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

SAR EVALUATION REPORT

For

Thinking Remote for Home Automation
Model: The NEEO Thinking Remote (6336-REMOTE)

FCC ID: 2AKK7-RM633601

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3.0	13 April 2017	The following amendments were made in the report: 1. Section 1: Updated the equipment class for 6LowPAN 2. Section 6.1: Typo corrected	Naseer Mirza

TABLE OF CONTENTS

1. Attestation of Test Results 4

2. Test Specification, Methods and Procedures 5
2.1. Test Specification 5
2.2. Methods and Procedures Reference Documentation 5
2.3. Definition of Measurement Equipment 5

3. Facilities and Accreditation 6

4. SAR Measurement System & Test Equipment 7
4.1. SAR Measurement System 7
4.2. SAR Measurement Procedure 8
4.3. Test Equipment 10

5. Measurement Uncertainty 12
5.1. Uncertainty – Freq. < 3 GHz Head and Body Configuration 10 g 13
5.2. Uncertainty – Freq. > 3 GHz Head and Body Configuration 10 g 14

6. Device Under Test (DUT) 15
6.1. DUT Description 15
6.2. Wireless Technologies 16
6.3. Nominal and Maximum Output Power 17

7. RF Exposure Conditions (Test Configurations) 18
7.1. RF Exposure Conditions (Test Configurations) 18
7.2. SAR Test Exclusion Consideration 18

8. Conducted output power measurements 19
8.1. RF Output Average Power Measurement: Wi-Fi 19
8.2. RF Output Average Power Measurement: IEEE 804.15.4 19

9. Dielectric Property Measurements & System Check 20
9.1. Tissue Dielectric Parameters 20
9.2. System Check 21
9.3. Reference Target SAR Values 21
9.4. Dielectric Property Measurements & System Check Results 22

10. Measurements, Examinations and Derived Result 23
10.1. Specific Absorption Rate - Test Results 23
10.2. SAR Measurement Variability 24

11. Highest Standalone SAR and Simultaneous Transmission 25
11.1. Highest Standalone Reported SAR 25

12. Appendixes 26
12.1. Photos and Ports Location 26
12.2. System Check Plots 40
12.3. SAR Distribution Plots 42
12.4. Calibration Certificate for E-Field Probe 55
12.5. Calibration Certificate for Dipole 56
12.6. Tissues-Equivalent Media Recipes 57

1. Attestation of Test Results

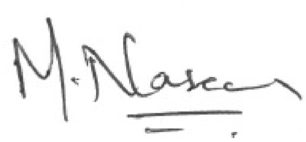
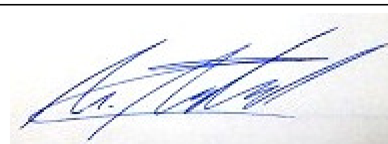
Applicant Name:	Neeo AG
Model:	The NEEO Thinking Remote (6336-REMOTE)
Test Device is	A representative test sample
Device category	Remote controller
Date Tested	03 March 2017
ICNIRP Guidelines Limits for SAR Exposure Characteristics	General Population/Localised SAR (Extremity) – 10g SAR limit 4.0 W/kg
The highest reported SAR values for Localized SAR	See table below
Applicable Standards	FCC 47 CFR part 2 (2.1093) KDB publications IEEE Std 1528-2013
Test Results	Pass

The highest reported SAR values for Localized SAR

RF Exposure Conditions		Equipment Class			
		Licensed	DTS	U-NII	DSS
Standalone	Extremity	N/A	0.407 W/kg	N/A	N/A
Simultaneous Transmission	Extremity	N/A	0.646 W/kg	N/A	N/A

UL VS 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 VS 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 VS Ltd. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL VS 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.

Approved & Released By:	Prepared By:
	
Naseer Mirza Project Lead UL VS Ltd.	Marc Montserrat Laboratory 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 v01r04
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 4.0 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 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04
KDB 865664 D02 SAR 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 measurement facilities used to collect data are located at

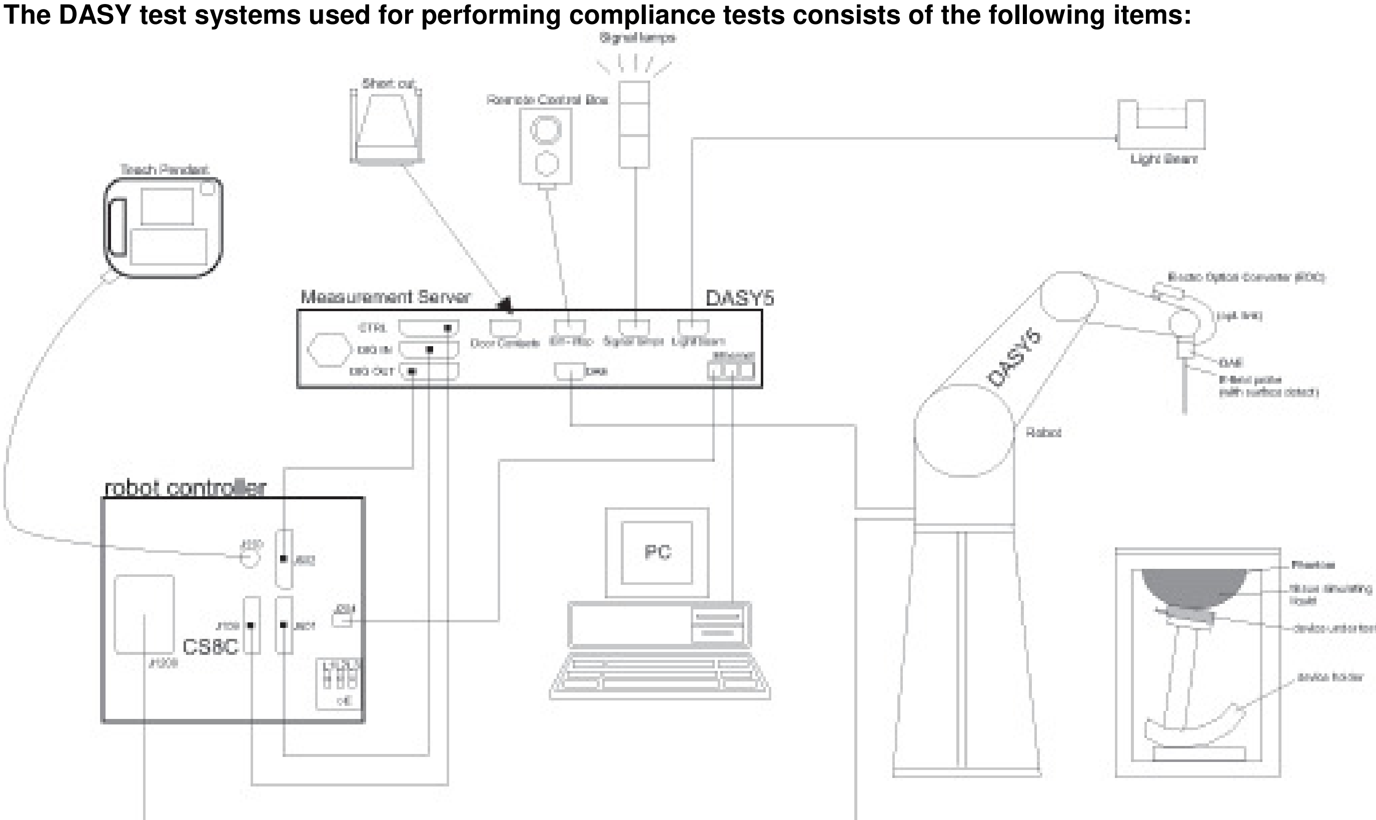
Pavilion A, Ashwood Park, Ashwood Way, Basingstoke, Hampshire, RG23 8BG UK	Facility Type
SAR Lab 61	Controlled Environment Chamber

UL VS Limited is accredited by UKAS (United Kingdom Accreditation Service, Accredited to ISO/IEC 17025: 2005), Laboratory UKAS Code 0644.

4. SAR Measurement System & Test Equipment

4.1. SAR Measurement System

The DASY test systems 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 and Win7 with DASY software installed.
- 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	$\frac{1}{2} \cdot \delta \cdot \ln(2)$ 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	$\leq 1.5 \cdot \Delta z_{Zoom}(n-1)$	
Minimum zoom scan volume	x, y, z		≥ 30 mm	3 – 4 GHz: ≥ 28 mm 4 – 5 GHz: ≥ 25 mm 5 – 6 GHz: ≥ 22 mm

4.3. Test Equipment

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

UL No.	Instrument	Manufacturer	Type No.	Serial No.	Date Last Calibrated	Cal. Interval (Months)
A2547	Data Acquisition Electronics	SPEAG	DAE4	1438	25 Apr 2016	12
A2544	Probe	SPEAG	EX3 DV4	3994	21 Mar 2016	12
A1322	2450 MHz Dipole	SPEAG	D2450V2	725	29 Sep 2016	12
G0612	Robot Power Supply	SPEAG	DASY52	F14/5T5ZA1/C/01	Calibrated as part of system	-
M1877	Robot Arm	Staubli	TX60 L	F14/5T5ZA1/A/01	Calibrated as part of system	-
A2440	Body Handset Positioner	SPEAG	MD4HACV5	None	Calibrated before use	-
M1755	DAK Fluid Probe	SPEAG	SM DAK 040 CA	1089	Calibrated before use	-
M1015	Network Analyser	Agilent Technologies	8753ES	US39172406	26 Sept 2016	12
M1855	Power Sensor	R & S	NRP-Z51	103246	08 Nov 2016	12
A2621	Digital Camera	Nikon	S3600	41010357	N/A	-
M1838	Signal Generator	R & S	SME06	1038.6002.06	07 Apr 2016	12
M1023	Dual Channel Power Meter	R & S	NRVD	863715/030	13 Apr 2016	12
M1635	Power Sensor	R & S	NRV-Z1	826515/015	13 Apr 2016	12
M1634	Power Sensor	R & S	NRV-Z1	860462/016	13 Apr 2016	12
A2100	Directional Coupler	RF-Lambda	11101300748	None	Calibrated before use	-
A2689	Amplifier	Mini-Circuits	ZVE-8G	910401427	Calibrated before use	-
A2549	Phantom	SPEAG	Eli Phantom	1252	Calibrated as part of system	-
PRE0141350	Phantom Support Structure	SPEAG	DASY6 Phantom Table	-	Calibrated as part of system	-
M1270	RS Hygrometer	RS Components	N/A	N/A	18 March 2016	12
PRE0140104	RF Coax Cable	RM Coax	FB311A1020003 030	-	Calibrated before use	-

4.3.1. SAR System Specifications

Robot System	
Positioner:	Stäubli Unimation Corp. Robot Model: TX60L
Repeatability:	±0.030 mm
No. of Axis:	6
Serial Number:	F14/5T5ZA1/A/01
Reach:	920 mm
Payload:	2.0 kg
Control Unit:	CS8C
Programming Language:	V+
Data Acquisition Electronic (DAE) System	
Serial Number:	DAE4 SN: 1438
PC Controller	
PC:	Dell Precision 340
Operating System:	Windows 2000
Data Card:	DASY5 Measurement Servers
Serial Number:	1080
Data Converter	
Features:	Signal Amplifier, multiplexer, A/D converted and control logic.
Software:	DASY5 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 DAE3 and 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
Serial No:	3994
Construction:	Triangular core
Frequency:	10 MHz to >6 GHz
Linearity:	±0.2 dB (30 MHz to 6 GHz)
Probe Length (mm):	337
Probe Diameter (mm):	10
Tip Length (mm):	9
Tip Diameter (mm):	2.5
Sensor X Offset (mm):	1
Sensor Y Offset (mm):	1
Sensor Z Offset (mm):	1

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 10 g	95%	±19.67%
Uncertainty- Freq. > 3 GHz Body Configuration 10 g	95%	±16.84%

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 10 g

Type	Source of uncertainty	+ Value	- Value	Probability Distribution	Divisor	$c_{i\ (10g)}$	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	3.080	3.080	normal (k=1)	1.0000	1.0000	3.080	3.080	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	0.4300	1.241	1.241	∞
A	Liquid Conductivity (measured value)	2.470	2.470	normal (k=1)	1.0000	0.4300	1.062	1.062	5
B	Liquid Permittivity (target value)	5.000	5.000	Rectangular	1.7321	0.4900	1.415	1.415	∞
A	Liquid Permittivity (measured value)	2.430	2.430	normal (k=1)	1.0000	0.4900	1.191	1.191	5
	Combined standard uncertainty			t-distribution			10.04	10.04	>500
	Expanded uncertainty			k = 1.96			19.67	19.67	>500

5.2. Uncertainty – Freq. > 3 GHz Body Configuration 10 g

Type	Source of uncertainty	+ Value	- Value	Probability Distribution	Divisor	$c_{i\,(10g)}$	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	0.000	0.000	Rectangular	1.7321	1.0000	0.000	0.000	∞
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	2.430	2.430	normal (k=1)	1.0000	1.0000	2.430	2.430	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)	0.770	0.770	normal (k=1)	1.0000	0.6400	0.493	0.493	5
B	Liquid Permittivity (target value)	5.000	5.000	Rectangular	1.7321	0.6000	1.732	1.732	∞
A	Liquid Permittivity (measured value)	0.990	0.990	normal (k=1)	1.0000	0.6000	0.594	0.594	5
	Combined standard uncertainty			t-distribution			8.59	8.59	>500
	Expanded uncertainty			k = 1.96			16.84	16.84	>500

6. Device Under Test (DUT)

6.1. DUT Description

DUT Description:	The DUT is a remote controller for home automation and it supports Wi-Fi 2.4 GHz (802.11 b/g/n) and 6LoWPAN (IEEE 802.15.4).	
Serial Number:	The following samples were used to perform SAR measurements: - SN: MBA09: Wi-Fi 2.4 GHz / IEEE 802.15.4 (6LoWPAN 2.4 GHz) The following sample was used to perform conducted power measurements: - SN: MBA22: Wi-Fi 2.4 GHz / IEEE 802.15.4 (6LoWPAN 2.4 GHz)	
Hardware Version Number:	Hardware Rev. 10	
Software Version Number:	0.21.4	
Country of Manufacture:	Switzerland	
Device dimension	Overall (Height x Width x Depth): 181.65 mm x 48.50 mm x 10.79 mm	
Date of Receipt:	27 February 2017	
Back Cover	☒ Normal Battery Cover ☐ Normal Battery Cover with NFC ☐ Wireless Charger Battery Cover ☐ Wireless Charger Battery Cover with NFC	
Accessory	☐ Headset	
Battery Options	☒ Standard – Lithium-ion battery ☐ Extended (large capacity)	
Antenna Type:	Internal integral	
Antenna Length:	None Stated	
Number of Antenna Positions:	Antenna A ~ Wi-Fi Antenna	1 fixed
	Antenna B ~ 6LoWPAN Antenna	1 fixed

6.2. Wireless Technologies

Wireless technologies	Frequency bands	Operating mode	Duty Cycle
Wi-Fi	2.4 GHz	802.11b 802.11g 802.11n (HT20)	15%
6LoWPAN	2.4 GHz	802.15.4	100%

Additional Information Related to Testing:

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				
	3	2422.0				
	4	2427.0				
	5	2432.0				
	6	2437.0				
	7	2442.0				
	8	2447.0				
	9	2452.0				
	10	2457.0				
	11	2462.0				

IEEE 802.15.4 - 6LoWPAN		
Band	Description	
	Ch.#	Frq. (MHz)
6LoWPAN 2.4 GHz	11	2405
	12	2410
	13	2415
	14	2420
	15	2425
	16	2430
	17	2435
	18	2440
	19	2445
	20	2450
	21	2455
	22	2460
	23	2465
	24	2470
	25	2475
	26	2480

6.3. Nominal and Maximum Output Power

(From customer)

			Target (dBm) applicable to antenna A only								
Band	Channel	Center Frequency (MHz)	802.11b			802.11g					802.11n HT20
			1DSSS	2DSSS	11CCK	6OFDM	9OFDM	18OFDM	36OFDM	54OFDM	MCS7
Wi-Fi 2.4 GHz	1	2412	15.56	15.56	15.66	13.01	13.01	12.76	11.26	10.91	10.06
	2	2417	15.54	15.54	15.71	14.76	14.76	14.76	13.26	11.36	10.06
	3	2422	16.01	16.01	16.26	15.31	15.31	15.36	13.86	11.76	10.56
	4	2427	15.96	15.96	16.21	15.36	15.36	15.41	13.91	11.91	10.56
	5	2432	15.91	15.91	16.21	15.41	15.41	15.41	13.91	11.91	10.66
	6	2437	16.41	16.41	16.71	16.27	16.27	16.36	14.86	12.96	11.71
	7	2442	16.86	16.86	17.06	16.06	16.06	16.16	14.66	12.66	11.31
	8	2447	16.26	16.26	16.56	16.06	16.06	16.16	14.66	12.66	11.46
	9	2452	15.81	15.81	16.06	15.26	15.26	15.26	13.76	11.81	10.46
	10	2457	15.86	15.86	16.16	15.26	15.26	15.26	13.76	11.81	10.56
	11	2462	15.96	15.96	16.21	13.26	13.26	12.76	11.26	10.96	10.66
	12	2467	Not Supported								
	13	2472									

WiFi 2.4 GHz - Tolerance (dB)	+/-1.85	+/-1.85	+/-1.85	+/-1.85	+/-1.85	+/-1.85	+/-2.10	+/-2.10	+/-2.10

		Target (dBm) applicable to antenna B only
Band	Channel	
6LoWPAN	ALL	11.50

6LoWPAN - Tolerance (dB)	+/-2.08

Note:

1. The nominal and maximum average source based rated powers declared and supplied by manufacturer are shown in the above tables.

7. RF Exposure Conditions (Test Configurations)

7.1. RF Exposure Conditions (Test Configurations)

Technology Antenna	Configuration	Antenna-to-User Separation	Position	Antenna-to-Edge Separation (mm)	Evaluation Considered
Antenna A ~ WLAN ~ Wi-Fi Antenna	Extremity (Body)	0mm	Front	<25mm	Yes
			Back	<25mm	Yes
			Edge 1 (Top Edge)	<25mm	Yes
			Edge 2 (Right Edge)	>25mm	No
			Edge 3 (Bottom Edge)	>25mm	No
			Edge 4 (Left Edge)	<25mm	Yes
Antenna B ~ WPAN ~ 6LoWPAN Antenna	Extremity (Body)	0mm	Front	<25mm	Yes
			Back	<25mm	Yes
			Edge 1 (Top Edge)	<25mm	Yes
			Edge 2 (Right Edge)	<25mm	Yes
			Edge 3 (Bottom Edge)	>25mm	No
			Edge 4 (Left Edge)	>25mm	No

7.2. SAR Test Exclusion Consideration

Frequency Band	Configuration(s)	
	Extremity	
	Antenna A - WLAN	Antenna B - WPAN
WLAN 2.4 GHz	No	N/A
6LoWPAN 2.4GHz	N/A	No

Note:

1. As per KDB publication 447498 D01, The Frequency Bands with Rated Power including Upper tolerance, which qualify for **Standalone SAR Test Exclusion**, are as per the above table.
2. The details for the Maximum Rated Power and tolerance(s) can be found in section 6.3

8. Conducted output power measurements

8.1. RF Output Average Power Measurement: Wi-Fi

8.1.1. Wi-Fi 802.11b/g/n (2.4 GHz)

		Avg Power (dBm)	
		Antenna A	
Channel Number	Frequency (MHz)	11 Mbps	Operating Mode
1	2412	15.55	802.11b (11CCK)
2	2417	15.56	
3	2422	16.17	
4	2427	16.23	
5	2432	16.28	
6	2437	16.85	
7	2442	17.38	
8	2447	16.88	
9	2452	16.41	
10	2457	16.45	
11	2462	16.48	
12	2467	Not Supported	
13	2472	Not Supported	

Note:
Conducted power measurements were not performed for mode 802.11g and 802.11n HT20 due to max. rated power being equal or lower to mode 802.11b.

8.2.RF Output Average Power Measurement: IEEE 804.15.4

8.2.1. IEEE 804.15.4 – 6LoWPAN (2.4 GHz)

		Avg Power (dBm)	
Channel Number	Frequency (MHZ)	Antenna B	Operating Mode
11	2405.0	12.90	6LoWPAN
18	2440.0	12.81	
26	2480.0	12.64	

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)	Body	
	ε_r	σ (S/m)
150	61.9	0.80
300	58.2	0.92
450	56.7	0.94
750	-	-
835	55.2	0.97
900	55.0	1.05
915	55.0	1.06
1450	54.0	1.30
1500	-	-
1610	53.8	1.40
1640	-	-
1750	-	-
1800	53.3	1.52
1900	53.3	1.52
2000	53.3	1.52
2100	-	-
2300	-	-
2450	52.7	1.95
2600	-	-
3000	52.0	2.73
3500	-	-
4000	-	-
4500	-	-
5000	49.3	5.07
5100	49.1	5.18
5200	49.0	5.30
5250	48.9	5.36
5300	48.9	5.42
5400	48.7	5.53
5500	48.6	5.65
5600	48.5	5.77
5700	48.3	5.88
5750	48.3	5.94
5800	48.2	6.00
6000	-	-

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 1.00 Watt.

System Dipole	Serial No.	Cal. Date	Freq. (MHz)	Target SAR Values (mW/g)	
				1g/10g	**Body**
D2450V2	725	29 Sep 2016	2450	1g	50.30
				10g	23.80

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 ±5% of the manufacturer calibrated dipole SAR target. The internal limit is set to ±5%.

Site 59

System check 2450 Body
Date: 28/02/2017
Validation dipole and Serial Number: D2450V2 / SN: 725

Simulant	Frequency (MHz)	Room Temp (℃)	Liquid Temp (℃)	Parameters	Target Value	Measured Value	Deviation (%)	Limit (%)
Body	2450	23.0	21.0	εr	52.70	53.48	1.48	5.00
				Σ	1.95	2.03	4.00	5.00
				1g (W/kg)	50.30	51.60	2.58	5.00
				10g (W/kg)	23.80	24.04	1.01	5.00

10. Measurements, Examinations and Derived Result

10.1. Specific Absorption Rate - Test Results

For All SAR measurement in this report the 10g-SAR limit tested to is 4.0 W/Kg

10.1.1. Wi-Fi 2.4 GHz – Extremity 10g

Max. Reported SAR = 0.407 (W/kg)

					Power (dBm) - ANT A		10g: SAR Results (W/kg) - ANT A				
Mod.	Dist (mm)	EUT Position	CH #	Freq (MHz)	Tune up Limit	Meas. Power	Meas.	Reported Before Scaling	Scale Factor	Reported	Scan No.
11CCK (802.11b 11Mbps)	0.0	Front	7	2442.0	18.91	17.38	0.000	0.000	6.67	0.000	1
	0.0	Back	7	2442.0	18.91	17.38	0.039	0.055	6.67	0.367	2
	0.0	Top	7	2442.0	18.91	17.38	0.000	0.000	6.67	0.000	3
	0.0	Left Hand Side	7	2442.0	18.91	17.38	0.000	0.000	6.67	0.000	4
	0.0	Back	1	2412.0	17.51	15.55	0.039	0.061	6.67	0.407	5
	0.0	Back	11	2462.0	18.06	16.48	0.025	0.036	6.67	0.240	6

Note:
As per KDB publication 248227 D01, since continuous transmission is restricted by the device and only a duty cycle of 15% can be achieved, reported SAR has been scaled to 100% transmission duty factor to determine compliance at the maximum tune-up tolerance.

Scale-up has been performed using a linear scale factor of:

$$\frac{100\ \%\ [Desired\ Duty\ Cycle]}{15\ \%\ [Actual\ Highest\ Duty\ Cycle]} = 6.67$$

10.1.2. IEEE 802.15.4 – 6LoWPAN 2.4 GHz – Extremity 10g

Max. Reported SAR: 0.239 (W/kg)

					Power (dBm) - ANT B		10g: SAR Results (W/kg) - ANT B		
Mod.	Dist (mm)	EUT Position	CH #	Freq (MHz)	Tune up Limit	Meas. Power	Meas.	Reported	Scan No.
6LoWPAN	0.0	Front	11	2405.0	13.58	12.90	0.002	0.002	7
	0.0	Back	11	2405.0	13.58	12.90	0.204	0.239	8
	0.0	Top	11	2405.0	13.58	12.90	0.017	0.020	9
	0.0	Right Hand Side	11	2405.0	13.58	12.90	0.022	0.026	10
	0.0	Back	18	2440.0	13.58	12.81	0.141	0.168	11
	0.0	Back	26	2480.0	13.58	12.64	0.092	0.114	12

10.2. 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 < 2.00 W/kg; steps 2) through 4) do not apply.
2) When the original highest measured SAR is ≥ 2.00 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 ≥ 3.60 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 ≥3.75 W/kg and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20.

Note: Measure 10g-SAR levels < 2.000 W/Kg, repeat measurements are not required.

11. Highest Standalone SAR and Simultaneous Transmission

11.1. Highest Standalone Reported SAR

KDB 447498 D01 General RF Exposure Guidance, introduces a new formula for calculating the SAR to Peak Location Ratio (SPLSR) between pairs of simultaneously transmitting antennas:

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

Where:

SAR_1 is the highest reported or estimated SAR for the first of a pair of simultaneous transmitting antennas, in a specific test operating mode and exposure condition
SAR_2 is the highest reported or estimated SAR for the second of a pair of simultaneous transmitting antennas, in the same test operating mode and exposure condition as the first
Ri is the separation distance between the pair of simultaneous transmitting antennas. When the SAR is measured for both antennas in the pair, it is determined by the actual x, y, and z coordinates in the 1-g SAR for each SAR Peak Location; based on the extrapolated and interpolated result in the zoom scan measurement using the formula:

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

A new threshold of 0.10 when 10g SAR applies is also introduced in the KDB 447498. Thus, in order for a pair of simultaneously transmitting antennas, with the sum of 10g SAR > 4.0 W/kg for (Extremity Test Condition only), to qualify for exemption from Simultaneous Transmission SAR measurements, it has to satisfy the condition of:

$$(SAR_1 + SAR_2)^{1.5} / Ri < 0.10$$

The worst case simultaneous transmission analysis is considered for the following cases:

1. WLAN + 6LoWPAN

Worst Case Simultaneous Transmission SAR Analysis:

Exposure Combinations	Technology Band	Configuration	Highest Reported 10g SAR (W/kg)	Max Rated Source base Avg Power + Max Tolerance [dBm]	Highest Reported Sum-SAR 10g-SAR (W/kg)	SPLSR Ratio
WWAN + 6LoWPAN	WLAN 2.4 GHz	Extremity	0.407	17.51	0.646	N/A
	6LoWPAN 2.4 GHz		0.239	13.58		