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SAR GUIDANCE FOR IEEE 802.11 (Wi-Fi) TRANSMITTERS

1. INTRODUCTION

The SAR evaluation guidance provided in this document is intended for Wi-Fi® devices authorized under §§15.247 and 15.407 of Commission rules in the 2.4 GHz and 5 GHz bands that are implemented according to IEEE Std 802.11-2012 (802.11 a/b/g/n) and IEEE Std 802.11ac-2013.[1] The guidance in this KDB publication does not apply to Wi-Fi devices that are subject to other FCC rule parts or using variants of the IEEE 802.11 protocols.[2] The test procedures in this document are applicable to Wi-Fi transmitters operating in consumer products that require SAR evaluation.[3]

Wi-Fi technology has evolved from the simple frequency hopping and DSSS configurations at 2.4 GHz to today's highly complex OFDM implementations for 802.11a/g/n and 802.11ac. Numerous combinations of signal modulations, data rates, channel bandwidths and multiple antenna transmission schemes are included in IEEE 802.11 protocols to provide substantial flexibility for improving coverage and data throughput. As new generation Wi-Fi products continue to emerge, coexistence with previously deployed devices is necessary to maintain migration continuity. Compatibility with older products may require typical Wi-Fi devices to support both 2.4 GHz and some or all of the 5 GHz bands. Without streamlining the SAR test requirements, measurements for hundreds of Wi-Fi transmission configurations are required to demonstrate compliance.

For many devices, the maximum output power specifications, simultaneous transmission schemes or other operating parameters may vary across transmission modes and operating configurations in a frequency band; therefore, additional guidance beyond the basic procedures is necessary for SAR measurement. This KDB publication provides procedures for the most common implementations of Wi-Fi protocols; when ad hoc or proprietary configurations are used additional guidance from the FCC may be necessary. The fundamental SAR measurement procedures and reporting requirements are described, respectively, in KDB Publication 865664 D01 and D02. The SAR test requirements for product platform and technology specific configurations are described in the KDB publications identified in KDB Publication 447498 D01.[4] The guidance in these publications also applies to Wi-Fi devices. This KDB publication covers the most common types of SAR test configurations. For configurations that are not included here or using special implementations, a KDB inquiry is required to obtain further guidance. In the following clauses and subclauses, the general SAR measurement considerations and frequency

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[1] Wi-Fi® is a trademark of *Wi-Fi Alliance*.

[2] This KDB Publication does not fully apply to Wi-Fi devices operating in the 4.94 – 4.99 GHz band, with respect to §§90.1213 and 90.1215, or other 802.11 related frequency bands such as the 5.85 – 5.925 GHz band in §90.377 for OBU/RSU or Part 15 subpart H; further consideration is required. Also, see Appendix A for handling special Wi-Fi usage modes like Wi-Fi Direct and TDLS.

[3] Evaluation includes addressing RF exposure compliance by analysis, SAR test exclusion, measurement or other acceptable methods.

[4] See Introduction section of KDB Publication 447498 D01.

band specific test requirements are first discussed, followed by the power and SAR measurement procedures. While 1-g SAR thresholds are specified in the procedures for SAR test reduction and exclusion, these thresholds should be multiplied by 2.5 when 10-g extremity SAR is considered.

2. GENERAL SAR MEASUREMENT CONSIDERATIONS

A brief summary of the 802.11 PHY and typical peer-to-peer Wi-Fi configurations, such as TDLS, Mesh Services and Wi-Fi Direct, is included in Appendix A to identify applicable wireless configurations, modulations and data rates etc. that need consideration to apply the SAR measurement procedures. Transmit diversity, Multiple-Input-Multiple-Output (MIMO) and Transmit Beam Forming (TxBF) configurations typically used in Wi-Fi transmitters are also summarized in Appendix A. The 5 GHz 802.11 channel configurations are illustrated in Appendix B. SAR measurement for standalone peer-to-peer configurations is generally not necessary provided the Wi-Fi transmission is not coordinated with other transmitters; for example, 3G/4G operations, or supporting additional exposure conditions. When simultaneous transmission is supported for Wi-Fi in multiple frequency bands or in conjunction with other wireless technologies, SAR compliance must be determined according to the applicable exposure conditions and SAR test positions for each simultaneous transmission configuration. For OFDM transmission modes, the SAR system validation procedures in KDB Publication 865664 D01 must be applied to address high peak to average power ratio SAR probe calibration and measurement concerns.

2.1 SAR Measurement and Test Reduction Configurations

The SAR measurement and test reduction procedures are structured according to either the DSSS or OFDM transmission mode configurations used in each standalone frequency band and aggregated band. For devices that operate in exposure configurations that require multiple test positions, additional SAR test reduction may be applied. The maximum output power specified for production units, including tune-up tolerance, are used to determine initial SAR test requirements for the 802.11 transmission modes in a frequency band. SAR is measured using the highest measured maximum output power channel for the initial test configuration (see 5.3.2 and 5.3.3). SAR measurement and test reduction for the remaining 802.11 modes and test channels are determined according to measured or specified maximum output power and *reported* SAR of the initial measurements. The general test reduction and SAR measurement approaches are summarized in the following:

a) The maximum output power specified for production units are determined for all applicable 802.11 transmission modes in each standalone and aggregated frequency band. Maximum output power is measured for the highest maximum output power configuration(s) in each frequency band according to the default power measurement procedures (see Clause 4).
b) For OFDM transmission configurations in the 2.4 GHz and 5 GHz bands, an "initial test configuration" (see 5.3.2) is first determined for each standalone and aggregated frequency band according to the maximum output power and tune-up tolerance specified for production units.
    1) When the same maximum power is specified for multiple transmission modes in a frequency band, the largest channel bandwidth, lowest order modulation, lowest data rate and lowest order 802.11a/g/n/ac mode is used for SAR measurement, on the highest measured output power channel in the initial test configuration, for each frequency band.
    2) SAR is measured for OFDM configurations using the initial test configuration procedures (see 5.3.3). Additional frequency band specific SAR test reduction may be considered for individual frequency bands (see 5.2.2 and 5.3.1).
    3) Depending on the *reported* SAR of the highest maximum output power channel tested in the initial test configuration, SAR test reduction may apply to subsequent highest output channels in the initial test configuration to reduce the number of SAR measurements.

c) The Initial test configuration does not apply to DSSS. The 2.4 GHz band SAR test requirements (see 3.1) and 802.11b DSSS procedures (see 5.2.1) are used to establish the transmission configurations required for SAR measurement.

d) An "initial test position" (see 5.1) is applied to further reduce the number of SAR tests for devices operating in next to the ear, UMPC mini-tablet or hotspot mode exposure configurations that require multiple test positions.
   1) SAR is measured for 802.11b according to the 2.4 GHz DSSS procedure (see 5.2.1) using the exposure condition established by the initial test position.
   2) SAR is measured for 2.4 GHz and 5 GHz OFDM configurations using the initial test configuration.

e) The Initial test position does not apply to devices that require a fixed exposure test position. SAR is measured in a fixed exposure test position for these devices in 802.11b according to the 2.4 GHz DSSS procedure (see 5.2.1) or in 2.4 GHz and 5 GHz OFDM configurations using the initial test configuration procedures (see 5.3.3).

f) The "subsequent test configuration" (see 5.3.4) procedures are applied to determine if additional SAR measurements are required for the remaining OFDM transmission modes that have not been tested in the initial test configuration. SAR test exclusion is determined according to *reported* SAR in the initial test configuration and maximum output power specified or measured for these other OFDM configurations.

2.2 Duty Factor Control

Wi-Fi transmitters are designed to operate seamlessly across networks where traffic conditions are asynchronous and dynamic. Collision avoidance and retransmission of error packets are part of the network behavior, which can result in substantial variations in transmission patterns. The random transmission characteristics of Wi-Fi networks are not suitable for configuring devices to support SAR measurements. Loopback test modes similar to those used by 3G/4G WWAN transmitters are not defined in 802.11 protocols. Various vendor specific external test software and chipset based internal test modes are typically used for SAR measurement. These chipset based test mode utilities are generally hardware and manufacturer dependent, and often include substantial flexibility to reconfigure or reprogram a device. It must be ensured that the unmodified settings in production units, including maximum output power, amplifier gain and other RF performance or tuning parameters, are used for SAR measurement.

A Wi-Fi device must be configured to transmit continuously at the required data rate, channel bandwidth and signal modulation, using the highest transmission duty factor supported by the test mode tools for SAR measurement. The test frequencies established using test mode must correspond to the actual channel frequencies required for operations in the U.S. When 802.11 frame gaps are accounted for in the transmission, a maximum transmission duty factor of 92 - 96% is typically achievable in most test mode configurations. A minimum transmission duty factor of 85% is required to avoid certain hardware and device implementation issues related to wide range SAR scaling. In addition, a periodic transmission duty factor is required for current generation SAR systems to measure SAR correctly. Unless it is permitted by specific KDB procedures or continuous transmission is specifically restricted by the device, the *reported* SAR must be scaled to 100% transmission duty factor to determine compliance at the maximum tune-up tolerance limit. When a device is not capable of sustaining continuous transmission or the output can become nonlinear, and it is limited by hardware design and unable to transmit at higher than 85% duty factor, a periodic duty factor within 15% of the maximum duty factor the device is capable of transmitting should be used. The *reported* SAR must be scaled to the maximum transmission duty factor to determine compliance. Descriptions of the procedures applied to establish the specific duty factor used for SAR testing are required in SAR reports to support the test results.

2.3 SAR Probe Calibration Requirements

To adequately cover the 5 GHz bands, SAR probes used for testing Wi-Fi devices should be calibrated with at least ± 100 MHz coverage, according to the tissue dielectric parameter requirements in KDB Publication 865664 D01, to minimize the number of probe calibration points required. The SAR system validation dipoles must be calibrated within the frequency range covered by the probe calibration points required for device testing, according to KDB Publication 865664 D01 requirements. The SAR probe calibration frequencies indicated in Table 1 may be considered to reduce the number of calibration frequency points. The probe calibration point at 5.60 GHz is expected to be marginal for the bandedge channels in U-NII-2C (standalone) band. The U-NII-2C band is 200 MHz (5.5 – 5.7 GHz) wide between the channel center frequencies of the bandedge channels and 220 MHz (5.49 – 5.71 GHz) after accounting for channel bandwidth. Therefore, when a bandedge channel is tested, the tissue dielectric parameters must be within 5% of the required targets at the test frequency and the SAR error compensation provisions described in KDB Publication 865664 D01 for allowing up to 10% tissue parameter tolerance should not be applied. Aggregating the portion of U-NII-2C band above 5.65 GHz with 5.8 GHz U-NII-3 or §15.247 band to use a single SAR probe calibration point at 5.75 GHz is optional; test labs may continue to use multiple probe calibration frequency points according to KDB Publication 865664 D01 requirements.

Table 1

Probe Calibration Frequency (GHz)	Wi-Fi Bands	Frequency Range	
		Channels	Calibration
		GHz	MHz
5.25	U-NII-1, U-NII-2A	5.17 – 5.33	± 80
5.60	U-NII-2C (standalone)	5.49 – 5.71	± 110
	U-NII-2C (< 5.65 GHz)*	5.49 – 5.65	-110/+50
5.75	U-NII-3, §15.247 (standalone)	5.735 – 5.835	-15/+85
	U-NII-2C (> 5.65 GHz) + U-NII- 3 or §15.247 across band gap	5.65 – 5.835	-100/+85

* Aggregating U-NII-2C and U-NII-3 or 5.8 GHz §15.247 bands is optional. The portion above 5.65 GHz in U-NII-2C band is tested using the 5.75 GHz probe calibration point; see 3.3. Test labs may continue to use multiple SAR probe calibration frequency points according to KDB 865664 D01requirements.

3. FREQUENCY BAND SPECIFIC TEST CONSIDERATIONS

SAR test requirements may vary for different wireless protocols and FCC rule requirements. The SAR test configurations required for Wi-Fi measurements are organized according to 802.11 transmission modes, as either DSSS or OFDM. The procedures are applied to each standalone and aggregated frequency band according to channel bandwidths and exposure conditions (i.e., operating configurations and exposure test positions). For purpose of SAR evaluation, simultaneously transmitting two non-contiguous channels or contiguous but independent and non-aggregated channels, regardless of using the same or different channel bandwidth, is not equivalent to transmitting a single contiguous channel. Two non-contiguous 80 MHz channels in 802.11ac VHT is not equivalent to a 160 MHz channel; these must be considered separately for SAR compliance. The SAR procedures also provide the option to support measurements across selected adjacent frequency bands that are within the frequency range covered by one or more SAR probe calibration points to streamline the SAR measurement. The frequency band specific SAR test configurations are described in this clause.

3.1 2.4 GHz Band (§15.247)

The maximum output power permitted for devices authorized under §15.247 is 1 W conducted and 36 dBm EIRP.[5] Within the frequency range of 2400 – 2483.5 MHz, currently a total of 13 channels may be used in the U.S. However, non-overlapping frequency channels are necessary to minimize interference degradation; therefore, channels 1, 6 and 11 are used most often. Channels 12 and 13, in general, require reduced output power to satisfy bandedge radiated field strength requirements at 2483.5 MHz. Provided higher maximum output power is not specified for the other channels, channels 1, 6 and 11 are used to configure 22 MHz DSSS and 20 MHz OFDM channels for SAR measurements; otherwise, the closest adjacent channel with the highest maximum output power specified for production units should be tested instead of channels 1, 6 or 11.[6] When 40 MHz channels are supported, and provided higher maximum output power is not specified for other applicable 40 MHz channels, channel 6 is used to measure SAR; otherwise, the channel with highest specified maximum output power should be tested instead. In addition, SAR test reduction with respect to *reported* SAR and transmission band width according to 4.3.3 of KDB Publication 447498 D01 may also be applied.

3.2 U-NII-1 and U-NII-2A Bands (§15.407)

The maximum output power permitted for devices authorized under §15.407 U-NII-1 band (5.15 – 5.25 GHz), is 250 - 1000 mW conducted and 21 – 36 dBm EIRP, depending on transmitter configurations and antenna operating requirements.[7] For U-NII-2A band (5.25 – 5.35 GHz), the maximum output power is 250 mW conducted and 30 dBm EIRP. When applicable, a lower maximum output power may be required to satisfy emission bandwidth restrictions for these bands. When both bands apply to a device, SAR test reduction may be considered for each exposure configuration according to procedures in 5.3.1.

3.3 U-NII-2C, U-NII-3 Bands (§15.407) and 5.8 GHz Band (§15.247)

The maximum output power permitted for devices authorized under §15.407 U-NII-2C band (5.470 – 5.725) is 250 mW conducted and 30 dBm EIRP. For U-NII-3 band (5.725 – 5.850 GHz) the maximum output power permitted is 1 W conducted and 36 dBm EIRP.[8] When applicable, a lower maximum output power may be required due to emission bandwidth restrictions for these bands. In addition, when

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[5] As described in KDB Publication 447498 D01, EIRP may not be relevant for evaluating SAR of small portable transmitters designed to operate next to persons.

[6] Channels 1, 6 and 11 are each considered separately to determine the closest adjacent channel with higher output power.

[7] The FCC adopted new rules for U-NII-1 band in ET Docket No. 13-49 (FCC 14-30; U-NII Order). The rules permit devices to be approved under previous rules where the maximum power is limited to 50 mW conducted and 23 dBm EIRP. New devices may be approved under the old rules till June 1, 2015. See KDB Publication 926956 D01 for U-NII Transition Plan. The new rules also permit point-to-point operations for antenna gain up to 23 dBi at 1.0 W conducted maximum power; however, SAR and portable exposure conditions typically do not apply to point-to-point configurations. To satisfy SAR limit, it may be necessary for some devices to operate at maximum output power levels less than that permitted by the rules.

[8] The U-NII Order also removed §15.247 rules for devices operating in the 5.725 – 5.850 GHz band. The transition rules permit new devices to be approved under the previous rules till December 2, 2015 (FCC-15-61A). See KDB Publication 926956 D01 for further information. For point-to-point operations, up to 23 dBi antenna gain at 1.0 W conducted maximum power is permitted for U-NII-3 band; however, SAR and portable exposure conditions typically do not apply to point-to-point configurations. For some devices, lower than permitted maximum output power may be necessary to meet SAR limit.

Terminal Doppler Weather Radar (TDWR) restriction applies (for permissive change only), the channels at 5.60 – 5.65 GHz in U-NII-2C band must be disabled with acceptable mechanisms and documented in the equipment certification to avoid SAR requirements.[9] TDWR restriction does not apply under the new rules; all channels that operate at 5.60 – 5.65 GHz must be included to apply the SAR test reduction and measurement procedures.

When the same transmitter and antenna(s) are used for U-NII-2C band and U-NII-3 band or 5.8 GHz band of §15.247, the bands may be aggregated to enable additional channels with 20, 40 or 80 MHz bandwidth to span across the band gap, as illustrated in Appendix B. The maximum output power for the additional band gap channels is limited to the lower of those certified for the bands. Unless band gap channels are permanently disabled, they must be considered for SAR testing. The frequency range covered by these bands is 380 MHz (5.47 – 5.85 GHz), which requires a minimum of at least two SAR probe calibration frequency points to support SAR measurements. The typical SAR probe calibration point in this frequency range should cover at least ± 100 MHz. The difference in tissue-equivalent media conductivity among the bands is about 8%, which is larger than the 5% tissue dielectric tolerance required for SAR probe calibration (see 2.3). To maintain SAR measurement accuracy and to facilitate test reduction, the channels in U-NII-2C band above 5.65 GHz may be grouped with the 5.8 GHz channels in U-NII-3 or §15.247 band to enable two SAR probe calibration frequency points to cover the bands, including the band gap channels.[10] When band gap channels are supported and the bands are not aggregated for SAR testing, band gap channels must be considered independently in each band according to the normally required OFDM SAR measurement and probe calibration frequency points requirements.

A single 160 MHz channel may be supported by U-NII-2C band for client devices that are certified to operate at 5.60 – 5.65 GHz without TDWR restriction. Band aggregation for 160 MHz channel across U-NII-2C and U-NII-3 bands is not defined in IEEE Std 802.11ac-2013 for VHT; however, transmitters may operate with proprietary implementations to transmit across the bands. When applicable, these types of implementations and configurations must be taken into consideration to determine SAR compliance. A KDB inquiry is necessary to determine the test configurations.

4. POWER MEASUREMENT REQUIREMENTS

The maximum output power of typical 802.11 transmitters may vary with transmission modes, frequency bands, antenna implementation and operating conditions. The peak to average output power ratio of signals in different transmission modes is typically a function of channel bandwidth and transmission scheme. While different modulations may be applied to the raw data bits in DSSS and OFDM, for example, BPSK, CCK, PBCC, ERP, QPSK, 16- to 256-QAM, etc., these are generally not expected to have significant influence to the DSSS or OFDM RF output characteristics and SAR. The choice of modulation and data rate used in SAR measurements is mostly for maintaining test configuration consistency.

Maximum output power must be measured according to the default power measurement procedures in this clause. When SAR measurement is required, power measurement is also required to confirm output power settings and to determine ***reported*** SAR according to procedures in KDB Publication 447498 D01. Additional power measurements may be necessary to determine SAR test reduction for test channels in a transmission mode. When different maximum output power is specified across the channels in a Wi-Fi transmission mode, a KDB inquiry should be considered to verify the test requirements. If the required

[9] Provisions for excluding TDWR channels in U-NII-2C band expire after June 1, 2015 for new device approvals and June 1, 2016 for permissive changes.

[10] Aggregating U-NII-2C band with 5.8 GHz U-NII-3 or §15.247 band is optional. Test labs may continue to use multiple SAR probe calibration frequency points according to KDB Publication 865664 D01 requirements.

power measurement is not included in the default configurations, it is typically measured immediately before and/or after the SAR measurement. Otherwise, when power measurement is not required for a transmission mode, the maximum output power and tune-up tolerance specified for production units can generally be used to determine SAR test exclusion and reduction.

The default power measurement procedures are:

a) Power must be measured at each transmit antenna port according to the DSSS and OFDM transmission configurations in each standalone and aggregated frequency band.
b) Power measurement is required for the transmission mode configuration with the highest maximum output power specified for production units.[11]
    1) When the same highest maximum output power specification applies to multiple transmission modes, the largest channel bandwidth configuration with the lowest order modulation and lowest data rate is measured.
    2) When the same highest maximum output power is specified for multiple largest channel bandwidth configurations with the same lowest order modulation or lowest order modulation and lowest data rate, power measurement is required for all equivalent 802.11 configurations with the same maximum output power.[12]
c) For each transmission mode configuration, power must be measured for the highest and lowest channels; and at the mid-band channel(s) when there are at least 3 channels.   For configurations with multiple mid-band channels, due to an even number of channels, both channels should be measured.

5. SAR TEST PROCEDURES

SAR test reduction is determined according to 802.11 transmission mode configurations and certain exposure conditions with multiple test positions. In the 2.4 GHz band, separate SAR procedures are applied to DSSS and OFDM configurations to simplify DSSS test requirements. For OFDM, in both 2.4 and 5 GHz bands, an <u>initial test configuration</u> must be determined for each standalone and aggregated frequency band, according to the transmission mode configuration with the highest maximum output power specified for production units to perform SAR measurements. If the same highest maximum output power applies to different combinations of channel bandwidths, modulations and data rates, additional procedures (see 5.3.2) are applied to determine which test configurations require SAR measurement. When applicable, an <u>initial test position</u> may be applied to reduce the number of SAR measurements required for next to the ear, UMPC mini-tablet or hotspot mode configurations with multiple test positions. For 2.4 GHz 802.11b DSSS, either the <u>initial test position</u> procedure for multiple exposure test positions or the DSSS procedure for fixed exposure position is applied; these are mutually exclusive. For 2.4 GHz and 5 GHz OFDM configurations, the <u>initial test configuration</u> is applied to measure SAR using either the <u>initial test position</u> procedure for multiple exposure test position configurations or the <u>initial test configuration</u> procedures for fixed exposure test conditions. Based on the <u>*reported*</u> SAR of the measured configurations and maximum output power of the transmission mode configurations that are not included in the <u>initial test configuration</u>, the <u>subsequent test configuration</u> and <u>initial test position</u> procedures are applied to determine if SAR measurements are required for the remaining OFDM transmission configurations. In general, the number of test channels that require SAR measurement is minimized based on maximum output power measured for the test sample(s).

[11] The Wi-Fi transmission modes include all channel bandwidth, modulation and data rate combinations for the 802.11a/g/n/ac OFDM configurations in a standalone or aggregated frequency band. For 2.4 GHz, 802.11b DSSS and 802.11g/n OFDM configurations are considered separately.

[12] The procedure in item 4) of section 5.3.2 for selecting equivalent OFDM configurations does not apply to power measurement.

5.1 Multiple Exposure Test Position SAR Test Reduction

The following procedures are applied to select an initial test position for handsets operating next to the ear, hotspot mode or UMPC mini-tablet configurations to minimize the number of SAR measurements normally required for the multiple test positions.[13] SAR is measured for the highest measured maximum output power channel using the initial test position. The *reported* SAR and power measurement results are used to determine if SAR measurements are required for the other exposure positions and test channels.

The relative SAR levels of multiple exposure test positions can be established by area scan measurements on the highest measured output power channel to determine the initial test position.[14] The area scans must be measured using the same SAR measurement configurations, including test channel, maximum output power, probe sensor to phantom shell distance, scan resolution etc. for the results to be comparable. The highest SAR at each peak SAR location is extrapolated to the phantom surface. The exposure test position with the highest extrapolated SAR is used for the initial test position. Instead of extrapolated SAR, the 1-g estimated SAR procedures (fast SAR) in KDB Publication 447498 D01 may be used instead. The extrapolated or 1-g estimated SAR must be scaled according to *reported* SAR requirements to determine the most conservative exposure test position.

As an alternative, when antenna location and implementation details, such as antenna orientation, polarization and other design and performance details, are available from device manufacturers to determine the test separation distance between the outer surfaces of a device and the phantom, at the geometric center of the Wi-Fi antenna, and antenna to phantom RF coupling conditions, a test lab may consider using such information to determine the initial test position.[15] However, if the required information is unavailable, insufficient or the test separation distance and antenna to phantom RF coupling conditions of multiple test positions are indistinguishable, area scans must be measured to determine the initial test position. Explanations of how the initial test position is established must be clearly described in the SAR report for results to be acceptable.

a) Head Exposure Configuration: The left, right, touch and tilt test positions for next to ear exposure testing using the SAM phantom may be considered collectively as one head exposure configuration to facilitate initial test position SAR test reduction. The initial test position is determined according to area scans or by the side (left or right) of the SAM phantom and test position (touch or tilt) with the smallest test separation distance from the device outer surface, at the Wi-Fi antenna location, to the SAM phantom and maximum antenna to phantom RF coupling conditions.
b) Hotspot mode and UMPC mini-tablets: The surfaces and edges that require SAR measurement in hotspot mode or UMPC mini-tablet configuration may be considered collectively as one exposure configuration to facilitate SAR test reduction. The initial test position is determined according to area scans or by the test position with the smallest test separation distance from the device outer surface, at

[13] The initial test position test reduction considerations are based on the range of output power, exposure and use configurations for Wi-Fi transmitters used in typical consumer products and host configurations. The SAR margins identified for Wi-Fi are not applicable to WWAN or other transmitters operating at higher output power levels or different conditions. Due to differences in SAR measurement requirements the initial test position procedure is not applicable to full size tablets tested according to KDB Publication 616217 D04.

[14] When necessary, apply the procedures in section 5.3.2 to determine the maximum output power channel.

[15] Instead of using the geometric center of a Wi-Fi antenna, locations within the antenna structure that are demonstrated to be equivalent or more conservative may be used. This alternative must be fully justified by the transmitter manufacturer and clearly explained in test reports, according to antenna design and device implementation requirements, to demonstrate separation distance and RF coupling conservativeness among the exposure test positions; otherwise, area scan measurements are required to determine the initial test position.

the Wi-Fi antenna location, to the flat phantom and maximum antenna to phantom RF coupling conditions.

5.1.1 Initial Test Position SAR Test Reduction Procedure

DSSS and OFDM configurations are considered separately according to the required SAR procedures. SAR is measured in the initial test position using the 802.11 transmission mode configuration required by the DSSS procedure or initial test configuration and subsequent test configuration(s) according to the OFDM procedures.[16] The initial test position procedure is described in the following:

a) When the *reported* SAR of the initial test position is ≤ 0.4 W/kg, further SAR measurement is not required for the other (remaining) test positions in that exposure configuration and 802.11 transmission mode combinations within the frequency band or aggregated band. SAR is also not required for that exposure configuration in the subsequent test configuration(s).
b) When the *reported* SAR of the initial test position is > 0.4 W/kg, SAR is repeated for the 802.11 transmission mode configuration tested in the initial test position using subsequent highest extrapolated or estimated 1-g SAR conditions determined by area scans or next closest/smallest test separation distance and maximum RF coupling test positions based on manufacturer justification, on the highest maximum output power channel, until the *reported* SAR is ≤ 0.8 W/kg or all required test positions (left, right, touch, tilt or subsequent surfaces and edges) are tested.[17]
c) For all positions/configurations tested using the initial test position and subsequent test positions, when the *reported* SAR is > 0.8 W/kg, SAR is measured for these test positions/configurations on the subsequent next highest measured output power channel(s) until the *reported* SAR is ≤ 1.2 W/kg or all required channels are tested.
   Additional power measurements may be required for this step, which should be limited to those necessary for identifying the subsequent highest output power channels.

5.2 2.4 GHz SAR Procedures

Separate SAR procedures are applied to DSSS and OFDM configurations in the 2.4 GHz band to simplify DSSS test requirements. For 802.11b DSSS SAR measurements, DSSS SAR procedure applies to fixed exposure test position and initial test position procedure applies to multiple exposure test positions. When SAR measurement is required for an OFDM configuration, the initial test configuration, subsequent test configuration and initial test position procedures are applied. The SAR test exclusion requirements for 802.11g/n OFDM configurations are described in 5.2.2.

5.2.1 802.11b DSSS SAR Test Requirements

SAR is measured for 2.4 GHz 802.11b DSSS using either a fixed test position or, when applicable, the initial test position procedure. SAR test reduction is determined according to the following:

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[16] For OFDM, the initial test position applies to both the initial test configuration and subsequent test configuration(s).

[17] The subsequent next highest SAR configuration in the 802.11 transmission mode, test position and exposure configuration determined by the initial test position area scans or according to manufacturer details is used. For example, if four area scans are performed to determine the initial test position with 0.8, 0.75, 0.72 and 0.7 W/kg, respectively, as the extrapolated (or 1-g estimated) SAR results scaled according to *reported* SAR procedures; the 0.8 W/kg configuration would correspond to the initial test position and, when SAR measurement is required, the other configurations (in descending SAR) would correspond to the subsequent test positions. The test lab should be able to minimize the number of area scans based on the *reported* SAR obtained from the first few area scans.

a) When the *reported* SAR of the highest measured maximum output power channel (see 3.1) for the exposure configuration is ≤ 0.8 W/kg, no further SAR testing is required for 802.11b DSSS in that exposure configuration.
b) When the *reported* SAR is > 0.8 W/kg, SAR is required for that exposure configuration using the next highest measured output power channel. When any *reported* SAR is > 1.2 W/kg, SAR is required for the third channel; i.e., all channels require testing.

5.2.2 2.4 GHz 802.11g/n OFDM SAR Test Exclusion Requirements

When SAR measurement is required for 2.4 GHz 802.11g/n OFDM configurations, the measurement and test reduction procedures for OFDM are applied (see 5.3, including subclauses). SAR is not required for the following 2.4 GHz OFDM conditions.

a) When KDB Publication 447498 D01 SAR test exclusion applies to the OFDM configuration.
b) When the highest *reported* SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and the adjusted SAR is ≤ 1.2 W/kg.

5.3 SAR Test Requirements for OFDM Configurations

When SAR measurement is required for 802.11 a/g/n/ac OFDM configurations, each standalone and aggregated frequency band is considered separately for SAR test reduction. When the same transmitter and antenna(s) are used for U-NII-1 and U-NII-2A bands, additional SAR test reduction applies. When band gap channels between U-NII-2C band and 5.8 GHz U-NII-3 or §15.247 band are supported and the aggregated band option of 2.3 and 3.3 is used, the highest maximum output power transmission mode configuration and maximum output power channel across the bands must be used to determine SAR test reduction, according to the initial test configuration and subsequent test configuration requirements.[18] In applying the initial test configuration and subsequent test configuration procedures, the 802.11 transmission configuration with the highest specified maximum output power and the channel within a test configuration with the highest measured maximum output power should be clearly distinguished to apply the procedures (see 5.3.2).

5.3.1 U-NII-1 and U-NII-2A Bands

For devices that operate in only one of the U-NII-1 and U-NII-2A bands, the normally required SAR procedures for OFDM configurations are applied. For devices that operate in both U-NII bands using the same transmitter and antenna(s), SAR test reduction is determined according to the following, with respect to the highest *reported* SAR and maximum output power specified for production units. The procedures are applied independently to each exposure configuration; for example, head, body, hotspot mode etc.

a) When the same maximum output power is specified for both bands, begin SAR measurement in U-NII-2A band by applying the OFDM SAR requirements.[19] If the highest *reported* SAR for a test configuration is ≤ 1.2 W/kg, SAR is not required for U-NII-1 band for that configuration (802.11 mode and exposure condition); otherwise, each band is tested independently for SAR.
b) When different maximum output power is specified for the bands, begin SAR measurement in the band with higher specified maximum output power. The highest *reported* SAR for the tested

[18] Band gap channels must satisfy the maximum output power and equipment certification requirements for both adjacent bands.

[19] The applicable procedures for OFDM configurations include the initial test configuration, initial test position and subsequent test configuration procedures.

configuration is adjusted by the ratio of lower to higher specified maximum output power for the two bands. When the adjusted SAR is ≤ 1.2 W/kg, SAR is not required for the band with lower maximum output power in that test configuration; otherwise, each band is tested independently for SAR.[20]

c) The two U-NII bands may be aggregated to support a 160 MHz channel on channel number 50. Without additional testing, the maximum output power for this is limited to the lower of the maximum output power certified for the two bands. When SAR measurement is required for at least one of the bands and the highest *reported* SAR adjusted by the ratio of specified maximum output power of aggregated to standalone band is > 1.2 W/kg, SAR is required for the 160 MHz channel. This procedure does not apply to an aggregated band with maximum output higher than the standalone band(s); the aggregated band must be tested independently for SAR. SAR is not required when the 160 MHz channel is operating at a reduced maximum power and also qualifies for SAR test exclusion.

5.3.2 OFDM Transmission Mode SAR Test Configuration and Channel Selection Requirements

The initial test configuration for 2.4 GHz and 5 GHz OFDM transmission modes is determined by the 802.11 configuration with the highest maximum output power specified for production units, including tune-up tolerance, in each standalone and aggregated frequency band. SAR for the initial test configuration is measured using the highest maximum output power channel determined by the default power measurement procedures (see Clause 4).

a) When multiple channel bandwidth configurations in a frequency band have the same specified maximum output power, the initial test configuration is determined by applying the following steps sequentially.
    1) The largest channel bandwidth configuration is selected among the multiple configurations in a frequency band with the same specified maximum output power.
    2) If multiple configurations have the same specified maximum output power and largest channel bandwidth, the lowest order modulation among the largest channel bandwidth configurations is selected.
    3) If multiple configurations have the same specified maximum output power, largest channel bandwidth and lowest order modulation, the lowest data rate configuration among these configurations is selected.
    4) When multiple transmission modes (802.11a/g/n/ac) have the same specified maximum output power, largest channel bandwidth, lowest order modulation and lowest data rate, the lowest order 802.11 mode is selected; i.e., 802.11a is chosen over 802.11n then 802.11ac or 802.11g is chosen over 802.11n.
b) After an initial test configuration is determined, if multiple test channels have the same measured maximum output power, the channel chosen for SAR measurement is determined according to the following. These channel selection procedures apply to both the initial test configuration and subsequent test configuration(s), with respect to the default power measurement procedures or additional power measurements required for further SAR test reduction. The same procedures also apply to subsequent highest output power channel(s) selection.
    1) The channel closest to mid-band frequency is selected for SAR measurement.
    2) For channels with equal separation from mid-band frequency; for example, high and low channels or two mid-band channels, the higher frequency (number) channel is selected for SAR measurement.

[20] For example, if the highest *reported* SAR in a 802.11 mode and exposure condition for U-NII-1 band is 1.4 W/kg and the specified maximum output power for U-NII-1 and U-NII-2A bands are 250 mW and 200 mW respectively, the adjusted SAR is 1.4 × 200/250 = 1.12 W/kg. The adjusted SAR is ≤ 1.2 W/kg; therefore, SAR is not required for that 802.11 mode configuration and exposure condition in U-NII-2A band.

An illustrative example applying the SAR test reduction and channel selection procedures for OFDM transmission mode configurations according to assumed maximum output power values is given in Appendix C. A power measurement template is also included and configurations with the same or different specified and measured maximum output power conditions are also shown in the example.

5.3.3 Initial Test Configuration Procedures

An initial test configuration is determined for OFDM transmission modes according to the channel bandwidth, modulation and data rate combination(s) with the highest maximum output power specified for production units in each standalone and aggregated frequency band. SAR is measured using the highest measured maximum output power channel. For configurations with the same specified or measured maximum output power, additional transmission mode and test channel selection procedures are required (see 5.3.2). SAR test reduction for subsequent highest output test channels is determined according to *reported* SAR of the initial test configuration.

For next to the ear, hotspot mode and UMC mini-tablet exposure configurations where multiple test positions are required, the initial test position procedure is applied to minimize the number of test positions required for SAR measurement using the initial test configuration transmission mode.[21] For fixed exposure conditions that do not have multiple SAR test positions, SAR is measured in the transmission mode determined by the initial test configuration.

When the *reported* SAR of the initial test configuration is > 0.8 W/kg, SAR measurement is required for subsequent next highest measured output power channel(s) in the initial test configuration until *reported* SAR is ≤ 1.2 W/kg or all required channels are tested.[22]

5.3.4 Subsequent Test Configuration Procedures

SAR measurement requirements for the remaining 802.11 transmission mode configurations that have not been tested in the initial test configuration are determined separately for each standalone and aggregated frequency band, in each exposure condition, according to the maximum output power specified for production units. The initial test position procedure is applied to next to the ear, UMPC mini-tablet and hotspot mode configurations. When the same maximum output power is specified for multiple transmission modes, the procedures in 5.3.2 are applied to determine the test configuration. Additional power measurements may be required to determine if SAR measurements are required for subsequent highest output power channels in a subsequent test configuration. The subsequent test configuration and SAR measurement procedures are described in the following.

a) When SAR test exclusion provisions of KDB Publication 447498 D01 are applicable and SAR measurement is not required for the initial test configuration, SAR is also not required for the next highest maximum output power transmission mode subsequent test configuration(s) in that frequency band or aggregated band and exposure configuration.
b) When the highest *reported* SAR for the initial test configuration (when applicable, include subsequent highest output channels), according to the initial test position or fixed exposure position requirements, is adjusted by the ratio of the subsequent test configuration to initial test configuration specified

[21] When a test lab chooses not to apply the initial test position procedure, the initial test configuration procedures must be applied separately to each exposure test position.

[22] Required channels are those identified in Appendix B and according to procedures described in this document; for example, 2.4 GHz band in section 3.1. Also see section 5.3.2 for channels with the same measured maximum output power, multiple mid-band channels or equivalent 802.11 transmission modes etc.

maximum output power and the adjusted SAR is ≤ 1.2 W/kg, SAR is not required for that subsequent test configuration.

c) The number of channels in the initial test configuration and subsequent test configuration can be different due to differences in channel bandwidth. When SAR measurement is required for a subsequent test configuration and the channel bandwidth is smaller than that in the initial test configuration, all channels in the subsequent test configuration that overlap with the larger bandwidth channel tested in the initial test configuration should be used to determine the highest maximum output power channel. This step requires additional power measurement to identify the highest maximum output power channel in the subsequent test configuration to determine SAR test reduction.
   1) SAR should first be measured for the channel with highest measured output power in the subsequent test configuration.
   2) SAR for subsequent highest measured maximum output power channels in the subsequent test configuration is required only when the *reported* SAR of the preceding higher maximum output power channel(s) in the subsequent test configuration is > 1.2 W/kg or until all required channels are tested. For channels with the same measured maximum output power, SAR should be measured using the channel closest to the center frequency of the larger channel bandwidth channel in the initial test configuration.

d) SAR measurements for the remaining highest specified maximum output power OFDM transmission mode configurations that have not been tested in the initial test configuration (highest maximum output) or subsequent test configuration(s) (subsequent next highest maximum output power) is determined by recursively applying the subsequent test configuration procedures in this subclause to the remaining configurations according to the following:
   1) replace "subsequent test configuration" with "next subsequent test configuration" (i.e., subsequent next highest specified maximum output power configuration)
   2) replace "initial test configuration" with "all tested higher output power configurations"

6. SIMULTANEOUS TRANSMISSION SAR CONSIDERATIONS

For MIMO, TxBF and other simultaneous transmission configurations, a transmission duty factor of 100% is required to determine SAR compliance. The following discussions are based on common SAR testing issues found in recent generation Wi-Fi devices. It should be emphasized that the procedures can be insufficient for more complex implementations found in proprietary designs, evolving products or future generation devices. Under such circumstances, a KDB inquiry is required to determine simultaneous transmission SAR test exclusion and measurement requirements.

6.1 Antenna Spatial Configurations

When antennas are spatially separated to the extent that SAR distributions do not overlap and can be treated independently, SAR compliance for simultaneous transmission is determined separately for each individual antenna. In general, when the aggregate SAR from multiple antennas at any location in the combined SAR distribution is either ≤ 1.2 W/kg where at least 90% of the SAR is attributed to a single SAR distribution or ≤ 0.4 W/kg where no more than one SAR distribution is contributing > 0.1 W/kg, the antennas may be considered spatially separated.[23] The conditions can be established either by inspection or quantitative comparison using interpolated results from area scans to determine that the antennas are spatially separated. The area scans must be measured with the same probe sensor to phantom shell distance according to requirements of KDB publication 865664 D01.[24] Under such circumstances, each

[23] These conditions apply separately to all locations, both near a peak SAR location and away from any peaks in the combined SAR distribution.

[24] The smallest measurement distance (probe sensor to phantom shell) required by the highest frequency area scan must be used for all area scans to identify spatially separated antenna configurations. The measurement distance must

transmitting antenna is tested independently, one at a time, according to procedures in this document. Otherwise, when SAR distributions overlap, the simultaneous transmission SAR test exclusion provisions in KDB Publication 447498 D01 or SAR measurement requirements in KDB Publication 865664 D01 are applied to determine compliance.

6.2 Switched Transmit Diversity

Switched transmit diversity is a feature commonly used in early generation Wi-Fi devices. The output power is time and spatially multiplexed dynamically among the diversity antennas. Since energy is dispersed both temporally and spatially, with only one antenna transmitting at a time, the *reported* SAR of the antennas are averaged to determine compliance. Both measured and *reported* SAR for all diversity antennas are required in the SAR report to support compliance.

6.3 Simultaneous Transmission of MIMO Chains and TxBF

The simultaneous transmission conditions for MIMO, TxBF and other similar configurations must be considered separately for each standalone and aggregated frequency band according to the 802.11 transmission mode configurations and exposure conditions to determine SAR compliance. The aggregate maximum output power of all simultaneous transmitting antennas in all transmission chains may be used to determine SAR test exclusion for each frequency band and transmission mode configuration. The most conservative SAR test separation distance among the antennas must be used to apply the standalone SAR test exclusion provisions in KDB Publication 447498 D01.[25] When this power-based standalone SAR test exclusion does not apply, the sum of 1-g SAR provision in KDB Publication 447498 D01 should be used to determine simultaneous transmission SAR test exclusion.

For MIMO configurations, when lower order subsets of the maximum number of MIMO chains are used; for example, different 2×2 subsets of a 3×3 MIMO configuration, all MIMO chain combinations must be accounted for to determine compliance, either by SAR test exclusion or measurement; especially when there is a difference in maximum output power among the MIMO chains or when antenna interaction is expected in an integrated MIMO antenna structure.

6.4 Simultaneous Transmission of Wi-Fi and Other Wireless Transmitters

Besides simultaneous transmission of MIMO and TxBF in 802.11 Wi-Fi configurations, simultaneous transmission of Wi-Fi and other wireless technologies also need consideration; for example, 3G and 4G. When the initial test position or initial test configuration procedure is applied to 802.11 Wi-Fi configurations that also transmit simultaneously with other wireless technologies, SAR is typically not measured for all test positions and Wi-Fi transmission mode configurations as a result of the test reduction. The highest SAR measured for the initial test position or initial test configuration should be used to determine SAR test exclusion according to the sum of 1-g SAR and SAR peak to location ratio provisions in KDB Publication 447498 D01. When a test position does not qualify for simultaneous transmission SAR test exclusion, that specific test position must be used in the simultaneous transmission SAR measurement irrespective of the initial test position used to determine SAR test exclusion. The 802.11 transmission mode configuration associated with the initial test position or initial test configuration for determining simultaneous transmission SAR test exclusion is used in the simultaneous transmission SAR measurement. In addition, a test lab may also choose to perform standalone SAR

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be consistent with that used to test the device in normal SAR measurements; i.e., measurement distance is not intentionally increased. While minor variations in SAR can be expected due to small differences in measurement distance, the concerns should be insignificant as additional margins are already included in the test conditions and separate SAR measurements are required for the antennas to determine compliance.

[25] This applies to simultaneous transmission in the same frequency band for 802.11 MIMO and TxBF only.

measurements for test positions and 802.11 configurations that are not required by the initial test position or initial test configuration procedures and apply the results to determine simultaneous transmission SAR test exclusion, according to sum of 1-g and SAR peak to location ratio requirements to reduce the number of simultaneous transmission SAR measurements.

6.5 KDB Publication 447498 D01 Simultaneous Transmission SAR Test Exclusion Considerations

When estimated SAR is required for Wi-Fi configurations that that do not require standalone SAR measurement, simultaneous transmission SAR test exclusion is determined by the smaller of the estimated SAR or highest *reported* SAR for the 802.11 transmission modes in that frequency band. The SAR peak to location ratio provision in KDB Publication 447498 D01 is intended for peak SAR locations measured in the same (2D) plane within the phantom. When the peak SAR location is estimated because standalone SAR measurement is not required and the antenna is located at > 5 cm from the phantom, there could be substantial overestimation when applying peak SAR to location ratio test exclusion. Under such circumstances, a standalone SAR measurement may be considered to facilitate the SAR test exclusion.

The simultaneous transmission SAR test exclusion provisions in KDB Publication 447498 D01 can be applied to avoid simultaneous transmission SAR measurement or to reduce the number of tests. For the typical circumstances, the number of simultaneous transmission SAR measurements can usually be kept to less than two to three. To correctly apply simultaneous transmission SAR test exclusion, the *reported* standalone SAR results must be examined according to all combinations of channel bandwidths, maximum output power, 802.11 transmission modes, frequency bands, exposure configurations and test positions to determine if certain combinations may be considered collectively to apply the SAR test exclusion procedures according to the highest *reported* SAR for the group. The decision to consolidate standalone SAR results into meaningful groups according to 802.11 transmission mode configurations, exposure conditions and test positions etc. must be consistent with the actual transmission and use conditions. When the sum of 1-g SAR is used to determine SAR test exclusion for all simultaneous transmission configurations in a group, the highest *reported* standalone SAR in each frequency band, among all transmission modes and exposure configurations, for each antenna must be used to determine if simultaneous transmission SAR measurement is unnecessary. However, if SAR peak to location ratio is also applied to some of the configurations for further SAR test reduction, it is generally inappropriate to consider these transmission and exposure configurations collectively with respect to the highest SAR used for sum of 1-g test exclusion because the SAR peak to location ratio procedure is specific to the simultaneous transmitting antennas and test configuration considered.[26]

To apply the simultaneous transmission SAR test exclusion procedures in KDB Publication 447498 D01, it must be ensured that the maximum output power of each antenna during simultaneous transmission is not greater than that used in standalone transmission. When power reduction is applied to simultaneous transmission, instead of the higher maximum power for standalone transmission, additional standalone SAR measurements at the (reduced) maximum output power may be considered to apply simultaneous transmission SAR test exclusion. The number of additional standalone measurements at the reduced maximum power may be minimized by demonstrating that SAR scaling is applicable; however, a KDB inquiry may be required to address the details for individual circumstances. When simultaneous transmission SAR test exclusion is not satisfied for a transmission mode and exposure configuration, simultaneous transmission SAR measurement is required for the specific configuration. Unless the

[26] See simultaneous transmission SAR test exclusion section of KDB Publication 447498 D01 for additional explanation.

antennas are spatially separated and SAR distributions do not overlap, when antennas transmit simultaneously in the same frequency band and within the frequency range covered by a single SAR probe calibration point, SAR is generally measured with all applicable antennas transmitting simultaneously at maximum output power in a single SAR measurement.[27]

CHANGE NOTICE

06/08/2015: 248227 D01 802.11 Wi-Fi SAR v02 is replaced by 248227 D01 802.11 Wi-Fi SAR v02r01. Changes include the following: The test channel selection requirement for channels within ¼ dB of each other in footnotes 5, 7 and 25; section 5.3.2 and Table C.3 etc. have been removed to avoid conflicts. The illustrative example in Appendix C has been updated to be consistent with procedures in section 5.3.2 and removal of the ¼ dB channel selection condition. The procedures in section 6.1 for spatially separated antennas have been updated for clarity. Footnote 30 has been updated for clarity regarding *reported* SAR requirements for simultaneous transmission SAR measurements. Extension of §15.247 5.8 GHz band approval according to FCC-15-62A is identified in footnote 9.

10/23/2015: 248227 D01 802.11 Wi-Fi SAR v02r01 is replaced by 248227 D01 802.11 Wi-Fi SAR v02r02. Adjusted bullet list numbering format and removed inapplicable 40 MHz 802.11g columns from tables in Appendix C.

[27] Separate SAR distributions are measured for multiple frequency bands to determine simultaneous transmission SAR. The distributions may be considered separately by some SAR measurement systems to derive separate scaling factors for the SAR distributions to determine *reported* SAR. For simultaneous transmission within the same frequency band, scaling factors cannot be derived for the individual antennas from the single SAR distribution. A KDB inquiry should be submitted to determine how *reported* SAR may be considered for these circumstances according to the measured SAR distribution or, if applicable, measure SAR separately for each antenna according to simultaneous transmission SAR measurement requirements in KDB 865665 D01 to facilitate the scaling.

APPENDIX A

BRIEF SUMMARY OF 802.11 CONFIGURATIONS AND PARAMETERS

A.1. 802.11 PHY Configurations

The 802.11 PHY configurations described in this clause provide a brief summary of the applicable wireless transmission modes, modulations and data rates etc. that need consideration when applying the SAR measurement procedures.[28] In general, before applying the procedures in this document, a test lab should confirm the operating capabilities of individual device implementations with the Wi-Fi device manufacturers to ensure all wireless modes and exposure conditions are considered.

a) Frequency Hopping PHY (802.11) is considered obsolete in IEEE Std 802.11-2012 and may be removed in future revisions. Frequency hopping should be tested on the high, middle and low channels in the 2.4 GHz band according to normally required SAR measurement procedures. The transmitter must be locked to each required test frequency channel with frequency hopping disabled for the SAR measurement. The SAR procedures described in this KDB publication do not apply to 2.4 GHz frequency hopping operations.
b) DSSS RF LAN (802.11) systems provide WLAN operations in the 2.4 GHz band with 1 and 2 Mb/s data rates using DBPSK and DQPSK baseband modulations, respectively. This mode is supported by 802.11b for backward compatibility.
c) High Rate PHY (802.11b) extension increases DSSS RF LAN data rates to 5.5 and 11 Mb/s using 8-chip CCK modulation at a chipping rate of 11 MHz, with the same occupied channel bandwidth as DSSS systems, and CCK may be optionally replaced with HR/DSSS/PBCC. However, PBCC is considered obsolete in IEEE Std 802.11-2012 and may be removed in future revisions. HR/DSSS/short and HR/DSSS/PBCC/short are optional modes that allow increased data throughput at 2, 5.5, and 11 Mb/s using a shorter PLCP preamble.
d) ERP (802.11g) provides further data rate extension for DSSS and HR/DSSS in the 2.4 GHz band. The additional data rates include 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. Data rates at 1, 2, 5.5, 6, 11, 12, and 24 Mb/s are mandatory. ERP-PBCC modulation is optional for supporting 22 and 33 Mb/s data rates. DSSS-OFDM is also optional for 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s data rates. ERP has the capability to decode all DSSS and HR/DSSS PLCPs and all ERP-OFDM PLCPs. It is mandatory for all ERP-compliant equipment to send and receive short preamble, which is optional for HR/DSSS.
e) OFDM PHY (802.11a) supports 6, 12, 24, 36, 48 and 54 Mb/s data rates. Data rates higher than 24 Mb/s are optional. There are 52 subcarriers modulated using BPSK, QPSK, 16-QAM or 64-QAM with forward error correction convolutional coding rates of 1/2, 2/3 or 3/4. "Half-clocked" operation with 10 MHz channel spacing at 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s and "quarter-clocked" operation with 5 MHz channel spacing at 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s data rates may be used.[29]
f) OFDM HT PHY (802.11n) expands the OFDM PHY to support up to four 20 or 40 MHz bandwidth spatial streams and provide optional features such as 400 ns short guard interval (GI), transmit beamforming, HT-greenfield format, and STBC. Modulation, coding, and number of spatial streams are identified by MCS indices 0 - 76. MCSs 0 - 7 and 32 use a single spatial stream. MCS 8 to 31 use multiple spatial streams with equal modulation (EQM) for all streams. MCS 33 - 76 use multiple spatial streams with unequal modulation (UEQM) for the spatial streams. MCS 0 - 7 are mandatory for all stations using 20 MHz bandwidth with 800 ns GI. MCS 0 - 15 are mandatory for APs using 20 MHz bandwidth and 800 ns GI. All other MCSs and modes are optional, including support for 400 ns GI, 40 MHz bandwidth and support of MCS 16 - 76. All EQM rates are supported by non-AP HT stations using MCS 0 - 7 for 20 MHz bandwidth with one spatial stream. All EQM rates are

[28] Refer to IEEE Std 802.11-2012 and IEEE Std 802.11ac-2013 for definitions of specific terms, abbreviations and protocol details.

[29] Unless the maximum output power for half-clocked or quarter-clocked mode is higher than that in the normal mode, SAR is generally not required.

supported by HT APs using MCS 0 - 15 for 20 MHz bandwidth with one or two spatial streams. A 40 MHz channel is specified by two fields: the primary channel number and whether the secondary channel is above or below the primary channel.

g) OFDM VHT PHY (802.11ac) supports frequency bands below 6 GHz, excluding the 2.4 GHz band. OFDM HT stations supporting VHT also support DSSS. Support for 20, 40 and 80 MHz channel bandwidth is mandatory for VHT. Support for 160 MHz and 80 + 80 MHz bandwidths, NDP (null data packet) transmit beamforming sounding, STBC, LDPC and downlink multi-user (MU) transmissions are optional. The maximum number of space-time streams supported by VHT is eight. VHT can support four users and up to four space-time streams per user with a total of up to eight space-time streams for downlink MU transmission. The subcarriers are modulated using BPSK, QPSK, 16-QAM, 64-QAM or 256-QAM with forward error correction (FEC) convolutional or LDPC coding rates of 1/2, 2/3, 3/4 and 5/6. Support of single spatial stream for all channel bandwidths using VHT MCS 0 - 7 is mandatory. Support of two or more spatial streams, 400 ns short GI and VHT MCS 8 and 9 are optional. Cyclic shifts are applied to the modulated preamble and data fields to prevent unintended beamforming when correlated signals are transmitted in multiple space-time streams. MCS 0 - 9 are defined in 802.11 VHT to identify modulations and code rates; however, the number of streams and channel bandwidths allowed are not specified by MCS, which is different from the MCS configurations used in 802.11n. There are also exceptions for certain MCS configurations; for example, MCS 6 does not support 3 and 7 streams for 80 MHz channels, MCS 9 does not support 1, 2, 4, 5, 7 and 8 streams for 20 MHz channels, 6 streams for 80 MHz channels or 3 streams for 160 MHz channels. During transmission, the channel bandwidth for 802.11 VHT can change frame by frame.

A.2. Peer-to-Peer Wi-Fi Configurations

The typical peer-to-peer Wi-Fi configurations supported by IEEE Std 802.11-2012 or the *Wi-Fi Alliance* may include tunneled direct-link setup (TDLS), Mesh Services, Wi-Fi Direct and other similar *ad hoc* network (IBSS) connections. The exposure characteristics of these Wi-Fi operating modes are usually covered by the normally required SAR test conditions for infrastructure mode operations.

a) TDLS service is established by applying IEEE 802.11z protocol to transmit encapsulated signaling frames transparently within the regular 802.11 data frames through an AP. It enables devices to connect directly with each other using improved connection speed and overall bandwidth efficiency without adhering to the functionalities and requirements of an AP. The AP is unaware of the TDLS setup and not required to provide any support for the link. The more efficient 802.11 modes supported by TDLS devices, including different channel bandwidths and frequency bands, that are not available from an AP can be used over a direct link between TDLS devices. TDLS may be used with all existing and new APs because it is transparent.

b) Mesh Services enable the creation and operation of a mesh basic service set (MBSS) to support mutual exchange of messages between autonomous neighboring stations and to transfer messages between stations that are not in direct communication using multi-hop capability. It enables data transfer between stations in a mesh BSS that are not within range of each other. A mesh station is not a member of an *ad hoc* network (IBSS) or an infrastructure BSS. Mesh stations do not communicate with non-mesh stations.

c) Wi-Fi Direct is a *Wi-Fi Alliance* feature that enables Wi-Fi devices to establish direct connection groups to support printing, sync or share contents conveniently when an AP or router is unavailable. A Wi-Fi Direct network can be a one-to-one or one-to-many connection under the control of a group leader. Simultaneous transmission at 2.4 GHz and 5 GHz in Wi-Fi Direct and AP modes or 3G/4G hotspot mode may be supported by certain device implementations. The hotspot mode SAR procedure in KDB Publication 941225 D06 is for connections between Wi-Fi and 3G/4G transmitters in specific host platform configurations; it does not apply to cross connections using AP equivalent features where the simultaneous transmission is for multiple Wi-Fi transmitters within the device.

TDLS services may also be supported in Wi-Fi Direct mode by tunneling through the group leader, which serves as the equivalent of an AP.

A.3. Antenna Diversity, MIMO and Transmit Beamforming Considerations

Transmit diversity, MIMO, beamforming etc. are features found in 802.11 Wi-Fi transmitters for improving coverage and data throughput. The SAR measurement concerns associated with these enhancement features typically vary with the flexibility and complexity of individual implementations. When multiple antennas are transmitting simultaneously, transmission characteristics and antenna spatial arrangements can influence the test configurations required for SAR measurement. The simultaneous transmission schemes and antenna characteristics must be clearly identified to determine SAR test requirements. When there are noticeable differences in maximum output power or antenna performance among the simultaneous transmitting antennas or transmission chains, the normally required SAR test procedures may not fully apply. In addition, frequency, signal correlation, antenna proximity, antenna interactions and transmission conditions are some of the factors that may require SAR to be measured, either independently for each antenna or with all antennas transmitting simultaneously, according to the measurement and post-processing procedures supported by individual SAR measurement systems.[30]

a) Typical MIMO Configurations
    1) *Spatial Multiplexing* (SM): The data is subdivided into multiple streams for transmission through different antennas by spatial multiplexing. The spatial streams from the antennas are expected to propagate along different transmission paths and arrive at the destination with different signal strengths and delays. When two spatial streams are multiplexed onto a single RF channel, the maximum data rate is effectively doubled. All APs operating in OFDM HT mode (802.11n) are required to support at least two spatial streams and up to a maximum of four. Non-AP devices can support one or more spatial streams. When multiple spatial streams are transmitted, SAR compliance for simultaneous transmission is required.
    2) *Space-Time Block Coding* (STBC): STBC transmits redundant data in blocks that are coded differently for transmission through separate antennas. While multiple receive antennas can improve performance, it is not required for STBC. When the number of transmit antennas are more than the number of receive antennas, STBC may be applied in conjunction with spatial multiplexing.
b) Transmit Beamforming (TxBF) applies channel knowledge acquired either implicitly or explicitly to steer the signal to a desired direction. Improved receive signal strength and data rates can be achieved by exploiting reflection and multipath phenomena. TxBF has not been widely used in OFDM HT (802.11n) because of highly flexible protocols that include a substantially large number of configurations with increased implementation complexity. In OFDM VHT (802.11ac), however, more restrictive configurations with better defined implementation requirements are specified to limit the number of configurations, which are expected to encourage TxBF in Wi-Fi devices. VHT TxBF (802.11ac) requires the streams to have equal modulation (EQM). Null data packets (NDP) are required for sounding. For HT TxBF (802.11n), streams with unequal modulations (UEQM) are allowed.
    1) *Implicit feedback* TxBF assumes the channel is reciprocal, where the propagation condition is identical in both directions. The beamformer can request and use the training symbols (sounding PPDU) received from the beamformee to estimate channel conditions and compute the transmit steering matrix. Implicit feedback can be unidirectional or bidirectional where a Wi-Fi device can be both the beamformer and beamformee.

[30] Correlated and coherent signal concerns for SAR are mainly in the near-field of the transmitting antennas where the exposed person is located. These conditions are generally unrelated to the far-field conditions associated with EMC testing requirements and procedures described in KDB Publication 662911 D01 and D02.

2) *Explicit feedback* TxBF allows the beamformee to estimate channel conditions from training symbols sent by the beamformer to prepare CSI (Channel State Information) or steering feedback matrix (V). Transmit steering vector matrix (Q) is determined by the beamformer according to beamformee feedback.

c) Cyclic Shift Requirements

When correlated signals are transmitted in multiple space-time streams, MIMO and TxBF requirements specified in IEEE Std 802.11 require cyclic shifts to be applied to data streams transmitted from different antennas to prevent unintended beamforming. The SAR measurement issues relating to correlated signals and coherent transmissions generally do not apply to these implementations. However, Wi-Fi devices that use other proprietary implementations or antenna array configurations and coherent transmission schemes to enhance throughput and coverage must address coherent transmission SAR issues for test results to be acceptable (see KDB Publication 865664 D01).

A.4. Signal Coherence

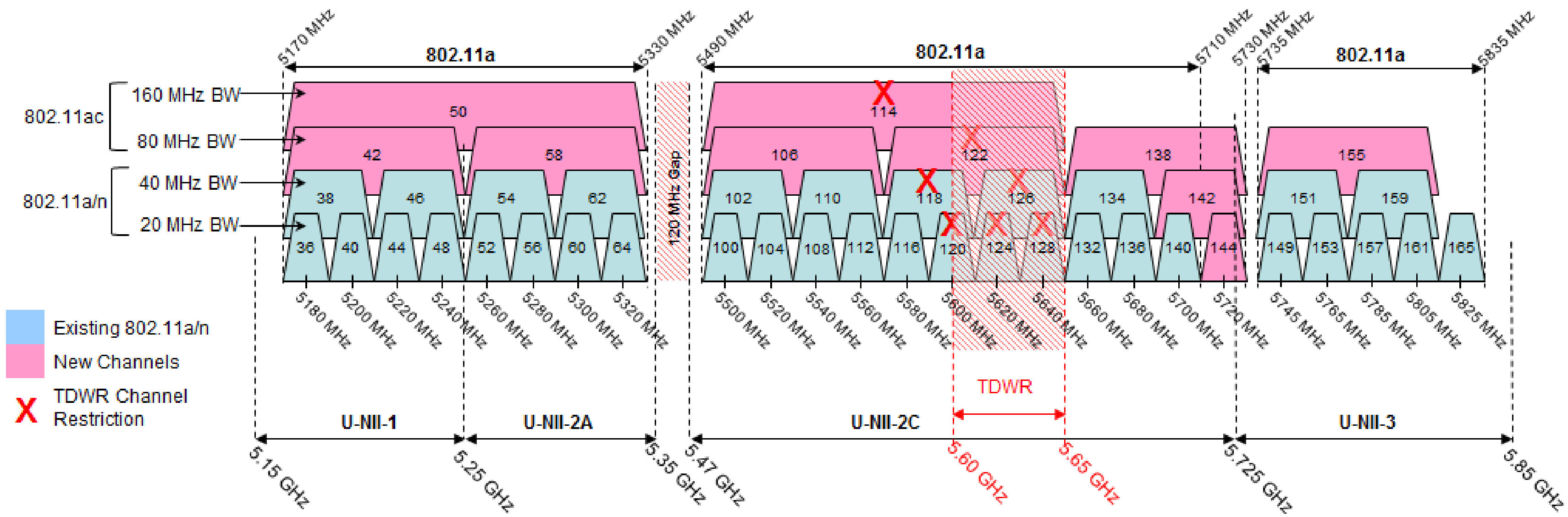
When correlated signals are transmitted in multiple space-time streams, cyclic shifts are applied to IEEE Std 802.11 compliant MIMO and TxBF configurations to prevent unintended beamforming. For SAR measurement purposes, the HT and VHT TxBF applied to individual OFDM sub-carriers are not expected to result in significant or noticeable signal coherence at the OFDM channel output of antenna chains. However, for other implementations that allow or promote energy focusing in the near-field, SAR issues relating to coherent signals must be addressed according to the individual implementation. When signal coherence applies, the maximum worst-case SAR is a function of N^2, where N is the number of coherent signals; i.e., 4, 9 and 16 times for 2, 3 and 4 coherent transmission streams. The extent of focusing is expected to be highly dependent on antenna proximity, antenna to phantom separation and use configurations; therefore, a KDB inquiry is required to address the SAR measurement issues.

The SAR probes used in SAR measurements are designed to measure scalar fields, which are insufficient for measuring coherent signals. However, the measured scalar results may be used to estimate coherent signal SAR based on IEC/TR 62630 recommendations, on a case-by-case basis according to individual product design and implementation. Except when antennas are sufficiently far apart with no noticeable overlapping SAR distributions, the simultaneous transmission SAR test exclusion provisions in KDB Publication 447498 D01 generally do not apply to coherent signal configurations.

APPENDIX B

5 GHz 802.11 CHANNEL CONFIGURATIONS

(For Illustration Only)



APPENDIX C

SAR TEST REDUCTION ILLUSTRATIVE EXAMPLE

C.1. Typical steps to consider for SAR test reduction of OFDM configurations

a) Identify the maximum output power specified at each antenna port of production units for the applicable OFDM configurations; as in Table C.1.
   1) An initial test configuration is selected for each antenna port based on the highest maximum output power specified for production units and according to channel bandwidth, modulation and data rate combinations in each standalone and aggregated frequency band.
      i) For most products, the same maximum output power is typically used for the modulations and/or data rates in each channel bandwidth.
      ii) When different maximum output power levels are specified for different modulations and data rates, the combination(s) with the highest maximum output power specified for a channel bandwidth should be entered in the table. Variations should be identified using footnotes or modify the table accordingly.
      iii) The maximum output power specified for production units are used to determine which OFDM configuration is tested initially for each frequency band to reduce the number of subsequent SAR tests required for lower power OFDM modes.

Table C.1 – Example entries of OFDM mode specified maximum output power at an antenna port

802.11 Modes	a	g	n (HT)@		ac (VHT)@			
Channel Bandwidth (MHz)	20	20	20	40	20	40	80	160
§15.247 (2.4 GHz)		X	X	X				
U-NII-1	X		X	X	X	X	X	
U-NII-2A	X		X	X	X	X	X	
U-NII-1 + U-NII-2A								X
U-NII-2C	X		X	X	X*	X*	X*	X#
U-NII-3	X		X	X	X*	X*	X*	
§15.247 (5.8 GHz)	X		X	X	X*	X*	X*	

- X: maximum (conducted) output power (mW), including tolerance, specified for production units at each antenna port
- @: use multiple tables for multiple antenna ports or repeat applicable columns for additional antenna ports used for MIMO or TxBF
- #: this configuration only applies to the new rules in FCC 14-30, without TDWR restriction
- *: when applicable, include the band gap channels

b) Apply the default power measurement procedures to measure maximum output power for each standalone and aggregated frequency band.
   1) When band gap channels between U-NII-2C band and U-NII-3 band or §15.247 5.8 GHz band are supported and the bands are aggregated for SAR testing according to 2.3 and 3.3 above, apply the following to determine high, middle and low channels for power measurement and SAR test reduction.
      i) channels in U-NII-2C band below 5.65 GHz are considered as one band
      ii) channels above 5.65 GHz, together with channels in 5.8 GHz U-NII-3 or §15.247 band, are considered as a separate band
   2) The maximum output power of band gap channels is limited to the lowest maximum output power certified for the adjacent bands regardless of whether band aggregation is applied for SAR testing.
   3) The measured maximum output power results are used to reduce the number of channels that need testing.
c) Apply initial test configuration procedures to each standalone or aggregated frequency band.
   1) For next to the ear, UMPC mini-tablet or hotspot mode exposure configurations with multiple test positions, the initial test position procedure is applied to measure SAR using the initial test configuration to reduce the number of test positions.
   2) For fixed exposure positions, apply the initial test configuration procedures.
d) Subsequent test configuration procedures are applied to determine if the remaining OFDM transmission mode configurations may need testing.
   1) All channels in a smaller channel bandwidth subsequent test configuration that overlap with a larger channel bandwidth in the initial test configuration need consideration.
   2) Additional test reduction may apply, according to highest *reported* SAR in the initial test configuration or previous subsequent test configuration(s).
e) Apply simultaneous transmission SAR test exclusion and, when required, perform simultaneous transmission SAR measurement.
   1) Apply KDB Publication 447498 D01 estimated SAR procedures or use highest *reported* SAR for the 802.11 mode in that frequency band, whichever has a smaller value, to configurations that do not require standalone SAR measurement.
   2) See Clause 6 for simultaneous transmission SAR test reduction and exclusion of Wi-Fi transmitters only, in MIMO and TxBF configurations, and Wi-Fi with other transmitters (3G/4G, etc.).

C.2. SAR Test Reduction Illustrative Example

Table C.2 – Maximum output power specified at the antenna port of production units for the applicable OFDM configurations of an illustrative test sample									
802.11 Modes		a	g	n (HT)@		ac (VHT)@			
Channel Bandwidth (MHz)		20	20	20	40	20	40	80	160
§15.247 (2.4 GHz)	mW		50	50	45				
U-NII-1		50		50	45	50	45	30	
U-NII-2A		50		50	45	50	45	30	
U-NII-1 + U-NII-2A									25
U-NII-2C		45		45	40	45*	40*	30*	25#
U-NII-3		45		45	40	45*	40*	30*	
§15.247 (5.8 GHz)		50		50	45	50*	45*	30*	

- See Table C.1 for definition of symbols #, @, * etc.
- The maximum output power specified for production units in this illustrative example is assumed to be the same for all channels, modulations and data rates in each channel bandwidth configuration of the 802.11 a/g/n/ac modes.
- The blue highlighted cells represent highest output configurations in each standalone or aggregated frequency band, with tune-up tolerance included. The 5.8 GHz U-NII-3 and §15.247 bands are treated as one band; specified maximum output power is higher in §15.247 band.
- Output power measurement is required for multiple configurations of the same channel bandwidth that have the same specified maximum output power. These maximum output power configurations are used in conjunction with the applicable test channel selection procedures (see 5.3.2) to determine default power measurement and SAR test configurations in Tables C.3 – C.5.
- For SAR test reduction in the 2.4 GHz band, the maximum output specified for production units is assumed to be 50 mW for 802.11b and the highest ***reported*** SAR for DSSS is assumed to be 0.75 W/kg for this illustrative example.

Table C.3 – Maximum output power measured at the antenna port of the illustrative test sample in Table C.2, for the applicable OFDM configurations according to the default power measurement procedures for selecting initial test configurations									
802.11 Modes		**a**	**g**	**n (HT)@**		**ac (VHT)@**			
Channel Bandwidth (MHz)		**20**	**20**	**20**	**40**	**20**	**40**	**80**	**160**
§15.247 (2.4 GHz)	*Ch. #*		*1/6/11*	*1/6/11*	*6*				
	mW		48/46/47	47/48/46	lower power				
U-NII-1	*Ch. #*	*36/40/44/48*		*36/40/44/48*	*38/46*	*36/40/44/48*	*38/46*	*42*	
	mW	45/46/46/48		46/45/48/47	lower power	46/48/47/46	lower power	lower power	
U-NII-2A	*Ch. #*	*52/56/60/64*		*52/56/60/64*	*54/62*	*52/56/60/64*	*54/62*	*58*	
	mW	46/45/48/47		45/46/46/48	lower power	48/46/49/47	lower power	lower power	
U-NII-1 + U-NII-2A	*Ch. #*								*50*
	mW								lower power
U-NII-2C	*Ch. #*	*100/112/116/128*		*100/112/116/128*	*102/110/118/126*	*100/112/116/128*	*102/110/118/126*	*106/112*	*114*
	mW	42/44/43/44		43/44/42/43	lower power	42/43/44/43*	lower power*	lower power*	lower power#
U-NII-3	*Ch. #*	*132/149/165*		*132/149/165*	*134/142/151/159*	*132/149/165*	*134/142/151/159*	*138/155*	
	mW	lower power		lower power	lower power	lower power*	lower power*	lower power*	
§15.247 (5.8 GHz)	*Ch. #*	*132/149/165*		*132/149/165*	*134/142/151/159*	*132/149/165*	*134/142/151/159*	*138/155*	
	mW	48/46/49		49/48/46	lower power	43/47/49*	lower power*	lower power*	

- This example assumes the same modulations and data rates are used for the same channel bandwidth configurations in each 802.11 mode. The measured power corresponds to the lowest order modulation and lowest data rate configuration in each 802.11 mode and channel bandwidth configuration.
- Arbitrary values of measured power are assigned (selected) according to the power specifications assumed in Table C.2. The following 2 steps are applied in sequence.
  - When there are multiple 802.11 a/g/n/ac mode configurations in a standalone or aggregate frequency band with the same specified maximum output power for the same channel bandwidth, modulation and data rate, according to largest channel bandwidth, lowest order modulation and lowest data rate selection criteria in 5.3.2, the lower order/sequence 802.11 mode (i.e. a, g, n then ac) is selected for the initial test configuration.
  - When multiple test channels have the same measured maximum output power, choose the channel closest to mid-band frequency for the initial test configuration. When two test channels have the same measured maximum output power and also with equal separation from mid-band frequency; for example, high and low channels or multiple mid-band channels, the higher frequency channel is selected.
- An entry of "lower power" means power measurement is not required according to the default power measurement procedures. The specified maximum output power is higher for 5.8 GHz §15.247; therefore, power measurement is not required for U-NII-3.
- Channels selected for initial test configuration(s) are highlighted in yellow. *See item 4) of 5.3.2 802.11a is selected in U-NII-2A* according to specified power.
- This example assumes the new rules in FCC 14-30 are applied, without TDWR restriction.
- Band gap channels enabled for U-NII-2C and 5.8 GHz U-NII-3 or §15.247. The optional aggregated band procedure for SAR probe calibration is applied.

Table C.4 – *Reported* SAR of initial test configuration determined according to Table C.3 with frequency band test reduction taken into consideration

802.11 Modes		a	g	n (HT)@		ac (VHT)@			
Channel Bandwidth (MHz)		20	20	20	40	20	40	80	160
§15.247 (2.4 GHz)	*Ch. #*		*1/6/11*	*1/6/11*	*6*				
	W/kg		SAR not required for OFDM; 802.11b adjusted SAR ≤ 1.2 W/kg						
U-NII-1	*Ch. #*	*36/40/44/48*		*36/40/44/48*	*38/46*	*36/40/44/48*	*38/46*	*42*	
	W/kg	U-NII-2A exclusion applied							
U-NII-2A	*Ch. #*	*52/56/60/64*		*52/56/60/64*	*54/62*	*52/56/60/64*	*54/62*	*58*	
	W/kg	**0.85**							
U-NII-1 + U-NII-2A	*Ch. #*								*50*
	W/kg								
U-NII-2C	*Ch. #*	*100/112/116/128*		*100/112/116/128*	*102/110/118/126*	*100/112/116/128*	*102/110/118/126*	*106/112*	*114*
	W/kg	**0.95**							
U-NII-3	*Ch. #*	*132/149/165*		*132/149/165*	*134/142/151/159*	*132/149/165*	*134/142/151/159*	*138/155*	
	W/kg								
§15.247 (5.8 GHz)	*Ch. #*	*132/149/165*		*132/149/165*	*134/142/151/159*	*132/149/165*	*134/142/151/159*	*138/155*	
	W/kg	**1.08**							

- This example assumes the device has a fixed exposure test position; therefore, initial test position SAR test reduction does not apply.
- It is also assumed that the test separation distance and measured power (illustrated in Table C.3) do not qualify for the standalone SAR test exclusion provisions in KDB Publication 447498 D01.
- SAR probe(s) are assumed to have valid calibrations at 5.25, 5.60 and 5.75 GHz.
- The illustrated SAR values are already scaled to 100% transmission duty factor and according to *reported* SAR procedure.
- U-NII-1 and U-NII-2A bands have the same specified maximum output and tolerance; SAR is measured for U-NII-2A band first. Adjusted SAR of U-NII-2A band is ≤ 1.2 W/kg, SAR is not required for U-NII-1 band.

Table C.5 – ***Reported*** **SAR of next highest measured output channel in** **Initial test configuration**									
802.11 Modes		**a**	**g**	**n (HT)@**		**ac (VHT)@**			
Channel Bandwidth (MHz)		**20**	**20**	**20**	**40**	**20**	**40**	**80**	**160**
§15.247 (2.4 GHz)	*Ch. #*		*1/6/11*	*1/6/11*	*6*				
	W/kg		SAR not required for OFDM; 802.11b adjusted SAR ≤ 1.2 W/kg						
U-NII-1	*Ch. #*	*36/40/44/48*		*36/40/44/48*	*38/46*	*36/40/44/48*	*38/46*	*42*	
	W/kg	U-NII-2A exclusion applied							
U-NII-2A	*Ch. #*	*52/56/60/64*		*52/56/60/64*	*54/62*	*52/56/60/64*	*54/62*	*58*	
	W/kg	**0.85 / 0.92**							
U-NII-1 + U-NII-2A	*Ch. #*								*50*
	W/kg								
U-NII-2C	*Ch. #*	*100/112/116/128*		*100/112/116/128*	*102/110/118/126*	*100/112/116/128*	*102/110/118/126*	*106/112*	*114*
	W/kg	**0.95 / 0.98**							
U-NII-3	*Ch. #*	*132/149/165*		*132/149/165*	*134/142/151/159*	*132/149/165*	*134/142/151/159*	*138/155*	
	W/kg								
§15.247 (5.8 GHz)	*Ch. #*	*132/149/165*		*132/149/165*	*134/142/151/159*	*132/149/165*	*134/142/151/159*	*138/155*	
	W/kg	**0.97 / 1.08**							

- The green highlighted channels are next highest measured output channel in the initial test configuration. Highest measured output power channel tested initially are in yellow highlight.
- Initial test configuration SAR for U-NII-2A band is > 0.8 W/kg, SAR is required for next highest output channel in initial test configuration. The next highest output channel SAR is ≤ 1.2 W/kg, SAR is not required for subsequent next highest output channel. Similar circumstances apply to U-NII-2C band and 5.8 GHz band in §15.247.
- Note: If *reported* SAR of next highest output channel for U-NII-2A band, U-NII-2C or 5.8 GHz band in §15.247 is > 1.2 W/kg (does not apply to this example), subsequent next highest output power channels would also need testing until *reported* SAR is ≤ 1.2 W/kg or all required channels are tested.
- The *reported* SAR of all initial test configurations are ≤ 1.2 W/kg. Adjusted SAR according to the ratio of the specified maximum output power of subsequent test configuration to initial test configuration will result in lower SAR; therefore, subsequent test configuration SAR is not required for this example.