SAR Evaluation Report

EUT Information

Manufacturer	X-Rite Switzerland GmbH
Model Name	Topaz
Contains FCC ID	LSV-TOPAZ
Contains IC Number	20894-TOPAZ
EUT Type	TOP-Spectrophotometer / hand-held device

Prepared by

Testing Laboratory	IMST GmbH, Test Center Carl-Friedrich-Gauß-Str. 2 – 4 47475 Kamp-Lintfort Germany
Laboratory Accreditation	The Test Center facility 'Dosimetric Test Lab' within IMST GmbH is accredited by the German National 'Deutsche Akkreditierungsstelle GmbH (DAkkS)' for testing according to the scope as listed in the accreditation certificate: D-PL-12139-01-00. The German Bundesnetzagentur (BNetzA) recognizes IMST GmbH as CAB-EMC on the basis of the Council Decision of 22. June 1998 concerning the conclusion of the MRA between the European Community and the United States of America (1999/178/EC) in accordance with § 4 of the Recognition Ordinance of 11. January 2016. The recognition is valid until 20. July 2021 under the registration number: BNetzA-CAB-16/21-14.

Prepared for

Applicant	X-Rite Switzerland GmbH Althardstrasse 70 8105 Regensdorf Switzerland

Test Specification

Applied Rules/Standards	IEEE 1528-2013; RSS-102 Issue 5; FCC CFR 47 § 2.1093 ☒ general public / uncontrolled exposure ☐ occupational / controlled exposure

Report Information

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Remarks	This report relates only to the item(s) evaluated. This report shall not be reproduced, except in its entirety, without the prior written approval of IMST GmbH. The results and statements contained in this report reflect the evaluation for the certain model described above. The manufacturer is responsible for ensuring that all production devices meet the intent of the requirements described in this report.

Table of Contents

1 Subject of Investigation and Test Results

1.1 Technical Data of EUT

Product Specifications	
Model Name	Topaz
IMEI / SN	radiated sample: DE1266000aa01; conducted sample: DE1266000ab01
Operation Mode	IEEE 802.11 bgn (2.4 GHz)
Usage Configuration	extremity exposure configuration
Antenna Type	integrated
Max. Output Power	refer chapter 6.3
Power Supply	internal battery
Used Accessory	-
Notes:	

1.2 Antenna Configuration

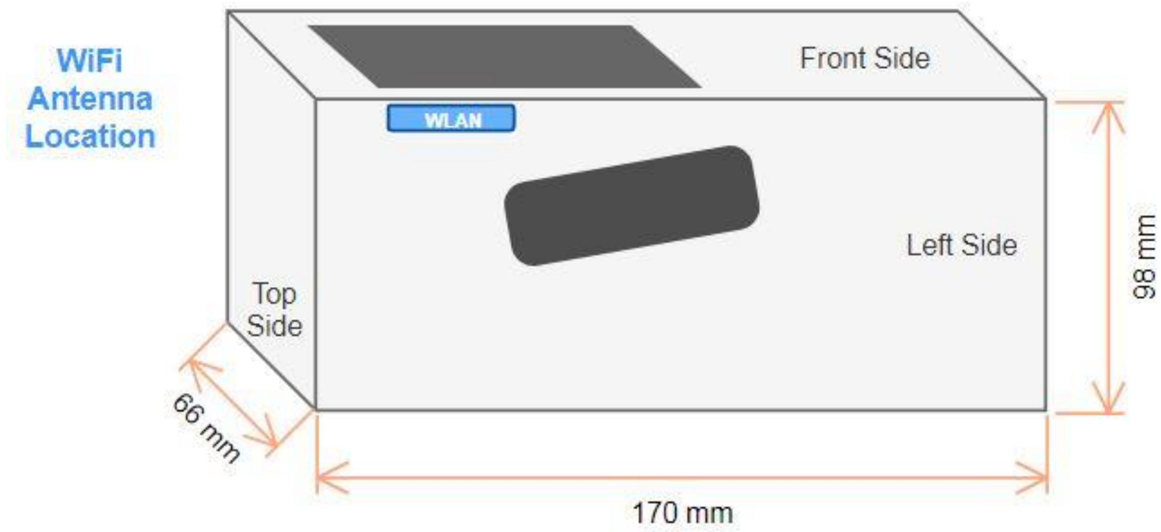

Fig. 1: Antenna location of the EUT.

1.3 Test Specification / Normative References

The tests documented in this report were performed according to the standards and rules described below.

Test Specifications			
	Test Standard / Rule	Description	Issue Date
☒	IEEE 1528-2013	IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques.	June 14, 2013
☐	FCC CFR 47 § 2.1091	Code of Federal Regulations; Title 47. Radiofrequency radiation exposure evaluation: **Mobile Devices.**	October 01, 2010
☒	FCC CFR 47 § 2.1093	Code of Federal Regulations; Title 47. Radiofrequency radiation exposure evaluation: **Portable Devices.**	October 01, 2010
☒	RSS-102, Issue 5	Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)	March, 2015
Measurement Methodology KDB			
☒	KDB 865664 D01 v01r04	SAR measurement 100 MHz to 6 GHz	August 07, 2015
Product KDB			
☒	KDB 447498 D01 v06	General RF Exposure Guidance	October 23, 2015
Technology KDB			
☒	KDB 248227 D01 v02r02	802.11 Wi-Fi SAR	October 23, 2015

1.4 Attestation of Test Results

Highest Reported SAR_{10g} [W/kg]									
Band	Frequency [MHz]	CH	Exposure Configuration		Gap [mm]	Pic. No.	Highest Reported SAR10g [W/kg]	SAR10g Limit [W/kg]	
IEEE 802.11	2462	11	Extremity	Front Side	0	5	0.205	4.0	PASS

Notes: To establish a connection at a specific channel and with maximum output power, engineering test software has been used.
All measured SAR results and configurations are shown in chapter 6.5 on page 17.

Prepared by: ....

Dessislava Patrishkova
Test Engineer

Reviewed by: ....

Alexander Rahn
Quality Assurance

2 Exposure Criteria and Limits

2.1 SAR Limits

Human Exposure Limits				
Condition	Uncontrolled Environment (General Population)		Controlled Environment (Occupational)	
	SAR Limit [W/kg]	**Mass Avg.**	**SAR Limit [W/kg]**	**Mass Avg.**
SAR averaged over the whole body mass	0.08	whole body	0.4	whole body
Peak spatially-averaged SAR for the head, neck & trunk	1.6	1g of tissue*	8.0	1g of tissue*
Peak spatially-averaged SAR in the limbs	4.0	10g of tissue*	20.0	10g of tissue*
Note: *Defined as a tissue volume in the shape of a cube				

Table 1: SAR limits.

In this report the comparison between the exposure limits and the measured data is made using the spatial peak SAR; the power level of the device under test guarantees that the whole body averaged SAR is not exceeded.

2.2 Exposure Categories

General Public / Uncontrolled Exposure
General population comprises individuals of all ages and of varying health status, and may include particularly susceptible groups or individuals. In many cases, members of the public are unaware of their exposure to electromagnetic fields. Moreover, individual members of the public cannot reasonably be expected to take precautions to minimize or avoid exposure.
Occupational / Controlled Exposure
The occupationally exposed population consists of adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions.

Table 2: RF exposure categories.

2.3 Distinction between Maximum Permissible Exposure and SAR Limits

The biological relevant parameter describing the effects of electromagnetic fields in the frequency range of interest is the specific absorption rate SAR (dimension: power/mass). It is a measure of the power absorbed per unit mass. The SAR may be spatially averaged over the total mass of an exposed body or its parts. The SAR is calculated from the r.m.s. electric field strength E inside the human body, the conductivity σ and the mass density ρ of the biological tissue:

$$SAR = \sigma \frac{E^2}{\rho} = c \left. \frac{\partial T}{\partial t} \right|_{t \to 0+} . \quad (1)$$

The specific absorption rate describes the initial rate of temperature rise $\partial T / \partial t$ as a function of the specific heat capacity c of the tissue. A limitation of the specific absorption rate prevents an excessive heating of the human body by electromagnetic energy.

As it is sometimes difficult to determine the SAR directly by measurement (e.g. whole body averaged SAR), the standard specifies more readily measurable maximum permissible exposures in terms of external electric E and magnetic field strength H and power density S, derived from the SAR limits. The limits for E, H and S have been fixed so that even under worst case conditions, the limits for the specific absorption rate SAR are not exceeded.

3 Measurement Procedure

3.1 General Requirement

The test shall be performed in a laboratory with an environment which avoids influence on SAR measurements by ambient EM sources and any reflection from the environment itself. The ambient temperature shall be in the range of 20°C to 26°C and 30-70% humidity. All tests have been conducted according the latest version of all relevant KDBs.

3.1.1 Phantom Requirements

The phantom is a simplified representation of the human anatomy and comprised of material with electrical properties similar to the corresponding tissues. For body-worn and other configurations a flat phantom shall be used which is comprised of material with electrical properties similar to the corresponding tissues.

3.1.2 Extremity exposure conditions

Devices that are designed or intended for use on extremities or mainly operated in extremity only exposure conditions; i.e. hands, wrist, feet and ankles, may require extremity SAR evaluation according 4.2.3 of KDB 447498 D01.

The device shall be placed directly against the flat phantom for those sides of the device that are in contact with the hand during intended use.

3.2 Information for IEEE 802.11 (Wi-Fi) Transmitters

For both DSSS and OFDM wireless modes an initial test position must be established for each applicable exposure configuration using either:

- Design implementation defined by the manufacturer, or
- Investigative results by the test lab based on:
    - Exclusions based on the distance from the antenna to the surface, or
    - Highest measured SAR from the area-scan-only measurements on all applicable test positions at the Initial Test Configuration, if found to require SAR tests.

Then, the initial test position procedure defines the required complete SAR scan measurements on each exposure configuration as following:

- When the reported SAR of the initial test position is ≤ 0.4 W/kg, further SAR measurements is not required for the remaining test positions in that configuration as well as 802.11 transmission mode combinations within the frequency or aggregated band.
- When the reported SAR of the initial test position is > 0.4 W/kg, further SAR measurements is required in the initial test position or next closest/smallest test separation distance based on manufacturer justification, on the following highest maximum output power channel, until the reported SAR is ≤ 0.8 W/kg or all required test positions are tested.
- When the reported SAR for all initial and subsequent test positions is > 0.8 W/kg, further SAR measurements is required on these positions on the subsequent next highest measured output power channels, until the reported SAR is ≤ 1.2 W/kg or all required channels have been tested.

For OFDM transmission configurations in 2.4 GHz and 5 GHz bands, it is important to determine SAR Initial Test Configuration for each stand alone and aggregated frequency band according to the maximum output power and tune-up tolerance specified for production units. The procedure is as following:

- Highest output power channel is chosen; if there are channels with same maximum output power then the closest to the mid-band frequency is preferred. If there are more than one channel with same maximum output power and same distance to the mid-band frequency, then the channel with the higher frequency is preferred.
- When SAR measurement is required for a subsequent test configuration and the channel bandwidth is smaller than that in the initial test configuration, all channels in the subsequent test configuration that overlap with the larger bandwidth channel tested in the initial test configuration should be used to determine the highest maximum output power channel in the subsequent test configuration.

Along with the initial test position reduction guidelines, the following procedures are also applied to SAR measurement requirements when multiple OFDM configurations are supported:

- When the reported SAR of the initial test configuration with the highest output power channel is > 0.8 W/kg, further SAR measurements is required for next highest output power channel in the initial test configuration, until the reported SAR is ≤ 1.2 W/kg or all required channels have been tested.
- When the reported SAR of the subsequent test configuration with the highest output power channel is > 1.2 W/kg, further SAR measurements is required for next highest output power channel in this test configuration, until the reported SAR is ≤ 1.2 W/kg or all required channels have been tested.
- When the reported SAR of the subsequent test configuration is > 1.2 W/kg, further SAR measurements for the following subsequent test configurations are required.

3.3 Measurement Variability

According KDB 865664 repeated measurements are required only when the measured SAR is ≥ 0.80 W/kg. If the measured SAR value of the initial repeated measurement is < 1.45 W/kg with ≤ 20% variation, only one repeated measurement is required to reaffirm that the results are not expected to have substantial variations, which may introduce significant compliance concerns. A second repeated measurement is required only if the measured result for the initial repeated measurement is within 10% of the SAR limit and vary by more than 20%, which are often related to device and measurement setup difficulties. The following procedures are applied to determine if repeated measurements are required.

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.

4 The Measurement System

DASY is an abbreviation of „Dosimetric Assessment System“ and describes a system that is able to determine the SAR distribution inside a phantom of a human being according to different standards. The DASY4 system consists of the following items as shown in Fig: 2. Additionally, Fig: 3 shows the equipment, similar to the installations in other laboratories.

- Fully compliant with all current measurement standards as stated in Fig. 4
- High precision robot with controller
- Measurement server (for surveillance of the robot operation and signal filtering)
- Data acquisition electronics DAE (for signal amplification and filtering)
- Field probes calibrated for use in liquids
- Electro-optical converter EOC (conversion from the optical into a digital signal)
- Light beam (improving of the absolute probe positioning accuracy)
- Two SAM phantoms filled with tissue simulating liquid
- DASY4 software
- SEMCAD

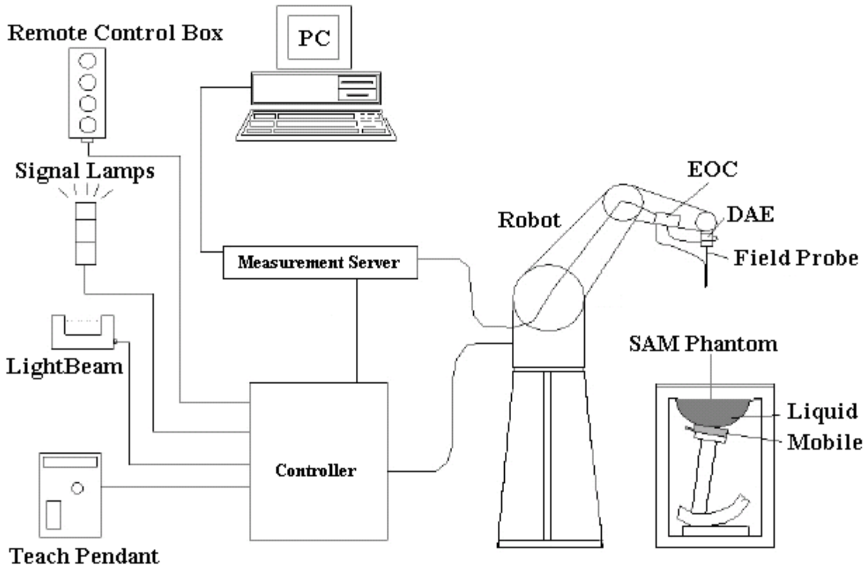

Fig. 2: The DASY4 measurement system.

Fig. 3: The measurement set-up with two SAM phantoms containing tissue simulating liquid.

The EUT operating at the maximum power level is placed by a non-metallic device holder (delivered from Schmid & Partner) in the above described positions at a shell phantom of a human being. The distribution of the electric field strength *E* is measured in the tissue simulating liquid within the shell phantom. For this miniaturised field probes with high sensitivity and low field disturbance are used. Afterwards the corresponding SAR values are calculated with the known electrical conductivity σ and the mass density ρ of the tissue in the SEMCAD FDTD software. The software is able to determine the averaged SAR values (averaging region 1 g or 10 g) for compliance testing.

The measurements are done by two scans: first a coarse scan determines the region of the maximum SAR, afterwards the averaged SAR is measured in a second scan within the shape of a cube.

4.1 Phantoms

TWIN SAM PHANTOM V4.0	
	Specific Anthropomorphic Mannequin defined in IEEE 1528 and IEC 62209-1 and delivered by Schmid & Partner Engineering AG. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. The details and the Certificate of conformity can be found in Fig. 5.
Shell Thickness	2 ± 0.2 mm (6 ± 0.2 mm at ear point)
Dimensions	Length: 1000 mm; Width: 500 mm Height: adjustable feet
Filling Volume	approx. 25 liters

ELI4 PHANTOM	
	Phantom for compliance testing of handheld and body-mounted wireless devices in the frequency range of 30 MHz to 6 GHz. The details and the Certificate of conformity can be found in Fig.6.
Shell Thickness	2.0 ± 0.2 mm (bottom plate)
Dimensions	Major axis: 600 mm Minor axis: 400 mm
Filling Volume	approx. 30 liters

4.2 E-Field-Probes

For the measurements the Dosimetric E-Field Probes ET3DV6R or EX3DV4 with following specifications are used. They are manufactured and calibrated in accordance with FCC and IEEE 1528-2013 recommendations annually by Schmid & Partner Engineering AG.

ET3DV6R	
Construction	Symmetrical design with triangular core Built-in optical fiber for surface detection system (ET3DV6 only) Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)
Dimensions	Overall length: 337 mm (Tip: 16 mm) Tip diameter: 6.8 mm (Body: 12 mm) Distance from probe tip to dipole centers: 2.7 mm
Frequency	10 MHz to 2.3 GHz Linearity: ± 0.2 dB (30 MHz to 2.3 GHz)
Directivity	Axial isotropy: ± 0.2 dB in TSL (rotation around probe axis) Spherical isotropy: ± 0.4 dB in TSL (rotation normal to probe axis)
Dynamic Range	5 µW/g to > 100 mW/g; Linearity: ± 0.2 dB
Calibration Range	450 MHz / 750 MHz / 900 MHz / 1750 MHz / 1900 MHz / 1950 MHz for head and body simulating liquid

EX3DV4	
Construction	Symmetrical design with triangular core Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)
Dimensions	Overall length: 337 mm (Tip: 20 mm) Tip diameter: 2.5 mm (Body: 12 mm) Typical distance from probe tip to dipole centers: 1 mm
Frequency	10 MHz to > 6 GHz Linearity: ± 0.2 dB (30 MHz to 6 GHz)
Directivity	Axial isotropy: ± 0.3 dB in TSL (rotation around probe axis) Spherical isotropy: ± 0.5 dB in TSL (rotation normal to probe axis)
Dynamic Range	10 µW/g to > 100 mW/g Linearity: ± 0.2 dB (noise: typically < 1 µW/g)
Calibration Range	1950 MHz / 2450 MHz / 2600 MHz / 3500 MHz / 5200 MHz / 5300 MHz / 5600 MHz / 5800 MHz for head and body simulating liquid

4.3 Measurement Procedure

The following steps are used for each test position:

- Establish a call with the maximum output power with a base station simulator. The connection between the mobile phone and the base station simulator is established via air interface.
- Measurement of the local E-field value at a fixed location (P1). This value serves as a reference value for calculating a possible power drift.
- Measurement of the SAR distribution with resolution settings for area scan and zoom scan according KDB 865664 D01 as shown in Table *3*.
- The used extrapolation and interpolation routines are all based on the modified Quadratic Shepard´s method [DASY4].
- Repetition of the E-field measurement at the fixed location (P1) and repetition of the whole procedure if the two results differ by more than ± 0.21dB.

<table>
<tr><th colspan="3"></th><th>≤ 3 GHz</th><th>≥ 3 GHz</th></tr>
<tr><td colspan="3">Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface</td><td>5 ± 1 mm</td><td>½·δ·ln(2) ± 0.5 mm</td></tr>
<tr><td colspan="3">Maximum probe angle from probe axis to phantom surface normal at the measurement location</td><td>30° ± 1°</td><td>20° ± 1°</td></tr>
<tr><td colspan="3" rowspan="2">Maximum area scan spatial resolution: Δx_{Area}, Δy_{Area}</td><td>≤ 2 GHz: ≤ 15 mm
2 - 3 GHz: ≤ 12 mm</td><td>3 - 4 GHz: ≤ 12 mm
4 - 6 GHz: ≤ 10 mm</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td colspan="3">Maximum zoom scan spatial resolution: ΔX_{Zoom}, ΔY_{Zoom}</td><td>≤ 2 GHz: ≤ 8 mm
2 - 3 GHz: ≤ 5 mm*</td><td>3 - 4 GHz: ≤ 5 mm*
4 - 6 GHz: ≤ 4 mm*</td></tr>
<tr><td rowspan="3">Maximum zoom scan spatial resolution, normal to phantom surface</td><td colspan="2">Uniform grid: $\Delta Z_{Zoom}(n)$</td><td>≤ 5 mm</td><td>3 - 4 GHz: ≤ 4 mm
4 - 5 GHz: ≤ 3 mm
5 - 6 GHz: ≤ 2 mm</td></tr>
<tr><td rowspan="2">graded grid</td><td>$\Delta Z_{Zoom}(1)$: between 1st two points closest to phantom surface</td><td>≤ 4 mm</td><td>3 - 4 GHz: ≤ 3 mm
4 - 5 GHz: ≤ 2.5 mm
5 - 6 GHz: ≤ 2 mm</td></tr>
<tr><td>$\Delta Z_{Zoom}(n>1)$: between subsequent points</td><td colspan="2">≤ 1.5· $\Delta Z_{Zoom}(n-1)$</td></tr>
<tr><td>Minimum zoom scan volume</td><td colspan="2">x, y, z</td><td>≥ 30 mm</td><td>3 - 4 GHz: ≥ 28 mm
4 - 5 GHz: ≥ 25 mm
5 - 6 GHz: ≥ 22 mm</td></tr>
<tr><td colspan="5">Note: δ is the penetration depth of a plane-wave at normal incidence to the tissue medium: see draft standard IEEE P1528-2011 for details.
* When zoom scan is required and the reported SAR from the area scan based 1-g SAR estimation procedures of KDB 447498 is ≤ 1.4 W/kg, ≤ 8 mm, ≤ 7 mm and ≤ 5 mm zoom scan resolution may be applied, respectively, for 2 GHz to 3 GHz, 3 GHz to 4 GHz and 4 GHz to 6 GHz</td></tr>
</table>

Table 3: Parameters for SAR scan procedures.

5 System Verification and Test Conditions

5.1 Date of Testing

Date of Testing			
Band	**Frequency [MHz]**	**Date of System Check**	**Date of SAR Measurement**
IEEE 802.11 / WLAN 2.4 GHz	2450	Nov. 15, 2017	Nov. 16, 2017

Table 4: Date of testing.

5.2 Environment Conditions

Environment Conditions		
Ambient Temperature[°C]	**Liquid Temperature [°C]**	**Humidity [%]**
22.0 ± 2	22.0 ± 2	40.0 ± 10
Notes: To comply with the required noise level (less than 12 mW/kg) periodically measurements without a DUT were conducted.		

Table 5: Environment Conditions.

5.3 Tissue Simulating Liquid Recipes

Tissue Simulating Liquid										
	Frequency Range [MHz]	**Water [%]**	**Sugar [%]**	**Cellulose [%]**	**Salt [%]**	**Preventol [%]**	**DGBE [%]**	**Triton X/100 [%]**	**TWEEN 80 [%]**	**GERMABEN [%]**
Head Tissue										
☐	300	37.1	56.1	0.9	5.8	0.2	-	-	-	-
☐	450	38.9	56.9	0.3	3.8	0.1	-	-	-	-
☐	835	40.3	57.9	0.2	1.4	0.2	-	-	-	-
☐	900	40.3	57.9	0.2	1.4	0.2	-	-	-	-
☐	1800	55.2	-	-	0.3	-	44.5	-	-	-
☐	1900	55.4	-	-	0.1	-	44.5	-	-	-
☐	2450	55.0	-	-	-	-	45.0	-	-	-
☐	2600	54.8	-	-	0.1	-	45.1	-	-	-
☐	5000 - 6000	65.5	-	-	-	-	17.2	17.25	-	-
Body Tissue										
☐	450	46.2	51.2	0.2	2.3	0.1	-	-	-	-
☐	835	52.4	45.0	1.0	1.5	0.1	-	-	-	-
☐	900	50.8	48.2	-	0.9	0.1	-	-	-	-
☐	1800	70.2	-	-	0.4	-	29.4	-	-	-
☐	1900	69.8	-	-	0.2	-	30.0	-	-	-
☒	2450	68.6	-	-	-	-	31.4	-	-	-
☐	2600	68.1	-	-	0.1	-	31.8	-	-	-
☐	5000 - 6000	79.7	-	-	-	-	-	-	20.0	0.3

Table 6: Recipes of the tissue simulating liquid.

5.4 Tissue Simulating Liquid Parameters

For the measurement of the following parameters the Speag DAK-3.5 dielectric probe kit is used, representing the open-ended coaxial probe measurement procedure.

Tissue Simulating Liquids									
Ambient Temperature(C) : 22.0 ± 2				Liquid Temperature(C) : 22.0 ± 2			Humidity(%) : 40.0 ± 10		
Band	**Date**	**Frequency**	**Channel**	**Permittivity**			**Conductivity**		
				Measured	**Target**	**Delta**	**Measured**	**Target**	**Delta**
		[MHz]		**ε'**	**ε'**	**+/- 5 [%]**	**σ [S/m]**	**σ [S/m]**	**+/- 5 [%]**
WLAN 2.4 GHz	Nov. 15, 2017	*2450.0*	*System Check*	*50.5*	*52.7*	*-4.2*	*2.02*	*1.95*	*3.8*
		2412.0	1	50.6	52.8	-4.1	1.98	1.91	3.6
		2437.0	6	50.5	52.7	-4.2	2.01	1.94	3.7
		2462.0	11	50.4	52.7	-4.3	2.04	1.96	3.6
Notes: Liquid depth is at least 15 cm for all frequency ranged measurements.									

Table 7: Parameters of the body tissue simulating liquid.

5.5 Simplified Performance Checking

The simplified performance check was realized using the dipole validation kit. The input power of the dipole antenna was 250 mW (CW) and it was placed under the flat part of the SAM phantom. The target and measured results are listed in the table 8 and shown in Appendix C - System Verification Plots. The target values were adopted from the calibration certificates found also in the appendix.

System Check Results										
Frequency [MHz]	**Dipole #SN**	**SAR Values with Body TSL [W/kg]**								
		Measured				**Target**		**Delta**		**Date**
		with 250 mW		**scaled to 1 W**		**normalized to 1 W**		**+/- 10 [%]**		
		1g	**10g**	**1g**	**10g**	**1g**	**10g**	**1g**	**10g**	
2450	D2450V2 #709	12.80	5.93	51.20	23.72	52.30	24.70	-2.10	-3.97	Nov. 15, 2017

Table 8: Dipole target and measured results.

6 SAR Measurement Conditions and Results

6.1 Test Conditions

Test Conditions					
Band	**TX Range [MHz]**	**RX Range [MHz]**	**Used Channels**	**Crest Factor**	**Phantom**
WLAN 2.4 GHz	2412.0 – 2462.0	2412.0 – 2462.0	1, 6, 11	1*	SAM Twin Phantom V4.0
Notes: * WiFi testing has been performed with configuration of100% continues wave with engineering test mode.					

Table 9: Used channels and crest factors during the test.

6.2 Tune-Up Information

Tune-Up Information			
Band	**CH / Mode**	**Frequency [MHz]**	**Max. Tune-Up Tolerance Limit [dBm]**
WLAN 2.4 GHz	b-mode	2412 – 2462	18.0
	g-mode		16.0
	n-mode HT20		14.0

Table 10: Maximum transmitting output power values declared by the manufacturer for WLAN.

6.3 Measured Output Power

6.3.1 WLAN 2.4 GHz Output Power

Measurements for IEEE 802.11 b/g/n has been performed with test software settings with power level supported by the device and provided by the manufacturer.

Max. Averaged Output Power (RMS) [dBm]										
Mode	**Frequency [MHz]**	**CH**	**PWL 17**							
			Data Rate [Mbit/s]							
			1		**2**		**5.5**		**11**	
2.4 GHz Range										
b	2412	1	16.8		17.1		17.3		17.0	
	2437	6	16.6		16.8		17.0		16.8	
	2462	11	16.7		16.9		17.0		16.8	
Mode	**Frequency [MHz]**	**CH**	**PWL 16**							
			Data Rate [Mbit/s]							
			6.0	**9**	**12**	**18**	**24**	**36**	**48**	**54**
g	2412	1	15.2	15.1	15.1	14.9	14.9	14.7	14.5	14.4
	2437	6	15.0	14.9	14.9	14.7	14.7	14.5	14.3	14.2
	2462	11	15.1	15.0	15.0	14.8	14.7	14.5	14.3	14.3
Mode	**Frequency [MHz]**	**CH**	**PWL 15**							
			MCS Index No.							
			MCS0	**MCS1**	**MCS2**	**MCS3**	**MCS4**	**MCS5**	**MCS6**	**MCS7**
n HT20	2412	1	13.9	13.9	13.6	13.5	13.4	13.2	13.2	13.1
	2437	6	13.8	13.6	13.5	13.2	13.1	13.0	12.9	12.8
	2462	11	13.8	13.7	13.6	13.5	13.3	13.2	13.1	13.0
Notes: SAR measurements have been performed on channel 1, 6 and 11 representing the worst case scenarios with the highest output power being.										

Table 11: Conducted output power values for IEEE 802.11 b/g/n.

6.4 Standalone SAR Test Exclusion

SAR test exclusion is determined for the EUT according to KDB 447498 D01v05 with 1g SAR exclusion thresholds for 100 MHz to 6GHz at test separation distances ≤ 50 mm determined by:

*[(max power of channel. incl. tune-up tolerance. mW) / (min test separation distance. mm)] * [√f(GHz)]*

≤ 3.0 for 1g SAR and ≤ 7.5 for 10g extremity SAR, where

• f(GHz) is the RF channel transmit frequency in GHz
• Power and distance are rounded to the nearest mW and mm before calculation
• The result is rounded to one decimal place for comparison

When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.

Standalone SAR Test Exclusion								
Mode	**Frequency [MHz]**	**Distance [mm]**	**Pavg [dBm]**	**Pavg [mW]**	**Calculated Values**	**Exclusion Threshold SAR 1g**	**Testing Exclusion**	**Testing Required**
WLAN	2450	5	18.0	63.10	19.8	≤ 7.5	NO	YES

Table 12: Standalone SAR test exclusion for the applicable transmitter.

When the standalone SAR test exclusion applies to an antenna that transmits simultaneously with other antennas the standalone SAR must be estimated according to KDB 447498 in order to determine simultaneous transmission SAR test exclusion:

- *(max. power of channel. including tune-up tolerance. mW)/(min. test separation distance. mm)]·[√f(GHz)/x] W/kg for test separation distances ≤ 50 mm;*

  where x = 7.5 for 1-g SAR and x = 18.75 for 10-g SAR

When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.

- *0.4 W/kg for 1g SAR and 1.0 W/kg for 10g SAR. when the test separation distance is > 50 mm*

6.5 SAR Results

The tables below contain the measured SAR values averaged over a mass of 1g. SAR assessment was conducted in the worst case configuration with output power values according to the table for output power values in Chapter 6.3. According KDB 447498 D01 V05, the reported SAR is the measured SAR value adjusted for maximum tune-up tolerance.

- Scaling Factor = tune-up limit power (mW) / RF power (mW)
- Reported SAR = measured SAR * scaling factor

Furthermore, testing of other required channels within the operating mode of frequency band is not required when the reported SAR for the mid-band or highest output power channel is ≤ 0.4 W/kg for transmission band ≥ 200 MHz.

Measured and Reported SAR [W/kg]												
Band / Mode	**Data Rate [Mbps]**	**Freq. [MHz]**	**CH**	**Test Position of EUT**	**Pic. No.**	**Measured SAR10g**	**Power Drift [dB]**	**Output Power [dBm]**		**Scaling Factor**	**Reported SAR10g**	**Plot No.**
								Measured	**Limit**			
IEEE 802.11 b	5.5	2437.0	6	Front	5	0.141	0.021	17.0	18.0	1.259	0.178	-
		2437.0	6	Right	6	0.028	-0.085	17.0	18.0	1.259	0.035	-
		2437.0	6	Left	7	0.026	0.084	17.0	18.0	1.259	0.033	-
		2412.0	1	Front	5	0.117	-0.001	17.3	18.0	1.175	0.137	-
		2462.0	11		5	0.163	0.098	17.0	18.0	1.259	0.205	-

Notes: SAR measurement have been performed on channel 1, 6 and 11 representing the worst case scenarios with the highest output power (refer to Section 6.3.1).

Since there is no possibility to use the engineering test mode and transmit the test signal continuously without a programming cable, SAR measurements have been performed with attached cable as shown on the pictures.

Table 13: SAR results for IEEE 802.11 band in extremity exposure configuration.

To control the output power stability during the SAR test the used DASY4 system calculates the power drift by measuring the e-field at the same location at the beginning and at the end of the measurement for each test position. These drift values can be found in the above tables labeled as: (Power Drift [dB]). This ensures that the power drift during one measurement is within 5%.

7 Administrative Measurement Data

7.1 Calibration of Test Equipment

Test Equipment Overview						
	Test Equipment	**Manufacturer**	**Model**	**Serial Number**	**Last Calibration**	**Next Calibration**
DASY System Components						
☒	Software Versions DASY4	SPEAG	V4.7	N/A	N/A	N/A
☒	Software Versions SEMCAD	SPEAG	V1.8	N/A	N/A	N/A
☐	Dosimetric E-Field Probe	SPEAG	ET3DV6R	1579	02/2016	02/2018
☐	Dosimetric E-Field Probe	SPEAG	ET3DV6R	1669	02/2017	02/2019
☐	Dosimetric E-Field Probe	SPEAG	EX3DV4	3536	09/2016	09/2018
☒	Dosimetric E-Field Probe	SPEAG	EX3DV4	3860	09/2017	09/2019
☒	Data Acquisition Electronics	SPEAG	DAE 3	335	02/2017	02/2019
☐	Data Acquisition Electronics	SPEAG	DAE 4	631	09/2016	09/2018
☐	Phantom	SPEAG	SAM	1059	N/A	N/A
☒	Phantom	SPEAG	SAM	1176	N/A	N/A
☐	Phantom	SPEAG	SAM	1340	N/A	N/A
☐	Phantom	SPEAG	SAM	1341	N/A	N/A
☐	Phantom	SPEAG	ELI4	1004	N/A	N/A
Dipoles						
☐	System Validation Dipole	SPEAG	D450V2	1014	03/2015	03/2018
☐	System Validation Dipole	SPEAG	D835V2	470	03/2015	03/2018
☐	System Validation Dipole	SPEAG	D900V2	006	11/2015	11/2018
☐	System Validation Dipole	SPEAG	D1640V2	311	09/2015	09/2018
☐	System Validation Dipole	SPEAG	D1750V2	1005	03/2015	03/2018
☐	System Validation Dipole	SPEAG	D1900V2	535	03/2015	03/2018
☒	System Validation Dipole	SPEAG	D2450V2	709	11/2015	11/2018
☐	System Validation Dipole	SPEAG	D2600V2	1019	11/2015	11/2018
☐	System Validation Dipole	SPEAG	D5GHzV2	1028	05/2017	05/2020
Material Measurement						
☒	Network Analyzer	Agilent	E5071C	MY46103220	08/2017	08/2019
☒	Dielectric Probe Kit	SPEAG	DAK-3.5	1234	01/2016	01/2018
☒	Thermometer	LKMelectronic	DTM3000	3511	01/2016	01/2018
Power Meters and Sensors						
☒	Power Meter	Anritsu	ML2488A	6K00002319	06/2016	06/2018
☒	Power Sensor	Anritsu	MA2490A	6K00002078	06/2016	06/2018
☒	Power Meter	Anritsu	ML2472A	002122	06/2016	06/2018
☒	Power Sensor	Anritsu	MA2472A	990365	06/2016	06/2018
RF Sources						
☐	Network Analyzer	Agilent	E5071C	MY46103220	08/2017	08/2019
☒	RF Generator	Rohde & Schwarz	SM300	100142	N/A	N/A
Amplifiers						
☒	Amplifier 10 MHz – 4200 MHz	Mini Circuits	ZHL-42-42W	D080504-1	N/A	N/A
☐	Amplifier 2 GHz – 6 GHz	Ciao Wireless	CA26-451	37452	N/A	N/A
Radio Tester						
☐	Radio Communication Tester	Anritsu	MT8815B	6200576536	04/2016	04/2018
☐	Radio Communication Tester	Anritsu	MT8820C	6200918336	04/2016	04/2018
Notes: Used test equipment for measurement is checked above.						

Table 14: Calibration of test equipment.

7.2 Uncertainty Assessment

Uncertainty Budget for SAR Measurements according to IEEE 1528-2013 (300 MHz - 6 GHz)								
Error Sources	**Uncertainty Value [± %]**	**Probability Distribution**	**Divisor**	**ci**	**ci**	**Standard Uncertainty [± %]**		**vi² or veff**
Measurement System				1g	10g	1g	10g	
Probe calibration	6.7	Normal	1	1	1	6.7	6.7	∞
Axial isotropy	0.3	Rectangular	√3	√0.5	√0.5	0.1	0.1	∞
Hemispherical isotropy	1.3	Rectangular	√3	√0.5	√0.5	0.5	0.5	∞
Boundary effects	1.0	Rectangular	√3	1	1	0.6	0.6	∞
Linearity	0.3	Rectangular	√3	1	1	0.2	0.2	∞
System detection limit	1.0	Rectangular	√3	1	1	0.6	0.6	∞
Modulation response	4.0	Rectangular	√3	1	1	2.3	2.3	∞
Readout electronics	0.3	Normal	1	1	1	0.3	0.3	∞
Response time	0.8	Rectangular	√3	1	1	0.5	0.5	∞
Integration time	1.4	Rectangular	√3	1	1	0.8	0.8	∞
RF ambient conditions - noise	3.0	Rectangular	√3	1	1	1.7	1.7	∞
RF ambient conditions - refl.	3.0	Rectangular	√3	1	1	1.7	1.7	∞
Probe positioner mech. tol.	0.4	Rectangular	√3	1	1	0.2	0.2	∞
Probe positioning	2.9	Rectangular	√3	1	1	1.7	1.7	∞
Algorithms for max SAR eval.	4.0	Rectangular	√3	1	1	2.3	2.3	∞
Test Sample Related								
Test sample positioning	2.9	Normal	1	1	1	2.9	2.9	145
Device holder uncertainty	3.6	Normal	1	1	1	3.6	3.6	5
SAR drift measurement (< 0.2 dB)	4.7	Rectangular	√3	1	1	2.7	2.7	∞
SAR scaling	2.0	Rectangular	√3	1	1	1.2	1.2	∞
Phantom and Set-up								
Phantom uncertainty	4.0	Rectangular	√3	1	1	2.3	2.3	∞
SAR correction for perm./cond.	1.9	Normal	1	1	0.84	1.9	1.6	∞
Liquid conductivity (meas.)	5.0	Normal	1	0.78	0.71	3.9	3.6	∞
Liquid permittivity (meas.)	5.0	Normal	1	0.23	0.26	1.2	1.3	∞
Liquid conductivity temp. unc.	2.9	Rectangular	√3	0.78	0.71	1.3	1.2	∞
Liquid permittivity temp. unc.	1.8	Rectangular	√3	0.23	0.26	0.2	0.3	∞
Combined Standard Uncertainty						11.1	11.0	
Coverage Factor for 95%						kp=2		
Expanded Standard Uncertainty						**22.2**	**21.9**	
Notes: *Worst case probe calibration uncertainty has been applied for all available probes and frequencies.*								

Table 15: Uncertainty budget for SAR measurements.

Uncertainty Budget for SAR System Validation according to IEEE 1528-2013 (300 MHz - 6 GHz)								
Error Sources	**Uncertainty Value [± %]**	**Probability Distribution**	**Divisor**	**ci**	**ci**	**Standard Uncertainty [± %]**		**vi² or veff**
Measurement System				1g	10g	1g	10g	
Probe calibration	6.7	Normal	1	1	1	6.7	6.7	∞
Axial isotropy	0.3	Rectangular	√3	1	1	0.1	0.1	∞
Hemispherical isotropy	1.3	Rectangular	√3	0	0	0.0	0.0	∞
Boundary effects	1.0	Rectangular	√3	1	1	0.6	0.6	∞
Linearity	0.3	Rectangular	√3	1	1	0.2	0.2	∞
System detection limit	1.0	Rectangular	√3	1	1	0.6	0.6	∞
Modulation response	0.0	Rectangular	√3	0	0	0.0	0.0	∞
Readout electronics	0.3	Normal	1	1	1	0.3	0.3	∞
Response time	0.0	Rectangular	√3	0	0	0.0	0.0	∞
Integration time	0.0	Rectangular	√3	0	0	0.0	0.0	∞
RF ambient conditions - noise	1.0	Rectangular	√3	1	1	0.6	0.6	∞
RF ambient conditions - refl.	1.0	Rectangular	√3	1	1	0.6	0.6	∞
Probe positioner mech. tol.	0.4	Rectangular	√3	1	1	0.2	0.2	∞
Probe positioning	2.9	Rectangular	√3	1	1	1.7	1.7	∞
Algorithms for max SAR eval.	4.0	Rectangular	√3	1	1	2.3	2.3	∞
Validation Dipole								
Dev. of exp. dipole from num.	5.0	Normal	1	1	1	5.0	5.0	∞
Input power and SAR drift (< 0.2 dB)	4.7	Rectangular	√3	1	1	2.7	2.7	∞
Dipole axis to liquid distance (< 2deg)	2.0	Rectangular	√3	1	1	1.2	1.2	∞
Phantom and Set-up								
Phantom uncertainty	4.0	Rectangular	√3	1	1	2.3	2.3	∞
SAR correction for perm./cond.	1.9	Normal	1	1	0.84	1.9	1.6	∞
Liquid conductivity (meas.)	5.0	Normal	1	0.78	0.71	3.9	3.6	∞
Liquid permittivity (meas.)	5.0	Normal	1	0.23	0.26	1.2	1.3	∞
Liquid conductivity temp. unc.	2.9	Rectangular	√3	0.78	0.71	1.3	1.2	∞
Liquid permittivity temp. unc.	1.8	Rectangular	√3	0.23	0.26	0.2	0.3	∞
Combined Standard Uncertainty						10.7	10.6	
Coverage Factor for 95%						kp=2		
Expanded Standard Uncertainty						**21.5**	**21.2**	
Notes: *Worst case probe calibration uncertainty has been applied for all available probes and frequencies.*								

Table 16: Uncertainty budget for SAR system validation.

8 Report History

Revision History				
Revision	**Description of Revision**	**Date**	**Revised Page**	**Revised By**
/	Initial Release	November 28, 2017	-	-
- 1 -	FCC ID and IC number changed, frequency range changed, channel 13 removed, highest reported SAR changed, plot for channel 11 added	March 29, 2018	1,4,14,15,17,27	AR

END OF THE SAR REPORT

Please refer to separated appendix file for the following data:

- Appendix A - Pictures
- Appendix B - SAR Distribution Plots
- Appendix C - System Verification Plots
- Appendix D – Certificates of Conformity
- Appendix E – Calibration Certificates for DAEs
- Appendix F – Calibration Certificates for E-Field Probes
- Appendix G – Calibration Certificates for Dipoles