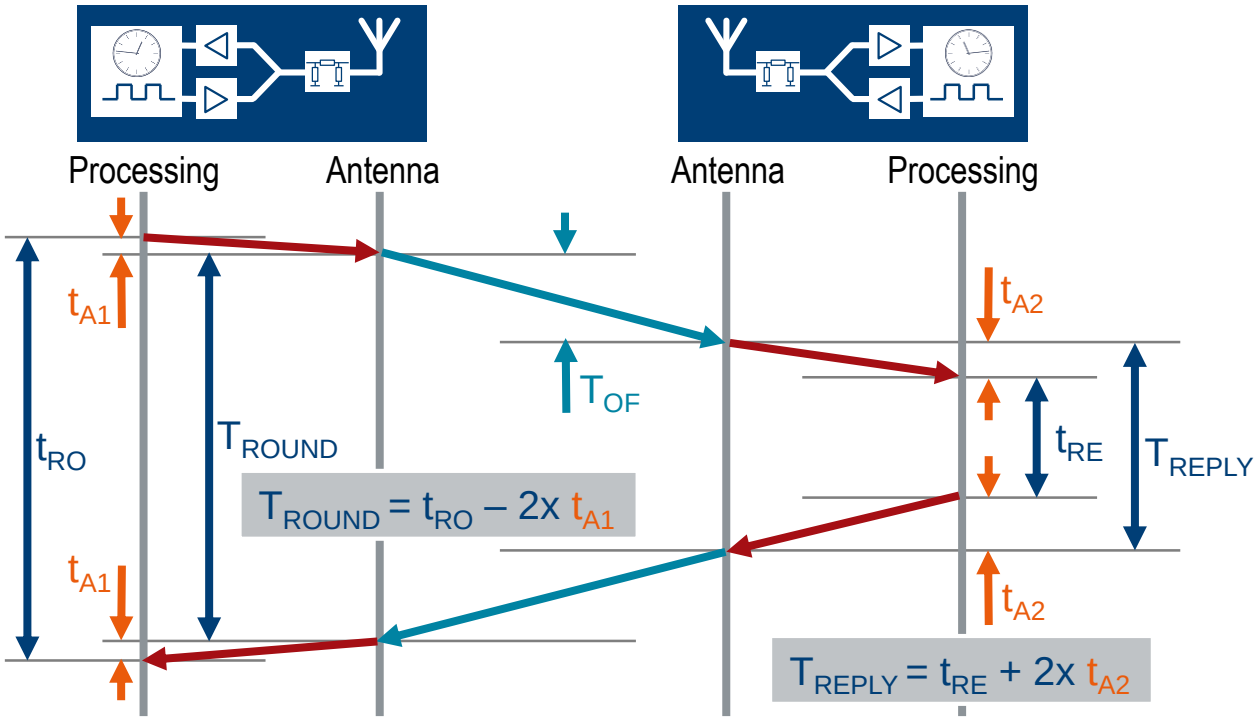
$$c_{AIR} = 29.97\ cm / ns$$

DS-TWR: double-sided two-way ranging



$$\hat{T}_{prop} = \frac{T_{Around} \times T_{Bround} - T_{Areply} \times T_{Breply}}{T_{Around} + T_{Bround} + T_{Areply} + T_{Breply}}$$

The on-board antenna delay determines the accuracy of the ToF and AoA measurements – need to calibrate and verify!



Dependent on the implementation the onboard antenna delay can easily vary by 1 ns which could result in a ranging error of more than 30 cm

Selected solutions for test and verification of mobile devices

Performance

R&S®CMW270/500

CMX500

Conformance

R&S®TS8997

R&S®TS8980

Production

R&S®CMP200

R&S®TS7124

R&S®CMQ200

R&S®CMW100

RF design and compliance

R&S®ZNA

R&S®FSW

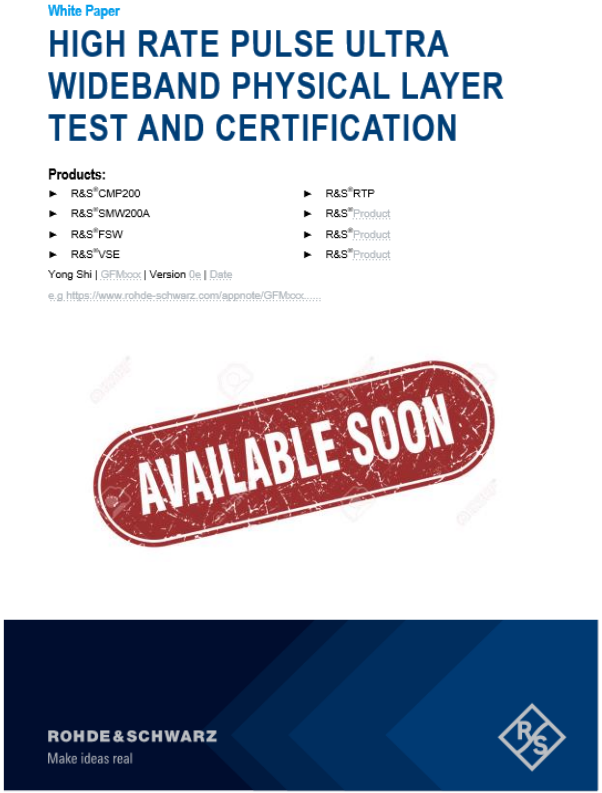
R&S®SMW200A

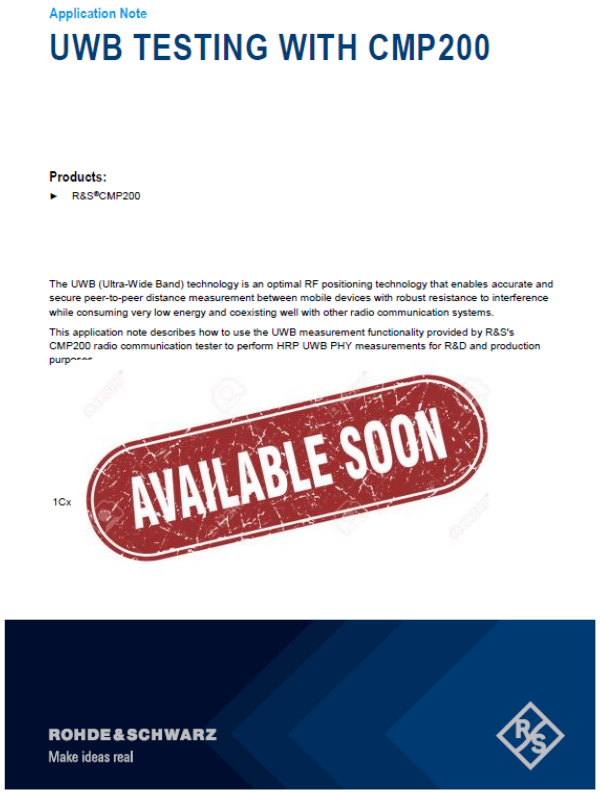
Embedded design and power

R&S®NGM200

R&S®RTP

Continous promotion of our UWB solutions





R&S Webinar
'Testing UWB in Automotive

May 19th 2021

presented by
Martina Neuherz
Nikola Serdar
Werner Dürport

ROHDE&SCHWARZ

Make ideas real

thank YOU