Wireless Communication

REALIZING EXTREME HIGH THROUGHPUT WITH Wi-Fi 7

A view on the next generation Wi-Fi physical layer

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ROHDE&SCHWARZ

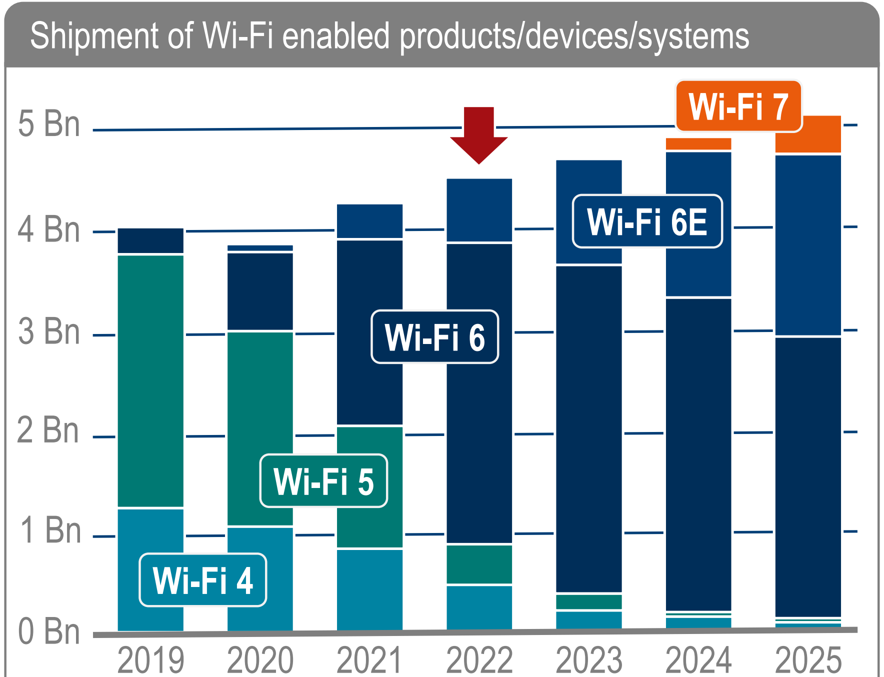
Make ideas real

Where are we today in terms of Wi-Fi adoption?

18Bn
Devices and more in use[1)]

4.4Bn
Devices shipping in 2022[1)]

50%
Wi-Fi 6 market adoption reached[1)]



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

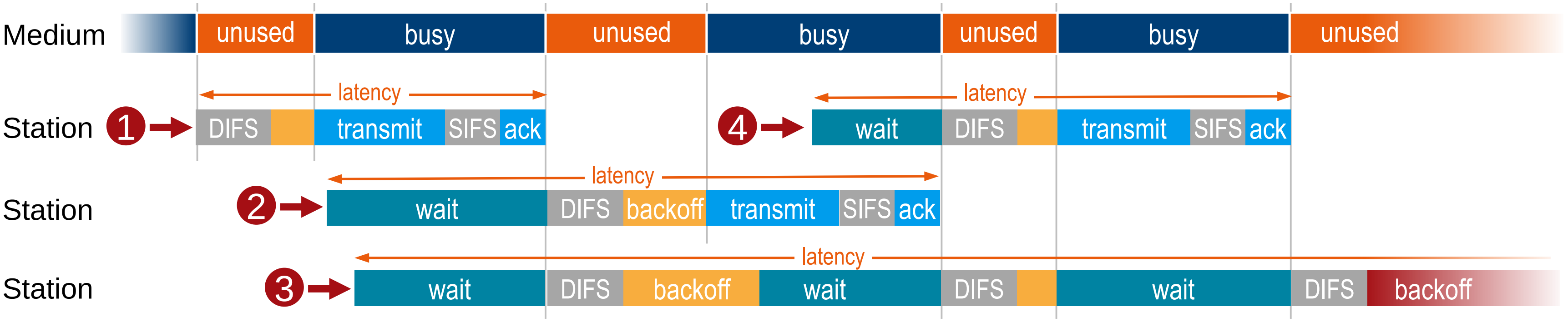
Wi-Fi product pictures: LANCOM System GmbH a Rohde & Schwarz Company

1) Wi-Fi alliance 2022 trends : https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-2022-wi-fi-trends

The 6th generation of Wi-Fi® for high efficiency in dense areas (indoor and outdoor environments)

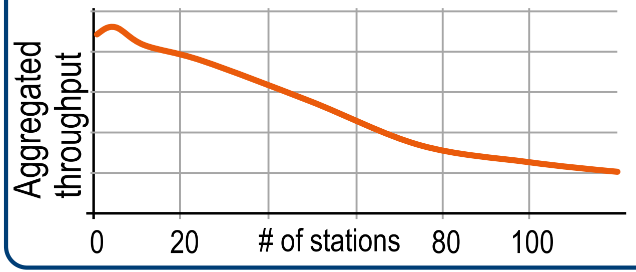
Wi-Fi® is a registered trademark of Wi-Fi Alliance

Wi-Fi access scheme based on CSMA/CA has some limitations in dense environments



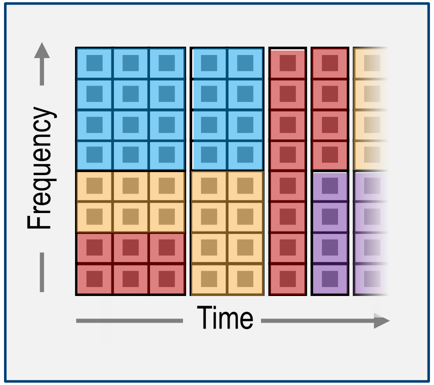
Works well for small # of clients …, but fails in traffic jam

Throughput depend on # of stations

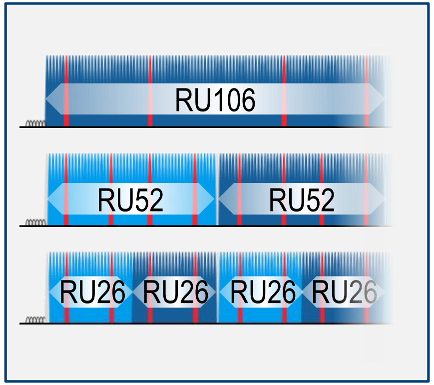


A kind of Wi-Fi revolution in Wi-Fi 6 (IEEE 802.11ax) by introducing OFDMA for more efficiency

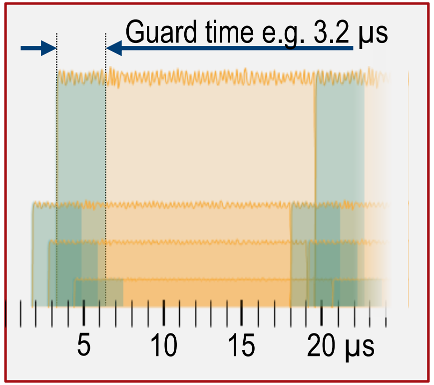
OFDMA



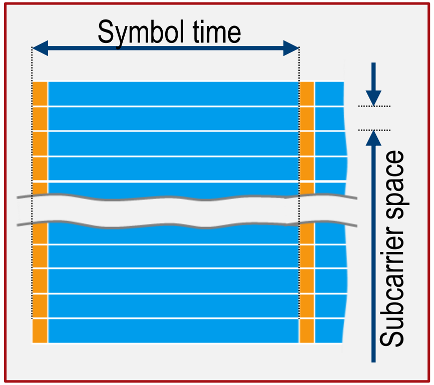
Resource units



Long guard interval



Long symbol time



- Efficient use of available spectrum
- Multi-user operation and latency reduction

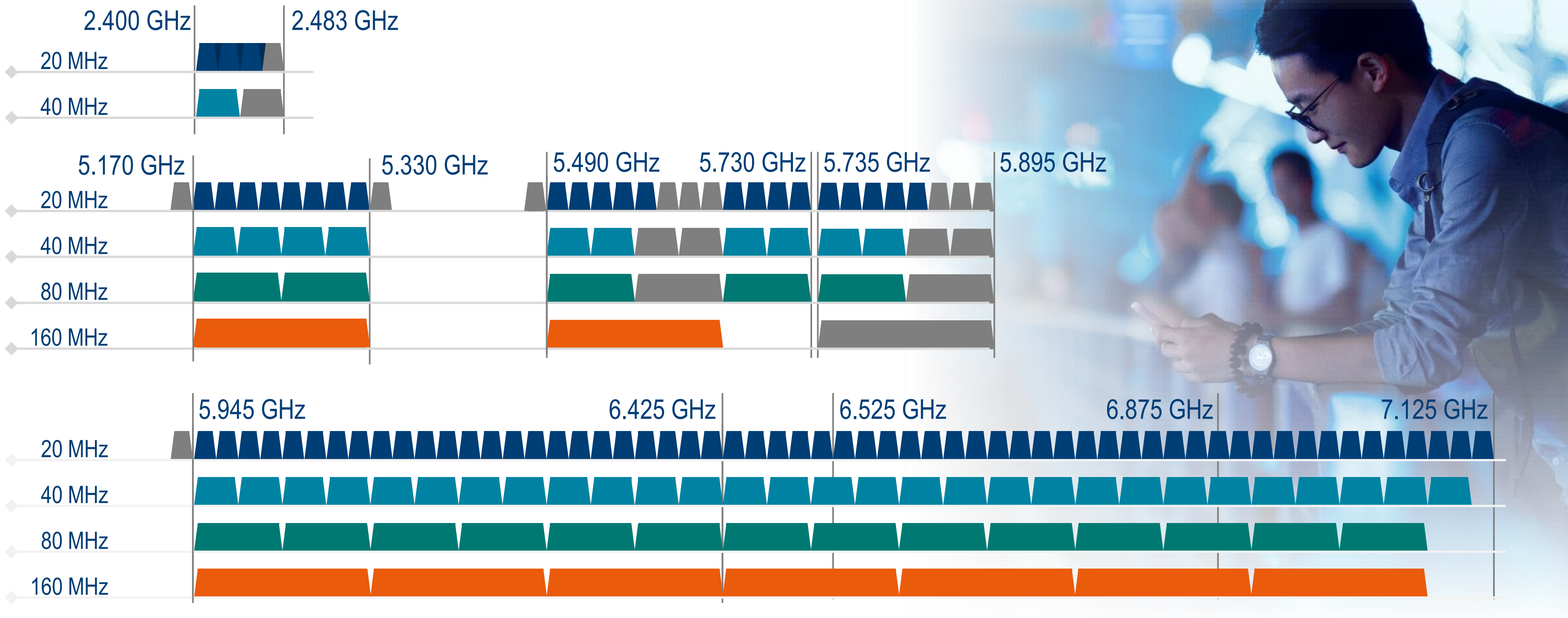
- Avoiding inter-symbol interferences
- More efficient use of available resources

In a nutshell, what was new in Wi-Fi 6 (physical layer)?

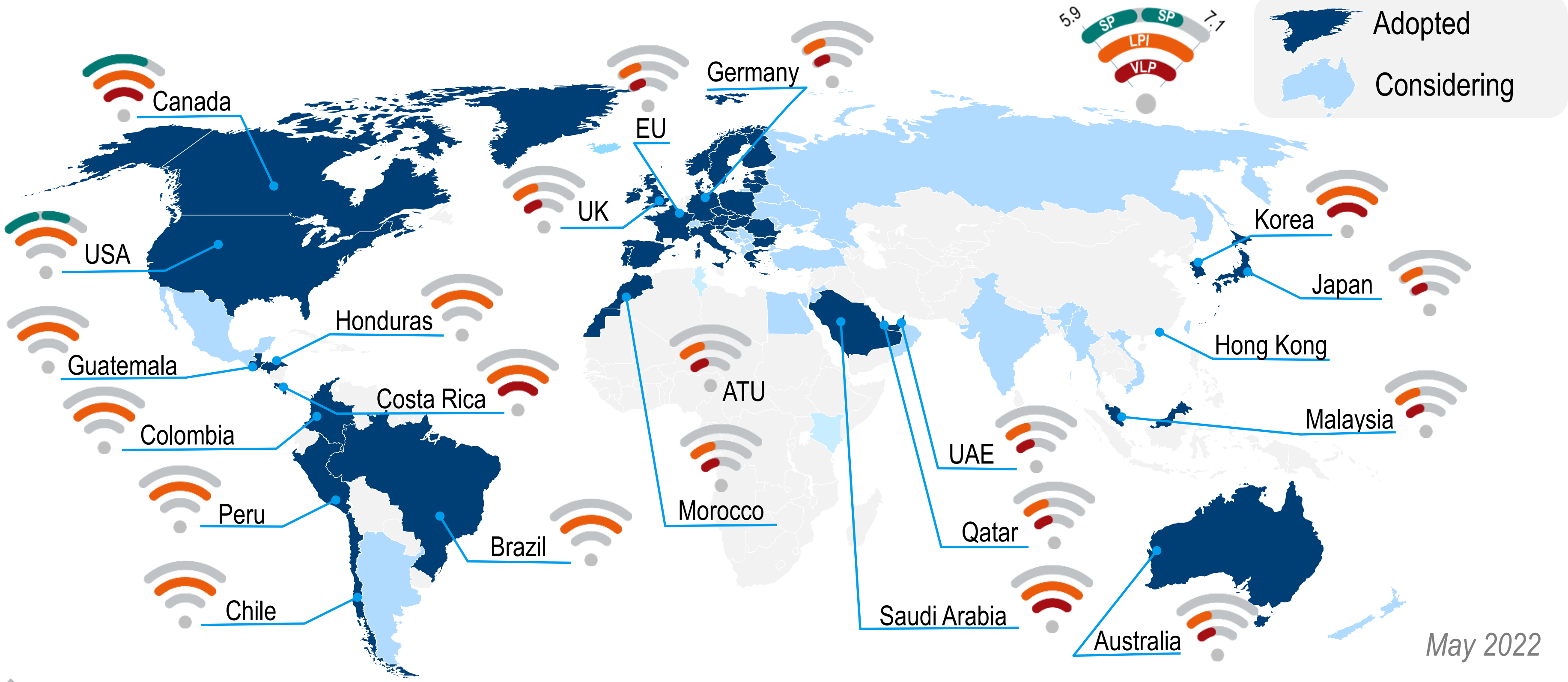
	Wi-Fi 4 (802.11n) *High Throughput (HT)*	Wi-Fi 5 (802.11ac) *Very High Throughput (VHT)*	Wi-Fi 6 (802.11ax) *High Efficiency (HE)*
Supported bands	2 GHz, 5 GHz	5 GHz	2 GHz, 5 GHz
Channel bandwidth (MHz)	20, 40	20, 40, 80, 80+80, 160	20, 40, 80, 80+80, 160
Transmission scheme	OFDM	OFDM	OFDM, **OFDMA**
Subcarrier spacing	312.5 kHz	312.5 kHz	**78.125 kHz**
Guard interval	0.4 µs, 0.8 µs	0.4 µs, 0.8 µs	0.8 µs, **1.6 µs, 3.2 µs**
Spatial streams	4x4 (SU-MIMO only)	8x8 (incl. DL-MU-MIMO)	8x8 (incl. MU-MIMO)
Modulation (highest)	64QAM	256QAM	**1024QAM**
Max. data rate*	*540 Mbps**	*6 934 Mbps**	*9 765 Mbps**

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

But, only the availability of more spectrum will allow Wi-Fi 6 (IEEE 802.11ax) to unfold its full power



More than 60 countries have already or are considering making the 6 GHz band available for RLAN (e.g. Wi-Fi)



May 2022

Just two examples of regulation in 6 GHz band

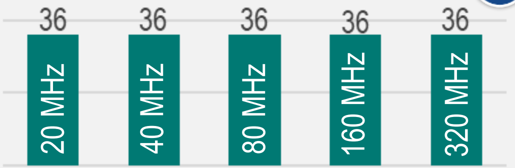
	Standard Power (SP w/ AFC)	Low Power Indoor (LPI)	Very Low Power (VLP)

Canada

Standard Power (SP w/ AFC)

5 925 — 6 875

5 925 to 6 875 MHz (950 MHz)

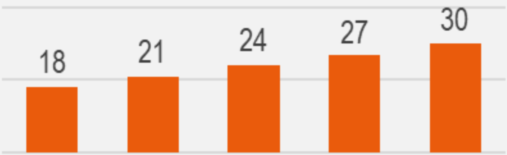


EIRP: 36 dBm & PSD: 23 dBm/MHz

Low Power Indoor (LPI)

5 925 — 7 125

5 925 to 7 125 MHz (1 200 MHz)

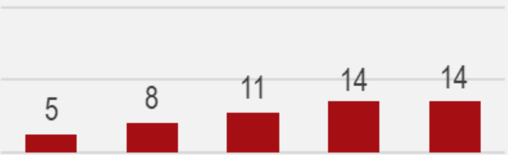


EIRP: 30 dBm & PSD: 5 dBm/MHz

Very Low Power (VLP)

5 925 — 7 125

5 925 to 7 125 MHz (1 200 MHz)



EIRP: 14 dBm & PSD: -8 dBm/MHz

See: https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11698.html

Germany

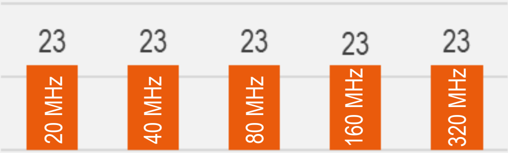
Standard Power (SP w/ AFC)

N.A.

Low Power Indoor (LPI)

5 945 — 6 425

5 945 to 6 425 MHz (480 MHz)

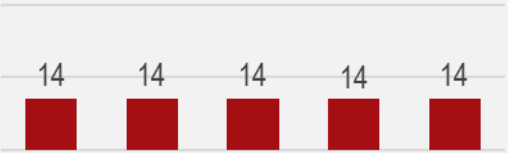


EIRP: 23 dBm & PSD: 10 dBm/MHz

Very Low Power (VLP)

5 945 — 6 425

5 945 to 6 425 MHz (480 MHz)

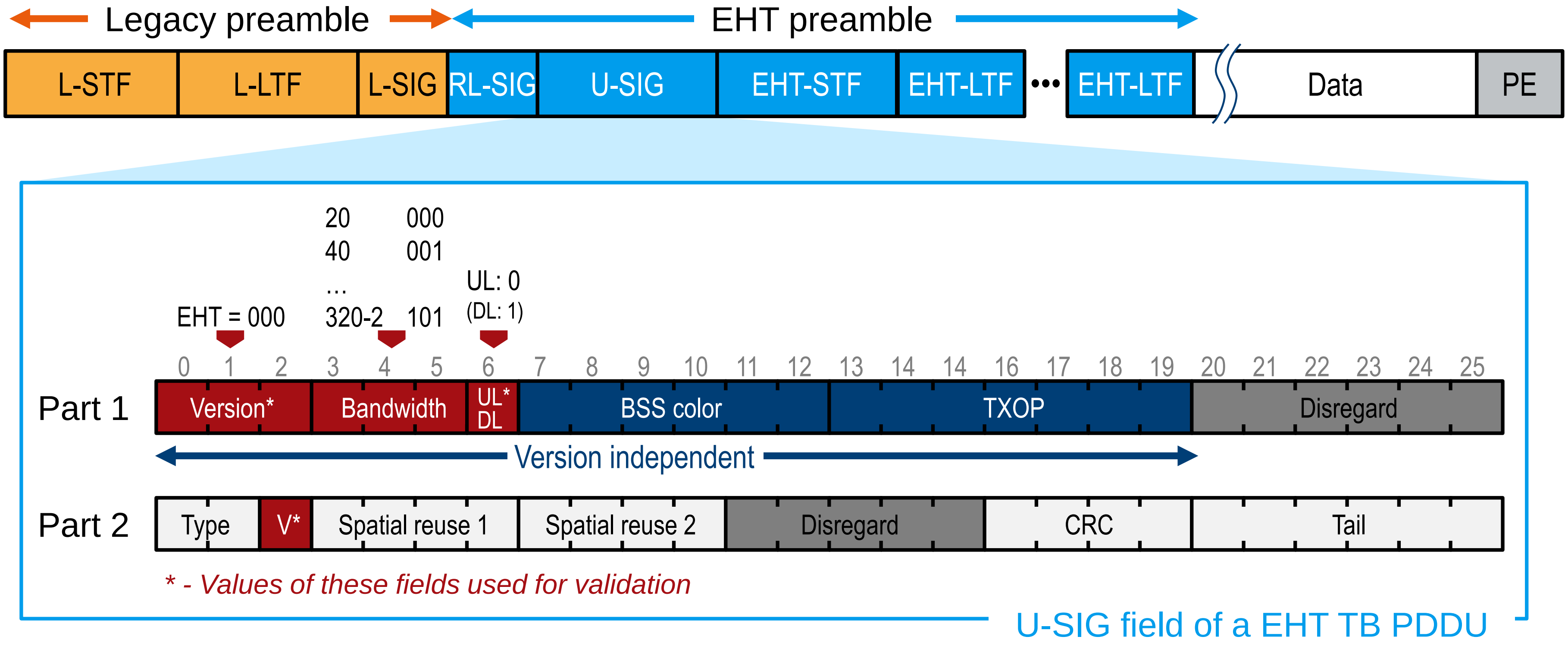


EIRP: 14 dBm & PSD: 1 dBm/MHz

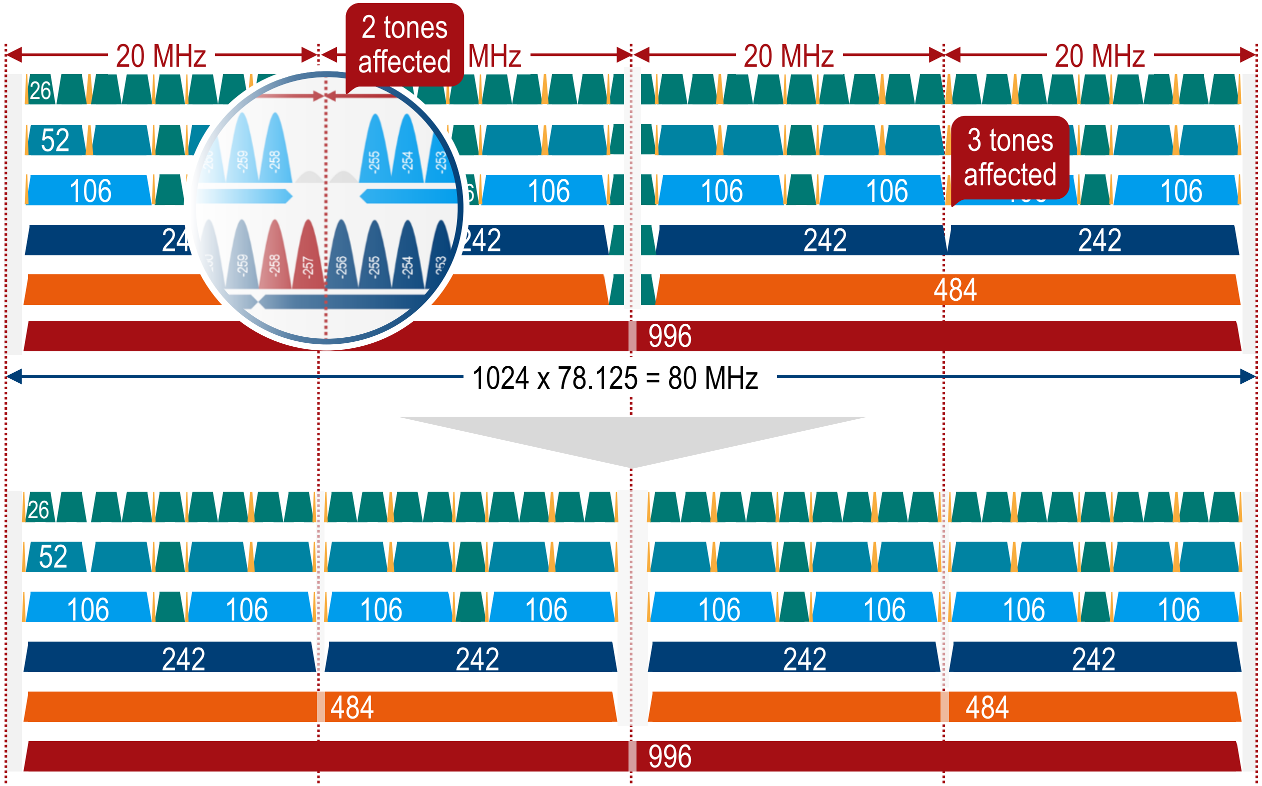
See: https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/Allgemeinzuteilungen/MobilfunkDectWlanCBFunk/vfg552021WLAN6GHz.pdf?__blob=publicationFile&v=3

The 7th generation of Wi-Fi (IEEE802.11be) for Extreme High Throughput (EHT)

IEEE 802.11be housekeeping:
EHT preamble designed for the future (example EHT TB PDDU)

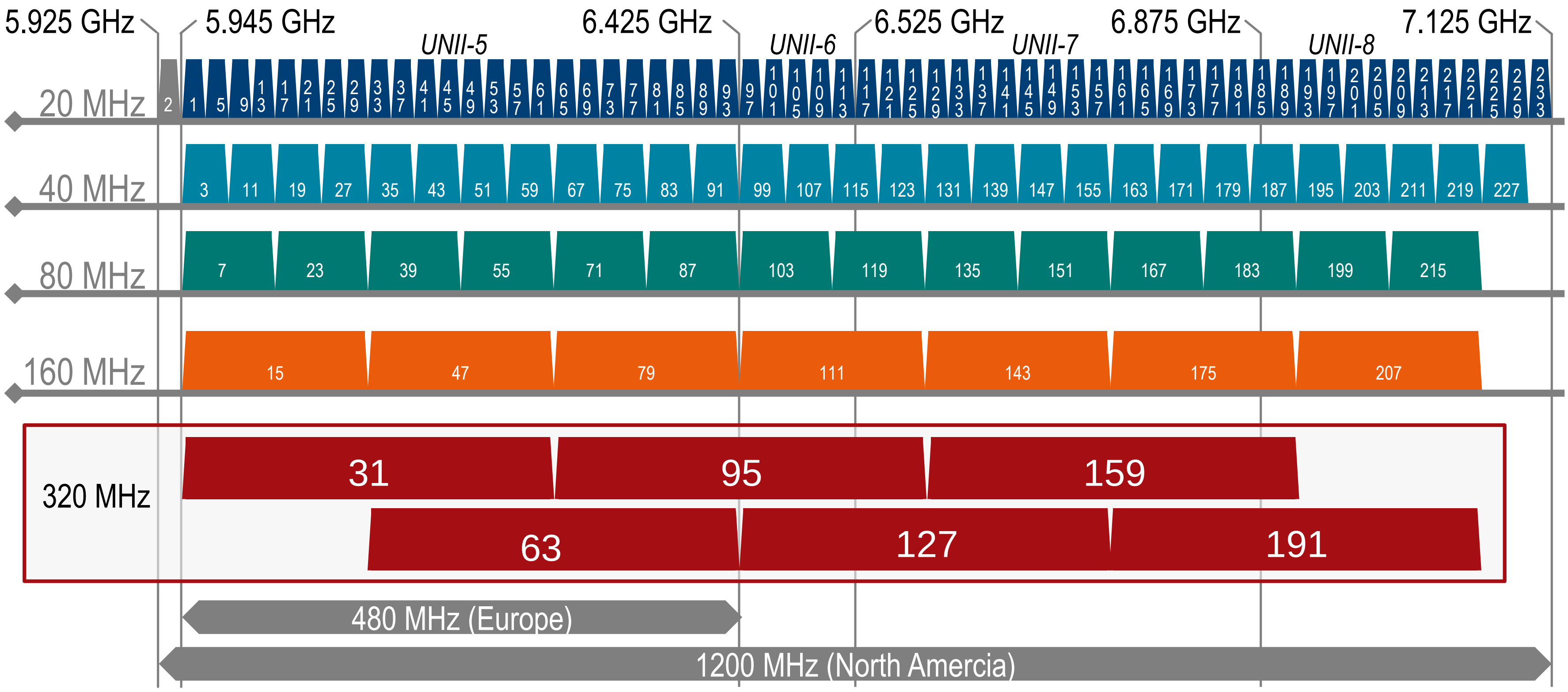


IEEE 802.11be housekeeping: the modified tone-plan ≥ 80 MHz

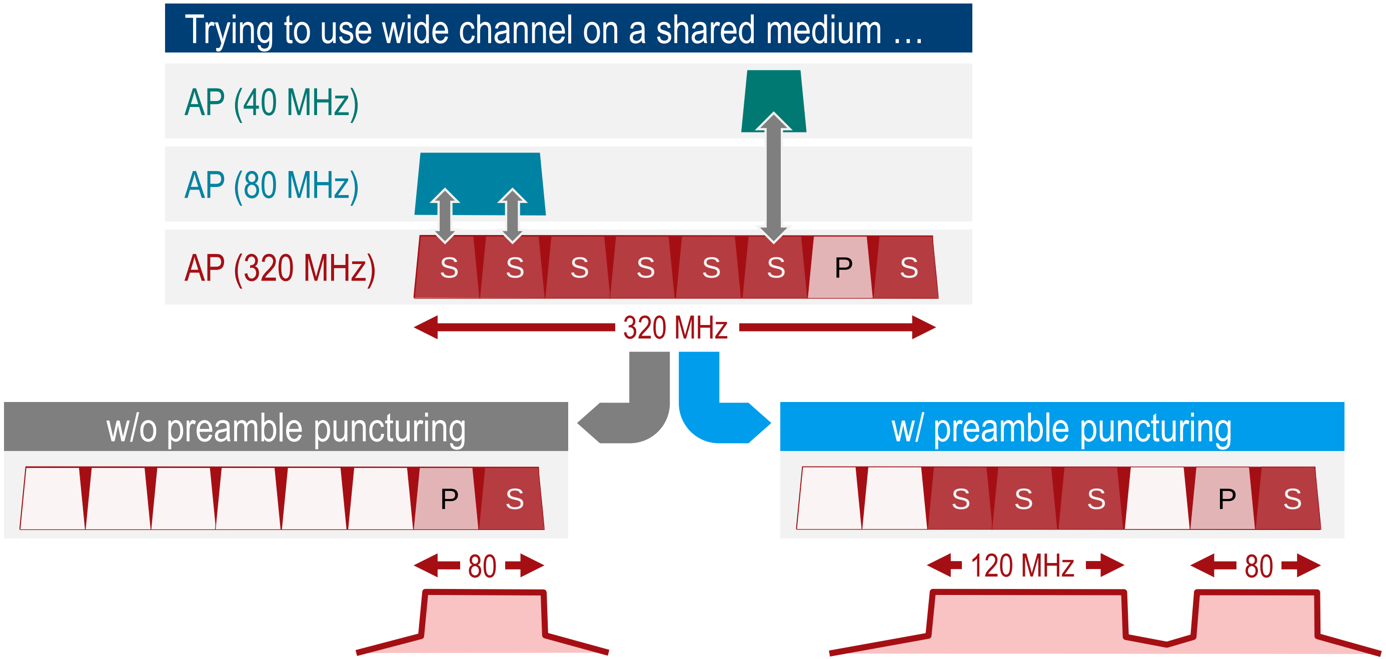


- IEEE 802.11be tone plan is based on 20/40 MHz PPDU 11ax tone plan
- IEEE 802.11be modifies the HE80 MHz OFDMA tone plan to fix the problems with regulation and puncturing (20 MHz boundary)
- The 80 MHz OFDMA design applies to any RU < 996 for all modes of transmission, SU, DL MU, TB PPDU, with and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

A few overlapping 320 MHz channels in the 6 GHz band



Preamble puncturing becomes more important



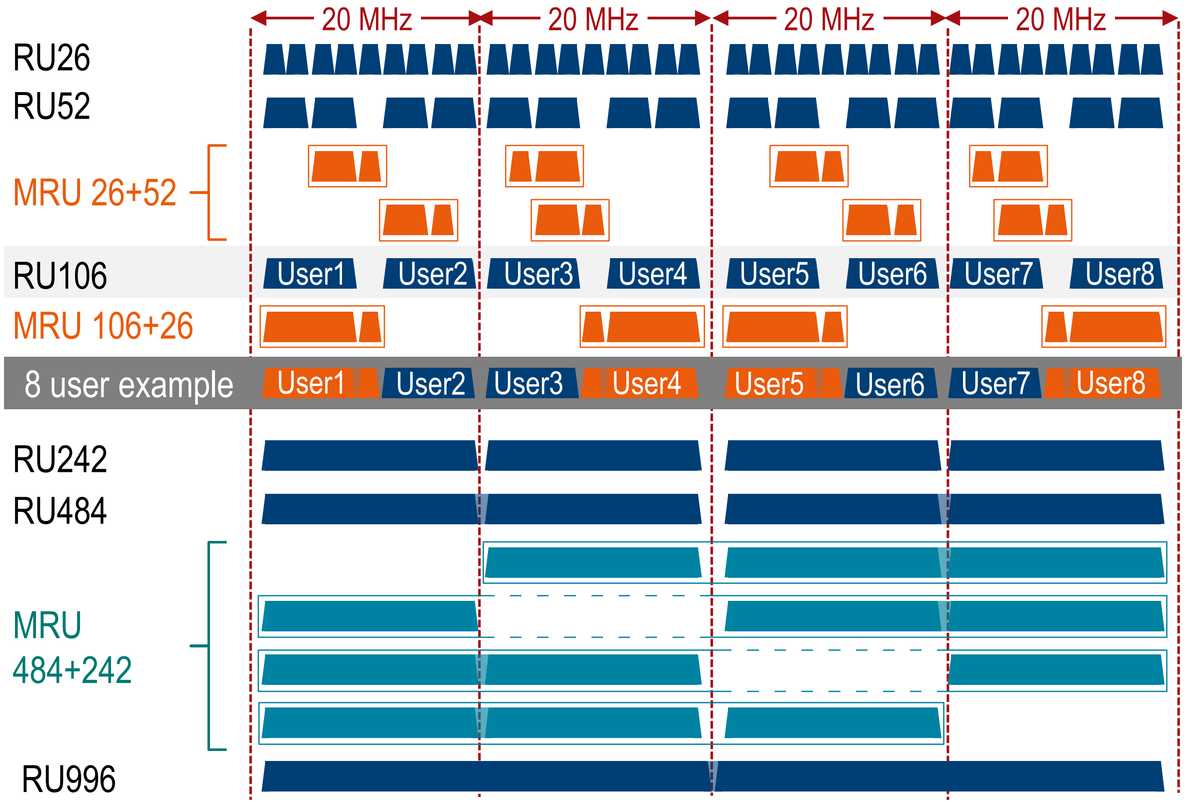
Example non-OFDMA puncture patterns for 320 MHz PPDUs

No puncturing	1	1	1	1	1	1	1	1
40 MHz	X	1	1	1	1	1	1	1
	1	X	1	1	1	1	1	1
	1	1	X	1	1	1	1	1
	1	1	1	X	1	1	1	1
	1	1	1	1	X	1	1	1
	1	1	1	1	1	X	1	1
	1	1	1	1	1	1	X	1
	1	1	1	1	1	1	1	X
80 MHz	X	X	1	1	1	1	1	1
	1	1	X	X	1	1	1	1
	1	1	1	1	X	X	1	1
	1	1	1	1	1	1	X	X
80+40 MHz	X	X	X	1	1	1	1	1
	X	X	1	X	1	1	1	1
	X	X	1	1	X	1	1	1
	X	X	1	1	1	X	1	1
	X	X	1	1	1	1	X	1
	X	X	1	1	1	1	1	X
	X	1	1	1	1	1	X	X
	1	X	1	1	1	1	X	X
	1	1	X	1	1	1	X	X
	1	1	1	X	1	1	X	X
	1	1	1	1	X	1	X	X
	1	1	1	1	1	X	X	X

OFDMA: Defined per 80 MHz subblock with 20 MHz subchannels

Non-OFDMA: Defined for 80/160 MHz PDDUs with a 20 MHz subchannel granularity and for 320 MHz channels with 40 MHz subchannels.

Multiple resource units (MRU) per user for spectrum efficiency



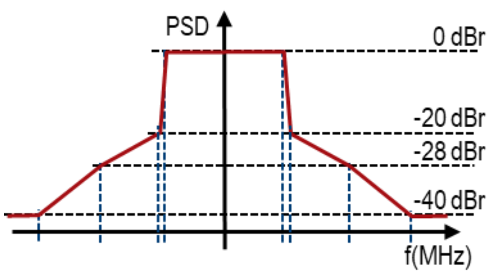
A **small size MRU** (i.e. 26, 52, 106 tone) can only be combined for **efficiency** with another small size RU to form an MRU. RUs in the MRU need to be contiguous and within a 20 MHz channel boundary.

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.

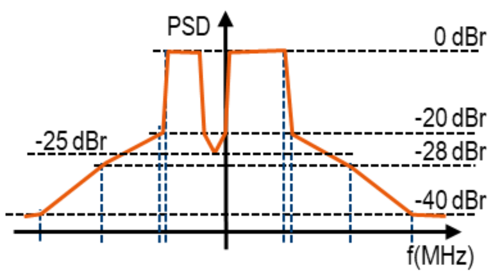
Receiver and transmitter requirement based on IEEE 802.11be

- Spectral flatness
- Center frequ. leakage
- Min. input sensitivity
- Channel rejection
- Maximum input level

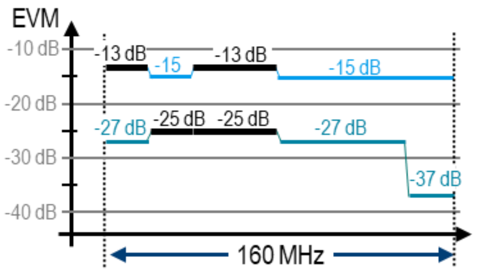
320 MHz spectrum mask



Punctured spectrum mask



MRU unused tone error



Transmitter constellation error

MCS	Mod.	Coding	Error Vector Magnitude of EHT MU PDDU		
				EHT TB PDDU	
				P > MCS7	P ≤ MCS7
12	4096 QAM	3/4	-38 dB	-38 dB	- 38 dB
13		5/6	-38 dB	-38 dB	-38 dB

- Absolut power accuracy
- Relative power accuracy
- RSSI meas. accuracy
- Carrier frequency offset
- Timing drift

Today’s test setup and used instruments for Wi-Fi7

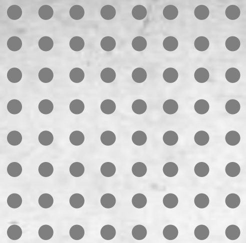
R&S®SMW200A
vector signal generator

- ▶ Frequency range up to 67 GHz
- ▶ 2 GHz modulation bandwidth
- ▶ Outstanding phase noise performance
- ▶ Integrated MIMO and fading

R&S®FSW
signal and spectrum analyzer

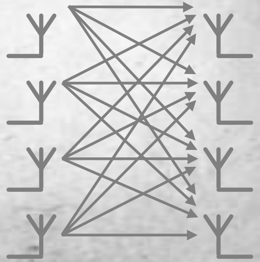
- ▶ Frequency range up to 90 GHz
- ▶ Up to 8.3 GHz internal analysis bandwidth
- ▶ Unparalleled low phase noise and sensitivity
- ▶ High dynamic range for an excellent EVM performance

How to achieve higher throughput on the physical layer



$$Max\ physical\ data\ rate\ per\ link = N_{SD}\frac{N_{CBPS}\cdot R}{T_{SYM}}N_{SS}$$

- # modulated bits: N_{CBPS}
- code rate: R
- # of data carriers: N_{SD}
- symbol time: T_{SYM}
- #spatial streams: N_{SS}



Extreme high throughput with Wi-Fi 7 for smart glasses

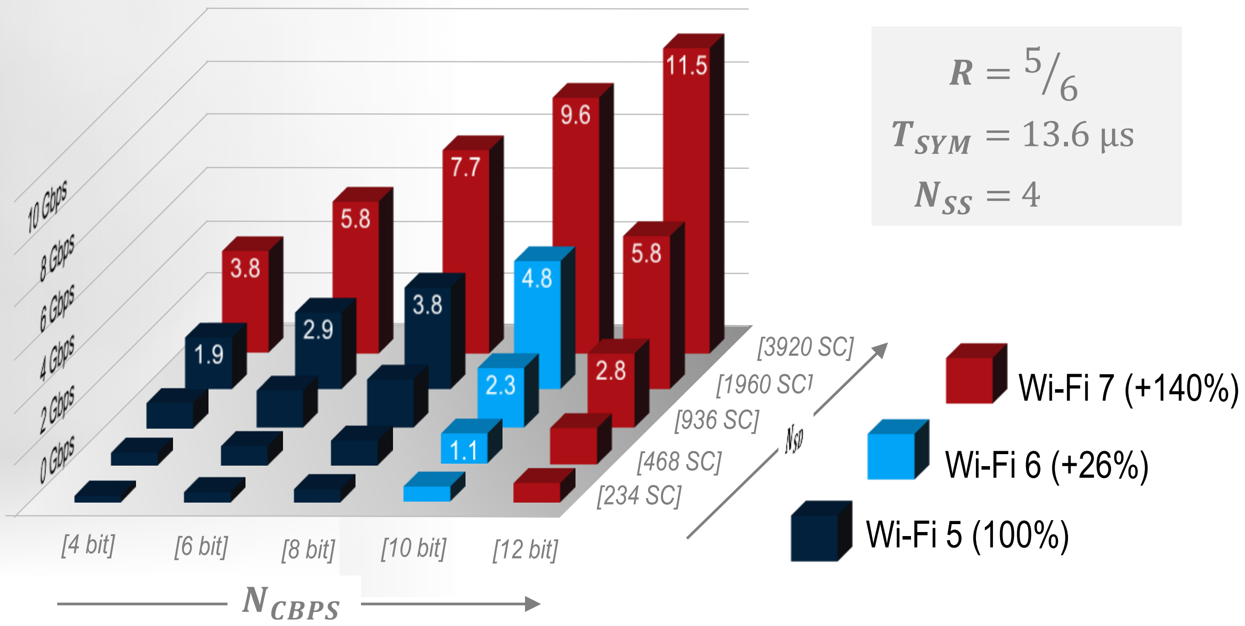
$$\text{Max physical data rate per link} = N_{SD}\,\frac{N_{CBPS}\cdot R}{T_{SYM}}\,N_{SS}$$

modulated bits; code rate; # of data carriers; symbol time; #spatial streams

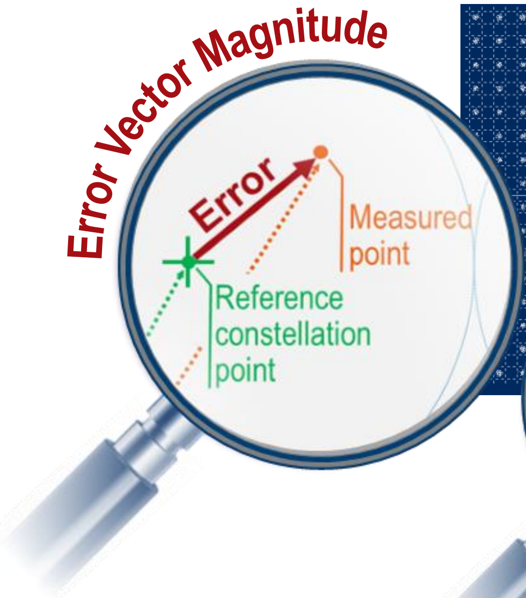
$R = 5/6$

$T_{SYM} = 13.6\ \mu s$

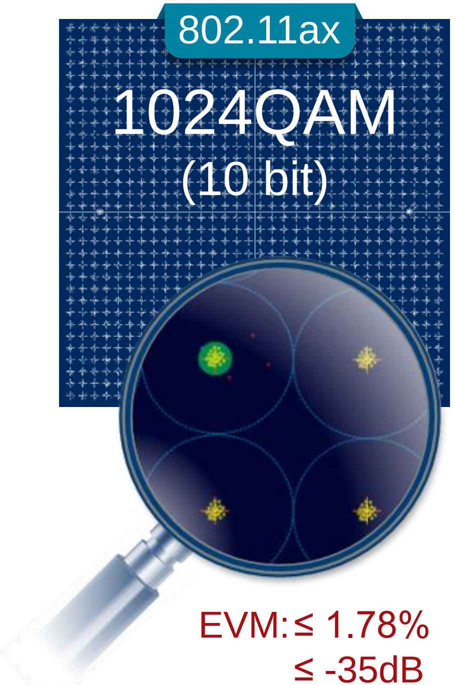
$N_{SS} = 4$



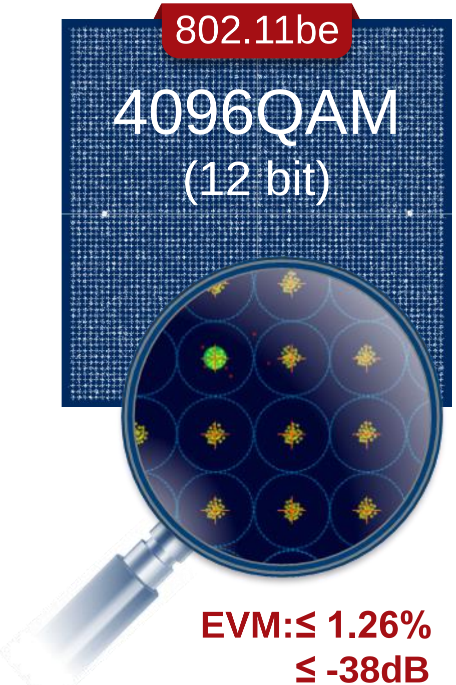
Wi-Fi 7 pushes RF performance requirements and drives test equipment performance to the next level



EVM:≤ 3.16%
≤ -30dB

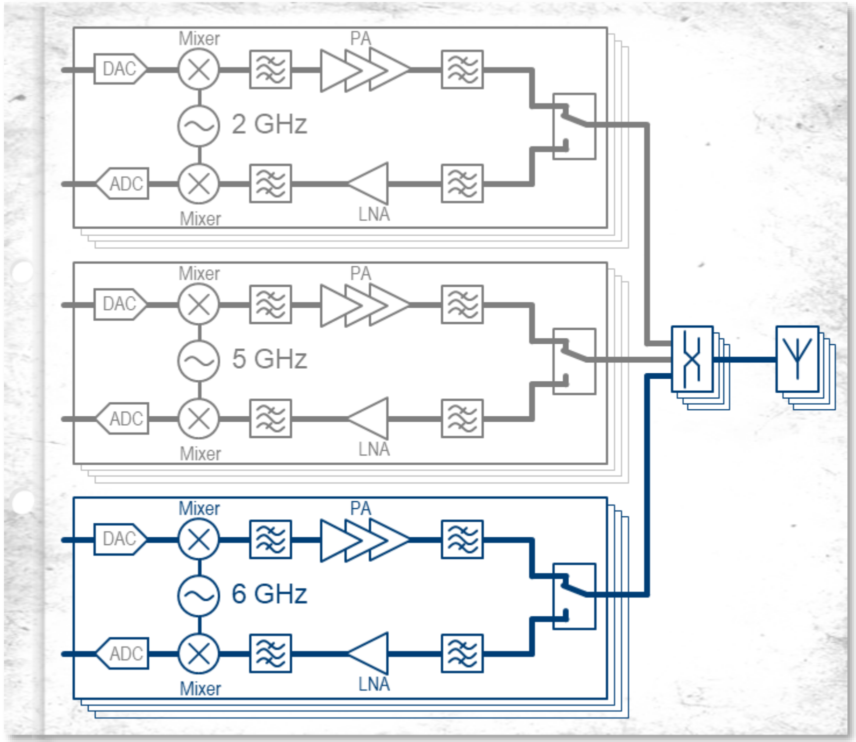


EVM:≤ 1.78%
≤ -35dB

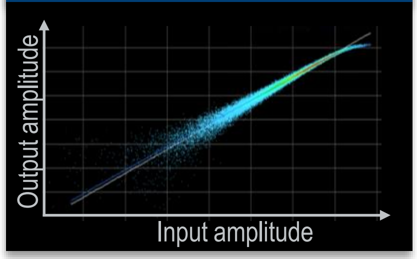


EVM:≤ 1.26%
≤ -38dB

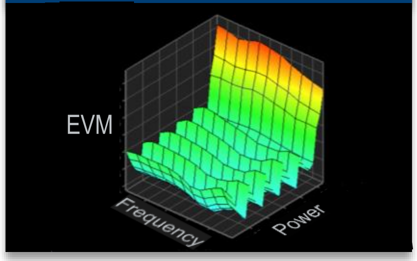
Wi-Fi 6E/7 will drive innovation in RF design to provide highest performance in the most efficient way



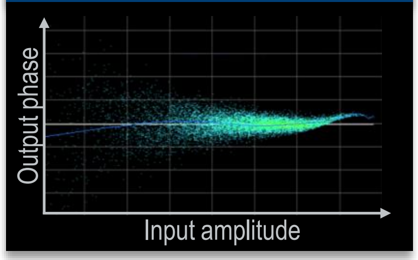
Amplifier gain



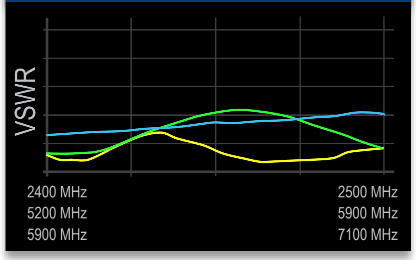
EVM vs. frequency/power



Phase noise



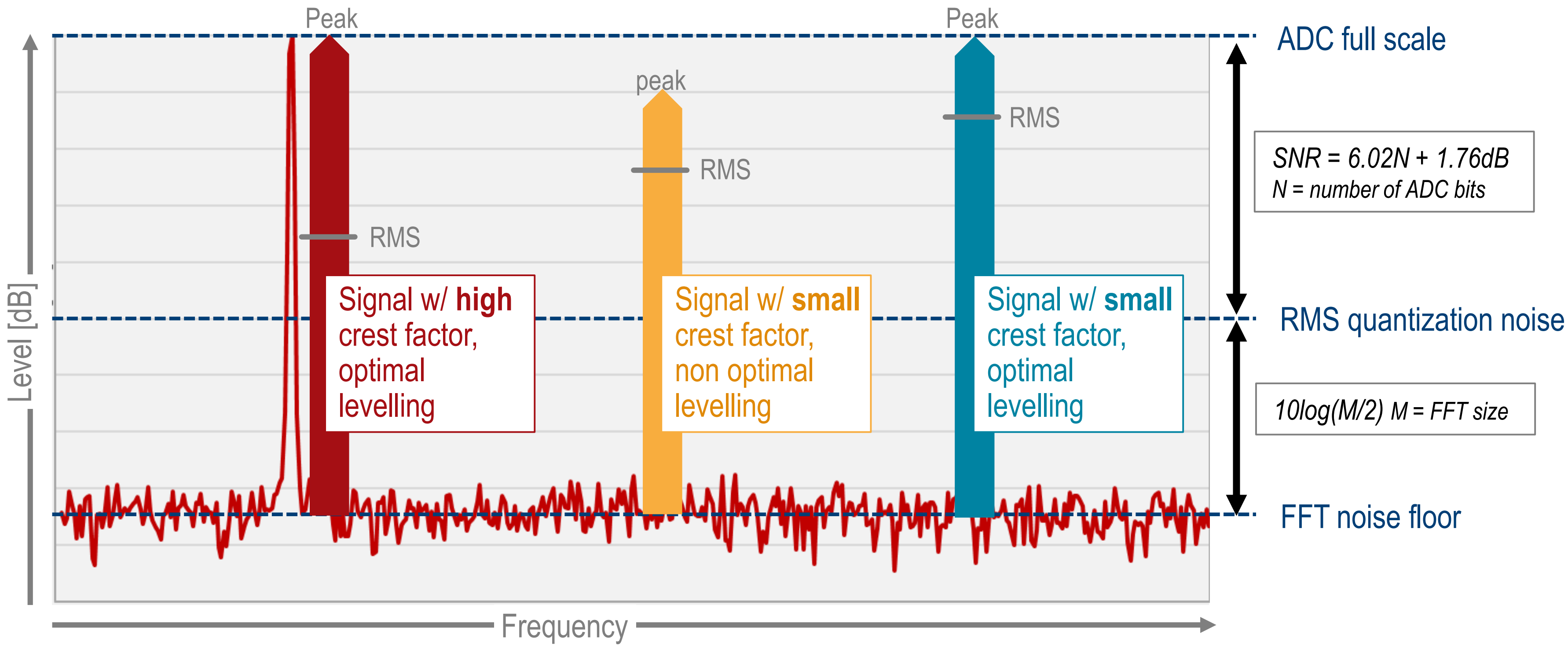
Antenna performance



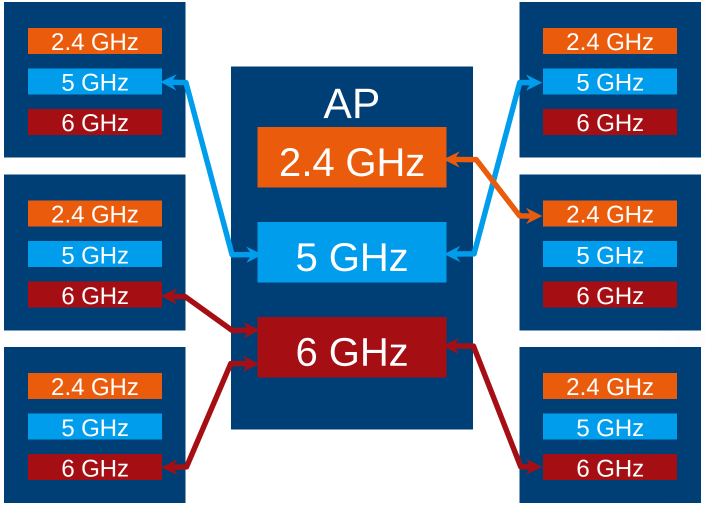
Power efficiency

Thermal performance

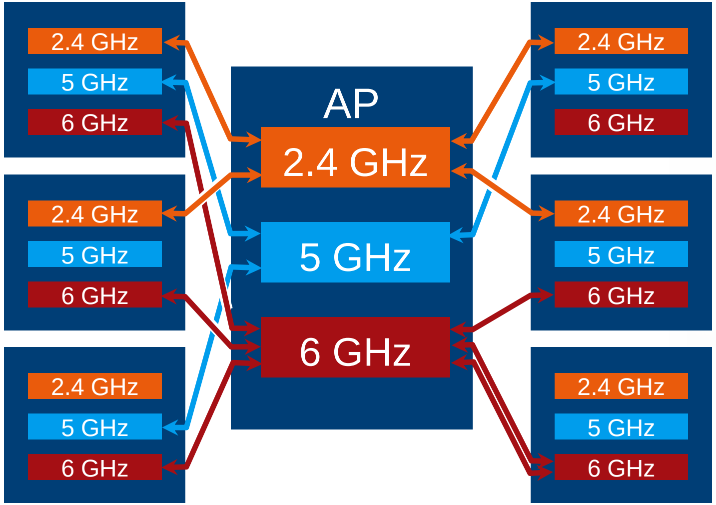
Considering aspects of analog/digital conversion and the signal crest factor (peak/RMS)

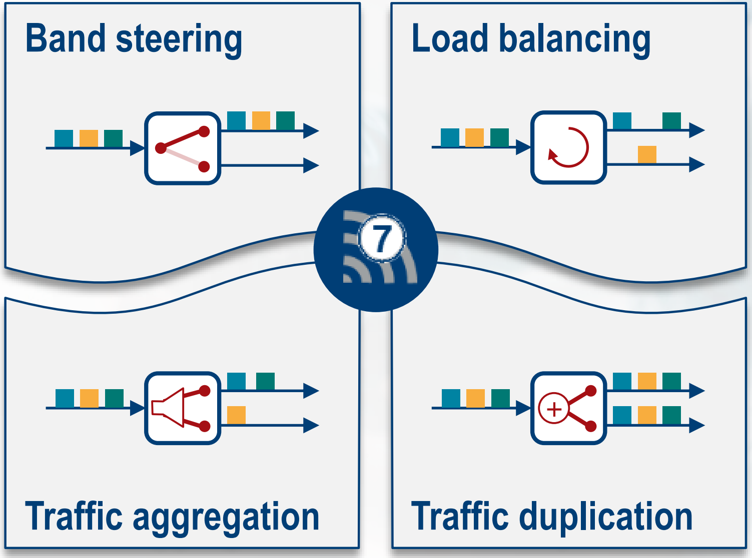


Multi-band access point operation is well established



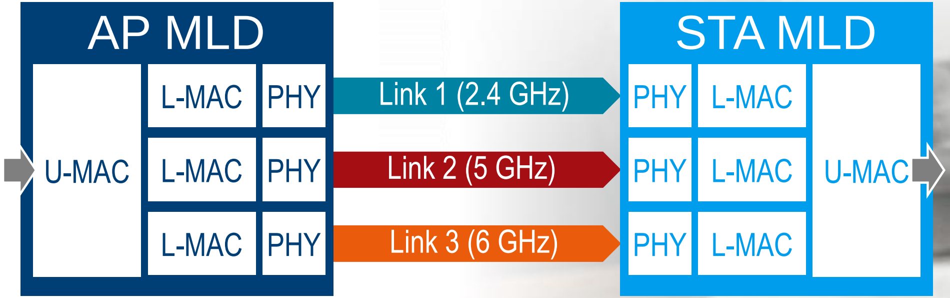
Wi-Fi 7 will allow simultaneous multi-link operation



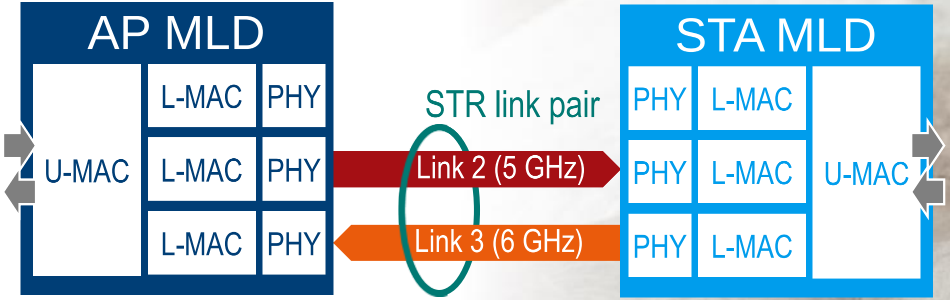


Multi-link operation (MLO) to improve throughput, latency and efficiency

Non-simultaneous transmit & receive (NSTR) operation



Simultaneous transmit & receive (STR) operation



Wi-Fi test solutions for today and tomorrow

Conformance

R&S®TS8997

RF performance

R&S®CMW500/270

R&S®CMP180

Production

R&S®TS7124

R&S®DST200

R&S®CMW100

R&S®CMP180

R&S®ZNA

R&S®FSW

R&S®SMM100A

R&S®VSE

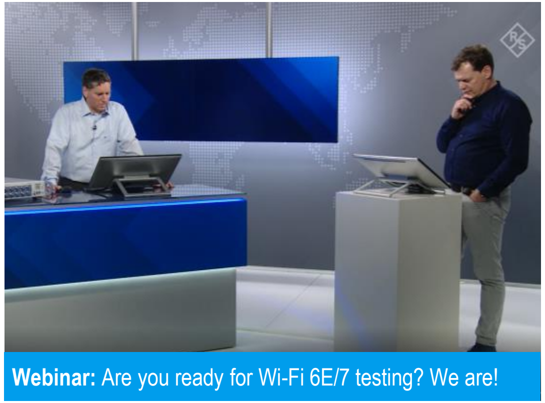
RF design and compliance

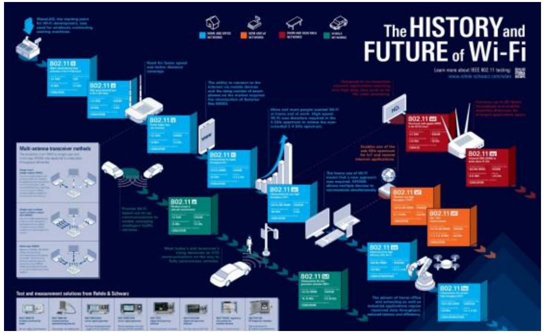
R&S®NGU

R&S®RTP

Embedded design & power

Some recommendations ....





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