SAR TEST REPORT

for

MODEL NO. 1836
FCC ID: C3K1836

Test Report No. S-TR136-FCCSAR-3
Issue Date: Jun 07, 2018

FCC CFR 47 PART 2.1093

IEEE 1528-2013

Prepared by
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A2LA ACCREDITED
TESTING CERT #3472.01

1 Record of Revisions

Revision	Date	Section	Page(s)	Summary of Changes	Author/Revised By:
1.0	05/23/2018	All	All	First Version	Wei Sun
2.0	05/30/2018	6	9	Deleted reference to MIMO mode.	Wei Sun
3.0	06/07/2018	6.4	10	Corrected details for FW and driver details of the test samples.	Wei Sun

Test Report Attestation

Microsoft Corporation
Model: 1836

Applicable Standards

Specification	Test Result
FCC CFR 47 PART 2.1093 IEEE 1528-2013	Pass

Microsoft EMC Laboratory attests that the product model identified in this report has been tested to and meets the requirements identified in the above standards. The test results in this report solely pertains to the specific sample tested, under the conditions and operating modes as provided by the customer.

This report shall not be used to claim product certification, approval, or endorsement by A2LA or any agency of any Government. Reproduction, duplication or publication of extracts from this test report is prohibited and requires prior written approval of Microsoft EMC Laboratory.

This test report replaces the previously issued report #S-TR136-FCCSAR-2 issued by Microsoft EMC Labs on 05/30/2018.

Written By: Wei Sun
SAR Test Engineer

Reviewed/ Issued By: Sajay Jose
EMC/RF Compliance Lab Manager

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2 Deviations from Standard

None.

3 Facilities and Accreditation

3.1 TEST FACILITY

All test facilities used to collect the test data are located at Microsoft EMC Laboratory: 17760 NE 67th Ct, Redmond, WA, 98052, USA.

3.2 ACCREDITATIONS

The lab is established and follows procedures as outlined in IEC/ISO 17025 and A2LA accreditation requirements.

A2LA Accredited Testing Certificate Number: 3472.01
Expiration Date: Aug 31, 2019

3.3 Test Equipment

The site and related equipment are constructed in conformance with the requirements of IEEE 1528-2013 and other equivalent applicable standards.
The calibrations of the measuring instruments, including any accessories that may affect such calibration, are checked frequently to assure their accuracy. Adjustments are made and correction factors are applied in accordance with instructions contained in the user manual for the measuring equipment.

4 Highest Reported SAR Values

Exposure Condition	Equipment Class	Mode of Operation	Test Position	1-g Reported SAR (W/kg)
Body Exposure	NII	802.11a	Bottom	0.457

Reported SAR Values are obtained by scaling the measured SAR values up to the maximum allowable output power for each configuration using the following equation:

$$SAR = MEASURED * 10^{\frac{(PMAX-P)}{10}}$$

where

SAR = Reported SAR (W/kg)
MEASURED = Measured SAR (W/kg)
PMAX = Maximum Conducted Average Output Power (dBm)
P = Measured Conducted Average Output Power (dBm)

4.1 SAR Limits

The following are the relevant SAR limits for FCC and IC based on the recommendations of ANSI C95.1-1992:

Exposure Condition	Limit (W/kg)
Localized Body SAR	1.6 (1-g cube)

5 Test Equipment List

Manufacturer	Description	Model	SN	Identifier	Cal. Due	Cal. Cycle
Agilent	Signal Generator	N5181A	MY50144778	SAR-051	11/29/2018	1 yr
PRANA	Power Amplifier + Directional Coupler	UX15	1305-1354	SAR-046	N/A	N/A
Agilent	Power Meter	1914A	MY50901710	SAR-052	12/4/2018	1 yr
Agilent	Power Sensor	9304A	MY53040024	SAR-064	12/5/2018	1 yr
Agilent	Power Sensor	9304A	MY53040018	SAR-063	12/5/2018	1 yr
Agilent	Network Analyzer	E5071C	MY46316847	SAR-002	12/10/2018	1 yr
Agilent	Dielectric Probe Kit	85070E	MY44300736	SAR-003	N/A	1 yr
SPEAG	DASY Data Acquisition Electronics	DAE4	1445	SAR-109	11/28/2018	1 yr
SPEAG	Dosimetric E-Field Probe	EX3DV4	3999	SAR-108	12/06/2018	1 yr
SPEAG	SAR Validation Dipole, 2450 MHz	D2450V2	916	SAR-023	04/11/2019	1 yr
SPEAG	SAR Validation Dipole, 5 GHz	D5GHzV2	1158	SAR-015	04/17/2019	1 yr
SPEAG	Elliptical Phantom	ELI V5.0	1217	N/A	N/A	N/A
Thomas Scientific	Thermometer	1230N27	150530613	SAR-113	8/4/2018	1 yr
MadgeTech	THP Monitor	PRHTemp2000	P25366	SAR-091	8/10/2018	1 yr

6 Product Description

Company Name:	Microsoft Corporation			
Address:	One Microsoft Way			
City, State, Zip:	Redmond, WA 98052			
Customer Contact:	Pamela Galvan			
Functional Description of the EUT:	Microsoft Wireless Input Device			
RF Exposure Conditions:	Body Exposure			
Model:	1836			
FCC ID:	C3K1836			
IC ID:	3048A-1836			
Radio Descriptions:	WLAN 2.4 GHz: 802.11g, 802.11n 20 MHz BW's WLAN 5 GHz: 802.11a, 802.11n 20MHz BW's Bluetooth™ (Basic and Enhanced Data Rates)			
Frequency Range of Operation:	WLAN Radio:	2412 – 2462 MHz		
		5180 – 5825 MHz		
	BT:	2402 – 2480 MHz		
Modulations:	WLAN: CCK, BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM Bluetooth: GFSK, $\frac{\pi}{4}$ DQPSK, and 8 DPSK			
Antenna Peak Gains (dBi):	Radio	Band	Main	Diversity
	WLAN/BT	2400 – 2483.5 MHz	4.7	-
	WLAN	5150 – 5250 MHz	6.2	6.7
		5250 – 5350 MHz	6.2	6.0
		5470 – 5725 MHz	5.9	6.1
		5725 – 5850 MHz	5.6	6.4
Equipment Design State:	Prototype/Production Equivalent			
Equipment Condition:	Good			
Dates of Testing:	05/04/2018 – 05/08/2018			

6.1 TEST CONFIGURATIONS

For Bluetooth, measurements were performed with customer-provided test software "Combo Tool Ver 2.1509.00, Build Date: 2/26/2015" to program the EUT in continuous transmit mode.
For WLAN, measurements were performed with customer-provided test software "Indium QA Tool" (Ver 1.19) to program the EUT in continuous transmit mode.

6.2 ENVIRONMENTAL CONDITIONS

Ambient air temperature of the test site was within the range of 18 ºC to 25 ºC. Testing conditions were within tolerance and any deviations required from the EUT are reported.

6.3 EQUIPMENT MODIFICATIONS

No modifications were made during testing.

6.4 EQUIPMENT UNDER TEST

Model Number	Serial Number	Internal Lab ID:
1836	02560002607814	S-136-04262018-01
1836	02560002237814	S-136-04262018-02

Radio FW: 4.5.213.0

Radio Driver Version: FTDI Driver v2.12.28.0

6.5 Supported Air Interfaces and Transmission Configurations

The EUT has three antennas which support the following air interfaces and transmission configurations. The antennas are labeled as Main Antenna and Diversity Antenna for 802.11 WLAN 5GHz, and the third is labeled as Primary Antenna for WLAN 2.4GHz and BT.

Band	Air Interface	BW (MHz)		
		20	40	80
WLAN 2.4 GH	802.11g	X		
	802.11n	X		
WLAN 5 GHz	802.11a	X		
	802.11n	X		
2.4 GHz	Bluetooth	NA		

6.5.1 Transmission Configurations

Main Antenna	Diversity Antenna	Primary Antenna
WLAN 5 GHz		
	WLAN 5 GHz	
		WLAN 2.4 GHz
		Bluetooth

7 Test Methodology

Test setup and procedure are performed according to **IEEE 1528-2013 Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communication Devices: Measurement Techniques.**

In addition, the following publications were used as guidance-

For FCC SAR testing and reporting according to FCC standards the following KDBs were adhered to:

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

8 Conducted RF Average Output Power Measurements

Bluetooth and WLAN output power measurements are made with the DUT connected to the power sensor of a broadband power meter.

8.1 Bluetooth Conducted Output Power Measurements

Mode	Channel	Frequency (MHz)	Maximum Conducted Average Output Power (dBm)	
			Primary Antenna	
			Measured	Max
1DH1	0	2402	-2.83	5
	39	2441	-1.79	5
	78	2480	-1.51	5
1DH3	0	2402	3.77	5
	39	2441	4.78	5
	78	2480	5	5
1DH5	0	2402	3.25	5
	39	2441	4.24	5
	78	2480	4.5	5
2DH1	0	2402	-5.32	5
	39	2441	-4.31	5
	78	2480	-4.03	5
2DH3	0	2402	0.56	5
	39	2441	1.57	5
	78	2480	1.85	5
2DH5	0	2402	-0.09	5
	39	2441	0.94	5
	78	2480	1.21	5
3DH1	0	2402	-5.3	5
	39	2441	-4.29	5
	78	2480	-4	5
3DH3	0	2402	-0.55	5
	39	2441	1.55	5
	78	2480	1.84	5
3DH5	0	2402	-0.08	5
	39	2441	0.93	5
	78	2480	1.22	5

8.2 WLAN Power Measurement Requirements

According to **KDB 248227 v02r02 Section 4,** maximum output power must be measured according to the default power measurement procedures below. When SAR measurement is required, power measurement is also required to confirm output power settings and to determine reported SAR. Additional power measurements may be necessary to determine SAR test reduction for test channels in a transmission mode. If the required power measurement is not included in the default configuration, it is typically measured immediately before and/or after the SAR measurement. Otherwise, when power measurement is not required for a transmission mode, the maximum output power and tune-up tolerance specified for production units can generally be used to determine SAR test exclusion and reduction.

The default power measurement procedures are:

1) Power must be measured at each transmit antenna port according to the DSSS and OFDM transmission configuration in each standalone and aggregated frequency band.
2) Power measurement is required for the transmission mode configuration with the highest maximum output power specified for production units.
   a) When the same higher maximum output power specification applies to multiple transmission modes, the largest channel bandwidth configuration with the lowest order modulation and lowest data rate is measured.
   b) When the same highest maximum output power is specified for multiple largest channel bandwidth configurations with the same lowest order modulation or lowest order modulation and lowest data rate, power measurement is required for all equivalent 802.11 configurations with the same maximum output power.
3) For each transmission mode configuration, power must be measured for the highest and lowest channels; and at the mid-band channel(s) when there are at least 3 channels. For configurations with multiple mid-band channels, due to an even number of channels, both channels should be measured.

8.3 Initial Test Configuration for OFDM Configurations

*The Initial Test Configuration was chosen according to KDB 248227 v02r02 Section 5.3 from the mode with the highest maximum output power including tune-up tolerances, the highest channel bandwidth among those modes, the lowest order modulation, and the lowest data rate. The channel with the highest output power in that mode is chosen as the initial test channel. If multiple test channels have the same measured maximum output power, the channel chosen for SAR measurement is chosen by the following (applicable to subsequent test configuration as well).

1) The channel closest to mid-band frequency is selected for SAR measurement.
2) For channels with equal separation from mid-band frequency, for example, high and low channels or two mid-band channels, the higher frequency (number) channel is selected for SAR measurement.

8.4 WLAN 2.4 GHz Conducted Output Power Measurements

Mode	Channel	Frequency (MHz)	Maximum Conducted Average Output Power (dBm)	
			Primary Antenna	
			Measured	Max
802.11g 6Mbps	1	2412	5.57	6.5
	6	2437	5.45	6.5
	11	2462	5.8	6.5
802.11n HT20 MCS0	1	2412	5.16	6.5
	6	2437	5.02	6.5
	11	2462	5.44	6.5

8.5 WLAN 5 GHz Conducted Output Power Measurements

8.5.1 5.2 GHz Conducted Measurements (U-NII-1)

Mode	Channel	Frequency (MHz)	Maximum Conducted Average Output Power (dBm)			
			Main Antenna		Diversity Antenna	
			Measured	Max	Measured	Max
802.11a 6Mbps	36	5180	8.82	9.5	9.04	9.5
	40	5200	8.7	9.5	8.91	9.5
	44	5220	8.58	9.5	8.87	9.5
	48	5240	8.41	9.5	8.67	9.5
802.11n HT20 MCS0	36	5180	8.25	9.5	8.58	9.5
	40	5200	8.14	9.5	8.47	9.5
	44	5220	8.13	9.5	8.29	9.5
	48	5240	8	9.5	8.26	9.5

8.5.2 5.3 GHz Conducted Measurements (U-NII-2A)

Mode	Channel	Frequency (MHz)	Maximum Conducted Average Output Power (dBm)			
			Main Antenna		Diversity Antenna	
			Measured	Max	Measured	Max
802.11a 6Mbps	52	5260	8.02	9.5	8.32	9.5
	56	5280	7.9	9.5	8.22	9.5
	60	5300	7.74	9.5	8.07	9.5
	64	5320	7.71	9.5	8.07	9.5
802.11n HT20 MCS0	52	5260	7.45	9.5	7.76	9.5
	56	5280	7.38	9.5	7.66	9.5
	60	5300	7.39	9.5	7.7	9.5
	64	5320	7.25	9.5	7.55	9.5

8.5.3 5.6 GHz Conducted Measurements (U-NII-2C)

Mode	Channel	Frequency (MHz)	Maximum Conducted Average Output Power (dBm)			
			Main Antenna		Diversity Antenna	
			Measured	Max	Measured	Max
802.11a 6Mbps	100	5500	8.52	9.5	8.71	9.5
	104	5520	8.42	9.5	8.58	9.5
	108	5540	8.27	9.5	8.53	9.5
	112	5560	8.12	9.5	8.46	9.5
	116	5580	8.03	9.5	8.51	9.5
	120	5600	7.03	9.5	8.16	9.5
	124	5620	7.77	9.5	8.11	9.5
	128	5640	8.84	9.5	8.92	9.5
	132	5660	8.39	9.5	8.8	9.5
	136	5680	8.14	9.5	8.65	9.5
	140	5700	7.84	9.5	8.4	9.5
802.11n HT20 MCS0	100	5500	8.04	9.5	8.2	9.5
	104	5520	7.95	9.5	8.19	9.5
	108	5540	7.8	9.5	8.15	9.5
	112	5560	7.73	9.5	8.08	9.5
	116	5580	7.62	9.5	7.98	9.5
	120	5600	7.51	9.5	7.77	9.5
	124	5620	7.57	9.5	7.73	9.5
	128	5640	7.97	9.5	8.39	9.5
	132	5660	7.83	9.5	8.26	9.5
	136	5680	7.77	9.5	8.28	9.5
	140	5700	7.54	9.5	7.83	9.5

8.5.4 5.8 GHz Conducted Measurements (U-NII-3)

Mode	Channel	Frequency (MHz)	Maximum Conducted Average Output Power (dBm)			
			Main Antenna		Diversity Antenna	
			Measured	Max	Measured	Max
802.11a 6Mbps	149	5745	8.12	9.5	8.83	9.5
	153	5765	8.38	9.5	8.79	9.5
	157	5785	8.88	9.5	8.74	9.5
	161	5805	7.57	9.5	7.8	9.5
	165	5825	8.1	9.5	8.36	9.5
802.11n HT20 MCS0	149	5745	8.05	9.5	8.43	9.5
	153	5765	8	9.5	8.28	9.5
	157	5785	7.88	9.5	8.23	9.5
	161	5805	7.5	9.5	7.59	9.5
	165	5825	7.77	9.5	7.88	9.5

9 Test Configurations

The standalone SAR test exclusion equations (KDB 447498 D01 4.3.1) are used to determine which device edges and faces require testing for a given antenna and air interface technology. From **KDB 616217 D04 v01r02** (SAR for laptop and tablets) section 4.3, the SAR test exclusion threshold from KDB 447498 can be applied to determine SAR test exclusion for adjacent edge configurations. The closest distance from the antenna to an adjacent edge is used to determine if SAR testing is required for the adjacent edges.

1) For antenna to edge separation distances ≤ 50mm, the 1-g SAR test exclusion threshold can be determined by evaluating whether the following is true:

$$\frac{Pmax}{d} * \sqrt{f} \leq 3.0$$

- P_{max} = maximum possible average conducted power of transmitter, including tolerances, rounded to the nearest mW.
- d = closest intended separation distance between transmitting antenna and edge / face of device (mm) (5mm at the least)
- f = frequency of the transmitter for that power level in GHz

2) For antenna to edge separation distances > 50mm, the SAR test exclusion threshold is determined according to the following:
   a) [Power allowed at numeric threshold for 50 mm in step 1) + (test separation distance - 50 mm)·(f(MHz)/150)] mW, at 100 MHz to 1500 MHz
   b) [Power allowed at numeric threshold for 50 mm in step 1) + (test separation distance - 50 mm)·10] mW at > 1500 MHz and ≤ 6 GHz

9.1 Evaluation of Required Test Configurations

The following table shows the maximum frequency of each transmitter in GHz and the maximum output power levels including tolerances rounded to the nearest mW:

Parameters used to Evaluate SAR Test Exclusion	Air Interface		
	WLAN 2.4 GHz	WLAN 5 GHz	BT
Max Freq. (GHz)	2.462	5.825	2.48
Max Power (mW)	4.47	8.91	3.16

9.1.1 SAR Test Exclusion Evaluation for antenna-user separation distances less than 50mm

SAR evaluation is not required when the values below are **≤ 3.0 (numeric threshold).** These values are calculated from each frequency (GHz), output power (mW), and antenna-user separation distance less than 50mm.

Standalone SAR Test Exclusion	WLAN Main Antenna		WLAN Diversity Antenna		WLAN/BT Primary Antenna		
Device Side	Separation Distance (mm)	Calculated Value	Separation Distance (mm)	Calculated Value	Separation Distance (mm)	Calculated Value	
		WLAN 5 GHz		WLAN 5 GHz		WLAN 2.4 GHz	BT
Top Face	**9.8**	**0.72**	**9.8**	**2.19**	**9.8**	**0.72**	**0.51**
Bottom Face	**6**	**3.58**	**6**	**3.58**	**6**	**1.17**	**0.83**
Left Edge	**> 50**	**-**	**> 50**	**-**	**3.5**	**1.4**	**1.00**
Bottom Edge	**> 50**	**-**	**26**	**0.83**	**33**	**0.21**	**0.15**
Right Edge	**> 50**	**-**	**> 50**	**-**	**> 50**	**-**	**-**
Top Edge	**> 50**	**-**	**> 50**	**-**	**> 50**	**-**	**-**

See attachments for antenna locations diagram.

	SAR Testing Performed
	SAR Testing Not Required

9.1.2 SAR Test Exclusion Evaluation for antenna-user separation distances greater than 50mm

The **SAR exclusion thresholds** calculated from each frequency (GHz) and antenna-user separation distance greater than 50mm are shown below. SAR testing is not required for the given edge / face and frequency combination when the maximum output power is less than the exclusion threshold shown here.

Standalone SAR Test Exclusion	WLAN Main Antenna		WLAN Diversity Antenna		WLAN/BT Primary Antenna		
Device Side	Separation Distance (mm)	Exclusion Threshold (mW)	Separation Distance (mm)	Exclusion Threshold (mW)	Separation Distance (mm)	Exclusion Threshold (mW)	
		WLAN 5 GHz		WLAN 5 GHz		WLAN 2.4 GHz	BT
Top Edge	**60**	**162**	**105**	**612**	**84**	**436**	**435**
Left Edge	**79**	**352**	**79**	**352**	**< 50**	**-**	**-**
Bottom Edge	**< 50**	**-**	**70**	**262**	**< 50**	**-**	**-**
Right Edge	**207**	**1632**	**207**	**1632**	**284**	**2436**	**2435**

See attachments for antenna locations diagram.

	SAR Testing Performed
	SAR Testing Not Required

9.2 Test Positions

See previous section for justification of test positions for this configuration.

Exposure Condition	**Phantom Used**	**DUT Test Position**	**Test Setup Photo (See Appendix)**
Body	Flat Section (SAM, ELI, or Triple-Flat)	Bottom 0mm	Photo 1

10 SAR Test Procedures

The SAR Evaluation was performed in the following steps:

- **Power Reference Measurement.**
  The Power Measurement and Power Drift Measurements are for monitoring the power drift of the device under test. 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 set to 2mm for the EX3DV4 probe as recommended by SPEAG. The Power Reference Measurement is taken at a point close to the antenna whose output is being measured in order to maximize SNR, thus minimizing drift error.

- **Area Scan**
  The Area Scan is used as a fast scan in two dimensions to find the areas of high field values (or hot spots), before doing a fine measurement around the hotspot. The sophisticated interpolation routines implemented in DASY5 software can find the maximum locations even in relatively coarse grids. When an Area Scan has measured all reachable points, it computes the field maxima found and lists all maxima found in the scan area within a certain range of the global maximum. A 2 dB range is required by IEEE STD 1528. Zoom scans need only be performed on all secondary maxima within this range when the absolute maximum found is under 2 dB less than the SAR limit in question (i.e., less than 1 W/kg for the 1.6 W/kg SAR limit). Otherwise, the zoom scan is only performed at the highest maxima found in the area scan.

  The following x-y grid spacings for the given transmitter frequency ranges are used for area scans in accordance with FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz:

  700 MHz – 2 GHz: ≤ 15 mm
  2 GHz – 4 GHz: ≤ 12 mm
  4 GHz – 6 GHz: ≤ 10 mm

- **Zoom Scan**
  Zoom Scans are used to assess the peak spatial SAR values within a cubic averaging volume containing 1g or 10g of simulated tissue. When the measurement is done, the Zoom Scan evaluates the averaged SAR for 1g and 10g and displays these values next to the job's label. The sides of the zoom scan cube should be parallel to the edges of the EUT when possible. The dimensions of a Zoom Scan and spacing between measurement points vary by frequency according to FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz, shown in Table 2 below:

Table 2: Zoom Scan Dimensions

Transmitter Frequency Range	Cube Dimensions	x-y coordinate spatial resolution	z coordinate spatial resolution
700 MHz – 2 GHz	≥ 30 mm	≤ 8 mm	≤ 5 mm
2 GHz – 3 GHz	≥ 28 mm	≤ 5 mm, *≤ 8 mm	≤ 4 mm
3 – 4 GHz	≥ 25 mm	≤ 5 mm, *≤ 7 mm	≤ 3 mm
4 – 6 GHz	≥ 22 mm	≤ 4 mm, *≤ 5 mm	≤ 2 mm

*optional x-y coordinate spatial resolution when Area Scan SAR ≤ 87.5% of applicable SAR limit

- **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. The absolute value of this difference must be ≤ 0.21 dB; if it is not, the entire test is repeated or the difference accounted for.

11 SAR Test Results

11.1 General SAR Testing Notes

- From **KDB 447498 D01 General RF Exposure Guidance v06**, the following test channel reduction was applied to each test position of an exposure condition in each wireless mode and configuration. Initial testing for each test position for each band was performed on the middle required test channel (or required test channel with the highest measured power for WLAN modes). 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

- All WLAN measurements were made with the device transmitting at 100% duty cycle.
- Tissue-simulating liquid temperature was maintained within +/- 2°C of that which was measured during liquid verification.

11.2 WLAN 5 GHz SAR Testing Notes

In accordance with **KDB 248227 D01 v02r02 Section 5:**

- When the initial test channel had a reported SAR below 0.8 W/kg, further SAR measurement on the channel with next highest power was not needed.
- U-NII-1:
  - SAR is not required for U-NII-1 band since the same maximum output power is specified for both U-NII-1, U-NII-2A bands and the highest reported SAR for U-NII-2A band is below 1.2 W/kg.
- U-NII-2A:
  - 802.11a was used as the initial test configuration since it has the same specific maximum power as 802.11n HT20 but a lower data rate.
- U-NII-2C:
  - 802.11a was used as the initial test configuration since it has the same specific maximum power as 802.11n HT20 but a lower data rate.
- U-NII-3:
  - 802.11a was used as the initial test configuration since it has the same specific maximum power as 802.11n HT20 but a lower data rate.

11.2.1 WLAN 5.2 GHz SAR Test Results

According to **KDB 248227 v02r02 Section 5.3.1:**

When the same maximum output power is specified for both U-NII-1 and U-NII-2A bands, begin SAR measurement in U-NII-2A band by applying the OFDM SAR requirements. If the highest *reported* SAR for a test configuration is ≤ 1.2 W/kg, SAR is not required for U-NII-1 band for that configuration.

Since the highest reported SAR in U-NII-2A is ≤ 1.2 W/kg SAR testing was not performed in U-NII-1.

11.2.2 WLAN 5.3 GH **Main Antenna** SAR Test Results

Mode	BW (MHz)	Ant.	Position	Ch.	Freq. (MHz)	Avg. Pwr. (dBm)	Max. Pwr. (dBm)	Meas. 1g SAR (W/kg)	Reported 1g SAR (W/kg)
802.11a 6 Mbps	20	Main	Bottom	52	5260	8.02	9.5	0.201	0.283

11.2.3 WLAN 5.3 GHz **Diversity Antenna** SAR Test Results

Mode	BW (MHz)	Ant.	Position	Ch.	Freq. (MHz)	Avg. Pwr. (dBm)	Max. Pwr. (dBm)	Meas. 1g SAR (W/kg)	Reported 1g SAR (W/kg)
802.11a 6 Mbps	20	Div.	Bottom	52	5260	8.32	9.5	0.251	**0.329 (Plot 1)**

11.2.4 WLAN 5.6 GHz Main Antenna SAR Test Results

Mode	BW (MHz)	Ant.	Position	Ch.	Freq. (MHz)	Avg. Pwr. (dBm)	Max. Pwr. (dBm)	Meas. 1g SAR (W/kg)	Reported 1g SAR (W/kg)
802.11a 6 Mbps	20	Main	Bottom	128	5640	8.84	9.5	0.335	0.39

11.2.5 WLAN 5.6 GHz Diversity Antenna SAR Test Results

Mode	BW (MHz)	Ant.	Position	Ch.	Freq. (MHz)	Avg. Pwr. (dBm)	Max. Pwr. (dBm)	Meas. 1g SAR (W/kg)	Reported 1g SAR (W/kg)
802.11a 6 Mbps	20	Div.	Bottom	128	5640	8.92	9.5	0.374	**0.427 (Plot 2)**

11.2.6 WLAN 5.8 GHz Main Antenna SAR Test Results

Mode	BW (MHz)	Ant.	Position	Ch.	Freq. (MHz)	Avg. Pwr. (dBm)	Max. Pwr. (dBm)	Meas. 1g SAR (W/kg)	Reported 1g SAR (W/kg)
802.11a 6 Mbps	20	Main	Bottom	149	5745	8.12	9.5	0.295	0.405
	20	Main	Bottom	157	5785	8.88	9.5	0.345	0.398
	20	Main	Bottom	165	5825	8.1	9.5	0.289	0.399

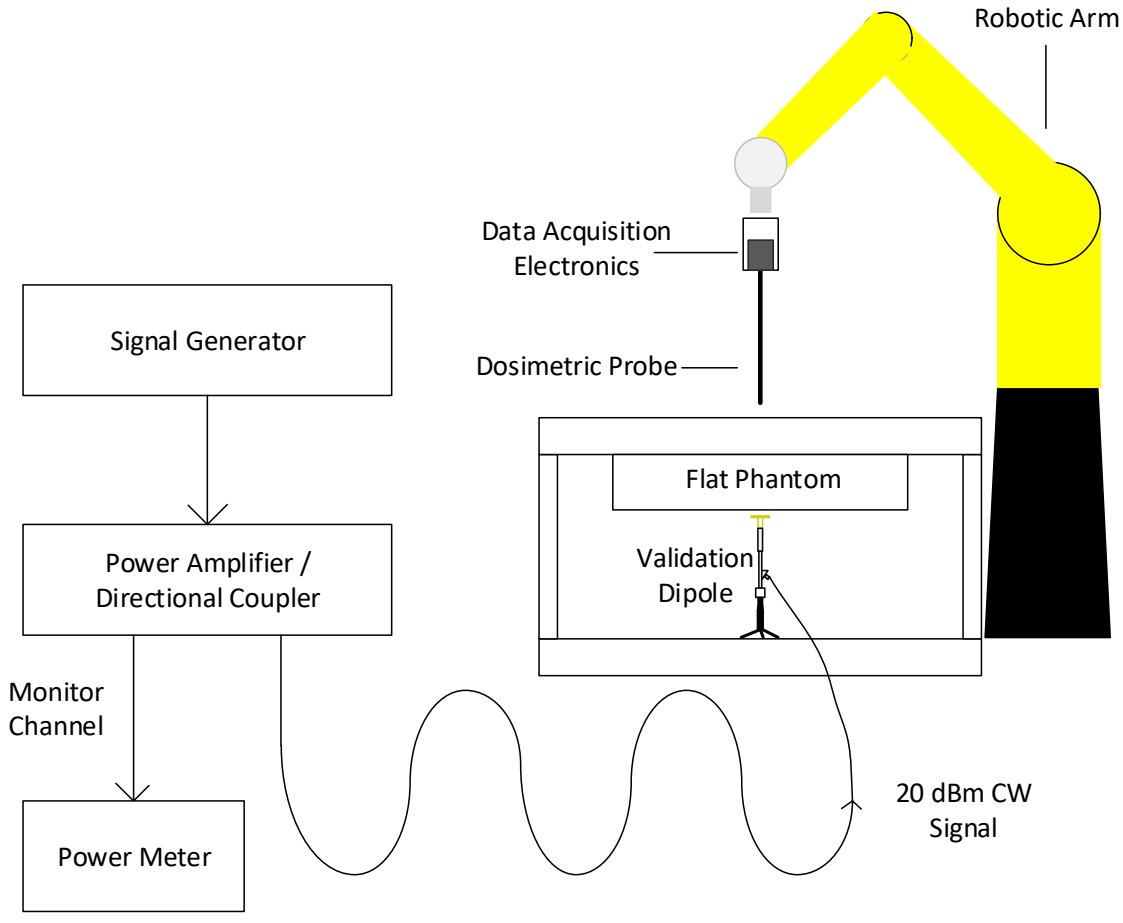
11.2.7 WLAN 5.8 GHz Diversity Antenna SAR Test Results

Mode	BW (MHz)	Ant.	Position	Ch.	Freq. (MHz)	Avg. Pwr. (dBm)	Max. Pwr. (dBm)	Meas. 1g SAR (W/kg)	Reported 1g SAR (W/kg)
802.11a 6 Mbps	20	Main	Bottom	149	5745	8.83	9.5	0.392	**0.457 (Plot 3)**
	20	Main	Bottom	157	5785	8.74	9.5	0.383	0.456
	20	Main	Bottom	165	5825	8.36	9.5	0.347	0.451

12 SAR System Verification

System Verifications were performed in accordance with **IEEE 1528-2013** and **KDB 865664 D01 v01r04.** Verifications were 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 liquid combinations used with each SAR system for system verification were used for device testing. Verifications were performed before each series of SAR measurements using the same calibration point and tissue-equivalent medium and every three days thereafter when necessary.

The test setup diagram is shown below. A CW signal is created by a signal generator and fed through a power amplifier with directional coupler outputs. The forward output power is adjusted to 20 dBm while the coupled output power is normalized to 0dB for easy monitoring. When the forward power is attached to the dipole, the power is then adjusted if necessary so that the coupled channel again reads 0 dB on the power meter. Tissue-simulating liquid depth in the phantom is maintained to be at least 15 cm for frequencies below 3 GHz and 10 cm for frequencies above 5 GHz.



System Verification Setup

12.1 SAR System Verification Results

All verifications are performed with a 100 mW (20 dBm) input to the dipole. The resultant measured SAR is normalized to 1 W (30 dBm) for comparison to calibrated dipole targets. All normalized SAR system verification results were within 10% of the respective dipole target values.

Date	Tissue-Sim. Liquid	Probe SN	Dipole	Freq. (MHz)	Meas. 1-g SAR (W/kg)	Norm. 1-g SAR (W/kg)	Dipole Target 1-g SAR (W/kg)	Dev. from Target 1-g SAR (%)
5/7/2018	MSL	3999	D5GHzV2/1158	5250	7.6	76	75	**1.33 (Plot 4)**
5/7/2018	MSL	3999	D5GHzV2/1158	5600	7.87	78.7	80.5	**-2.24 (Plot 5)**
5/7/2018	MSL	3999	D5GHzV2/1158	5750	7.49	74.9	76.7	**-2.35 (Plot 6)**

13 Tissue-Simulating Liquid Verification

(KDB 854664 D01 v01r04 Section 2.4) The tissue dielectric parameters of tissue-equivalent media used for SAR measurements must be characterized within a temperature range of 18°C to 25°C, measured with calibrated instruments and apparatuses, such as network analyzers and temperature probes. The temperature of the tissue-equivalent medium during SAR measurement must also be within 18°C to 25°C and within ± 2°C of the temperature when the tissue parameters are characterized. The tissue dielectric measurement system must be calibrated before use. 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.

The target parameters for the tissue-simulating liquids are obtained from the following table from KDB 865664 D01:

Target Frequency	Head		Body	
(MHz)	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
5800	35.3	5.27	48.2	6.00

(ε_r = relative permittivity, σ = conductivity and ρ = 1000 kg/m^3)

13.1 Tissue-Simulating Liquid Ingredients and Maintenance

The Tissue-simulating liquids were manufactured by SPEAG. The following information on the maintenance of

MSL 2450 Ingredients: Water, DGBE

MBBL 3500 – 5800 Ingredients: Water, Mineral Oil, Emulsifiers, Sodium Chloride

DGBE BASED LIQUIDS
DGBE is easily dissolved in water. Given a DGBE-water mixture, mainly water will evaporate, however DGBE will evaporate to a smaller percentage. For the frequency liquids around 2.5 GHz, no NaCl is contained and should therefore not be added for any corrections.
Evaporated water can be replaced and will mainly increase the permittivity, and to a small extent the conductivity, typically as follows:

HSLxxxxV2: permittivity 0.8 to 1.0 per % of water, conductivity 0 to 0.1 per % of water

MSLxxxxV2: permittivity 0.8 per % of water, conductivity 0 to 0.01 per % of water

OIL BASED LIQUIDS
Oil based liquids are an emulsion of a complex mixture of ingredients. Their appearance is yellow or brown transparent or slightly opaque / milky in most cases. Some older liquids may show a non-transparent upper zone with a creamy appearance after some time without stirring. Before using or handling the liquid, it must therefore be stirred to become entirely homogeneous. An opaque appearance is possible but will not influence the dielectric parameters if it is homogeneous during the measurement at the probe surface.
Evaporated water can be replaced and will increase the permittivity, and to a smaller extent the conductivity.

The **sensitivities to water addition** (% parameter increase per weight% water added) of oil based SPEAG broadband tissue simulating liquids at the frequencies of interest are typically in the following range:

HBBL3500-5800V5	at 3.5 GHz:	permittivity 0.79, conductivity 0.14
	at 5.5 GHz:	permittivity 0.83, conductivity 0.41
MBBL3500-5800V5	at 3.5 GHz:	permittivity 0.44, conductivity 0.00
	at 5.5 GHz:	permittivity 0.48, conductivity 0.18

The **temperature gradients** shall be observed especially during conductivity measurement:

HBBL3500-5800V5	at 3.5 GHz:	permittivity -0.07, conductivity -0.43 %/°C
	at 5.5 GHz:	permittivity -0.23, conductivity -0.96 %/°C
MBBL3500-5800V5	at 3.5 GHz:	permittivity -0.35, conductivity -1.14 %/°C
	at 5.5 GHz:	permittivity -0.08, conductivity -1.52 %/°C

13.2 Tissue-Simulating Liquid Measurements

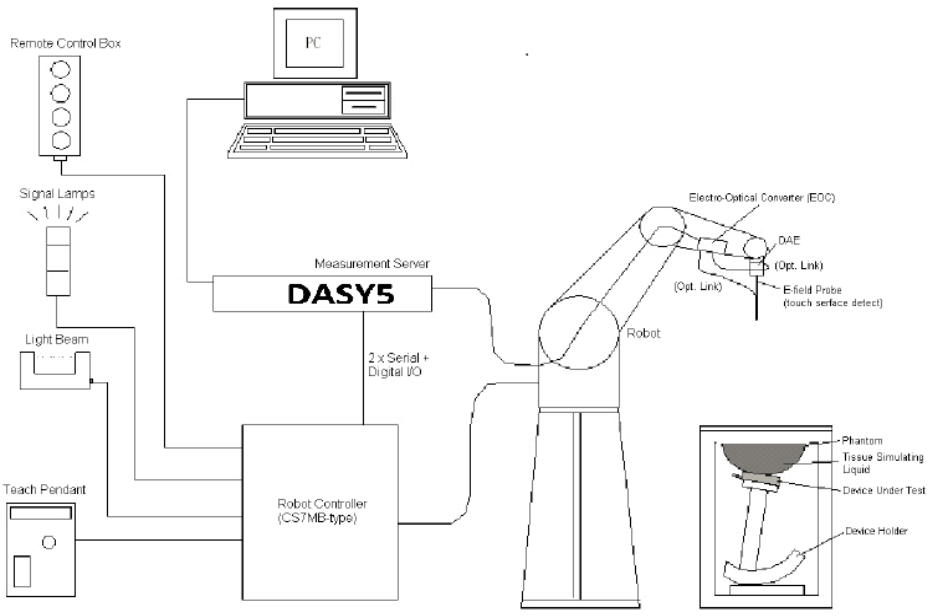
Date	Tissue-Simulating Liquid	Freq. (MHz)	Rel. Perm. ε'_r	Target ε'_r	ε'_r Dev. %	Cond. σ (S/m)	Target σ (S/m)	σ Dev. %
5/7/2018	MBBL 600-6000 160204-3 22.5 °C	5250	47.18	48.95	**-3.62**	5.445	5.36	**1.59**
		5260	47.13	48.9	**-3.62**	5.449	5.37	**1.47**
		5320	46.91	48.85	**-3.97**	5.568	5.44	**2.35**
		5350	46.97	48.82	**-3.78**	5.598	5.47	**2.34**
5/7/2018	MBBL 600-6000 160204-3 22.4 °C	5500	47.82	48.61	**-1.63**	5.45	5.65	**-3.54**
		5600	47.64	48.47	**-1.71**	5.595	5.77	**-3.03**
		5700	47.46	48.34	**-1.82**	5.743	5.88	**-2.33**
5/7/2018	MBBL 600-6000 160204-3 22.5 °C	5725	47.75	48.2	**-0.93**	5.802	5.91	**-1.83**
		5800	47.64	48.2	**-1.16**	5.906	6	**-1.57**
		5825	47.57	48.17	**-1.25**	5.946	6.03	**-1.39**

14 System Specification

14.1 SPEAG DASY5 SYSTEM

DASY 5 system performing SAR testing contains the following items, which are illustrated in the figure below.

- 6-axis robot (model: TX90XL) with controller and teach pendant.
- Dosimetric E-field probe.
- Light beam unit which allows automatic “tooling” of the probe.
- The electro-optical convertor (EOC) which is mounted on the robot arm.
- The data acquisition electronics (DAE).
- Elliptical Phantom
- Device holder.
- Remote control.
- PC.
- DASY5 software.
- Validation dipole.



DASY5 System Setup

15 Measurement Uncertainty

KDB 865664 D01 v01r04 section 2.8.2 says:

Extensive SAR measurement uncertainty analysis is required in SAR reports only when the highest measured SAR in a frequency band is ≥ 1.5 W/kg for 1-g SAR.

The highest **measured** 1-g SAR in this report is 0.392 W/kg. Therefore, SAR measurement uncertainty analysis is not required for this report.

Overall SAR system measurement uncertainty is less than 30% with a confidence factor k=2 in order to meet standard requirements.

16 Appendices

The following are contained in the attached appendices:

- Highest SAR Test and SAR System Verification Plots
- SAR Test Setup Photos
- Calibration Report Documents for:
    - Validation Dipole D5GHzV2-1158_April18
    - Dosimetric Probe EX3-3999_Dec17

End of Test Report