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A Teradyne Company

Wi-Fi 6 Updates

Essential Tests, Product Certification
and New Spectrum on the Horizon

Wi-Fi Ecosystem

Wi-Fi Alliance

- **Who are they?**

- **They invented the word Wi-Fi**
- **They are a network of member companies**
- **LitePoint is a member of the Wi-Fi Alliance**
- **They are responsible for defining certification: Wi-Fi CERTIFIED™**
- **Certification for products indicates that they have met industry-agreed standards for interoperability, security, and protocols**
- **The Wi-Fi Alliance has decided to introduce a simplified naming scheme for Wi-Fi standards to help users identify devices that provide the latest Wi-Fi experience**

Wi-Fi 6: What Does the Naming Mean for You?

- In reality, very little – this is meant to help with consumer confusion to indicate generations of technology.
  - **6 is a bigger number than 5, it must be better!**

- **Wi-Fi 6** to identify devices that support **802.11ax** technology
- **Wi-Fi 5** to identify devices that support **802.11ac** technology
- **Wi-Fi 4** to identify devices that support **802.11n** technology

Generation of network connection	Sample user interface visual
Wi-Fi 6	
Wi-Fi 5	
Wi-Fi 4	

Wi-Fi 6 Certification starting End Q3 2019

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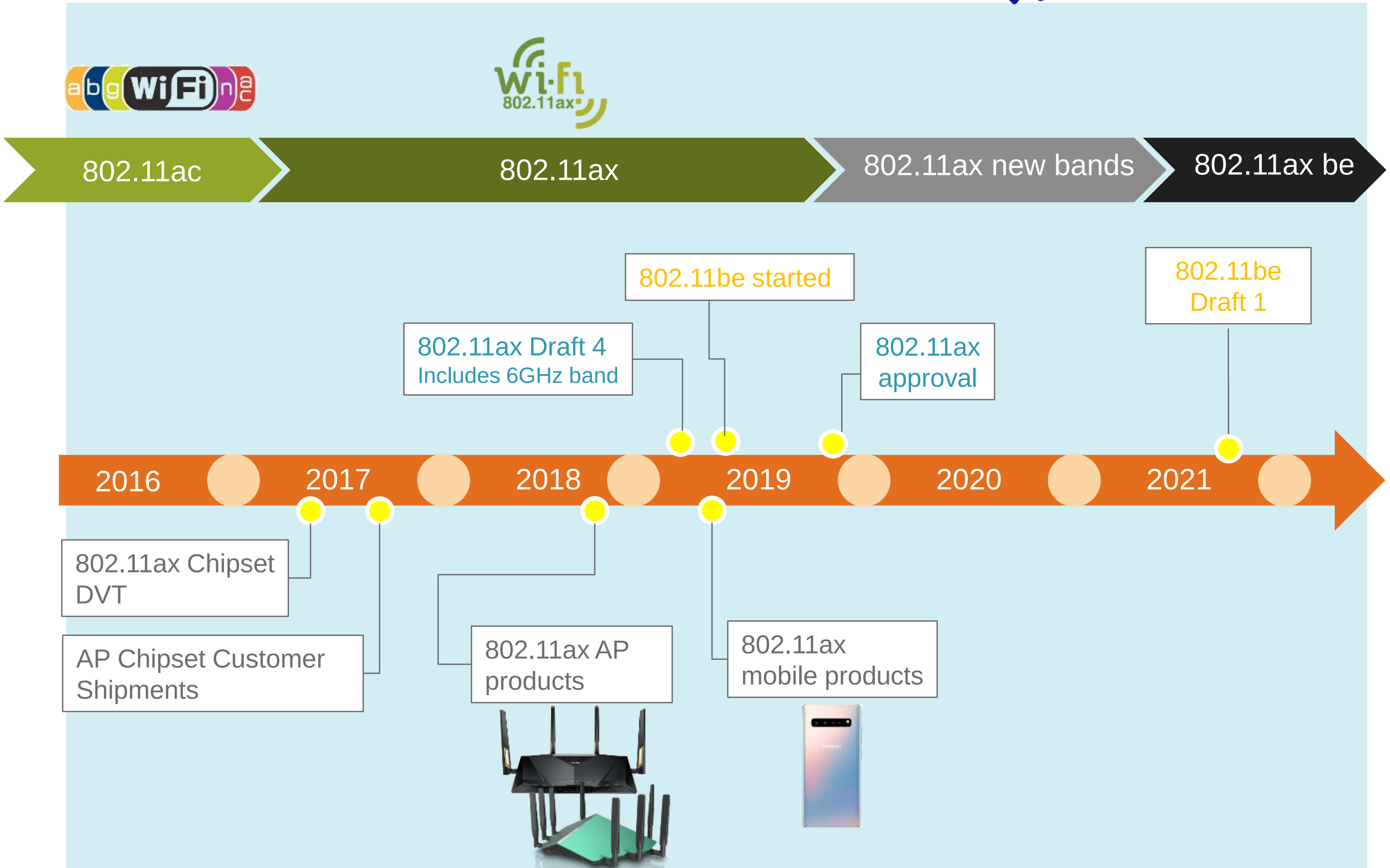
Wi-Fi 6 Test Suite

Wi Fi ALLIANCE
AUTHORIZED TEST LABORATORY

Test Equipment

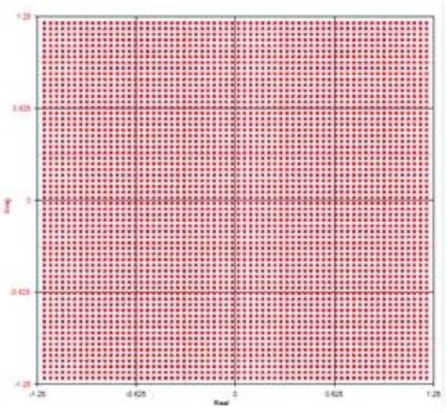
IEEE Standard Timeline



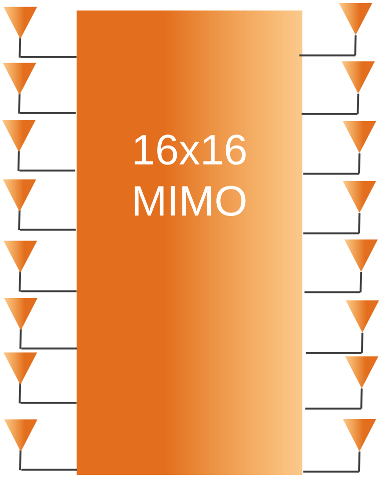
802.11be EHT Extreme High Throughput

- Target Performance
- Low Latency: < 5 ms (full immersion VR)
- High Throughput: 30 Gbps

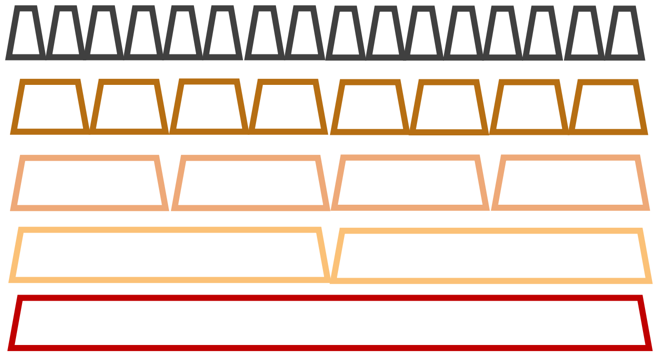
- Candidate Features:



4096 QAM



16 Spatial Streams



320 MHz Channel

Contiguous 320MHz / non-contiguous 320MHz
(160+160 / 160+80+80 / 80+80+80+80 MHz)

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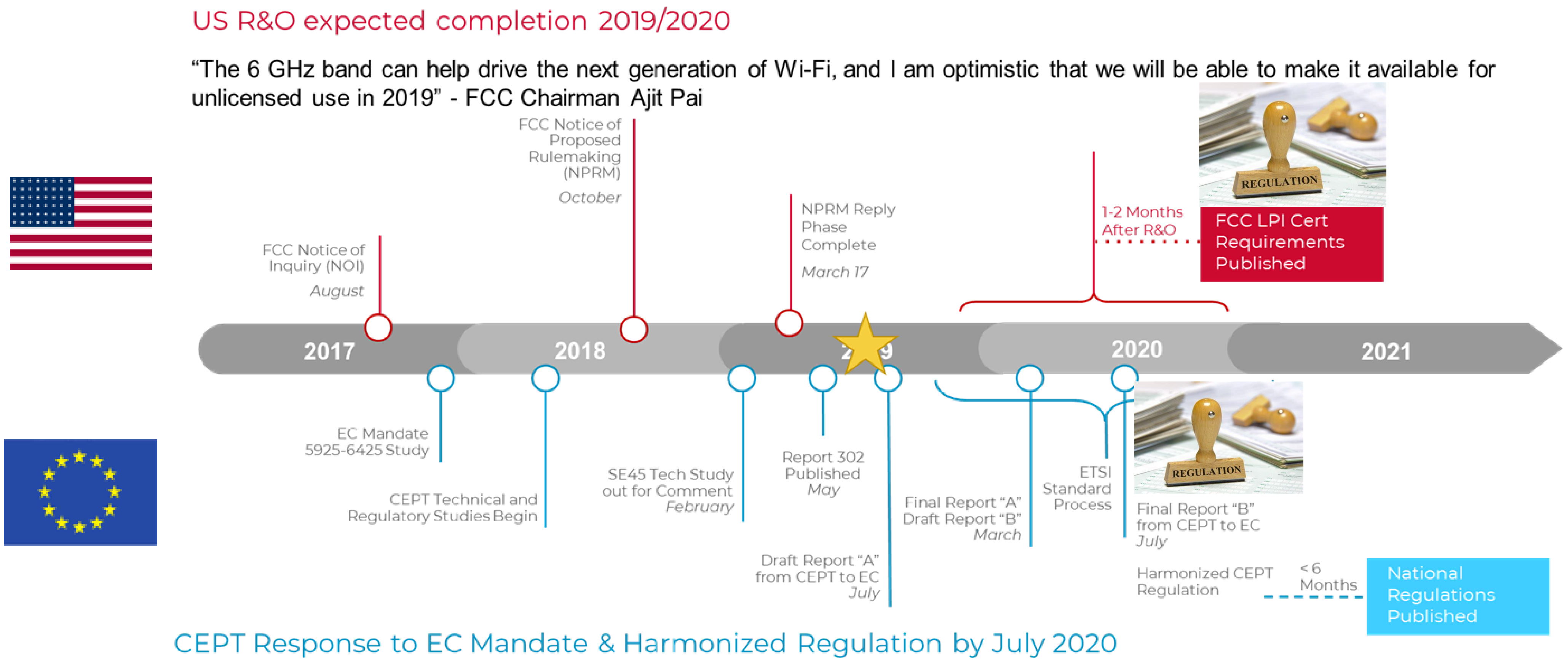
FCC Federal Communications Commission

- **Who are they?**

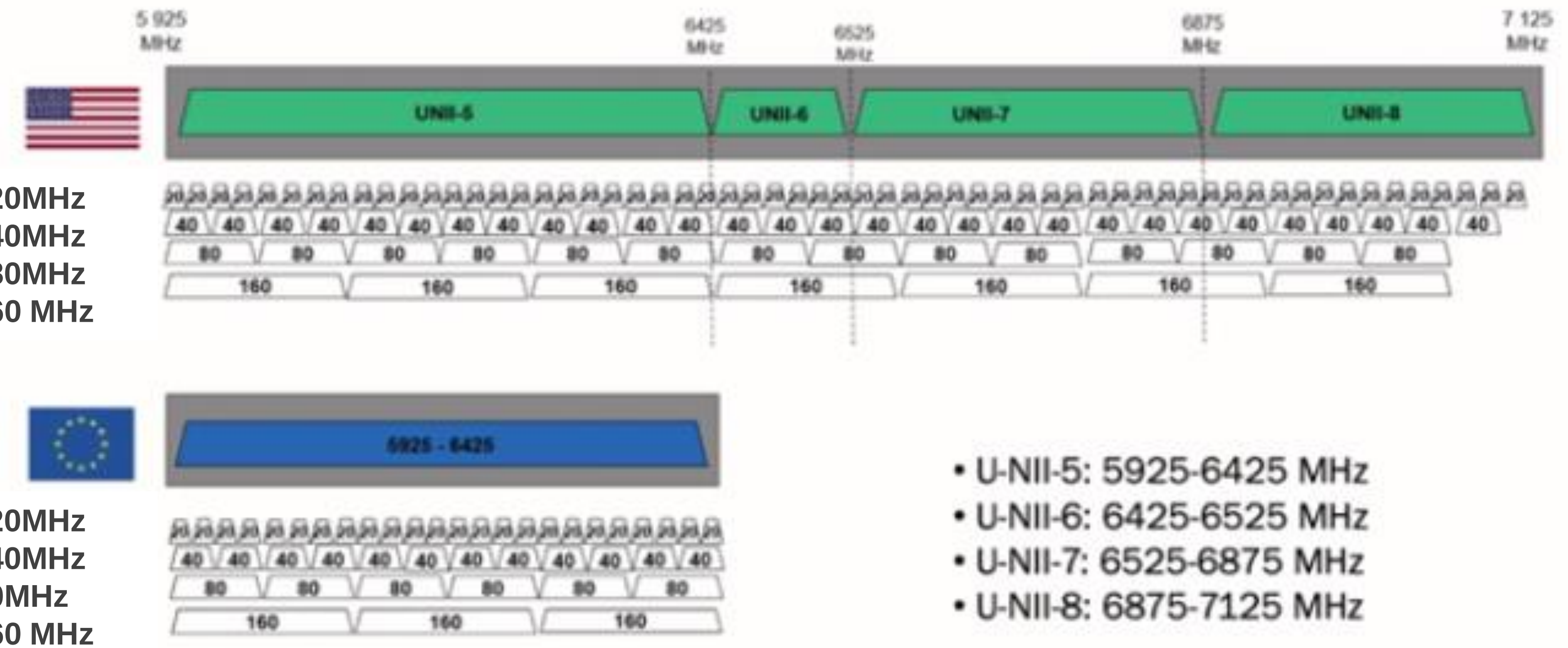
- **US Government agency in charge of regulating communications**
- **They assign RF spectrum allocation**
- **In October 2018 they announced a Notice of Proposed Rulemaking to promote new opportunities for unlicensed use in portions of the 1200 megahertz of spectrum in the 5.925-7.125 (6 GHz) band**

Regulatory Update



Source Wi-Fi Now

802.11ax “6 GHz” Band Allocations



59 x 20MHz
29 x 40MHz
14 x 80MHz
7 x 160 MHz

24 x 20MHz
12 x 40MHz
6 x 80MHz
3 x 160 MHz

Some frequency bands may require reduced power for incumbent protection

Some bands may required AFC (Automated Frequency Coordination) for incumbent protection

Refresher: Key Changes in Wi-Fi 6

	802.11n	802.11ac	802.11ax	
Operating Bands	2.4 & 5GHz	5GHz	2.4 & 5GHz 6GHz*	*Optional
Technology	OFDM	OFDM	OFDMA	
MU-MIMO	No	DL MU-MIMO*	DL / UL MU-MIMO*	*Optional
Subcarrier Spacing	312.5kHz	312.5kHz	78.125kHz	
Modulation	64QAM	256QAM	1024QAM	
User Streams	4	Up to 8 user streams*		*Optional
Bandwidth	40 MHz	20, 40, 80, 80+80 and 160MHz		

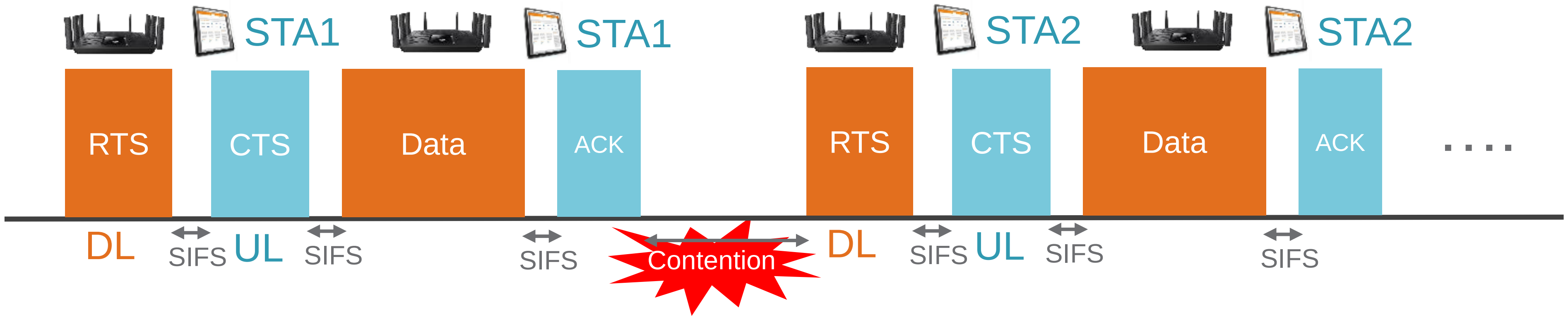
Key changes impacting test:
- More radios: 1 or 2 moving to 4+
- More OFDMA configurations to test
- Power & timing control

Wi-Fi 6 Essential Tests for OFDMA

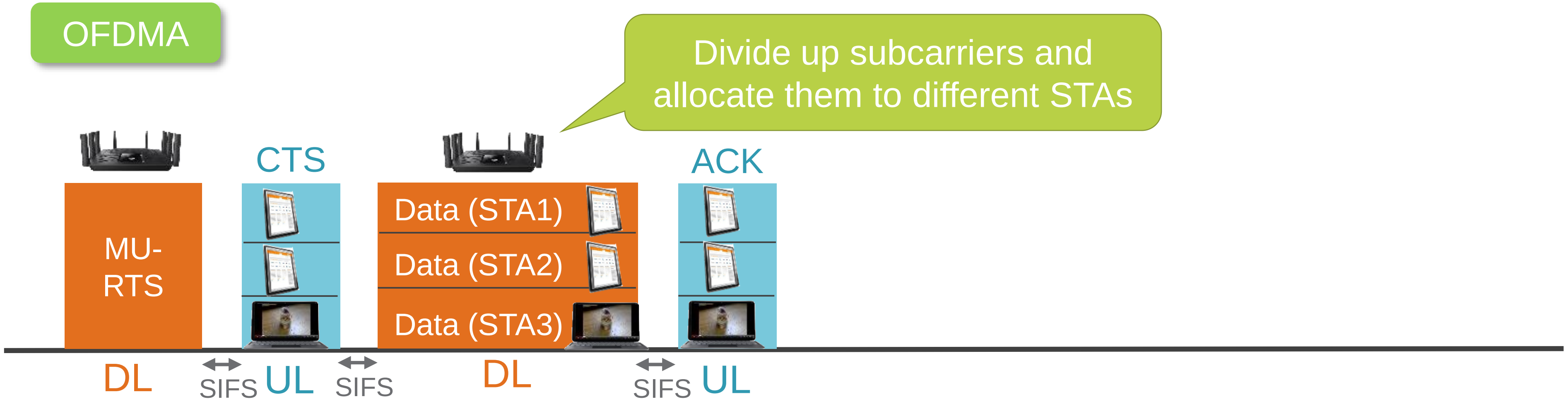
OFDM vs. OFDMA: Downlink

OFDMA improves overall network efficiency by serving multiple STAs

OFDM

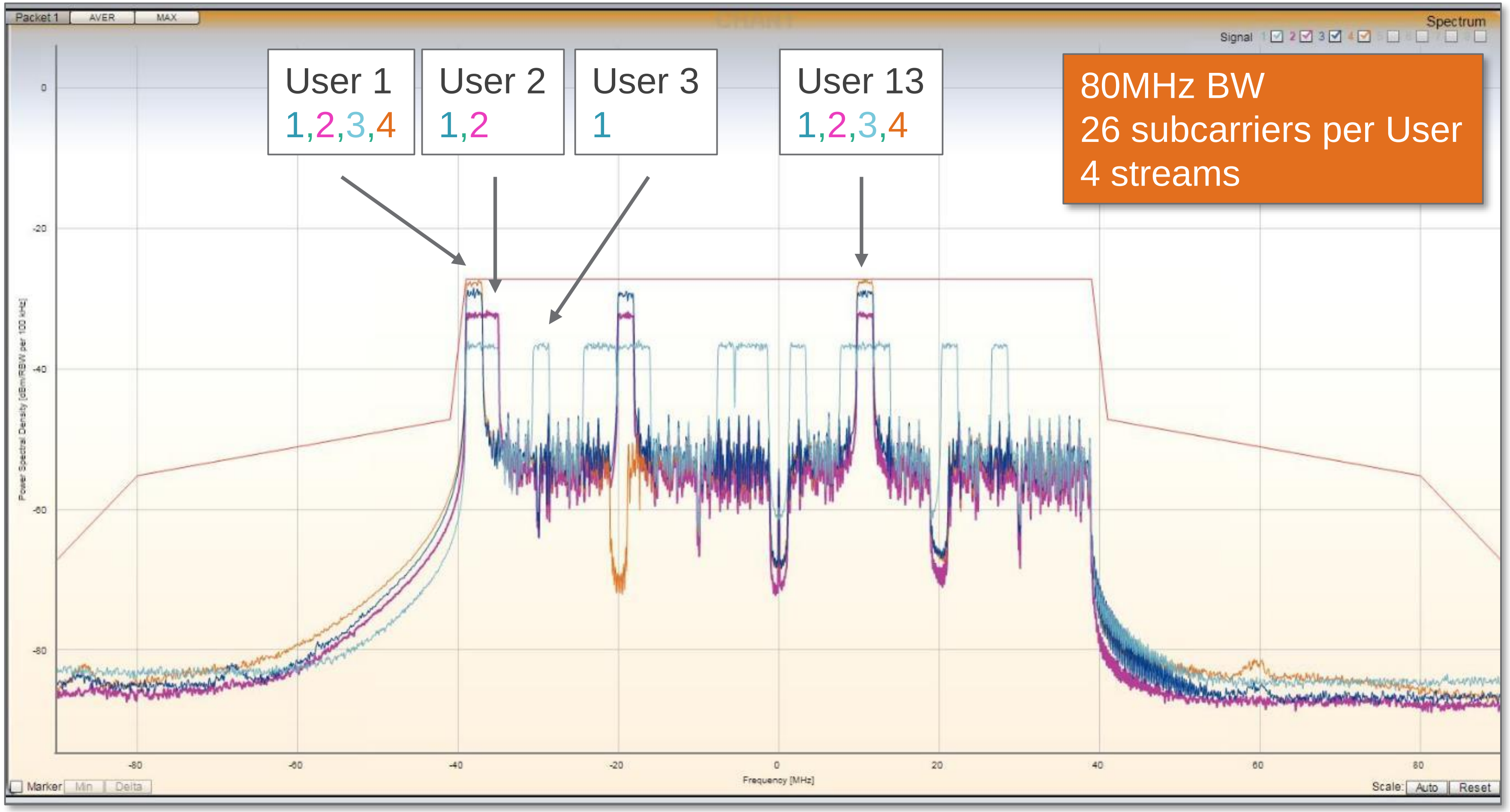


OFDMA



OFDMA Brings Large Number of Test Permutations

- AP simultaneously serves multiple users
  - Varying # of users, RU combinations, # of streams



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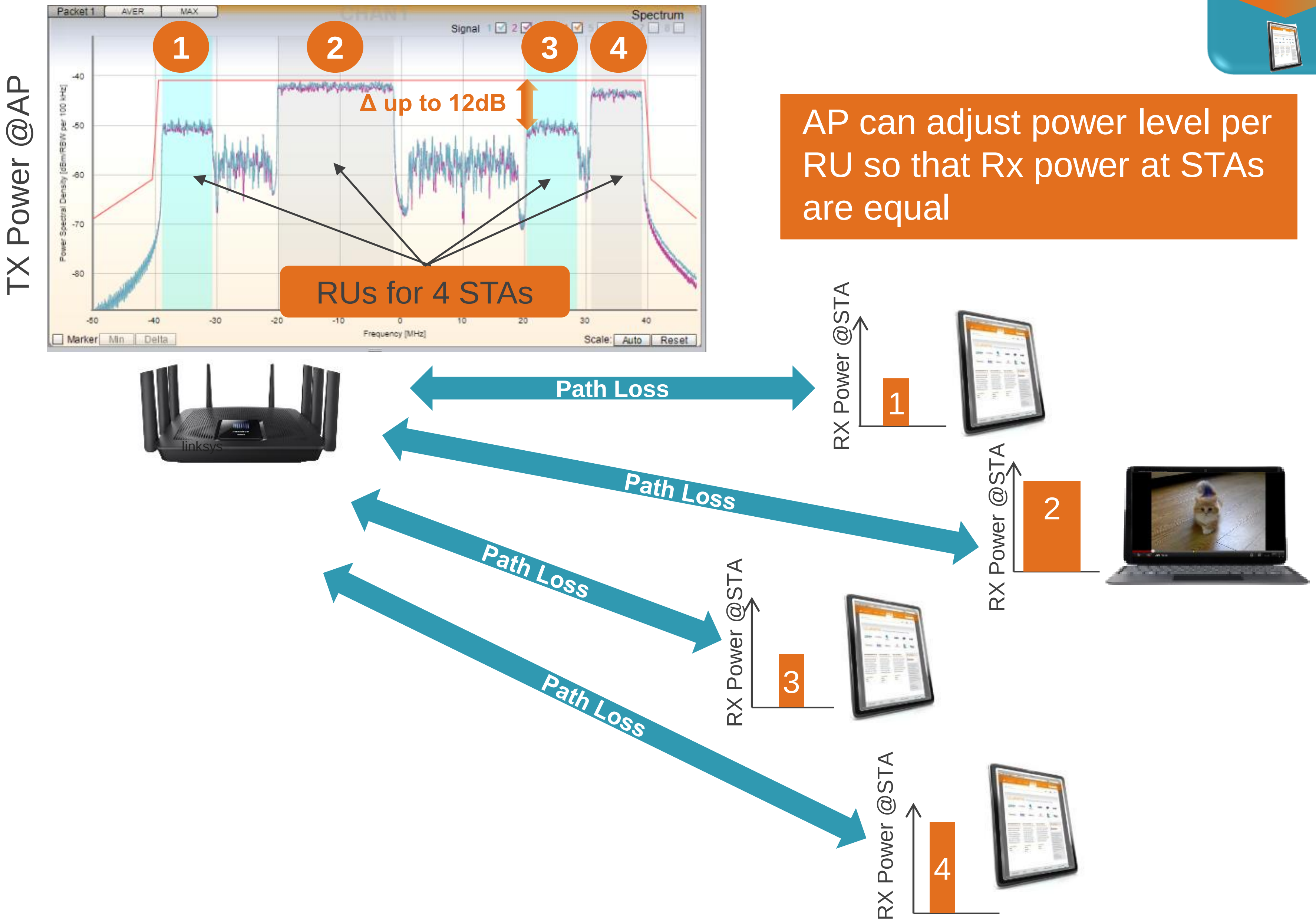
Multi-User OFDMA Power Control (“Power Boost”)



AP can adjust power level per RU so that Rx power at STAs are equal

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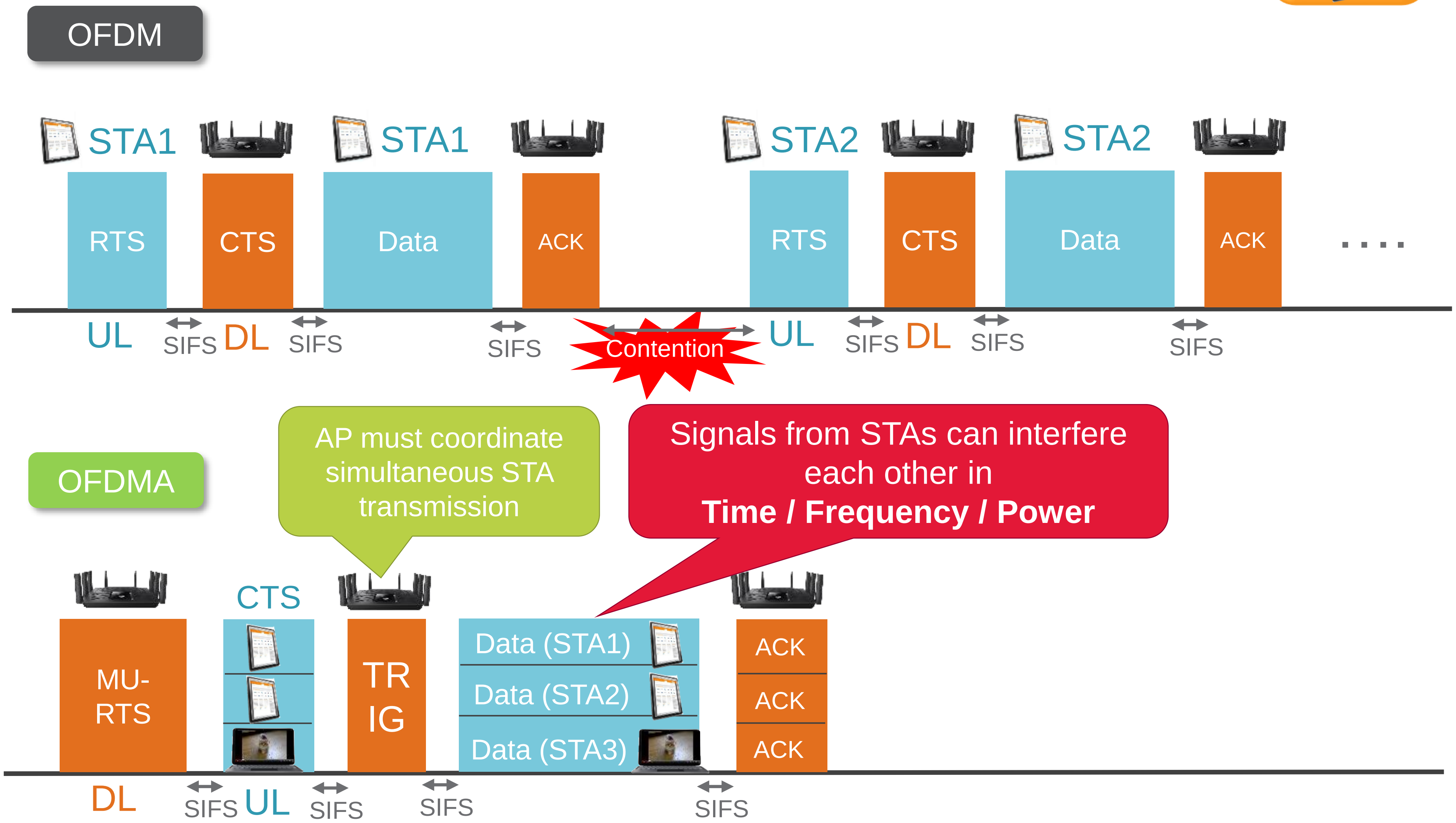
OFDM vs. OFDMA: Uplink

Uplink Tx requires precise frequency, timing, and power control



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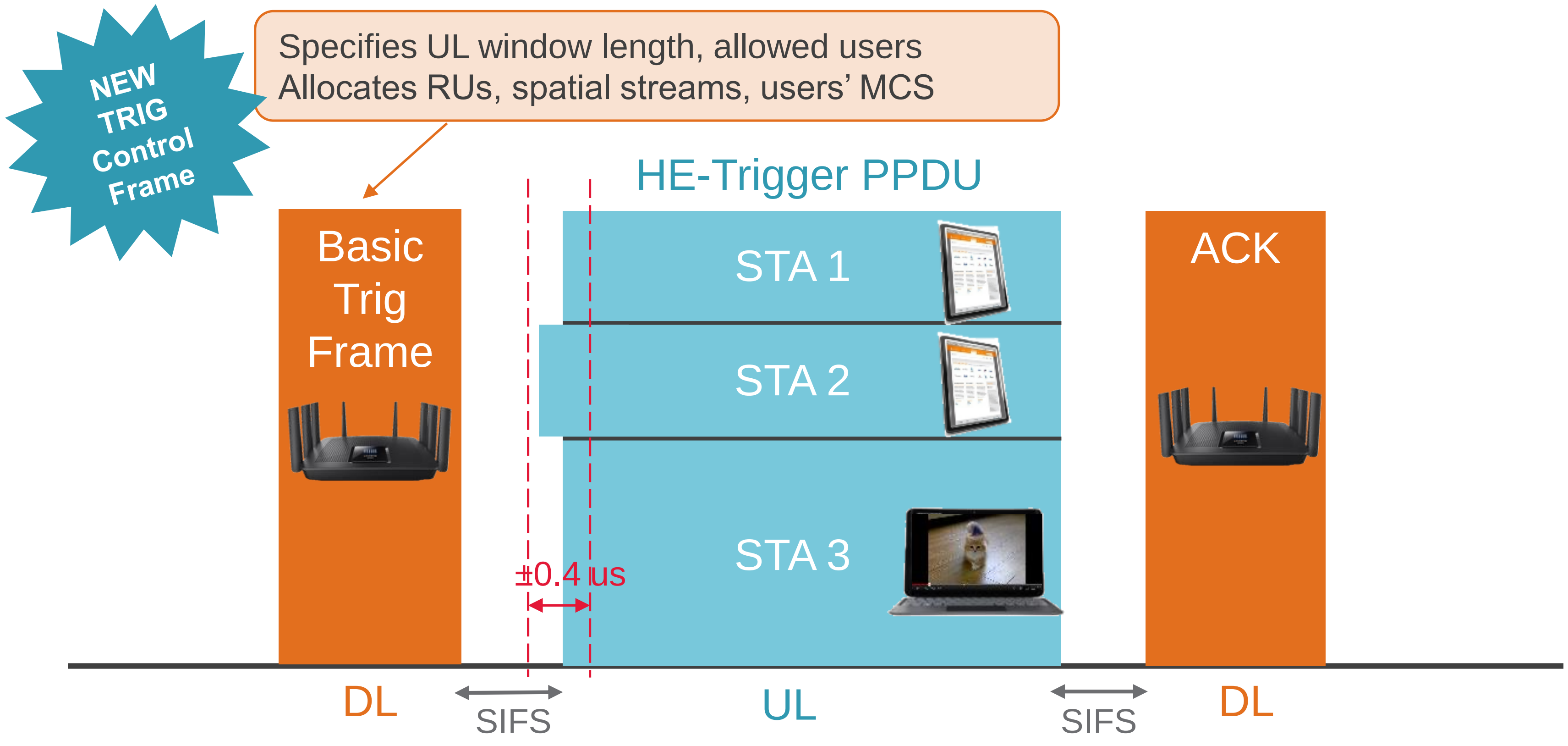
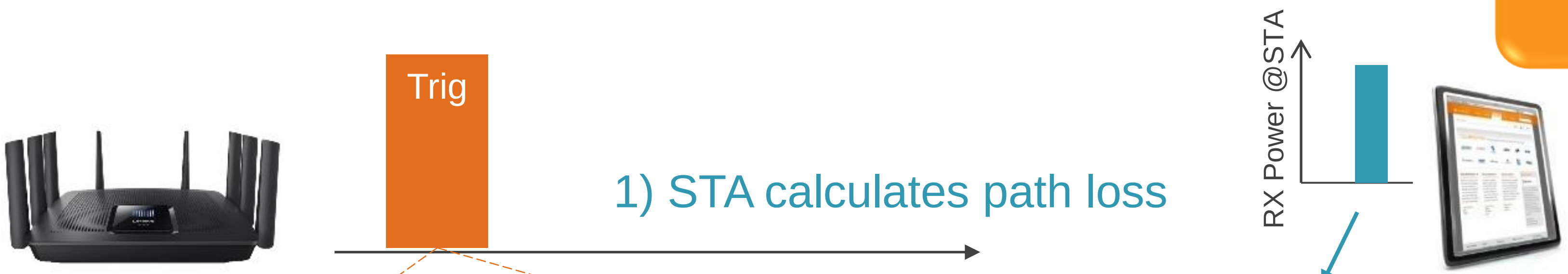
AP as Mini Base Station

- AP pre-coordinates with STAs to minimize interference
  - Power balance among STAs *Power*
  - System synchchronization among STAs
    1) Transmit at the same time (< **0.4us** difference) *Timing*
    2) Transmit at the same carrier frequency (<**350 Hz** difference) *Frequency*



How Does Power Pre-correction Work?

Maintain power balance among STAs in Uplink



1) STA calculates path loss

$$Pathloss_{DL} = Tx_{AP\ power} - DL_{RSSI}$$

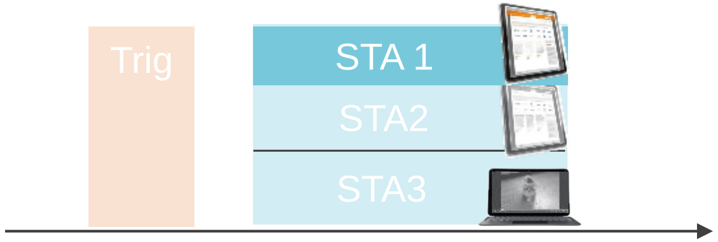
Trig Frame

MAC header

	Frame Control	Duration	RA	TA	Common Info	User Info	...	User Info	Padding	FCS
Octets:	2	2	6	6	8 or more	5 or more		5 or more	variable	4

2) STA calculates UL transmit power $Tx_{STA\ power} = Pathloss_{DL} + Target_{RSSI}$

3) STA sends HE TB PPDU in response to AP Trig at Tx $_{STA\ power}$



Ensures STA power does not interfere with other participating STAs

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STA Device Calibration

More Stringent Requirement in 11ax

- Transmit power accuracy : For uplink Tx accuracy
- RSSI measurement accuracy : To correctly calculate path loss

Accurate power control is critical in ensuring power received from STAs at AP is equal

Parameter	Minimum Requirement		Comments
	Class A	Class B	
Absolute transmit power accuracy	±3 dB	±9 dB	Accuracy of achieving a specified transmit power.
RSSI measurement accuracy	±3 dB	±5 dB	The difference between the RSSI and the received power. Requirements are valid from minimum Rx to maximum Rx input power.
Relative transmit power accuracy	N/A	±3 dB	Accuracy of achieving a change in transmit power for consecutive HE TB PPDU. The relative transmit power accuracy is applicable only to Class B devices.

802.11ax Draft 2.2 Table 28-43 STA power / RSSI Accuracy Requirements

11ax type test – UL OFDMA (STA)

Transmitter Tests

- ❑Transmit spectrum mask(IEEE **28.3.18.1)**
- ❑Spectral Flatness(IEEE **28.3.18.2)**
- ❑Transmit center frequency leakage(IEEE **28.3.18.4.2)**
- ❑Transmit center frequency tolerance(IEEE **28.3.18.3)**
- ❑Symbol Clock frequency tolerance(IEEE **28.3.18.3)**
- ❑Transmit constellation error(IEEE **28.3.18.4.3)**
- ❑Power Control Test(IEEE **28.3.14.3)**
- ❑ Transmitter modulation accuracy (EVM) test(IEEE **28.3.18.4.4)**
- ❑Residual CFO Test (IEEE **28.3.14.3)**
- ❑Timing Synchronization (IEEE**28.3.14.3)**

Receiver Tests

- ❑Minimum Input level (IEEE **28.3.17.2)**
- ❑Maximum input level(IEEE **28.3.17.3)**
- ❑Adjacent channel rejection(IEEE **28.3.17.4)**
- ❑Non-Adjacent channel rejection(IEEE **28.3.17.4)**
- ❑Sensitivity with MU DL signal (spec not define but important)

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LitePoint solutions for Wi-Fi 6

IQxel-MW 7G Product Family
IQfact+
IQsniffer

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First fully integrated tester for Wi-Fi 6 in the 6 GHz band

IQxel-M2W 7G for DVT

IQxel-M8W 7G for Mobile (STA) Manufacturing

IQxel-M16W 7G for Access Point Manufacturing

IQxel-M2W 7G

- For DVT
- 2 VSA/VSG and 2 ports active

IQxel-M8W 7G

- For STA manufacturing
- Multi-DUT
- Configurations available:
  - 2x4: 2 VSA/VSG and 4 ports active
  - 2x8: 2 VSA/VSG and 8 ports active

IQxel-M16W 7G

- For AP manufacturing
- Configurations available:
  - 4x4: 4 VSA/VSG and 4 ports active
  - 4x8: 4 VSA/VSG and 8 ports active
  - 4x16: 4 VSA/VSG and 16 ports active
- Designed for True MIMO testing up to 4x4 on a single unit and up to 8x8 with extension.

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IQxel-MW 7G Product Highlights

The *IQxel-MW 7G* is LitePoint’s test solution for advanced Wi-Fi 6 testing on 2.4GHz, 5 GHz and 6 GHz frequency bands

- Frequency range from 400 MHz to 7300 MHz
- Addresses the requirements of the IEEE 802.11ax (Wi-Fi 6) and 802.11ac (Wi-Fi 5) specifications and tests all IEEE 802.11 legacy specifications
- Native support for per-port 160 MH, 80+80 MHz and future 160+160 MHz signal combinations
- Exceptional residual EVM performance for 1024 QAM
- Single-user OFDMA, Trigger based Test multi-user OFDMA, Uplink and Downlink testing with easy-to-edit RU allocations
- Wi-Fi 6 Carrier Frequency Offset (CFO), power and timing control verification
- Tests all Bluetooth device standards (1.x, 2.x, 3.0, 4.x, 5) and the newly released BT 5.1
- Test support for DECT (ETSI EN 300 176-1), ZigBee, Z-Wave and WiSUN and LPWAN technologies LoRa and Sigfox

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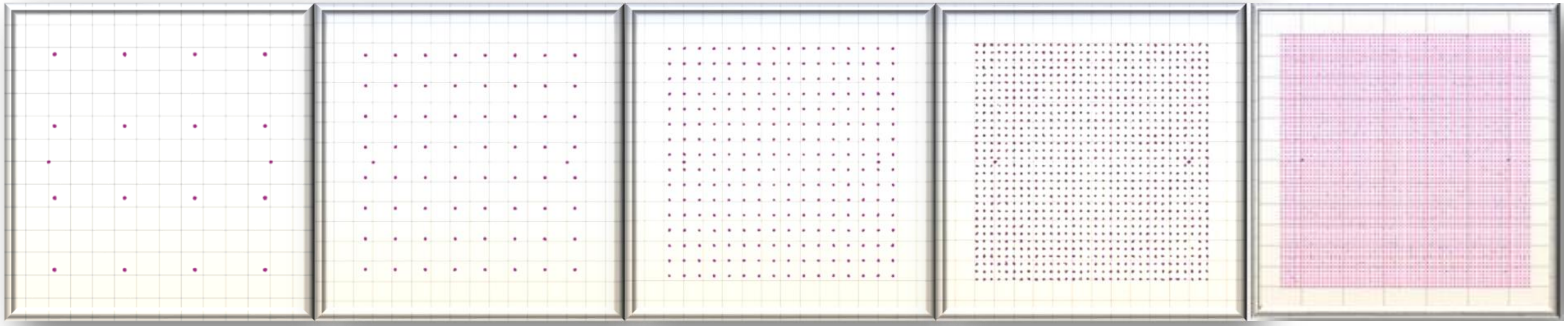
Higher Tester Performance for Linearity and Signal to Noise to make sure the EVM accuracy, so that insure the CPK and pass rate in MFG

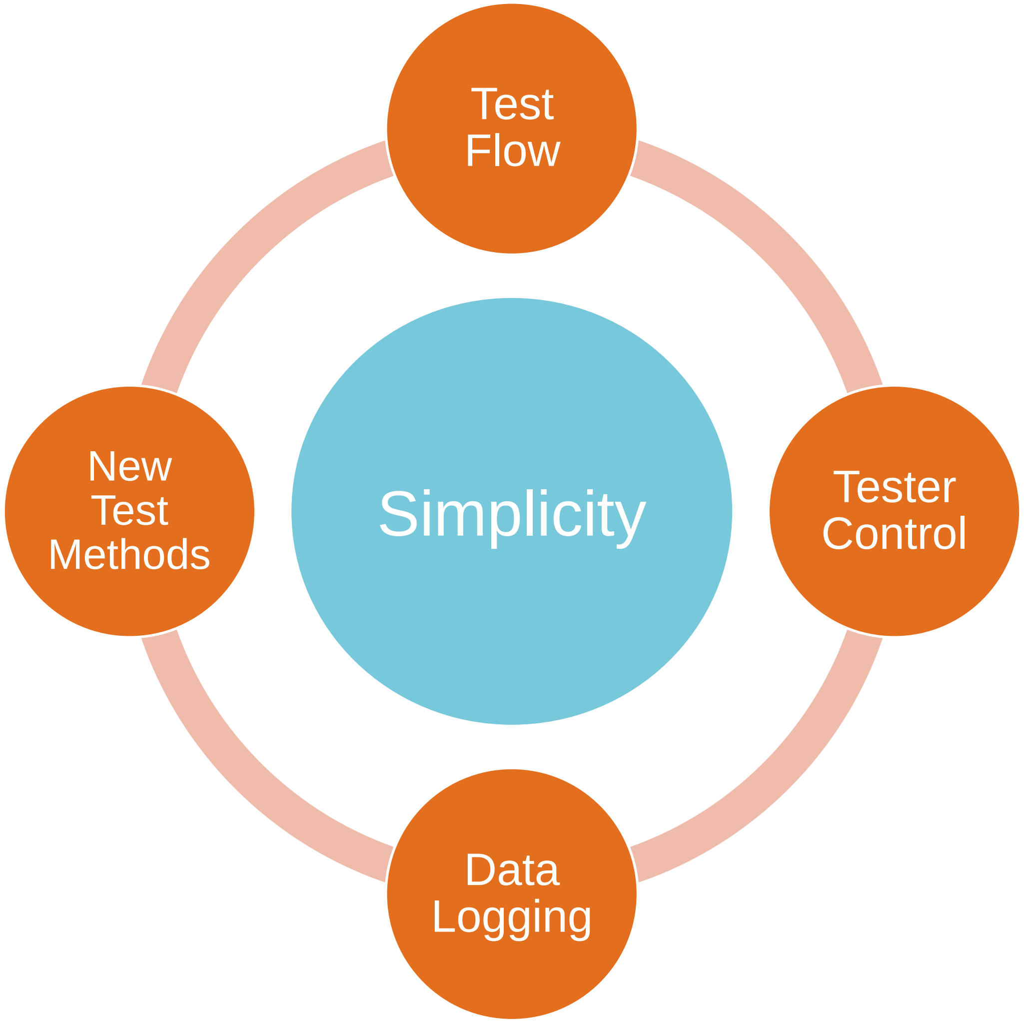


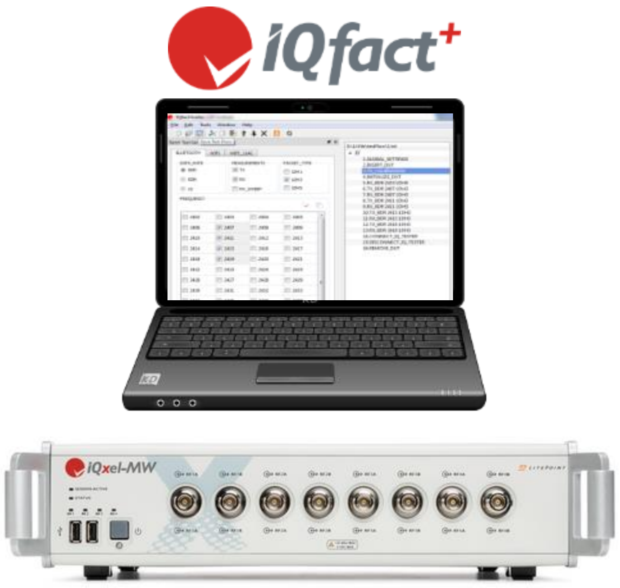
16 QAM	64 QAM	256 QAM	1024 QAM	4096QAM
-19 dB	-27 dB	-32 dB	**-35 dB**	**-38 dB**

IQxel-MW 7G EVM accuracy < -48dB in loopback measurement with LTF channel estimation, and reach up to < -51dB with full packet channel estimation.

Automation Reduces 802.11ax Test Complexity

11ax has more test combinations and test requirements than previous Wi-Fi standards





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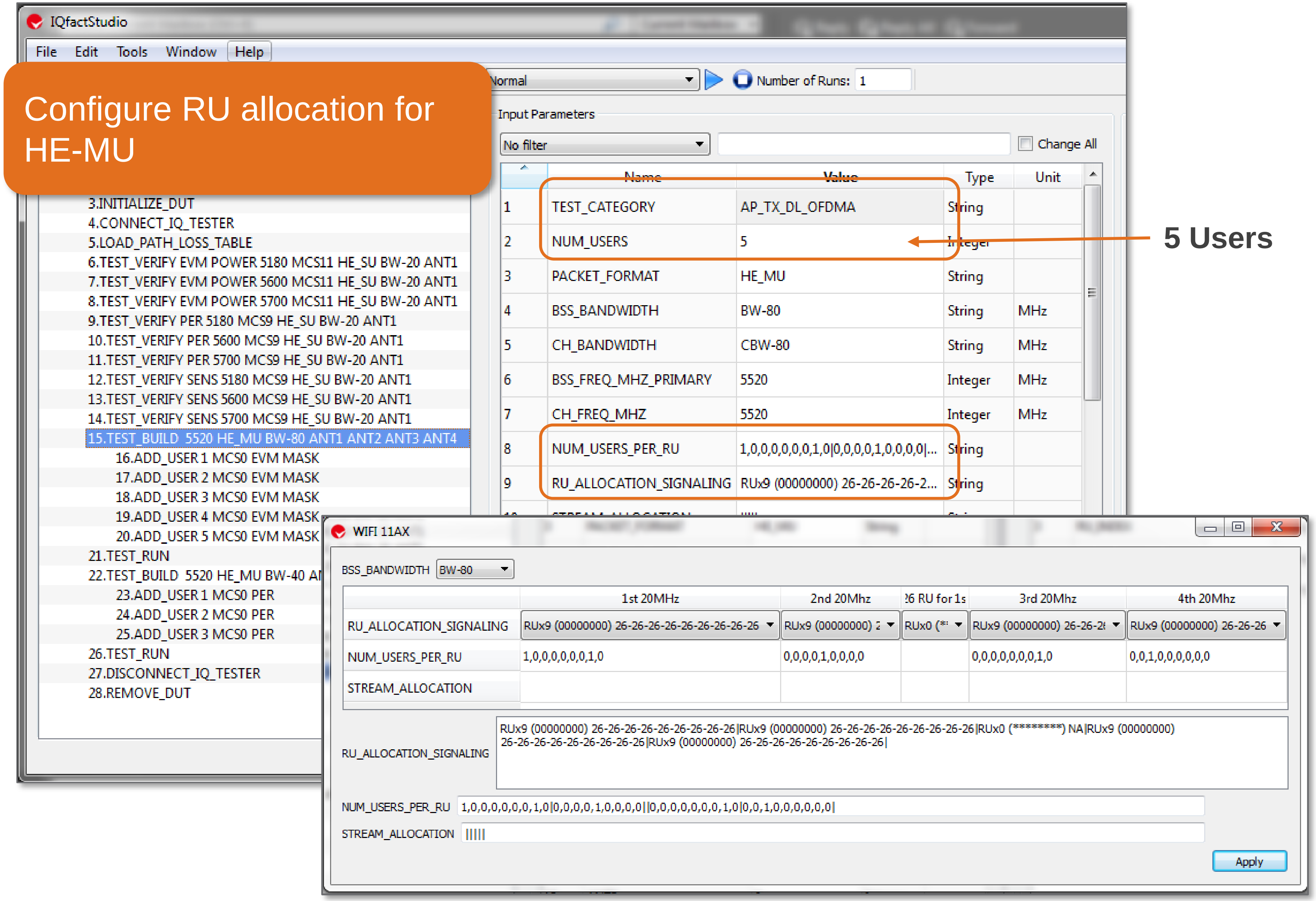
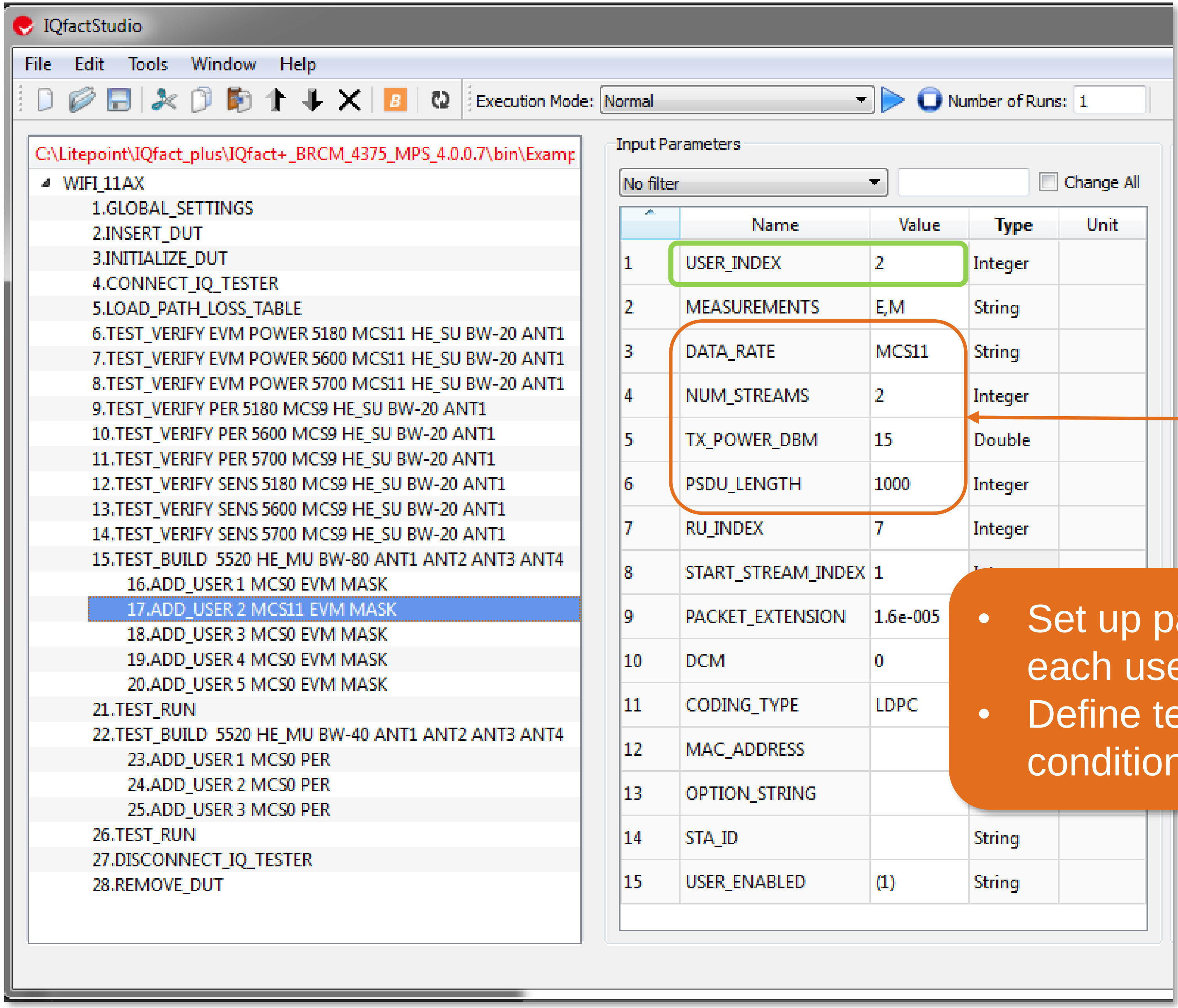
Creating 11ax Test Flow for AP with iQfact+



Creating 11ax Test Flow for AP with IQfact+



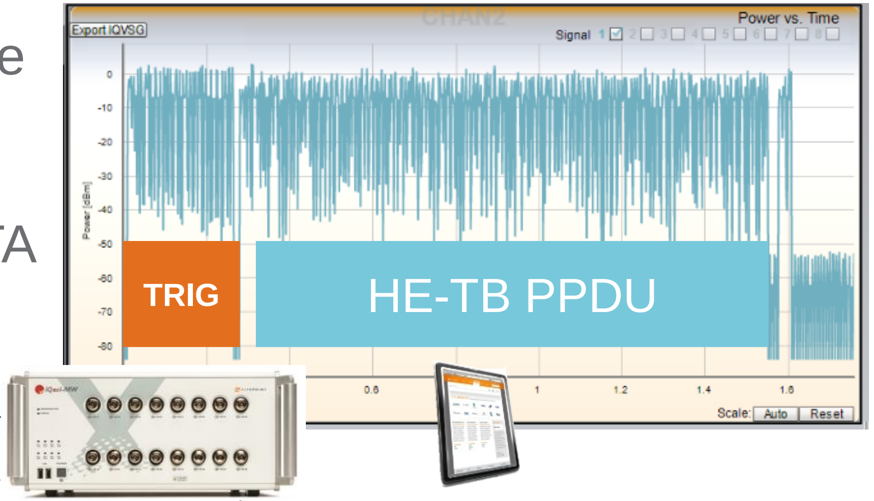
Different for each RU / user

- Set up parameters for each user
- Define test types and conditions

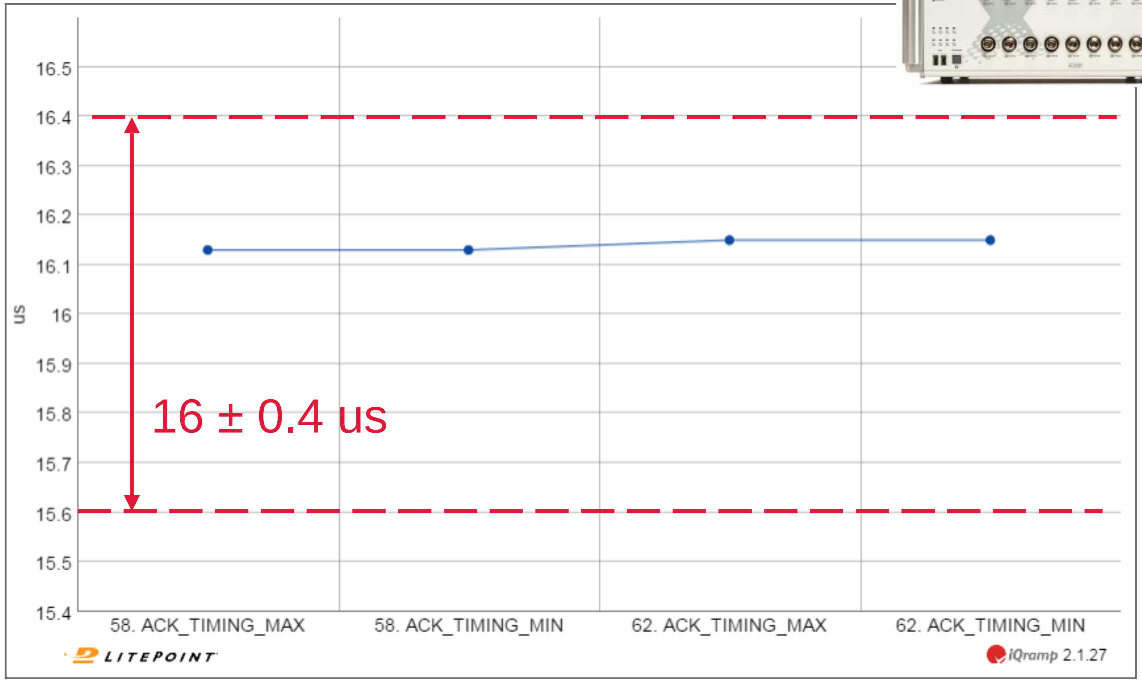
IQfact+ Data Example: Trigger Based Testing

IQfact+ automatically handles precise timing control necessary for TBT

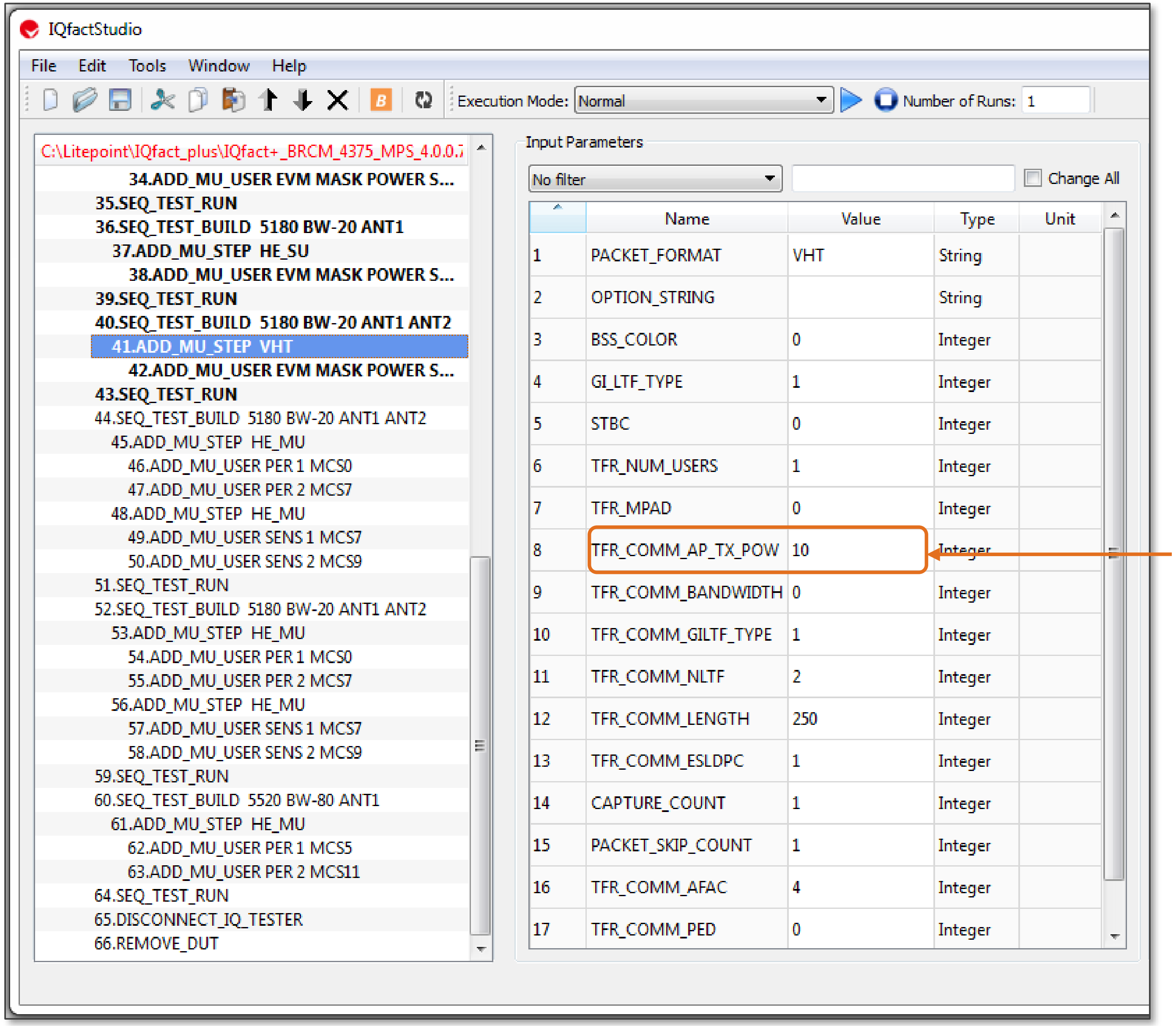
1. Tester VSG: Transmit a Trigger frame
2. Tester switches VSG to VSA
3. Tester VSA captures HE-TB from STA for analysis



TBT (Timing measurement)

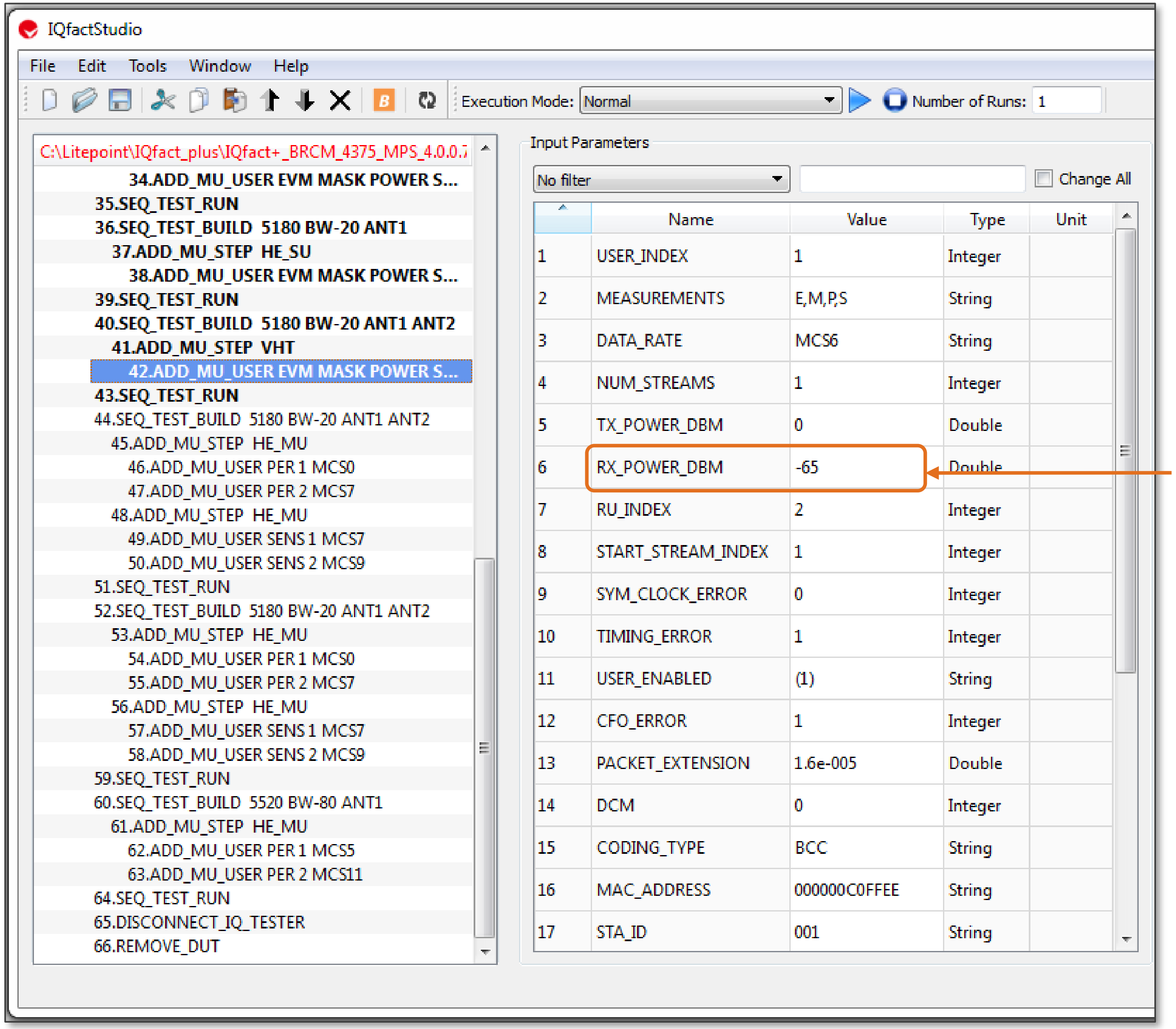


Configuring Trigger Based Test with iQfact+



Sets AP Tx power in Trigger frame (dBm)

Configuring Trigger Based Test with IQfact+



Sets target Rx signal power in Trigger frame (dBm)

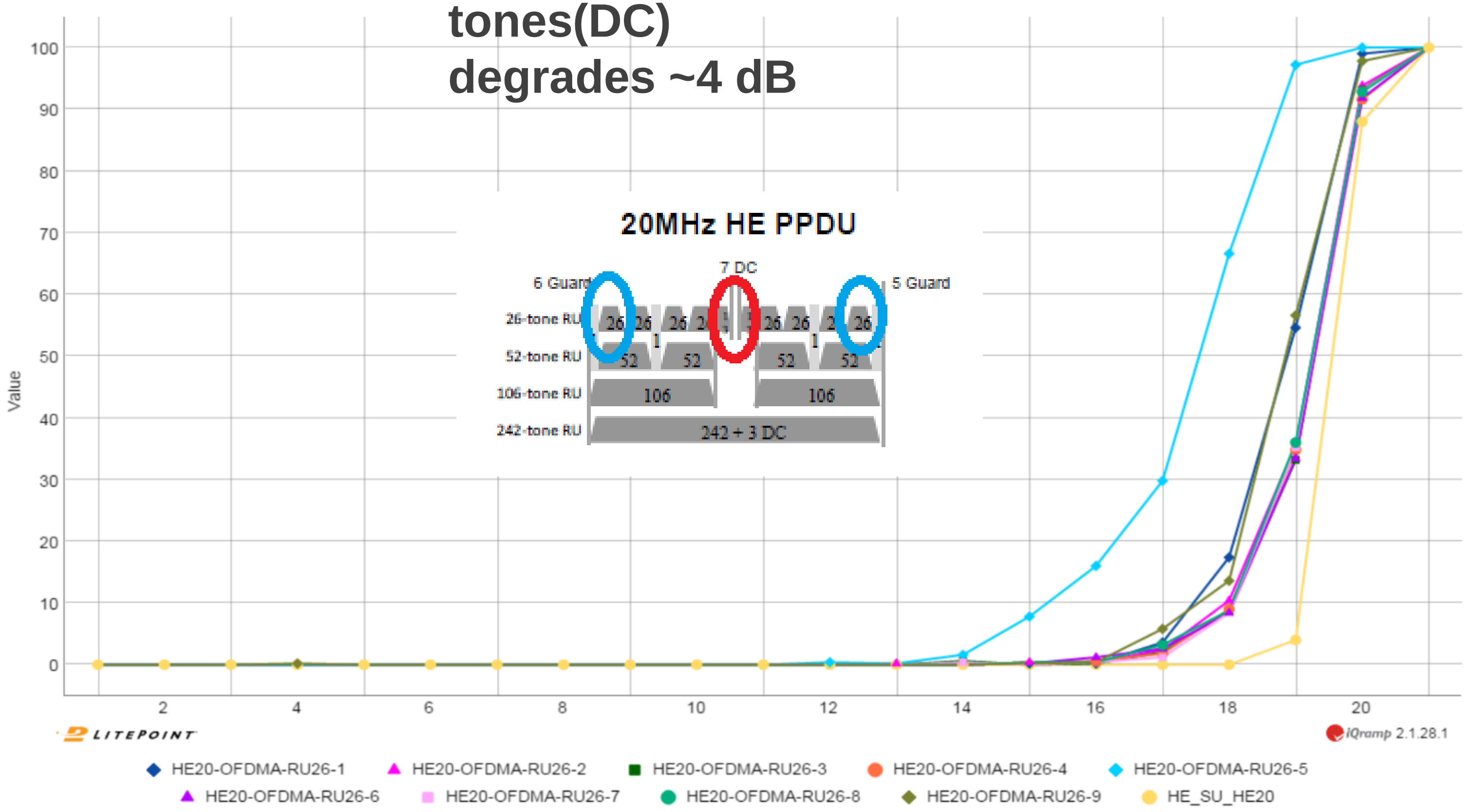
DL-OFDMA for STA receiver sensitivity testing

HE_SU	RU26	RU26	RU26	RU26	RU26	RU26	RU26	RU26	RU26
-78.15	-76.46	-76.95	-77.05	-77.04	-74.27	-77.06	-77.06	-77.04	-76.54

The edge RU26 degrades ~1.5 dB

Sensitivity at central RU26 tones(DC) degrades ~4 dB

Other RU26 degrades ~1 dB.



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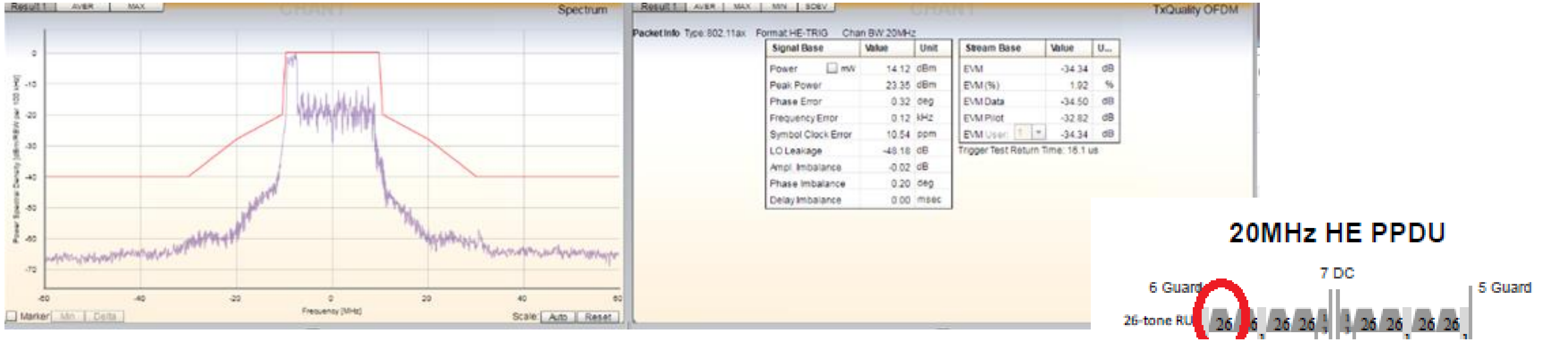
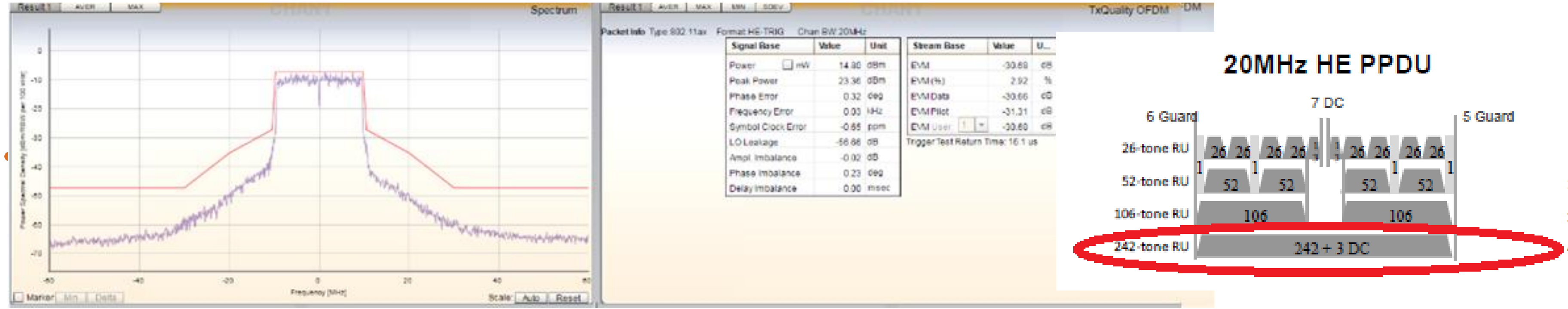
TX UL-OFDMA for STA EVM

- EVM -34.34dB, power 14.12dBm





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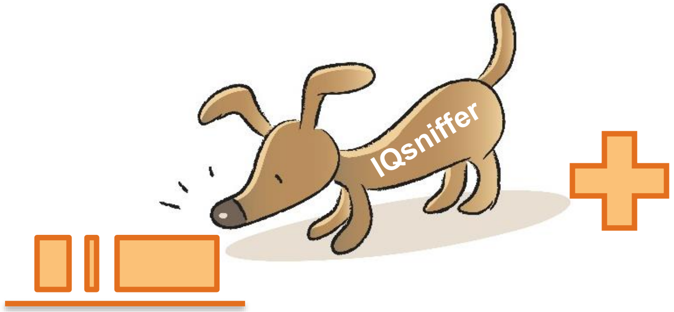
IQsniffer – WiFi PHY Traffic Analysis Simplified



- **IQsniffer is useful for product characterization and Pre-correction test**
- **Key Features:**
  - **PHY layer analysis:** Uncovers timing information and behavior not visible at MAC layer
    - Parametric measurements(EVM, Power, Spectrum, etc.)
    - Timing information
    - PPDU information: packet format, coding, spatial stream info
  - **MAC layer information available:**
    - Packet type, sub-type
    - MAC address(es)
    - Whole PSDU

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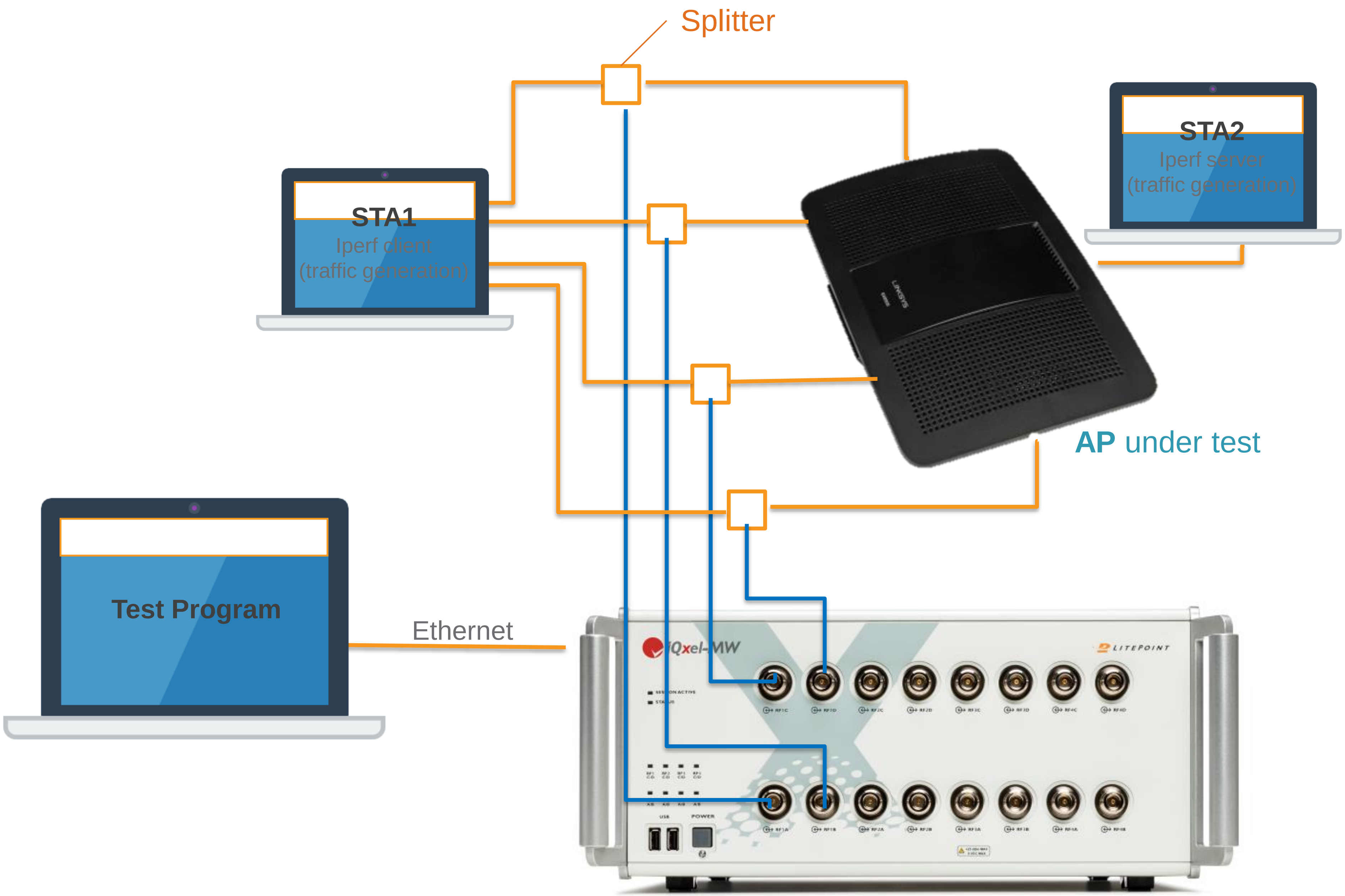
IQsniffer PHY Traffic Monitoring (4x4) on IQxel-MW



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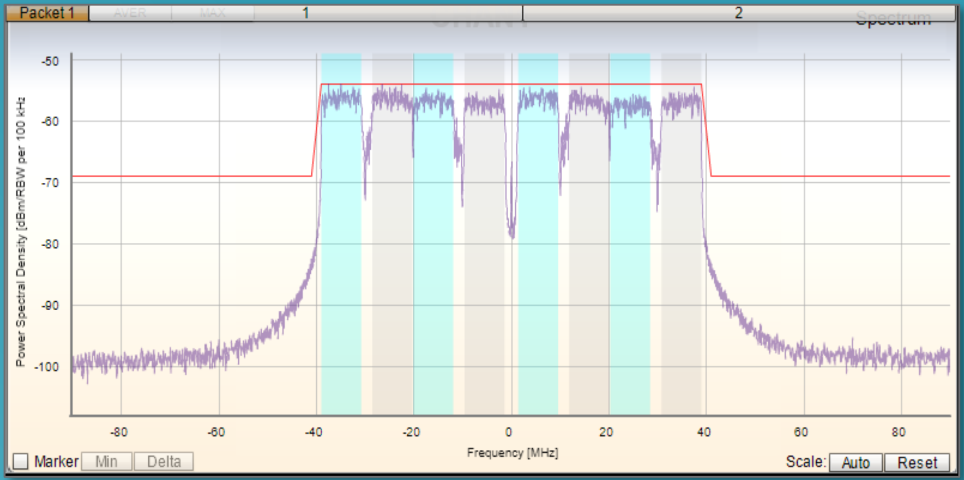
Using IQsniffer:
PHY Parameters for 802.11ax HE-MU



Packet 1 — CHAN1 — TxQuality Multi-User

User	RU Idx	RU Size	Mod Ty...	MCS	#Stream	EVM (dB)	Power (dBm)
1	1	106	BPSK	0	1	-42.65	-36.95
2	2	106	BPSK	0	1	-42.13	-36.92
3	3	106	BPSK	0	1	-42.03	-37.41
4	4	106	BPSK	0	1	-41.74	-37.90
5	5	106	BPSK	0	1	-42.57	-37.12
6	6	106	BPSK	0	1	-41.88	-37.35
7	7	106	BPSK	0	1	-40.88	-38.24
8	8	106	BPSK	0	1	-41.47	-37.63

Packet 1 — CHAN1 — TxQuality Info OFDM

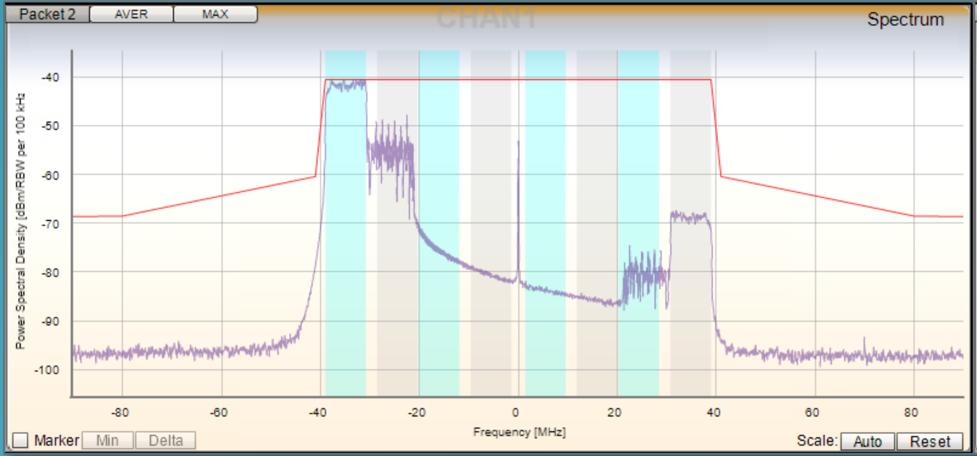
Export PSDU

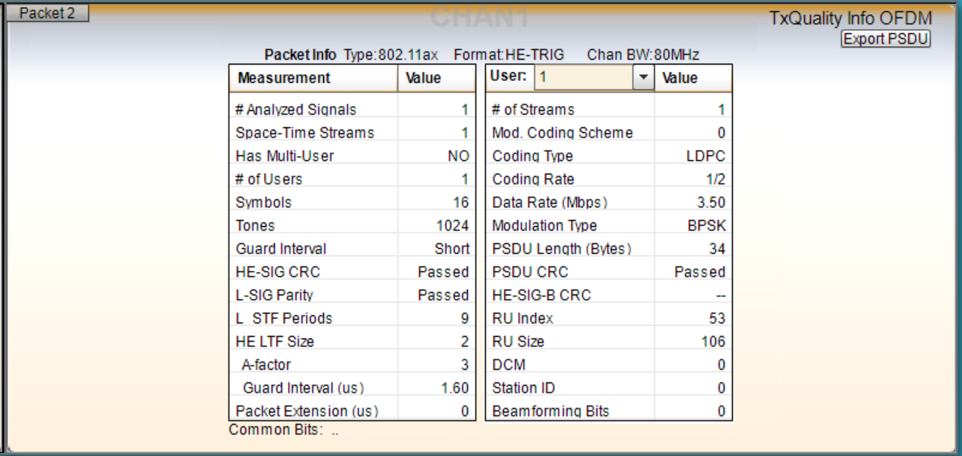
Packet Info Type:802.11ax Format:HE-MU Chan BW:80MHz

Measurement	Value
# Analyzed Signals	1
Space-Time Streams	1
Has Multi-User	Yes
# of Users	8
Symbols	7
Tones	1024
Guard Interval	Long
HE-SIG CRC	Passed
L-SIG Parity	Passed
L STF Periods	10
HE LTF Size	2
A-factor	3
Guard Interval (us)	0.80
Packet Extension (us)	0

User: 1	Value
# of Streams	1
Mod. Coding Scheme	0
Coding Type	LDPC
Coding Rate	1/2
Data Rate (Mbps)	3.80
Modulation Type	BPSK
PSDU Length (Bytes)	38
PSDU CRC	Passed
HE-SIG-B CRC	Passed
RU Index	1
RU Size	106
DCM	0
Station ID	53
Beamforming Bits	0

Using IQsniffer: PHY Parameters for 802.11ax HE-TRIG




Packet 2

TxQuality Info OFDM

Export PSDU

Packet Info Type:802.11ax Format:HE-TRIG Chan BW:80MHz

Measurement	Value	User: 1	Value
# Analyzed Signals	1	# of Streams	1
Space-Time Streams	1	Mod. Coding Scheme	0
Has Multi-User	NO	Coding Type	LDPC
# of Users	1	Coding Rate	1/2
Symbols	16	Data Rate (Mbps)	3.50
Tones	1024	Modulation Type	BPSK
Guard Interval	Short	PSDU Length (Bytes)	34
HE-SIG CRC	Passed	PSDU CRC	Passed
L-SIG Parity	Passed	HE-SIG-B CRC	--
L STF Periods	9	RU Index	53
HE LTF Size	2	RU Size	106
A-factor	3	DCM	0
Guard Interval (us)	1.60	Station ID	0
Packet Extension (us)	0	Beamforming Bits	0

Common Bits: ..

IQsniffer Packet Duration Measurement

IQsniffer SIFS Measurement