




LITEPOINT

A Teradyne Company

Wi-Fi 6 Updates

Essential Tests, Product Certification
and New Spectrum on the Horizon



Wi-Fi Ecosystem

FC



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

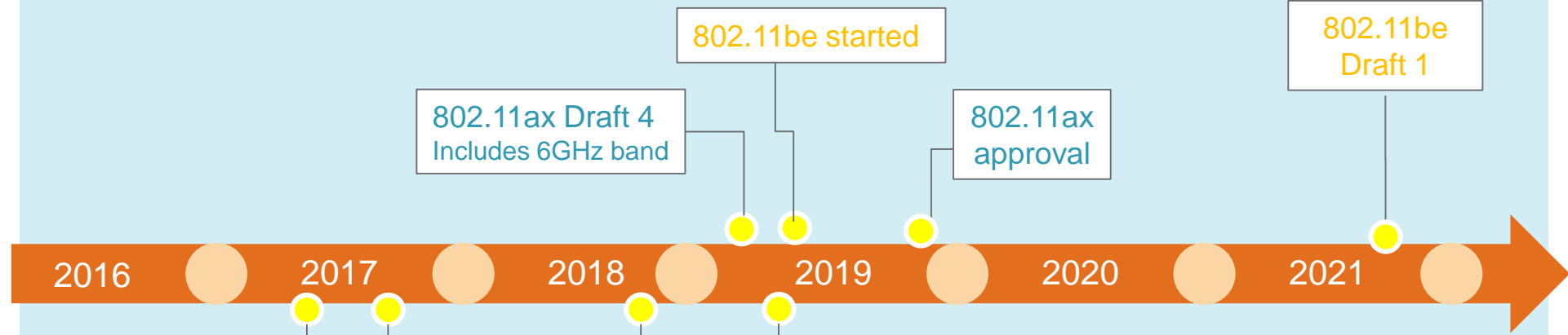


Wi-Fi 6 Test Suite



Test Equipment

IEEE Standard Timeline



802.11ax Chipset DVT

AP Chipset Customer Shipments

802.11ax AP products



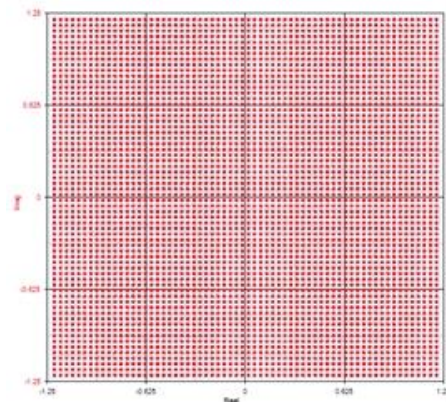
802.11ax mobile products



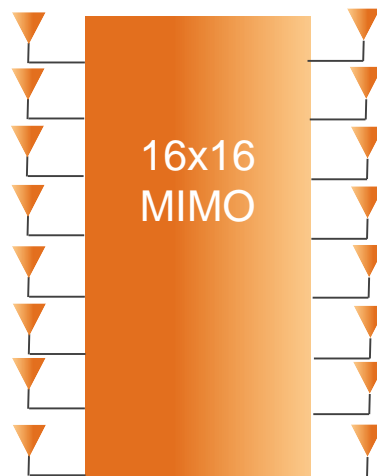
802.11be EHT Extreme High Throughput



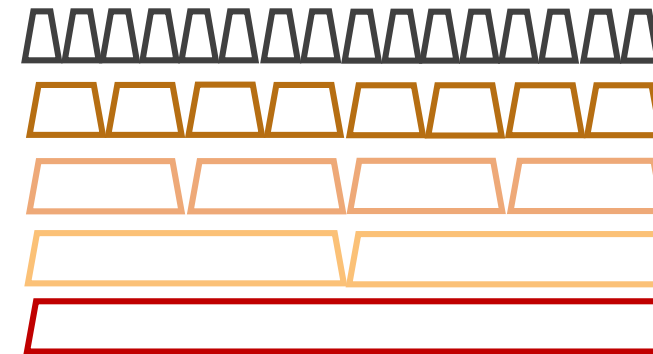
- Target Performance
- Low Latency: $< 5 \text{ ms}$ (full immersion VR)
- High Throughput: 30 Gbps
- Candidate Features:



4096 QAM



16 Spatial Streams



320 MHz Channel

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

FCC Federal Communications Commission



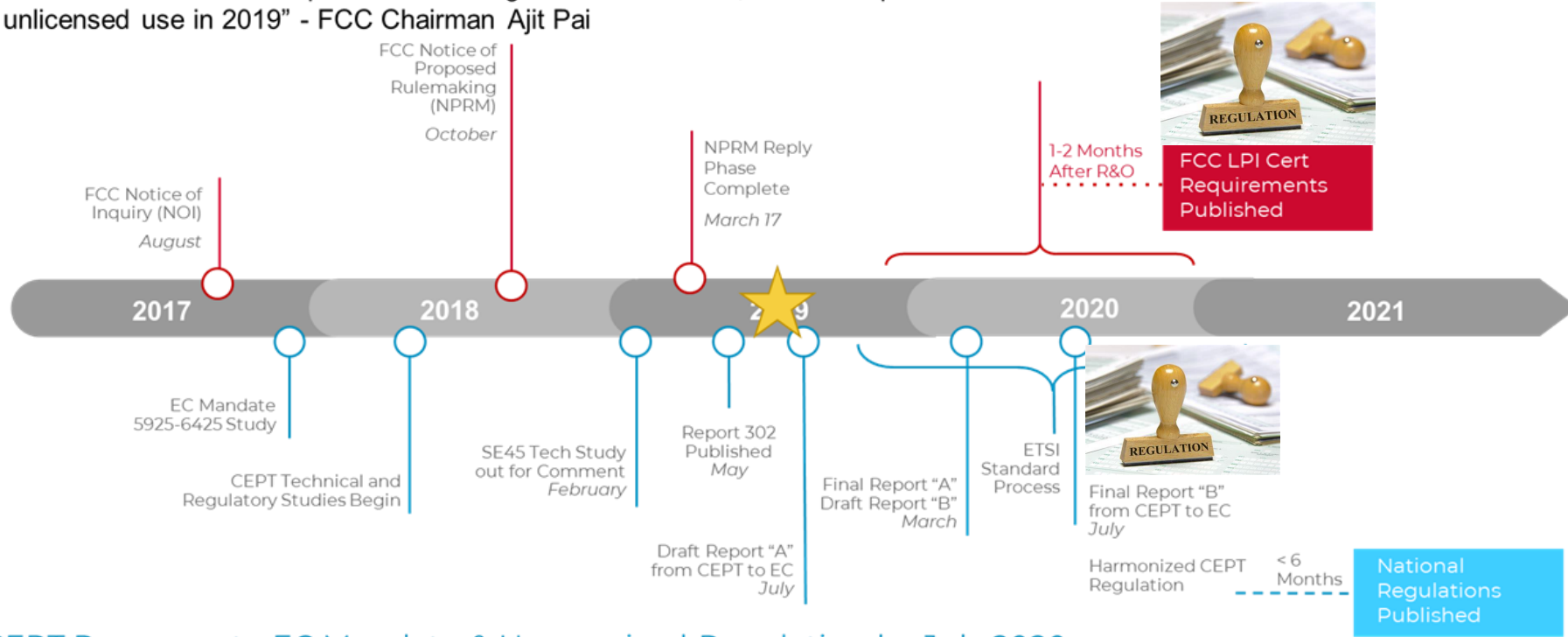
- **Who are they?**
- US Government agency in charge of **regulating communications**
- They assign RF **spectrum** allocation
- In October 2018 they announced a Notice of Proposed Rulemaking to promote new opportunities for **unlicensed use** in portions of the 1200 megahertz of spectrum in the **5.925-7.125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



Regulatory Update

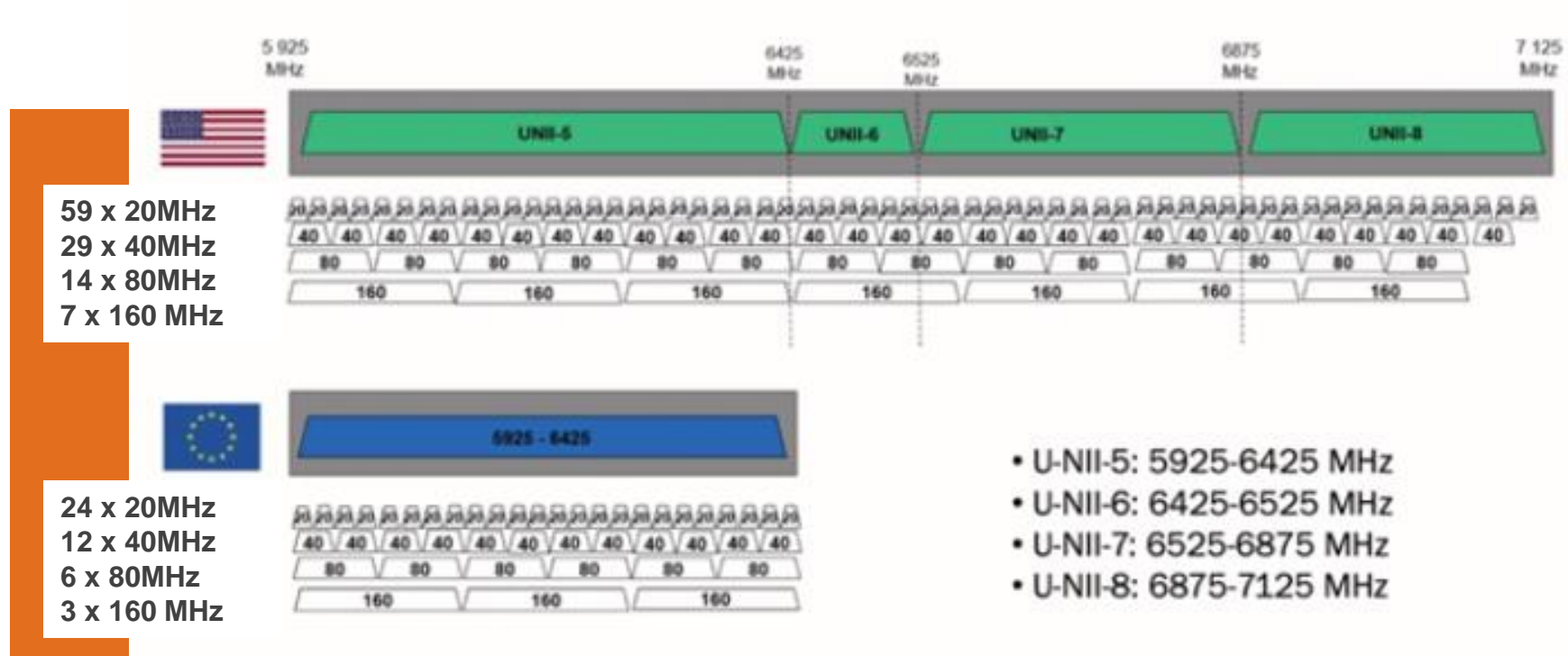
US R&O expected completion 2019/2020

“The 6 GHz band can help drive the next generation of Wi-Fi, and I am optimistic that we will be able to make it available for unlicensed use in 2019” - FCC Chairman Ajit Pai



CEPT Response to EC Mandate & Harmonized Regulation by July 2020

802.11ax “6 GHz” Band Allocations



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



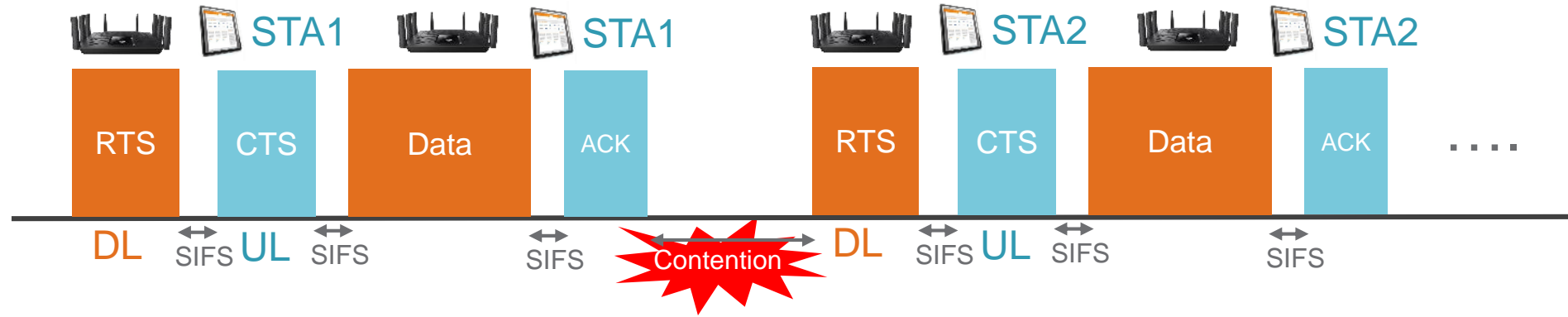
Wi-Fi 6 Essential Tests for OFDMA

OFDM vs. OFDMA: Downlink

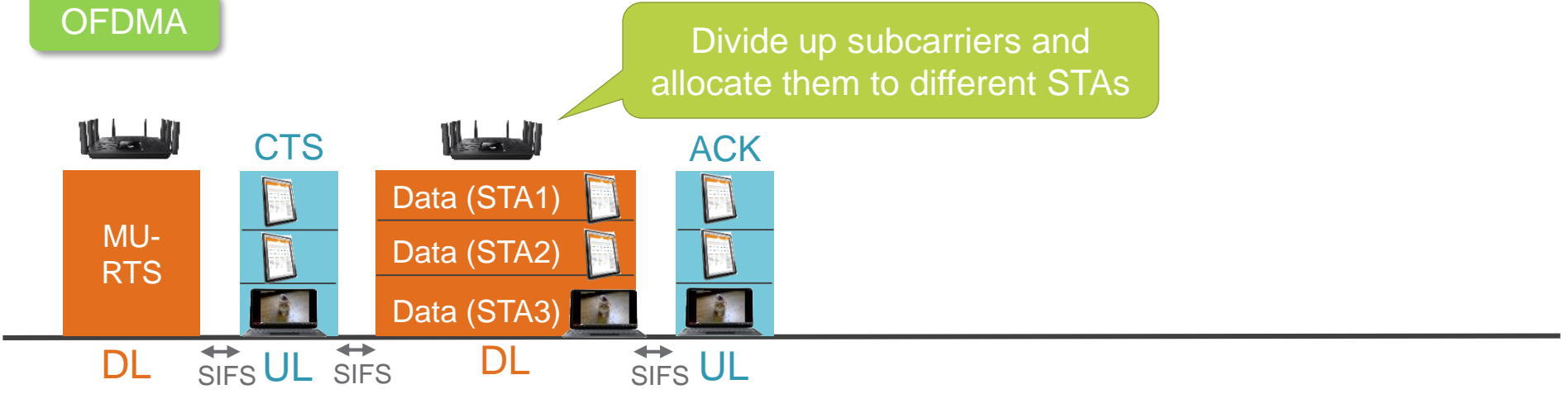


OFDMA improves overall network efficiency by serving multiple STAs

OFDM

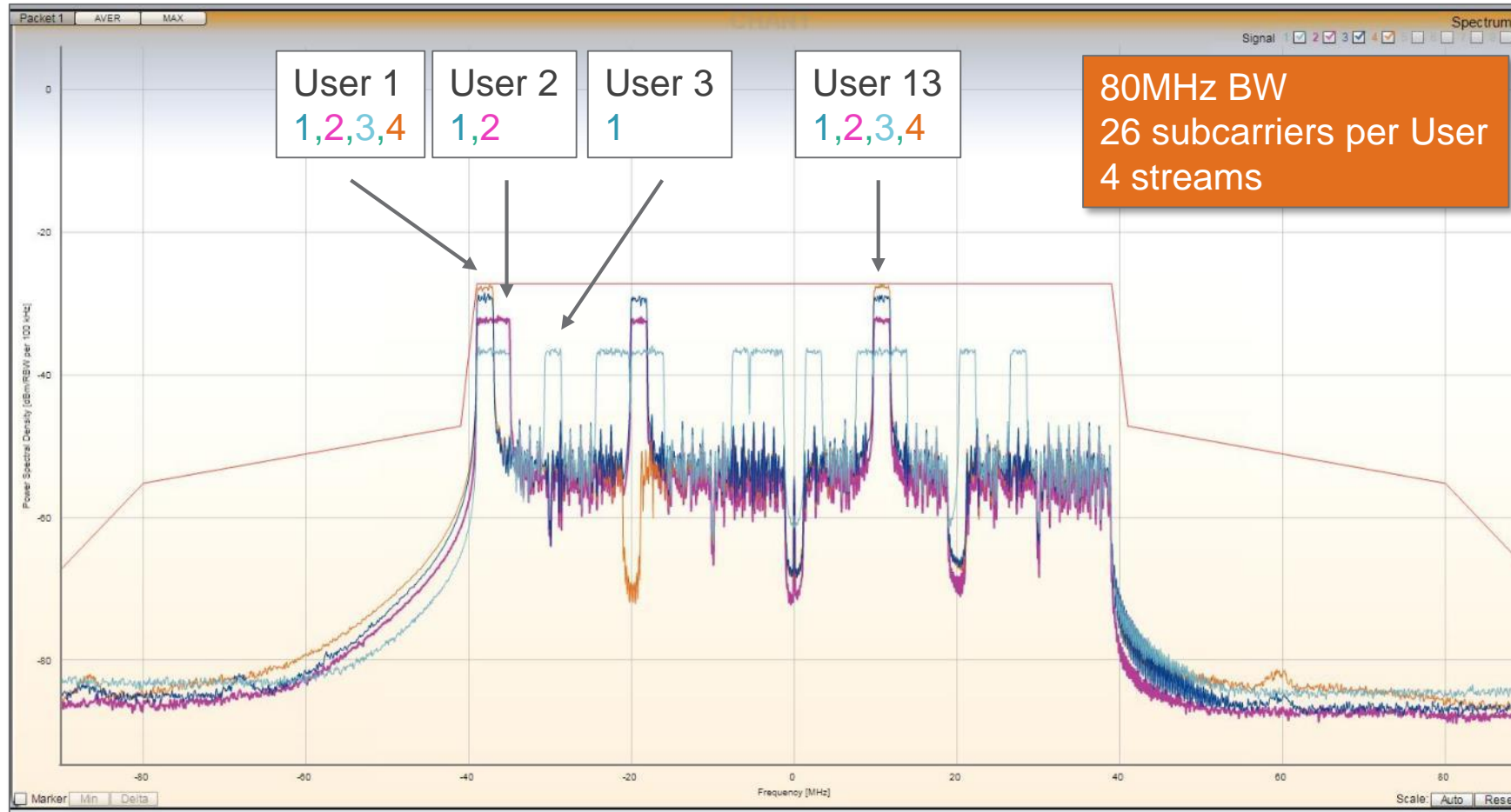


OFDMA

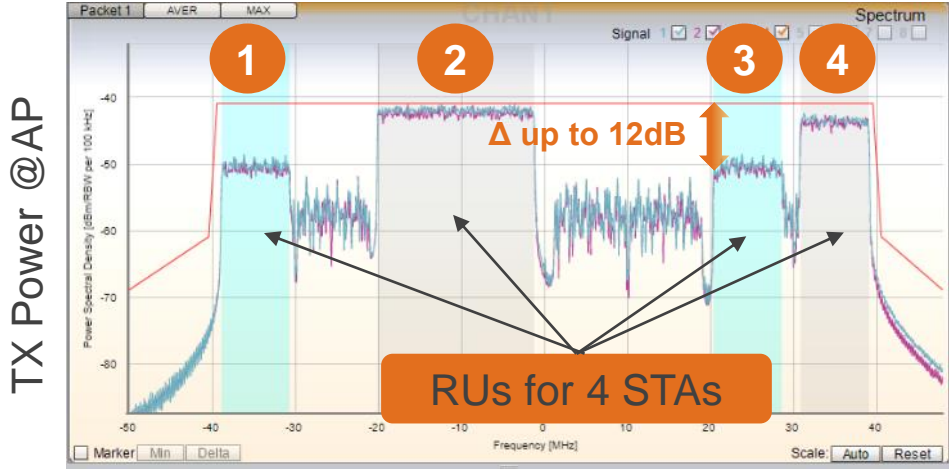


OFDMA Brings Large Number of Test Permutations

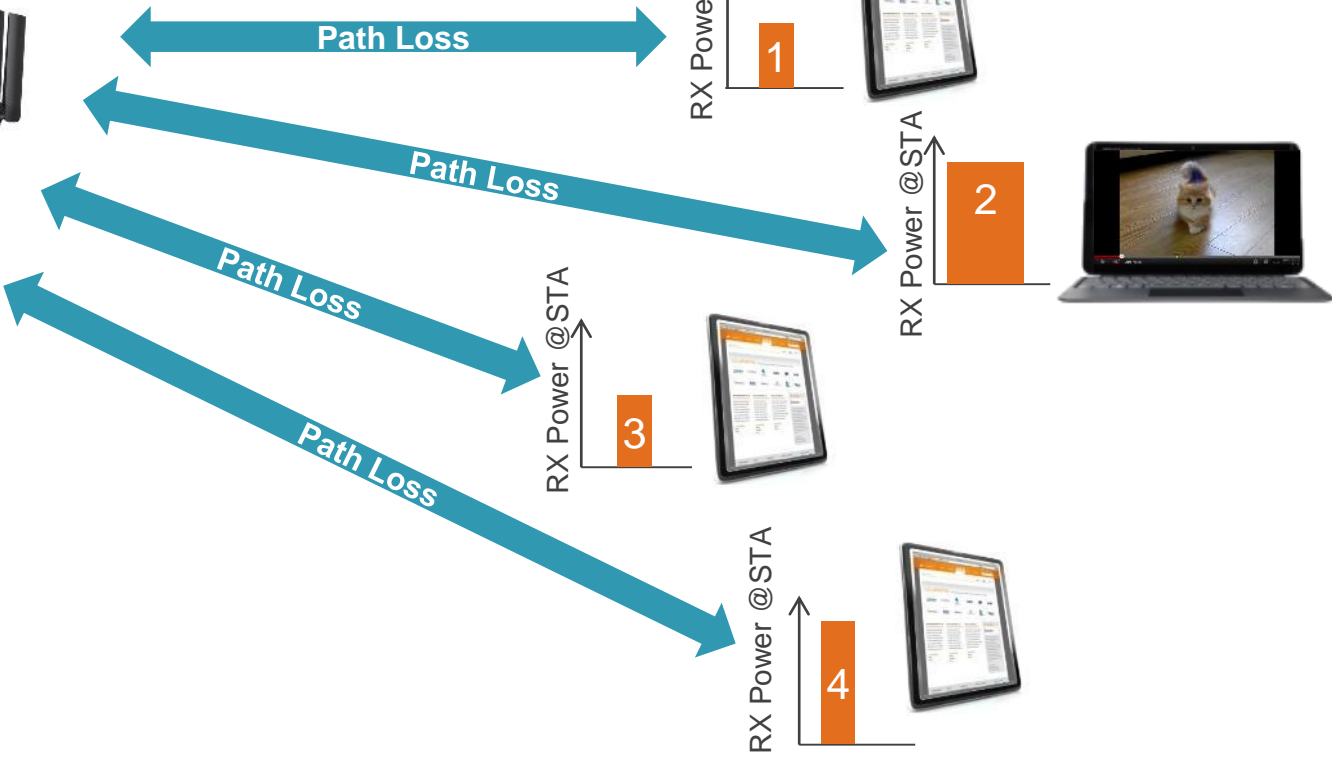
- AP simultaneously serves multiple users
 - Varying # of users, RU combinations, # of streams



Multi-User OFDMA Power Control ("Power Boost")



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

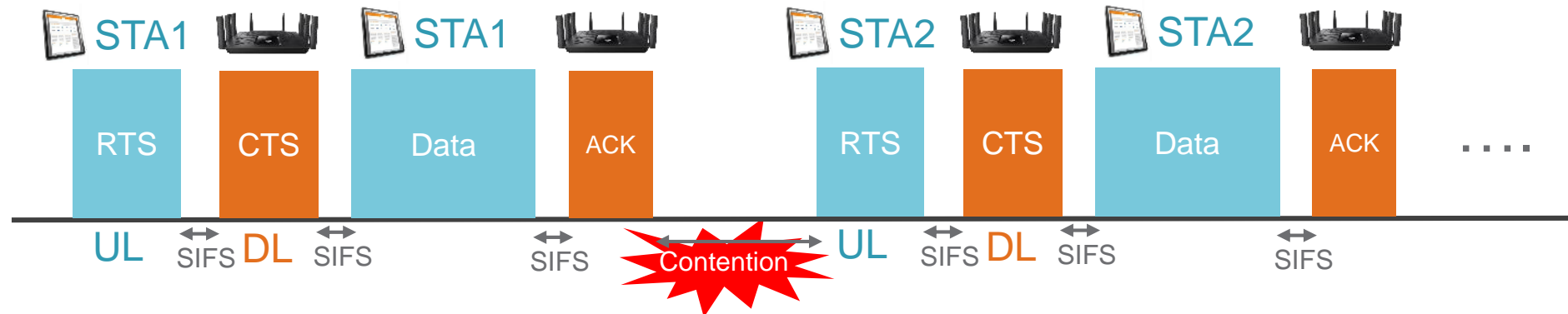


OFDM vs. OFDMA: Uplink

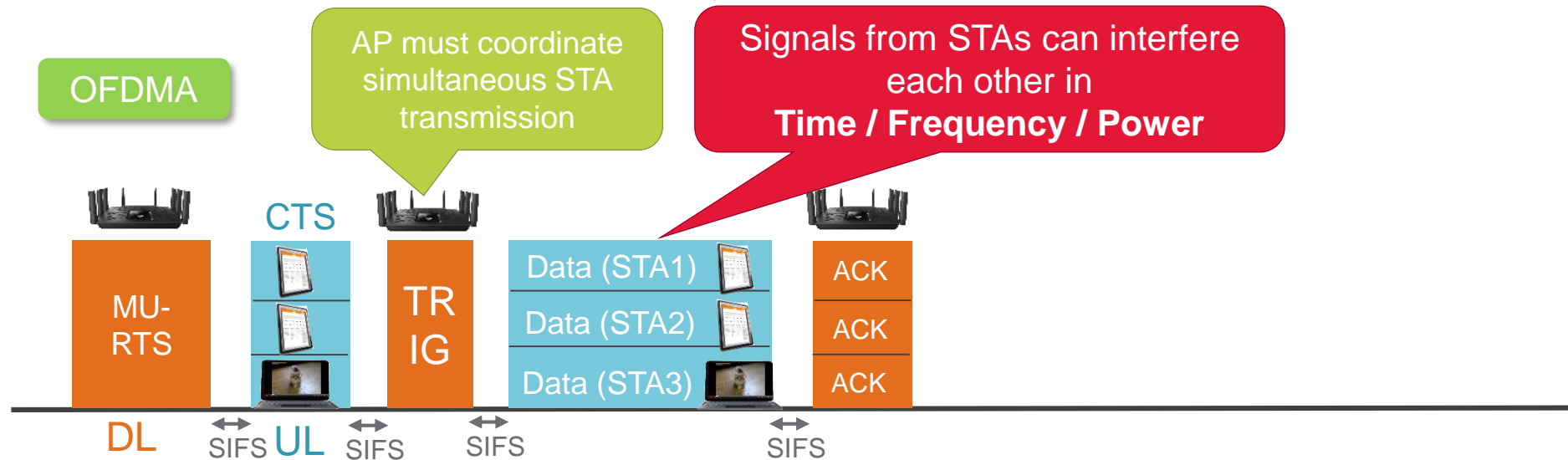


Uplink Tx requires precise frequency, timing, and power control

OFDM



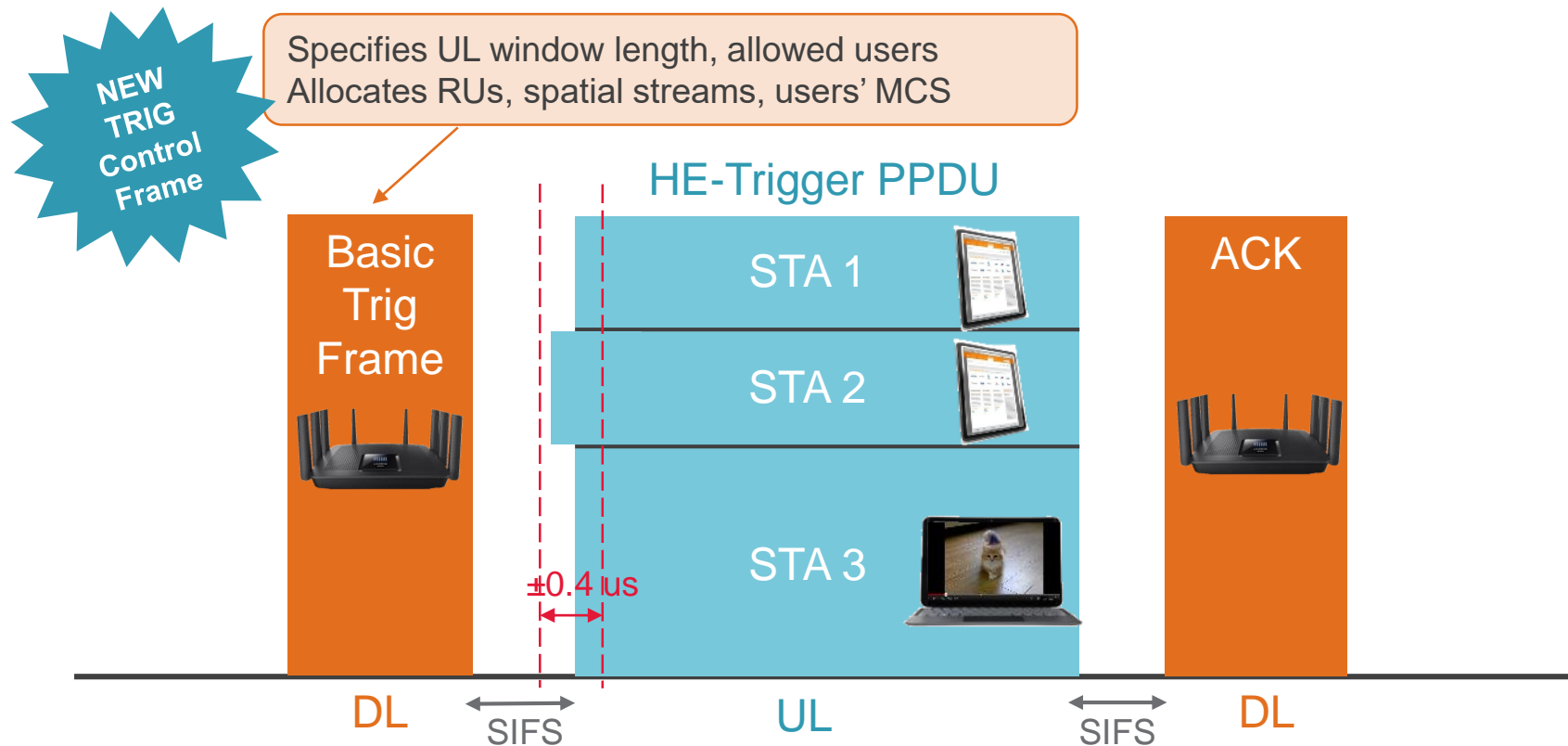
OFDMA



AP as Mini Base Station

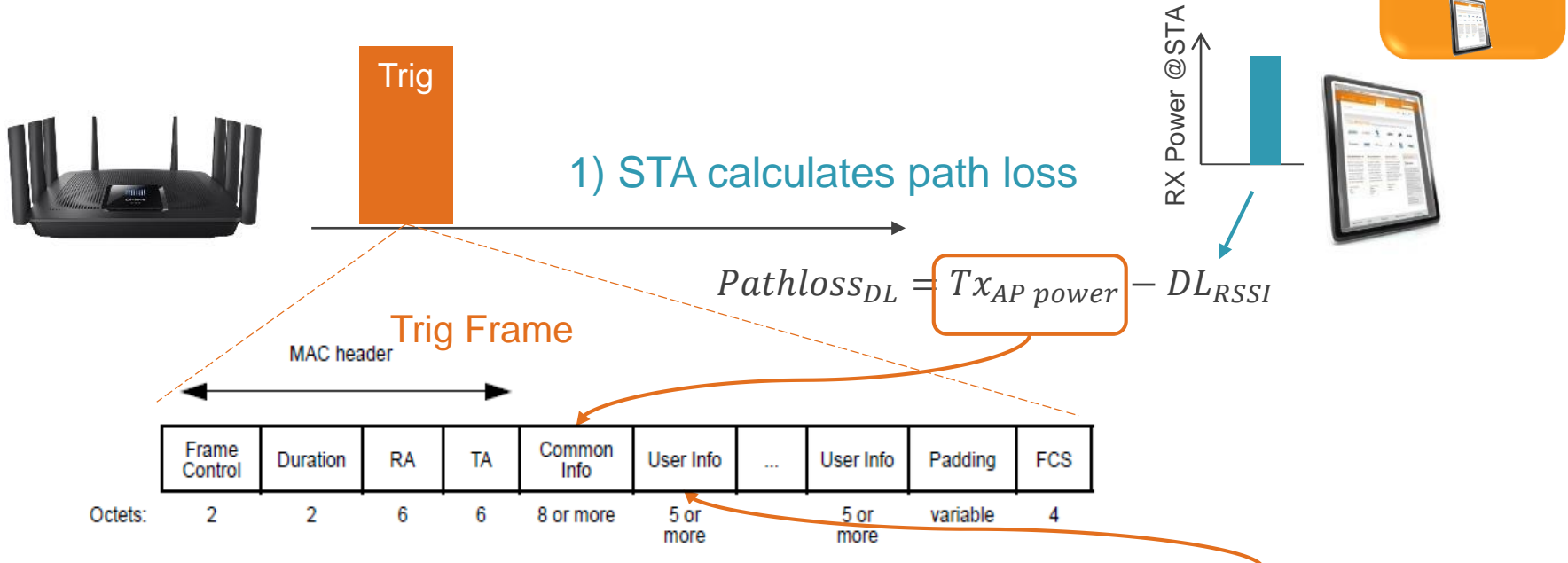


- AP pre-coordinates with STAs to minimize interference
 - Power balance among STAs *Power*
 - System synchronization among STAs
 - 1) Transmit at the same time (< **0.4us** difference) *Timing*
 - 2) Transmit at the same carrier frequency (<**350 Hz** difference) *Frequency*



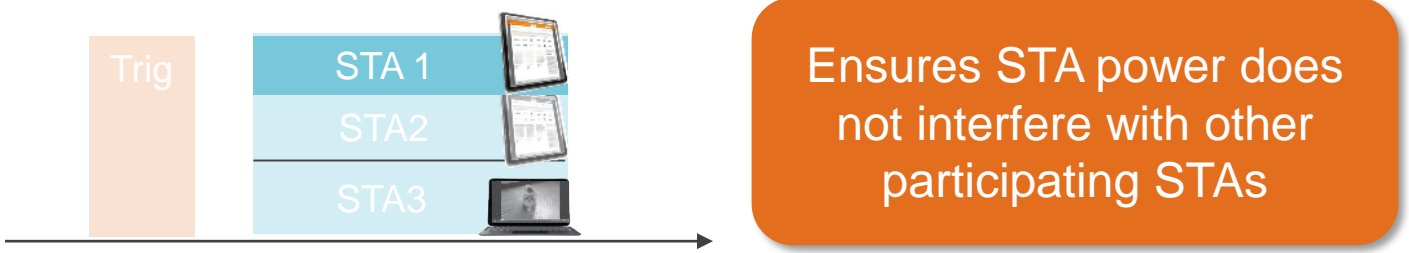
How Does Power Pre-correction Work?

Maintain power balance among STAs in Uplink



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 $Tx_{STA} power$



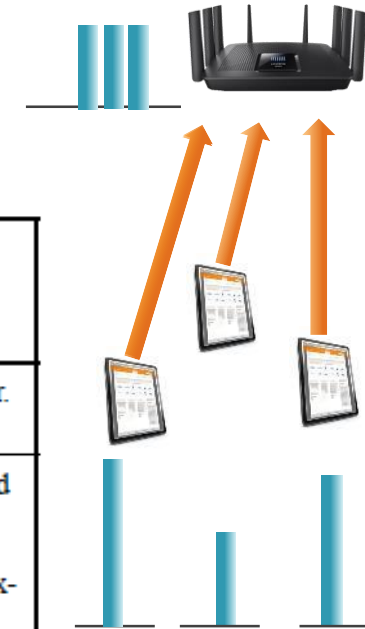
STA Device Calibration

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)

The background of the slide is a dark blue gradient. The upper portion features a pattern of white binary digits (0s and 1s) that are slightly blurred and appear to be receding into the distance. The lower portion shows a city skyline at night, with various skyscrapers illuminated with lights. The overall aesthetic is high-tech and modern.

LitePoint solutions for Wi-Fi 6

IQxel-MW 7G Product Family
IQfact+
IQsniffer

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

IQxel-M2W 7G for DVT



IQxel-M2W7G

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

IQxel-M8W 7G for Mobile (STA) Manufacturing



IQxel-M8W7G

- 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 Access Point Manufacturing



IQxel-M16W7G

- 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.

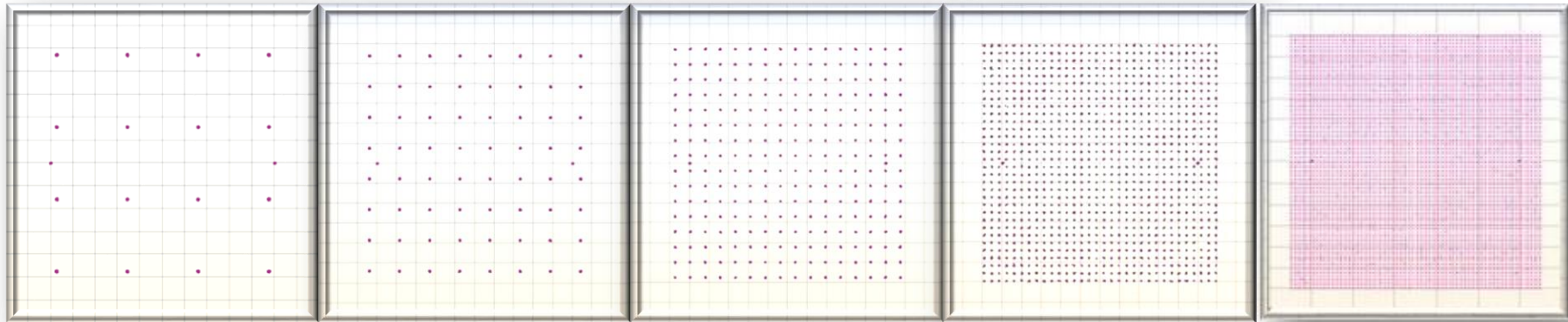
IQxel-MW 7G Product Highlights



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 MHz, 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

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

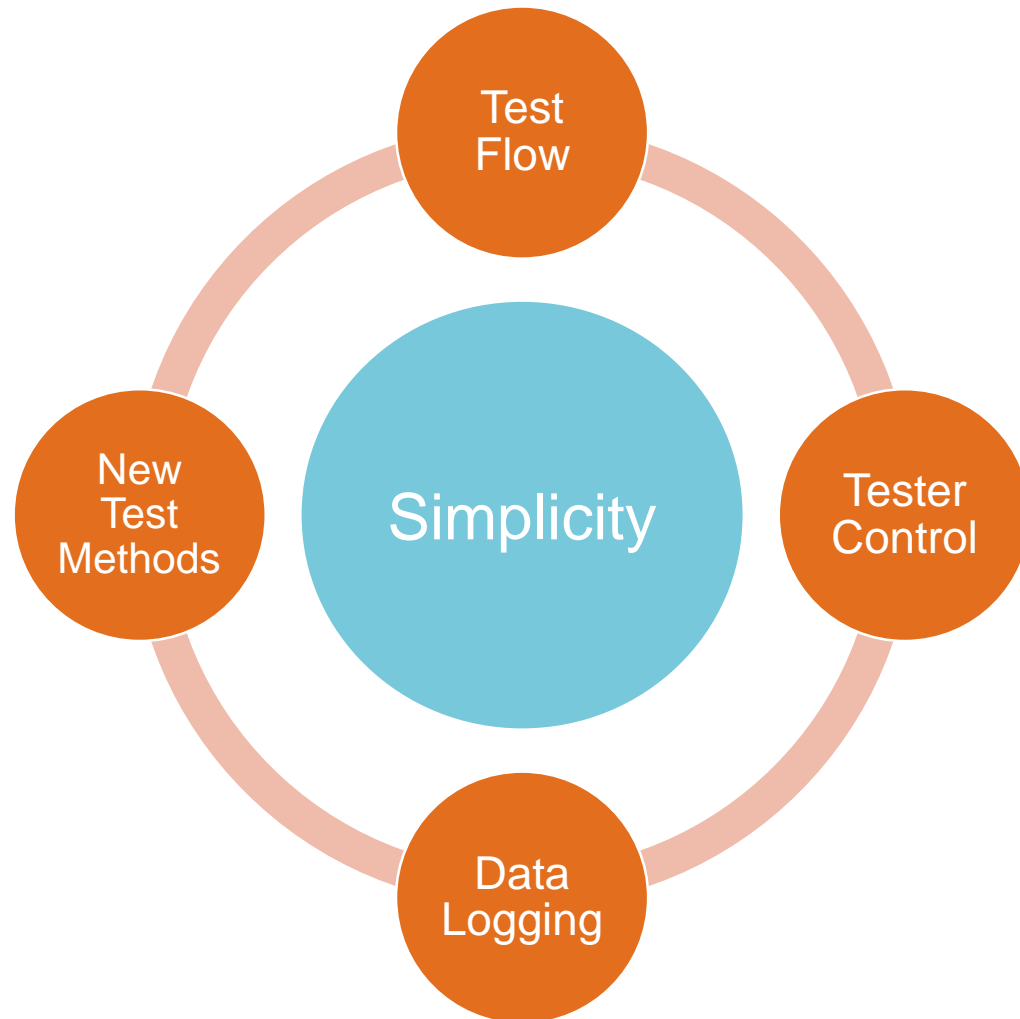


16 QAM	64 QAM	256 QAM	1024 QAM	4096QAM
-19 dB	-27 dB	-32 dB	-35 dB	-38 dB

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



Creating 11ax Test Flow for AP with

Configure RU allocation for HE-MU

	Name	Value	Type	Unit
1	TEST_CATEGORY	AP_TX_DL_OFDMA	String	
2	NUM_USERS	5	Integer	
3	PACKET_FORMAT	HE_MU	String	
4	BSS_BANDWIDTH	BW-80	String	MHz
5	CH_BANDWIDTH	CBW-80	String	MHz
6	BSS_FREQ_MHZ_PRIMARY	5520	Integer	MHz
7	CH_FREQ_MHZ	5520	Integer	MHz
8	NUM_USERS_PER_RU	1,0,0,0,0,0,1,0 0,0,0,0,1,0,0,0,0 ...	String	
9	RU_ALLOCATION_SIGNALING	RUx9 (00000000) 26-26-26-26-2...	String	

5 Users

- 3.INITIALIZE_DUT
- 4.CONNECT_IQ_TESTER
- 5.LOAD_PATH_LOSS_TABLE
- 6.TEST_VERIFY EVM POWER 5180 MCS11 HE_SU BW-20 ANT1
- 7.TEST_VERIFY EVM POWER 5600 MCS11 HE_SU BW-20 ANT1
- 8.TEST_VERIFY EVM POWER 5700 MCS11 HE_SU BW-20 ANT1
- 9.TEST_VERIFY PER 5180 MCS9 HE_SU BW-20 ANT1
- 10.TEST_VERIFY PER 5600 MCS9 HE_SU BW-20 ANT1
- 11.TEST_VERIFY PER 5700 MCS9 HE_SU BW-20 ANT1
- 12.TEST_VERIFY SENS 5180 MCS9 HE_SU BW-20 ANT1
- 13.TEST_VERIFY SENS 5600 MCS9 HE_SU BW-20 ANT1
- 14.TEST_VERIFY SENS 5700 MCS9 HE_SU BW-20 ANT1
- 15.TEST_BUILD 5520 HE_MU BW-80 ANT1 ANT2 ANT3 ANT4**
- 16.ADD_USER 1 MCS0 EVM MASK
- 17.ADD_USER 2 MCS0 EVM MASK
- 18.ADD_USER 3 MCS0 EVM MASK
- 19.ADD_USER 4 MCS0 EVM MASK
- 20.ADD_USER 5 MCS0 EVM MASK
- 21.TEST_RUN
- 22.TEST_BUILD 5520 HE_MU BW-40 ANT1 ANT2
- 23.ADD_USER 1 MCS0 PER
- 24.ADD_USER 2 MCS0 PER
- 25.ADD_USER 3 MCS0 PER
- 26.TEST_RUN
- 27.DISCONNECT_IQ_TESTER
- 28.REMOVE_DUT

WIFI 11AX

BSS_BANDWIDTH: BW-80

	1st 20MHz	2nd 20MHz	3rd 20MHz	4th 20MHz
RU_ALLOCATION_SIGNALING	RUx9 (00000000) 26-26-26-26-26-26-26-26	RUx9 (00000000) 2	RUx0 (*)	RUx9 (00000000) 26-26-26-26
NUM_USERS_PER_RU	1,0,0,0,0,0,1,0	0,0,0,0,1,0,0,0,0	0,0,0,0,0,0,0,1,0	0,0,1,0,0,0,0,0,0
STREAM_ALLOCATION				

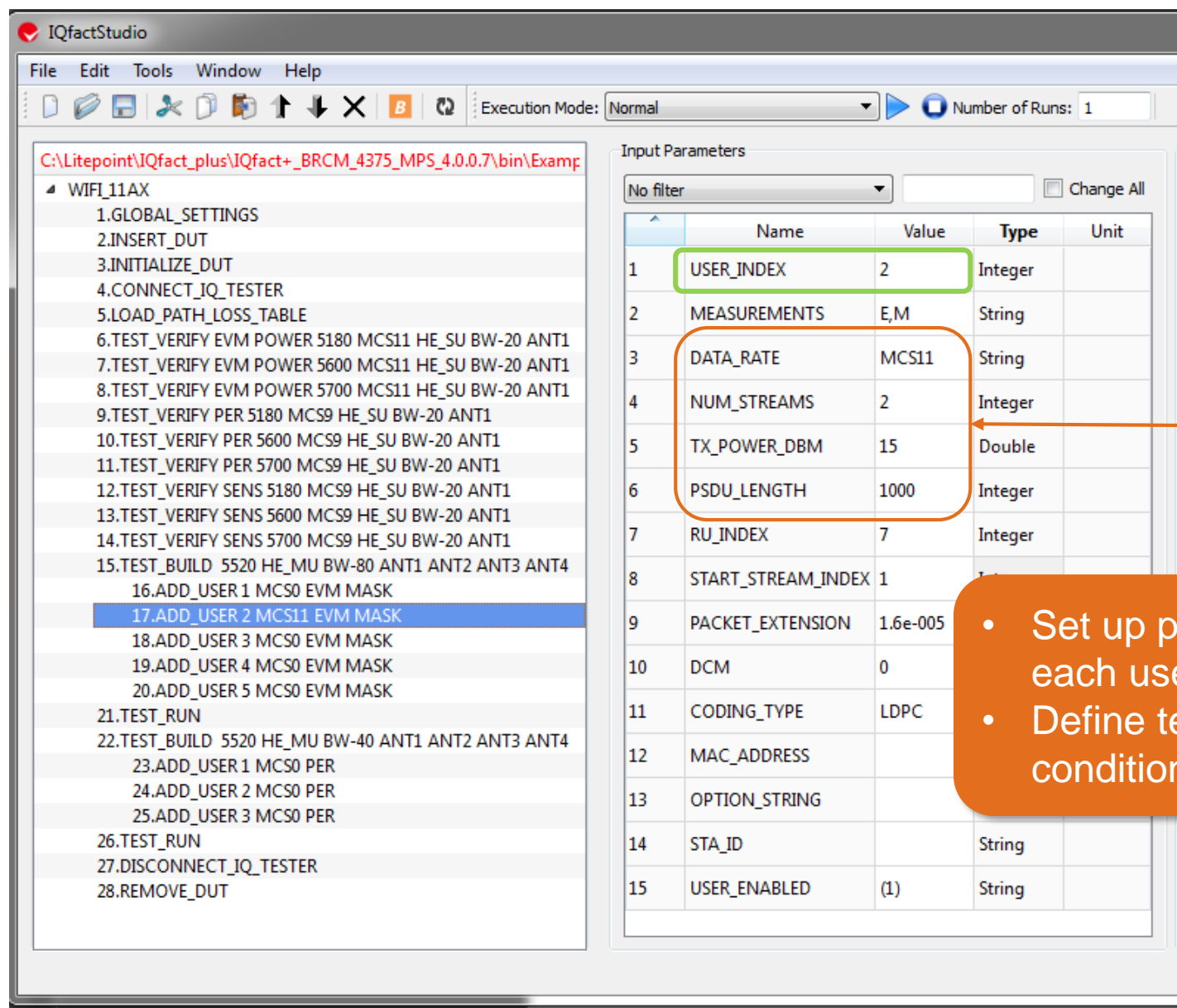
RU_ALLOCATION_SIGNALING: RUx9 (00000000) 26-26-26-26-26-26-26-26|RUx9 (00000000) 26-26-26-26-26-26-26-26|RUx0 (******) NA|RUx9 (00000000) 26-26-26-26-26-26-26-26|RUx9 (00000000) 26-26-26-26-26-26-26-26

NUM_USERS_PER_RU: 1,0,0,0,0,0,0,1,0|0,0,0,0,0,0,1,0|0,0,0,0,0,0,0,1,0|0,0,1,0,0,0,0,0,0|

STREAM_ALLOCATION: |||||

Apply

Creating 11ax Test Flow for AP with



Execution Mode: Normal Number of Runs: 1

C:\Litepoint\IQfact_plus\IQfact+_BRM_4375_MPS_4.0.0.7\bin\Examp

- WIFI_11AX
 - 1.GLOBAL_SETTINGS
 - 2.INSERT_DUT
 - 3.INITIALIZE_DUT
 - 4.CONNECT_IQ_TESTER
 - 5.LOAD_PATH_LOSS_TABLE
 - 6.TEST_VERIFY EVM POWER 5180 MCS11 HE_SU BW-20 ANT1
 - 7.TEST_VERIFY EVM POWER 5600 MCS11 HE_SU BW-20 ANT1
 - 8.TEST_VERIFY EVM POWER 5700 MCS11 HE_SU BW-20 ANT1
 - 9.TEST_VERIFY PER 5180 MCS9 HE_SU BW-20 ANT1
 - 10.TEST_VERIFY PER 5600 MCS9 HE_SU BW-20 ANT1
 - 11.TEST_VERIFY PER 5700 MCS9 HE_SU BW-20 ANT1
 - 12.TEST_VERIFY SENS 5180 MCS9 HE_SU BW-20 ANT1
 - 13.TEST_VERIFY SENS 5600 MCS9 HE_SU BW-20 ANT1
 - 14.TEST_VERIFY SENS 5700 MCS9 HE_SU BW-20 ANT1
 - 15.TEST_BUILD 5520 HE_MU BW-80 ANT1 ANT2 ANT3 ANT4
 - 16.ADD_USER 1 MCS0 EVM MASK
 - 17.ADD_USER 2 MCS11 EVM MASK
 - 18.ADD_USER 3 MCS0 EVM MASK
 - 19.ADD_USER 4 MCS0 EVM MASK
 - 20.ADD_USER 5 MCS0 EVM MASK
 - 21.TEST_RUN
 - 22.TEST_BUILD 5520 HE_MU BW-40 ANT1 ANT2 ANT3 ANT4
 - 23.ADD_USER 1 MCS0 PER
 - 24.ADD_USER 2 MCS0 PER
 - 25.ADD_USER 3 MCS0 PER
 - 26.TEST_RUN
 - 27.DISCONNECT_IQ_TESTER
 - 28.REMOVE_DUT

	Name	Value	Type	Unit
1	USER_INDEX	2	Integer	
2	MEASUREMENTS	E,M	String	
3	DATA_RATE	MCS11	String	
4	NUM_STREAMS	2	Integer	
5	TX_POWER_DBM	15	Double	
6	PSDU_LENGTH	1000	Integer	
7	RU_INDEX	7	Integer	
8	START_STREAM_INDEX	1	Integer	
9	PACKET_EXTENSION	1.6e-005	Double	
10	DCM	0	Integer	
11	CODING_TYPE	LDPC	String	
12	MAC_ADDRESS		String	
13	OPTION_STRING		String	
14	STA_ID		String	
15	USER_ENABLED	(1)	String	

Different for each RU / user

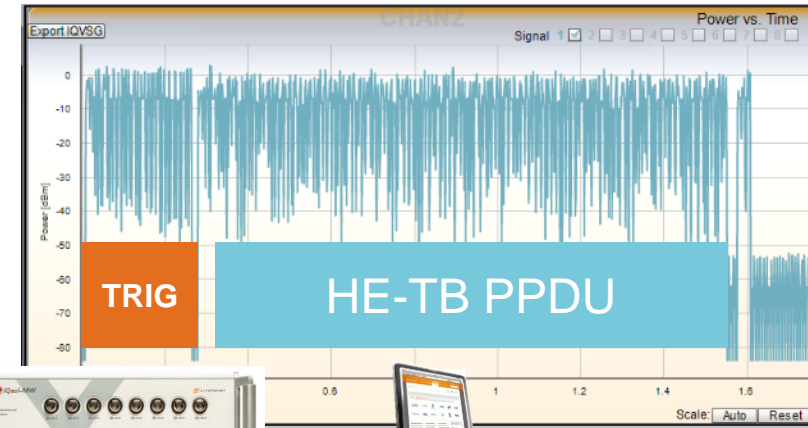
- Set up parameters for each user
- Define test types and conditions

IQfact+ Data Example: Trigger Based Testing

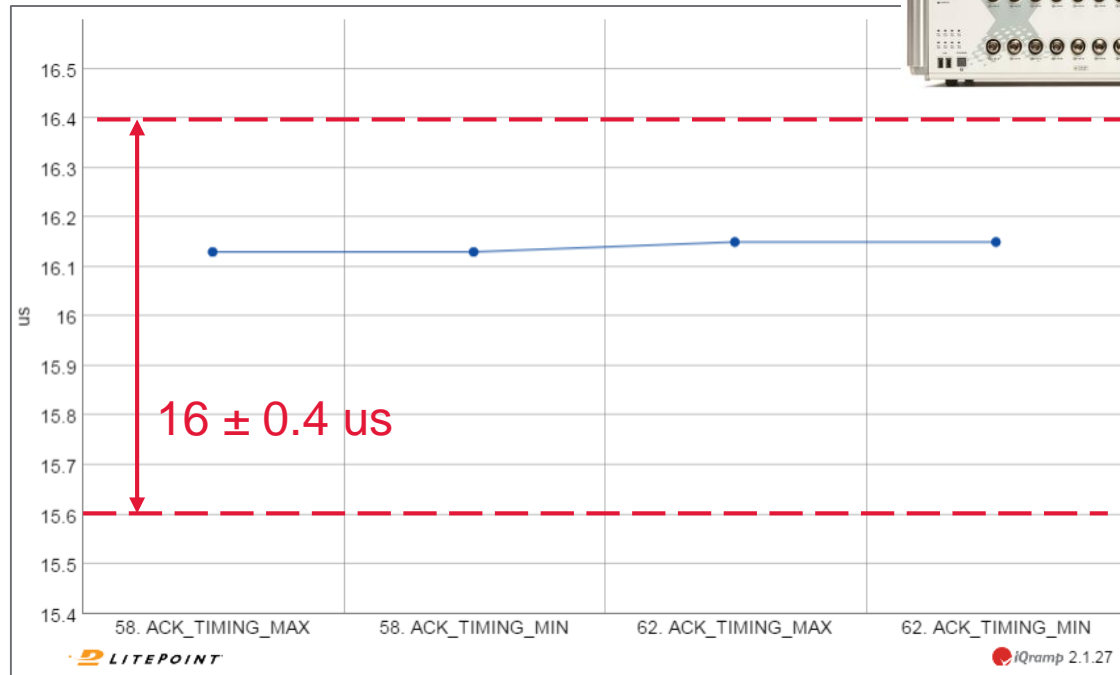


IQfact+ **automatically** handles precise timing control necessary for TBT

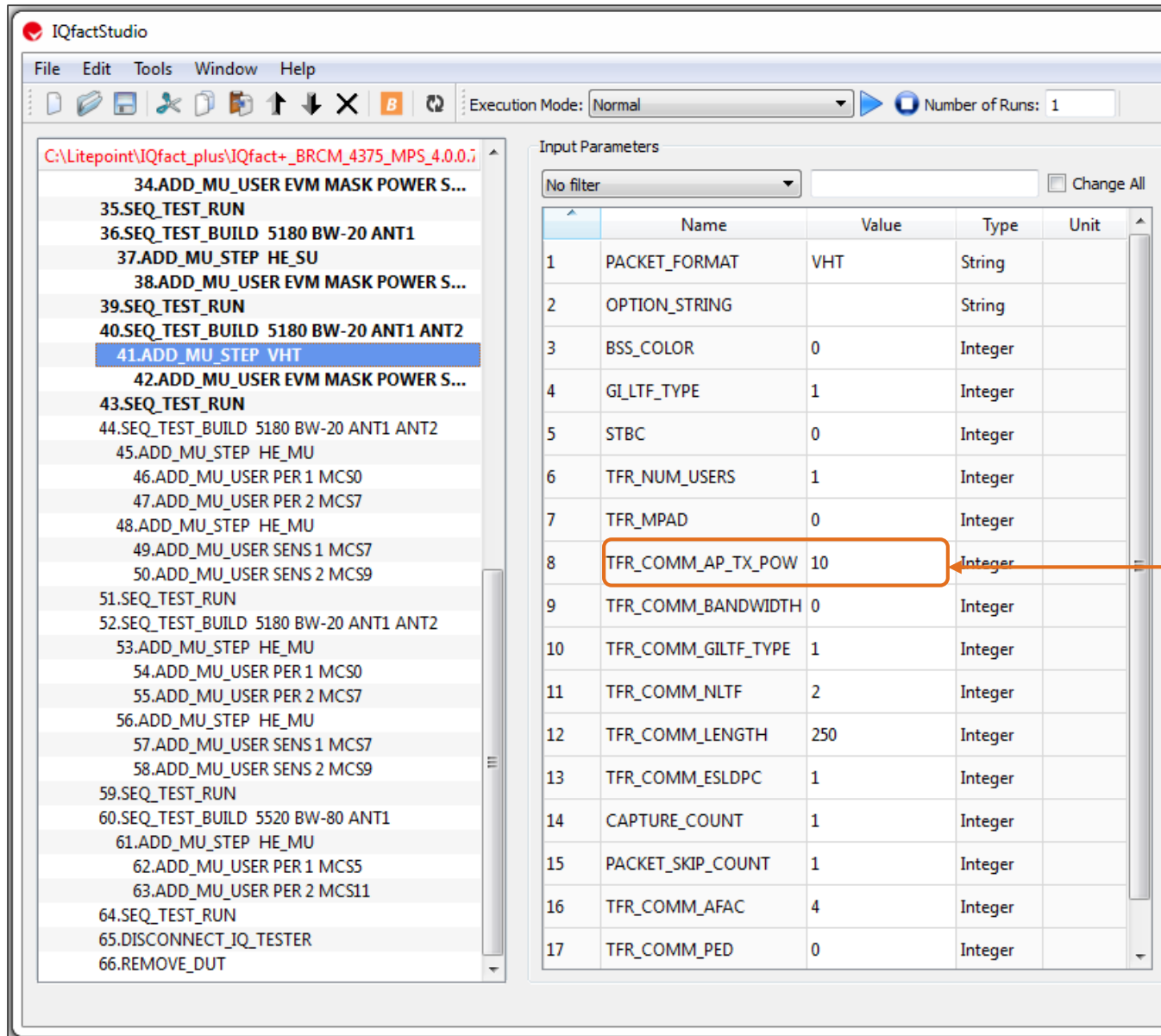
1. Tester VSG: Transmit a Trigger frame
2. Tester switches VSG to VSA
3. Tester VSA captures HE-TB from STA for analysis



TBT (Timing measurement)



Configuring Trigger Based Test with



The screenshot shows the IQfactStudio interface. On the left, a test sequence is listed, with step 41, '41.ADD_MU_STEP VHT', highlighted in blue. On the right, the 'Input Parameters' table is displayed. The table has columns for Name, Value, Type, and Unit. The parameter 'TFR_COMM_AP_TX_POW' is highlighted with an orange box, and an orange arrow points from this box to the text annotation on the right.

	Name	Value	Type	Unit
1	PACKET_FORMAT	VHT	String	
2	OPTION_STRING		String	
3	BSS_COLOR	0	Integer	
4	GI_LTF_TYPE	1	Integer	
5	STBC	0	Integer	
6	TFR_NUM_USERS	1	Integer	
7	TFR_MPAD	0	Integer	
8	TFR_COMM_AP_TX_POW	10	Integer	
9	TFR_COMM_BANDWIDTH	0	Integer	
10	TFR_COMM_GILTF_TYPE	1	Integer	
11	TFR_COMM_NLTF	2	Integer	
12	TFR_COMM_LENGTH	250	Integer	
13	TFR_COMM_ESLDPC	1	Integer	
14	CAPTURE_COUNT	1	Integer	
15	PACKET_SKIP_COUNT	1	Integer	
16	TFR_COMM_AFAC	4	Integer	
17	TFR_COMM_PED	0	Integer	

Sets AP Tx power
in Trigger frame
(dBm)

Configuring Trigger Based Test with IQfact+



IQfactStudio

File Edit Tools Window Help

Execution Mode: Normal Number of Runs: 1

C:\Litepoint\IQfact_plus\IQfact+_BRM_4375_MPS_4.0.0.7

34.ADD_MU_USER EVM MASK POWER S...
35.SEQ_TEST_RUN
36.SEQ_TEST_BUILD 5180 BW-20 ANT1
37.ADD_MU_STEP HE_SU
38.ADD_MU_USER EVM MASK POWER S...
39.SEQ_TEST_RUN
40.SEQ_TEST_BUILD 5180 BW-20 ANT1 ANT2
41.ADD_MU_STEP VHT
42.ADD_MU_USER EVM MASK POWER S...
43.SEQ_TEST_RUN
44.SEQ_TEST_BUILD 5180 BW-20 ANT1 ANT2
45.ADD_MU_STEP HE_MU
46.ADD_MU_USER PER 1 MCS0
47.ADD_MU_USER PER 2 MCS7
48.ADD_MU_STEP HE_MU
49.ADD_MU_USER SENS 1 MCS7
50.ADD_MU_USER SENS 2 MCS9
51.SEQ_TEST_RUN
52.SEQ_TEST_BUILD 5180 BW-20 ANT1 ANT2
53.ADD_MU_STEP HE_MU
54.ADD_MU_USER PER 1 MCS0
55.ADD_MU_USER PER 2 MCS7
56.ADD_MU_STEP HE_MU
57.ADD_MU_USER SENS 1 MCS7
58.ADD_MU_USER SENS 2 MCS9
59.SEQ_TEST_RUN
60.SEQ_TEST_BUILD 5520 BW-80 ANT1
61.ADD_MU_STEP HE_MU
62.ADD_MU_USER PER 1 MCS5
63.ADD_MU_USER PER 2 MCS11
64.SEQ_TEST_RUN
65.DISCONNECT_IQ_TESTER
66.REMOVE_DUT

Input Parameters

No filter Change All

	Name	Value	Type	Unit
1	USER_INDEX	1	Integer	
2	MEASUREMENTS	E,M,P,S	String	
3	DATA_RATE	MCS6	String	
4	NUM_STREAMS	1	Integer	
5	TX_POWER_DBM	0	Double	
6	RX_POWER_DBM	-65	Double	
7	RU_INDEX	2	Integer	
8	START_STREAM_INDEX	1	Integer	
9	SYM_CLOCK_ERROR	0	Integer	
10	TIMING_ERROR	1	Integer	
11	USER_ENABLED	(1)	String	
12	CFO_ERROR	1	Integer	
13	PACKET_EXTENSION	1.6e-005	Double	
14	DCM	0	Integer	
15	CODING_TYPE	BCC	String	
16	MAC_ADDRESS	000000C0FFEE	String	
17	STA_ID	001	String	

Sets target Rx signal power in Trigger frame (dBm)

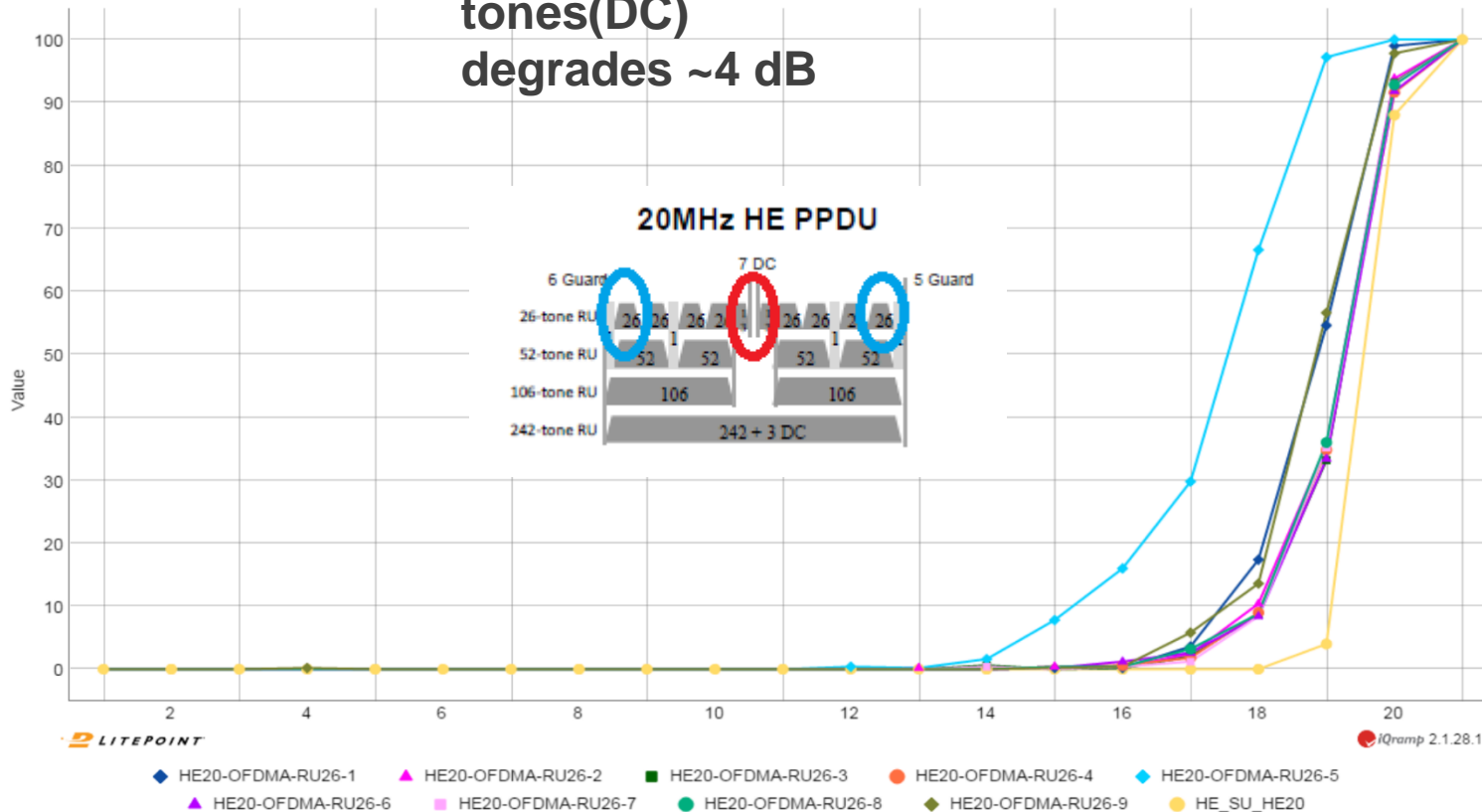
DL-OFDMA for STA receiver sensitivity testing

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

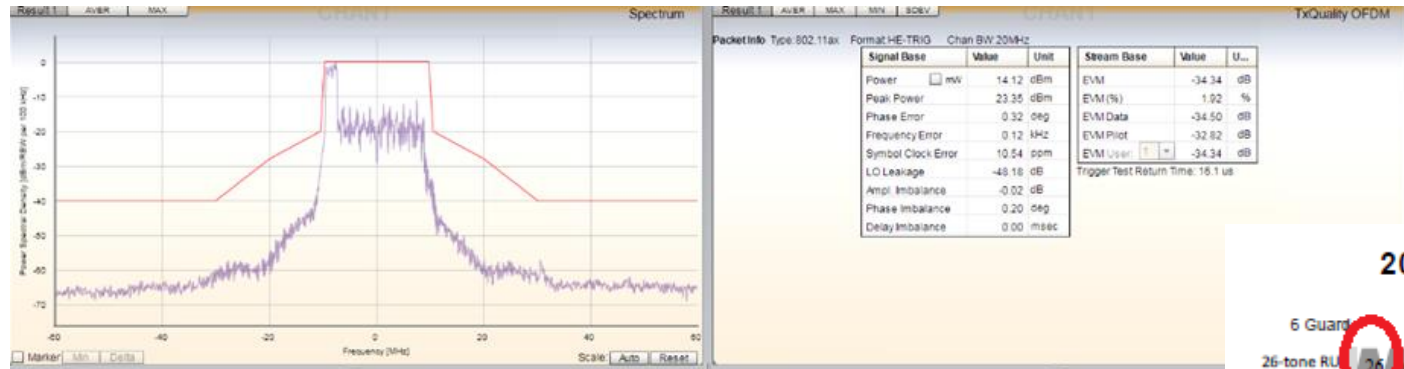
Sensitivity at central RU26 tones(DC) degrades ~4 dB

Other RU26 degrades ~1 dB.

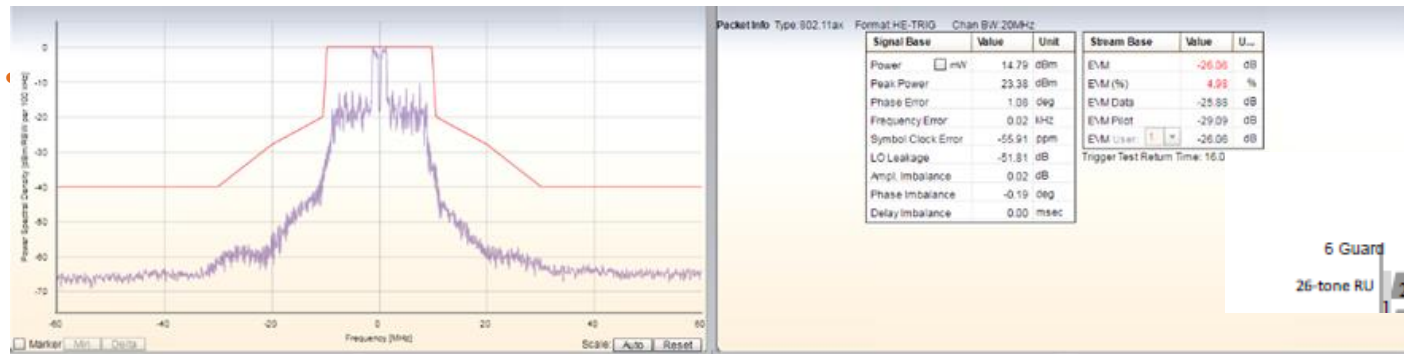


TX UL-OFDMA for STA EVM

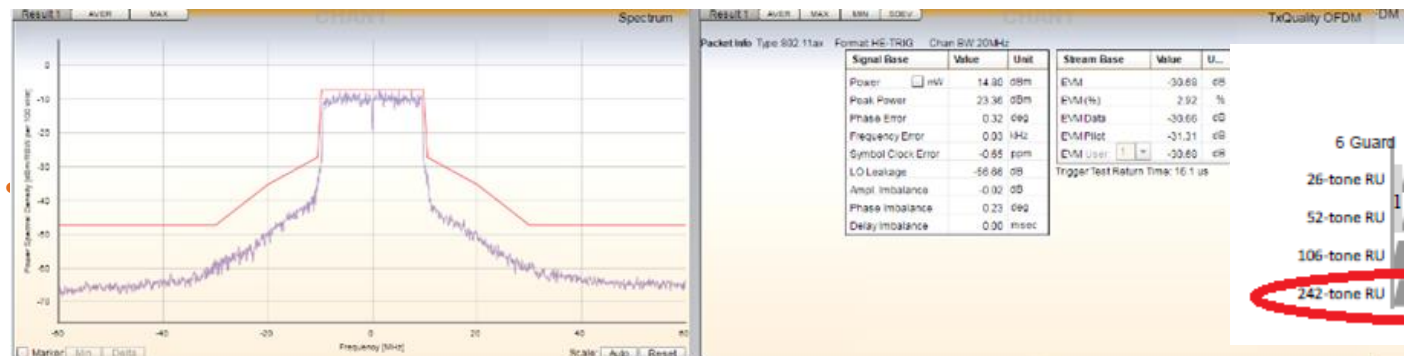
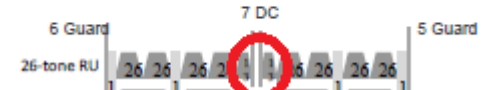
- EVM -34.34dB, power 14.12dBm



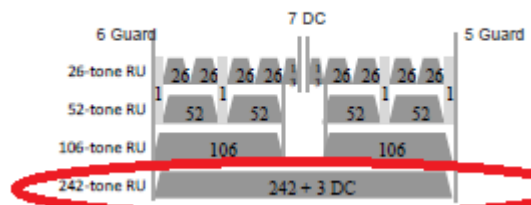
20MHz HE PPDU



20MHz HE PPDU



20MHz HE PPDU

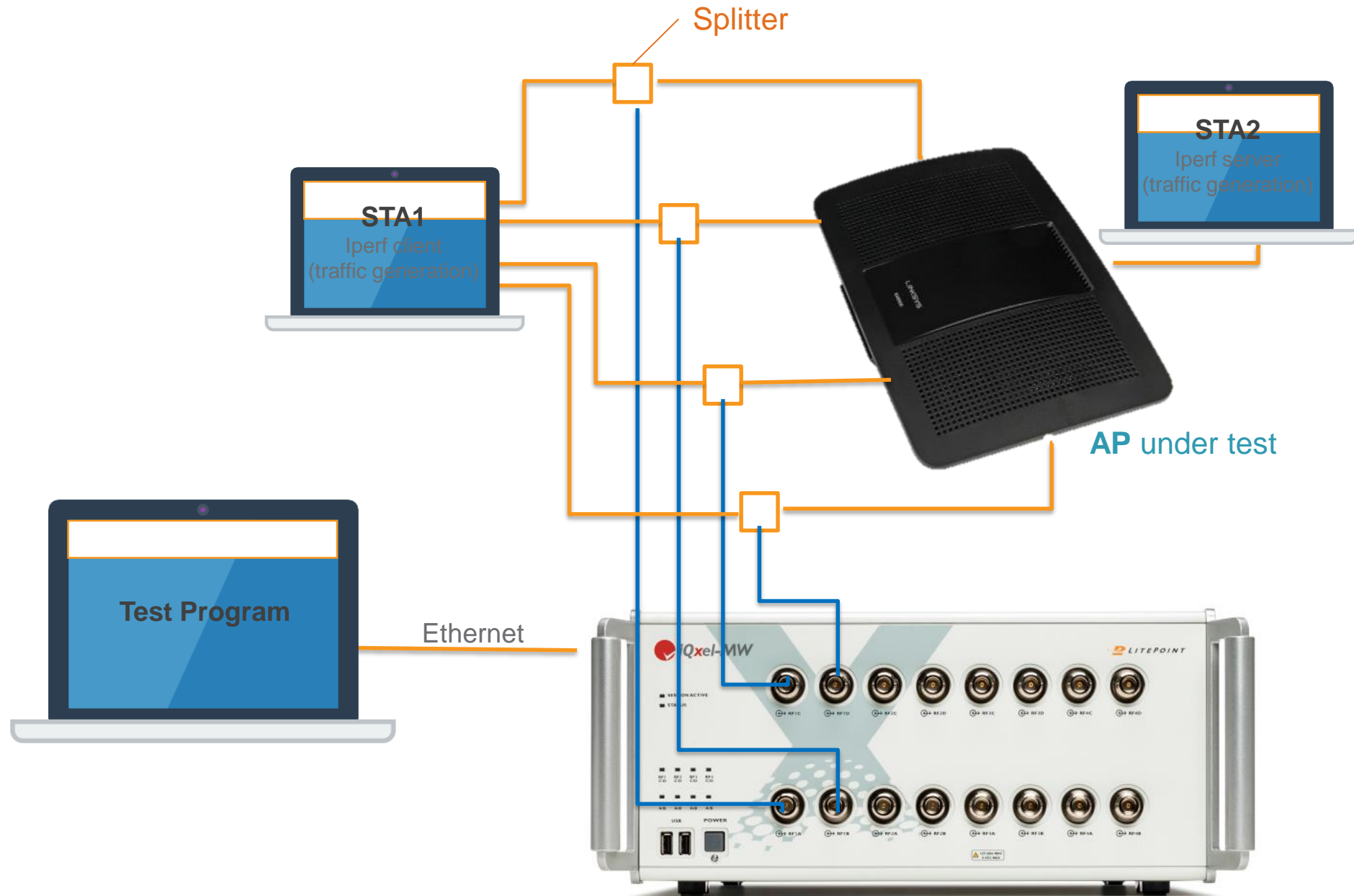


IQsniffer – WiFi PHY Traffic Analysis Simplified

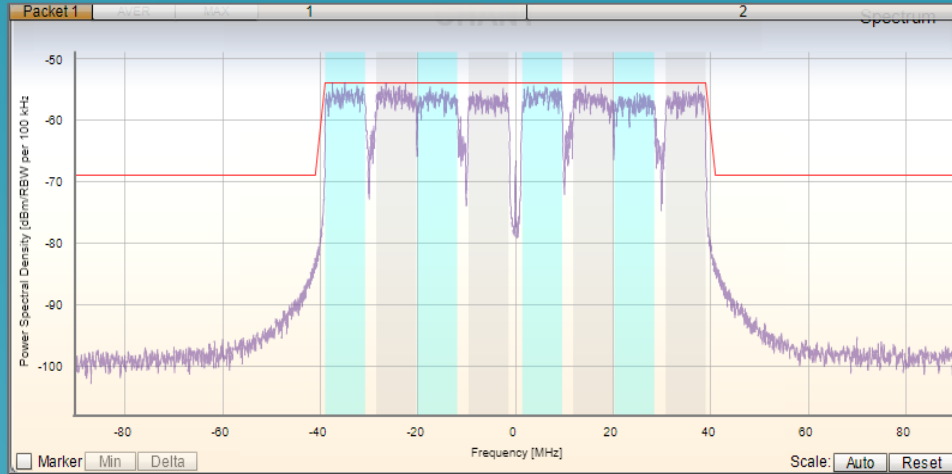


- IQsniffer is useful for **product characterization** and **Pre-correction test**
- **Key Features:**
 - **PHY layer analysis:** Uncovers timing information and behavior not visible at MAC layer
Parametric measurements(EVM, Power, Spectrum, etc.)
Timing information
PPDU information: packet format, coding,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

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



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

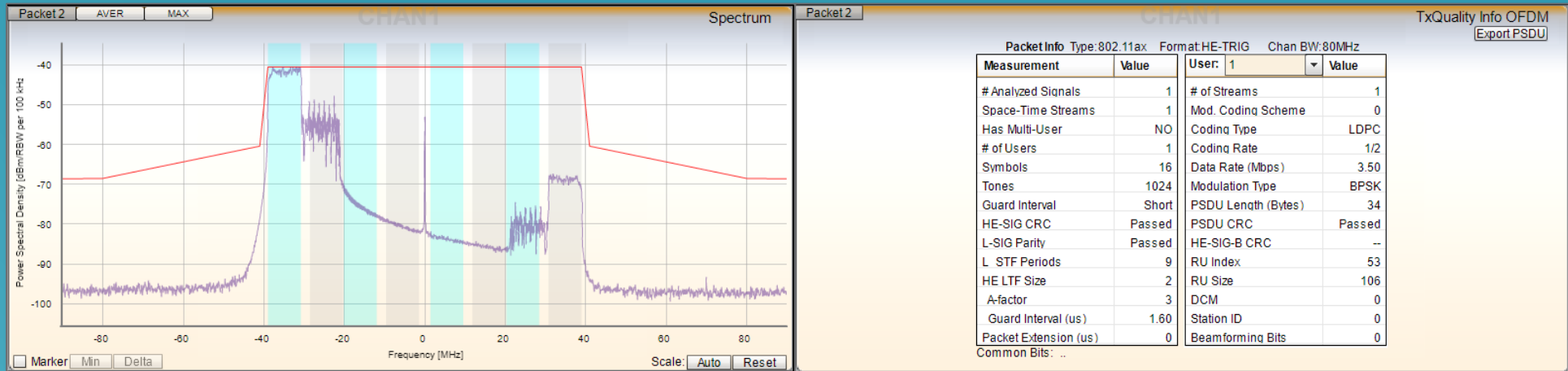
TxQuality Info OFDM

Export PSDU

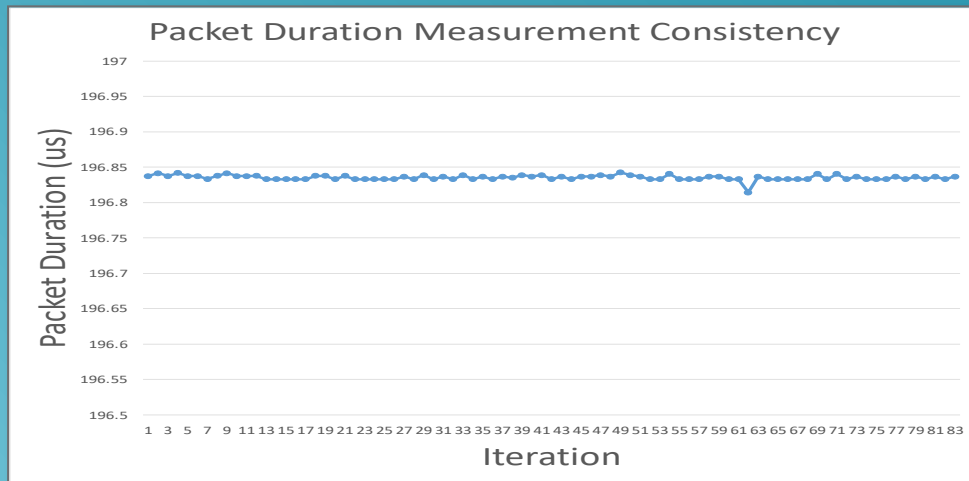
Packet Info Type: 802.11ax Format: HE-MU Chan BW: 80MHz

Measurement	Value	User: 1	Value
# Analyzed Signals	1	# of Streams	1
Space-Time Streams	1	Mod. Coding Scheme	0
Has Multi-User	Yes	Coding Type	LDPC
# of Users	8	Coding Rate	1/2
Symbols	7	Data Rate (Mbps)	3.80
Tones	1024	Modulation Type	BPSK
Guard Interval	Long	PSDU Length (Bytes)	38
HE-SIG CRC	Passed	PSDU CRC	Passed
L-SIG Parity	Passed	HE-SIG-B CRC	Passed
L STF Periods	10	RU Index	1
HE LTF Size	2	RU Size	106
A-factor	3	DCM	0
Guard Interval (us)	0.80	Station ID	53
Packet Extension (us)	0	Beamforming Bits	0

Using IQsniffer: PHY Parameters for 802.11ax HE-TRIG



IQsniffer Packet Duration Measurement



IQsniffer SIFS Measurement

