Federal Communications Commission
Office of Engineering and Technology
Laboratory Division

August 9, 2023

GUIDELINES FOR COMPLIANCE TESTING OF
UNLICENSED NATIONAL INFORMATION INFRASTRUCTURE 6 GHz (U-NII) DEVISES
PART 15, SUBPART E

I. INTRODUCTION

This document provides guidance for determining 6 GHz U-NII device emissions compliance under Part 15, Subpart E of the FCC rules.

This document includes acceptable procedures for measuring emission bandwidth, maximum conducted output power, power spectral density, and unwanted emissions both in and out of the restricted bands, in-band emissions and contention-based protocol. For equipment under test (EUT) that can transmit on multiple outputs simultaneously (e.g., MIMO or beamforming devices), see KDB Publication 662911 for additional guidance.

All EUT operating modes and data rates must satisfy all requirements. The operating mode and data rate that is the worst case for one test may not be the worst case for another test. Data rate settings may have a significant effect on test results.

Note that average emission measurements in the restricted bands are based on continuous transmission by the U-NII device during the measurement interval. Downward adjustment of test data based on actual operational duty cycle of the device is not permitted.

II. MEASUREMENT PROCEDURES

A. General Guidance

Refer to KDB 789033 & also for Frequency Stability

B. Duty Cycle (x), Transmission Duration (T), and Maximum Power Control Level

Refer to KDB 789033 or as specified in this section where applicable.

C. Emission Bandwidth (EBW)

Refer to KDB 789033

D. 99% Occupied Bandwidth

Refer to KDB 789033

E. Maximum Conducted Output Power

Refer to KDB 789033. Any of the methods in this section of 789033 for conducted power can be used.

F. Maximum Power Spectral Density (PSD)

Refer to KDB 789033

G. Unwanted Emission Measurement

Use guidance in KDB 789033 for measurements below 1000 MHz and above 1000 MHz. Unwanted emissions outside of restricted bands are measured with a RMS detector. In addition, 15.35(b) applies where the peak emissions must be limited to no more than 20 dB above the average limit.

H. Measurement of emission at elevation angles higher than 30° from horizon

For an outdoor standard power access point and fixed client device operating in the 5.925-6.425 GHz and 6.525-6.875 GHz bands, the maximum EIRP at any elevation angle above 30 degrees as measured from the horizon must not exceed 125 mW (21 dBm). This restriction leads to a general requirement for the antenna pattern: if the EIRP within the 3 dB elevation beamwidth of any radiation lobe is higher than 125 mW, this lobe must be controlled, either mechanically or electrically, so that the 3 dB elevation beamwidth of this lobe is below the 30° elevation angle relative to the horizon.

For compliance purposes, information for all the antenna types must be included in the filing. For antennas to be considered of similar type, the antenna patterns as well as other characteristics of the antenna must also be similar.

Note: Elevation angle is defined as 0° is horizontal and 90° is straight-up.

1. For fixed infrastructure, not electrically or mechanically steerable beam antenna

a) If elevation plane radiation pattern is available:

i) Determine the device intended mounting elevation angle and define 0° reference angle on the elevation plane radiation pattern.

ii) Indicate any radiation pattern between 30° and 90° which has the highest gain.

iii) Calculate the EIRP based on this highest gain and conducted output power.

iv) Compare to the 125 mW limit to establish compliance.

v) Include the elevation pattern data in the application filing with the test report to show how the calculations are made.

Note: For MIMO devices, take the maximum gain of each antenna and apply the guidance in KDB Publication 662911 for calculating the overall gain including directional gain for the maximum EIRP calculation.

b) If the elevation plane radiation pattern is not available, but the antenna type (such as dipole omnidirectional, Yagi, parabolic, or sector antenna) has a symmetrical elevation plane pattern referenced at the main beam and all lobes on the main beam elevation plane have highest gains, then the following measurement method is acceptable to determine compliance:

i) Determine the device's intended mounting elevation angle referenced to the horizon.

ii) Rotate the EUT antenna by 90° around the main beam axis in a horizontal position to transform the measurement in elevation angle into an azimuth angle and define a 0° reference angle based on the device's intended mounting elevation angle.

iii) Move the test antenna along the horizontal arc, or rotate the turntable with the EUT antenna placed at the center, between 30° and 90° relative to the 0° reference angle, and then continuing down from 90° to 30° on the other side of the pattern, while maintaining the test antenna pointing with constant distance to the EUT antenna. Search for the spot which has the highest measured emission. Both horizontal and vertical polarization shall be investigated to determine the maximum radiated emission level.

Note: Moving the test antenna along the horizontal arc, or rotating the turntable, shall be performed in an angular step size as small as possible, but not larger than 3°.

iv) Calculate the EIRP based on the highest measured emission. Compare to the limit of 125 mW to determine compliance.

v) The antenna pattern measurements must be included in the filing.

2. For All Other Antenna Types

For all other antenna types (such as patch antennas, array antennas, antennas with irregular radiator shapes, etc.) which have any combination of following characteristics:

- Asymmetrical, complex radiation patterns
- 2-D or 3-D steerable beam
- Portable/mobile, not fixed infrastructure device

Provide the following information in the report:

a) Describe what type of antenna is used.

b) Determine by calculation, measurement or simulation, all radiation lobes/beams, which have EIRP higher than 125 mW within a 3-dB elevation beamwidth.

c) Provide an explanation of how these antenna beams are controlled to be kept below the 30° elevation angle. The explanation should include device installation instructions, mechanical control, electro-mechanical control or software algorithms, if the beams are electrically controlled by software.

I. Contention Based Protocol

Indoor access points, subordinate devices and client devices operating in the 5.925-7.125 GHz band (herein referred to as unlicensed devices) are required to use technologies that include a contention-based protocol to avoid co-channel interference with incumbent devices sharing the band. To ensure incumbent co-channel operations are detected in a technology-agnostic manner, unlicensed devices are required to detect co-channel radio frequency energy (energy detect) and avoid simultaneous transmission.

Unlicensed low-power indoor devices must detect co-channel radio frequency power that is at least -62 dBm or lower. Upon detection of energy in the band, unlicensed low power indoor devices must vacate the channel (in which incumbent signal is transmitted) and stay off the incumbent channel as long as detected radio frequency power is equal to or greater than the threshold (-62 dBm)[1]. The -62 dBm (or lower) threshold is referenced to a 0 dBi antenna gain.

To ensure incumbent operations are reliably detected in the band, low power indoor devices must detect RF energy throughout their intended operating channel. For example, an 802.11 device that plans to transmit a 40 MHz- wide signal (on a primary 20 MHz channel and a secondary 20 MHz channel) must detect energy throughout the entire 40 MHz channel. Additionally, low-power indoor devices must detect co-channel energy with 90% or greater certainty.

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[1] Unlicensed low- power indoor devices must use its contention-based protocol to ensure a channel is available each time it intends to transmit, including on the same channel(s) previously used after any continuous transmission ends.

Test Procedure

a) Simulating Incumbent Signal

The incumbent signal is assumed to be noise-like. One example of such transmission could be Digital Video Broadcasting (DVB) systems that use Orthogonal Frequency Division Multiplexing (OFDM). Incumbent systems may also use different bandwidths for their transmissions. A 10 MHz-wide additive white Gaussian noise (AWGN) signal is selected to simulate and represent incumbent transmission.

b) Required number of tests

Incumbent and EUT (access point, subordinate or client) signals may occupy different portions of the channel. Depending on the EUT transmission bandwidth and incumbent signal center frequency (simulated by a 10 MHz-wide AWGN signal), the center frequency of the EUT signal f_{c1} may fall within the incumbent's occupied bandwidth (Figure 1.a), or outside of it (Figure 1.b).

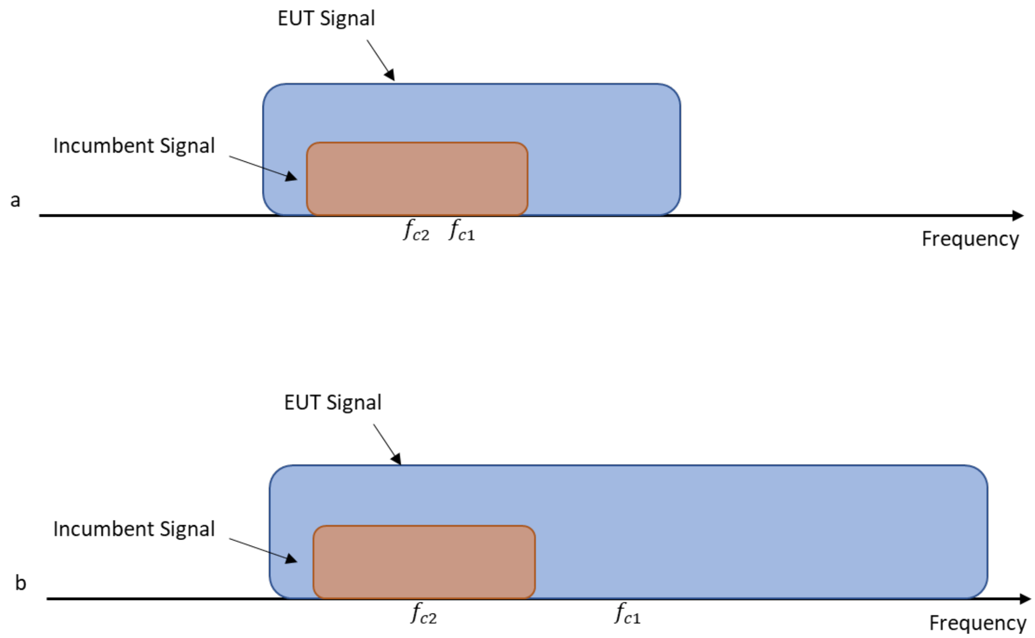

Figure 1. Two possible scenarios where a) center frequency of EUT transmission falls within incumbent's bandwidth, or b) outside of it

To ensure EUT reliably detects an incumbent signal in both scenarios shown in Figure 1, the detection threshold test may be repeated more than once with the incumbent signal (having center frequency f_{c2}) tuned to different center frequencies within the UT transmission bandwidth. The criteria specified in Table 1 determines how many times the detection threshold test must be performed;

Table 1. Criteria to determine number of times detection threshold test may be performed

If	Number of Tests	Placement of Incumbent Transmission
$BW_{EUT} \leq BW_{Inc}$	Once	Tune incumbent and EUT transmissions ($f_{c1} = f_{c2}$)
$BW_{Inc} < BW_{EUT} \leq 2BW_{Inc}$	Once	Incumbent transmission is contained within BW_{EUT}
$2BW_{Inc} < BW_{EUT} \leq 4BW_{Inc}$	Twice. Incumbent transmission is contained within BW_{EUT}	Incumbent transmission is located as closely as possible to the lower edge and upper edge, respectively, of the EUT channel
$BW_{EUT} > 4BW_{Inc}$	Three times	Incumbent transmission is located as closely as possible to the lower edge of the EUT channel, in the middle of EUT channel, and as closely as possible to the upper edge of the EUT channel

where:

BW_{EUT}: Transmission bandwidth of EUT signal
BW_{Inc}: Transmission bandwidth of the simulated incumbent signal (10 MHz wide AWGN signal)
f_{c1}: Center frequency of EUT transmission
f_{c2}: Center frequency of simulated incumbent signal

c) Test Setup

To ensure the EUT is capable of detecting co-channel energy, the first step is to configure the EUT to transmit with a constant duty cycle.[2] To simulate an incumbent signal, a signal generator (or similar source) that is capable of generating band-limited additive white Gaussian noise (AWGN) is required. Depending on the EUT antenna configuration, the AWGN signal can be provided to the EUT receiver via a conducted method (Figure 2) or a radiated method (Figure 3). Figure 2 shows the conducted test setup where a band-limited AWGN signal is generated at a very low power level and injected into the EUT's antenna port. The AWGN signal power level is then incrementally increased while the EUT transmission is monitored on a signal analyzer 2 to verify if the EUT can sense the AWGN signal and can subsequently cease its transmission. A triggered measurement, as shown in Figure 2, is optional, and assists with determining the time it takes the EUT to cease transmission (or vacate the channel) upon detecting RF energy. If the EUT has only one antenna port, then an AWGN signal source can be connected to the same antenna port.

[2] The EUT does not have to be configured to transmit with constant duty cycle if the sole purpose of the test is to verify whether the EUT can detect the incumbent signal and cease transmission upon detection. However, if it is desired to also determine the time it takes the EUT to cease transmission, then having a constant duty cycle will help with an accurate measurement of the time it takes the EUT to detect an incumbent signal and cease transmission.

d) Step-by-Step Procedure, Conducted Setup

1. Configure the EUT to transmit with a constant duty cycle.
2. Set the operating parameters of the EUT including power level, operating frequency, modulation and bandwidth.
3. Set the signal analyzer center frequency to the nominal EEUT channel center frequency. The span range of the signal analyzer shall be between two times and five times the OBW of the EUT. Connect the output port of the EUT to the signal analyzer 2, as shown in Figure 2. Ensure that the attenuator 2 provides enough attenuation to not overload the signal analyzer 2 receiver.
4. Monitoring the signal analyzer 2, verify the EUT is operating and transmitting with the parameters set at step two.
5. Using an AWGN signal source, generate (but do not transmit, i.e., RF OFF) a 10 MHz-wide AWGN signal. Use Table 1 to determine the center frequency of the 10 MHz AWGN signal relative to the EUT's channel bandwidth and center frequency.
6. Set the AWGN signal power to an extremely low level (more than 20 dB below the -62 dBm threshold). Connect the AWGN signal source, via a 3-dB splitter, to the signal analyzer 1 and the EUT as shown in Figure 2.
7. Transmit the AWGN signal (RF ON) and verify its characteristics on the signal analyzer 1.
8. Monitor the signal analyzer 2 to verify if the AWGN signal has been detected and the EUT has ceased transmission. If the EUT continues to transmit, then incrementally increase the AWGN signal power level until the EUT stops transmitting.
9. (Including all losses in the RF paths) Determine and record the AWGN signal power level (at the EUT's antenna port) at which the EUT ceased transmission. Repeat the procedure at least 10 times to verify the EUT can detect an AWGN signal with 90% (or better) level of certainty.
10. Refer to Table 1 to determine number of times the detection threshold testing needs to be repeated. If testing is required more than once, then go back to step 5, choose a different center frequency for the AWGN signal and repeat the process.

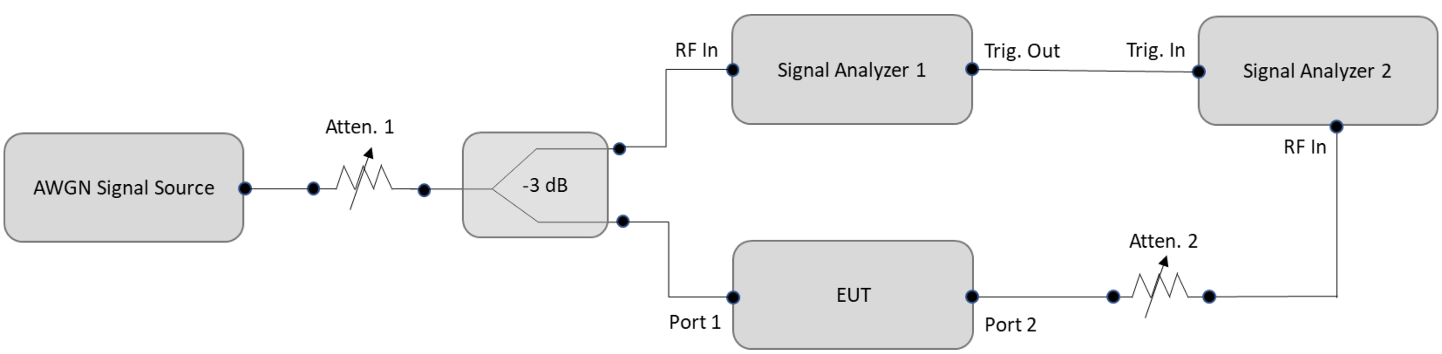

Figure 2. Contention-based protocol test setup, conducted method

e) Step-by-Step Procedure, Radiated Setup

To perform the same test in a radiated fashion, it is imperative to ensure that the AWGN signal can be radiated in a controlled environment, the AWGN radiated signal can illuminate the EUT antenna entirely, and the AWGN signal power level can be accurately measured at the EUT antenna's exact location. Figure 3 shows the radiated test setup where the AWGN signal is generated and transmitted via antenna 1. It should be noted that antenna 1 must be selected such that its 3 dB beamwidth can illuminate the EUT entirely. To ensure the AWGN signal level can be accurately measured at the EUT location, the EUT is initially replaced by antenna 2 which has a known gain, as shown in Figure 3. The radiated signal level is then measured using antenna 2. Antennas 1 and 2 are aligned and placed at a distance R which is greater than the far field distances of both antenna 1 and antenna 2. The AWGN signal power level is measured by the signal analyzer 1. The measured power P_{meas} is then corrected by the gain of antenna 2, G_2, and by all cable losses and attenuations L, to determine the AWGN signal power level at antenna 2, P_2, according to

$$P_2 = P_{meas} + L - G_2 \quad (1)$$

The EUT is then placed exactly where antenna 2 was, as shown in Figure 4.

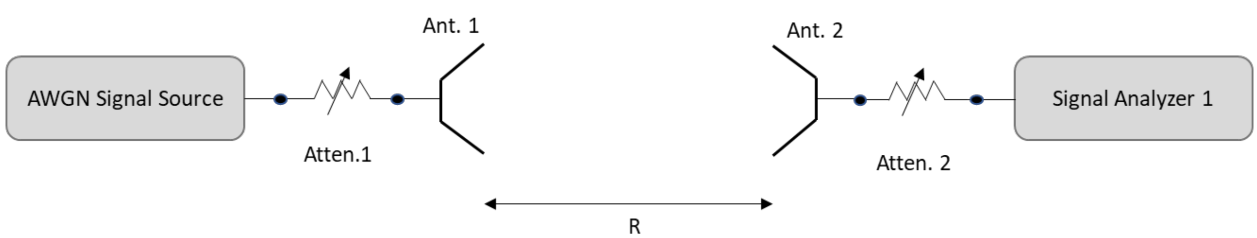

Figure 3. Contention-based protocol test setup, radiated method, power measurement

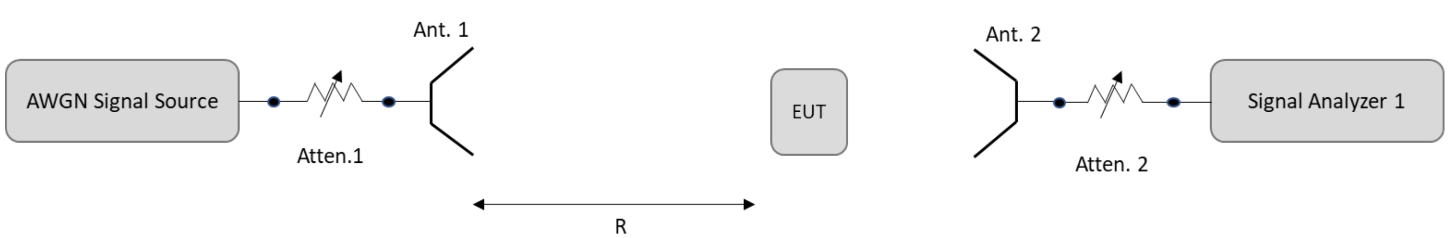

Figure 4. Contention-based protocol test setup, radiated method, detection threshold measurement

The following is a step-by-step procedure for testing the contention-based protocol using the radiated setup described above:

1. Using the AWGN signal source, generate (but do not transmit, i.e., RF OFF) a 10 MHz-wide AWGN signal. Use Table 1 to determine the center frequency of the 10 MHz AWGN signal relative to the EUT's channel bandwidth and center frequency.
2. Connect the AWGN signal source to antenna 1, as shown in Figure 3, and transmit the signal (RF ON).
3. Using signal analyzer 1 and antenna 2, measure the AWGN signal power level. Align antenna 2 and antenna 1 to maximize emission.
4. Using equation 1, correct the measured power P_{meas} by the gain of antenna 2, G_2 and all cable losses and attenuations L to obtain the AWGN signal power level at antenna 2, P_2.

5. Set the corrected power P_2 to an extremely low level (more than 20 dB below the -62 dBm threshold).
6. Place the EUT exactly where antenna 2 was. Configure the EUT to transmit a constant duty cycle.
7. Set the operating parameters of the EUT including power level, operating frequency, modulation and bandwidth.
8. Set the signal analyzer 1 center frequency to the nominal EUT channel center frequency. The span range of the signal analyzer shall be between two times and five times the OBW of EUT.
9. Monitor the signal analyzer 1 to verify if AWGN signal has been detected and EUT has ceased transmission. If the EUT continues to transmit, then incrementally increase the AWGN signal power level until the EUT stops transmitting.
10. Determine and record the AWGN signal power level at which the EUT ceased transmission. Repeat the procedure at least 10 times to verify the EUT can detect the AWGN signal with 90% (or better) level of certainty.
11. Refer to Table 1 to determine number of times the detection threshold testing needs to be repeated. If testing is required more than once, then go back to step 1, choose a different center frequency for the AWGN signal and repeat the process.

J. In-Band Emissions (Mask Figure 5)

1. Connect output of the antenna port to a spectrum analyzer or EMI receiver, with appropriate attenuation, as to not damage the instrumentation.
2. Set the reference level of the measuring equipment in accordance with procedure 4.1.5.2 of ANSI C63.10-2013.
3. Measure the 26 dB EBW using the test procedure 12.4.1 of ANSI C63.10-2013. (This will be used to determine the channel edge.)
4. Measure the power spectral density (which will be used for emissions mask reference) using the following procedure:
   a) Set the span to encompass the entire 26 dB EBW of the signal.
   b) Set RBW = same RBW used for 26 dB EBW measurement.
   c) Set VBW ≥ 3 X RBW
   d) Number of points in sweep ≥ [2 X span / RBW].
   e) Sweep time = auto.
   f) Detector = RMS (i.e., power averaging)
   g) Trace average at least 100 traces in power averaging (rms) mode.
   h) Use the peak search function on the instrument to find the peak of the spectrum.
5. For the purposes of developing the emission mask, the channel bandwidth is defined as the 26 dB EBW or 99% of the occupied bandwidth.
6. Using the measuring equipment limit line function, develop the emissions mask based on the following requirements. The emissions power spectral density must be reduced below the peak power spectral density (in dB) as follows:

a) Suppressed by 20 dB at 1 MHz outside of the channel edge. (The channel edge is defined as the 26-dB point on either side of the carrier center frequency.)

b) Suppressed by 28 dB at one channel bandwidth from the channel center.

c) Suppressed by 40 dB at one- and one-half times the channel bandwidth from the channel center.

7. Adjust the span to encompass the entire mask as necessary.
8. Clear trace.
9. Trace average at least 100 traces in power averaging (rms) mode.
10. Adjust the reference level as necessary so that the crest of the channel touches the top of the emission mask.

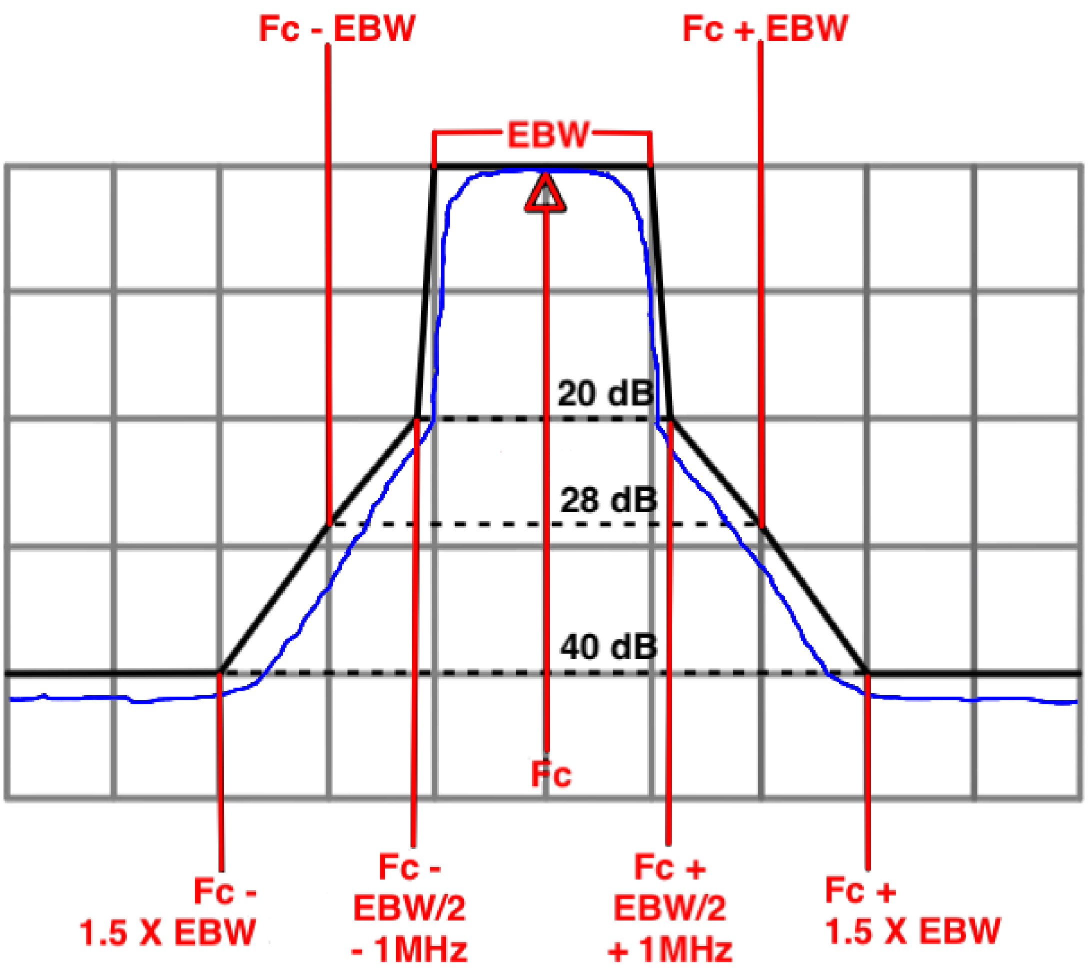

Figure 5. Generic Emission Mask

If a device utilizes channel puncturing the following additional requirements shall be met.

1. Standard Power Devices:

   a. The device shall meet the FCC mask for the full nominal bandwidth regardless of whether the punctured channel portion is at the channel edge or internal to the channel. As an example, if a 40 megahertz sub-channel is punctured from a 160 megahertz channel, this new configuration shall still meet the FCC mask based on a 160 megahertz nominal bandwidth; i.e., at the edges of the nominal channel. Nominal bandwidth as defined here refers to 20, 40, 80, 160 & 320 megahertz bandwidths. Test data shall be provided for each nominal bandwidth capable of puncturing with at least one configuration where the puncturing is at the outer edge of the nominal bandwidth and several configurations where the puncturing is internal to the nominal bandwidth (puncturing using 20*N subchannels, where N is an integer). The mask is constructed based on 26 dB bandwidth; and

   b. The device, when deployed must comply with all the AFC requirements; i.e., the power transmitted within the punctured region must be at or below the power that an AFC would permit for transmitting across the punctured channels' bandwidth.

2. Low Power Indoor Devices: Channel puncturing is not permitted because, unlike standard power devices which receive channel/power information from the AFC, LPI devices have no such mechanism for ascertaining the level of suppression needed in the punctured region to protect incumbent operations.

K. Dual Client Test, Demonstration of Proper Power Adjustment based on Associated AP

A client device may connect to a Standard Power AP with a maximum power level of 30 dBm EIRP. A client may also connect to a Low Power indoor AP, but the power level is limited to a maximum of 24 dBm EIRP. If a client has the flexibility to connect to both APs, verification is needed to show that it can distinguish between the two configurations, and then control the power levels accordingly.

TEST PROCEDURE:

1. Connect equipment as shown in Figure 6 below.
2. Adjust Atten 2 to Std Power AP so as to facilitate error free communication with the Client (Atten 1 should be set to High on the RF path to the Low Power AP).
3. Configure the Client and APs so that they associate and start sending data (stream data). It is important that the client is configured to transmit at its highest power level. Initially, because the attenuation on Atten 1 is set high, the Client will only associate with the Std Power AP.
4. Verify transmission between Client and Std Power AP. Additional attenuators may be required to protect measurement equipment. Measure the Client RF power using any of the methods in C63.10 for NII devices.
5. Gradually increase Atten 2 while at the same time decreasing Atten 1. This simulates the Client moving from outdoors to indoors. At some level of attenuation the Client should associate with the Low Power indor AP. Verify transmission between Client and Low Power AP.
6. Measure the RF power of the Client device using the same method as in step 4. Verify the power is no more than 24 dBm EIRP.
   Note – measuring Client RF power reliably from a directional coupler measurement port may be tricky. Due to coupling, some energy from the AP will show up on the measurement port. Signal isolation techniques on the measurement analyzer will need to be used.

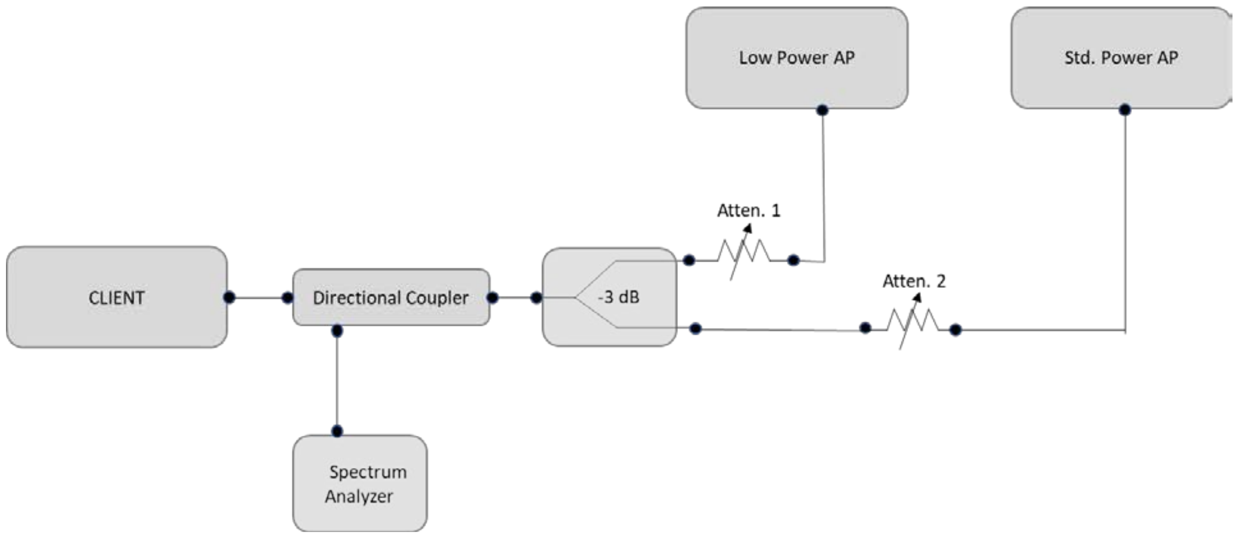

Figure 6. Test setup for conducted testing

L. Proper Power Adjustment, Client Devices Connected to a Standard Power Access Point

A client device that connects to a Standard Power AP must limit its power to a minimum of 6 dB lower than its associated Standard Power access point's authorized transmit power. The term "authorized" means the AFC-approved power level for the AP to use on a particular channel.

Test procedure to show that the client device can lower its power accordingly.

TEST PROCEDURE:

1. Connect equipment as shown in Figure 7 below.
2. Adjust Atten 1 to Std Power AP so as to facilitate error free communication with the Client but protect the Client receiver from overload or damage.
3. Configure the Client and AP so that they associate and start sending data (stream data). The AP should be configured such that its registered power is 36 dBm EIRP.
4. Verify transmission between Client and Std Power AP. Additional attenuators may be required to protect measurement equipment. Measure the Client RF power using any of the methods in C63.10 for NII devices. Use this power, along with its antenna gain, to calculate the Client EIRP.
5. The Client EIRP should be minimally 6 dB lower than that of the AP.
6. Repeat Steps 2 through 5 at two other selected measurement points – the first at the midpoint and the second at the lowest rated power of the client as declared by the manufacturer.

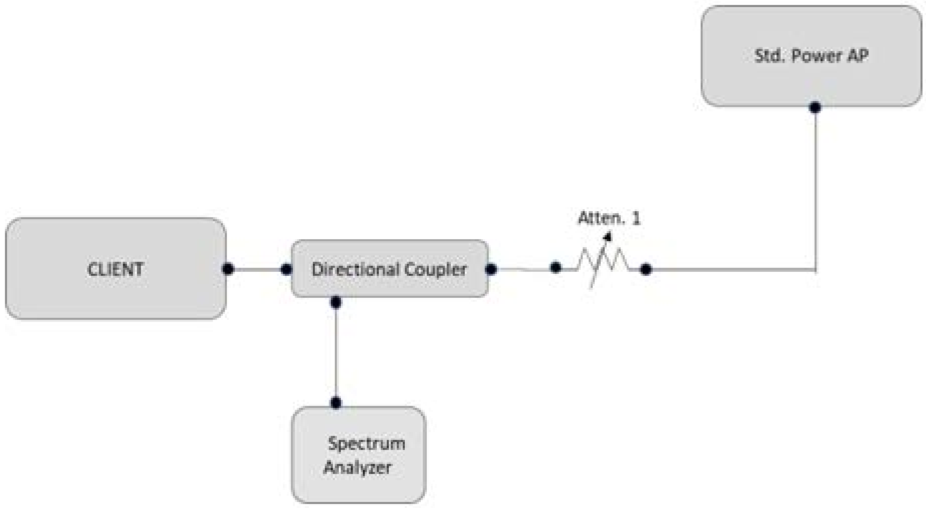

Figure 7. Test setup for conducted testing

Change Notice:
02/04/2021: 987594 D02 U-NII 6GHz EMC Measurement v01r01 replaces 987594 D02 U-NII 6GHz EMC Measurement v01. Changes to the document include the following:

- Added additional qualifiers to the statement “unlicensed low power indoor devices must vacate the channel (in which incumbent signal is transmitted) and stay off the incumbent channel as long as detected radio frequency power is equal to or greater than the threshold (-62 dBm).” to clarify the unlicensed low power indoor devices must vacate only the channel that is occupied by the incumbent signal.
- Added footnote 1 on page 4 to emphasize unlicensed low power indoor devices must always use contention-based protocol and on every channel, it intends to transmit, including on the same channel(s) previously used after any continuous transmission ends.

08/7/2023: 987594 D02 U-NII 6 GHz EMC Measurement v02 replaces 987594 D02 U-NII 6 GHz EMC Measurement v01r01. Phase 2 restriction removed .

08/9/2023: 987594 D02 U-NII 6 GHz EMC Measurement v02r01 replaces 987594 D02 U-NII 6 GHz EMC Measurement v02. Phase 2 restriction removed . Clarified section II. MEASUREMENT PROCEDURES section L. From “a Standard Power AP must limit its power to no more than 6 dB below its associated Standard Power access point's authorized transmit power” to “ a Standard Power AP must limit its power to a minimum of 6 dB lower than its associated Standard Power access point's authorized transmit power” and clarified TEST PROCEDURE: step 6 from “one at the midpoint and the second at the lower end of the operating power range of the client” to “ the first at the midpoint and the second at the lowest rated power of the client as declared by the manufacturer”.