SAR EVALUATION REPORT

IEEE Std 1528-2013

For
Portable Computing Device

FCC ID: C3K1872
Model Name: 1872

Report Number: 12935947-S1V2
Issue Date: 9/9/2019

Prepared for
Microsoft Corporation
One Microsoft Way
Redmond, WA 98052 USA

Prepared by
UL VERIFICATION SERVICES INC.
47173 BENICIA STREET
FREMONT, CA 94538, USA
TEL: (510) 319-4000
FAX: (510) 661-0888

NVLAP LAB CODE 200065-0

Revision History

Rev.	Date	Revisions	Revised By
V1	9/6/2019	Initial Issue	--
V2	9/9/2019	Updated per TCB feedback	Coltyce Sanders

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1. Attestation of Test Results

Applicant Name	MICROSOFT CORPORATION			
FCC ID	C3K1872			
Model Name	1872			
Exposure Category	General Population/Uncontrolled Exposure			
Applicable Standards	Published RF exposure KDB procedures IEEE Std 1528-2013			
Exposure Category	SAR Limits (W/Kg)			
	Peak spatial-average (1g of tissue)		Extremities (hands, wrists, ankles, etc.) (10g of tissue)	
General population / Uncontrolled exposure	1.6		4	
RF Exposure Conditions	Equipment Class - Highest Reported SAR (W/kg)			
	PCB	DTS	NII	DSS
Standalone	N/A	0.923	0.918	N/A
Simultaneous TX		1.461	1.578	1.578
Date Tested	8/26/2019 to 8/29/2019			
Test Results	Pass			

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

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Approved & Released By:	Prepared By:
	
Dave Weaver Operations Leader UL Verification Services Inc.	Remi Rodberg Laboratory Technician UL Verification Services Inc.

2. Test Specification, Methods and Procedures

The tests documented in this report were performed in accordance with FCC 47 CFR § 2.1093, IEEE STD 1528-2013, the following FCC Published RF exposure KDB procedures:

- KDB 865664 D01 (Section 3.5): SAR Measurement 100 MHz to 6 GHz v01r04
- KDB 248227 D01: 802.11 Wi-Fi SAR v02r02
- KDB 447498 D01: General RF exposure Guidance v06 (see Notice-DRS0001 for exemptions)
- KDB 616217 D04: SAR for Laptops and Tablets v01r02

In addition to the above, the following information was used:

- TCB workshop October 2016; RF Exposure Procedures (DUT Holder Perturbations)
- TCB workshop May 2017; RF Exposure Procedures (Broadband Liquid Above 3 GHz)
- TCB workshop April 2019; RF Exposure Procedures (Tissue Simulating Liquids (TSL))
- TCB workshop October 2016; RF Exposure Procedures (Bluetooth Duty Factor)

3. Facilities and Accreditation

The test sites and measurement facilities used to collect data are located at

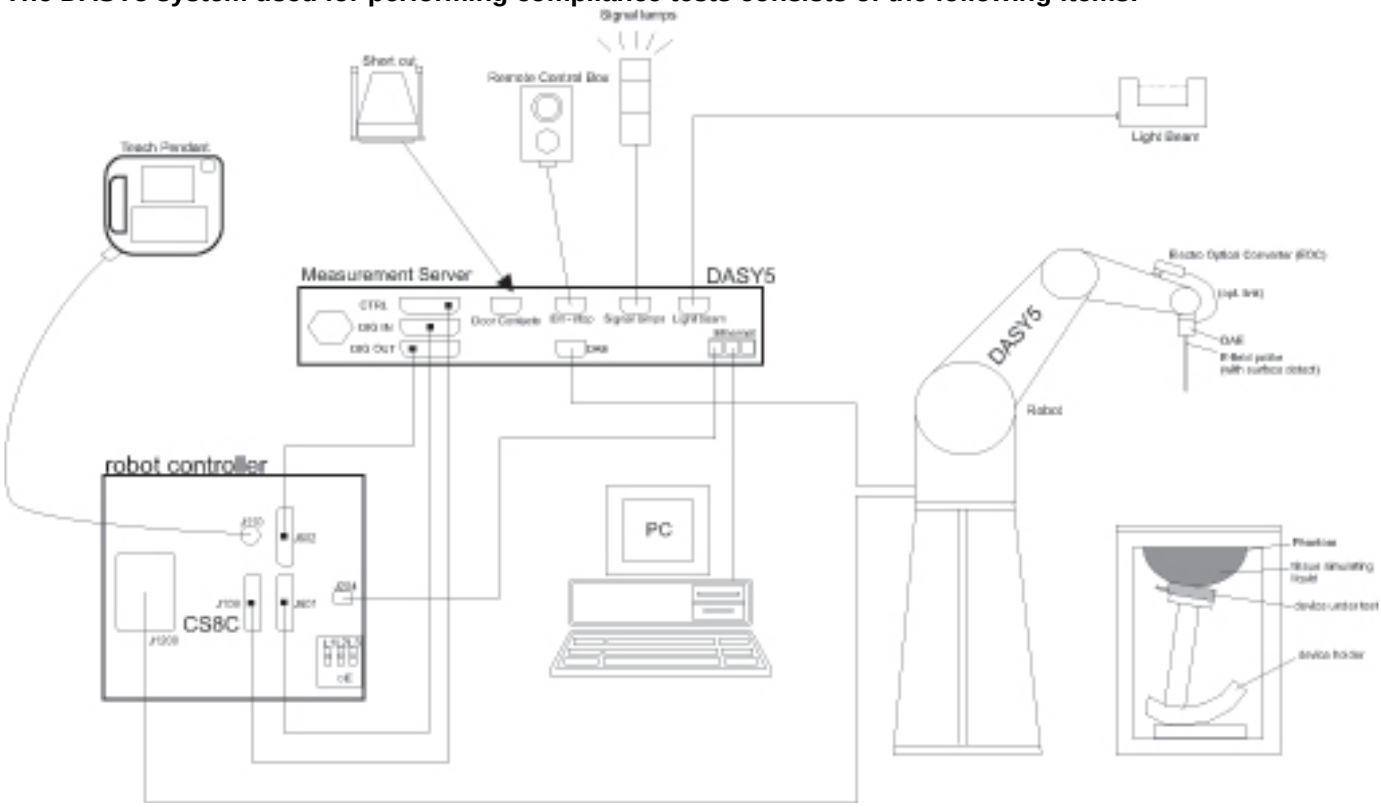
47173 Benicia Street	47266 Benicia Street
SAR Lab A	SAR Lab 1
SAR Lab B	SAR Lab 2
SAR Lab C	SAR Lab 3
SAR Lab D	SAR Lab 4
SAR Lab E	SAR Lab 5
SAR Lab F	SAR Lab 6
SAR Lab G	SAR Lab 7
SAR Lab H	SAR Lab 8

UL Verification Services Inc. is accredited by NVLAP, Laboratory Code 200065-0.

4. SAR Measurement System & Test Equipment

4.1. SAR Measurement System

The DASY5 system used for performing compliance tests consists of the following items:



- A standard high precision 6-axis robot with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).
- An isotropic Field probe optimized and calibrated for the targeted measurement.
- A data acquisition electronics (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
- The Electro-optical converter (EOC) performs the conversion from optical to electrical signals for the digital communication to the DAE. To use optical surface detection, a special version of the EOC is required. The EOC signal is transmitted to the measurement server.
- The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
- The Light Beam used is for probe alignment. This improves the (absolute) accuracy of the probe positioning.
- A computer running WinXP or Win7 and the DASY5 software.
- Remote control and teach pendant as well as additional circuitry for robot safety such as warning lamps, etc.
- The phantom, the device holder and other accessories according to the targeted measurement.

4.2. SAR Scan Procedures

Step 1: Power Reference Measurement

The Power Reference Measurement and Power Drift Measurements are for monitoring the power drift of the device under test in the batch process. The minimum distance of probe sensors to surface determines the closest measurement point to phantom surface. The minimum distance of probe sensors to surface is 2.1 mm. This distance cannot be smaller than the distance of sensor calibration points to probe tip as defined in the probe properties.

Step 2: Area Scan

The Area Scan is used as a fast scan in two dimensions to find the area of high field values, before doing a fine measurement around the hot spot. The sophisticated interpolation routines implemented in DASY software can find the maximum locations even in relatively coarse grids. When an Area Scan has measured all reachable points, it computes the field maximal found in the scanned area, within a range of the global maximum. The range (in dB) is specified in the standards for compliance testing. For example, a 2 dB range is required in IEEE Standard 1528 and IEC 62209 standards, whereby 3 dB is a requirement when compliance is assessed in accordance with the ARIB standard (Japan). If only one Zoom Scan follows the Area Scan, then only the absolute maximum will be taken as reference. For cases where multiple maximums are detected, the number of Zoom Scans has to be increased accordingly.

Area Scan Parameters extracted from KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

	≤ 3 GHz	> 3 GHz
Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface	5 ± 1 mm	½·δ·ln(2) ± 0.5 mm
Maximum probe angle from probe axis to phantom surface normal at the measurement location	30° ± 1°	20° ± 1°
Maximum area scan spatial resolution: Δx_{Area}, Δy_{Area}	≤ 2 GHz: ≤ 15 mm 2 – 3 GHz: ≤ 12 mm	3 – 4 GHz: ≤ 12 mm 4 – 6 GHz: ≤ 10 mm
	When the x or y dimension of the test device, in the measurement plane orientation, is smaller than the above, the measurement resolution must be ≤ the corresponding x or y dimension of the test device with at least one measurement point on the test device.	

Step 3: Zoom Scan

Zoom Scans are used to assess the peak spatial SAR values within a cubic averaging volume containing 1 g and 10 g of simulated tissue. The Zoom Scan measures points (refer to table below) within a cube whose base faces are centered on the maxima found in a preceding area scan job within the same procedure. When the measurement is done, the Zoom Scan evaluates the averaged SAR for 1 g and 10 g and displays these values next to the job's label.

Zoom Scan Parameters extracted from KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

			≤ 3 GHz	> 3 GHz
Maximum zoom scan spatial resolution: Δx_{Zoom}, Δy_{Zoom}			≤ 2 GHz: ≤ 8 mm 2 – 3 GHz: ≤ 5 mm*	3 – 4 GHz: ≤ 5 mm* 4 – 6 GHz: ≤ 4 mm*
Maximum zoom scan spatial resolution, normal to phantom surface	uniform grid: $\Delta z_{Zoom}(n)$		≤ 5 mm	3 – 4 GHz: ≤ 4 mm 4 – 5 GHz: ≤ 3 mm 5 – 6 GHz: ≤ 2 mm
	graded grid	$\Delta z_{Zoom}(1)$: between 1st two points closest to phantom surface	≤ 4 mm	3 – 4 GHz: ≤ 3 mm 4 – 5 GHz: ≤ 2.5 mm 5 – 6 GHz: ≤ 2 mm
		$\Delta z_{Zoom}(n>1)$: between subsequent points	≤ $1.5 \cdot \Delta z_{Zoom}(n-1)$	
Minimum zoom scan volume	x, y, z		≥ 30 mm	3 – 4 GHz: ≥ 28 mm 4 – 5 GHz: ≥ 25 mm 5 – 6 GHz: ≥ 22 mm

Note: δ is the penetration depth of a plane-wave at normal incidence to the tissue medium; see draft standard IEEE P1528-2011 for details.

* When zoom scan is required and the *reported* SAR from the *area scan based 1-g SAR estimation* procedures of KDB 447498 is ≤ 1.4 W/kg, ≤ 8 mm, ≤ 7 mm and ≤ 5 mm zoom scan resolution may be applied, respectively, for 2 GHz to 3 GHz, 3 GHz to 4 GHz and 4 GHz to 6 GHz.

Step 4: Power drift measurement

The Power Drift Measurement measures the field at the same location as the most recent power reference measurement within the same procedure, and with the same settings. The Power Drift Measurement gives the field difference in dB from the reading conducted within the last Power Reference Measurement. This allows a user to monitor the power drift of the device under test within a batch process. The measurement procedure is the same as Step 1.

4.3. Test Equipment

The measuring equipment used to perform the tests documented in this report has been calibrated in accordance with the manufacturers' recommendations, and is traceable to recognized national standards.

Dielectric Property Measurements

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Vector Network Analyzer	Rhode & Schwarz	ZNLE6	101273-va	4/24/2020
Dielectric Probe kit	SPEAG	DAK-3.5	1103	2/12/2020
Shorting Block	SPEAG	DAK-3.5 Short	SM DAK 200 DA	9/11/2019
Thermometer	Keysight	Traceable	170064398	5/21/2020

System Check

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Synthesized Signal Generator	Agilent	N5181A	MY50140610	1/31/2020
Power Meter	Keysight	N1912A	MY55196007	1/30/2020
Power Sensor	Agilent	N1921A	MY53260001	2/5/2020
Power Sensor	Agilent	N1921A	MY52200012	2/6/2020
Amplifier	MITEQ	AMF-4D-00400600-50-30P	1795092	N/A
Directional coupler	Werlatone	C8060-102	2149	N/A
DC Power Supply	Sorensen	XT 15-4	1817A02680	N/A
Signal Generator	Rhode & Schwarz	SMB100A	180969-yC	2/13/2020
Power Sensor	Rhode & Schwarz	NRP18A	100995-hs	2/15/2020
Signal Generator	Rhode & Schwarz	SMB100A	180968-gX	2/14/2020
Power Sensor	Rhode & Schwarz	NRP18A	100992-iu	2/15/2020

Lab Equipment

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
E-Field Probe (SAR Lab 1)	SPEAG	EX3DV4	3885	9/18/2019
E-Field Probe (SAR Lab 3)	SPEAG	EX3DV4	7500	4/18/2020
Data Acquisition Electronics (SAR Lab 1)	SPEAG	DAE4	1544	3/19/2020
Data Acquisition Electronics (SAR Lab 3)	SPEAG	DAE4	1472	3/21/2020
System Validation Dipole	SPEAG	D2450V2	899	3/22/2020
System Validation Dipole	SPEAG	D5GHzV2	1003	2/19/2020
System Validation Dipole	SPEAG	D5GHzV2	1168	11/30/2019

Other

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Power Meter	Agilent	N1921A	MY55196004	1/30/2020
Power Sensor	Agilent	N1921A	MY52270022	2/6/2020
Power Sensor	Agilent	N1921A	MY53260010	2/6/2020

5. Measurement Uncertainty

Per KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz, when the highest measured 1-g SAR within a frequency band is < 1.5 W/kg and the measured 10-g SAR within a frequency band is < 3.75 W/kg. The expanded SAR measurement uncertainty must be ≤ 30%, for a confidence interval of k = 2. If these conditions are met, extensive SAR measurement uncertainty analysis described in IEEE Std 1528-2013 is not required in SAR reports submitted for equipment approval.

Therefore, the measurement uncertainty is not required.

6. Device Under Test (DUT) Information

6.1. DUT Description

Device Dimension	See Appendix A		
Back Cover	The Back Cover is not removable		
Battery Options	The battery is not user accessible.		
Accessory	N/A		
Test sample information	**S/N**	**IMEI**	**Notes**
	12475292957	N/A	WLAN Radiated/Conducted
	14813492757	N/A	WLAN Radiated/Conducted
Hardware Version	DV		
Software Version	MTEOS 1.652.0		

6.2. Wireless Technologies

Wireless technologies	Frequency bands	Operating mode	Duty Cycle used for SAR testing
Wi-Fi	2.4 GHz	802.11b 802.11g 802.11n (HT20) 802.11n (HT40) 802.11ax (HE40)	99.26% (802.11b) [1]
	5 GHz	802.11a 802.11n (HT20) 802.11n (HT40) 802.11ac (VHT20) 802.11ac (VHT40) 802.11ac (VHT80) 802.11ac (VHT160) 802.11ax (HE20) 802.11ax (HE40) 802.11ax (HE80) 802.11ax (HE160)	98.95% (802.11n HT40) [1] 98.95% (802.11ac VHT80MHz BW) [1] 98.66% (802.11ax 80MHz BW)
	Bluetooth	BR, EDR, LE	N/A[2]
	Does this device support bands 5.60 ~ 5.65 GHz? ☒ Yes ☐ No		
	Does this device support Band gap channel(s)? ☒ Yes ☐ No		

Notes:

1. Duty cycle for Wi-Fi is referenced from sections 9.1 (DTS) and 9.2 (U-NII).
2. Measured Duty Cycle is not required due to SAR test exemption

7. RF Exposure Conditions (Test Configurations)

Refer to Appendix A for the specific details of the antenna-to-antenna and antenna-to-edge(s) distances.

Wireless technologies	RF Exposure Conditions	DUT-to-User Separation	Test Position	Antenna-to-edge/surface	SAR Required
WLAN/BT Chain 0	Standalone	0 mm	Rear	N/A	Yes
WLAN Chain 1	Standalone	0 mm	Rear	N/A	Yes

8. Dielectric Property Measurements & System Check

8.1. Dielectric Property Measurements

The temperature of the tissue-equivalent medium used during measurement must also be within 18°C to 25°C and within ± 2°C of the temperature when the tissue parameters are characterized.
The dielectric parameters must be measured before the tissue-equivalent medium is used in a series of SAR measurements. The parameters should be re-measured after each 3 – 4 days of use; or earlier if the dielectric parameters can become out of tolerance; for example, when the parameters are marginal at the beginning of the measurement series.
Tissue dielectric parameters were measured at the low, middle and high frequency of each operating frequency range of the test device.
The dielectric constant (εr) and conductivity (σ) of typical tissue-equivalent media recipes are expected to be within ± 5% of the required target values; but for SAR measurement systems that have implemented the SAR error compensation algorithms documented in IEEE Std 1528-2013, to automatically compensate the measured SAR results for deviations between the measured and required tissue dielectric parameters, the tolerance for εr and σ may be relaxed to ± 10%. This is limited to frequencies ≤ 3 GHz.

Tissue Dielectric Parameters

FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

Target Frequency (MHz)	Head		Body	
	ε_r	σ (S/m)	ε_r	σ (S/m)
150	52.3	0.76	61.9	0.80
300	45.3	0.87	58.2	0.92
450	43.5	0.87	56.7	0.94
835	41.5	0.90	55.2	0.97
900	41.5	0.97	55.0	1.05
915	41.5	0.98	55.0	1.06
1450	40.5	1.20	54.0	1.30
1610	40.3	1.29	53.8	1.40
1800 – 2000	40.0	1.40	53.3	1.52
2450	39.2	1.80	52.7	1.95
3000	38.5	2.40	52.0	2.73
5000	36.2	4.45	49.3	5.07
5100	36.1	4.55	49.1	5.18
5200	36.0	4.66	49.0	5.30
5300	35.9	4.76	48.9	5.42
5400	35.8	4.86	48.7	5.53
5500	35.6	4.96	48.6	5.65
5600	35.5	5.07	48.5	5.77
5700	35.4	5.17	48.3	5.88
5800	35.3	5.27	48.2	6.00

IEEE Std 1528-2013

Refer to Table 3 within the IEEE Std 1528-2013

Dielectric Property Measurements Results:

SAR Lab	Date	Band (MHz)	Tissue Type	Frequency (MHz)	Relative Permittivity (εr)			Conductivity (σ)		
					Measured	Target	Delta (%)	Measured	Target	Delta (%)
1	8/26/2019	2450	Body	2450	50.26	52.70	-4.63	2.03	1.95	4.26
				2400	50.31	52.77	-4.67	1.99	1.90	4.64
				2480	50.26	52.66	-4.56	2.05	1.99	2.90
3	8/26/2019	5250	Body	5250	48.30	48.95	-1.33	5.33	5.35	-0.35
				5150	48.49	49.09	-1.22	5.19	5.24	-0.91
				5350	48.09	48.82	-1.49	5.48	5.47	0.12
3	8/26/2019	5600	Body	5600	47.60	48.48	-1.81	5.85	5.76	1.46
				5500	47.79	48.61	-1.69	5.69	5.64	0.86
				5725	47.36	48.31	-1.96	6.03	5.91	2.02
3	8/26/2019	5750	Body	5750	47.30	48.27	-2.04	6.07	5.94	2.18
				5700	47.41	48.34	-1.93	5.99	5.88	1.96
				5850	47.10	48.20	-2.28	6.22	6.00	3.58

8.2. System Check

SAR system verification is required to confirm measurement accuracy, according to the tissue dielectric media, probe calibration points and other system operating parameters required for measuring the SAR of a test device. The system verification must be performed for each frequency band and within the valid range of each probe calibration point required for testing the device. The same SAR probe(s) and tissue-equivalent media combinations used with each specific SAR system for system verification must be used for device testing. When multiple probe calibration points are required to cover substantially large transmission bands, independent system verifications are required for each probe calibration point. A system verification must be performed before each series of SAR measurements using the same probe calibration point and tissue-equivalent medium. Additional system verification should be considered according to the conditions of the tissue-equivalent medium and measured tissue dielectric parameters, typically every three to four days when the liquid parameters are re-measured or sooner when marginal liquid parameters are used at the beginning of a series of measurements.

System Performance Check Measurement Conditions:

- The measurements were performed in the flat section of the TWIN SAM or ELI phantom, shell thickness: 2.0 ±0.2 mm (bottom plate) filled with Body or Head simulating liquid of the following parameters.
- The depth of tissue-equivalent liquid in a phantom must be ≥ 15.0 cm for SAR measurements ≤ 3 GHz and ≥ 10.0 cm for measurements > 3 GHz.
- The DASY system with an E-Field Probe was used for the measurements.
- The dipole was mounted on the small tripod so that the dipole feed point was positioned below the center marking of the flat phantom section and the dipole was oriented parallel to the body axis (the long side of the phantom). The standard measuring distance was 10 mm (above 1 GHz) and 15 mm (below 1 GHz) from dipole center to the simulating liquid surface.
- The coarse grid with a grid spacing of 15 mm was aligned with the dipole.
  For 5 GHz band - The coarse grid with a grid spacing of 10 mm was aligned with the dipole.
- Special 7x7x7 (below 3 GHz) and/or 8x8x7 (above 3 GHz) fine cube was chosen for the cube.
- Distance between probe sensors and phantom surface was set to 3 mm.
  For 5 GHz band - Distance between probe sensors and phantom surface was set to 2.5 mm
- The dipole input power (forward power) was 100 mW.
- The results are normalized to 1 W input power.

System Check Results

The 1-g and 10-g SAR measured with a reference dipole, using the required tissue-equivalent medium at the test frequency, must be within ±10% of the manufacturer calibrated dipole SAR target. Refer to Appendix B for the SAR System Check Plots.

SAR Lab	Date	Tissue Type	Dipole Type _Serial #	Dipole Cal. Due Data	Measured Results for 1g SAR				Measured Results for 10g SAR				Plot No.
					Zoom Scan to 100 mW	Normalize to 1 W	Target (Ref. Value)	Delta ±10 %	Zoom Scan to 100 mW	Normalize to 1 W	Target (Ref. Value)	Delta ±10 %	
1	8/26/2019	Body	D2450V2 SN:899	3/22/2020	5.350	53.50	50.00	7.00	2.460	24.60	23.50	4.68	1,2
3	8/26/2019	Body	D5GHzV2 SN:1003 (5.25 GHz)	2/19/2020	7.350	73.50	74.40	-1.21	2.090	20.90	20.80	0.48	3,4
3	8/26/2019	Body	D5GHzV2 SN:1003 (5.60 GHz)	2/19/2020	8.600	86.00	79.30	8.45	2.420	24.20	22.30	8.52	5,6
3	8/26/2019	Body	D5GHzV2 SN:1003 (5.75 GHz)	2/19/2020	8.270	82.70	76.20	8.53	2.310	23.10	21.40	7.94	7,8

9. Conducted Output Power Measurements

9.1. Wi-Fi 2.4GHz (DTS Band)

Maximum Output Power (Tune-up Limit) for Wi-Fi 2.4 GHz

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.

For “Not required”, SAR Test reduction was applied from KDB 248227 guidance, Sec. 2.1, b), 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 802.11b/g/n mode is used for SAR measurement, on the highest measured output power channel in the initial test configuration, for each frequency band. Additional output power measurements were not deemed necessary.

Wi-Fi 2.4GHz Measured Results

Band	Mode	Ch #	Freq. (MHz)	Chain 0 Average Power (dBm)			Chain 1 Average Power (dBm)		
				Meas Pwr	Tune-up	SAR Test (Yes/No)	Meas Pwr	Tune-up	SAR Test (Yes/No)
DSSS 2.4 GHz	802.11b	1	2412	19.1	20.0	Yes	19.4	20.0	Yes
		6	2437	19.0	20.0		19.4	20.0	
		11	2462	19.1	20.0		19.2	20.0	
		12	2467	Not Required	20.0		Not Required	20.0	
		13	2472	Not Required	19.0		Not Required	19.0	
OFDM 2.4 GHz	802.11g	1	2412		19.5	No		19.5	No
		2	2417		20.0			20.0	
		6	2437		20.0			20.0	
		10	2457		20.0			20.0	
		11	2462		18.5			18.5	
		12	2467		15.5			15.5	
		13	2472		13.0			13.0	
	802.11n (HT20)	1	2412		17.5	No		17.5	No
		2	2417		20.0			20.0	
		6	2437		20.0			20.0	
		9	2452		20.0			20.0	
		10	2457		19.5			19.5	
		11	2462		16.5			16.5	
		12	2467		14.5			14.5	
		13	2472		11.0			11.0	
	802.11n (HT40)	3	2422		17.0	No		17.0	No
		5	2432		18.0			18.0	
		6	2437		18.0			18.0	
		7	2442		17.5			17.5	
		11	2462		15.0			15.0	
OFDMA 2.4 GHz	802.11ax (HE20)	1	2412		16.0	No		16.0	No
		2	2417		19.5			19.5	
		3	2422		20.0			20.0	
		6	2437		20.0			20.0	
		9	2452		20.0			20.0	
		10	2457		18.5			18.5	
		11	2462		14.5			14.5	
		12	2467		13.5			13.5	
		13	2472		12.5			12.5	
	802.11ax (HE40)	3	2422		15.5			15.5	No
		5	2432		17.5	No		17.5	
		6	2437		18.5			18.5	
		8	2447		17.0			17.0	
		11	2462		11.5			11.5	

Note(s):

SAR is not required for channel 12 and 13 because the tune-up limit and the measured output power for these two channels are not greater than those for the default test channels. Refer to KDB 248227 D01 section 3.1

Duty Factor Measured Results:

Band	Antenna	Mode	Data Rate	T on (ms)	Period (ms)	Duty Cycle	Crest Factor (1/duty cycle)
2.4G	Chain 0	802.11b	1 Mbps	8.346	8.408	99.26%	1.01
	Chain 1			8.346	8.408	99.26%	1.01

Note(s):

Duty Cycle = (T on / period) * 100%

Duty Cycle plots

802.11b

Chain 0

Chain 1

9.2. Wi-Fi 5GHz (U-NII Bands)

Maximum Output Power (Tune-up Limit) for Wi-Fi 5 GHz

When the same transmission mode configurations have the same maximum output power on the same channel for the 802.11 a/g/n/ac/ax modes, the channel in the lower order/sequence 802.11 transmission mode is selected.

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.

For “Not required”, SAR Test reduction was applied from KDB 248227 guidance, Sec. 2.1, b), 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/ax mode is used for SAR measurement, on the highest measured output power channel in the initial test configuration, for each frequency band. Additional output power measurements were not deemed necessary.

When the specified maximum output power is the same for both UNII 1 and UNII 2A, begin SAR measurements in UNII 2A with the channel with the highest measured output power. If the reported SAR for UNII 2A is ≤ 1.2 W/kg, SAR is not required for UNII 1; otherwise treat the remaining bands separately and test them independently for SAR.

Wi-Fi 5 GHz Measured Results

Band	Mode	Ch #	Freq. (MHz)	Chain 0 Average Power (dBm)			Chain 1 Average Power (dBm)		
				Meas Pwr	Tune-up	SAR Test (Yes/No)	Meas Pwr	Tune-up	SAR Test (Yes/No)
UNII-1 5.2 GHz	802.11a	36	5180		11.5	No		11.5	No
		40	5200		11.5			11.5	
		44	5220		11.5			11.5	
		48	5240		11.5			11.5	
	802.11n (HT20)	36	5180		14.5	No		14.5	No
		40	5200		14.5			14.5	
		44	5220		14.5			14.5	
		48	5240		14.5			14.5	
	802.11ax (HE20)	36	5180		15.0	No		15.0	No
		40	5200		15.0			15.0	
		44	5220		15.0			15.0	
		48	5240		15.0			15.0	
	802.11n (HT40)	38	5190		16.5	No		16.5	No
		46	5230		16.5			16.5	
	802.11ax (HE40)	38	5190		16.5	No		16.5	No
		46	5230		16.5			16.5	
	802.11ac (VHT80)	42	5210	14.9	16.5	Yes	14.8	16.5	Yes
	802.11ax (HE80)	42	5210		16.5	No		16.5	No

Band	Mode	Ch #	Freq. (MHz)	Chain 0 Average Power (dBm)			Chain 1 Average Power (dBm)		
				Meas Pwr	Tune-up	SAR Test (Yes/No)	Meas Pwr	Tune-up	SAR Test (Yes/No)
UNII-2A 5.3 GHz	802.11a	52	5260		16.5	No		16.5	No
		56	5280		16.5			16.5	
		60	5300		16.5			16.5	
		64	5320		16.5			16.5	
	802.11n (HT20)	52	5260		20.0	No		20.0	No
		56	5280		20.0			20.0	
		60	5300		20.0			20.0	
		64	5320		19.0			19.0	
	802.11ax (HE20)	52	5260		20.0	No		20.0	No
		56	5280		20.0			20.0	
		60	5300		20.0			20.0	
		64	5320		20.0			20.0	
	802.11n (HT40)	54	5270	19.3	20.0	Yes	18.9	20.0	Yes
		62	5310	Not Required	17.0		Not Required	17.0	
	802.11ax (HE40)	54	5270		17.5	No		17.5	No
		62	5310		17.5			17.5	
	802.11ac (VHT80)	58	5290		16.0	No		16.0	No
	802.11ax (HE80)	58	5290		17.5	No		17.5	No
UNII-1 & 2A	802.11ac (VHT160)	50	5250		15.5	No		15.5	No
	802.11ax (HE160)	50	5250		15.5	No		15.5	No

Wi-Fi 5 GHz Measured Results (Continued)

Band	Mode	Ch #	Freq. (MHz)	Chain 0 Average Power (dBm)			Chain 1 Average Power (dBm)		
				Meas Pwr	Tune-up	SAR Test (Yes/No)	Meas Pwr	Tune-up	SAR Test (Yes/No)
UNII-2C 5.6 GHz	802.11a	100	5500		16.0	No		16.0	No
		116	5580		16.0			16.0	
		124	5620		16.0			16.0	
		144	5720		16.0			16.0	
	802.11n (HT20)	100	5500		20.0	No		20.0	No
		116	5580		20.0			20.0	
		124	5620		20.0			20.0	
		144	5720		19.5			19.5	
	802.11ax (HE20)	108	5540		20.0	No		20.0	No
		116	5580		20.0			20.0	
		124	5620		20.0			20.0	
		132	5660		20.0			20.0	
	802.11n (HT40)	102	5510		17.5	No		17.5	No
		118	5590		20.0			20.0	
		126	5630		20.0			20.0	
		142	5710		20.0			20.0	
	802.11ax (HE40)	102	5510		17.5	No		17.5	No
		118	5590		19.0			19.0	
		126	5630		19.0			19.0	
		142	5710		20.0			20.0	
	802.11ac (VHT80)	106	5530	Not Required	17.0	Yes	Not Required	17.0	Yes
		122	5610	18.4	20.0		18.4	20.0	
		138	5690	18.4	20.0		18.4	20.0	
	802.11ax (HE80)	106	5530	Not Required	18.0	No	Not Required	18.0	No
		122	5610	18.5	20.0		18.3	20.0	
		138	5690	18.5	20.0		18.4	20.0	
UNII-2C 5.6 GHz	802.11ac (VHT160)	114	5570		14.5	No		14.5	No
	802.11ax (HE160)	114	5570		10.5	No		10.5	No

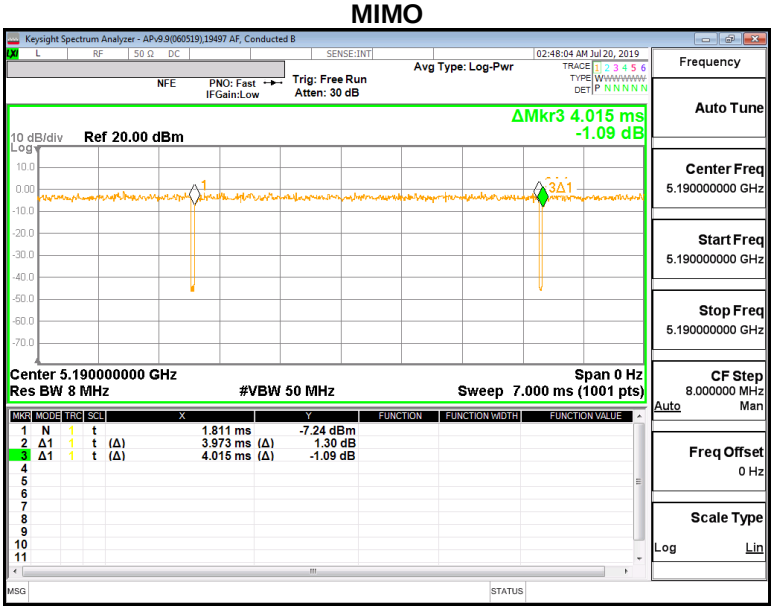
Band	Mode	Ch #	Freq. (MHz)	Chain 0 Average Power (dBm)			Chain 1 Average Power (dBm)		
				Meas Pwr	Tune-up	SAR Test (Yes/No)	Meas Pwr	Tune-up	SAR Test (Yes/No)
UNII-3 5.8 GHz	802.11a	149	5745		20.0	No		20.0	No
		157	5785		20.0			20.0	
		165	5825		20.0			20.0	
	802.11n (HT20)	149	5745		20.0	No		20.0	No
		157	5785		20.0			20.0	
		165	5825		20.0			20.0	
	802.11ax (HE20)	149	5745		20.0	No		20.0	No
		157	5785		20.0			20.0	
		165	5825		20.0			20.0	
	802.11n (HT40)	151	5755		20.0	No		20.0	No
		159	5795		20.0			20.0	
	802.11ax (HE40)	151	5755		19.0	No		19.0	No
		159	5795		19.5			19.5	
	802.11ac (VHT80)	155	5775		19.5	No		19.5	No
	802.11ax (HE80)	155	5775	18.5	20.0	Yes	18.5	20.0	Yes

Duty Factor Measured Results:

Band	Antenna	Mode	Data Rate	T on (ms)	Period (ms)	Duty Cycle	Crest Factor (1/duty cycle)
5.3G	MIMO	802.11n HT40	MCS0	3.973	4.015	98.95%	1.01
5.6G	MIMO	802.11ac VHT80	MCS0	3.973	4.015	98.95%	1.01
5.8G	MIMO	802.11ax HE80	MCS0	3.976	4.030	98.66%	1.01

Duty Cycle plot for 802.11n HT40

MIMO

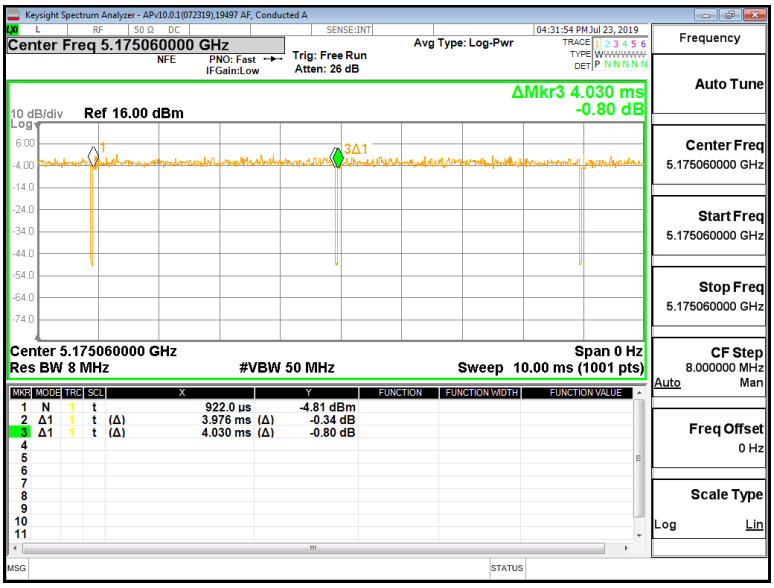


Duty Cycle plot for 802.11ac VHT80

MIMO

Duty Cycle plot for 802.11ax HE80

MIMO



10. Measured and Reported (Scaled) SAR Results

SAR Test Reduction criteria are as follows:

- Reported SAR(W/kg) for Wi-Fi = Measured SAR * Tune-up scaling factor * Duty Cycle scaling factor
- Duty Cycle scaling factor = 1 / Duty cycle (%)

KDB 447498 D01 General RF Exposure Guidance:

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
- ≤ 0.6 W/kg or 1.5 W/kg, for 1-g or 10-g respectively, when the transmission band is between 100 MHz and 200 MHz
- ≤ 0.4 W/kg or 1.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≥ 200 MHz

KDB 248227 D01 SAR meas for 802.11:

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 *initial test position(s)* is measured using the highest measured maximum output power channel in the required wireless mode test configuration(s). When the *reported* SAR for the *initial test position* is:

- ≤ 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.
- > 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.
  - For subsequent test positions with equivalent test separation distance or when exposure is dominated by coupling conditions, the position for maximum coupling condition should be tested.
  - When it is unclear, all equivalent conditions must be tested.
- 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.
  - The additional power measurements required for this step should be limited to those necessary for identifying subsequent highest output power channels to apply the test reduction.
- When the specified maximum output power is the same for both UNII 1 and UNII 2A, begin SAR measurements in UNII 2A with the channel with the highest measured output power. If the reported SAR for UNII 2A is ≤ 1.2 W/kg, SAR is not required for UNII 1; otherwise treat the remaining bands separately and test them independently for SAR.
- When the specified maximum output power is different between UNII 1 and UNII 2A, begin SAR with the band that has the higher specified maximum output. If the highest reported SAR for the band with the highest specified power is ≤ 1.2 W/kg, testing for the band with the lower specified output power is not required; otherwise test the remaining bands independently for SAR.

10.1. Wi-Fi (DTS Band)

RF Exposure Conditions	Mode	Antenna	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		Plot No.
								Tune-up Limit	Meas.	Meas.	Scaled	
Standalone	802.11b 1 Mbps	Chain 0	0	Rear	1	2412	99.26%	20.0	19.10	0.745	**0.923**	1
					11	2462	99.26%	20.0	19.07	0.553	0.690	
Standalone	802.11b 1 Mbps	Chain 1	0	Rear	6	2437	99.26%	20.0	19.38	0.463	**0.538**	2

10.2. Wi-Fi (U-NII Band)

RF Exposure Conditions	Mode	Antenna	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		Plot No.
								Tune-up Limit	Meas.	Meas.	Scaled	
Standalone	802.11n HT40	Chain 0	0	Rear	54	5270	98.95%	20.0	19.3	0.295	**0.350**	3
Standalone	802.11n HT40	Chain 1	0	Rear	54	5270	98.95%	20.0	18.9	0.511	**0.665**	4

RF Exposure Conditions	Mode	Antenna	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		Plot No.
								Tune-up Limit	Meas.	Meas.	Scaled	
Standalone	802.11ac VHT80	Chain 0	0	Rear	122	5610	98.95%	20.0	18.4	0.289	**0.422**	5
Standalone	802.11ac VHT80	Chain 1	0	Rear	122	5610	98.95%	20.0	18.4	0.535	**0.782**	6

RF Exposure Conditions	Mode	Antenna	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		Plot No.
								Tune-up Limit	Meas.	Meas.	Scaled	
Standalone	802.11ax HE80	Chain 0	0	Rear	155	5775	98.66%	20.0	18.5	0.579	**0.829**	7
Standalone	802.11ax HE80	Chain 1	0	Rear	155	5775	98.66%	20.0	18.5	0.641	**0.918**	8

10.3. Standalone SAR Test Exclusion Considerations & Estimated SAR

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

[(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)]·[√f(GHz)] ≤ 3.0, for 1-g SAR and ≤ 7.5 for 10-g extremity SAR, where

- $f_{(GHz)}$ 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

The test exclusions are applicable only when the minimum test separation distance is ≤ 50 mm and for transmission frequencies between 100 MHz and 6 GHz. When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.

When the standalone SAR test exclusion is applied to an antenna that transmits simultaneously with other antennas, the standalone SAR must be estimated according to following to determine simultaneous transmission SAR test exclusion:

- *(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)]·[√$f_{(GHz)}$/x]* W/kg for test separation distances ≤ 50 mm;
  where x = 7.5 for 1-g SAR, and x = 18.75 for 10-g SAR.
- 0.4 W/kg for 1-g SAR and 1.0 W/kg for 10-g SAR, when the test separation distances is > 50 mm.

RF Air interface	RF Exposure Conditions	Frequency (GHz)	Max. tune-up tolerance Power		Min. test separation distance (mm)	SAR test exclusion Result*	Estimated 1-g SAR (W/kg)
			(dBm)	(mW)			
Bluetooth	Body-worn	2.480	3.5	2	5	0.6	0.084

Conclusion:

*: The computed value is ≤ 3; therefore, Bluetooth qualifies for Standalone SAR test exclusion.

11. SAR Measurement Variability

In accordance with published RF Exposure KDB 865664 D01 SAR measurement 100 MHz to 6 GHz. 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.

1) Repeated measurement is not required when the original highest measured SAR is <0.8 or 2 W/kg (1-g or 10-g respectively); steps 2) through 4) do not apply.
2) When the original highest measured SAR is ≥ 0.8 or 2 W/kg (1-g or 10-g respectively), 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 > 1.20 or when the original or repeated measurement is ≥ 1.45 or 3.6 W/kg (~ 10% from the 1-g or 10-g respective SAR limit).
4) Perform a third repeated measurement only if the original, first, or second repeated measurement is ≥ 1.5 or 3.75 W/kg (1-g or 10-g respectively) and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20.

Conclusion:

Repeated measurement is not required since the original highest measured SAR is <0.8 W/kg.

12. Simultaneous Transmission SAR Analysis

Simultaneous Transmission Condition:

RF Exposure Condition	Item	Capable Transmit Configurations		
		Chain 0		Chain 1
Standalone	1	DTS	+	DTS
	2	U-NII	+	U-NII
	3	U-NII & BT	+	U-NII

Notes:
1. Bluetooth Radio is only supported on Chain 0.
2. DTS Radio cannot transmit simultaneously with Bluetooth Radio
3. U-NII Radio can transmit simultaneously with Bluetooth Radio.

12.1. Sum of the SAR for Wi-Fi & BT

RF Exposure Conditions	Test Position	Standalone SAR (W/kg)					∑ 1-g SAR (W/kg)		
		1	2	3	4	5	1+2	3+4	3+4+5
		Wi-Fi 2.4G Chain# 0	Wi-Fi 2.4G Chain# 1	Wi-Fi 5G Chain# 0	Wi-Fi 5G Chain# 1	BT Chain# 0			
Standalone	Rear	0.923	0.538	0.829	0.918	0.084	**1.461**	1.747	1.831
				0.829	0.665	0.084		1.494	**1.578**

Note(s):

Worst Case Sum of SAR for 5GHz and BT was >1.6 W/kg, therefore additional sum of SAR cases were evaluated in order to find the worst case sum of SAR < 1.6 W/kg for Highest Reported SAR purposes.

Worst Case SAR to Peak Location Separation Ratio (SPLSR):

RF Exposure Conditions	Test Position	Standalone SAR (W/kg)			∑ 1-g SAR (W/kg)		Calculated distance (mm)	SPLSR (≤ 0.04)	Volume Scan (Yes/ No)
		3	4	5					
		Wi-Fi 5G Chain# 0	Wi-Fi 5G Chain# 1	BT Chain# 0					
Standalone	Rear	0.829	0.918	0.084	3 + 4 + 5	1.831	151.4	0.02	No
		0.829	0.918		3 + 4	1.747	163.0	0.01	No
			0.918	0.084	4 + 5	1.002	151.4	0.01	No

RF Exposure Conditions	Test Position	Mode		Peak SAR	X	Y	Z	d: Calculated distance (mm)	
				W/kg	m	m	m		
Standalone	Rear	5G Chain# 0	3	1.360	0.110	0.068	-0.174	3 + 4	163.0
		5G Chain# 1	4	1.530	0.112	-0.095	-0.174		
Standalone	Rear	5G Chain# 1	4	1.530	0.112	-0.095	-0.174	4 + 5	151.4
		2.4G Chain# 0	5	1.260	0.113	0.056	-0.177		

BT SAR is estimated, therefore the shortest distance between Chain 0 feed point and Chain 1 is being used to determine SPLSR exclusion for BT

The Peak Location Separation Distance is computed by using the formula: SQRT((X1-X2)^2+(Y1-Y2)^2+(Z1-Z2)^2)

Conclusion:

1. Worst case SPLSR analysis was < 0.04, therefore additional cases was not evaluated.
2. Simultaneous transmission SAR measurement (Volume Scan) is not required because the SPLSR is ≤ 0.04.

Appendixes

Refer to separated files for the following appendixes.

Appendix A: SAR Setup Photos

Appendix B: SAR System Check Plots

Appendix C: SAR Highest Test Plots

Appendix D: SAR Tissue Ingredients

Appendix E: SAR Probe Certificates

Appendix F: SAR Dipole Certificates

END OF REPORT