HWG | HARRIS, WILTSHIRE & GRANNIS LLP

January 25, 2016

**Ex Parte**

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

*Re: Office of Engineering and Technology and Wireless Telecommunications Bureau Seek Information on Current Trends In LTE-U and LAA Technology, ET Docket No. 15-105; Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, ET Docket No. 13-49*

Dear Ms. Dortch:

On January 21, 2016, Christopher Szymanski, Director of International Government Relations at Broadcom Corporation, Gary Wong of Broadcom, and I met with Julius Knapp, Chief of the Office of Engineering and Technology, and Bruce Romano, Mark Settle, Karen Rackley, and Aole Wilkins of OET regarding the above-referenced proceedings.

During these meetings, Broadcom discussed the topics set forth in the attached presentations. Pursuant to the Commission's rules, a copy of this notice is being filed electronically in the above-referenced dockets. If you require any additional information please contact the undersigned.

Sincerely,

*/s/ Paul Margie*

Paul Margie
*Counsel to Broadcom Corporation*

Enc.

cc: meeting participants

# FCC UNII-3 OOBE LIMIT
# BROADCOM PROPOSAL

Jan 21, 2016

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# INTRODUCTION

- **April 10, 2013, the Commission published the 13-49 NPRM that among other things substantially tightening out of band emissions (OOBE) into TDWR (5600-5650) and other radar installations**
- **Broadcom, like the rest of the entire industry, would be significantly negatively impacted by the contemplated emissions mask**
  - 802.11ac chips designed for integration into retail routers for home and enterprise will be most negatively impacted
- **November 4, a coalition of entities circulated a proposal for an adjusted mask--this proposal <u>does not</u> represent industry consensus for all use cases because it does not represent the views of the retail router segment**
- **Retail routers have a much smaller likelihood in creating harmful interference into TDWR and other radar installations, than those uses supporting the Ubiquity Modified Proposal**
- **Without an adjustment to account for retail routers, this proposal would not meet the goals specified by the Commission in the December 2015 Waiver Order for the retail router industry**
  - *"To facilitate the transition to the new technical requirements without unduly impairing the availability of U-NII devices, creating unnecessary costs for such devices, or imposing undue burdens on manufacturers…"*

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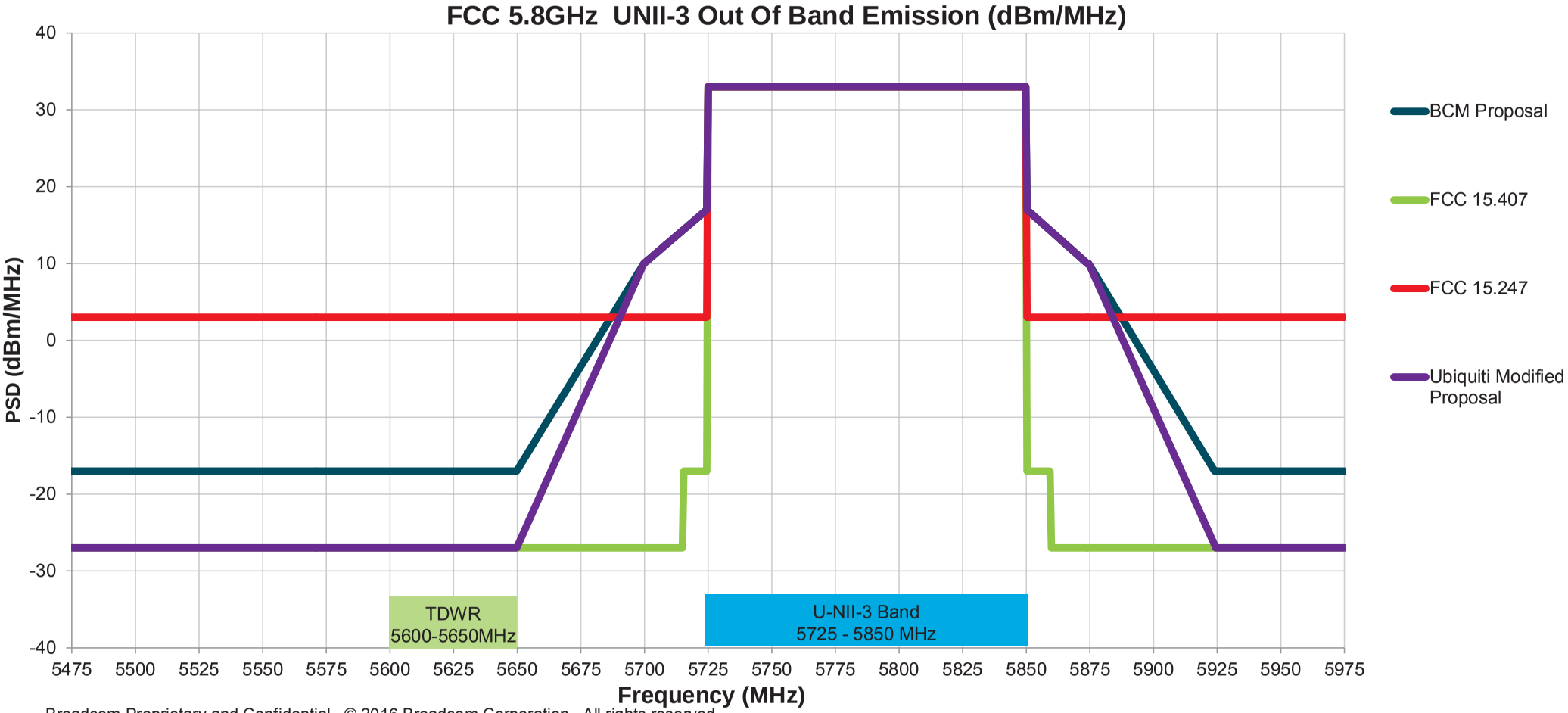
# PROPOSED -17DBM UNII-3 BAND OOBE LIMIT ADJUSTMENT FOR MAXIMUM 36DBM EIRP TRANSMISSIONS

- **Broadcom proposes adjusting the proposal as shown for typical enterprise and retail use**

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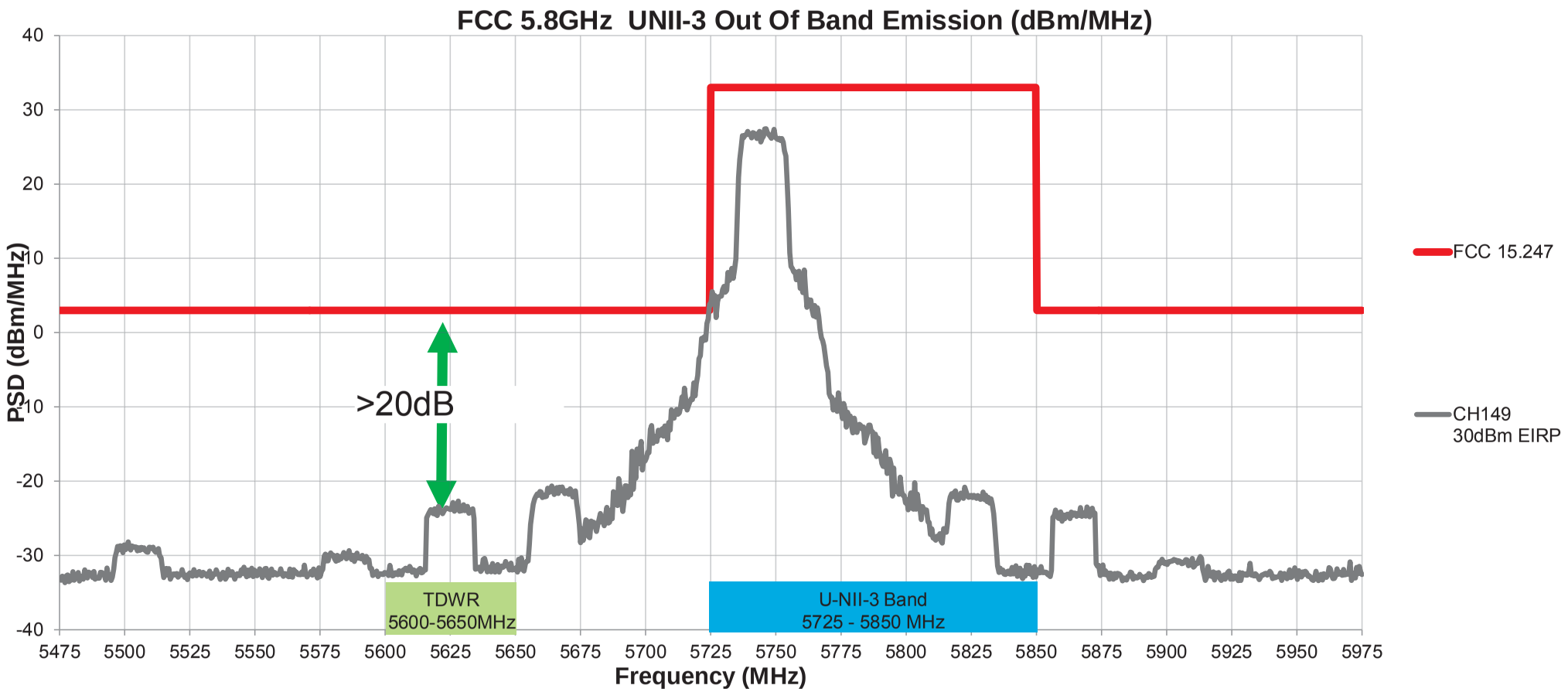
# SIGNIFICANT MARGIN WHEN CHIP WAS DESIGNED

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# DIFFERENCES IN USE CASES

- **Broadcom 802.11ac chips are used broadly in retail routers for home and office, as well as for enterprise use**
- **These routers are predominantly used indoors, or if outdoors, near buildings or other areas of clutter**
  - For enterprise use, they typically have antenna gain at or below 13 dBi
  - For home and small office use, the antenna gain is typically below 6 dBi
- **Last mile access contemplated by the joint petitioners can have antenna gains of up to 30 dBi**
- **Indoor routers must be ~62 times closer, and outdoor routers must be 5 times closer to a radar installation operating in the TDWR band in order to have equivalent impact**

| Use Case | Antenna Gain | Range to TDWR Interference | Path Loss |
|---|---|---|---|
| WISP Outdoor/Lamp Post | 27 dBi | X Distance | Free Space |
| Enterprise Routers (Outdoor) | 13 dBi | .2X Distance | Free Space |
| Retail Routers (Indoor) | 6 dBi | .016X Distance | Free Space, 15 dB Building Loss |

- **This does not even take into account antenna height, antenna direction, and the likely clutter surrounding such retail/enterprise routers**

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# NO EVIDENCE OF HARMFUL INTERFERENCE CASES INTO TDWR BAND DUE TO OOBE/ADJACENT CHANNELS

- **The FCC has found that more stringent emissions requirements for OOBE and adjacent channel operations next to TDWR were not required**
  - *"We have not seen evidence in the harmful interference cases that we have investigated that problems are being caused by unwanted emissions from properly certified and properly functioning equipment."*
  - The Commission went on to say, *"… unwanted emissions from properly certified and properly functioning equipment would be overly restrictive and would not provide any long-term interference mitigation, that no harmful interference cases appear to be caused by adjacent channel operations."*

**REF:**

- TR-12-486
- R&O 14-30

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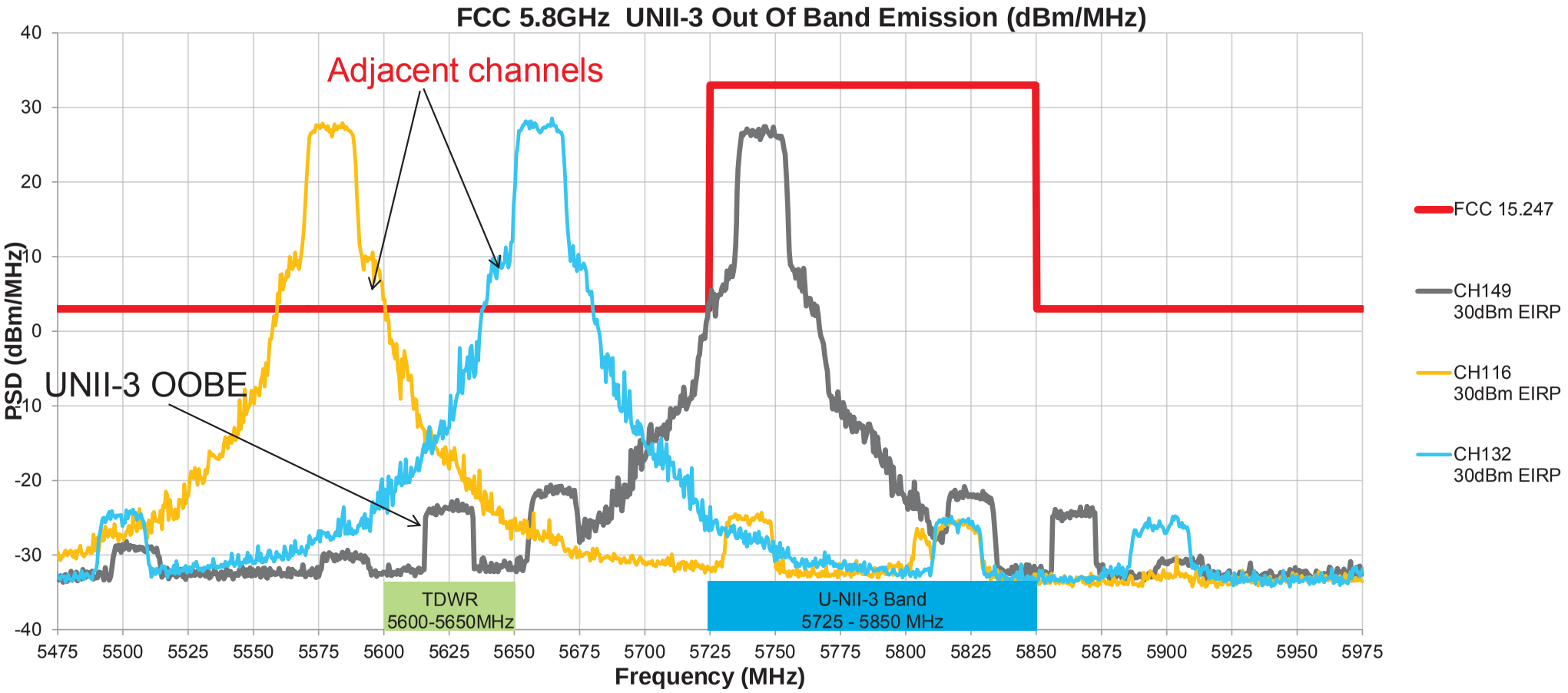
# OUT OF BAND (UNII-3) VS IN BAND (UNII-2C)

**UNII-3 OOBE in compliance with Old 15.247 limit vs UNII-2C in-band adjacent channels**

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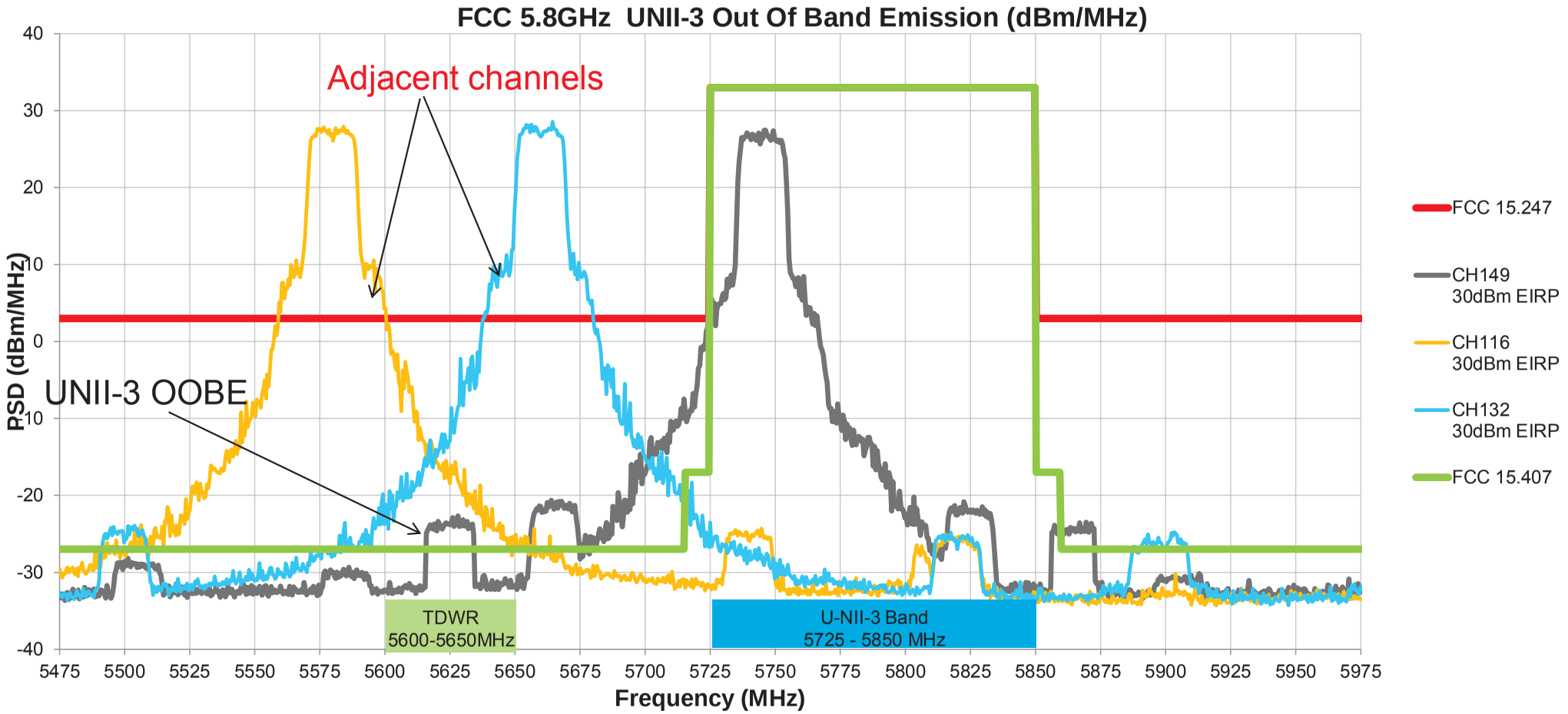
# OUT OF BAND (UNII-3) VS IN BAND (UNII-2C)

**UNII-3 OOBE and UNII-2C in-band adjacent channels vs 15.407 limit**

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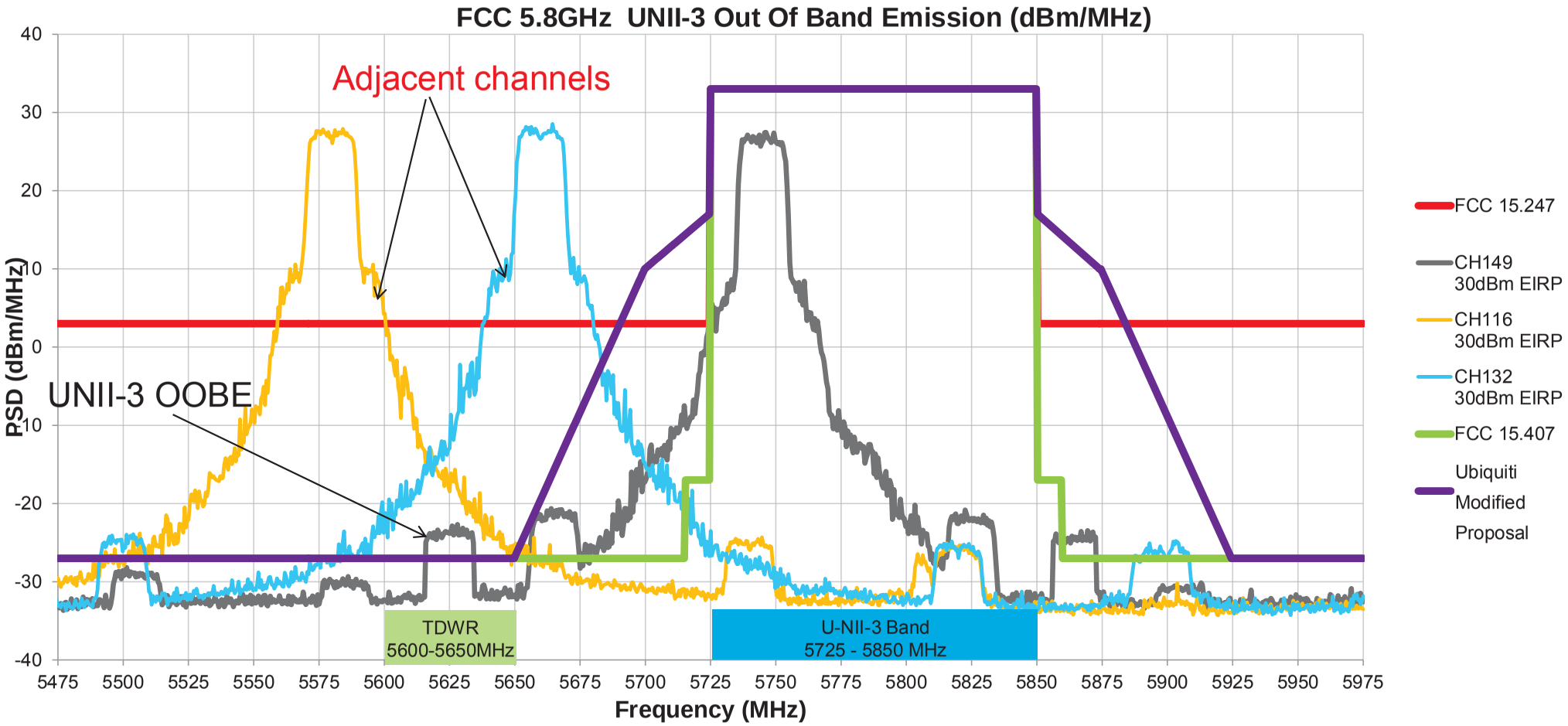
# OUT OF BAND (UNII-3) VS IN BAND (UNII-2C)

**UNII-3 OOBE and UNII-2C in-band adjacent channels vs 15.407 and Ubiquiti modified proposed limit**

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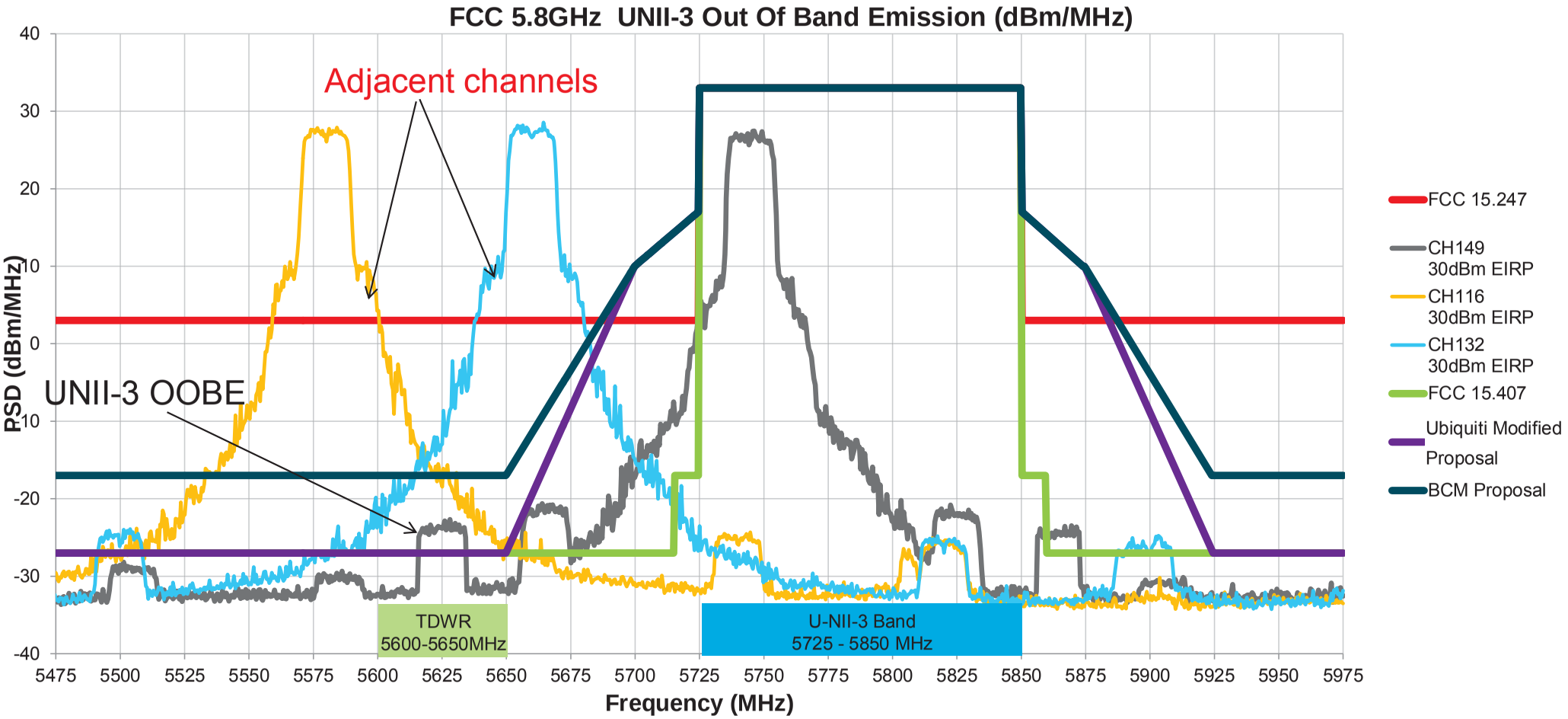
# OUT OF BAND (UNII-3) VS IN BAND (UNII-2C)

**Proposed UNII-3 OOBE limit by Broadcom is still up to 27dB lower in interference than the adjacent channel emissions**

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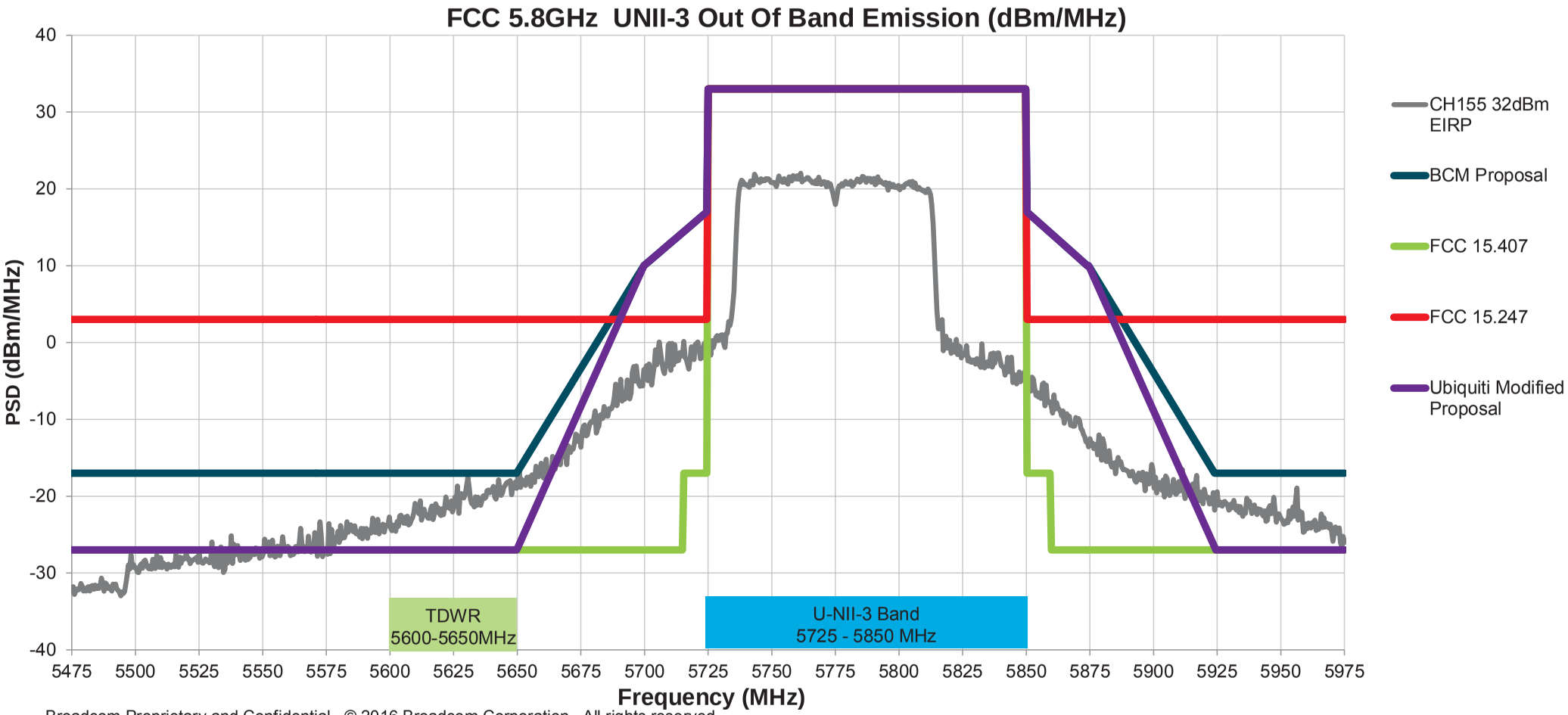
# BROADCOM PROPOSAL FOR 80MHZ CHANNEL (UNII-3)

**Broadcom proposed OOBE Mask would also protect the typical 80MHz router transmission**

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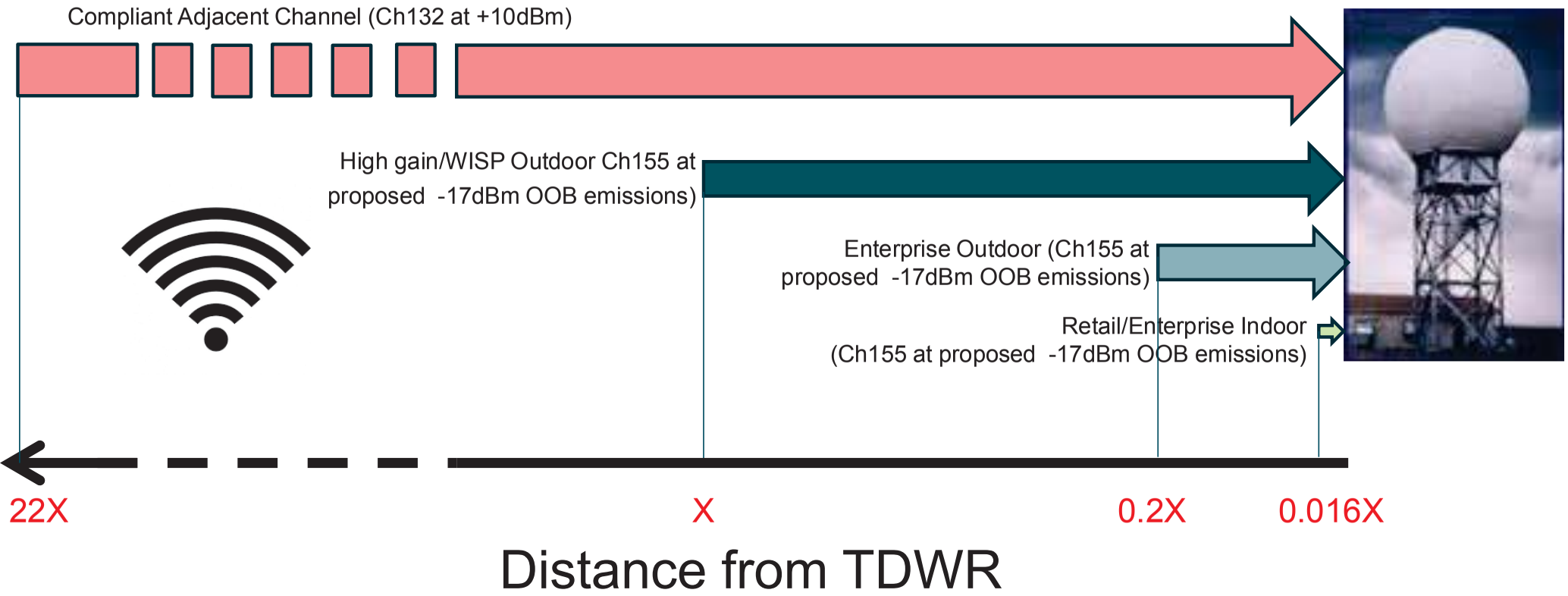
# TDWR INTERFERENCE FOR TYPICAL USE CASES (MAINBEAM COUPLING)




Distance from TDWR

*Distance = Inv* $\log_{10}((EIRP_{max} + 119dBm/MHz + 50dBi - 32.5 - 20\ Log_{10}(5650)/20))$
**15dB factored for indoor attenuation*

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# CONCLUSION

- **Broadcom proposed UNII-3 OOBE limit of -17dBm/MHz**
  - 3 order of magnitude (1000 time less) lower risk of interference than adjacent channel emissions
  - 5x lower risk of interference for typical outdoor enterprise routers than last mile access
  - 62x lower risk of interference for typical indoor retail routers than last mile access
- **Would meet the commissions goal of "*facilitat[ing] the transition to the new technical requirements without unduly impairing the availability of U-NII devices, creating unnecessary costs for such devices, or imposing undue burdens on manufacturers*"**

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# UNLICENSED LTE & WI-FI COEXISTENCE

## January 2016

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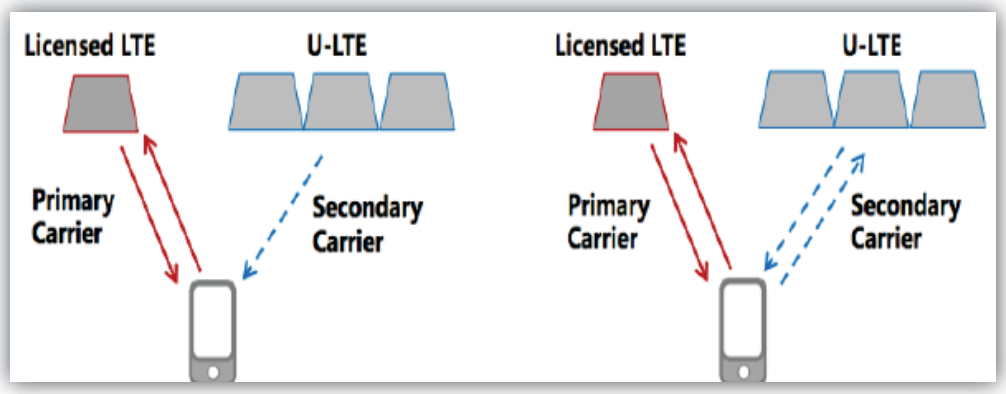
# LTE-U & LAA




LTE-U & LAA are envisioned to complement existing LTE networks with carriers in unlicensed band (5 GHz)

- LTE-U: Pre standard version developed by LTE-U Forum
- LAA: Version nearing standards completion in 3GPP Release 13

Release 13 is for downlink traffic only on LAA carriers, but release 14 will encompass uplink

Primarily best effort data and streaming video to be serviced by the unlicensed band

- QoS sensitive applications such as two way video and voice continue to use licensed band

Primarily restricted to small-cell usage models

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# UNLICENSED LTE (LTE-U AND LAA) COEXISTENCE WITH WI-FI

- **Broadcom believes**
  - LTE-U using only baseline LTE-U Forum specification for coexistence (e.g., duty cycle) cannot adequately coexist with Wi-Fi and creates overall system harm
  - LAA minimum coexistence as currently contemplated by RAN1 is far superior to LTE-U, but still harms Wi-Fi
  - Device makers will likely need to introduce advanced coexistence mechanisms on top of LTE-U/LAA specifications to guarantee better protection for Wi-Fi (e.g., using Wi-Fi MAC for media access)
- **Multicarrier impact also remains a significant concern**

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# LTE-U IMPACT ON WI-FI AT REALISTIC SIGNAL AND INTERFERENCE LEVELS

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# MOTIVATION FOR TEST

## KEY FACT: A significant % of WiFi traffic is received at signals below -62 dBm

- **90% of Wi-Fi communications are at signals weaker than -62 dBm and operation data samples from major deployments demonstrate that ~50% of Wi-Fi communications are below -80 dBm**
- **Both downlink and uplink Wi-Fi traffic are degraded**

## TEST SET-UP (BCM4366 4x4 Wi-Fi and LTE + Wi-Fi Small-Cell platform)

- **Interference impact on median signal strength (-80 dBm) Wi-Fi throughput (20 MHz)**
  - 20MHz chosen for simplicity. 80MHz deployments of Wi-Fi 11ac are more common and will be included in future results to highlight implications of Multi-channel operation and coexistence with LAA
- **LTE-U interference variation**
  - Duty cycles of 10%, 50%, and 90% (ON period of 20 ms, varying OFF period)
  - Interferer signal strengths demonstrated at -60 dBm, -65 dBm, -75 dBm, and -90 dBm
- **Observe drop in Wi-Fi throughput for LTE-U interference vs.**
  - Baseline (no interference)
  - Wi-Fi interferer

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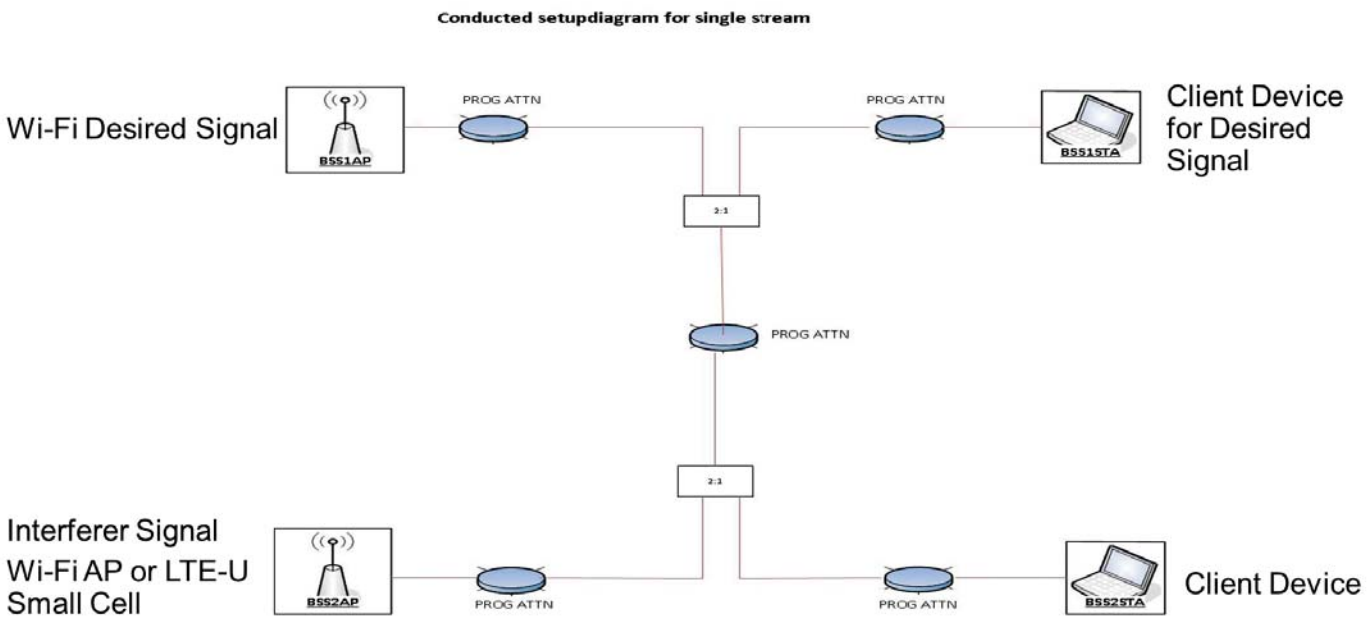
# SET-UP WITH CABLE CONNECTION

- Simple coexistence test with cable connections, RF isolation boxes, and RF attenuators for precise interference control and measurements
- Tests involves only a single Wi-Fi reference access point + client, and single interferer – most basic scenario for coexistence

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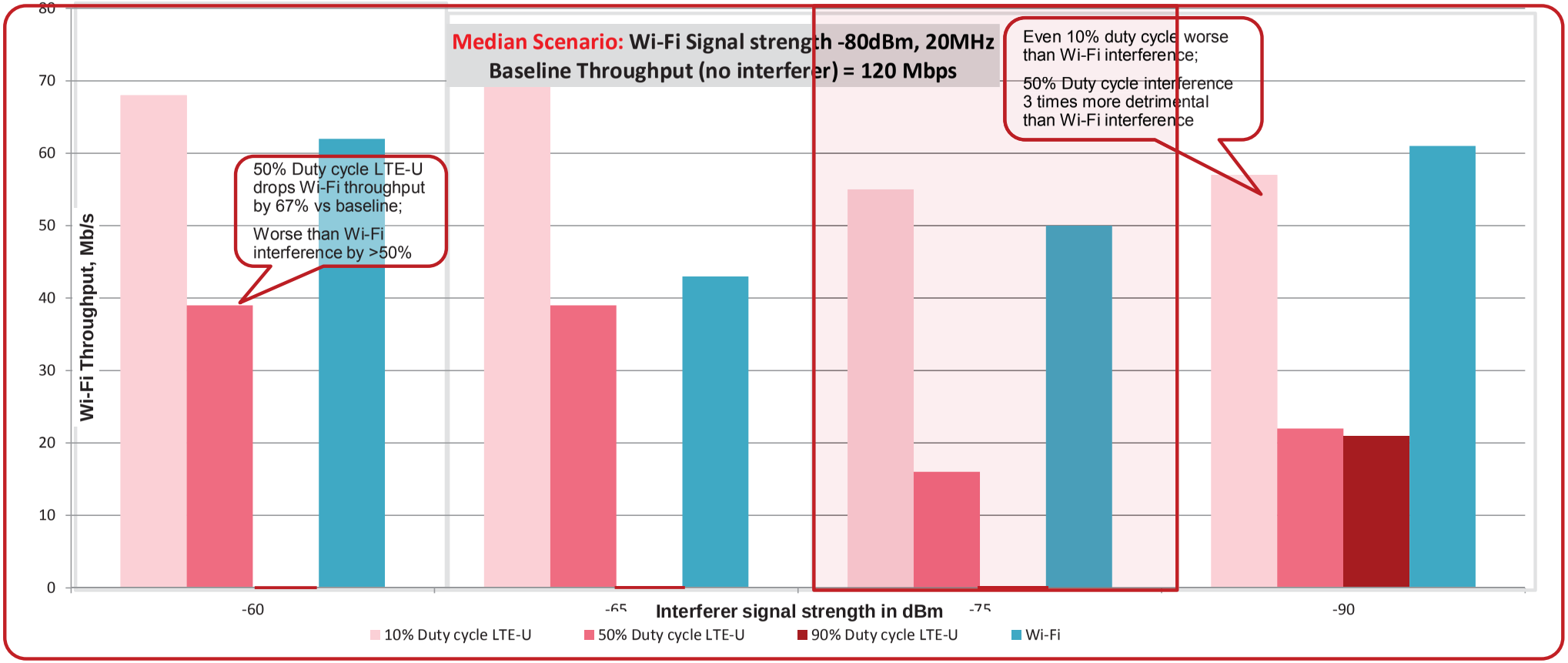
# LTE-U HAS DETRIMENTAL IMPACT ON WI-FI SPEEDS




For median Wi-Fi signal strength, LTE-U has detrimental impact on Wi-Fi performance, even at low duty cycles

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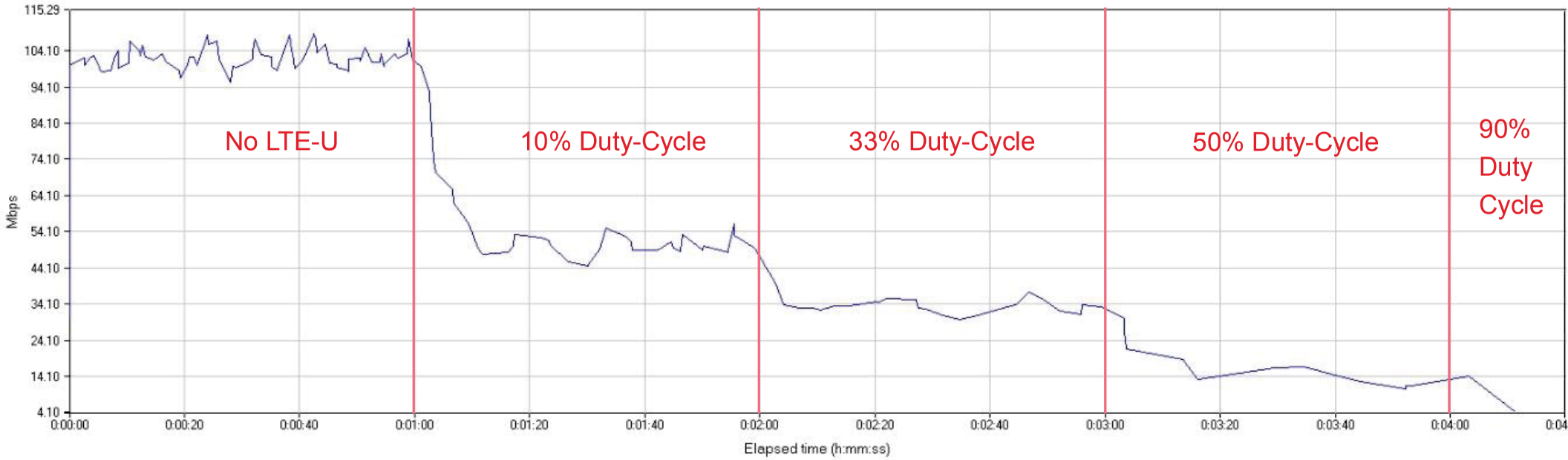
# LTE-U DUTY CYCLE INCREASE DESTROYS WI-FI CONNECTIVITY




- Wi-Fi AP-STA RSSI ~ -80dBm
- LTE-U interference ~ -75dBm

LTE-U CSAT can gradually increase the duty-cycle when it cannot detect Wi-Fi (below the Energy Detect threshold). Thus, nearby Wi-Fi devices can lose all network connectivity!

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# LAA COEXISTENCE

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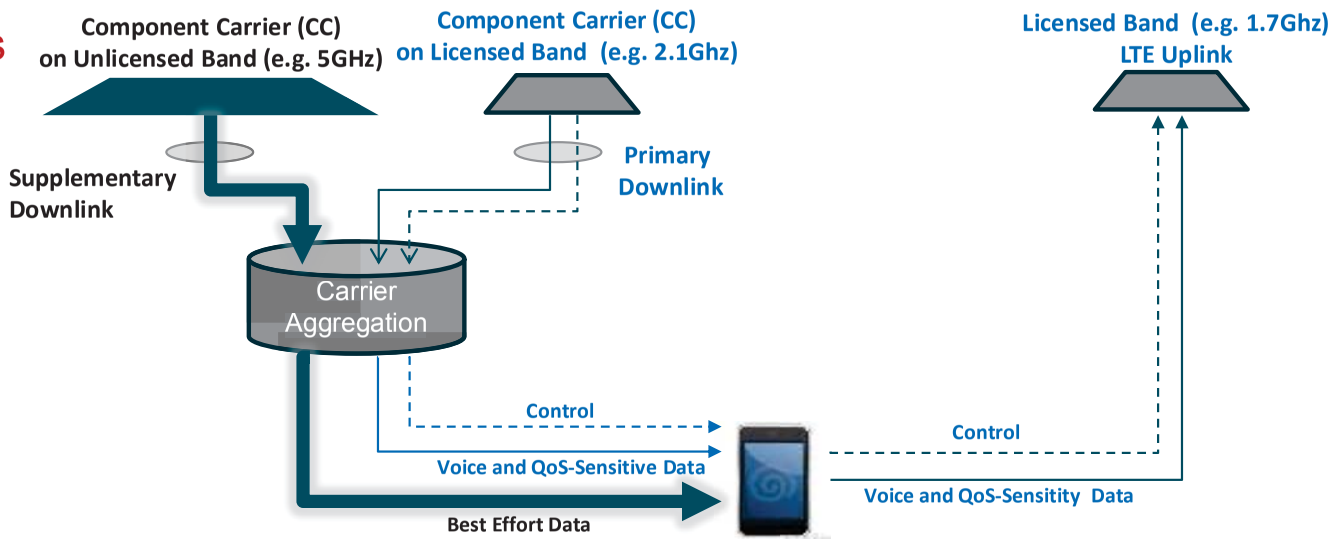
# LAA COEXISTENCE IS IMPORTANT PER 3GPP

- **LAA is 3GPP endorsed version of LTE operation in the unlicensed spectrum**
- **It is built on top of:**
  - Carrier Aggregation (CA) of Licensed carrier and Unlicensed carrier(s), and
  - Supposed to ensure fair coexistence between unlicensed LTE carrier with WiFi

"Fair coexistence between LTE and other technologies such as Wi-Fi as well as between LTE operators is seen necessary."

"However, it is not enough to minimize interference simply for regulatory aspects. It is also essential to insure that a deployed system will operate as a 'good neighbor', and not significantly impact legacy systems."

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# DESIGN MANDATE FOR ROBUST COEXISTENCE: AS FAIR AS WI-FI

Broadcom suggested standardization of at least a three-pronged approach to healthy coexistence among broadband unlicensed technologies in a 20 MHz signal bandwidth:

DONE

- **Let other data transmissions and handshake mechanisms complete before transmitting; be adaptive to current occupants**
  - Solution: LTE-U/LAA should deliberately wait for a nominally acceptable time before transmissions
  - Possible Technical solution: Initial wait for ~43 microseconds prior to arbitration - similar to Wi-Fi

DONE

- **Back-off transmissions rapidly when significant interference with other users is detected; be adaptive to congestion**
  - Solution: LTE-U/LAA should implement technologies similar to those in Wi-Fi such as “Exponential Back-off” which defer transmissions upon detection of interference

DENIED

- **Detect signals that are far below regulatory requirements to maintain thriving unlicensed ecosystem**
  - Proposed Technical Solution: Match Wi-Fi mechanisms, which detect other Wi-Fi signals 1000 times below regulatory requirements with energy and preamble detection mechanisms

COMPROMISE

**3GPP Result: LAA should operate at -72 dBm for energy detection assuming 20 MHz signal bandwidth at 23 dBm EIRP, but allows threshold to be relaxed to -62 dBm when power is reduced below 23 dBm EIRP**

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# LAA INTEGRATED COEXISTENCE CONSIDERATIONS FOR BETTER WI-FI PROTECTION

## Coexistence mechanisms beyond those proposed in RAN1 are necessary to protect Wi-Fi

- **More integrated approach will help LAA and Wi-Fi to coexist naturally**
- **Broadcom's prototype demonstrated better coexistence thru**
  - Transmission decisions based on clear channel assessment (CCA) rules of Wi-Fi
  - Wi-Fi preambles and deferred transmissions
  - Wi-Fi Beacons and free channel selection (if available)
  - Medium reservation for transmissions after CCA by sending CTS on its behalf
- **Broadcom's prototype coexistence demonstrates that integrated approach significantly reduces detrimental impact on Wi-Fi**
  - Wi-Fi only, without LTE: ~ 100Mb/s throughput
  - With integrated coexistence: Wi-Fi throughput ~ 55Mb/s

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# MULTICHANNEL CONSIDERATIONS

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# LAA MULTI-CHANNEL TRANSMISSIONS

- **3GPP TSG RAN WG1 Meeting #83**
  - Multi-carrier operation is strongly recommended to use adjacent channels, but this is not mandatory and may not align with Wi-Fi 80 MHz channels
  - Multi-carrier contention rules do not follow the rules of multi-carrier Wi-Fi very closely and are complex

- **Excerpt from BRAN(15)000177**
  - "For equipment having simultaneous transmissions on multiple (adjacent or non-adjacent) operating channels, the equipment is allowed to continue transmissions on other Operating Channels providing the other Operating Channels are unoccupied and have been unoccupied for at least 25 µs."

- **The proposals do not address the channel alignment issue between LAA & Wi-Fi**
- **The proposals also lack details related to multi-channel access operation**

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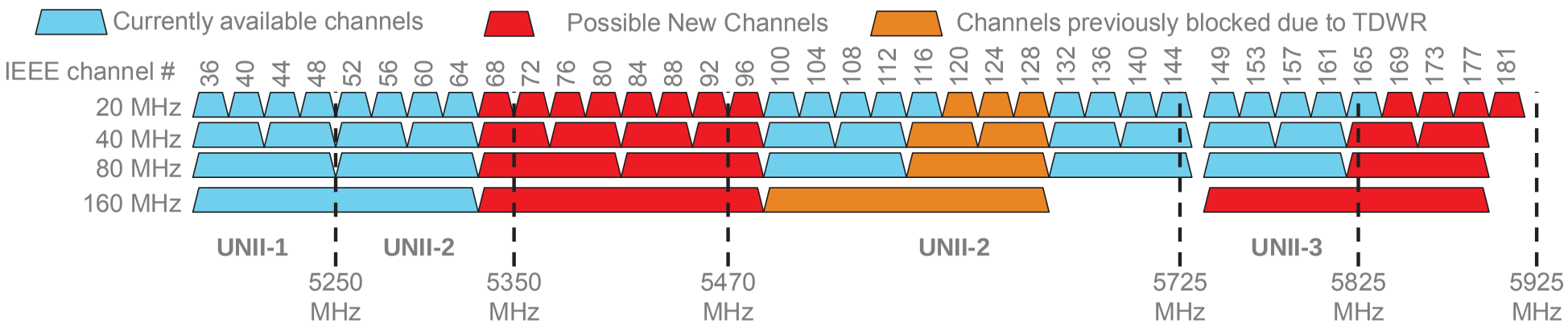
# CONSIDERATIONS FOR LAA & WI-FI MULTI-CHANNEL OPERATION




- **Channels must be aligned with IEEE boundaries, be contiguous, and incorporate LBT in each channel in order to ensure fair media access for all unlicensed technologies**
  - **Aggregation & Channel Alignment**: LAA and Wi-Fi must use common aggregation and channel alignment of 20 MHz carriers to form 40 MHz and 80 MHz channels
  - **Clustering**: To support extremely high speed operation, clustering must be performed up to 4 carriers at a time before using more than 4 carriers and forming a new cluster separated in frequency
  - **Multicarrier LBT**: LBT must be performed on all carriers including either a common or independent contention counter and a common or independent exponential backoff to adapt to high density scenarios
  - **Transmission Synchronization**: Transmissions within a cluster must start at the same time after performing LBT on all carriers and transmissions should stop at the same time.

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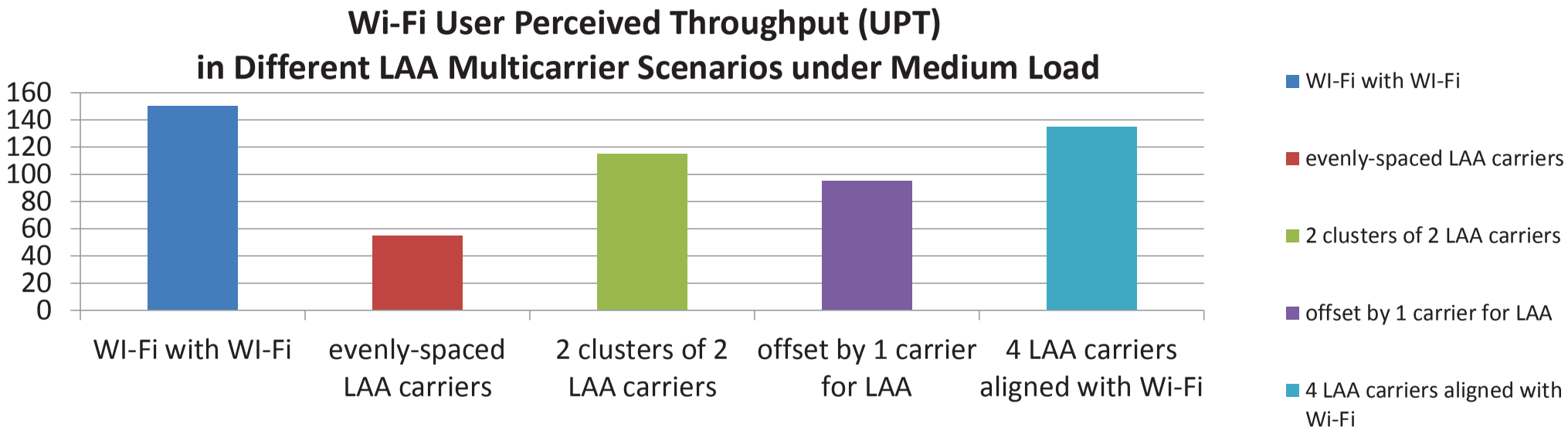
# LAA MULTI-CHANNEL COEXISTENCE CONSIDERATIONS FOR 3GPP




Alignment of LAA and Wi-Fi carriers provides the most fair operation in Multi-channel Scenarios!

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# MINIMUM TEST PLAN PROPOSALS

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# MINIMUM COEXISTENCE TEST PLAN REQUIREMENTS

- **Scenarios should encompass:**
  - Median Wi-Fi AP and STA RSSI level of -80dBm
  - Interference level sweep from low to high
  - Different Wi-Fi, LTE and LAA network sizes and Vendor mixes
  - Multiple uncoordinated LTE-U and LAA carriers in the same frequency
  - Different multi-channel LAA scenarios and 20 / 40 / 80 / 80+80 / 160MHz Wi-Fi channels
  - Traffic types: FTP, Video, VoIP
  - LTE effect on fast varying Wi-Fi traffic (e.g., Video, VoIP)
  - Over the Air (OTA) models vs Conducted vs Hybrid
  - Regulatory Requirements
- **Performance Metrics:**
  - Throughput
  - Packet Loss and Beacon Loss
  - Delay and Jitter
  - Rate vs Range
  - Channel utilization of each technology and accounting for TDD vs FDD differences
  - Network Capacity (LTE+WiFi, LAA+Wi-Fi, Wi-Fi+Wi-Fi)
  - STA Association time with different Authentication protocols
  - Power management impact on STA-s

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# Thank You