SAR EVALUATION REPORT

IEEE Std 1528-2013

For
iPod touch

FCC ID: BCG-A2178
Model Name: A2178

Report Number: 12646381-S1V1
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Prepared for
APPLE INC.
1 APPLE PARK WAY
CUPERTINO, CA 95014

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

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Table of Contents

1. Attestation of Test Results 5

2. Test Specification, Methods and Procedures 6

3. Facilities and Accreditation 6

4. SAR Measurement System & Test Equipment 7

4.1. SAR Measurement System 7

4.2. SAR Scan Procedures 8

4.3. Test Equipment 10

5. Measurement Uncertainty 10

6. Device Under Test (DUT) Information 11

6.1. DUT Description 11

6.2. Wireless Technologies 11

7. RF Exposure Conditions (Test Configurations) 12

8. Dielectric Property Measurements & System Check 13

8.1. Dielectric Property Measurements 13

8.2. System Check 15

9. Conducted Output Power Measurements 16

9.1. Wi-Fi 2.4GHz (DTS Band) 16

9.2. Wi-Fi 5GHz (U-NII Bands) 17

9.3. Bluetooth 19

10. Measured and Reported (Scaled) SAR Results 21

10.1. Wi-Fi (DTS Band) 22

10.2. Wi-Fi (U-NII Band) 22

10.3. Bluetooth 22

11. SAR Measurement Variability 23

12. Simultaneous Transmission Conditions 24

12.1.1. Sum of SAR 24

12.1.2. SAR to Peak Location Ratio (SPLSR) 24

12.2. Sum of the SAR for Wi-Fi & BT 24

Appendixes 25

Appendix A: SAR Setup Photos 25

Appendix B: SAR System Check Plots 25

Appendix C: SAR Highest Test Plots 25

Appendix D: SAR Tissue Ingredients..... 25
Appendix E: SAR Probe Certificates..... 25
Appendix F: SAR Dipole Certificates..... 25

1. Attestation of Test Results

Applicant Name	APPLE, INC.			
FCC ID	BCG-A2178			
Model Name	A2178			
Applicable Standards	FCC 47 CFR § 2.1093 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)			
	PCE	DTS	NII	DSS
Standalone	N/A	1.141	1.168	0.242
Simultaneous TX	N/A	N/A	1.410	1.410
Date Tested	3/25/2019 to 4/3/2019			
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.

This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, any agency of the Federal Government, or any agency of the U.S. government.

Approved & Released By:	Prepared By:
	
Devin Chang Senior Test Engineer UL Verification Services Inc.	Chakrit Thammanavarat Senior Test Engineer 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:

- 248227 D01 802.11 Wi-Fi SAR v02r02
- 447498 D01 General RF Exposure Guidance v06
- 447498 D03 Supplement C Cross-Reference v01
- 865664 D01 SAR measurement 100 MHz to 6 GHz v01r04
- 865664 D02 RF Exposure Reporting v01r02
- 941225 D07 UMPC Mini Tablet v01r02

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

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

3. Facilities and Accreditation

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

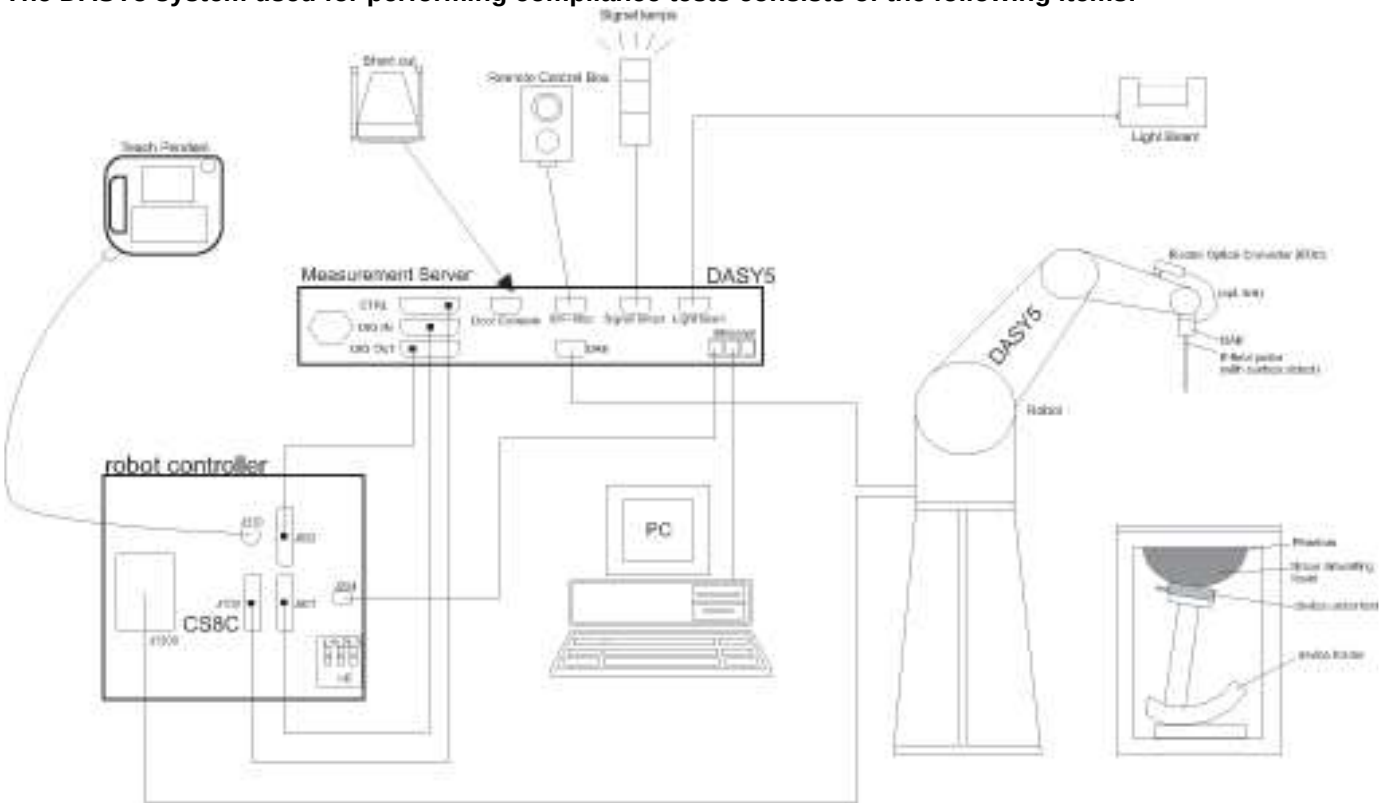
47173 Benicia Street	47266 Benicia Street
SAR Lab A	SAR Lab 1
SAR Lab B	SAR Lab 2
SAR Lab C	SAR Lab 3
SAR Lab D	SAR Lab 4
SAR Lab E	SAR Lab 5
SAR Lab F	
SAR Lab G	
SAR Lab H	

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	$\frac{1}{2}\cdot\delta\cdot\ln(2) \pm 0.5$ 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
Network Analyzer	R&S	ZNLE6	PRE0181650	7/16/2019
Dielectric Probe kit	SPEAG	DAK-3.5	1082	9/11/2019
Shorting block	SPEAG	DAK-3.5 Short	SM DAK 200 DA	9/11/2019
Thermometer	Traceable Calibration Control Co.	15-1078-179	150378159	6/6/2019

System Check

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Signal Generator	Rhode & Schwarz	SMB100A	180970-zC	2/13/2020
Power Sensor	Rhode & Schwarz	NRP18A	100994-RE	2/15/2020

Lab Equipment

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
E-Field Probe (SAR Lab 1)	SPEAG	EX3DV4	3749	1/25/2020
E-Field Probe (SAR Lab 4)	SPEAG	EX3DV4	7356	4/24/2019
Data Acquisition Electronics (SAR Lab 1)	SPEAG	DAE4	1546	1/25/2020
Data Acquisition Electronics (SAR Lab 4)	SPEAG	DAE4	1547	5/3/2019
System Validation Dipole	SPEAG	D2450V2	706	5/18/2019
System Validation Dipole	SPEAG	D5GHzV2	1138	8/21/2019
Thermometer	Fisherbrand	281 482-1714	181062309	2/21/2020

Other

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Power Meter	Agilent	N1912A	MY55196015	1/29/2020
Power Sensor	Agilent	N1921A	MY52270022	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	Overall (Length x Width): 123.4 mm x 58.6 mm Overall Diagonal: 131.0 mm Display Diagonal: 103.0 mm This is a UMPC mini-tablet device(an overall diagonal dimensions ≤ 20 cm)
Back Cover	The Back Cover is not removable
Battery Options	The rechargeable battery is not user accessible.

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)	100% (802.11b) [1] 98.9% (802.11g/n 20MHz BW) [1]
	5 GHz	802.11a 802.11n (HT20) 802.11n (HT40) 802.11ac (VHT20) 802.11ac (VHT40) 802.11ac (VHT80)	98.71% (802.11a/n/ac 20MHz BW) [1] 97.92% (802.11n/ac 40MHz BW) [1] 95.22% (802.11ac 80MHz BW) [1]
	Does this device support bands 5.60 ~ 5.65 GHz? ☒ Yes ☐ No		
	Does this device support Band gap channel(s)? ☒ Yes ☐ No		
Bluetooth	2.4 GHz	BR, EDR, LE	76.96% (DH5)

Notes:

1. Duty cycle for Wi-Fi is referenced from the DTS and UNII report.

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	Note
WLAN	Standalone	5 mm	Rear	< 25 mm	Yes	
			Front	< 25 mm	Yes	
			Edge 1 (Top)	< 25 mm	Yes	
			Edge 2 (Right)	> 25 mm	No	1
			Edge 3 (Bottom)	> 25 mm	No	1
			Edge 4 (Left)	< 25 mm	Yes	

Notes:

1. SAR is not required because the distance from the antenna to the edge is > 25 mm as per KDB 941225 D07 UMPC Mini Tablet.

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	3/25/2019	5250	Body	5250	49.02	48.95	0.14	5.55	5.35	3.70
				5150	49.29	49.09	0.41	5.37	5.24	2.47
				5350	48.68	48.82	-0.28	5.66	5.47	3.45
1	3/25/2019	5600	Body	5600	48.17	48.48	-0.63	5.97	5.76	3.70
				5500	48.43	48.61	-0.38	5.88	5.64	4.10
				5725	47.89	48.31	-0.87	6.13	5.91	3.75
1	3/25/2019	5750	Body	5750	47.80	48.27	-0.98	6.20	5.94	4.52
				5700	48.02	48.34	-0.67	6.04	5.88	2.83
				5850	47.64	48.20	-1.16	6.29	6.00	4.80
1	4/3/2019	2450	Body	2450	53.92	52.70	2.31	2.04	1.95	4.46
				2400	54.04	52.77	2.40	1.98	1.90	4.32
				2480	53.87	52.66	2.29	2.07	1.99	3.81
4	3/25/2019	2450	Body	2450	50.76	52.70	-3.68	1.92	1.95	-1.54
				2400	50.77	52.77	-3.79	1.88	1.90	-1.05
				2480	50.69	52.66	-3.74	1.94	1.99	-2.67

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	3/25/2019	Body	D5GHzV2 SN:1138 (5.25 GHz)	8/21/2019	7.380	73.80	76.60	-3.66	2.040	20.40	21.40	-4.67	1,2
1	3/25/2019	Body	D5GHzV2 SN:1138 (5.6 GHz)	8/21/2019	8.090	80.90	79.50	1.76	2.250	22.50	22.20	1.35	
1	3/25/2019	Body	D5GHzV2 SN:1138 (5.75 GHz)	8/21/2019	7.160	71.60	74.10	-3.37	1.980	19.80	20.60	-3.88	
1	4/3/2019	Body	D2450V2 SN:706	5/18/2019	5.220	52.20	50.60	3.16	2.410	24.10	23.70	1.69	3,4
4	3/25/2019	Body	D2450V2 SN:706	5/18/2019	5.200	52.00	50.60	2.77	2.390	23.90	23.70	0.84	5,6

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.

SAR testing is not required for OFDM mode(s) 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.

Channel	Frequency (MHz)	DSSS	OFDM	OFDM
		802.11b (SISO)	802.11g (SISO)	802.11n HT20 (SISO)
1	2412	17.00	15.00	15.00
2	2417	17.00	17.00	17.00
3	2422	17.00	17.00	17.00
4	2427	17.00	17.00	17.00
5	2432	17.00	17.00	17.00
6	2437	17.00	17.00	17.00
7	2442	17.00	17.00	17.00
8	2447	17.00	17.00	17.00
9	2452	17.00	17.00	17.00
10	2457	17.00	17.00	17.00
11	2462	17.00	13.50	13.50
12	2467	15.50	11.00	11.00
13	2472	12.00	3.00	3.00

Based on the above table. DSSS 802.11b mode power will be for SAR test required.

Wi-Fi 2.4GHz Measured Results

Band	Mode	Data Rate	Ch #	Freq. (MHz)	Average Power (dBm)		
					Meas Pwr	Tune-up	SAR Test (Yes/No)
DSSS 2.4 GHz	802.11b	1 Mbps	1	2412	16.20	17.00	Yes
			6	2437	16.20	17.00	
			11	2462	16.10	17.00	

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

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

Band	Channel	Frequency (MHz)	802.11a/n/ac HT20 (SISO)
U-NII-1	36	5180	13.00
	40	5200	13.00
	44	5220	13.00
	48	5240	13.00
U-NII-2A	52	5260	12.75
	56	5280	12.75
	60	5300	12.75
	64	5320	12.75
U-NII-2C	100	5500	13.00
	104	5520	13.00
	108	5540	13.00
	112	5560	13.00
	116	5580	13.00
	120	5600	13.00
	124	5620	13.00
	128	5640	13.00
	132	5660	13.00
	136	5680	13.00
	140	5700	13.00
	144	5720	13.00
U-NII-3	149	5745	13.00
	153	5765	13.00
	157	5785	13.00
	161	5805	13.00
	165	5825	13.00

Channel	Channel	Frequency (MHz)	802.11n/11ac HT40 (SISO)
U-NII-1	38	5190	11.50
	46	5230	13.00
U-NII-2A	54	5270	12.75
	62	5310	12.75
U-NII-2C	102	5510	13.00
	110	5550	13.00
	118	5590	13.00
	126	5630	13.00
	134	5670	13.00
	142	5710	13.00
U-NII-3	151	5755	13.00
	159	5795	13.00
Channel	**Channel**	**Frequency (MHz)**	**802.11ac VHT80 (SISO)**
U-NII-1	42	5210	11.00
U-NII-2A	58	5290	12.00
U-NII-2C	106	5530	12.00
	122	5610	13.00
	138	5690	13.00
U-NII-3	155	5775	13.00

Wi-Fi 5 GHz Measured Results

Band	Mode	Data Rate	Ch #	Freq. (MHz)	Average Power (dBm)		
					Meas Pwr	Tune-up	SAR Test (Yes/No)
UNII-1 5.2 GHz	802.11n (HT40)	13.5 Mbps	38	5190	11.50	11.50	Yes
			46	5230	12.75	13.00	
Band	**Mode**	**Data Rate**	**Ch #**	**Freq. (MHz)**	**Average Power (dBm)**		
					Meas Pwr	**Tune-up**	**SAR Test (Yes/No)**
UNII-2C 5.5 GHz	802.11ac (VHT80)	29.3 Mbps	106	5530	12.00	12.00	Yes
			122	5610	12.50	13.00	
			138	5690	12.50	13.00	
Band	**Mode**	**Data Rate**	**Ch #**	**Freq. (MHz)**	**Average Power (dBm)**		
					Meas Pwr	**Tune-up**	**SAR Test (Yes/No)**
UNII-3 5.8 GHz	802.11ac (VHT80)	29.3 Mbps	155	5775	12.75	13.00	Yes

9.3. Bluetooth

Maximum Output Power (Tune-up Limit) for Bluetooth

From October 2016 TCB workshop, Power and SAR were measured with the device connected to a call box with hopping disabled using DH5 modulation. The duty cycle value from the device is taken from the Duty Cycle plot below.
KDB 447498 sec.4.1.(3) at the maximum rated output power and within the tune-up tolerance range specified for the product, but not more than 2 dB lower than the maximum tune-up tolerance limit.

SAR measurement is not required for the EDR and LE. When the secondary mode is ≤ ¼ dB higher than the primary mode.

RF Operating mode	Max. RF Output Power (dBm)
Bluetooth BR	**12.00**
Bluetooth EDR	**10.00**
Bluetooth LE	**8.50**

Bluetooth Measured Results

Band	Mode	Ch #	Freq. (MHz)	Average Power (dBm)		
				Meas Pwr	Tune-up	SAR Test (Yes/No)
2.4	BR GFSK	0	2402	11.60	12.00	Yes
		39	2441	11.70	12.00	
		78	2480	11.80	12.00	

Duty Factor Measured Results

Mode	Type	T on (ms)	Period (ms)	Duty Cycle[1]	Crest Factor[2] (0.775/duty cycle)
GFSK	DH5	2.886	3.75	76.96%	1.01

Note(s):

1. Duty Cycle = (T on / period) * 100%
2. The reported SAR was scaled to Manufacturer limit of 77.5% transmission duty factor. Therefore, Crest Factor was 1.01.

Duty Cycle plots

GFSK

10. Measured and Reported (Scaled) SAR Results

SAR Test Reduction criteria are as follows:

- Reported SAR(W/kg) for Wi-Fi and Bluetooth = Measured SAR * Tune-up scaling factor * Duty Cycle scaling factor
- Duty Cycle scaling factor for Wi-Fi = 1 / Duty cycle (%)
- Duty Cycle scaling factor for Bluetooth = 0.775 / 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.

To determine the *initial test position*, Area Scans were performed to determine the position with the *Maximum Value of SAR (measured)*. The position that produced the highest *Maximum Value of SAR* is considered the worst case position; thus used as the *initial test position*.

10.1. Wi-Fi (DTS Band)

RF Exposure Conditions	Mode	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		10-g SAR (W/kg)		Plot No.
								Tune-up Limit	Meas.	Meas.	Scaled	Meas.	Scaled	
Standalone	802.11b	5	Rear	6	2437	1.07	100.0%	17.00	16.20	0.621	0.747	0.213	0.256	
			Front	1	2412	1.88	100.0%	17.00	16.20	0.949	1.141	0.345	0.415	1
				6	2437	1.42	100.0%	17.00	16.20	0.929	1.117	0.340	0.409	
				11	2462	1.78	100.0%	17.00	16.10	0.920	1.132	0.336	0.413	
			Edge 1	6	2437	0.43	100.0%	17.00	16.20	0.233	0.280	0.112	0.135	
			Edge 4	6	2437	0.39	100.0%	17.00	16.20	0.201	0.242	0.090	0.108	

10.2. Wi-Fi (U-NII Band)

RF Exposure Conditions	Mode	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		10-g SAR (W/kg)		Plot No.
								Tune-up Limit	Meas.	Meas.	Scaled	Meas.	Scaled	
Standalone	802.11n HT40	5	Rear	46	5230	0.68	97.92%	13.00	12.75	0.422	0.457	0.099	0.107	
			Front	38	5190	1.70	97.92%	11.50	11.50	0.870	0.888	0.234	0.239	
				46	5230	2.09	97.92%	13.00	12.75	0.972	1.051	0.271	0.293	2
			Edge 1	46	5230	0.37	97.92%	13.00	12.75	0.198	0.214	0.070	0.075	
			Edge 4	46	5230	0.21	97.92%	13.00	12.75	0.084	0.091	0.026	0.028	
RF Exposure Conditions	Mode	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		10-g SAR (W/kg)		Plot No.
								Tune-up Limit	Meas.	Meas.	Scaled	Meas.	Scaled	
Standalone	802.11ac VHT80	5	Rear	122	5610	0.927	95.22%	13.00	12.50	0.428	0.504	0.133	0.157	
			Front	106	5530	1.910	95.22%	12.00	12.00	0.852	0.895	0.237	0.249	
				122	5610	2.480	95.22%	13.00	12.50	0.921	1.085	0.261	0.308	3
				138	5690	2.210	95.22%	13.00	12.50	0.852	1.004	0.241	0.284	
			Edge 1	122	5610	0.310	95.22%	13.00	12.50	0.160	0.189	0.056	0.066	
			Edge 4	122	5610	0.162	95.22%	13.00	12.50	0.041	0.048	0.015	0.018	
RF Exposure Conditions	Mode	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Area Scan Max. SAR (W/kg)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		10-g SAR (W/kg)		Plot No.
								Tune-up Limit	Meas.	Meas.	Scaled	Meas.	Scaled	
Standalone	802.11ac VHT80	5	Rear	155	5775	1.020	95.22%	13.00	12.75	0.520	0.578	0.153	0.170	
			Front	155	5775	2.480	95.22%	13.00	12.75	1.050	1.168	0.286	0.318	4
			Edge 1	155	5775	0.387	95.22%	13.00	12.75	0.200	0.222	0.067	0.075	
			Edge 4	155	5775	0.171	95.22%	13.00	12.75	0.074	0.082	0.025	0.028	

10.3. Bluetooth

RF Exposure Conditions	Mode	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		10-g SAR (W/kg)		Plot No.
							Tune-up Limit	Meas.	Meas.	Scaled	Meas.	Scaled	
Standalone	GFSK	5	Rear	39	2441	76.96%	12.00	11.70	0.092	0.099	0.034	0.037	
			Front	39	2441	76.96%	12.00	11.70	0.224	0.242	0.082	0.088	5
			Edge 1	39	2441	76.96%	12.00	11.70	0.043	0.046	0.021	0.022	
			Edge 4	39	2441	76.96%	12.00	11.70	0.037	0.040	0.016	0.017	

Note(s):

The reported SAR was scaled to Manufacturer limit of 77.5% transmission duty factor.

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.

Frequency Band (MHz)	Air Interface	RF Exposure Conditions	Test Position	Repeated SAR (Yes/No)	Highest Measured SAR (W/kg)	First Repeated	
						Measured SAR (W/kg)	Largest to Smallest SAR Ratio
2400	Wi-Fi 802.11b/g/n	Standalone	Front	Yes	0.949	0.912	1.04
5200	Wi-Fi 802.11a/n/ac	Standalone	Front	Yes	0.972	0.969	1.00
5500	Wi-Fi 802.11a/n/ac	Standalone	Front	Yes	0.921	0.908	1.01
5800	Wi-Fi 802.11a/n/ac	Standalone	Front	Yes	1.050	1.01	1.04

Note(s):

Second Repeated Measurement is not required since the ratio of the largest to smallest SAR for the original and first repeated measurement is < 1.20.

12. Simultaneous Transmission Conditions

RF Exposure Condition	Item	Capable Transmit Configurations
Standalone	1	Wi-Fi 5GHz + Bluetooth

Notes:
1. DTS Radio cannot transmit simultaneously with Bluetooth Radio.
2. U-NII Radio can transmit simultaneously with Bluetooth Radio.

12.1.1. Sum of SAR

To qualify for simultaneous transmission SAR test exclusion based upon Sum of SAR the sum of the reported standalone SARs for all simultaneously transmitting antennas shall be below the applicable standalone SAR limit. If the sum of the SARs is above the applicable limit then simultaneous transmission SAR test exclusion may still apply if the requirements of the SAR to Peak Location Ratio (SPLSR) evaluation are met.

12.1.2. SAR to Peak Location Ratio (SPLSR)

KDB 447498 D01 General RF Exposure Guidance explains how to calculate the SAR to Peak Location Ratio (SPLSR) between pairs of simultaneously transmitting antennas:

$$SPLSR = (SAR_1 + SAR_2)^{1.5} / Ri$$

Where:

SAR_1 is the highest reported or estimated SAR for the first of a pair of simultaneous transmitting antennas, in a specific test operating mode and exposure condition

SAR_2 is the highest reported or estimated SAR for the second of a pair of simultaneous transmitting antennas, in the same test operating mode and exposure condition as the first

Ri is the separation distance between the pair of simultaneous transmitting antennas. When the SAR is measured, for both antennas in the pair, it is determined by the actual x, y and z coordinates in the 1-g SAR for each SAR peak location, based on the extrapolated and interpolated result in the zoom scan measurement, using the formula of

$$[(x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2]$$

In order for a pair of simultaneous transmitting antennas with the sum of 1-g SAR > 1.6 W/kg to qualify for exemption from Simultaneous Transmission SAR measurements, it has to satisfy the condition of:

$$(SAR_1 + SAR_2)^{1.5} / Ri \leq 0.04$$

When an individual antenna transmits at on two bands simultaneously, the sum of the highest *reported* SAR for the frequency bands should be used to determine SAR_1.or SAR_2. When SPLSR is necessary, the smallest distance between the peak SAR locations for the antenna pair with respect to the peaks from each antenna should be used.

The antennas in all antenna pairs that do not qualify for simultaneous transmission SAR test exclusion must be tested for SAR compliance, according to the enlarged zoom scan and volume scan post-processing procedures in KDB Publication 865664 D01

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

RF Exposure conditions	Test Position	Standalone SAR (W/kg)		∑ 1-g SAR (W/kg)
		1	2	1+2
		Wi-Fi 5G	BT	
Standalone	Rear	0.578	0.099	0.677
	Front	1.168	0.242	1.410
	Edge 1	0.222	0.046	0.268
	Edge 4	0.091	0.040	0.131

Conclusion:

Simultaneous transmission SAR measurement (Volume Scan) is not required because either the sum of the 1-g SAR is < 1.6 W/kg or the SPLSR is ≤ 0.04 for all circumstances that require SPLSR calculation.

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