

6 SAR Measurement variability and uncertainty

6.1 SAR measurement variability

In accordance with published RF Exposure KDB Procedure 865664 D01 SAR measurement 100 MHz to 6 GHz v01r04. These additional measurements are repeated after the completion of all measurements requiring the same head or body tissue-equivalent medium in a frequency band. The test device should be returned to ambient conditions (normal room temperature) with the battery fully charged before it is re-mounted on the device holder for the repeated measurement(s) to minimize any unexpected variations in the repeated results. The same Procedures should be adapted for measurements according to extremity exposure limits by applying a factor of 2.5 for extremity exposure.

- 1) Repeated measurement is not required when the original highest measured SAR is < 2.0 W/kg; steps 2) through 4) do not apply.
- 2) When the original highest measured SAR is ≥ 2.0 W/kg, repeat that measurement once.
- 3) Perform a second repeated measurement only if the ratio of largest to smallest SAR for the original and first repeated measurements is > 3.0 or when the original or repeated measurement is ≥ 3.6 W/kg ($\sim 10\%$ from the 10-g SAR limit).
- 4) Perform a third repeated measurement only if the original, first or second repeated measurement is ≥ 3.75 W/kg and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20 .

6.2 SAR measurement uncertainty

Per KDB865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04, when the highest measured 1-g SAR within a frequency band is < 1.5 W/kg, the extensive SAR measurement uncertainty analysis described in IEEE Std 1528-2013 is not required in SAR reports submitted for equipment approval. The equivalent ratio (1.5/1.6) is applied to extremity and occupational exposure conditions.

7 SAR Test Configuration

7.1 WI-FI 5G Test Configurations

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:

1.1) 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. 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, both bands are tested independently for SAR.

1.2) 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 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, both bands are tested independently for SAR.

1.3) 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.

2) U-NII-2C and U-NII-3 Bands

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. When Terminal Doppler Weather Radar (TDWR) restriction applies, 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. 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. 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.

3) OFDM Transmission Mode SAR Test Configuration and Channel Selection Requirements

The initial test configuration for 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. When multiple configurations in a frequency band have the same specified maximum output power, the initial test configuration is determined according to the following steps applied sequentially.

3.1) The largest channel bandwidth configuration is selected among the multiple configurations with the same specified maximum output power.

3.2) 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.

3.3) 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.

3.4) When multiple transmission modes (802.11a/g/n/ac/ax) 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.

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.

3.4.1) The channel closest to mid-band frequency is selected for SAR measurement.

3.4.2) 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.

4) SAR Test Requirements for OFDM configurations

When SAR measurement is required for 802.11 a/n/ac/ax OFDM configurations, each standalone and frequency aggregated 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, 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. 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.

7.2 WI-FI 2.4G Test Configurations

For Wi-Fi SAR testing, a communication link is set up with the testing software for Wi-Fi mode test. During the test, at the each test frequency channel, the EUT is operated at the RF continuous emission mode. The RF signal utilized in SAR measurement has 100% duty cycle and its crest factor is 1. The test Procedures in KDB 248227D01 v02r02 are applied.

Per KDB 248227 D01 802.11 Wi-Fi SAR v02r02, SAR Test Reduction criteria are as follows:

SAR test reduction for 802.11 Wi-Fi transmission mode configurations are considered separately for DSSS and OFDM. An initial test position is determined to reduce the number of tests required for certain exposure configurations with multiple test positions. An initial test configuration is determined for each frequency band and aggregated band according to maximum output power, channel bandwidth, wireless mode configurations and other operating parameters to streamline the measurement requirements. For 2.4 GHz DSSS, either the initial test position or DSSS Procedure is applied to reduce the number of SAR tests; these are mutually exclusive. For OFDM, an initial test position is only applicable to next to the ear, UMPC mini-tablet and hotspot mode configurations, which is tested using the initial test configuration to facilitate test reduction. For other exposure conditions with a fixed test position, SAR test reduction is determined using only the initial test configuration.

The multiple test positions require SAR measurements in head, hotspot mode or UMPC mini-tablet configurations may be reduced according to the highest reported SAR determined using the initial test position(s) by applying the DSSS or OFDM SAR measurement Procedures in the required wireless mode test configuration(s). 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. The area scans must be measured using the same SAR measurement configurations, including test channel, maximum output power, Probe tip to phantom distance, scan resolution etc.

When the reported SAR for the initial test position is:

- 1) ≤ 0.4 W/kg, further SAR measurement is not required for the other test positions in that exposure configuration and wireless mode combination within the frequency band or aggregated band. DSSS and OFDM configurations are considered separately according to the required SAR Procedures.
 - 2) > 0.4 W/kg, SAR is repeated using the same wireless mode test configuration tested in the initial test position to measure the subsequent next closet/smallest test separation distance and maximum coupling test position, on the highest maximum output power channel, until the reported SAR is ≤ 0.8 W/kg or all required test positions are tested.
 - 3) For all positions/configurations tested using the initial test position and subsequent test positions, when the reported SAR is > 0.8 W/kg, measure the SAR for these positions/configurations on the subsequent next highest measured output power channel(s) until the reported SAR is ≤ 1.2 W/kg or all required test channels are considered.
- SAR is not required for the following 2.4 GHz OFDM conditions.
- 1) When KDB Publication 447498 SAR test exclusion applies to the OFDM configuration.
 - 2) 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.

8 SAR Test Results

8.1 Conducted Power Measurements

8.1.1 Conducted Power of Wi-Fi 2.4G

The output power of Wi-Fi 2.4G is as following:

Mode	Channel	Frequency (MHz)	Data Rate (Mbps)	Tune-up	Peak Power(dBm)
802.11b	1	2412	1	13.00	11.79
	6	2437		13.00	12.66
	11	2462		13.00	12.68
802.11g	1	2412	6	12.50	11.08
	6	2437		12.50	12.19
	11	2462		12.50	12.17
802.11n (HT20)	1	2412	6.5	12.50	10.96
	6	2437		12.50	11.99
	11	2462		12.50	12.12
802.11ax (HE20)	1	2412	8	12.50	11.17
	6	2437		12.50	12.17
	11	2462		12.50	12.07

8.1.2 Conducted Power of Bluetooth

The output power of BT is as following:

For BT 3.0:

Peak Conducted Power(dBm)				Tune up tolerance (dBm)	Tune-up Power(dBm)
Channel	0CH	39CH	78CH		
GFSK	1.36	1.74	1.28	1.0±1.0	2.00
$\pi/4$ DQPSK	-3.28	-2.96	-3.31	-2.5±2.0	0.50
8DPSK	-3.22	-2.82	-3.24	-2.5±2.0	0.50

Note: channel /Frequency: 0/2402, 39/2441, 78/2480.

For BT (BLE):

Peak Conducted Power(dBm)				Tune up tolerance (dBm)	Tune-up Power(dBm)
Channel	0CH	19CH	39CH		
BLE_1M	9.92	10.11	9.68	9.5±1.0	10.50
BLE_2M	10.83	11.04	10.71	10.5±1.0	11.50

Note: channel /Frequency: 0/2402, 19/2440, 39/2480.

8.2 SAR test results

Notes:

1) Per KDB447498 D01v06, testing of other required channels within the operating mode of a frequency band is not required when the reported 1-g or 10-g SAR for the mid-band or highest output power channel is: ≤ 0.8 W/kg or 2.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≤ 100 MHz. When the maximum output power variation across the required test channels is $> \frac{1}{2}$ dB, instead of the middle channel, the highest output power channel must be used.

2) Per KDB447498 D01v06, All measurement SAR result is scaled-up to account for tune-up tolerance is compliant.

3) Per KDB865664 D01v01r04, for each frequency band, repeated SAR measurement is required only when the measured SAR is ≥ 0.8 W/Kg; if the deviation among the repeated measurement is $\leq 20\%$, and the measured SAR < 1.45 W/Kg, only one repeated measurement is required.

4) Per KDB865664 D02v01r02, SAR plot is only required for the highest measured SAR in each exposure configuration, wireless mode and frequency band combination; Plots are also required when the measured SAR is > 1.5 W/kg, or > 7.0 W/kg for occupational exposure. The same Procedures should be adapted for measurements according to extremity exposure limits by applying a factor of 2.5 for extremity exposure. The published RF exposure KDB Procedures may require additional plots; for example, to support SAR to peak location separation ratio test exclusion and/or volume scan post-Processing (Refer to appendix B for details).

8.2.1 Results overview of Wi-Fi 2.4G

Test Position With 0mm	Test channel /Freq. (MHz)	Test Mode	SAR Value (W/kg)		Power Drift (dBm)	Conduc ted Power (dBm)	Tune- up power (dBm)	Scaled SAR _{1-g} (W/kg)	Actual Duty Cycle	Reported SAR _{1-g} (W/kg)
			1-g	10-g						
Front Side	11/2462	802.11b	0.139	0.028	0.03	12.68	13.00	0.150	98.26%	0.152
Back Side	11/2462	802.11b	0.017	0.004	-0.08	12.68	13.00	0.018	98.26%	0.018
Left Side	11/2462	802.11b	0.003	0.001	0.05	12.68	13.00	0.003	98.26%	0.003
Right Side	11/2462	802.11b	0.004	0.001	-0.17	12.68	13.00	0.004	98.26%	0.004
Top Side	11/2462	802.11b	0.002	0.001	0.03	12.68	13.00	0.002	98.26%	0.002
Bottom Side	11/2462	802.11b	0.001	0.001	-0.04	12.68	13.00	0.001	98.26%	0.001
Front Side	1/2412	802.11b	0.146	0.039	-0.08	11.79	13.00	0.193	98.23%	0.196
Front Side	6/2437	802.11b	0.162	0.043	0.18	12.66	13.00	0.175	98.26%	0.178

Note: Per KDB248227D01:

- 1) SAR is measured for 2.4 GHz 802.11b DSSS using initial test position Procedure.
- 2) 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, 802.11g/n/ax OFDM SAR Test is not required.
- 3) Scaled SAR = SAR Value * $10(0.1 * (\text{Tune up Power} - \text{Conducted Power}))$
Reported SAR = SAR Value * $10(0.1 * (\text{Tune up Power} - \text{Conducted Power})) / \text{Duty factor} * 100$

8.2.2 Results overview of Bluetooth

Test Position With 0mm	Test channel /Freq. (MHz)	Test Mode	SAR Value (W/kg)		Power Drift (dBm)	Conduc ted Power (dBm)	Tune- up power (dBm)	Scaled SAR _{1-g} (W/kg)	Actual Duty Cycle	Reported SAR _{1-g} (W/kg)
			1-g	10-g						
Front Side	2440	GFSK	0.112	0.023	0.03	11.04	11.50	0.125	57.81%	0.215
Back Side	2440	GFSK	0.012	0.004	0.11	11.04	11.50	0.013	57.81%	0.023
Left Side	2440	GFSK	0.002	0.001	0.10	11.04	11.50	0.003	57.81%	0.004
Right Side	2440	GFSK	0.003	0.001	-0.08	11.04	11.50	0.004	57.81%	0.006
Top Side	2440	GFSK	0.002	0.001	-0.02	11.04	11.50	0.002	57.81%	0.004
Bottom Side	2440	GFSK	0.001	0.001	0.06	11.04	11.50	0.001	57.81%	0.002
Front Side	2402	GFSK	0.080	0.021	-0.02	10.83	11.50	0.093	57.81%	0.161
Front Side	2480	GFSK	0.135	0.025	-0.12	10.71	11.50	0.162	57.81%	0.280

Note: Per KDB248227D01:

1) Scaled SAR = SAR Value * 10(0.1*(Tune up Power-Conducted Power))

Reported SAR = SAR Value * 10(0.1*(Tune up Power-Conducted Power))/ Duty factor * 100

8.3 Multiple Transmitter Information

Refer to Appendix EED32S814757 Multiple Transmitter Information.

8.4 Stand-alone SAR

Per FCC KDB 447498D01:

- 1) The 1-g and 10-g SAR test exclusion thresholds for 100 MHz to 6 GHz at test separation distances $\leq$ 50 mm are determined by:

$$[(\text{max. power of channel, including tune-up tolerance, mW}) / (\text{min. test separation distance, mm})] \cdot [\sqrt{f(\text{GHz})}] \leq 3.0 \text{ for 1-g SAR and } \leq 7.5 \text{ for 10-g extremity SAR, where}$$

- $f(\text{GHz})$ is the RF channel transmit frequency in GHz
- Power and distance are rounded to the nearest mW and mm before calculation
- The result is rounded to one decimal place for comparison

When the minimum test separation distance is < 5 mm, a distance of 5mm is applied to determine SAR test exclusion.

8.5 Simultaneous Transmission Possibilities and Conclusion

The device does not support simultaneous Wi-Fi 2.4G and BT, because the Wi-Fi 2.4G and BT share the same antenna and can't transmit simultaneously. there is not simultaneous transmission possibility and the reported SAR results is not exceed the SAR limit, so the tested result is comply with the FCC limit.

Annex A: Appendix A: SAR System performance Check Plots

(Please See Appendix A)

Annex B: Appendix B: SAR Measurement results Plots

(Please See Appendix B)

Annex C: Appendix C: Calibration reports

(Please See Appendix C)

Annex D: Appendix D: Photo documentation

(Please See Appendix D)