

Federal Communications Commission
Office of Engineering and Technology
Laboratory Division Public Draft Review

4/23/2012

Draft Laboratory Division Publications Report

Title: Guidance for IEEE 802.11acTM and Pre-ac Device Emissions Testing

Short Title: Guidance for IEEE 802 11ac

Reason: New Publication

Publication: 644545

Keyword/Subject: 15.247, IEEE 802.11ac and Pre-802.11ac

First Category: Administrative Requirements

Second Category: Measurement Requirements

Third Category:

Question: What are the IEEE 802.11ac and pre-802.11ac emissions testing requirements for compliance with sections 15.247 and 15 subpart E (15.401 through 15.407) of the FCC rules? Also, how is simultaneous transmission by 802.11 devices under multiple rule sections (15.247, 15.407, and Part 90Y public safety) handled?

Answer:

The attached document below [644545 D01 Guidance for IEEE 802 11ac v01](#) provides guidance for emissions testing of IEEE 802.11acTM and pre-ac devices.

Attachment List:

[644545 D01 Guidance for IEEE 802 11ac v01](#)

Attachment

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Guidance for IEEE 802.11ac™ and Pre-ac Device Emissions Testing

This document provides guidance for emissions testing of IEEE 802.11ac™ and pre-ac devices for compliance with sections 15.247 and 15 subpart E (15.401 through 15.407) of the FCC rules. It also provides guidance for emissions testing of devices designed to earlier versions of the 802.11 standard if those devices are capable of simultaneous transmission in two or more bands above 5 GHz that are subject to different FCC operational and/or emissions requirements. Finally, it addresses simultaneous operation of IEEE 802.11™ devices under Part 15 (2.4 and 5 GHz) and public safety licenses in the 4.9 GHz band under Part 90 of the rules. SAR measurements for devices requiring RF exposure testing will also be affected by the provisions of IEEE 802.11ac™, but those requirements are not addressed in this document.

The guidance in this document supplements the following guidance for emissions testing:

- FCC KDB publication 558074 for 15.247;
- FCC KDB publication 789033 for 15.407 Unlicensed National Information Infrastructure (U-NII);
- FCC KDB publication 662911 for MIMO under any rule part;
- FCC 06-96 Appendix and FCC KDB publication 443999 for DFS under 15.407.

The draft IEEE 802.11ac™ standard as of this writing (draft D2.0) expands on previous versions of IEEE 802.11™ in several ways that impact emissions testing between 5 and 6 GHz. The following features have been added:

- Transmission bandwidths of 80 MHz and, optionally, 160 MHz;
- Optional transmission in non-contiguous 80 MHz channels (80+80 MHz mode);
- New channels that straddle the boundary between the upper pair of U-NII bands;
- Up to eight MIMO outputs;
- 256-QAM modulation.

Existing emissions testing guidance is adequate to cover the additional MIMO outputs and 256-QAM modulation mode. This new guidance document focuses on operations that involve simultaneous transmission in two or more bands that are subject to different FCC operational and/or emissions requirements.

Figure 1 depicts the operating channels in 5 – 6 GHz bands for IEEE 802.11ac™ devices in the U.S. The standard permits operation in any of the channels shown, as well as simultaneous operation in any two non-adjacent 80-MHz channels. The channels that were newly introduced in the IEEE 802.11ac™ standard are enclosed by a blue outline.

The following new features can lead to simultaneous transmission in two or more bands that are subject to different FCC operational and/or emissions requirements:

- Transmission on a 20, 40, or 80 MHz wide channel that extends across the 5.725 GHz boundary, as shown in red in Figure 1.
- Transmission on the 160 MHz channel that extends across the 5.25 GHz boundary between the lower pair of U-NII bands.
- Transmission on two non-contiguous 80 MHz channels that may be in different U-NII bands or in a U-NII band and the 5.8 GHz 15.247 band.

In addition, simultaneous transmission in multiple FCC bands can occur in ways that were also possible under previous versions of the standard:

- The emission bandwidth of transmissions on 20, 40, or the new 80 MHz channels adjacent to the 5.25 GHz boundary between the lower two U-NII bands could extend across that boundary.
- A device that implements the functionality of two or more IEEE 802.11™ systems could potentially transmit simultaneously in various combinations of bands and at various bandwidths.

Where simultaneous transmissions in two or more bands (including combinations of the four U-NII bands) can occur, care must be taken to ensure that all requirements of the individual bands, as well as aggregate requirements, are satisfied. As usual, all operating modes and data rates of the equipment under test (EUT) must satisfy all requirements. Testers must be aware that the operating mode and data rate that are the worst case for one test may not be the worst case for another test.

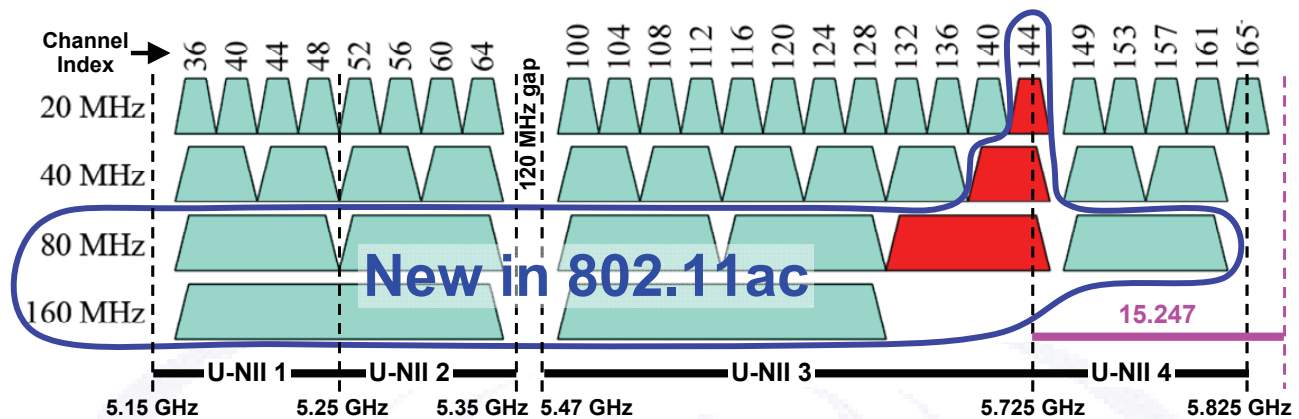


Figure 1. Operating Channels in 5-6 GHz Bands for IEEE 802.11ac™ Devices Operating in the U.S.

GUIDANCE

A) Permit but ask (PBA)

All devices that are capable of transmitting simultaneously in more than one Part-15 band between 5 and 6 GHz (i.e., in two or more of the four U-NII bands or in the 5.8 GHz 15.247 band and at least one U-NII band) are subject to Permit But Ask (PBA)¹ provisions. This includes devices marketed as IEEE 802.11ac™ or pre-ac.

B) Applicable rules

- 1) 2.4 – 2.4835 GHz: **15.247**
- 2) 4.94 – 4.99 GHz (public safety): **Part 90**, including subparts B, I, Y, and the appropriate emission mask (l) or (m) defined in section **90.210** of the rules. Note that Part 90Y limits channel bandwidth to a maximum of 20 MHz.
- 3) 5 GHz operations:
 - a) 5.15 – 5.25 GHz, 5.25 – 5.35 GHz, and 5.47 – 5.725: **15.407**.

¹ PBA permits equipment authorization by a Telecommunications Certification Body (TCB), but only after consultation with the FCC.

- (i) Operations in bands requiring DFS shall also comply with FCC 06-96 Appendix, *Compliance Measurement Procedures for Unlicensed National Information Infrastructure Devices operating in the 5250-5350 MHz and 5470-5725 MHz Bands Incorporating Dynamic Frequency Selection.*
 - (ii) Operation in 5.47 – 5.725 GHz shall also comply with **FCC KDB publication 443999**, *Interim Plans to Approve UNII Devices Operating in the 5470 - 5725 MHz Band with Radar Detection and DFS Capabilities.*
- b) Above 5.725 GHz: **15.247** or **15.407**, as specified in this document. (A device may use both rule sections for operations above 5.725 GHz—but not simultaneously.)

C) All operational requirements for each band of operation must be satisfied.

Examples include:

- 1) 5.15 – 5.25 GHz – Restricted to indoor operations per 15.407(e);
- 2) 5.25 – 5.35 GHz – Dynamic Frequency Selection (DFS) and Transmit Power Control (TCP) are required per 15.407(h);
- 3) 5.47 – 5.725 GHz – DFS and TCP are required per 15.407(h); in addition operations must comply with FCC KDB publication 443999, *Interim Plans to Approve UNII Devices Operating in the 5470 - 5725 MHz Band with Radar Detection and DFS Capabilities.*
- 4) 4.94 – 4.99 GHz – Requirements specified in Part 90, including subparts B, I, Y.

D) Limitations on simultaneous operation under 15.247 and 15.407 in 5 – 6 GHz bands

Operations above 5.725 GHz can potentially occur under either section 15.247 or section 15.407 (U-NII) of the rules; however, the following restrictions apply.

- 1) Simultaneous operation in the 5.725 – 5.825 GHz band under 15.407 and the 5.725 – 5.850 GHz band under 15.247 are prohibited.
- 2) Any spectrally contiguous segment of a transmission must be authorized under only one rule section (i.e., 15.247 or 15.407). Two transmissions shall be considered contiguous if their 26-dB emission bandwidths (EBWs) overlap.
- 3) The above pair of restrictions leads to the following requirements for 802.11 devices:
 - a) All transmissions above 5.725 GHz must be under **15.407** whenever operating on a channel where the EBW crosses 5.725 GHz (e.g., the channels shown in red in Figure 2).²
 - b) All transmissions above 5.725 GHz must be under **15.247** whenever operating on a channel where the EBW crosses 5.825 GHz (e.g., channel 165 in Figure 2).
 - c) Simultaneous operation on channels described in a) and b), above, are prohibited.
 - d) Except when operating on channels described in a) or b), above, the manufacturer or test lab is free to choose which of the two rule sections will be used for the transmissions above 5.725 GHz for any given transmit channel or combination of channels; however, the assignment of individual and multi-channel transmissions to each rule section must be identified in the test report. A transmit channel combination that includes 15.407

² The part of the transmission that is below 5.725 GHz is in a band that is permitted only under the 15.407 rules. The part of the transmission that is above 5.725 GHz is in a band that could normally be permitted under either 15.247 or 15.407, but because part of the signal is covered only by 15.407, the entire signal must comply with 15.407.

components and 15.247 components in 5-6 GHz bands must be identified in both the 15.407 and 15.247 test reports.

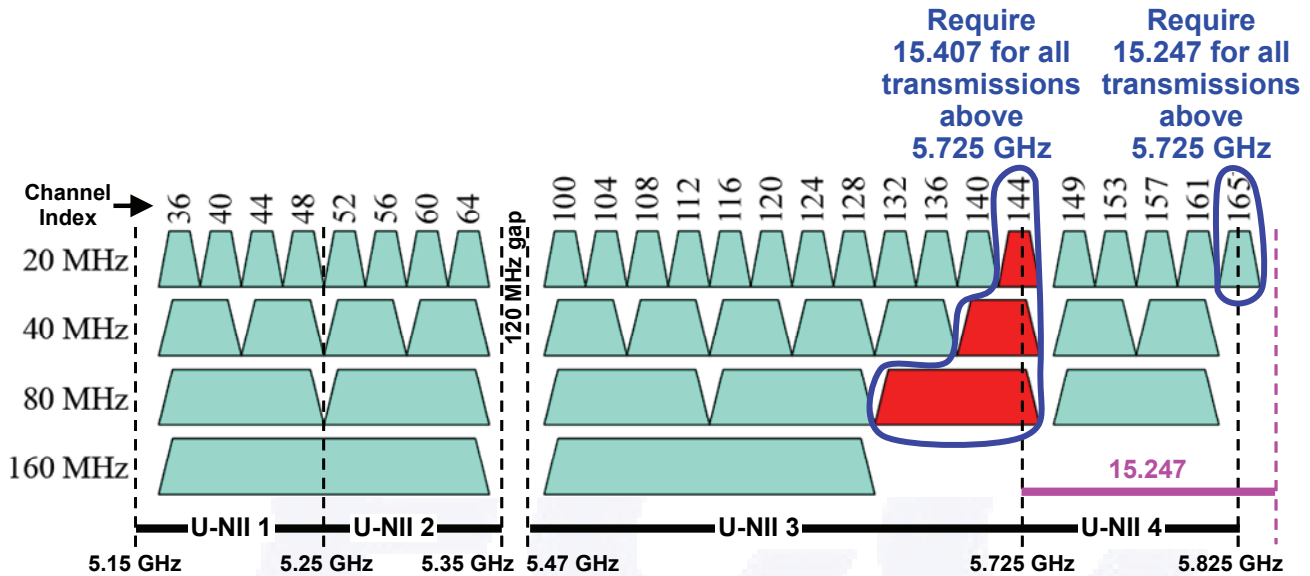


Figure 2. Examples of Limitations on Simultaneous Operation under 15.247 and 15.407 in 5-6 GHz

E) In-band emission limits when operating simultaneously in multiple bands

1) Emission bandwidth (EBW) in U-NII bands

- a) Transmissions with non-contiguous spectra. For intentional emissions that are not contiguous in frequency, total EBW is defined as follows:
 - (i) the difference between the outer -26 dB points if the 26-dB bandwidths overlap (Figure 3);
 - (ii) the sum of the individual 26 dB bandwidths if the 26 dB bandwidths do not overlap (Figure 4). The EBW of each non-contiguous segment is measured at points that are 26 dB below the maximum for that segment.
- b) Band-crossing emissions. For an emission that crosses the boundary between two adjacent U-NII bands, the boundary frequency between the bands serves as one edge for defining the portion of the EBW that falls within a particular U-NII band; however, the -26 dB points are measured relative to the highest point on the contiguous segment—regardless of which band contains that highest point.

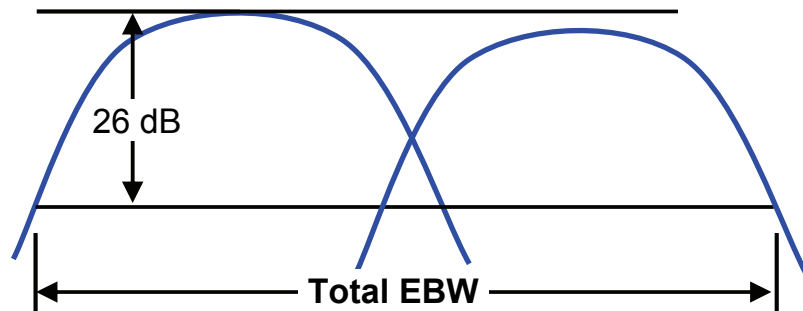


Figure 3. Total Emission Bandwidth (EBW) of Signals With Overlapping EBWs

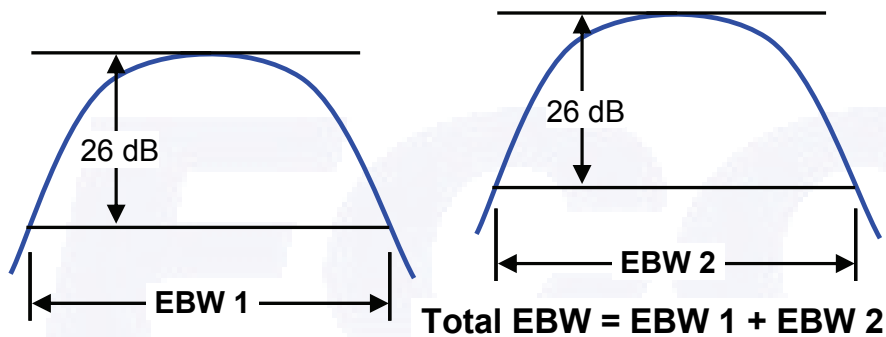


Figure 4. Total Emission Bandwidth (EBW) of Signals With Non-Overlapping EBWs

2) Power spectral density (PSD)

Emissions in each band shall comply with the PSD limits applicable to that band under the appropriate rule section, including requirements to reduce PSD limits based on antenna gain.

3) Maximum conducted output power

The treatment of limits on maximum conducted output power for multi-band transmissions is described below and illustrated in Figure 5 and Figure 6.

- a) Operations in the following four categories of bands shall comply with their respective power limits (including power reductions based on antenna gain) with no requirement to aggregate power across the categories:
 - (i) 2.400-2.4835 GHz transmissions under 15.247 of the rules.
 - (ii) 4.94-4.99 GHz public safety transmissions under Part 90 of the rules.
 - (iii) U-NII band transmissions under 15.407 of the rules, subject to the restrictions of sections D) and E)3)b) of this document.
 - (iv) 5.725-5.850 GHz transmissions under 15.247 of the rules.
- b) Simultaneous operations in multiple U-NII bands must comply with all of the following limits, as illustrated in Figure 6. For any given transmission, a device shall be deemed to be operating any U-NII bands that contain a portion of the 26-dB emission bandwidth of the transmission. [See 15.215(c) and 15.403(i).]

- (i) Individual band powers. Maximum conducted output power within each U-NII band (5.15-5.25 GHz, 5.25-5.35 GHz, 5.47-5.725 GHz, and 5.725-5.825 GHz) must comply with the limit specified for that band based on the portion of the EBW within that band.
- (ii) Aggregate (total) U-NII band power. For any possible combination of simultaneous transmissions, the total maximum conducted output power across all U-NII bands of operation must comply with the highest limit permitted for any one band of operation computed based on the total EBW across all U-NII bands of operation. The highest limit must be based only on the U-NII bands in which the device is currently transmitting under 15.407 of the rules.

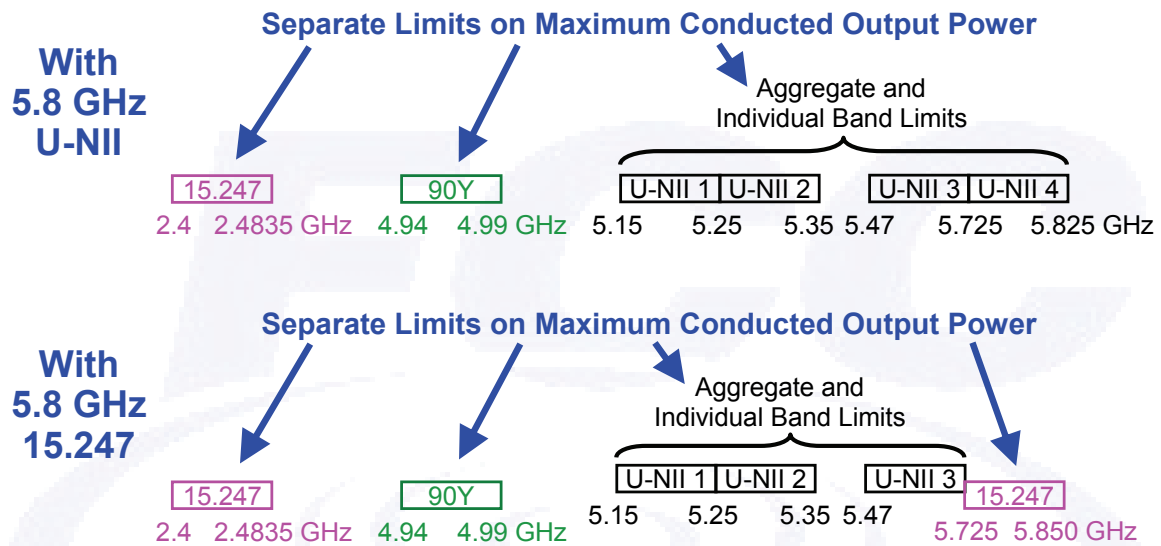
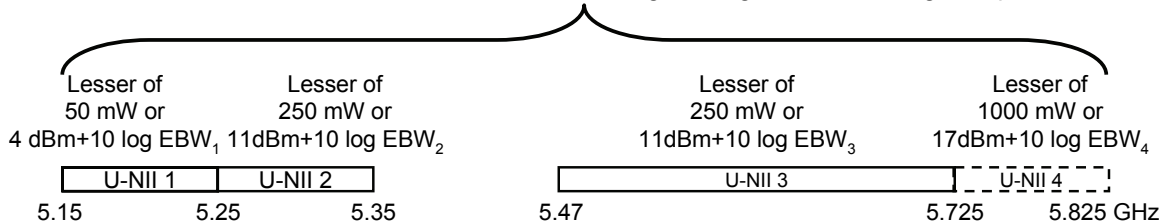


Figure 5. Limits on Maximum Conducted Output Power

Aggregate < highest limit among occupied U-NII bands based on $EBW_1+EBW_2+EBW_3+EBW_4$.
 (When operations above 5.725 GHz are under 15.247, aggregation is limited to bands below 5.725 GHz, EBW_4 is omitted, and the U-NII 4 is not included in determining “the highest limit among occupied U-NII bands.”)



The limits must be reduced if total antenna gain (including array gain) exceeds 6 dBi

Figure 6. Band and Aggregate Limits on Maximum Conducted Output Power for U-NII

Example 1. 80+80 MHz operation on channels centered at channel indices 42 and 106, as shown in Figure 7. Antenna gain is less than 6 dBi.

- The channel center frequencies are 5.210 GHz and 5.530 GHz.
- Emission bandwidths: For the example, we will assume that the measured 26-dB EBW of each signal is 82 MHz and that each EBW is centered on the channel center frequency. Thus, the EBW of the channel-42 signal extends from 5169 to 5251 MHz, and the EBW of the channel-106 signal extends from 5489 to 5571 MHz.
 - EBW in 5.15-5.25 GHz band = 5250 - 5169 MHz = 81 MHz
(Note that use of this band is restricted to indoor operation per 15.407(e).)
 - EBW in 5.25-5.35 GHz band = 5251 - 5250 MHz = 1 MHz
 - EBW in 5.47-5.725 GHz band = 5571 - 5489 MHz = 82 MHz
- Maximum conducted output power must satisfy all of the following
 - Power in 5.15-5.25 GHz is limited to the lesser of 50 mW or $4 \text{ dBm} + 10 \log(81) = 50 \text{ mW}$;
 - Power in 5.25-5.35 GHz is limited to the lesser of 250 mW or $11 \text{ dBm} + 10 \log(1) = 11 \text{ dBm}$;
 - Power in 5.47-5.725 GHz is limited to the lesser of 250 mW or $11 \text{ dBm} + 10 \log(82) = 250 \text{ mW}$;
 - The sum of the powers in the 5.15-5.25 GHz, 5.25-5.35 GHz, and 5.47-5.725 GHz U-NII bands is limited to the lesser of 250 mW or $11 \text{ dBm} + 10 \log(81+1+82) = 250 \text{ mW}$.

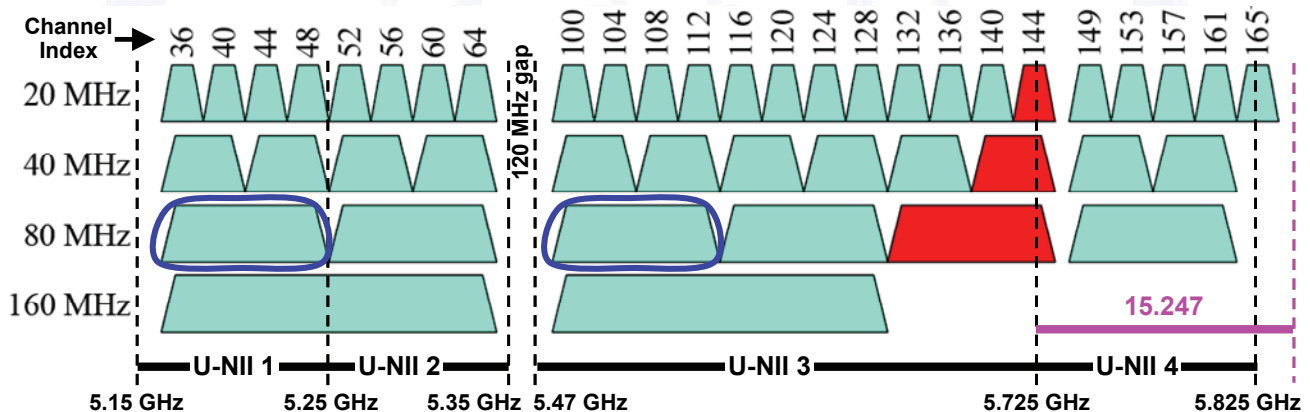


Figure 7. Example 1 – 80+80 MHz Mode on Channels Centered at Channel Indices 42 and 106

Example 2. Suppose that the device can operate as two 802.11 access points simultaneously, as shown in Figure 8. The first access point is operating as in example 1, and the second is transmitting on a 20 MHz wide channel at channel index 157 with an EBW of 21 MHz. Antenna gain is less than 6 dBi. Based on section

D)3)d) of this document, the tester is free to choose which rule section will be used for the channel-157 transmission.

- If 15.247 is chosen, then the power associated with the channel-157 transmission is subject to the 15.247 limit, and the powers of the 80+80 MHz transmissions are subject to the limits computed in Example 1. Because both rule parts are used simultaneously, the channel test combination must be identified in both the 15.407 and 15.247 test reports.
- If 15.407 is chosen, then the power associated with the channel-157 transmission is limited to the lesser of 1 W or $17 \text{ dBm} + 10 \log(21) = 1 \text{ W}$, and the aggregate power limit from example 1 is revised to include all three segments of the transmission as follows:

The sum of the powers in the 5.15-5.25 GHz, 5.25-5.35 GHz, 5.47-5.725 GHz, and 5.725-5.825 GHz U-NII bands is limited to the lesser of 1 W or $17 \text{ dBm} + 10 \log(81+1+82+21) = 1 \text{ W}$.

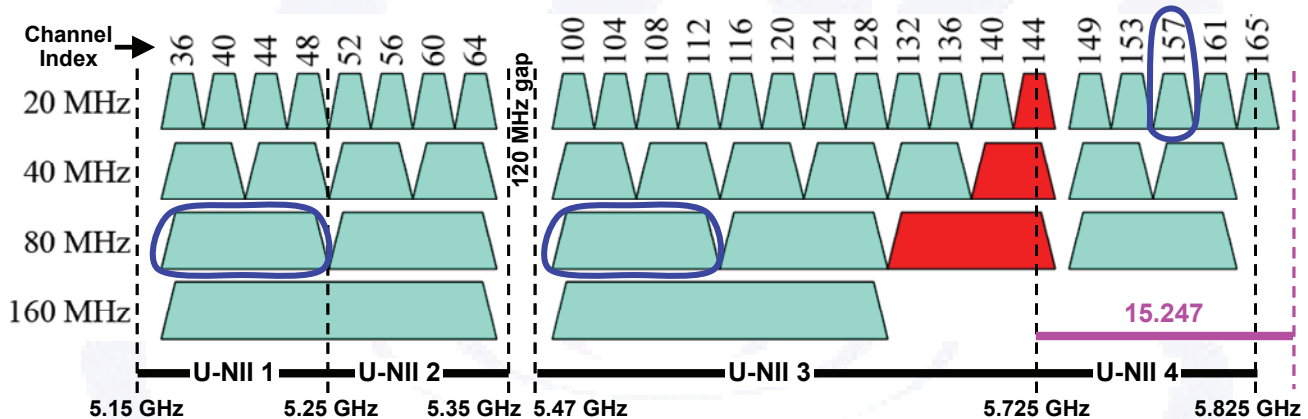


Figure 8. Example 2 – 80+80 MHz Mode Plus Second 802.11 Functionality on Channel Index 157

F) Unwanted emissions (out-of-band and spurious)

- 1) Bands of operation. A given transmission may include multiple spectral segments in different bands and/or individual spectral segments that overlap boundaries between bands. For any given transmission, the out-of-band and spurious emissions limits apply outside of the frequency bands of operation for that transmission.
 - a) 15.407 (U-NII). A transmission is considered to operate in any U-NII bands that contain a portion of the 26-dB EBW of at least one spectral segment for that transmission. Except as noted in sections 15.407(b)(1) and (b)(2) of the rules, emissions in any U-NII band not occupied by the current transmission comply with the out-of-band and spurious emissions limit.
- 2) Limits. For a device that operates under both sections 15.247 and 15.407 of the rules, all of the following requirements must be satisfied, in accordance with section 15.31(k) of the rules:
 - a) 15.247 transmissions must satisfy the out-of-band and spurious limits specified in 15.247(d);

- b) 15.407 emissions must satisfy the out-of-band and spurious emission limits specified in 15.407(b);
- c) Composite emissions involving both rule parts must satisfy the higher of the out-of-band and spurious limits among the two rule sections.

G) Measurement Procedures

- 1) The following measurement procedures apply:
 - a) FCC KDB publication 558074 for 15.247;
 - b) FCC KDB publication 789033 for 15.407 (U-NII);
 - c) FCC KDB publication 662911 for MIMO under any rule part;
 - d) FCC 06-96 Appendix and FCC KDB publication 443999 for DFS.
- 2) The following adjustments to those procedures apply when measuring U-NII transmissions that are not contiguous in frequency or that extend across the boundary between adjacent U-NII bands.
 - a) Emission bandwidth
 - (i) For transmissions that are not contiguous in frequency, see section E)1)a) above.
 - (ii) For an emission that crosses the boundary between adjacent U-NII bands, see section E)1)b).
 - (iii) Total U-NII EBW is used to compute the limit on total conducted output power within all U-NII bands. Total U-NII EBW shall be computed by summing EBWs of all active emissions across all U-NII bands, excluding U-NII band 4 if operations in that band are under 15.247.
 - b) Maximum conducted output power (See examples in Figure 9.)
 - (i) Transmissions with non-contiguous spectra. For transmission segments that are not contiguous in frequency, the total power of the spectrum segments can be determined by either of the following methods:
 - Measure the power of each spectrum segment by integrating across the EBW of that segment following the procedures of KDB publication 789033. Sum the power measurements.
 - Or, measure the total power of the segments simultaneously by integrating across a frequency range that encompasses the EBWs of all segments following the procedures of KDB publication 789033. (The power-meter based procedure, Method PM, may be used as an alternative.)
 - (ii) When measuring the portion of the maximum conducted output power within a single U-NII band, the power shall be integrated across only the portion of the EBW that falls within that band. That is, if an EBW extends across the boundary between two adjacent bands, the boundary frequency between the bands serves as one edge of the frequency range to be integrated. Integration across an entire band without regard to 26-dB points is acceptable for determining conducted output power within a band.

Conducted output power in each U-NII band (P_1 , P_2 , P_3 , and P_4): Integrate over the band or over the 26-dB EBW within the band.

Total conducted output power (P_{TOTAL}): Integrate over the outer span of -26 dB points or sum the band powers.

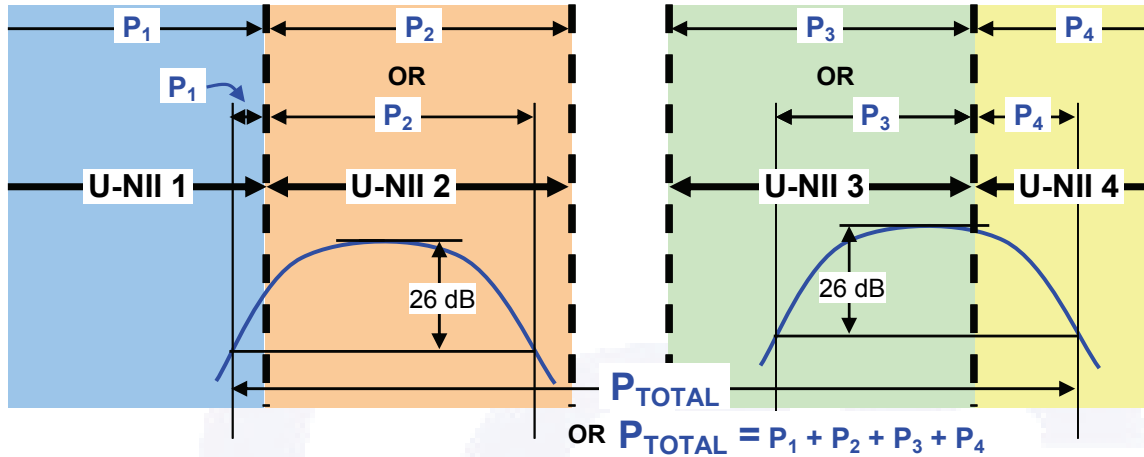


Figure 9. Conducted Output Power Measurement Examples