

Mobile Test Summit Korea 2024

IEEE 802.11be key-technical update & Connectivity solution

CMX500 – Radio Communication Tester

Joochan Kim (Rohde & Schwarz Korea)

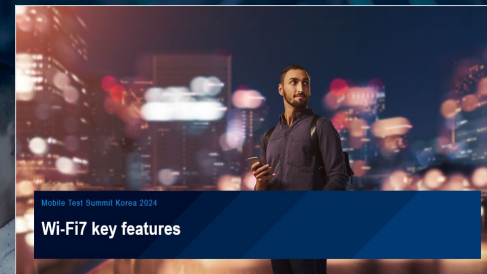
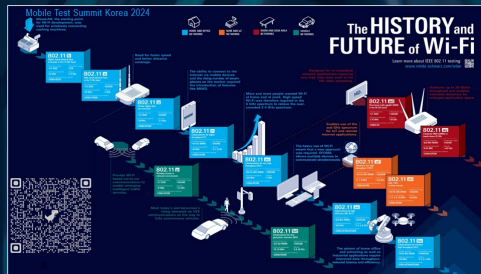
ROHDE & SCHWARZ

Make ideas real



AGENDA

- ▶ Wi-Fi History and Market
- ▶ Wi-Fi7 Key features
- ▶ Connectivity Test solutions
- ▶ Summary & Appendix



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



The HISTORY and FUTURE of Wi-Fi

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



802.11 b

Higher speed physical layer extension in the 2.4 GHz band

Speed streams	Modulation type
1x1 SISO	QPSK
Channel bandwidth	Bands
22 MHz	2.4 GHz
Transmission/access method	
CSMA/SSSS	

802.11 a

High speed physical layer in the 5 GHz band

Speed streams	Modulation type
1x1 SISO	64QAM
Channel bandwidth	Bands
20 MHz	5 GHz
Transmission/access method	
CSMA/OFDM	

Need for faster speed and better distance coverage.

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 g

Further higher data rate extension

Speed streams	Modulation type
1x1 SISO	64QAM
Channel bandwidth	Bands
20 MHz	2.4 GHz
Transmission/access method	
CSMA/OFDM	

802.11 n

Enhancements for higher throughput (HT)

Speed streams	Modulation type
4x4 SU-MIMO	64QAM
Channel bandwidth	Bands
40 MHz	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 overcrowded 2.4 GHz spectrum.

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

802.11 ad

Directed multi-gigabit (DMG) in the 60 GHz band

Speed streams	Modulation type
1x1 SISO	64QAM
Channel bandwidth	Bands
2.16 GHz	60 GHz
Transmission/access method	
CSMA/SC	

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

Speed streams	Modulation type
8x8 MU-MIMO	64QAM
Channel bandwidth	Bands
8.64 MHz	>45 GHz
Transmission/access method	
CSMA/OFDM	

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

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

802.11 ac

Enhancements for very high throughput (VHT)

Speed streams	Modulation type
8x8 MU-MIMO	256QAM
Channel bandwidth	Bands
160 MHz	5 GHz
Transmission/access method	
CSMA/OFDM	

802.11 ah

Television very high throughput (TVHT)

Speed streams	Modulation type
4x4 DL MU-MIMO	256QAM
Channel bandwidth	Bands
8, 16 MHz	sub GHz
Transmission/access method	
CSMA/OFDM	

802.11 ab

Sub 1 GHz license exempt

Speed streams	Modulation type
4x4 DL MU-MIMO	256QAM
Channel bandwidth	Bands
1, 2, 4, 8, 16 MHz	sub 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 p

Wireless access in vehicular environments

Speed streams	Modulation type
1x1 SISO	64QAM
Channel bandwidth	Bands
10 MHz	5.9 GHz
Transmission/access method	
CSMA/OFDM	

802.11 bd

Enhancements for next generation vehicular (NGV)

Speed streams	Modulation type
2x2 SU-MIMO	256QAM
Channel bandwidth	Bands
10, 20 MHz	5.9, 60 GHz
Transmission/access method	
CSMA/OFDM	

802.11 be

Enhancement for high efficiency (HE) Wi-Fi

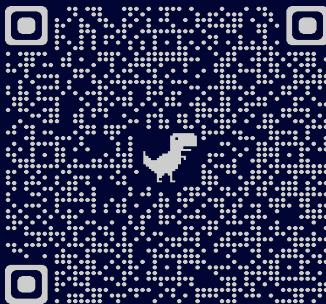
Speed streams	Modulation type
8x8 MU-MIMO	1024QAM
Channel bandwidth	Bands
160 MHz	2.4, 5, 6 GHz
Transmission/access method	
CSMA/OFDM/OFDMA	

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

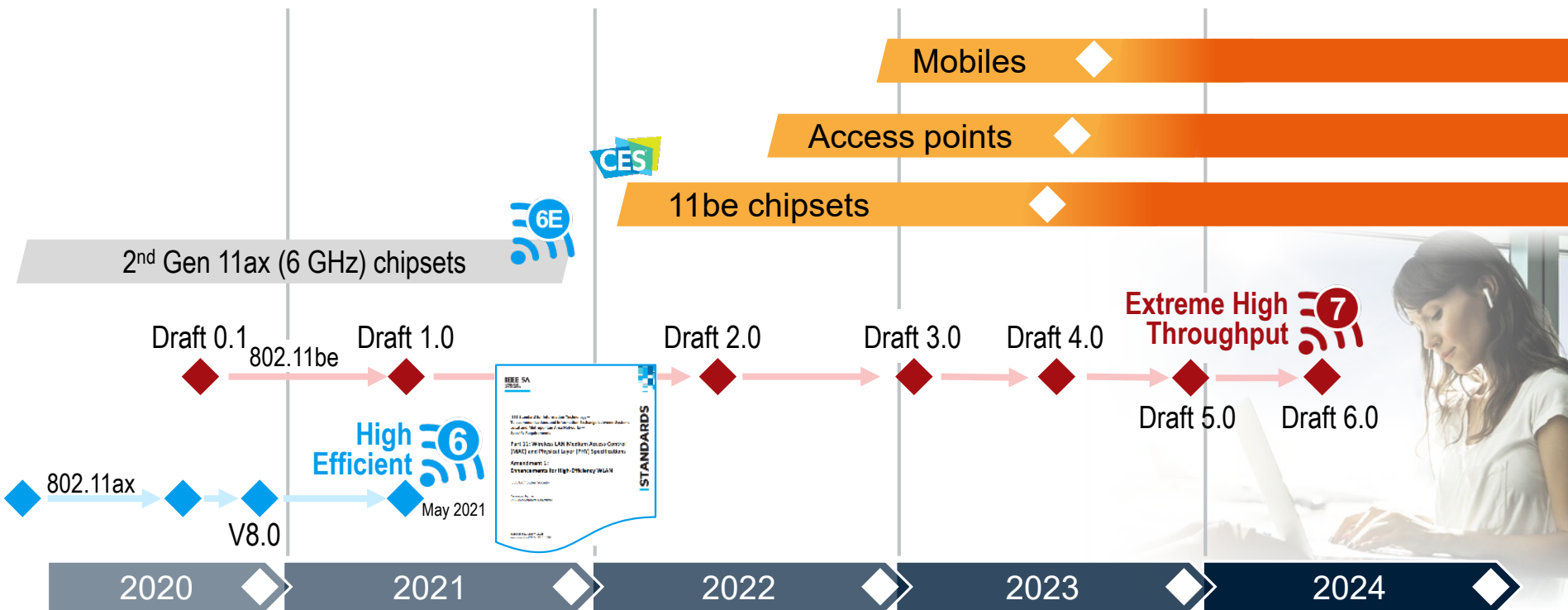
802.11 be

Enhancements for extreme high throughput (EH-T)

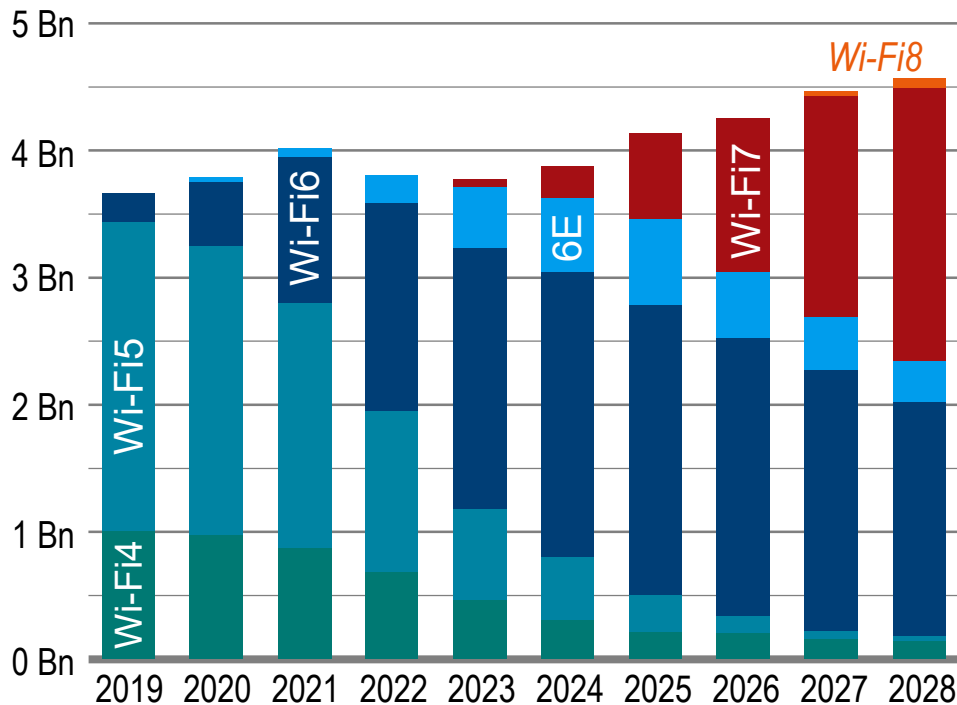
Speed streams	Modulation type
16x16 MU-MIMO	4096QAM
Channel bandwidth	Bands
320 MHz	2.4, 5, 6 GHz
Transmission/access method	
CSMA/OFDM/OFDMA	



Extreme high throughput WLAN (EHT – IEEE 802.11be – Wi-Fi7) is entering the market with amazing speed



Recovery of the Wi-Fi market after the 22/23 drop with Wi-Fi7



Source: IDC: Wi-Fi market update, March 2024

- Wi-Fi maturity means limited grow opportunities mainly for IoT market in the long-term
- Wi-Fi 6 and 6E combined will dominate through the forecast period
- 6 GHz Wi-Fi (6E and 7) will surpass non-6 GHz Wi-Fi in 2027.
- Wi-Fi 7 will be concentrated in smartphones, media tablets, PCs, Access Points and TVs








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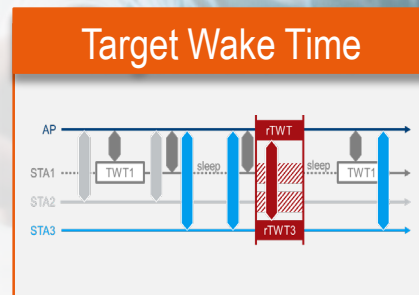
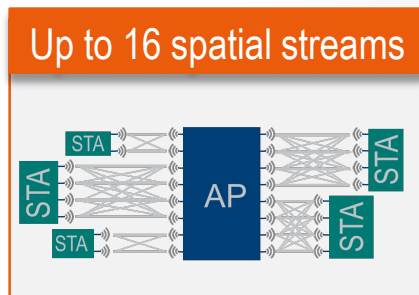
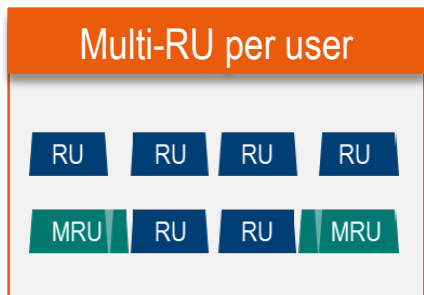
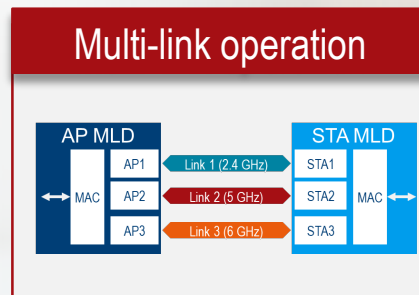
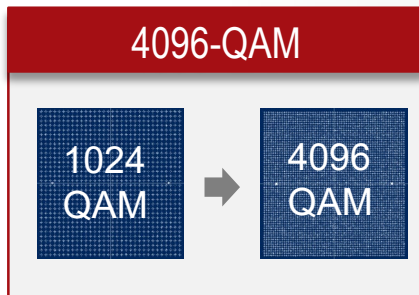
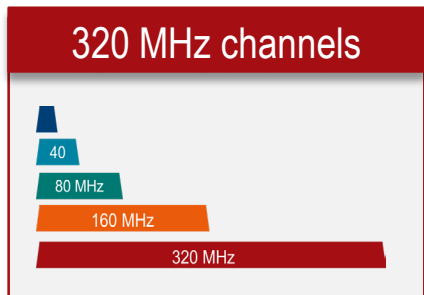
Wi-Fi7 key features

What is new in W-Fi7?

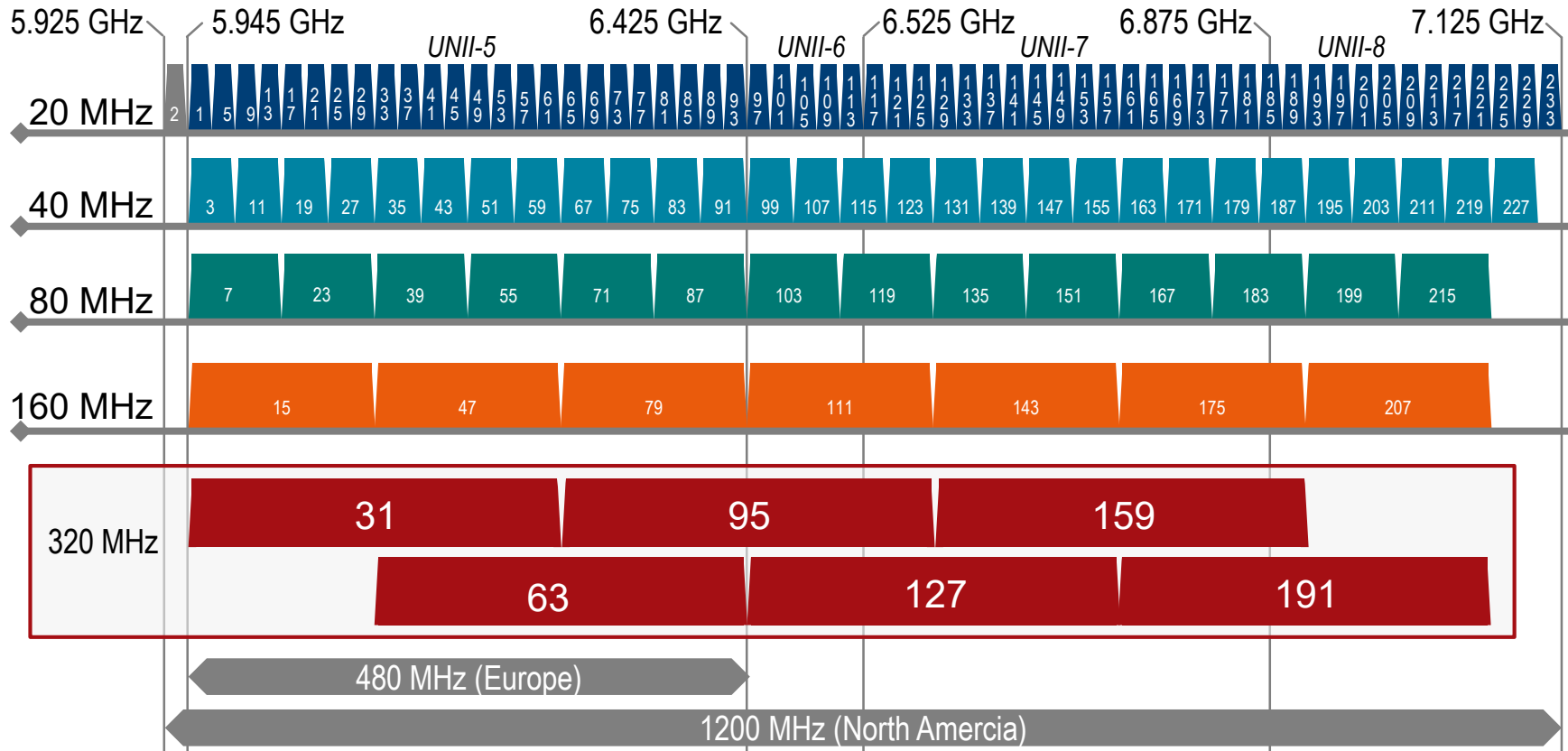
	 Wi-Fi 5 (802.11ac) <i>Very High Throughput (VHT)</i>	 Wi-Fi 6E (802.11ax) <i>High Efficiency (HE)</i>	 Wi-Fi 7 (802.11be) <i>Extreme High Throughput (EHT)</i>
Supported bands	5 GHz	2 GHz, 5 GHz, <u>6 GHz</u>	2 GHz, 5 GHz, 6 GHz
Channel bandwidth (MHz)	20, 40, 80, 80+80, 160	20, 40, 80, 80+80, 160	20, 40, 80, 160, <u>320</u>
Transmission scheme	OFDM	OFDM, <u>OFDMA</u>	OFDM, OFDMA
Subcarrier spacing	312.5 kHz	<u>78.125 kHz</u>	78.125 kHz
Guard interval	0.4 μs, 0.8 μs	0.8 μs, <u>1.6 μs</u> , <u>3.2 μs</u>	0.8 μs, 1.6 μs, 3.2 μs
Spatial streams	8x8 (incl. DL-MU-MIMO)	8x8 (incl. MU-MIMO)	8x8 (incl. MU-MIMO)
Modulation (highest)	256QAM (8 bit)	<u>1024QAM</u> (10 bit)	<u>4096QAM</u> (12 bit)
Max data rate*	1.2Gbps <small>*80 MHz BW 2x2 600 Mbps (4x4 1.2 Gbps)</small>	9.6Gbps <small>*160 MHz BW 2x2 2.4 Gbps (4x4 4.8 Gbps, 8x8 9.6 Gbps)</small>	23Gbps <small>*320 MHz 2x2 5.76 Gbps (4x4 11.528 Gbps, 8x8 23 Gbps, w/o MLO)</small>

* dependent on configuration (GI) and incl. signaling overhead

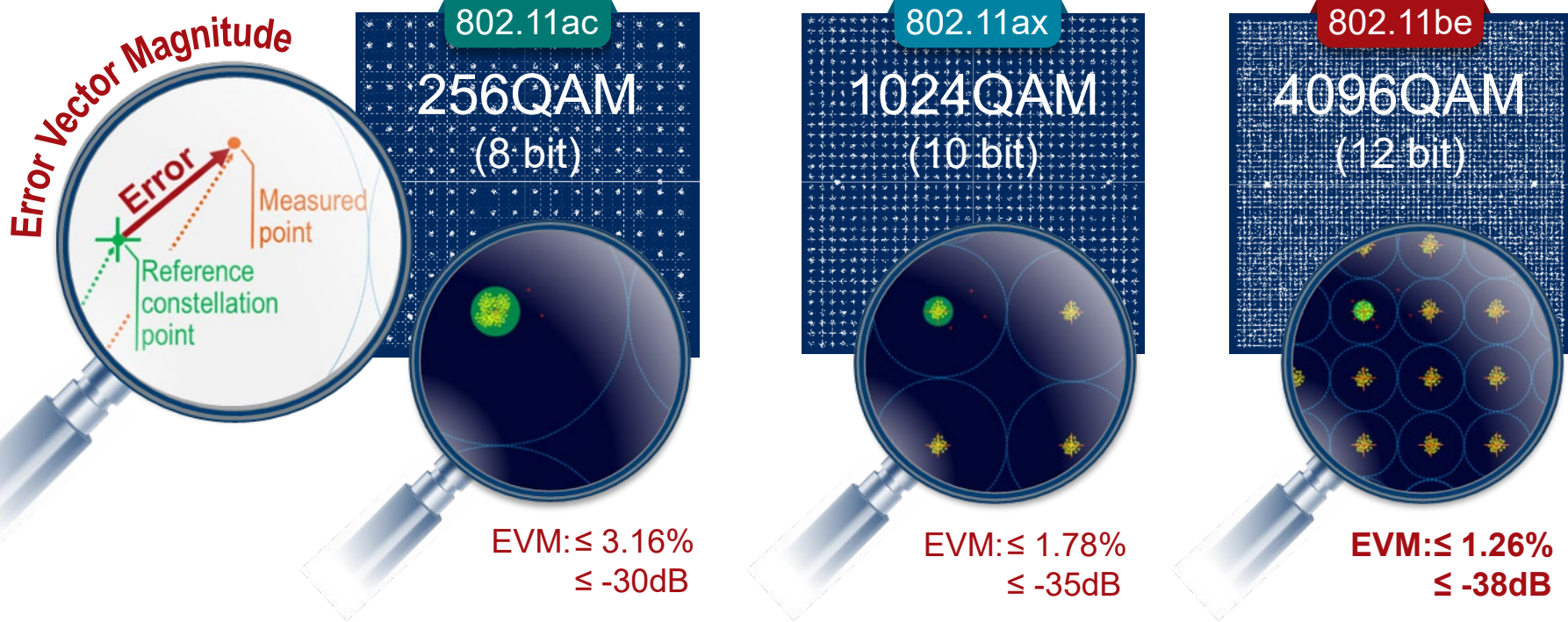
Wi-Fi7 for extreme high throughput (EHT) and



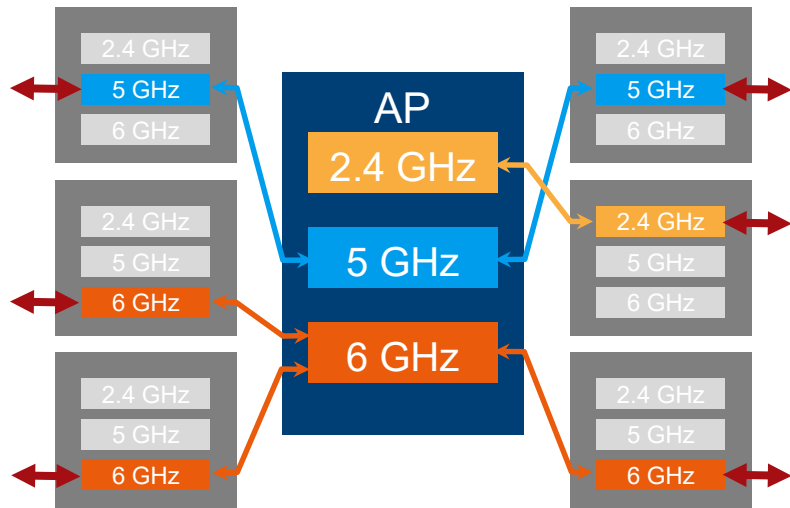
A few overlapping 320 MHz channels in the 6 GHz band



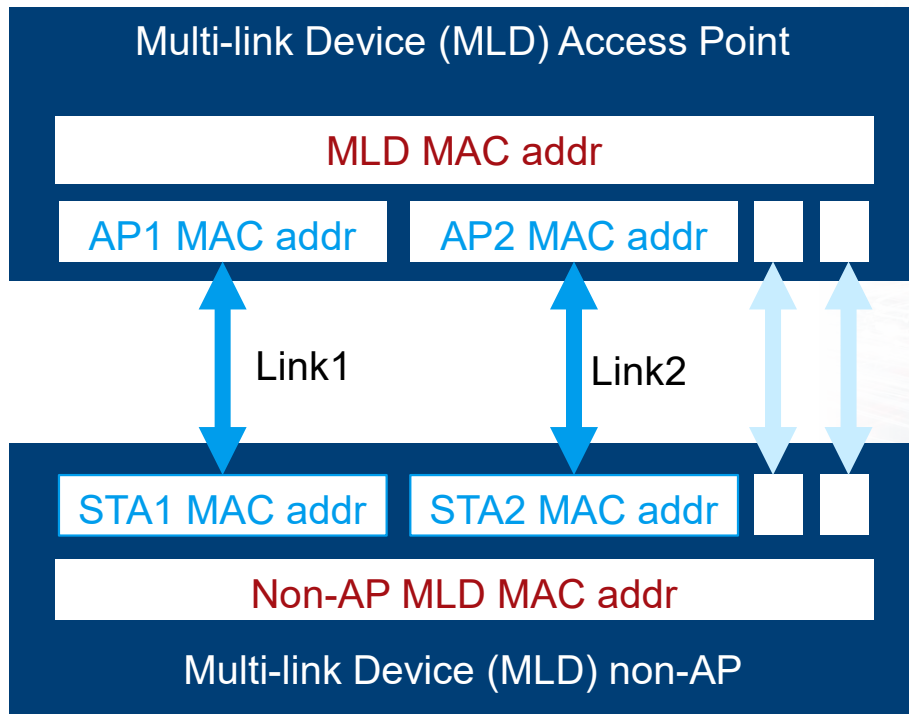
802.11be pushes RF performance requirements and test equipment quality to the next level



Multi-band operation of access points is well established



Reference model for multi-link operation of multi-link devices

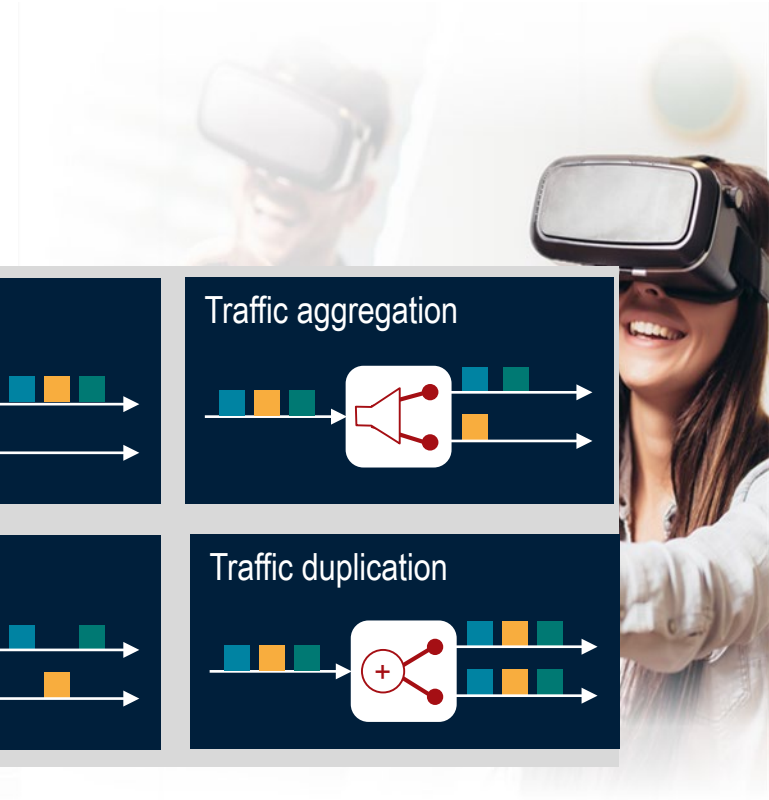
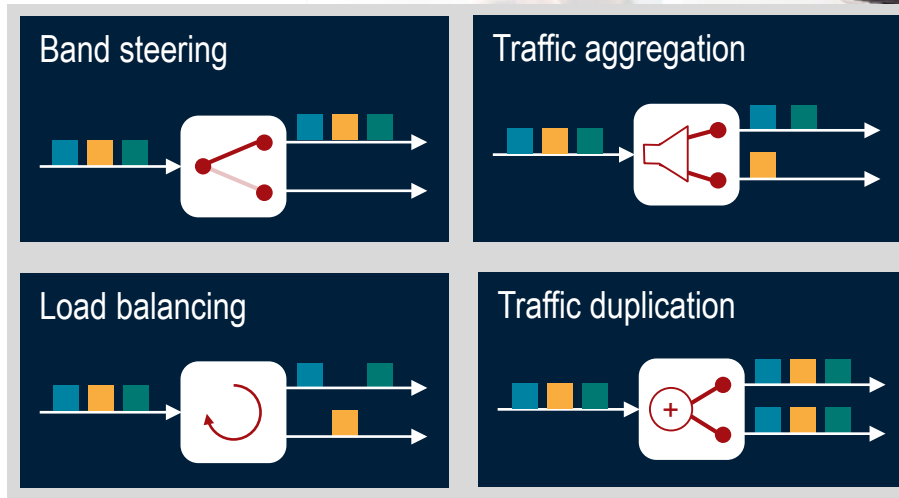
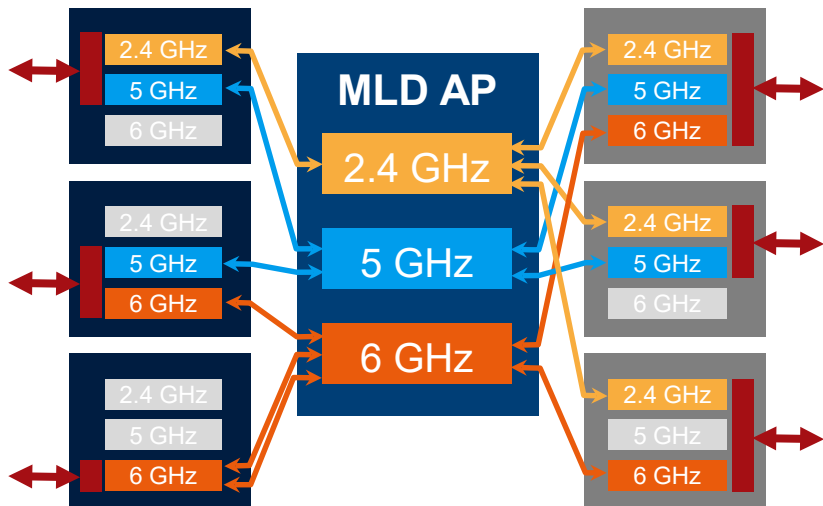


Multi-link operation (MLO) enables a non-AP **multi-link device (MLD)** to discover, authenticate, associate, and set up one or more links with an AP MLD.

Each link enables **channel access** and **frame exchanges** between the non-AP MLD and the AP MLD based on the supported capabilities exchanged during the association.

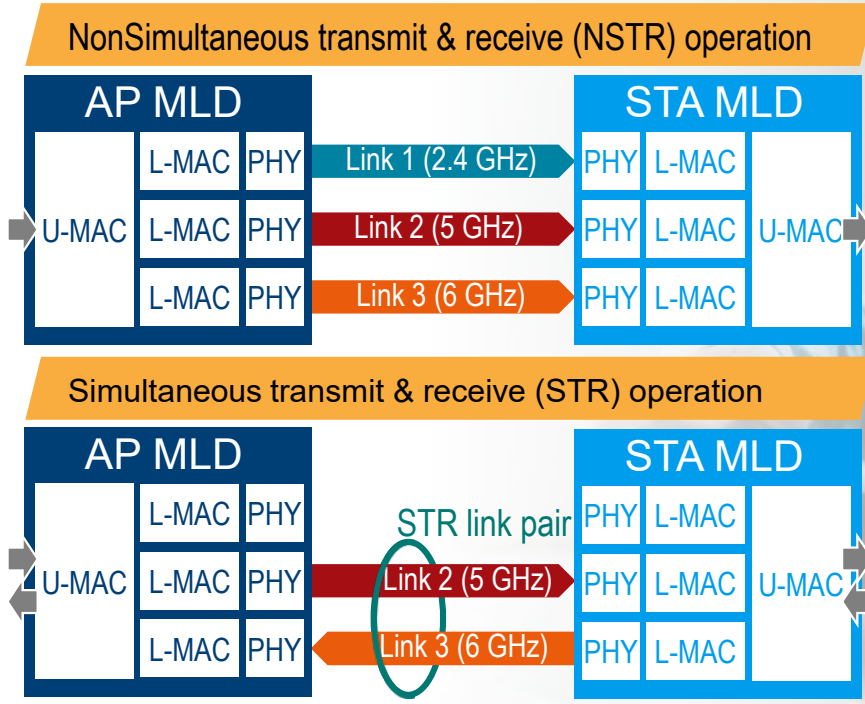
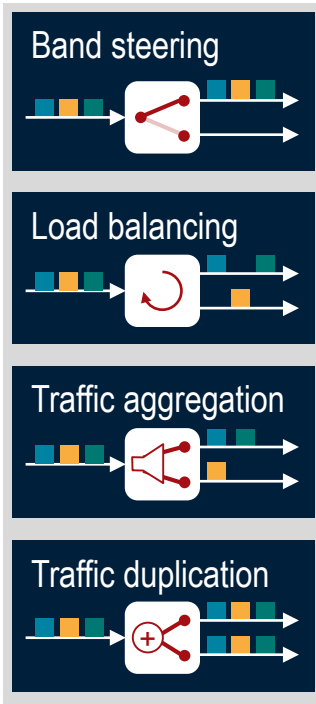
Multi-link Element (MLE) information is used to setup and manage MLO – added to beacons, probe request and reconfiguration

Wi-Fi 7 will allow multi-link operation

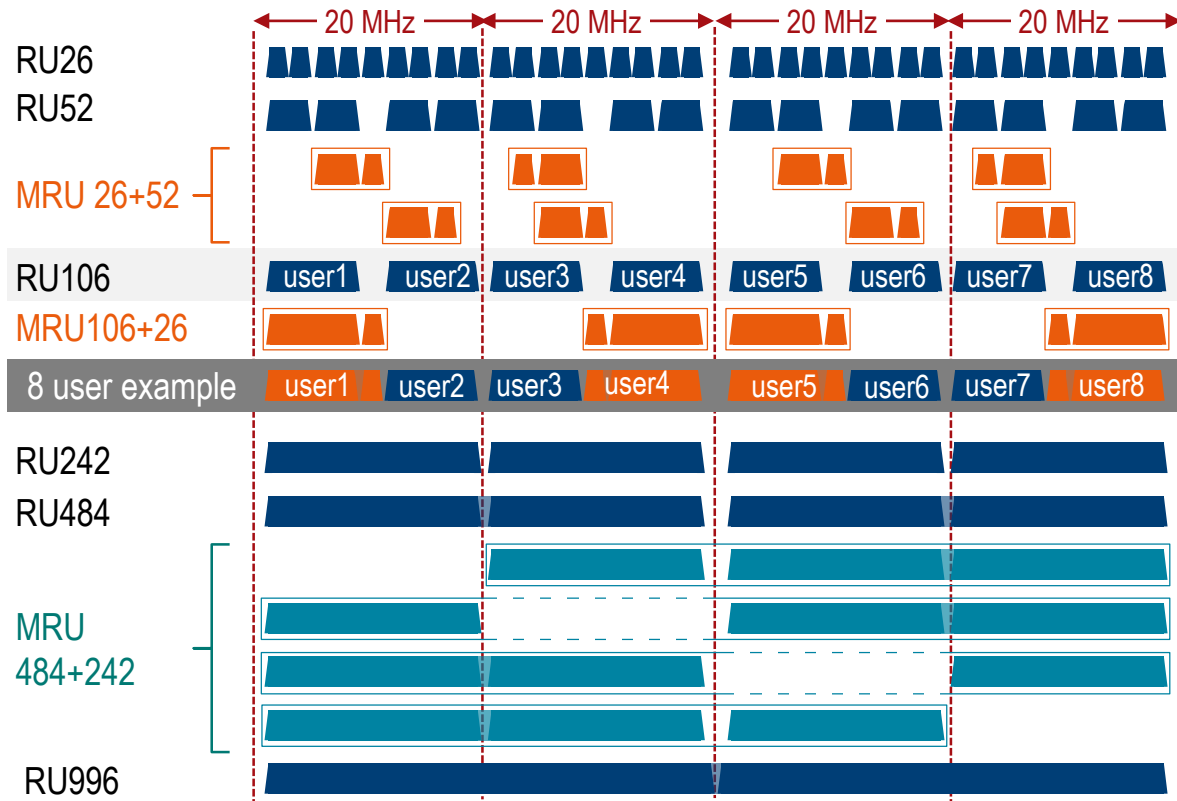


MLO provides higher throughput, lower latency and / or higher reliability, which are useful to a number of applications from VR/AR to industrial IoT

Further improve throughput, latency and efficiency with introducing **multi-link operation (MLO)**



Multiple Resource Units (MRU) per user for efficiency



A **small size MRU** (i.e. 26, 52, 106 tone) can only be combined for **efficiency** with another small size RU to form an MRU. RUs in the MRU need to be contiguous and within a 20 MHz channel boundary

The permitted **large size MRU** combinations (i.e. 242, 484, 996 tone) allow additional aggregated bandwidth options (e.g. 60 MHz) per user that don't need to be continuous.



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Connectivity Test solutions

Wi-Fi test solutions for today and tomorrow



Conformance



R&S®TS8997

RF performance



R&S®CMW500/270



R&S®CMX500 OBT



R&S®CMP180



R&S®CMW100



R&S®TS7124



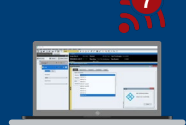
R&S®ZNA



R&S®FSW



R&S®SMM100A



R&S®VSE

RF design and compliance



R&S®NGU



R&S®RTP

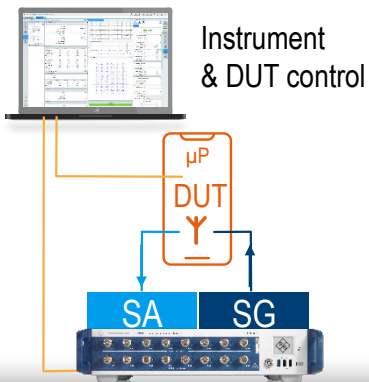
Embedded design & power

The different ways of testing performance of Wi-Fi devices

Non-Signaling Test

PHY

Device/chip specific test interfaces allow DUT control of testing used from early R&D to manufacturing

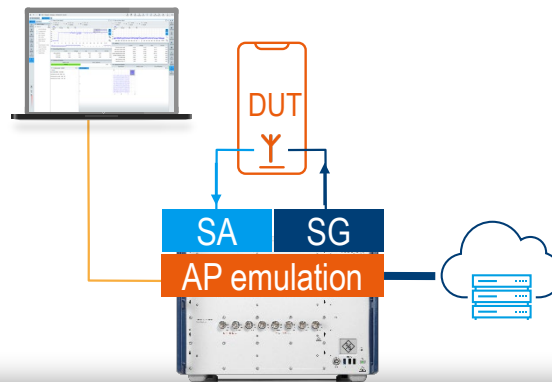


- ▶ Fast & reliable RF performance, compliance testing and calibration

Signaling Test

PHY/MAC

Emulating an AP/STA allows testing under well defined network conditions Without limitations (e.g. regulation)



- ▶ Full power of device testing with full control and maximum flexibility

High-performance radio communication tester R&S®CMP180 for R&D and production purposes with very high accuracy

Excellent RF performance

- ◆ 400 MHz up to 8 GHz
- ◆ Up to 500 MHz bandwidth
- ◆ High output power
- ◆ Extraordinary EVM value

Compact design (2 HU x 19")

- ◆ 2x 8 RF (in/out) ports
- ◆ up to two channels (VSA/VSG)
- ◆ Build-in controller
- ◆ Common platform (CMP200)

High-degree of flexibility

- ◆ up to 6 or 8 GHz
- ◆ 250 or 500 MHz bandwidth
- ◆ 1 or 2 channels in a box
- ◆ Stackable to get more channels



R&S®CMP180 supports RF testing of the primary wireless communication technologies

Technology	RF generator	RF analyzer
5G NR FR1	◆	◆
LTE-A	◆	◆
WCDMA/HSPA+	◆	◆
GSM/GPRS/EGPRS	◆	◆
eMTC	◆	◆
NB-IoT	◆	◆
C-V2X	◆	◆
CDMA2000, 1xRTT	◆	◆

Technology	RF generator	RF analyzer
IEEE802.11a/b/g/n/ac/ax/be	◆	◆
Bluetooth® BR, EDR, LE	◆	◆
UWB (production only)	◆	◆
Low Power IoT		
802.15.4 (Zigbee, Thread)	◆	◆
LoRa®	◆	(-)
SigFox	◆	(-)
GNSS	◆	(-)



R&S Wi-Fi/WLAN signaling test solutions

THE WIRELESS CONNECTIVITY TESTER



R&S®CMW270

- WLAN 11 a / b / g / n / ac / ax SISO and MIMO
- Wi-Fi6e extension for 6GHz Band
- Bluetooth Low Energy (BLE), Basic Rate and EDR

THE WIDEBAND RADIOCOM TESTER



R&S®CMW500

- Bluetooth and WLAN capability same as CMW270
- 2G (GSM...)
3G (WCDMA, c2k,...)
4G (LTE, LTE-A)

THE ALL-IN ONE BOX SIGNALING TESTER



R&S®CMX500

- 4G (LTE, LTE-A), 5G FR1/FR2 and WLAN
- Frequency range up to 8 GHz
- WLAN 11a / b / g / n / ac / ax / be SISO and MIMO

R&S®CMX500 - WI-FI SIGNALING TEST

- Up to **Wi-Fi7** (IEEE802.11be) on all channels and all bands (2.4, 5, 6 GHz)
- OFDMA multi-user and multi-link operation (**MLO**)
- Emulates access point (**AP**) or station (**STA**)
- **Multi-Technology signaling** tester allows testing of interference scenarios and **5G/Wi-Fi offloading**
- **Application testing** incl. Voice over WLAN
- Web GUI, Built-in automation tool

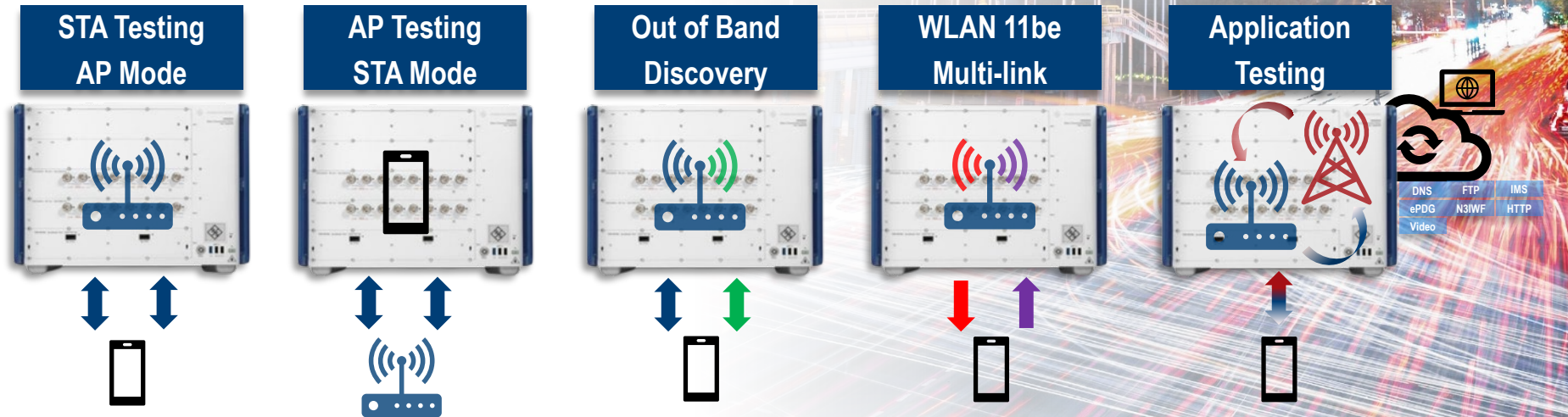


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R&S® CMX500 WLAN Test scenarios



Wi-Fi performance testing with R&S CMX500

Tx/Rx verification, performance, coexistence, audio testing and traffic offloading

Typical Wi-Fi7 test setup to verify the RF performance parameters of transmitters, filters, amplifiers etc.

Rx test items:

- Packet error rate
- Minimum input sensitivity
- Adjacent channel rejection
- Non-adjacent channel rejection
- Maximum input level

Tx test items:

- Transmit spectral mask
- Spectral flatness
- Transmit center frequency leakage
- Transmitter constellation error
- Unused tone error

R&S®SMM100A



Rx

Device Under Test

Tx

R&S®FSV3007



UWB test and measurement solutions for all phases of the product lifecycle from the UWB testing experts



R&S®ATS800R



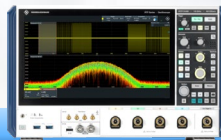
R&S®CMQ200 HS



R&S®CMP180
R&S®CMP200



UWB PHY Test Suite



R&S®RTP+VSE



R&S®SMM100



R&S®FSW26



R&S®TS7124



R&S®CMP200 – Ultra-Wideband and 5G mmW (FR2) Testing

CMP200 features

- One general purpose analyzer
Frequency range: 4 to 20 GHz
- One ARB generator
Replay of predefined waveforms (-100 dBm)
Frequency range: 6 to 20 GHz
- Planned for 802.15.4ab

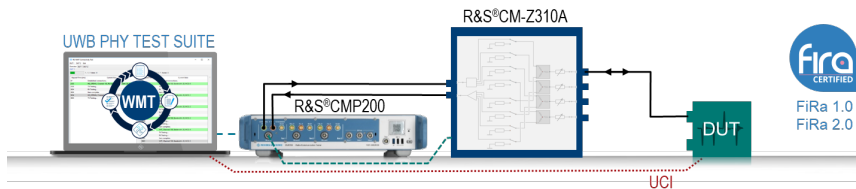
Compact UWB non-signaling tester for HRP in high band

- HRP UWB PHY TX measurements (802.15.4)
Band group 2: 6.5 to 9.5 GHz
- HRP UWB RX measurements by use of customer waveforms
or R&S®WinIQSIM2
- Time-of-flight and angle-of-arrival measurements
- New UWB Head for Multi DUT Testing

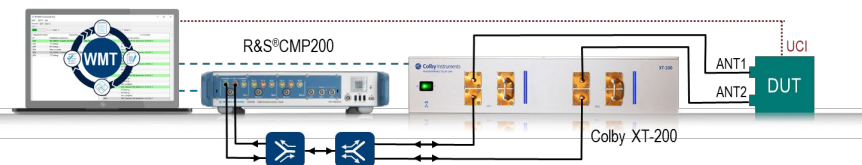


UWB test solution for different use cases based on the CMP200

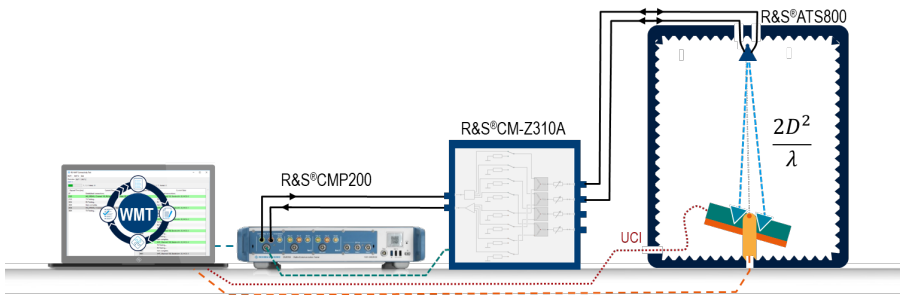
RF Performance and ToF incl FiRa



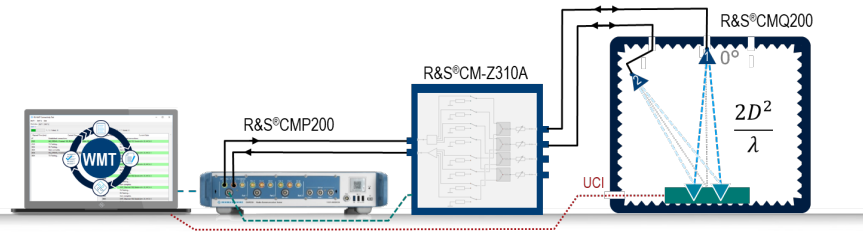
AoA verification and benchmarking



RF AoA verification and ref. calibration

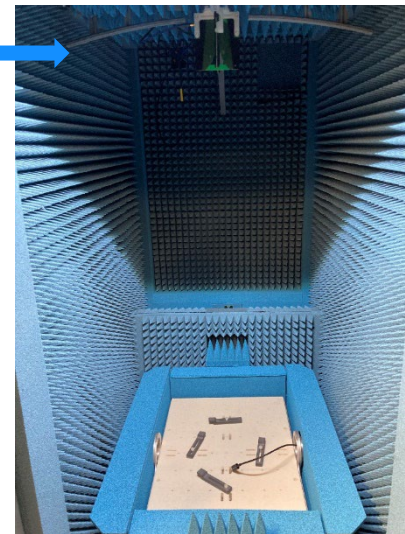
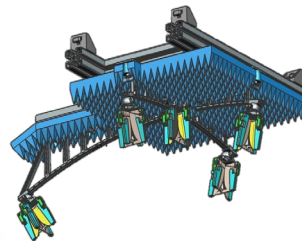
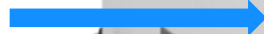


PHY Perf. Check, AoA/ToF calibration



R&S® ATS800R

Category	Value
Positioner Type	Tilt and pan
DUT Weight Max Size	< 2.5kg, centred 27cm x 41cm
Resolution	0.01 degrees
Accuracy	0.25 degrees @1kg 0.50 degrees @ 2.5kg
Tilt Range	+/- 90 degrees
Pan Range	+/- 90 degrees
Rotation speed	< 45 degree/sec



Antenna Arc

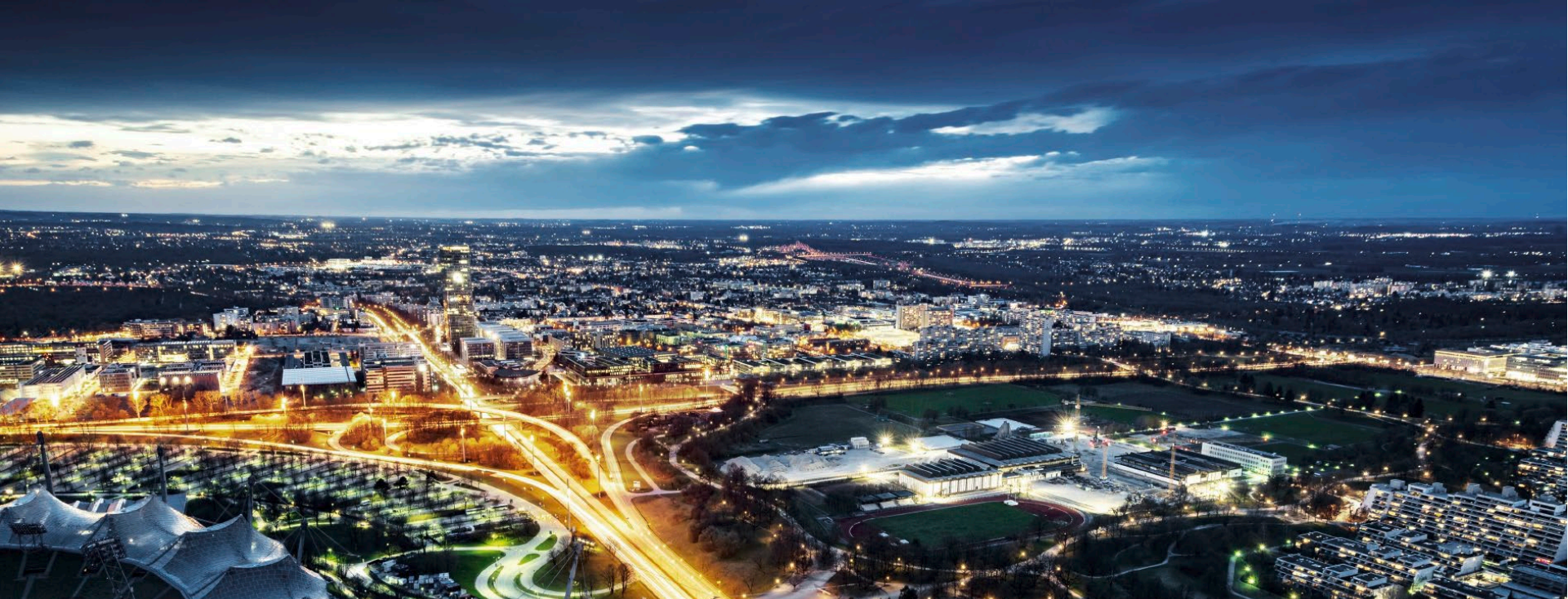
UWB testing/ SatCom/ NTN testing

Antenna Arc mounted instead of CATR reflector and feed

Fixed antenna in centre

Four Arc arms in all directions

Up to 5 antennas

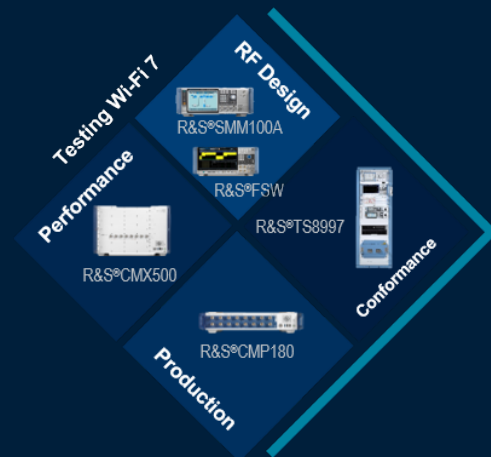
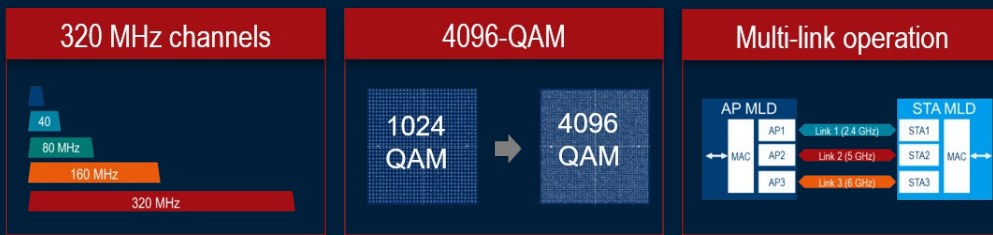


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Summary & Appendix

SUMMARY

Three cornerstones of **IEEE 802.11be - Wi-Fi7** to achieve extreme high throughput (EHT) and low latency



R&S®CMX500 Wireless signaling tester

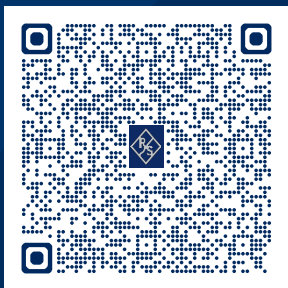
- LTE(FDD/TDD), 5G (FR1,2)SA / NSA
- IEEE 802.11 a/b/g/n/ac/ax/be(2.4, 5, 6 GHz)
- AP / STA Mode
- OFDMA multi-user and MLO(multi-link operation)
- Application test(incl. VoWiFi, 5G/Wi-fi Data offloading, Coexistence test)



For Wi-Fi, Worthwhile to read....

IEEE 802.11be TECHNOLOGY INTRODUCTION

White paper | Version 01.00 | Lisa Ward, Jörg Köpp

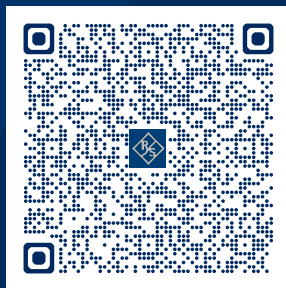


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IEEE 802.11ax TECHNOLOGY INTRODUCTION

White paper | Version 01.00 | Lisa Ward



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VERIFY RADIO PERFORMANCE OF IEEE 802.11be DEVICES

RF performance measurements for Wi-Fi 7



The next generation of Wi-Fi

The latest IEEE 802.11ax Wi-Fi standard was defined to improve efficiency and support a wider range of use cases such as large venues where several connected devices are active at the same time. Technology cornerstones include the introduction of OFDMA, 78.128 kHz sub-carrier spacing, longer guard intervals and 1024QAM as highest possible modulation scheme.

The new standard focuses on high data throughput at low latency for applications in homes, offices and factories.

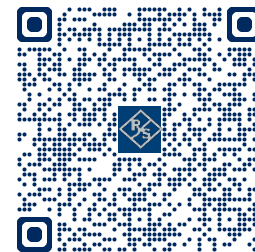
Two practical approaches help to improve data throughput on the physical link layer: applying higher modulation schemes and more flexible use of allocated frequency spectra, especially in environments with high user density.

Your task

Development of next generation Wi-Fi standards is now in full swing as seen in the current draft of the IEEE 802.11be specification, which has already been defined enough on the physical layer for specific implementations. Signal generators and signal analyzers help open up the Wi-Fi 7 signal world and allow initial testing for this new standard.

Typical test setup for IEEE 802.11 generator and R&S®FSV3030 sig

- ▶ Product entry code
- ▶ Measurement setup on
- ▶ Adjustment channel
- ▶ Time reference clock
- ▶ Modulation input b



Application Card | Version 01.00

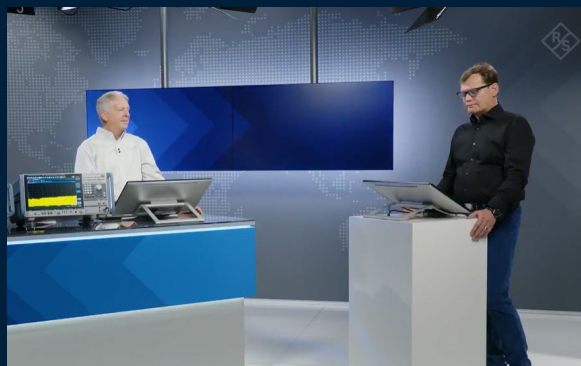
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For Wi-Fi, Worthwhile to watch...



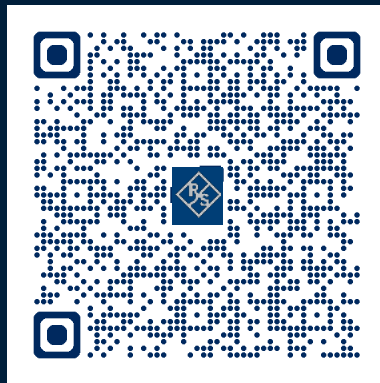
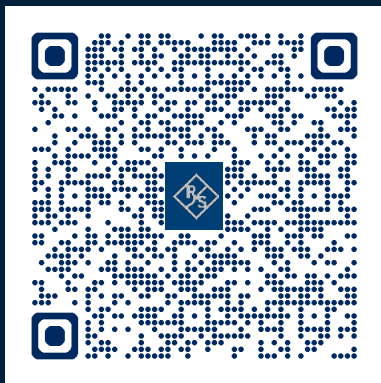
Are you ready for Wi-Fi 6E/7 testing? We are!



Realizing extreme high throughput with Wi-Fi 7



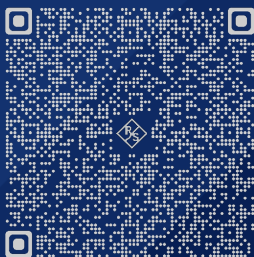
Unlocking the ultimate Wi-Fi 7 experience



For UWB, Worthwhile to read....

HIGH RATE PULSE ULTRAWIDEBAND PHYSICAL LAYER TESTING AND CERTIFICATION

White paper | Version 01.00 | Yong Shi



SIMPLIFY FiRa™ CERTIFICATION FOR YOUR UWB DEVICE



The validated UWB PHY test suite for the R&S®CMP200 radio communication tester simplifies FiRa™ Consortium PHY performance testing.



The physical layer requirements and certification test cases are derived from the related HRP LWB standard specified in IEEE802.15.4 clause 15 and complemented by FiRa™. FiRa™ focuses on enhanced ranging devices (ERDEV) supporting both modes: base pulse repetition frequency (BPRF) and high pulse repetition frequency (HPRF) in the high band (band group 2) for 489.2 MHz channels as specified in the latest standard amendment IEEE802.15.4z. For conformance testing, a couple of transmitter and receiver test cases were specified aimed at improving interoperability, quality and performance.

FiRa™ PHY test case coverage for BPRF and HPRF includes:

- Transmitter tests**
 - Check of transmitted packet format
 - Power spectral density mask
 - Carrier frequency tolerance
 - Pulse timing
 - Baseband impulse response
 - Transmit signal quality (BER/EIR)
- Receiver tests**
 - Packet reception capability

The value of conformance testing for interoperability
Seamless interoperability of UWB devices is of utmost importance for the success of UWB applications such as keyless entry, asset finding, sensing and navigation. It is essential to ensure a safe and effective user experience. The certification program established by the FiRa™ Consortium builds the cornerstone to drive it across the industry.

FiRa™ conformance testing
The FiRa™ certification program is intended interoperability of UWB devices which uses a flight (ToF) ranging measurements on different devices.

The certification program includes physical performance testing that needs to be executed authorized test laboratories (ATL) using FiRa test tools such as the UWB PHY test suite in R&S®CMP200.



Rohde & Schwarz is a PHY test conformance solution provided by the FiRa™ Consortium, it is based on the test suite that supports the signal generation.

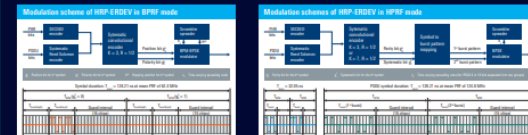
Application Card | Version 01.00

ROHDE & SCHWARZ
Make ideas real



UWB FOR ENHANCED RANGING DEVICES

Based on the IEEE standard 802.15.4z, IEEE standard amendment 15.4z, the physical layer for enhanced ranging devices (ERDEV). The use of narrow-band signals with a high sub-carrier (BPRF) supports frequency selective and power ranging applications.



ROHDE & SCHWARZ
Make ideas real



For UWB, Worthwhile to watch...



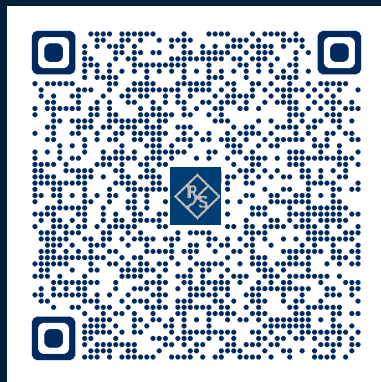
Discover the secrets of UWB based on IEEE 802.15.4z



Testing ultra-wideband for automotive applications



Reinforce a seamless UWB experience



Mobile Test Summit Korea 2024

THANK YOU

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