FCC 47 CFR Parts 1 & 2
Published RF Exposure KDB Procedures
IEEE Std 1528-2003 and IEEE 1528a-2005

(Class II Permissive Change)

SAR EVALUATION REPORT

For
802.11a/b/g/n/ac WLAN + Bluetooth PCI-E Mini Card

Model: BCM94352Z
FCC ID: QDS-BRCM1076

Report Number: 13U16189-1
Issue Date: 11/08/2013

Prepared for
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NVLAP LAB CODE 200065-0

Revision History

Rev.	Issue Date	Revisions	Revised By
--	11/08/2013	Initial Issue	--

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1. Attestation of Test Results

Applicant	Broadcom Corporation			
DUT description	802.11a/b/g/n/ac WLAN + Bluetooth PCI-E Mini Card			
Model	BCM94352Z			
Test device is	An identical prototype			
Device category	Portable			
Exposure category	General Population/Uncontrolled Exposure			
Date tested	10/14/2013 – 10/29/2013			
The highest reported SAR values	RF exposure condition	Licensed	DTS	UNII
	Body	N/A	0.577 W/kg (2.4GHz) 0.472 W/kg (5.8 GHz)	0.363 W/kg
	Simultaneous Transmission	N/A	N/A	N/A
Applicable Standards	FCC 47 CFR Parts 1 & 2 Published RF Exposure KDB Procedures, and TCB workshop updates IEEE Std 1528-2003 and IEEE Std 1528a-2005			
Test Results	Pass			

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by UL Verification Services Inc. based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. 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 any government (NIST Handbook 150, Annex A). This report is written to support regulatory compliance of the applicable standards stated above.

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2. Test Methodology

The tests documented in this report were performed in accordance with FCC 47 CFR Parts 1 & 2, IEEE STD 1528-2003, IEEE Std 1528a-2005, the following FCC Published RF exposure KDB procedures and TCB workshop updates:

- KDB 447498 D01 General RF Exposure Guidance v05r01
- KDB 248227 D01 SAR meas for 802 11abg v01r02
- KDB 865664 D01 SAR measurement 100 MHz to 6 GHz v01r01
- KDB 865664 D02 SAR Reporting v01r01
- KDB 690783 D01 SAR Listings on Grants v01r02
- KDB 616217 D04 SAR for laptop and tablets v02

3. Facilities and Accreditation

The test sites and measurement facilities used to collect data are located at 47173 Benicia Street, Fremont, California, USA.

UL Verification Services Inc. is accredited by NVLAP, Laboratory Code 200065-0. The full scope of accreditation can be viewed at http://www.ccsemc.com.

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4. Calibration and Uncertainty

4.1. Measuring Instrument Calibration

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.

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due date		
				MM	DD	Year
S-Parameter Network Analyzer	AGILENT	8753ES	MY4000980	2	20	2014
Dielectronic Probe kit	SPEAG	SM DAK 040 CA	1103	2	5	2014
Synthesized Signal Generator	AGILENT	8665B	3744A01155	3	6	2014
Power Meter	AGILENT	N1911A	MY53060002	4	4	2014
Power Meter	AGILENT	N1911A	MY53060016	8	3	2014
Power Sensor A	AGILENT	E9323A	MY53070003	4	3	2014
Power Sensor B	AGILENT	E9323A	MY53070007	4	3	2014
Amplifier	MITEQ	4D00400600-50-30P	1622052	N/A		
Directional coupler	Werlatone	C8060-102	2149	N/A		
Spectrum analyzer	AGILENT	8595E	3750U00957	8	28	2014
Thermometer	TRACEABLE	4242	122529163	9	19	2014
E-Field Probe	SPEAG	EX3DV4	3902	7	12	2014
E-Field Probe	SPEAG	EX3DV4	3929	6	24	2014
Data Acquisition Electronics	SPEAG	DAE 4	1259	2	7	2014
Data Acquisition Electronics	SPEAG	DAE 4	1377	7	15	2014
System Validation Dipole	SPEAG	D2450V2	706	5	29	2014
System Validation Dipole	SPEAG	D5GHzV2	1003	9	19	2014
Power Meter	AGILENT	N1912A	MY53040015	6	29	2014
Power Sensor C	AGILENT	N1921A	MY52020011	5	13	2014

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4.2. Measurement Uncertainty

Per KDB 865664, when no measured SAR values exceed 1.5 W/kg, measurement uncertainty analysis does not need to be provided in the test report.

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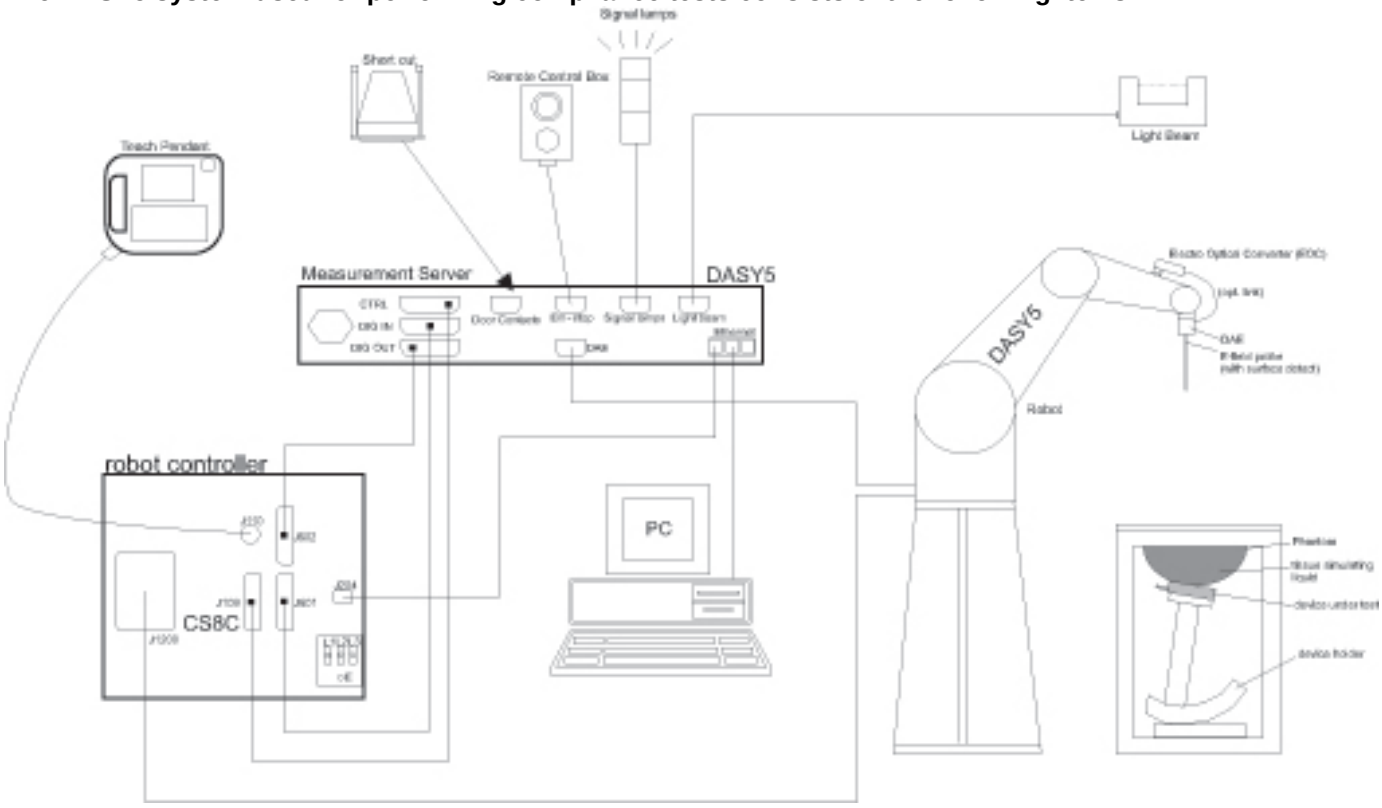
5. Measurement System Description and Setup

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.

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6. SAR Measurement Procedure

6.1. Normal SAR Measurement Procedure

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 v01

	≤ 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.	

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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 v01 (Draft)

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

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.

Step 5: Z-Scan (FCC only)

The Z Scan measures points along a vertical straight line. The line runs along the Z-axis of a one-dimensional grid. In order to get a reasonable extrapolation the extrapolated distance should not be larger than the step size in Z-direction.

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6.2. Volume Scan Procedures

Step 1: Repeat Step 1-4 in Section 6.1

Step 2: Volume Scan
Volume Scans are used to assess peak SAR and averaged SAR measurements in largely extended 3-dimensional volumes within any phantom. This measurement does not need any previous area scan. The grid can be anchored to a user specific point or to the current probe location.

Step 3: 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.

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7. Device Under Test

7.1. General Information

802.11a/b/g/n/ac WLAN + Bluetooth PCI-E Mini Card			
Operating Configuration(s)			
Antenna tested: Chain 0	Manufacturer	Antenna type	Part number
	ACON	PIFA	APP8P-700045
	Peak Gain: 0.3dBi (2.4GHz); -0.8dBi (5GHz)		
	Cable 50 ohm Coaxial, length: 152.4 mm		
RF Exposure Condition(s)	Body		

7.2. Band and Air Interfaces

Wireless Mode and Frequency Bands	WiFi 802.11a/b/g/n/ac Bluetooth 2.4 GHz
Air Interfaces	WiFi 2.4GHz (802.11b/g/n) - ☒ 802.11b - ☒ 802.11g - ☒ 802.11n (20 MHz) WiFi 5GHz - ☒ 802.11a - ☒ 802.11n (20 MHz) - ☒ 802.11n (40 MHz) - ☒ 802.11ac (80 MHz) Bluetooth Ver. 3.0 + EDR, 8-DPSK
Duty Cycle	WiFi 802.11a/b/g/n/ac: 100%

7.1. Simultaneous Transmission Condition

The DUT does not support simultaneous transmission.

7.2. Testing Rationale

All SAR testing was performed using chain 0 and was judged to be representative of chain 1 as the transmitters are identically implemented.

All testing was performed in 802.11b mode for 2.4GHz as the output power in the other modes was not more than 0.25dB higher.

In the 5GHz bands testing was performed in 802.11a mode as the output power in the other modes was not more than 0.25dB higher. Additional testing for the worst case orientations was performed for 802.11ac in accordance with the April 2013 TCB workshop SAR presentation.

The standalone (SISO) SAR results were considered acceptable for the MIMO simultaneous transmission analysis as the MIMO power does not exceed the SISO power and the antenna separation distance will not be less than 50mm.

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8. RF Exposure Conditions

Body

Test Configurations	Antenna-to-edge/surface	SAR Required	Note
Top	5 mm	Yes	
Bottom	5 mm	Yes	
Edge 1	5 mm	Yes	
Edge 2	5 mm	Yes	
Edge 3	5 mm	Yes	
Edge 4	5 mm	Yes	

The modular approach is applied to incorporate transmitters and modules in qualified laptop and tablet hosts. When the test separation distances and test setups described in this document for the laptop and tablet host platforms are satisfied by the antenna and host configurations and the highest reported SAR for a host platform is ≤ 0.8 W/kg, testing in representative hosts is optional for the modular approach as per KDB 616217 D04 v02.

The antenna to edge/surface separation distance was selected so that none of the reported SAR measurements would exceed 0.8 W/kg.

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9. RF Output Power Measurement

9.1. WiFi (2.4 GHz Band)

All target powers are absolute maximums

Required Test Channels per KDB 248227 D01

Mode	Band	GHz	Channel	"Default Test Channels"	
				802.11b	802.11g
802.11b/g	2.4 GHz	**2.412**	1#	√	∇
		2.437	6	√	∇
		2.462	11#	√	∇

Notes:
√ = "default test channels"
∇ = possible 802.11g channels with maximum average output ¼ dB ≥ the "default test channels"
= when output power is reduced for channel 1 and /or 11 to meet restricted band requirements the highest output channels closest to each of these channels should be tested.

Band (MHz)	Mode	Ch #	Freq. (MHz)	Target Pwr	Avg Pwr (dBm) (Chain	Avg Pwr (dBm) (Chain
2.4	802.11b	1	2412	16	16.0	16.0
		6	2437	16	16.0	16.0
		11	2462	16	16.0	16.0
	802.11g	1	2412	16	16.0	15.9
		6	2437	16	16.0	16.0
		11	2462	16	16.0	15.9
	802.11n (HT20)	1	2412	16	16.0	16.0
		6	2437	16	16.0	16.0
		11	2462	16	16.0	16.0
	802.11n (HT40)	3	2422	16	16.0	16.0
		6	2437	16	16.0	16.0
		9	2452	16	16.0	16.0

Note(s):

1. SAR is not required for 802.11g/n channels when the maximum average output power is less than 1/4 dB higher than that measured on the corresponding 802.11a/b channels. As per KDB 248227.

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9.2. WiFi (5 GHz Bands)

All target powers are absolute maximums

Required Test Channels per KDB 248227 D01

Mode		Band	GHz	Channel	"Default Test Channels"	
					802.11a	
802.11a	UNII (15.407)	5.2 GHz	5.180	36	√	
			5.200	40		*
			2.220	44		*
			5.240	48	√	
		5.3 GHz	5.260	52	√	
			5.280	56		*
			5.300	60		*
			5.320	64	√	
		5.5 GHz	5.500	100		*
			5.520	104	√	
			5.540	108		*
			5.560	112		*
			5.580	116	√	
			5.600	120		*
			5.620	124	√	
			5.640	128		*
			5.660	132		*
			5.680	136	√	
			5.700	140		*
	DTS (15.247)	5.8 GHz	5.745	149	√	
			5.765	153		*
			5.785	157	√	
			5.805	161		*
			5.825	165	√	

√ = "default test channels"

* = possible 802.11a channels with maximum average output > the "default test channels"

= when output power is reduced for channel 1 and /or 11 to meet restricted band requirements the highest output channels closest to each of these channels should be tested.

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Wi-Fi 5 GHz Bands Measured Results continued

Band (MHz)	Mode	Ch #	Freq. (MHz)	Target Pwr (dBm)	Avg Pwr (dBm) Chain0	Avg Pwr (dBm) Chain1
5.2	802.11a	36	5180	14.0	14.0	14.0
		40	5200	14.0	14.0	14.0
		44	5220	14.0	14.0	14.0
		48	5240	14.0	14.0	14.0
	802.11n (HT20)	36	5180	14.0	13.9	13.9
		40	5200	14.0	13.9	13.9
		48	5240	14.0	13.9	13.9
	802.11n (HT40)	38	5190	14.0	13.9	13.9
		46	5230	14.0	13.8	13.8
	802.11ac (VHT20)	36	5180	14.0	13.9	13.9
		40	5200	14.0	13.9	13.9
		48	5240	14.0	13.9	13.9
	802.11ac (VHT40)	38	5190	14.0	13.9	13.9
		46	5230	14.0	13.8	13.8
	802.11ac (VHT80)	42	5210	14.0	13.8	13.8
5.3	802.11a	52	5260	14.0	14.0	14.0
		56	5280	14.0	14.0	14.0
		60	5300	14.0	14.0	14.0
		64	5320	14.0	14.0	14.0
	802.11n (HT20)	52	5260	14.0	14.0	14.0
		60	5300	14.0	14.0	14.0
		64	5320	14.0	14.0	14.0
	802.11n (HT40)	54	5270	14.0	14.0	14.0
		62	5310	14.0	14.0	14.0
	802.11ac (VHT20)	52	5260	14.0	14.0	14.0
		60	5300	14.0	14.0	14.0
		64	5320	14.0	14.0	14.0
	802.11ac (VHT40)	54	5270	14.0	14.0	14.0
		62	5310	14.0	14.0	14.0
	802.11ac (VHT80)	58	5290	14.0	14.0	14.0

Note(s):

SAR is not required for 802.11n/ac HT20/HT40 channels when the maximum average output power is less than 1/4 dB higher than that measured on the corresponding 802.11a/b channels. As per KDB 248227.

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Wi-Fi 5 GHz Bands Measured Results continued

Band (MHz)	Mode	Ch #	Freq. (MHz)	Target Pwr (dBm)	Avg Pwr (dBm) Chain0	Avg Pwr (dBm) Chain1
5.5	802.11a	100	5500	16.0	16.0	16.0
		104	5520	16.0	16.0	16.0
		108	5540	16.0	16.0	16.0
		112	5560	16.0	16.0	16.0
		116	5580	16.0	16.0	16.0
		120	5600	16.0	16.0	16.0
		124	5620	16.0	16.0	16.0
		128	5640	16.0	16.0	16.0
		132	5660	16.0	16.0	16.0
		136	5680	16.0	16.0	16.0
		140	5700	16.0	16.0	16.0
	802.11n (HT20)	100	5500	16.0	16.0	16.0
		104	5520	16.0	16.0	16.0
		136	5680	16.0	16.0	16.0
		140	5700	16.0	16.0	16.0
	802.11n (HT40)	102	5510	16.0	16.0	16.0
		110	5550	16.0	16.0	16.0
		134	5670	16.0	16.0	16.0
	802.11ac (VHT20)	100	5500	16.0	16.0	16.0
		104	5520	16.0	16.0	16.0
		136	5680	16.0	16.0	16.0
		140	5700	16.0	16.0	16.0
		144	5720	16.0	16.0	16.0
	802.11ac (VHT40)	102	5510	16.0	16.0	16.0
		110	5550	16.0	16.0	16.0
		134	5670	16.0	16.0	16.0
		142	5710	16.0	16.0	16.0
	802.11ac (VHT80)	106	5530	16.0	16.0	16.0
		122	5610	16.0	16.0	16.0
		138	5690	16.0	16.0	16.0

Note(s):

SAR is not required for 802.11n/ac HT20/HT40 channels when the maximum average output power is less than 1/4 dB higher than that measured on the corresponding 802.11a/b channels. As per KDB 248227.

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Wi-Fi 5 GHz Bands Measured Results continued

Band (MHz)	Mode	Ch #	Freq. (MHz)	Target Pwr (dBm)	Avg Pwr (dBm) Chain0	Avg Pwr (dBm) Chain1
5.8	802.11a	149	5745	18.0	18.0	18.0
		153	5765	18.0	18.0	18.0
		157	5785	18.0	18.0	18.0
		161	5805	18.0	18.0	18.0
		165	5825	18.0	18.0	18.0
	802.11n (HT20)	149	5745	18.0	18.0	18.0
		157	5785	18.0	18.0	18.0
		165	5805	18.0	18.0	18.0
	802.11n (HT40)	151	5755	18.0	18.0	18.0
		159	5795	18.0	18.0	18.0
	802.11ac (VHT20)	149	5745	18.0	18.0	18.0
		157	5785	18.0	18.0	18.0
		165	5805	18.0	18.0	18.0
	802.11ac (VHT40)	151	5755	18.0	18.0	18.0
		159	5795	18.0	18.0	18.0
	802.11ac (VHT80)	155	5775	18.0	18.0	18.0

Note(s):

SAR is not required for 802.11n/ac HT20/HT40 channels when the maximum average output power is less than 1/4 dB higher than that measured on the corresponding 802.11a/b channels. As per KDB 248227.

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9.3. Bluetooth

Target Power 5.2dBm maximum

Mode	Channel #	Freq. (MHz)	Conducted Avg Power	
			(dBm)	(mW)
V3.0 + EDR, GFSK	0	2402	5.1	3.21
	39	2441	4.9	3.05
	78	2480	4.9	3.06
V3.0 + EDR, 8-DPSK	0	2402	5.2	3.32
	39	2441	5.0	3.18
	78	2480	4.8	2.99

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10. Tissue Dielectric Properties

IEEE Std 1528-2003 Table 2

Target Frequency (MHz)	Head	
	ε_r	σ (S/m)
300	45.3	0.87
450	43.5	0.87
835	41.5	0.90
900	41.5	0.97
1450	40.5	1.20
1800 – 2000	40.0	1.40
2450	39.2	1.80
2600	39.0	1.96
3000	38.5	2.40

FCC OET Bulletin 65 Supplement C 01-01

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

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10.1. Composition of Ingredients for the Tissue Material Used in the SAR Tests

The following tissue formulations are provided for reference only as some of the parameters have not been thoroughly verified. The composition of ingredients may be modified accordingly to achieve the desired target tissue parameters required for routine SAR evaluation.

Ingredients (% by weight)	Frequency (MHz)									
	450		835		915		1900		2450	
Tissue Type	Head	Body	Head	Body	Head	Body	Head	Body	Head	Body
Water	38.56	51.16	41.45	52.4	41.05	56.0	54.9	40.4	62.7	73.2
Salt (NaCl)	3.95	1.49	1.45	1.4	1.35	0.76	0.18	0.5	0.5	0.04
Sugar	56.32	46.78	56.0	45.0	56.5	41.76	0.0	58.0	0.0	0.0
HEC	0.98	0.52	1.0	1.0	1.0	1.21	0.0	1.0	0.0	0.0
Bactericide	0.19	0.05	0.1	0.1	0.1	0.27	0.0	0.1	0.0	0.0
Triton X-100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.8	0.0
DGBE	0.0	0.0	0.0	0.0	0.0	0.0	44.92	0.0	0.0	26.7
Dielectric Constant	43.42	58.0	42.54	56.1	42.0	56.8	39.9	54.0	39.8	52.5
Conductivity (S/m)	0.85	0.83	0.91	0.95	1.0	1.07	1.42	1.45	1.88	1.78

Salt: >99% Pure Sodium Chloride Sugar: >98% Pure Sucrose
Water: De-ionized, >16 MΩ resistivity HEC: Hydroxyethyl Cellulose
DGBE: >99% Di(ethylene glycol) butyl ether, [2-(2-butoxyethoxy)ethanol]
Triton X-100 (ultra pure): Polyethylene glycol mono [4-(1,1, 3, 3-tetramethylbutyl)phenyl]ether

Simulating Liquids for 5 GHz, Manufactured by SPEAG

Ingredients	(% by weight)
Water	78
Mineral oil	11
Emulsifiers	9
Additives and Salt	2

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10.2. Tissue Dielectric Parameter Check Results

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.

Date	Freq. (MHz)	Liquid Parameters			Measured	Target	Delta (%)	Limit ±(%)
10/14/2013	Body 2450	e'	51.7000	Relative Permittivity (ϵ_r):	51.70	52.70	-1.90	5
		e''	14.6700	Conductivity (σ):	2.00	1.95	2.49	5
	Body 2410	e'	51.8400	Relative Permittivity (ϵ_r):	51.84	52.76	-1.74	5
		e''	14.4800	Conductivity (σ):	1.94	1.91	1.72	5
	Body 2475	e'	51.5900	Relative Permittivity (ϵ_r):	51.59	52.67	-2.05	5
		e''	14.7900	Conductivity (σ):	2.04	1.99	2.53	5
10/14/2013	Body 5180	e'	48.9100	Relative Permittivity (ϵ_r):	48.91	49.05	-0.28	5
		e''	17.4800	Conductivity (σ):	5.03	5.27	-4.49	5
	Body 5200	e'	48.8800	Relative Permittivity (ϵ_r):	48.88	49.02	-0.28	5
		e''	17.5100	Conductivity (σ):	5.06	5.29	-4.38	5
	Body 5600	e'	48.3600	Relative Permittivity (ϵ_r):	48.36	48.48	-0.24	5
		e''	17.8800	Conductivity (σ):	5.57	5.76	-3.36	5
	Body 5800	e'	48.1300	Relative Permittivity (ϵ_r):	48.13	48.20	-0.15	5
		e''	18.0800	Conductivity (σ):	5.83	6.00	-2.82	5
	Body 5825	e'	48.0800	Relative Permittivity (ϵ_r):	48.08	48.20	-0.25	5
		e''	18.1000	Conductivity (σ):	5.86	6.00	-2.29	5
10/17/2013	Body 5180	e'	48.5000	Relative Permittivity (ϵ_r):	48.50	49.05	-1.11	5
		e''	18.6800	Conductivity (σ):	5.38	5.27	2.07	5
	Body 5200	e'	48.4800	Relative Permittivity (ϵ_r):	48.48	49.02	-1.10	5
		e''	18.7100	Conductivity (σ):	5.41	5.29	2.17	5
	Body 5600	e'	47.8000	Relative Permittivity (ϵ_r):	47.80	48.48	-1.40	5
		e''	19.1000	Conductivity (σ):	5.95	5.76	3.23	5
	Body 5800	e'	47.5700	Relative Permittivity (ϵ_r):	47.57	48.20	-1.31	5
		e''	19.2700	Conductivity (σ):	6.21	6.00	3.58	5
	Body 5825	e'	47.5000	Relative Permittivity (ϵ_r):	47.50	48.20	-1.45	5
		e''	19.3100	Conductivity (σ):	6.25	6.00	4.24	5
10/29/2013	Body 5180	e'	48.5200	Relative Permittivity (ϵ_r):	48.52	49.05	-1.07	5
		e''	18.8000	Conductivity (σ):	5.41	5.27	2.72	5
	Body 5200	e'	48.5300	Relative Permittivity (ϵ_r):	48.53	49.02	-1.00	5
		e''	18.7900	Conductivity (σ):	5.43	5.29	2.61	5
	Body 5600	e'	47.7800	Relative Permittivity (ϵ_r):	47.78	48.48	-1.44	5
		e''	19.1300	Conductivity (σ):	5.96	5.76	3.40	5
	Body 5800	e'	47.5200	Relative Permittivity (ϵ_r):	47.52	48.20	-1.41	5
		e''	19.3100	Conductivity (σ):	6.23	6.00	3.79	5
	Body 5825	e'	47.4300	Relative Permittivity (ϵ_r):	47.43	48.20	-1.60	5
		e''	19.3300	Conductivity (σ):	6.26	6.00	4.35	5

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11. System Performance 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 remeasured or sooner when marginal liquid parameters are used at the beginning of a series of measurements.

11.1. 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 ± 0.5 cm for SAR measurements ≤ 3 GHz and ≥ 10.0 cm ± 0.5 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.

11.2. Reference SAR Values for System Performance Check

The reference SAR values can be obtained from the calibration certificate of system validation dipoles

System Dipole	Serial No.	Cal. Date	Freq. (GHz)	Target SAR Values (mW/g)		
				1g/10g	Head	Body
D2450V2	706	05/29/2013	2450	1g	53.7	49.9
				10g	25.0	23.3
D5GHzV2	1003	09/19/2013	5200	1g	78.5	73.3
				10g	22.4	20.5
			5600	1g	81.0	78.6
				10g	23.0	21.8
			5800	1g	76.4	72.7
				10g	21.7	20.1

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11.3. System Performance 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.

Date Tested	System Dipole		T.S. Liquid		Measured Results			Target (Ref. Value)	Delta ±10 %	Est./Zoom Ratio ±3 %	Plot No.
	Type	Serial #			Area Scan	Zoom Scan	Normalize to 1 W				
10/14/2013	D2450V2	706	Body	1g	5.71	5.37	53.7	49.9	7.62	5.95	1,2
				10g	2.47	2.48	24.8	23.3	6.44		
	D5GHzV2 5.2GHz	1003	Body	1g	6.64	7.00	70.00	73.30	-4.50	-5.42	3,4
				10g	1.89	1.96	19.60	20.50	-4.39		
	D5GHzV2 5.6GHz	1003	Body	1g	6.49	7.52	75.20	78.60	-4.33	-15.87	5,6
				10g	1.85	2.10	21.00	21.80	-3.67		
	D5GHzV2 5.8GHz	1003	Body	1g	6.29	6.77	67.70	72.70	-6.88	-7.63	7,8
				10g	1.78	1.88	18.80	20.10	-6.47		
10/17/2013	D5GHzV2 5.2GHz	1003	Body	1g	8.54	7.39	73.90	73.30	0.82	13.47	9,10
				10g	2.47	2.08	20.80	20.50	1.46		
	D5GHzV2 5.6GHz	1003	Body	1g	9.87	8.50	85.00	78.60	8.14	13.88	11,12
				10g	2.79	2.36	23.60	21.80	8.26		
	D5GHzV2 5.8GHz	1003	Body	1g	8.18	7.24	72.40	72.70	-0.41	11.49	13,14
				10g	2.33	2.00	20.00	20.10	-0.50		
10/29/2013	D5GHzV2 5.2GHz	1003	Body	1g	6.62	7.03	70.30	73.30	-4.09	-6.19	15,16
				10g	1.85	1.96	19.60	20.50	-4.39		
	D5GHzV2 5.6GHz	1003	Body	1g	7.48	8.04	80.40	78.60	2.29	-7.49	17,18
				10g	2.07	2.23	22.30	21.80	2.29		
	D5GHzV2 5.8GHz	1003	Body	1g	6.58	6.99	69.90	72.70	-3.85	-6.23	19,20
				10g	1.81	1.93	19.30	20.10	-3.98		

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12. SAR Test Results

When the highest reported 1-g SAR is > 0.4 W/kg and ≤ 0.8 W/kg, modules and peripheral transmitters may be approved to operate in multiple host platforms. To qualify for multiple host platforms, the modular transmitter may be approved under one FCC ID, either in the initial filing or through Class II permissive changes. All subsequent Class II permissive changes must be within the scope of the defined host platform configurations and exposure conditions in the initial equipment approval as per KDB 447498 D01 v05r01.

12.1. Wi-Fi (2.4 GHz Band)

Test Position	Mode	Dist. (mm)	Ch #.	Freq. (MHz)	Power (dBm) Chain 0		1-g SAR (W/kg) Chain 0		Plot No	Note
					Tune-up limit	Meas.	Meas.	Scaled		
Top	802.11b	5	1	2412	16.0	16.0				1
			6	2437	16.0	16.0	0.307	0.307		
			11	2462	16.0	16.0				1
Bottom	802.11b	5	1	2412	16.0	16.0				1
			6	2437	16.0	16.0	**0.577**	0.577	1	
			11	2462	16.0	16.0				1
Edge 1	802.11b	5	1	2412	16.0	16.0				1
			6	2437	16.0	16.0	0.307	0.307		
			11	2462	16.0	16.0				1
Edge 2	802.11b	5	1	2412	16.0	16.0				1
			6	2437	16.0	16.0	<0.001	<0.001		
			11	2462	16.0	16.0				1
Edge 3	802.11b	5	1	2412	16.0	16.0				1
			6	2437	16.0	16.0	0.562	0.562		
			11	2462	16.0	16.0				1
Edge 4	802.11b	5	1	2412	16.0	16.0				1
			6	2437	16.0	16.0	0.015	0.015		
			11	2462	16.0	16.0				1

Note(s):

1. 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

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12.2. Wi-Fi (5 GHz Bands)

Band (GHz)	Test Position	Dist. (mm)	Mode	Ch #.	Freq. (MHz)	Power (dBm) Chain 0		1-g SAR (W/kg) Chain 0		Plot No.	Note
						Tune-up limit	Meas.	Meas.	Scaled		
5.2	Edge 1	5	802.11a	36	5180	14.0	14.0	0.348	0.348	2	
				48	5240	14.0	14.0				1
5.3	Edge 1	5	802.11a	52	5260	14.0	14.0	0.363	0.363	3	
				64	5320	14.0	14.0				1
5.5	Edge 1	5	802.11a	104	5520	16.0	16.0				1
				116	5580	16.0	16.0	0.326	0.326	4	
				124	5620	16.0	16.0				1
				136	5680	16.0	16.0				1
5.8	Edge 1	5	802.11a	149	5745	18.0	18.0				1
				157	5785	18.0	18.0	0.245	0.245		
				165	5825	18.0	18.0				1

Band (GHz)	Test Position	Dist. (mm)	Mode	Ch #.	Freq. (MHz)	Power (dBm) Chain 0		1-g SAR (W/kg) Chain 0		Plot No.	Note
						Tune-up limit	Meas.	Meas.	Scaled		
5.2	Edge 2	5	802.11a	36	5180	14.0	14.0	0.021	0.021		
				48	5240	14.0	14.0				1
5.3	Edge 2	5	802.11a	52	5260	14.0	14.0	0.034	0.034		
				64	5320	14.0	14.0				1
5.5	Edge 2	5	802.11a	104	5520	16.0	16.0				1
				116	5580	16.0	16.0	0.045	0.045		
				124	5620	16.0	16.0				1
				136	5680	16.0	16.0				1
5.8	Edge 2	5	802.11a	149	5745	18.0	18.0				1
				157	5785	18.0	18.0	0.044	0.044		
				165	5825	18.0	18.0				1

Band (GHz)	Test Position	Dist. (mm)	Mode	Ch #.	Freq. (MHz)	Power (dBm) Chain 0		1-g SAR (W/kg) Chain 0		Plot No.	Note
						Tune-up limit	Meas.	Meas.	Scaled		
5.2	Edge 3	5	802.11a	36	5180	14.0	14.0	0.124	0.124		
				48	5240	14.0	14.0				1
5.3	Edge 3	5	802.11a	52	5260	14.0	14.0	0.143	0.143		
				64	5320	14.0	14.0				1
5.5	Edge 3	5	802.11a	104	5520	16.0	16.0				1
				116	5580	16.0	16.0	0.101	0.101		
				124	5620	16.0	16.0				1
				136	5680	16.0	16.0				1
5.8	Edge 3	5	802.11a	149	5745	18.0	18.0				1
				157	5785	18.0	18.0	0.159	0.159		
				165	5825	18.0	18.0				1

Note(s):

1. 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

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Band (GHz)	Test Position	Dist. (mm)	Mode	Ch #.	Freq. (MHz)	Power (dBm) Chain 0		1-g SAR (W/kg) Chain 0		Plot No.	Note
						Tune-up limit	Meas.	Meas.	Scaled		
5.2	Edge 4	5	802.11a	36	5180	14.0	14.0	0.025	0.025		
				48	5240	14.0	14.0				1
5.3	Edge 4	5	802.11a	52	5260	14.0	14.0	0.020	0.020		
				64	5320	14.0	14.0				1
5.5	Edge 4	5	802.11a	104	5520	16.0	16.0				1
				116	5580	16.0	16.0	0.001	0.001		
				124	5620	16.0	16.0				1
				136	5680	16.0	16.0				1
5.8	Edge 4	5	802.11a	149	5745	18.0	18.0				1
				157	5785	18.0	18.0	0.031	0.031		
				165	5825	18.0	18.0				1

Band (GHz)	Test Position	Dist. (mm)	Mode	Ch #.	Freq. (MHz)	Power (dBm) Chain 0		1-g SAR (W/kg) Chain 0		Plot No.	Note
						Tune-up limit	Meas.	Meas.	Scaled		
5.2	Top	5	802.11a	36	5180	14.0	14.0	0.247	0.247		
				48	5240	14.0	14.0				1
5.3	Top	5	802.11a	52	5260	14.0	14.0	0.300	0.300		
				64	5320	14.0	14.0				1
5.5	Top	5	802.11a	104	5520	16.0	16.0				1
				116	5580	16.0	16.0	0.198	0.198		
				124	5620	16.0	16.0				1
				136	5680	16.0	16.0				1
5.8	Top	5	802.11a	149	5745	18.0	18.0				1
				157	5785	18.0	18.0	0.330	0.330		
				165	5825	18.0	18.0				1

Band (GHz)	Test Position	Dist. (mm)	Mode	Ch #.	Freq. (MHz)	Power (dBm) Chain 0		1-g SAR (W/kg) Chain 0		Plot No.	Note
						Tune-up limit	Meas.	Meas.	Scaled		
5.2	Bottom	5	802.11a	36	5180	14.0	14.0	0.236	0.236		
				48	5240	14.0	14.0				1
5.3	Bottom	5	802.11a	52	5260	14.0	14.0	0.288	0.288		
				64	5320	14.0	14.0				1
5.5	Bottom	5	802.11a	104	5520	16.0	16.0				1
				116	5580	16.0	16.0	0.277	0.277		
				124	5620	16.0	16.0				1
				136	5680	16.0	16.0				1
5.8	Bottom	5	802.11a	149	5745	18.0	18.0				1
				157	5785	18.0	18.0	0.472	0.472	5	
				165	5825	18.0	18.0				1

Note(s):

1. 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

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12.3. 5 GHz 802.11ac, performed on the worst-case test configuration of each 802.11a band

Band (GHz)	Test Position	Dist. (mm)	Mode	Ch #.	Freq. (MHz)	Power (dBm) Chain 0		1-g SAR (W/kg) Chain 0		Plot No.	Note
						Tune-up limit	Meas.	Meas.	Scaled		
5.2	Edge 1	5	802.11ac	36	5180	14.0	13.9	0.298	0.305		
5.3	Edge 1	5	802.11ac	52	5260	14.0	14.0	0.320	0.320		
5.5	Edge 1	5	802.11ac	116	5580	16.0	16.0	0.193	0.193		
5.8	Bottom	5	802.11ac	157	5785	18.0	18.0	0.380	0.380		

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12.4. Enhanced Energy Coupling

Enhanced Energy Coupling evaluation is not required according to KDB 447498 §5.2.4 as the highest measured SAR is >0.4W/kg

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13. SAR Measurement Variability

In accordance with published RF Exposure KDB procedure 865664 D01 SAR measurement 100 MHz to 6 GHz v01. 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 < 0.80 W/kg; steps 2) through 4) do not apply.
2) When the original highest measured SAR is ≥ 0.80 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 > 1.20 or when the original or repeated measurement is ≥ 1.45 W/kg (~ 10% from the 1-g SAR limit).
4) Perform a third repeated measurement only if the original, first or second repeated measurement is ≥1.5 W/kg and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20.

13.1. The Highest Measured SAR Configuration in Each Frequency Band

Body Exposure Condition

Not Applicable. Highest measured SAR is < 0.80 W/kg.

13.2. Repeated Measurement Results

Body Exposure Condition

Not Applicable. Highest measured SAR is < 0.80 W/kg.

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14. Estimated SAR for Bluetooth

14.1.1. Standalone SAR Test Exclusion

Antenna	Tx Interface	Frequency (MHz)	Output Power		Separation Distances (mm) All Configurations	Calculated Threshold Value (All Configurations)
			dBm	mW	Top	Top
Chain 0	Bluetooth	2402	5.2	3	5	0.9

Conclusion:

The computed values are < 3; therefore, Bluetooth qualifies for Standalone SAR test exclusion.

14.1.2. Estimated SAR

Antenna	Tx Interface	Frequency (MHz)	Output Power		Separation Distances (mm) (All Configurations)	Estimated 1-g SAR Value (W/kg) (All Configurations)
			dBm	mW		
Chain 0	Bluetooth	2402	5.2	3	5	0.124

Note(s):

1. Power and distance are rounded to the nearest mW and mm before calculation
2. If the minimum test separation distance is <5mm then 5mm is used in the calculation

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15. Appendixes

Refer to separated files for the following appendixes.

15.1. DUT and SAR setup Photos

15.2. System Performance Check Plots

15.3. Worst Case SAR Test Plots

15.4. Calibration Certificate for E-Field Probe EX3DV3- SN 3902

15.5. Calibration Certificate for E-Field Probe EX3DV- SN 3929

15.6. Calibration Certificate for D2450V2- SN 706

15.7. Calibration Certificate for D5GHzV2- SN 1003

END OF REPORT

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