KDB 865664 D01 SAR Measurement 100MHz to 6GHz
FCC 47 CFR part 2 (2.1093)

SAR EVALUATION REPORT

For

Laptop Computer with IEEE 802.11a/b/g/n/ac (MIMO 2X2) and Bluetooth Radio

Model: A2159
FCC ID: BCGA2159

Report Number UL-SAR-RP12743108JD04A V1.0
ISSUE DATE: 03 June 2019

Prepared for

APPLE INC.
ONE APPLE PARK WAY
CUPERTINO
CA 95014-2084, USA

Prepared by

UL VS LTD
UNIT 1 HORIZON, KINGSLAND BUSINESS PARK
WADE ROAD, BASINGSTOKE, HAMPSHIRE, RG24 8AH, UK
TEL: +44 (0) 1256 312000
FAX: +44 (0) 1256 312001

0644

REVISION HISTORY

Version	Issue Date	Revisions	Revised By
1.0	03 June 2019	Initial Issue	--

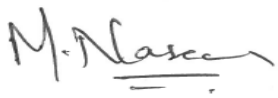
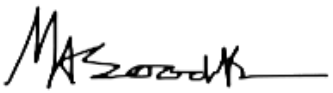
TABLE OF CONTENTS

1. Attestation of Test Results

Applicant Name	Apple Inc.					
Model	A2159					
Test Device is	A representative test sample					
Device category	Portable					
Date Tested	08 March 2019 to 18 March 2019					
ICNIRP Guidelines Limits for SAR Exposure Characteristics	General Population/Localised SAR (Head and trunk): 1g-SAR limit 1.6 W/kg					
The highest reported SAR values	RF Exposure Conditions		Equipment Class			
			Licensed	DTS	U-NII	DSS
	Standalone	Body	N/A	0.94 W/Kg	0.93 W/Kg	0.39 W/Kg
	Simultaneous Transmission	Body	N/A	N/A	0.90 W/Kg	0.90 W/Kg
Applicable Standards	FCC 47 CFR part 2 (2.1093) KDB publication					
Test Results	Pass					

UL Verification Services Ltd. 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 Ltd. based on interpretations and/or observations of test results. Measurement Uncertainties are in accordance with the above standard 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(s), 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 Ltd. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Ltd. 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 UKAS. This report is written to support regulatory compliance of the applicable standards stated above.

Issued By:	Prepared By:
	
Naseer Mirza Project Lead UL VS Ltd.	Masood Khan Lab Engineer UL VS Ltd.

2. Test Specification, Methods and Procedures

2.1. Test Specification

Reference:	KDB Publication Number: 865664 D01 SAR Measurement 100 MHz to 6 GHz
Title:	SAR Measurement Requirements for 100 MHz to 6 GHz
Introduction:	The SAR Measurement procedures for 100MHz to 6GHz are described in this document. Field probes, tissue dielectric properties, SAR scans, measurement accuracy and variability of the measured results are discussed. The field probe and SAR scan requirements are derived from criteria considered in standard IEEE 1528-2013. The wireless product and technology specific procedures in applicable KDB publications are required to be used unless further guidance has been approved by the FCC.
Purpose of Test:	To determine if the Equipment Under Test complies with the Specific Absorption Rate for general population/uncontrolled exposure limit of 1.6 W/kg as specified in FCC 47 CFR part 2 (2.1093).

2.2. Methods and Procedures Reference Documentation

The methods and procedures used were as detailed in:

IEEE 1528:2013

IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communication Devices: Measurement Techniques.

FCC KDB Publication:
KDB 248227 D01 802.11 Wi-Fi SAR v02r02
KDB 447498 D01 General RF Exposure Guidance v06
KDB 616217 D04 SAR for laptop and tablets v01r02
KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04
KDB 865664 D02 RF Exposure Reporting v01r02

2.3. Definition of Measurement Equipment

The measurement equipment used complied with the requirements of the standards referenced in the methods & procedures section above. Section 4.3 contains a list of the test equipment used.

3. Facilities and Accreditation

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

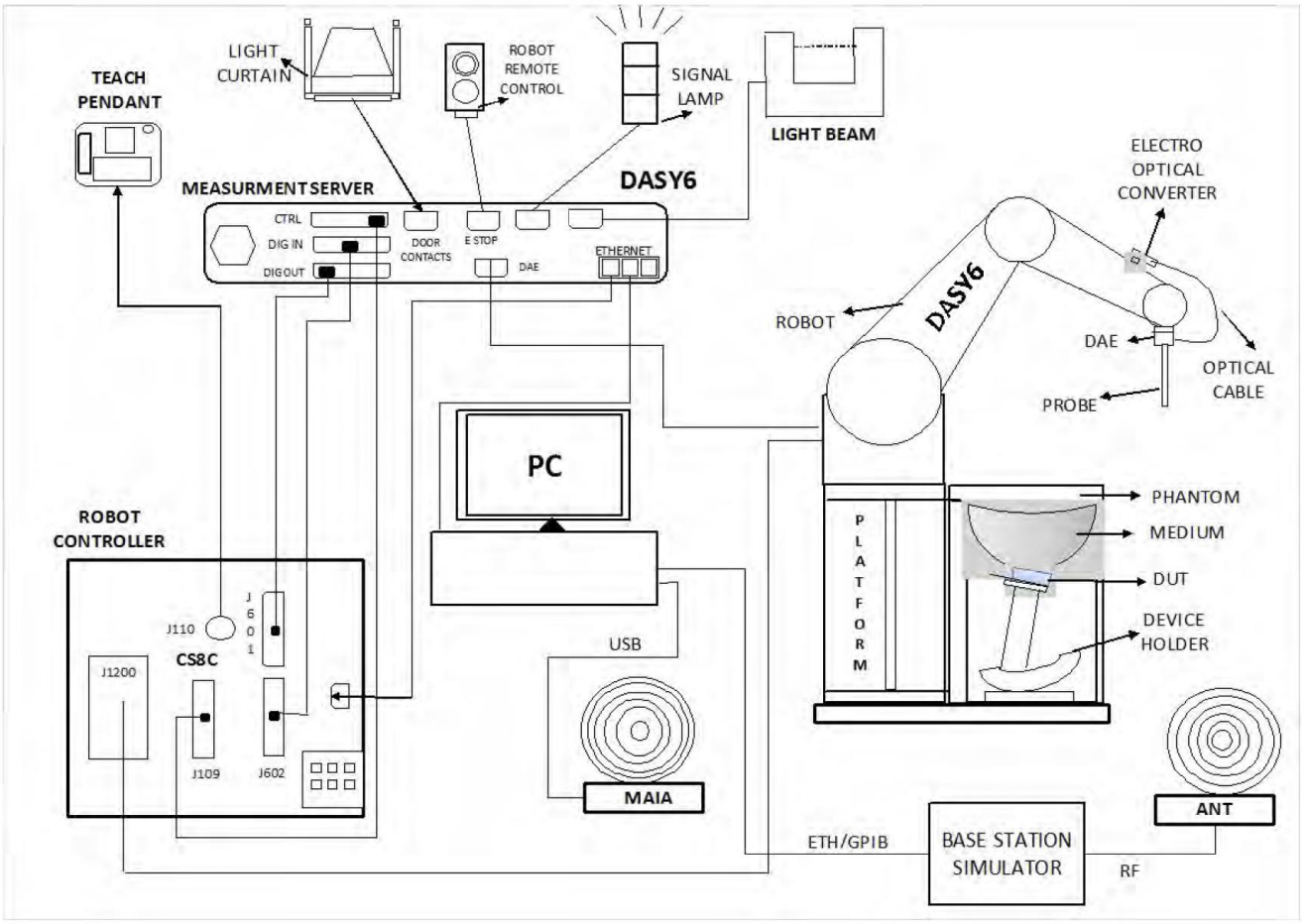
Horizon Unit 1, Wade Road, Kingsland Business Park, Basingstoke, Hampshire, RG24 8AH, UK	Facility Type
SAR Lab 60	Controlled Environment Chamber
SAR Lab 61	Controlled Environment Chamber

UL Verification Services Ltd, is accredited by UKAS (United Kingdom Accreditation Service), Laboratory UKAS Code 0644.

4. SAR Measurement System & Test Equipment

4.1. SAR Measurement System

The DASY 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 Win 8.1 or Win 10 and the DASY 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 Measurement Procedure

4.2.1. Normal SAR Measurement Procedure

The following procedure shall be performed for each of the test conditions Measure the local SAR at a test point within 8 mm of the phantom inner surface that is closest to the DUT.

a) Measure the two-dimensional SAR distribution within the phantom (area scan procedure).
b) The boundary of the measurement area shall not be closer than 20 mm from the phantom side walls. The distance between the measurement points should enable the detection of the location of local maximum with an accuracy of better than half the linear dimension of the tissue cube after interpolation. A maximum grid spacing of 20 mm for frequencies below 3 GHz and (60/f [GHz]) mm for frequencies of 3 GHz and greater is recommended. The maximum distance between the geometrical centre of the probe detectors and the inner surface of the phantom shall be 5 mm for frequencies below 3 GHz and δ ln(2)/2 mm for frequencies of 3 GHz and greater, where δ is the plane wave skin depth and ln(x) is the natural logarithm. The maximum variation of the sensor-phantom surface distance shall be ± 1 mm for frequencies below 3 GHz and ± 0,5 mm for frequencies of 3 GHz and greater. At all measurement points the angle of the probe with respect to the line normal to the surface should be less than 5°. If this cannot be achieved for a measurement distance to the phantom inner surface shorter than the probe diameter, additional uncertainty evaluation is needed.
c) From the scanned SAR distribution, identify the position of the maximum SAR value, in addition identify the positions of any local maxima with SAR values within 2 dB of the maximum value that will not be within the zoom scan of other peaks; additional peaks shall be measured only when the primary peak is within 2 dB 6 of the SAR compliance limit (e.g., 1 W/kg for 1,6 W /kg 1 g limit, or 1,26 W/kg for 2 W /kg, 10 g limit).
d) Measure the three-dimensional SAR distribution at the local maxima locations identified in step c) (zoom scan procedure). The horizontal grid step shall be (24 / f [GHz]) mm or less but not more than 8 mm. The minimum zoom scan size is 30 mm by 30 mm by 30 mm for frequencies below 3 GHz. For higher frequencies, the minimum zoom scan size can be reduced to 22 mm by 22 mm by 22 mm. The grid step in the vertical direction shall be (8-f [GHz]) mm or less but not more than 5 mm, if uniform spacing is used. If variable spacing is used in the vertical direction, the maximum spacing between the two closest measured points to the phantom shell shall be (12/f [GHz]) mm or less but not more than 4 mm, and the spacing between farther points shall increase by an incremental factor not exceeding 1,5. When variable spacing is used, extrapolation routines shall be tested with the same spacing as used in measurements. The maximum distance between the geometrical centre of the probe detectors and the inner surface of the phantom shall be 5 mm for frequencies below 3 GHz and δ ln(2)/2 mm for frequencies of 3 GHz and greater, where δ is the plane wave skin depth and ln(x) is the natural logarithm. Separate grids shall be centred on each of the local SAR maxima found in step c). Uncertainties due to field distortion between the media boundary and the dielectric enclosure of the probe should also be minimized, which is achieved if the distance between the phantom surface and physical tip of the probe is larger than probe tip diameter. Other methods may utilize correction procedures for these boundary effects that enable high precision measurements closer than half the probe diameter. For all measurement points, the angle of the probe with respect to the flat phantom surface shall be less than 5º.
e) Use post processing (e.g. interpolation and extrapolation) procedures to determine the local SAR values at the spatial resolution needed for mass averaging.
f) The local SAR should be measured at the same location as in Step a). SAR drift is assessed and reported in the uncertainty budget.
In the event that the evaluation of measurement drift exceeds the 5 % tolerance, it is required that SAR be reassessed following guidelines contained within this standard.
If the drift is larger than 5 %, then the measurement drift shall be considered a bias, not an uncertainty. A correction shall be applied to the measured SAR value. It is not necessary to record the drift in the uncertainty budget (i.e. ui = 0 %). The uncertainty budget reported in a measurement report should correspond to the highest SAR value reported (after correction, if applicable). Alternatively, the uncertainty budget reported should cover all measurements, i.e., it should report a conservative value.

Area Scan Parameters:

	≤ 3 GHz	> 3 GHz
Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface	5 mm ± 1 mm	$½·\delta·\ln(2)$ mm ± 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.	

Zoom Scan Parameters:

			≤ 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	≤ $1.5·\Delta z_{Zoom}(n-1)$	
Minimum zoom scan volume	x, y, z		≥ 30 mm	3 – 4 GHz: ≥ 28 mm 4 – 5 GHz: ≥ 25 mm 5 – 6 GHz: ≥ 22 mm

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.

UL No.	Instrument	Manufacturer	Type No.	Serial No.	Date Last Calibrated	Cal. Interval (Months)
A2110	Data Acquisition Electronics	SPEAG	DAE4	431	08 Jun 2018	12
A1234	Data Acquisition Electronics	SPEAG	DAE4	450	13 Sep 2018	12
A1322	2450 MHz Dipole Kit	SPEAG	D2450V2	725	17 Sep 2018	12
A1377	5.0 GHz Dipole Kit	SPEAG	D5GHzV2	1016	19 Feb 2019	12
A2781	5.0 GHz Dipole Kit	SPEAG	D5GHzV2	1222	13 Sep 2018	12
A2545	Probe	SPEAG	EX3DV4	3995	24 Apr 2018	12
PRE0189107	Probe	SPEAG	ES3DV3	3358	21 Jan 2019	12
PRE0178266	Probe	SPEAG	EX3DV4	7495	16 Mar 2018	12
G0612	Robot Power Supply	SPEAG	DASY52	F14/5T5ZA1/C/01	Calibrated as part of system	-
G0611	Robot Power Supply	SPEAG	DASY52	F14/5UA6A1/C/01	Calibrated as part of system	-
M1877	Robot Arm	Staubli	TX60 L	F14/5T5ZA1/A/01	Calibrated as part of system	-
M1876	Robot Arm	Staubli	TX60 L	F14/5UA6A1/A/01	Calibrated as part of system	-
A2808	Head Handset Positioner	SPEAG	MD4HHTV5	None	Calibrated before use	-
A2809	Head Handset Positioner	SPEAG	MD4HHTV5	None	Calibrated before use	-
M1755	DAK Fluid Probe	SPEAG	SM DAK 040 CA	1089	Calibrated before use	-
M1855	Power Sensor	R & S	NRV-Z51	103246	18 Jan 2019	12
PRE0159221	Power Source	SPEAG	SE UMS 160 AB	1026	Calibrated as part of system	-
PRE0151154	Network Analyser	R&S	ZND	100151	03 Jan 2019	12
A2621	Digital Camera	Nikon	S3600	41010357	N/A	-
A2252	Phantom	SPEAG	ELI Phantom	1177	Calibrated as part of system	-
A2550	Phantom	SPEAG	ELI Phantom	1252	Calibrated as part of system	-
PRE0141347	Phantom Support Structure	SPEAG	DASY6 Phantom Table	-	Calibrated as part of system	-
PRE0141348	Phantom Support Structure	SPEAG	DASY6 Phantom Table	-	Calibrated as part of system	-
PRE0155857	RS Hygrometer	RS Components	408-6109	612Q19R(2)	11 Apr 2018	12
M1853	RS Hygrometer	RS Components	408-6109	D10Q69	11 Apr 2018	12
PRE0178154	Signal Generator	R & S	SMB 100A	175325	09 Apr 2018	12

SAR System Specifications

Robot System		
Positioner:	Stäubli Unimation Corp. Robot Model: TX60L	
Repeatability:	±0.030 mm	
No. of Axis:	6	
Serial Number(s):	F14/5UA6A1/A/01; F14/5T5ZA1/A/01	
Reach:	800 mm	
Payload:	2.0 kg	
Control Unit:	CS8C	
Programming Language:	V+	
Data Acquisition Electronic (DAE) System		
Serial Number:	DAE4 SN: 431, 450	
PC Controller		
PC:	HP EliteDesk800	
Operating System:	Windows 10	
Data Card:	DASY5 Measurement Servers	
Data Converter		
Features:	Signal Amplifier, multiplexer, A/D converted and control logic.	
Software:	DASY6 PRO Software	
Connecting Lines:	Optical downlink for data and status info. Optical uplink for commands and clock.	
PC Interface Card		
Function:	24 bit (64 MHz) DSP for real time processing Link to DAE4 16 bit A/D converter for surface detection system serial link to robot direct emergency stop output for robot.	
Phantom		
Phantom:	Eli Phantom	
Shell Material:	Fibreglass	
Thickness:	2.0 ±0.1 mm	
E-Field Probe		
Model:	EX3DV4	ES3DV3
Serial No:	3995, 7495	3358
Construction:	Triangular core	Triangular core
Frequency:	10MHz to >6GHz	10 MHz to > 4 GHz
Linearity:	±0.2 dB (30 MHz to 6 GHz)	±0.2 dB (30 MHz to 4 GHz)
Probe Length (mm):	337	337
Probe Diameter (mm):	10	10
Tip Length (mm):	9	10
Tip Diameter (mm):	2.5	4
Sensor X Offset (mm):	1	2
Sensor Y Offset (mm):	1	2
Sensor Z Offset (mm):	1	2

5. Measurement Uncertainty

No measurement or test can ever be perfect and the imperfections give rise to error of measurement in the results. Consequently, the result of a measurement is only an approximation to the value of the measurand (the specific quantity subject to measurement) and is only complete when accompanied by a statement of the uncertainty of the approximation.

The expression of uncertainty of a measurement result allows realistic comparison of results with reference values and limits given in specifications and standards.

The uncertainty of the result may need to be taken into account when interpreting the measurement results.

The reported expanded uncertainties below are based on a standard uncertainty multiplied by an appropriate coverage factor, such that a confidence level of approximately 95% is maintained. For the purposes of this document “approximately” is interpreted as meaning “effectively” or “for most practical purposes”.

Test Name	Confidence Level	Calculated Uncertainty
Uncertainty- Freq. < 3 GHz Body Configuration 1g	95 %	±19.22 %
Uncertainty- Freq. > 3 GHz Body Configuration 1g	95 %	±16.37 %

The methods used to calculate the above uncertainties are in line with those recommended within the various measurement specifications. Where measurement specifications do not include guidelines for the evaluation of measurement uncertainty, the published guidance of the appropriate accreditation body is followed.

5.1. Uncertainty – Freq. < 3 GHz Body Configuration 1g

Type	Source of uncertainty	+ Value	- Value	Probability Distribution	Divisor	$c_{i\ (1g)}$	Standard Uncertainty		υ_i or υ_{eff}
							+ u (%)	- u (%)	
B	Probe calibration	5.050	5.050	normal (k=1)	1.0000	1.0000	5.050	5.050	∞
B	Axial Isotropy	0.250	0.250	normal (k=1)	1.0000	1.0000	0.250	0.250	∞
B	Hemispherical Isotropy	1.300	1.300	normal (k=1)	1.0000	1.0000	1.300	1.300	∞
B	Spatial Resolution	0.500	0.500	Rectangular	1.7321	1.0000	0.289	0.289	∞
B	Boundary Effect	0.769	0.769	Rectangular	1.7321	1.0000	0.444	0.444	∞
B	Linearity	0.300	0.300	Rectangular	1.7321	1.0000	0.173	0.173	∞
B	Detection Limits	0.200	0.200	Rectangular	1.7321	1.0000	0.115	0.115	∞
B	Readout Electronics	0.160	0.160	normal (k=1)	1.0000	1.0000	0.160	0.160	∞
B	Response Time	0.000	0.000	Rectangular	1.7321	1.0000	0.000	0.000	∞
B	Integration Time	8.520	8.520	Rectangular	1.7321	1.0000	4.919	4.919	∞
B	RF Ambient conditions	3.000	3.000	Rectangular	1.7321	1.0000	1.732	1.732	∞
B	Probe Positioner Mechanical Restrictions	4.000	4.000	Rectangular	1.7321	1.0000	2.309	2.309	∞
B	Probe Positioning with regard to Phantom Shell	2.850	2.850	Rectangular	1.7321	1.0000	1.645	1.645	∞
B	Extrapolation and integration/ Maximum SAR evaluation	5.080	5.080	Rectangular	1.7321	1.0000	2.933	2.933	∞
A	Test Sample Positioning	0.147	0.147	normal (k=1)	1.0000	1.0000	0.147	0.147	10
A	Device Holder uncertainty	0.154	0.154	normal (k=1)	1.0000	1.0000	0.154	0.154	10
B	Phantom Uncertainty	4.000	4.000	Rectangular	1.7321	1.0000	2.309	2.309	∞
B	Drift of output power	5.000	5.000	Rectangular	1.7321	1.0000	2.887	2.887	∞
B	Liquid Conductivity (target value)	5.000	5.000	Rectangular	1.7321	0.6400	1.848	1.848	∞
A	Liquid Conductivity (measured value)	2.470	2.470	normal (k=1)	1.0000	0.6400	1.581	1.581	5
B	Liquid Permittivity (target value)	5.000	5.000	Rectangular	1.7321	0.6000	1.732	1.732	∞
A	Liquid Permittivity (measured value)	2.430	2.430	normal (k=1)	1.0000	0.6000	1.458	1.458	5
	Combined standard uncertainty			t-distribution			9.81	9.81	>500
	Expanded uncertainty			k = 1.96			19.22	19.22	>500

5.2. Uncertainty – Freq. > 3 GHz Body Configuration 1g

Type	Source of uncertainty	+ Value	- Value	Probability Distribution	Divisor	$c_{i\ (1g)}$	Standard Uncertainty		υ_i or υ_{eff}
							+ u (%)	- u (%)	
B	Probe calibration	5.050	5.050	normal (k=1)	1.0000	1.0000	5.050	5.050	B
B	Axial Isotropy	0.250	0.250	normal (k=1)	1.0000	1.0000	0.250	0.250	B
B	Hemispherical Isotropy	1.300	1.300	normal (k=1)	1.0000	1.0000	1.300	1.300	B
B	Spatial Resolution	0.500	0.500	Rectangular	1.7321	1.0000	0.289	0.289	B
B	Boundary Effect	0.769	0.769	Rectangular	1.7321	1.0000	0.444	0.444	B
B	Linearity	0.300	0.300	Rectangular	1.7321	1.0000	0.173	0.173	B
B	Detection Limits	0.200	0.200	Rectangular	1.7321	1.0000	0.115	0.115	B
B	Readout Electronics	0.160	0.160	normal (k=1)	1.0000	1.0000	0.160	0.160	B
B	Response Time	0.000	0.000	Rectangular	1.7321	1.0000	0.000	0.000	B
B	Integration Time	0.000	0.000	Rectangular	1.7321	1.0000	0.000	0.000	B
B	RF Ambient conditions	3.000	3.000	Rectangular	1.7321	1.0000	1.732	1.732	B
B	Probe Positioner Mechanical Restrictions	4.000	4.000	Rectangular	1.7321	1.0000	2.309	2.309	B
B	Probe Positioning with regard to Phantom Shell	2.850	2.850	Rectangular	1.7321	1.0000	1.645	1.645	B
B	Extrapolation and integration/ Maximum SAR evaluation	5.080	5.080	Rectangular	1.7321	1.0000	2.933	2.933	B
A	Test Sample Positioning	1.360	1.360	normal (k=1)	1.0000	1.0000	1.360	1.360	A
A	Device Holder uncertainty	0.154	0.154	normal (k=1)	1.0000	1.0000	0.154	0.154	A
B	Phantom Uncertainty	4.000	4.000	Rectangular	1.7321	1.0000	2.309	2.309	B
B	Drift of output power	5.000	5.000	Rectangular	1.7321	1.0000	2.887	2.887	B
B	Liquid Conductivity (target value)	5.000	5.000	Rectangular	1.7321	0.6400	1.848	1.848	B
A	Liquid Conductivity (measured value)	0.770	0.770	normal (k=1)	1.0000	0.6400	0.493	0.493	A
B	Liquid Permittivity (target value)	5.000	5.000	Rectangular	1.7321	0.6000	1.732	1.732	B
A	Liquid Permittivity (measured value)	0.990	0.990	normal (k=1)	1.0000	0.6000	0.594	0.594	A
	Combined standard uncertainty			t-distribution			8.35	8.35	
	Expanded uncertainty			k = 1.96			16.37	16.37	

6. Device Under Test (DUT) Information

6.1. DUT Description

DUT Description:	The EUT supports WLAN 2.4 GHz (802.11 b/g/n) with MIMO 2X2, WLAN 5.0 GHz {802.11a/n (HT20, HT40), 802.11ac (VHT20, VHT40, VHT80)} with MIMO 2x2, *Bluetooth* (BDR, EDR, BLE and HDR). The device supports CDD, SDM, TxBF and non-TxBF modes for WLAN 2.4GHz and 5.0GHz MIMO.	
Sample Used:	SAR Test	Sample 1 (S/N: C02Y3005L59G) Sample 2 (S/N: C02Y3005L5C1)
	Conducted Power Measurements	Sample 2 (S/N: C02Y3005L5C1)
Hardware Version Number:	REV 1.0	
Software:	18F65	
Firmware WLAN):	16.30.151.1	
Firmware (BT):	V26	
Country of Manufacture:	China	
Device dimension	212.4 x 304.1 x 15.6 mm (Length x Width x Depth)	
Display Diagonal Dimension:	13 Inch (~ 330.2 mm)	
Date of Receipt:	07 February 2019	

Antenna Type:	Internal integral	
Number of Antenna Positions:	Antenna 1 (WF1) - WLAN / WPAN ~ Wi-Fi 2.4 GHz / 5.0 GHz / BT	1 fixed
	Antenna 2 (WF2) - WLAN ~ Wi-Fi 2.4 GHz / 5.0 GHz	1 fixed
Battery Type(s):	Embedded Li-ion	

6.2. Wireless Technologies

Wireless technologies	Frequency bands	Operating mode		Duty Cycle
Wi-Fi	2.4 GHz	802.11b 802.11g 802.11n (HT20)		100%
	5.0 GHz	802.11a 802.11n (HT20) 802.11n (HT40) 802.11ac (VHT20) 802.11ac (VHT40) 802.11ac (VHT80)		100%
Bluetooth	2.4 GHz	☐ Core Spec. 4.0 ☐ Core Spec. 4.1 ☐ Core Spec. 4.2 ☒ Core Spec. 5.0 ☒ Power Class 1 ☐ Power Class 2 ☐ Power Class 3	Basic Rate (BDR) Enhanced Data Rate (EDR) Low Energy (BLE) High Data Rate (HDR)	77% (DH5, 720Kb/s) 77% (2-DH5/3-DH5, 2Mbps and 3Mbps) 60.5% (255 Bytes, 1Mbps) (4-DH5/8-DH5, 4Mbps and 8Mbps)

Wireless Technologies (Continued):

Wi-Fi						
Band	Description					
	20 MHz BW Ch.#	Frq. (MHz)	40 MHz BW Ch.#	Frq. (MHz)	80 MHz BW Ch.#	Frq. (MHz)
Wi-Fi 2.4 GHz (802.11b/g/n)	1	2412.0	N/A			
	2	2417.0				
	6	2437.0				
	10	2457.0				
	11	2462.0				
	12	2467.0				
	13	2472.0				
Wi-Fi 5.0 GHz 5.2 (U-NII-1) (802.11a/n/ac)	36	5180.0	38	5190.0	-	
	40	5200.0	-		42	5210.0
	44	5220.0	46	5230.0		
	48	5240.0	-			
Wi-Fi 5.0 GHz 5.3 (U-NII-2A) (802.11a/n/ac)	52	5260.0	54	5270.0	-	
	56	5280.0	-		58	5290.0
	60	5300.0	62	5310.0		
	64	5320.0	-			
Wi-Fi 5.0 GHz 5.6 (U-NII-2C) (802.11a/n/ac)	100	5500.0	102	5510.0	-	
	104	5520.0	-		106	5530.0
	108	5540.0	110	5550.0		
	112	5560.0	-			
	116	5580.0	118	5590.0	-	
	120	5600.0	-		122	5610.0
	124	5620.0	126	5630.0	-	
	128	5640.0	-			
	132	5660.0	134	5670.0	-	
	136	5680.0	-		138	5690.0
	140	5700.0	142	5710.0	-	
	144	5720.0	-			
Wi-Fi 5.0 GHz 5.8 (U-NII-3) (802.11a/n/ac)	149	5745.0	151	5755.0	-	
	153	5765.0	-		155	5775.0
	157	5785.0	159	5795.0	-	
	161	5805.0	-			
	165	5825.0	-			

Bluetooth				
Band	Description			
	Frequency Range: 2402 - 2480 MHz			
	Mode	Channel Number	Channel Description	Frequency (MHz)
Bluetooth	BDR/EDR Mode	0	Low	2402.0
		39	Middle	2441.0
		78	High	2480.0
	LE Mode	1	Low	2404.0
		19	Middle	2440.0
		38	High	2478.0

6.3.Nominal and Maximum Output power: Wi-Fi and Bluetooth

Wi-Fi 2.4 GHz - WF1 Antenna

			Target + Max. Tolerances (dBm)					
Band	**Channel**	**Centre Frequency (MHz)**	**802.11b (SISO)**	**802.11g (SISO)**	**802.11n HT20 (SISO)**	**802.11n HT20 (2 Tx, DSSS)**	**802.11n HT20 (2 Tx, non-TXBF)**	**802.11n HT20 (2 Tx, TXBF)**
Wi-Fi 2.4 GHz	1	2412	17.00	14.00	14.00	17.00	13.00	11.00
	2	2417	17.00	16.50	16.50	17.00	16.50	14.50
	3	2422	17.00	17.00	17.00	17.00	17.00	16.00
	4	2427	17.00	17.00	17.00	17.00	17.00	17.00
	5	2432	17.00	17.00	17.00	17.00	17.00	17.00
	6	2437	17.00	17.00	17.00	17.00	17.00	17.00
	7	2442	17.00	17.00	17.00	17.00	17.00	17.00
	8	2447	17.00	17.00	17.00	17.00	17.00	16.50
	9	2452	17.00	17.00	17.00	17.00	15.50	15.00
	10	2457	17.00	17.00	17.00	17.00	14.50	13.50
	11	2462	17.00	12.50	12.50	17.00	10.50	9.50
	12	2467	14.00	10.50	10.50	12.50	8.50	7.50
	13	2472	11.00	0.00	0.00	10.50	-1.00	-3.00

Wi-Fi 2.4 GHz - WF2 Antenna

			Target + Max. Tolerances (dBm)					
Band	**Channel**	**Centre Frequency (MHz)**	**802.11b (SISO)**	**802.11g (SISO)**	**802.11n HT20 (SISO)**	**802.11n HT20 (2 Tx, DSSS)**	**802.11n HT20 (2 Tx, non-TXBF)**	**802.11n HT20 (2 Tx, TXBF)**
Wi-Fi 2.4 GHz	1	2412	17.75	14.00	14.00	17.75	13.00	11.00
	2	2417	17.75	16.50	16.50	17.75	16.50	14.50
	3	2422	17.75	17.75	17.75	17.75	17.75	16.00
	4	2427	17.75	17.75	17.75	17.75	17.75	17.75
	5	2432	17.75	17.75	17.75	17.75	17.75	17.75
	6	2437	17.75	17.75	17.75	17.75	17.75	17.75
	7	2442	17.75	17.75	17.75	17.75	17.75	17.75
	8	2447	17.75	17.75	17.75	17.75	17.75	16.50
	9	2452	17.75	17.75	17.75	17.75	15.50	15.00
	10	2457	17.75	17.00	17.00	17.75	14.50	13.50
	11	2462	17.75	12.50	12.50	17.00	10.50	9.50
	12	2467	14.00	10.50	10.50	12.50	8.50	7.50
	13	2472	11.00	0.00	0.00	10.50	-1.00	-3.00

The Bluetooth antenna operate in two stages: 5 GHz Off and 5GHz On

5GHz Off – In this stage, the Wi-Fi 5GHz radio is turned off and Bluetooth antenna transmits at the maximum power possible by the Chipset.

5GHz On – In this stage, the Wi-Fi 5GHz radios are turned on and allow the simultaneous transmission with the Bluetooth antenna. The Bluetooth antenna transmits at a reduced power in order to allow the simultaneous transmission or multi-band SAR evaluation.

Nominal and Maximum Output power: (Continued)

Bluetooth (With 5GHz OFF)- WF1 Antenna

		Target + Max. Tolerances (dBm)			
Band	**Channel**	**BDR (SISO)**	**EDR (SISO)**	**LE/LE2M (SISO)**	**HDR4/HDR8 (SISO)**
Bluetooth iPA	ALL	12.00	10.00	7.00	5.50
Bluetooth ePA	ALL	16.50	16.50	N/A	13.00

Note: Bluetooth operates only on Antenna WF1

Bluetooth (With 5GHz ON) - WF1 Antenna

		Target + Max. Tolerances (dBm) - applicable to WF1 antenna			
Band	**Channel**	**BDR (SISO)**	**EDR (SISO)**	**LE/LE2M (SISO)**	**HDR4/HDR8 (SISO)**
Bluetooth iPA	ALL	11.25	10.00	7.00	5.50
Bluetooth ePA	ALL	11.25	11.25	N/A	10.00

Note: Bluetooth operates only on Antenna WF1

Nominal and Maximum Output power: (Continued)

Wi-Fi 5.0 GHz - WF1 Antenna

			Target + Max. Tolerances (dBm)				
Band	**Channel (20 MHz BW)**	**Center Frequency (MHz)**	**802.11a (SISO)**	**802.11n HT20 (SISO)**	**802.11n HT20 (2 Tx CDD, non-TXBF)**	**802.11n HT20 (2 Tx SDM, non-TXBF)**	**802.11n HT20 (2 Tx, TXBF)**
5.2 GHz U-NII-1	36	5180	11.25	11.25	11.25	11.25	11.25
	40	5200	11.25	11.25	11.25	11.25	11.25
	44	5220	11.25	11.25	11.25	11.25	11.25
	48	5240	11.25	11.25	11.25	11.25	11.25
5.3 GHz U-NII-2A	52	5260	12.50	12.50	12.50	12.50	12.50
	56	5280	12.50	12.50	12.50	12.50	12.50
	60	5300	12.50	12.50	12.50	12.50	12.50
	64	5320	12.50	12.50	12.50	12.50	12.50
5.6 GHz U-NII-2C	100	5500	11.00	11.00	11.00	11.00	11.00
	104	5520	11.00	11.00	11.00	11.00	11.00
	108	5540	11.00	11.00	11.00	11.00	11.00
	112	5560	11.00	11.00	11.00	11.00	11.00
	116	5580	11.00	11.00	11.00	11.00	11.00
	120	5600	11.00	11.00	11.00	11.00	11.00
	124	5620	11.00	11.00	11.00	11.00	11.00
	128	5640	11.00	11.00	11.00	11.00	11.00
	132	5660	11.00	11.00	11.00	11.00	11.00
	136	5680	11.00	11.00	11.00	11.00	11.00
	140	5700	11.00	11.00	11.00	11.00	11.00
	144	5720	11.00	11.00	11.00	11.00	11.00
5.8 GHz U-NII-3	149	5745	11.75	11.75	11.75	11.75	11.75
	153	5765	11.75	11.75	11.75	11.75	11.75
	157	5785	11.75	11.75	11.75	11.75	11.75
	161	5805	11.75	11.75	11.75	11.75	11.75
	165	5825	11.75	11.75	11.75	11.75	11.75

			Target + Max. Tolerances (dBm)			
Band	**Channel (40 MHz BW)**	**Centre Frequency (MHz)**	**802.11n HT40 (1 Tx)**	**802.11n HT40 (2 Tx CDD, non-TXBF)**	**802.11n HT40 (2 Tx SDM, non-TXBF)**	**802.11n HT40 (2 Tx, TXBF)**
5.2 GHz U-NII-1	38	5190	11.25	11.25	11.25	11.25
	46	5230	11.25	11.25	11.25	11.25
5.3 GHz U-NII-2A	54	5270	12.50	12.50	12.50	12.50
	62	5310	12.50	12.50	12.50	12.50
5.6 GHz U-NII-2C	102	5510	11.00	11.00	11.00	11.00
	110	5550	11.00	11.00	11.00	11.00
	118	5590	11.00	11.00	11.00	11.00
	126	5630	11.00	11.00	11.00	11.00
	134	5670	11.00	11.00	11.00	11.00
	142	5710	11.00	11.00	11.00	11.00
5.8 GHz U-NII-3	151	5755	11.75	11.75	11.75	11.75
	159	5795	11.75	11.75	11.75	11.75

			Target + Max. Tolerances (dBm)			
Band	**Channel (80 MHz BW)**	**Centre Frequency (MHz)**	**802.11ac VHT80 (1 Tx)**	**802.11ac VHT80 (2 Tx CDD, non-TXBF)**	**802.11ac VHT80 (2 Tx SDM, non-TXBF)**	**802.11ac VHT80 (2 Tx, TXBF)**
5.2 GHz U-NII-1	42	5210	11.25	11.00	11.25	11.00
5.3 GHz U-NII-2A	58	5290	12.50	12.50	12.50	12.00
5.6 GHz U-NII-2C	106	5530	11.00	11.00	11.00	11.00
	122	5610	11.00	11.00	11.00	11.00
	138	5690	11.00	11.00	11.00	11.00
5.8 GHz U-NII-3	155	5775	11.75	11.75	11.75	11.75

Wi-Fi 5.0 GHz – WF2 Antenna

			Target + Max. Tolerances (dBm)				
Band	**Channel (20 MHz BW)**	**Center Frequency (MHz)**	**802.11a (SISO)**	**802.11n HT20 (SISO)**	**802.11n HT20 (2 Tx CDD, non-TXBF)**	**802.11n HT20 (2 Tx SDM, non-TXBF)**	**802.11n HT20 (2 Tx, TXBF)**
5.2 GHz U-NII-1	36	5180	12.75	12.75	12.75	12.75	12.00
	40	5200	12.75	12.75	12.75	12.75	12.75
	44	5220	12.75	12.75	12.75	12.75	12.75
	48	5240	12.75	12.75	12.75	12.75	12.75
5.3 GHz U-NII-2A	52	5260	13.75	13.75	13.75	13.75	13.75
	56	5280	13.75	13.75	13.75	13.75	13.75
	60	5300	13.75	13.75	13.75	13.75	13.75
	64	5320	13.75	13.75	13.75	13.75	13.75
5.6 GHz U-NII-2C	100	5500	12.75	12.75	12.75	12.75	12.75
	104	5520	12.75	12.75	12.75	12.75	12.75
	108	5540	12.75	12.75	12.75	12.75	12.75
	112	5560	12.75	12.75	12.75	12.75	12.75
	116	5580	12.75	12.75	12.75	12.75	12.75
	120	5600	12.75	12.75	12.75	12.75	12.75
	124	5620	12.75	12.75	12.75	12.75	12.75
	128	5640	12.75	12.75	12.75	12.75	12.75
	132	5660	12.75	12.75	12.75	12.75	12.75
	136	5680	12.75	12.75	12.75	12.75	12.75
	140	5700	12.75	12.75	12.75	12.75	12.75
	144	5720	12.75	12.75	12.75	12.75	12.75
5.8 GHz U-NII-3	149	5745	14.00	14.00	14.00	14.00	14.00
	153	5765	14.00	14.00	14.00	14.00	14.00
	157	5785	14.00	14.00	14.00	14.00	14.00
	161	5805	14.00	14.00	14.00	14.00	14.00
	165	5825	14.00	14.00	14.00	14.00	14.00

			Target + Max. Tolerances (dBm)			
Band	**Channel (40 MHz BW)**	**Centre Frequency (MHz)**	**802.11n HT40 (1 Tx)**	**802.11n HT40 (2 Tx CDD, non-TXBF)**	**802.11n HT40 (2 Tx SDM, non-TXBF)**	**802.11n HT40 (2 Tx, TXBF)**
5.2 GHz U-NII-1	38	5190	12.75	12.00	12.75	11.50
	46	5230	12.75	12.75	12.75	12.75
5.3 GHz U-NII-2A	54	5270	13.75	13.75	13.75	13.75
	62	5310	13.75	13.75	13.75	13.50
5.6 GHz U-NII-2C	102	5510	12.75	12.75	12.75	12.75
	110	5550	12.75	12.75	12.75	12.75
	118	5590	12.75	12.75	12.75	12.75
	126	5630	12.75	12.75	12.75	12.75
	134	5670	12.75	12.75	12.75	12.75
	142	5710	12.75	12.75	12.75	12.75
5.8 GHz U-NII-3	151	5755	14.00	14.00	14.00	14.00
	159	5795	14.00	14.00	14.00	14.00

			Target + Max. Tolerances (dBm)			
Band	**Channel (80 MHz BW)**	**Centre Frequency (MHz)**	**802.11ac VHT80 (1 Tx)**	**802.11ac VHT80 (2 Tx CDD, non-TXBF)**	**802.11ac VHT80 (2 Tx SDM, non-TXBF)**	**802.11ac VHT80 (2 Tx, TXBF)**
5.2 GHz U-NII-1	42	5210	12.75	11.00	12.50	11.00
5.3 GHz U-NII-2A	58	5290	13.75	12.50	12.50	12.00
5.6 GHz U-NII-2C	106	5530	12.75	12.75	12.75	12.75
	122	5610	12.75	12.75	12.75	12.75
	138	5690	12.75	12.75	12.75	12.75
5.8 GHz U-NII-3	155	5775	14.00	14.00	14.00	14.00

7. RF Exposure Conditions (Test Configurations)

7.1. Configuration Consideration

Technology Antenna	Configuration	Antenna-to-User Separation	Position	Antenna-to-Edge Separation (mm)	Evaluation Considered
WF1 WLAN / WPAN ~ (Wi-Fi 2.4 GHz/ Wi-Fi 5.0 GHz/BT)	Body	0mm	Back	< 25	Yes
			Right	> 25	No
			Left	> 25	No
			Display Side	< 25	Yes
WF2 WLAN ~ (Wi-Fi 2.4 GHz/ Wi-Fi 5.0 GHz)	Body	0mm	Back	< 25	Yes
			Right	> 25	No
			Left	> 25	No
			Display Side	< 25	Yes

Note: The Antenna to edge separation distances are indicated in the 'Antenna Schematics' located in Section 12.1 of this report.

7.2. SAR Test Exclusion Consideration

Frequency Band	Configuration(s)	
	Body	
	SISO	MIMO
WLAN 2.4 GHz	No	No
WLAN 5.2 GHz	Yes[1]	Yes[1]
WLAN 5.3 GHz	No	No
WLAN 5.6 GHz	No	No
WLAN 5.8 GHz	No	No
Bluetooth	No	N/A

Note:

1. As per KDB 248227, U-NII-2A was chosen for SAR evaluation as maximum rated power for U-NII-2A > U-NII-1. Based on the measurements obtained, SAR measurements on U-NII-1 band are not required as highest reported SAR from U-NII-2A band is ≤ 1.2 W/Kg.

8. Conducted Output Power Measurements

8.1. RF Output Average Power Measurement: Wi-Fi 2.4 GHz

Note: Additional Conducted power measurements are performed on adjacent Channels having same or higher Max. rated power than the standard Channels (i.e., 1, 6, and 11).

8.1.1. Wi-Fi 802.11b (2.4 GHz) - SISO

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	6Mbps	6Mbps	Operating Mode
		Body	Body	
1	2412	16.55	17.55	802.11b
6	2437	16.55	17.45	
10	2457	16.55	17.55	
11	2462	16.55	17.55	
12	2467	13.95	13.95	
13	2472	10.95	10.85	

Note: Conducted power measurements for 802.11g and 802.11n HT20 modes not required, as the Max. Rated Power for these mode was ≤ 802.11b mode

8.1.2. Wi-Fi 802.11n (2.4 GHz) – MIMO
WF1 + WF2

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	6.5Mbps	6.5Mbps	Operating Mode
		Body	Body	
1	2412	16.85	16.65	802.11n, HT20 DSSS
6	2437	16.85	16.55	
10	2457	16.95	16.65	
11	2462	16.85	16.65	
12	2467	11.85	11.65	
13	2472	9.85	9.65	

8.2. RF Output Average Power Measurement: Wi-Fi 5.0 GHz

8.2.1. Wi-Fi 802.11a/n/ac (5.0 GHz) – SISO (5.2 GHz U-NII-1)

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	29.3 Mbps	29.3 Mbps	Operating Mode
		Body	Body	
42	5210	11.15	12.45	**802.11ac VHT 80**

Note: Conducted power measurements for 802.11a / 802.11n HT20/ 802.11n HT40 (SISO) modes not required, as the Max. Rated Power for these mode was ≤ than higher bandwidth modes 802.11ac VHT80

8.2.2. Wi-Fi 802.11a/n/ac (5.0 GHz) – MIMO (5.2 GHz U-NII-1) WF1 + WF2

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	13.5 Mbps	13.5 Mbps	Operating Mode
		Body	Body	
38	5190	10.85	12.15	**802.11n HT40 (2 Tx SDM, non-TXBF)**
46	5230	11.05	12.25	

Note: Conducted power measurements for 802.11n HT20 / 802.11ac VHT80 (MIMO) modes not required, as the Max. Rated Power for this mode was ≤ than 802.11n HT40.

8.2.6. Wi-Fi 802.11a/n/ac (5.0 GHz) – SISO (5.3 GHz U-NII-2A)

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	29.3 Mbps	29.3 Mbps	Operating Mode
		Body	Body	
58	5290	12.45	13.45	**802.11ac VHT80**

Note: Conducted power measurements for 802.11a/802.11n HT20/802.11n HT40 (SISO) modes not required, as the Max. Rated Power for this mode was ≤ than higher bandwidth mode (VHT80).

8.2.7. Wi-Fi 802.11a/n/ac (5.0 GHz) – MIMO (5.3 GHz U-NII-2A) WF1 + WF2

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	13.5 Mbps	13.5 Mbps	Operating Mode
		Body	Body	
54	5270	12.05	13.25	**802.11n HT40 SDM, non-TxBF**
62	5310	12.15	13.35	

Note: Conducted power measurements for 802.11n HT20 / 802.11ac VHT80 (MIMO) modes not required, as the Max. Rated Power for this mode was ≤ than 802.11n HT40.

8.2.11. Wi-Fi 802.11a/n/ac (5.0 GHz) – SISO (5.6 GHz U-NII-2C)

Channel Number	Frequency (MHz)	29.3 Mbps	29.3 Mbps	Operating Mode
		Body	Body	
106	5530	10.75	12.45	802.11ac VHT80
122	5610	10.65	12.45	
138	5690	10.75	12.35	

Note: Conducted power measurements for 802.11a/802.11n HT20/802.11n HT40 (SISO) modes not required, as the Max. Rated Power for this mode was ≤ than higher bandwidth mode (VHT80).

8.2.12. Wi-Fi 802.11a/n/ac (5.0 GHz) – MIMO (5.6 GHz U-NII-2C) WF1 + WF2

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	29.3 Mbps	29.3 Mbps	Operating Mode
		Body	Body	
106	5530	10.75	12.30	802.11ac VHT80 SDM, non-TxBF
122	5610	10.65	12.30	
138	5690	10.65	12.45	

Note: Conducted power measurements for 802.11n HT20 / 802.11n HT40 (MIMO) modes not required, as the Max. Rated Power for this mode was ≤ than 802.11n HT40.

8.2.16. Wi-Fi 802.11a/n/ac (5.0 GHz) – SISO (5.8 GHz U-NII-3)

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	29.3 Mbps	29.3 Mbps	Operating Mode
		Body	Body	
155	5775	11.65	13.75	**802.11ac VHT80**

Note: Conducted power measurements for 802.11a/802.11n HT20/802.11n HT40 (SISO) modes not required, as the Max. Rated Power for this mode was ≤ than higher bandwidth mode (VHT80).

8.2.17. Wi-Fi 802.11a/n/ac (5.0 GHz) – MIMO (5.8 GHz U-NII-3) WF1 + WF2

		Avg Power (dBm)		
		WF1	WF2	
Channel Number	Frequency (MHz)	29.3 Mbps	29.3 Mbps	Operating Mode
		Body	Body	
155	5775	11.35	13.75	**802.11ac VHT80 SDM, non-TxBF**

Note: Conducted power measurements for 802.11n HT20 / 802.11n HT40 (MIMO) modes not required, as the Max. Rated Power for this mode was ≤ than 802.11n HT40.

8.3. RF Output Average Power Measurement: Bluetooth

8.3.1. Bluetooth 2.4GHz – ePA (5GHz OFF)

		Avg Power (dBm)	
		WF1	
Channel Number	Frequency (MHz)	Body	Operating Mode
0	2402	15.20	EDR (GFSK DH5)
39	2441	16.05	
78	2480	15.55	

8.3.2. Bluetooth 2.4GHz – ePA (5GHz ON)

		Avg Power (dBm)	
		WF1	
Channel Number	Frequency (MHz)	Body	Operating Mode
0	2402	10.65	EDR (GFSK DH5)
39	2441	10.80	
78	2480	11.10	

Notes:

1. Conducted power measurements were not performed on iPA (low power mode) as max. rated powers including tolerances was ≤ ePA.
2. Conducted power measurements on ePA continuous BDR and BLE operating modes were not performed, as not supported by DUT.

9. Dielectric Property Measurements & System Check

9.1.Tissue Dielectric Parameters

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.

IEEE 1528:2013

Target Frequency (MHz)	Head		Body (FCC only)	
	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
750	41.9	0.89	-	-
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
1500	40.4	1.23	-	-
1610	40.3	1.29	53.8	1.40
1640	40.2	1.31	-	-
1750	40.1	1.37	-	-
1800	40	1.40	53.3	1.52
1900	40	1.40	53.3	1.52
2000	40	1.40	53.3	1.52
2100	39.8	1.49	-	-
2300	39.5	1.67	-	-
2450	39.2	1.80	52.7	1.95
2600	39	1.96	-	-
3000	38.5	2.40	52.0	2.73
3500	37.9	2.91	-	-
4000	37.4	3.43	-	-
4500	36.8	3.94	-	-
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
5250	35.9	4.71	48.9	5.36
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
5750	35.4	5.22	48.3	5.94
5800	35.3	5.27	48.2	6.00
6000	35.1	5.48	-	-

NOTE: For convenience, permittivity and conductivity values at some frequencies that are not part of the original data from Drossos et al. [B60] or the extension to 5800 MHz are provided (i.e., the values shown in italics). These values were linearly interpolated between the values in this table that are immediately above and below these values, except the values at 6000 MHz that were linearly extrapolated from the values at 3000 MHz and 5800 MHz.

9.2. 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.

9.3. Reference Target SAR Values

The reference SAR values are obtained from the calibration certificate of system validation dipoles. The measured values are normalised to 1 Watt.

System Dipole	Serial No.	Cal. Date	Freq. (MHz)	Target SAR Values (mW/g)	
				1g/10g	Body
D2450V2	725	17 Sep 2018	2450	1g	50.8
				10g	23.8
D5GHzV2	1016	19 Feb 2019	5250	1g	73.3
				10g	20.5
			5600	1g	77.8
				10g	21.9
			5750	1g	76.0
				10g	21.4
D5GHzV2	1222	13 Sep 2018	5250	1g	77.2
				10g	21.5
			5600	1g	80.6
				10g	22.4
			5750	1g	77.9
				10g	21.6

9.4. Dielectric Property Measurements & System Check Results

The 1-g SAR 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. The internal limit is set to ±10%.

Site 60

System check 5250 Body

Date: 07/03/2019
Validation dipole and Serial Number: D5GHzV2 / SN: 1016

Simulant	Frequency (MHz)	Room Temp (℃)	Liquid Temp (℃)	Parameters	Target Value	Measured Value	Deviation (%)	Limit (%)
Body	5250.00	21.2	21.2	εr	48.90	48.35	-1.12	10.00
				Σ	5.36	5.46	1.93	10.00
				1g (W/kg)	73.30	75.22	-3.31	10.00
				10g (W/kg)	20.50	20.95	-4.33	10.00

Date: 11/03/2019
Validation dipole and Serial Number: D5GHzV2 / SN: 1016

Simulant	Frequency (MHz)	Room Temp (℃)	Liquid Temp (℃)	Parameters	Target Value	Measured Value	Deviation (%)	Limit (%)
Body	5250.00	23.0	22.9	εr	48.90	48.25	-1.33	10.00
				Σ	5.36	5.29	-1.30	10.00
				1g (W/kg)	73.30	74.30	1.36	10.00
				10g (W/kg)	20.50	20.90	1.95	10.00

System check 5600 Body

Date: 11/03/2019
Validation dipole and Serial Number: D5GHzV2 / SN: 1016

Simulant	Frequency (MHz)	Room Temp (℃)	Liquid Temp (℃)	Parameters	Target Value	Measured Value	Deviation (%)	Limit (%)
Body	5600.00	23.0	22.9	εr	48.50	47.62	-1.81	10.00
				Σ	5.77	5.78	0.23	10.00
				1g (W/kg)	77.80	76.60	-1.54	10.00
				10g (W/kg)	21.90	21.30	-2.73	10.00

Site 61

System check 2450 Body

Date: 11/03/2019
Validation dipole and Serial Number: D2450V2 / SN: 725

Simulant	Frequency (MHz)	Room Temp (℃)	Liquid Temp (℃)	Parameters	Target Value	Measured Value	Deviation (%)	Limit (%)
Body	2450.00	19.7	19.8	εr	52.70	52.70	0.00	10.00
				Σ	1.95	2.03	4.31	10.00
				1g (W/kg)	50.80	49.08	-3.37	10.00
				10g (W/kg)	23.80	22.74	-4.42	10.00

Date: 15/03/2019
Validation dipole and Serial Number: D2450V2 / SN: 725

Simulant	Frequency (MHz)	Room Temp (℃)	Liquid Temp (℃)	Parameters	Target Value	Measured Value	Deviation (%)	Limit (%)
Body	2450.00	21.9	22.4	εr	52.70	53.39	1.31	10.00
				Σ	1.95	2.03	3.97	10.00
				1g (W/kg)	50.80	49.68	-2.20	10.00
				10g (W/kg)	23.80	23.14	-2.75	10.00

System check 5750 Body

Date: 11/03/2019
Validation dipole and Serial Number: D5GHzv2 / SN: 1222

Simulant	Frequency (MHz)	Room Temp (℃)	Liquid Temp (℃)	Parameters	Target Value	Measured Value	Deviation (%)	Limit (%)
Body	5750.00	19.7	19.8	**εr**	48.30	46.49	-3.75	10.00
				Σ	5.94	6.17	3.94	10.00
				1g (W/kg)	77.90	75.20	-3.46	10.00
				10g (W/kg)	21.60	21.00	-2.77	10.00

Date: 15/03/2019
Validation dipole and Serial Number: D5GHzv2 / SN: 1222

Simulant	Frequency (MHz)	Room Temp (℃)	Liquid Temp (℃)	Parameters	Target Value	Measured Value	Deviation (%)	Limit (%)
Body	5750.00	21.9	22.4	**εr**	48.30	47.64	-1.37	10.00
				Σ	5.94	6.09	2.45	10.00
				1g (W/kg)	77.90	76.70	-1.54	10.00
				10g (W/kg)	21.60	21.50	-0.46	10.00

10. Measurements, Examinations and Derived Results

10.1. General Comments

SAR test was performed in accordance with the criteria in KDB 248227.

In the 2.4 GHz band, separate SAR procedures were applied to DSSS and OFDM configurations to simplify DSSS test requirements. SAR test was evaluated on the mode with the highest rated power, which is in this case was 802.11b mode. OFDM mode was not evaluated because when the highest reported SAR for DSSS was adjusted by the ratio of OFDM to DSSS specified maximum output power, the adjusted SAR obtained was < 1.2W/kg.

In the 5.0 GHz band, the initial test configuration transmission mode was determined by the 802.11 configuration with the highest maximum output power specified for production units, including upper tune-up tolerance, in each standalone and aggregated frequency band. Since multiple channel bandwidth configuration modes have the same specified maximum output power, SAR test was performed on the largest channel bandwidth with the lowest order modulation.

For the cases where the power was not flat throughout the mode to test, additional runs were also performed on the next highest bandwidth provided the power response was identical. This was performed in order to assess the SAR response throughout the frequency band and establish that all worst cases have been evaluated.

Note: SAR Values represented by “-“ indicate no SAR peaks were detected during area scans.

10.2.Specific Absorption Rate - Test Results - WLAN Antenna

10.2.1.WLAN 2.4GHz Body 1g - SISO

Max Reported SAR = 0.66 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11b	0	Back	1	2412.0	17.00	16.55	0.57	0.63	WF1	-	-
802.11b	0	Display Side	1	2412.0	17.00	16.55	0.03	0.04	WF1	-	-
802.11b	0	Back	1	2412.0	17.75	17.55	0.63	0.66	WF2	-	-
802.11b	0	Display Side	1	2412.0	17.75	17.55	0.07	0.07	WF2	-	-

Note(s):

10.2.2.WLAN 2.4GHz Body 1g - MIMO

Max Reported SAR = 0.94 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11n HT20	0	Back	10	2457.0	17.00	16.95	0.93	0.94	WF1	-	01
					17.75	16.65	-	-	WF2	-	
802.11n HT20	0	Back	1	2412.0	17.00	16.85	0.65	0.67	WF1	-	-
					17.75	16.65	-	-	WF2	-	
802.11n HT20	0	Back	6	2437.0	17.00	16.85	0.80	0.83	WF1	-	-
					17.75	16.55	-	-	WF2	-	

Note(s):

10.2.3.WLAN 5.2GHz Body 1g - SISO

As per KDB 248227, U-NII-2A was chosen for SAR evaluation as maximum rated power for U-NII-1 < U-NII-2A. Based on the measurements obtained, SAR measurements on U-NII-1 band are not required as highest reported SAR from U-NII-2A band is ≤ 1.2 W/Kg.

10.2.4.WLAN 5.2GHz Body 1g – MIMO

As per KDB 248227, U-NII-2A was chosen for SAR evaluation as maximum rated power for U-NII-1 < U-NII-2A. Based on the measurements obtained, SAR measurements on U-NII-1 band are not required as highest reported SAR from U-NII-2A band is ≤ 1.2 W/Kg.

10.2.5.WLAN 5.3GHz Body 1g - SISO

Max Reported SAR = 0.90 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11a c VHT80	0	Back	58	5290.0	12.50	12.45	0.75	0.76	WF1	-	-
802.11a c VHT80	0	Display Side	58	5290.0	12.50	12.45	0.14	0.14	WF1	-	-
802.11a c VHT80	0	Back	58	5290.0	13.75	13.45	0.84	0.90	WF2	-	02
802.11a c VHT80	0	Display Side	58	5290.0	13.75	13.45	0.13	0.14	WF2	-	-

Note(s):

10.2.6.WLAN 5.3GHz Body 1g - MIMO

Max Reported SAR = 0.67 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11n HT40	0	Back	62	5310.0	12.50	12.15	0.61	0.67	WF1	-	-
					13.75	13.35	0.50	0.54	WF2	-	

Note(s):

10.2.7.WLAN 5.6GHz Body 1g - SISO

Max Reported SAR = 0.80 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11ac VHT80	0	Back	106	5530.0	11.00	10.75	0.61	0.65	WF1	-	-
802.11ac VHT80	0	Display Side	106	5530.0	11.00	10.75	0.10	0.10	WF1	-	-
802.11ac VHT80	0	Back	106	5530.0	12.75	12.45	0.75	0.80	WF2	-	03
802.11ac VHT80	0	Back	122	5610.0	12.75	12.45	0.71	0.76	WF2	-	-
802.11ac VHT80	0	Back	138	5690.0	12.75	12.35	0.52	0.57	WF2	-	-
802.11ac VHT80	0	Display Side	106	5530.0	12.75	12.45	0.09	0.10	WF2	-	-

Note(s):

10.2.8.WLAN 5.6GHz Body 1g - MIMO

Max Reported SAR = 0.70 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11ac VHT80	0	Back	138	5690.0	11.00	10.65	0.65	0.70	WF1	-	-
					12.75	12.45	-	-	WF2	-	

Note(s):

10.2.9.WLAN 5.8GHz Body 1g - SISO

Max Reported SAR = 0.85 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11a c VHT80	0	Back	155	5775.0	11.75	11.65	0.65	0.67	WF1	-	-
802.11a c VHT80	0	Display Side	155	5775.0	11.75	11.65	0.12	0.12	WF1	-	-
802.11a c VHT80	0	Back	155	5775.0	14.00	13.75	0.81	0.85	WF2	-	-
802.11a c VHT80	0	Display Side	155	5775.0	14.00	13.75	0.15	0.16	WF2	-	-

Note(s):

10.2.10.WLAN 5.8GHz Body 1g - MIMO

Max Reported SAR = 0.93 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
802.11a c VHT80	0	Back	155	5775.0	11.75	11.35	-	-	WF1	-	04
					14.00	13.75	0.88	0.93	WF2	-	

Note(s):

The Bluetooth antenna operate in two stages: 5 GHz Off and 5GHz On

5GHz Off – In this stage, the Wi-Fi 5GHz radio is turned off and Bluetooth antenna transmits at the maximum power possible by the Chipset.

5GHz On – In this stage, the Wi-Fi 5GHz radios are turned on and allow the simultaneous transmission with the Bluetooth antenna. The Bluetooth antenna transmits at a reduced power in order to allow the simultaneous transmission or multi-band SAR evaluation.

10.2.11.Bluetooth Body 1g – SISO (5GHz OFF)

Max Reported SAR = 0.39 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
GFSK	0	Back	39	2441.0	16.50	16.05	0.28	0.31	WF1	-	-
GFSK	0	Display Side	39	2441.0	16.50	16.05	0.02	0.02	WF1	-	-
GFSK	0	Back	0	2402.0	16.50	15.20	0.16	0.22	WF1	-	-
GFSK	0	Back	78	2480.0	16.50	15.55	0.32	0.39	WF1	-	05

Note(s):

10.2.12.Bluetooth Body 1g – SISO (5GHz ON)

Max Reported SAR = 0.11 (W/kg)

					Power (dBm)		1g: SAR Results (W/kg)				
Mode	Dist. (mm)	EUT Position	Channel Number	Freq (MHz)	Tune Up Limit	Meas.	Meas. SAR Level	Reported SAR	Transmitting Antenna	Notes	Plot No.
GFSK	0	Back	78	2480.0	11.25	11.10	0.11	0.11	WF1	-	06
GFSK	0	Display Side	78	2480.0	11.25	11.10	0.01	0.01	WF1	-	-
GFSK	0	Back	0	2402.0	11.25	10.65	0.05	0.06	WF1	-	-
GFSK	0	Back	39	2441.0	11.25	10.80	0.09	0.10	WF1	-	-

10.3. SAR Measurement Variability

In accordance with published RF Exposure KDB procedure 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 < 0.80 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.

Exposure Configuration	Technology Band	Measured 1g -SAR (W/Kg)	Equipment Class	Max Meas. Source base Avg Power [dBm]	Ratio of Largest to Smallest SAR Measured
BODY (Separation Distance 0mm)	WLAN 2.4GHz	0.93	U-NII	16.95	1.04
		0.89			
	WLAN 5.3 GHz	0.84	U-NII	13.45	1.01
		0.83			
	WLAN 5.8 GHz	0.88	U-NII	13.75	1.10
		0.80			

11. Simultaneous Transmission Analysis

11.1. Highest Standalone Reported SAR

Individual Transmitter Evaluation per Band:

Exposure Configuration	Technology Band	Reported 1g - SAR (W/Kg)				Equipment Class	Highest Reported 1g - SAR (W/Kg)
		SISO		MIMO			
		WF1	WF2	WF1	WF2		
BODY (Separation Distance 0mm)	WLAN 2.4 GHz	0.63	0.66	0.94	-	DTS	0.94
	WLAN 5.3 GHz	0.76	0.90	0.67	0.54	U-NII	0.90
	WLAN 5.6 GHz	0.65	0.80	0.70	-	U-NII	0.80
	WLAN 5.8 GHz	0.67	0.85	-	0.93	U-NII	0.93
	Bluetooth (5 GHz OFF)	0.39	N/A	N/A	N/A	DSS	0.39
	Bluetooth (5 GHz ON)	0.11	N/A	N/A	N/A	DSS	0.11

11.2. Simultaneous Transmission analysis

Simultaneous transmission SAR test exclusion is determined for each operating configuration and exposure condition according to the *reported* standalone SAR of each applicable simultaneous transmitting antenna. The worst case simultaneous transmission analysis is considered for the following cases:

Cases	Simultaneous Transmission Conditions						
	WLAN						WPAN
	Wi-Fi 802.11b/g/n (2.4 GHz)			Wi-Fi 802.11a/n/ac (5.0 GHz)			*BT (5 GHz ON)*
	SISO		MIMO	SISO		MIMO	SISO
	WF1	WF2	WF1+ WF2	WF1	WF2	WF1 + WF2	WF1
1				X			X
2					X		X
3						X	X

Worst Case Simultaneous Transmission SAR Analysis:

Exposure Configuration	Case(s)	Technology Band	Highest Reported 1g SAR (W/kg)	Equipment Class	Highest Reported Sum-SAR 1g-SAR (W/kg)	SPLSR Ratio
BODY (Separation Distance 0mm)	1	WLAN 5.3 GHz (WF1)	0.76	U-NII	0.87	N/A
		Bluetooth (WF1)	0.11	DSS		
	2	WLAN 5.0GHz (WF2)	N/A	U-NII	0.11	N/A
		Bluetooth (WF1)	0.11	DSS		
	2	WLAN 5.3 GHz (WF2)	0.90	U-NII	0.90	N/A
		Bluetooth (WF1)	N/A	DSS		
	3	WLAN 5.6 GHz (WF1)	0.70	U-NII	0.81	N/A
		Bluetooth (WF1)	0.11	DSS		