



REPORT No. : SZ18030025S01

SAR TEST REPORT

APPLICANT : AsiaRF Co., Ltd

PRODUCT NAME : WIFI USB DONGLE

MODEL NAME : AW2405-AC1

BRAND NAME : N/A

FCC ID : TKZAW2405AC1

STANDARD(S) : 47 CFR §2.1093
IEEE 1528-2013

TEST DATE : 2018-03-19 to 2018-03-20

ISSUE DATE : 2018-03-23

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Change History		
Issue	Date	Reason for change
1.0	2018-03-23	First edition



1. Technical Information

Note: Provide by manufacturer.

1.1. Applicant and Manufacturer Information

Applicant:	AsiaRF Co., Ltd
Applicant Address:	3F, 215, Dehe Road, Yonghe Dist. New Taipei City 234, Taiwan
Manufacturer:	AsiaRF Co., Ltd
Manufacturer Address:	3F, 215, Dehe Road, Yonghe Dist. New Taipei City 234, Taiwan

1.2. Equipment Under Test (EUT) Description

Model Name:	AW2405-AC1		
Hardware Version:	N/A		
Software Version:	N/A		
Frequency Bands:	WLAN 2.4GHz Band: 2412 MHz ~ 2462 MHz WLAN 5.2GHz Band: 5180 MHz ~ 5240 MHz WLAN 5.8GHz Band: 5745 MHz ~ 5825 MHz		
Modulation Mode:	WLAN 2.4GHz 802.11b/g/n HT20/HT40	WLAN 5GHz 802.11a/n HT20/HT40	WLAN 5GHz 802.11ac VHT20/VHT40/ VHT80
The Highest Reported 1g-SAR(W/kg)	Hotspot	0.785 W/kg	1.6 W/kg

Note: For a more detailed description, please refer to specification or user's manual supplied by the applicant and/or manufacturer.



1.3. Photographs of the EUT

-	Frequency Band	Hotspot (Separation 10mm)
1g SAR (W/kg)		
WLAN	WLAN 2.4GHz	0.776
	WLAN 5GHz	0.785

1.4. Applied Reference Documents

Leading reference documents for testing:

No.	Identity	Document Title
1	47 CFR§2.1093	Radiofrequency Radiation Exposure Evaluation: Portable Devices
2	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
3	KDB 447498 D01v06	General RF Exposure Guidance
4	KDB 447498 D02v02	SAR Measurement Procedures for USB Dongle Transmitters
5	KDB 865664 D01v01r04	SAR Measurement 100 MHz to 6 GHz
6	KDB 865664 D02v01r02	SAR Reporting
7	KDB 248227 D01	SAR Guidance for IEEE 802.11 (Wi-Fi) Transmitters



2. Device Category and SAR Limits

Uncontrolled Environment

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure. The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity.

Limits for General Population/Uncontrolled Exposure (W/kg)

Whole-Body	Partial-Body	Hands, Wrists, Feet and Ankles
0.08	1.6	4.0

Controlled Environment

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation). In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. The exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

Limits for Occupational/Controlled Exposure (W/kg)

Whole-Body	Partial-Body	Hands, Wrists, Feet and Ankles
0.4	8.0	20.0

Note: This device belongs to portable device category because its radiating structure is allowed to be used within 20 centimeters of the body of the user. Limit for General Population/controlled exposure should be applied for this device, it is 8.0 W/kg as averaged over any 1 gram of tissue.



3. Specific Absorption Rate (SAR)

3.1. Introduction

SAR is related to the rate at which energy is absorbed per unit mass in an object exposed to a radio field. The SAR distribution in a biological body is complicated and is usually carried out by experimental techniques or numerical modeling. The standard recommends limits for two tiers of groups, occupational/controlled and general population/uncontrolled, based on a person's awareness and ability to exercise control over his or her exposure. In general, occupational/controlled exposure limits are Middle than the limits for general population/uncontrolled.

3.2. SAR Definition

The SAR definition is the time derivative (rate) of the incremental energy (dW) absorbed by(dissipated in) an incremental mass (dm) contained in a volume element (dv) of a given density. (ρ). The equation description is as below:

$$SAR = \frac{d}{dt} \left(\frac{dW}{dm} \right) = \frac{d}{dt} \left(\frac{dW}{\rho dv} \right)$$

SAR is expressed in units of Watts per kilogram (W/kg)

SAR measurement can be either related to the temperature elevation in tissue by,

$$SAR = C \left(\frac{\delta T}{\delta t} \right)$$

Where C is the specific heat capacity, δT is the temperature rise and δt the exposure duration, or related to the electrical field in the tissue by

$$SAR = \frac{\sigma |E|^2}{\rho}$$

Where ζ is the conductivity of the tissue, ρ is the mass density of the tissue and $|E|$ is the electrical field strength.

However for evaluating SAR of low power transmitter, electrical field measurement is typically applied.

4. SAR Measurement Setup

4.1. The Measurement System

Como SAR is a system that is able to determine the SAR distribution inside a phantom of human being according to different standards. The Como SAR system consists of the Following items:

- Main computer to control all the system
- 6 axis robot
- Data acquisition system
- Miniature E-field probe
- Phone holder
- Head simulating tissue

The Following figure shows the system.



The EUT under test operating at the maximum power level is placed in the phone holder, under the phantom, which is filled with head simulating liquid. The E-Field probe measures the electric field inside the phantom. The OpenSAR software computes the results to give a SAR value in a 1g or 10g mass.

4.2. Probe

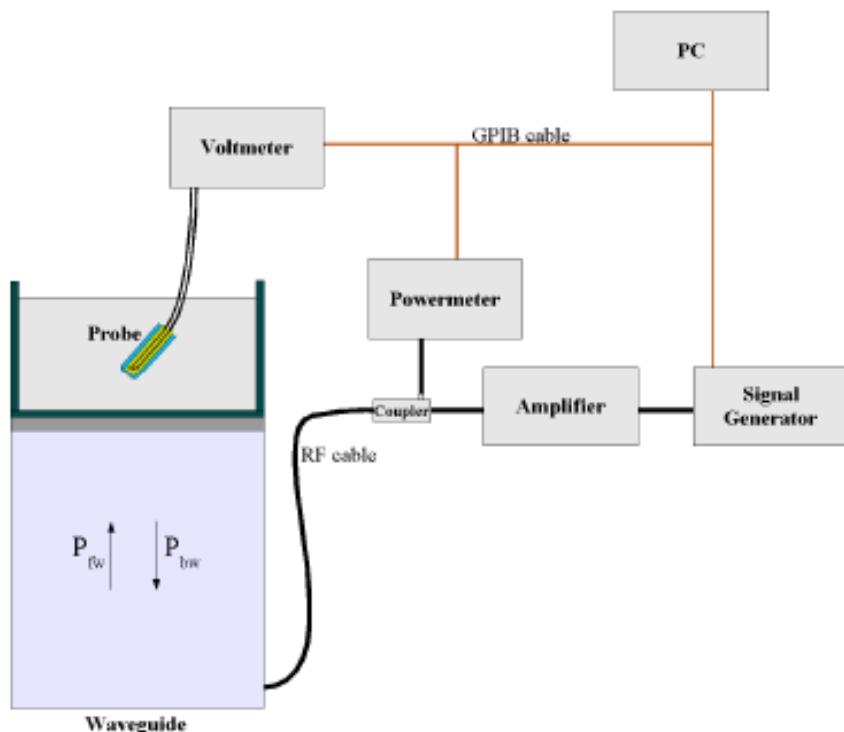
For the measurements the Specific Dosimetric E-Field Probe SN 37/08 EP80 with Following specifications is used

- Dynamic range: 0.01-100 W/kg
- Tip Diameter: 6.5 mm

- Distance between probe tip and sensor center: 2.5mm
- Distance between sensor center and the inner phantom surface: 4 mm
(repeatability better than +/- 1mm)
- Probe linearity: <0.25 dB
- Axial Isotropy: <0.25 dB
- Spherical Isotropy: <0.25 dB
- Calibration range: 835to 2500MHz for head & body simulating liquid.

Angle between probe axis (evaluation axis) and surface normal line: less than 30°

Probe calibration is realized, in compliance with CENELEC EN 62209 and IEEE 1528 std, with CALISAR, Antennessa proprietary calibration system. The calibration is performed with the EN 622091 annex technique using reference guide at the five frequencies.



$$SAR = \frac{4(P_{fw} - P_{bw})}{ab\delta} \cos^2\left(\pi \frac{y}{a}\right) e^{-(2z/\delta)}$$

Where :

- Pfw = Forward Power
- Pbw = Backward Power
- a and b = Waveguide dimensions
- δ = Skin depth



Keithley configuration:

Rate = Medium; Filter =ON; RDGS=10; FILTER TYPE =MOVING AVERAGE; RANGE AUTO

After each calibration, a SAR measurement is performed on a validation dipole and compared with aNPL calibrated probe, to verify it.

The calibration factors, CF(N), for the 3 sensors corresponding to dipole 1, dipole 2 and dipole 3 are:

$$CF(N) = SAR(N)/V_{lin}(N) \quad (N=1,2,3)$$

The linearised output voltage $V_{lin}(N)$ is obtained from the displayed output voltage $V(N)$ using

$$V_{lin}(N) = V(N) * (1 + V(N)/DCP(N)) \quad (N=1,2,3)$$

Where DCP is the diode compression point in mV.

4.3. Probe Calibration Process

Dosimetric Assessment Procedure

Each E-Probe/Probe Amplifier combination has unique calibration parameters. SATIMO Probe calibration procedure is conducted to determine the proper amplifier settings to enter in the probe parameters. The amplifier settings are determined for a given frequency by subjecting the probe to a known E-field density (1 mW/cm²) using an with CALISAR, Antenna proprietary calibration system.

Free Space Assessment Procedure

The free space E-field from amplified probe outputs is determined in a test chamber. This calibration can be performed in a TEM cell if the frequency is below 1 GHz and in a waveguide or other methodologies above 1 GHz for free space. For the free space calibration, the probe is placed in the volumetric center of the cavity and at the proper orientation with the field. The probe is rotated 360 degrees until the three channels show the maximum reading. The power density readings equates to 1 mW/cm².

Temperature Assessment Procedure

E-field temperature correlation calibration is performed in a flat phantom filled with the appropriate simulating head tissue. The E-field in the medium correlates with the temperature rise in the dielectric medium. For temperature correlation calibration a RF transparent thermistor-based temperature probe is used in conjunction with the E-field probe.

Where:

Δt = exposure time (30 seconds),

C = heat capacity of tissue (brain or muscle),

δT = temperature increase due to RF exposure.

SAR is proportional to $\Delta T/\Delta t$, the initial rate of tissue heating, before thermal diffusion takes place. The electric field in the simulated tissue can be used to estimate SAR by equating the thermally derived SAR to that with the E- field component.

Where:

ζ = simulated tissue conductivity,

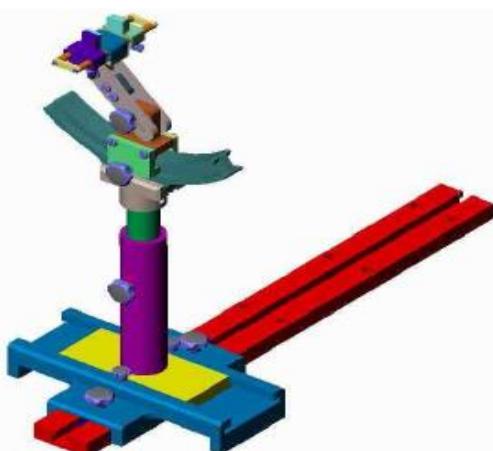
ρ = Tissue density (1.25 g/cm³ for brain tissue)

4.4. Phantom

For the measurements the Specific Anthropomorphic Mannequin (SAM) defined by the IEEE SCC-34/SC2 group is used. The phantom is a polyurethane shell integrated in a wooden table. The thickness of the phantom amounts to 2mm +/- 0.2mm. It enables the dosimetric evaluation of left and right phone usage and includes an additional flat phantom part for the simplified performance check. The phantom set-up includes a cover, which prevents the evaporation of the liquid.

4.5. Device Holder

The positioning system allows obtaining cheek and tilting position with a very good accuracy. In compliance with CENELEC, the tilt angle uncertainty is Middle than 1°.



Device holder

System Material	Permittivity	Loss Tangent
Delrin	3.7	0.005

5. Tissue Simulating Liquids

For SAR measurement of the field distribution inside the phantom, the phantom must be filled with Homogeneous tissue simulating liquid to a depth of at least 15cm. For head SAR testing, the liquid height from the ear reference point(ERP) of the phantom to the liquid top surface is larger than 15cm. For body SAR testing, the liquid height from the center of the flat phantom to the liquid top surface is larger than 15cm. The nominal dielectric values of the tissue simulating liquids in the phantom and the tolerance of 5% are listed in below table.

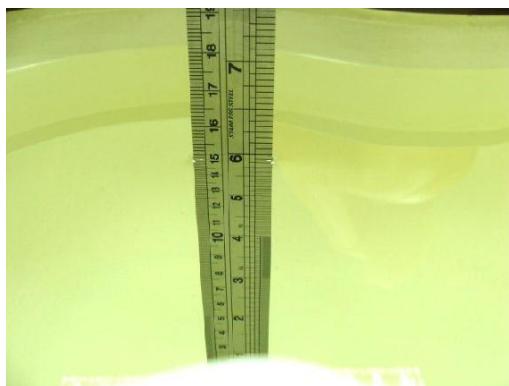


Fig 5.1 Photo of Liquid Height for Head SAR



Fig 5.2 Photo of Liquid Height for Body SAR

The following table gives the recipes for tissue simulating liquids

Frequency (MHz)	Water (%)	Sugar (%)	Cellulose (%)	Salt (%)	Preventol (%)	DGBE (%)	Conductivity (ζ)	Permittivity (ϵ_r)
Head								
750	41.1	57.0	0.2	1.4	0.2	0	0.89	41.9
835	40.3	57.9	0.2	1.4	0.2	0	0.90	41.5
1800, 1900, 2000	55.2	0	0	0.3	0	44.5	1.40	40.0
2450	55.0	0	0	0	0	45.0	1.80	39.2
2600	54.8	0	0	0.1	0	45.1	1.96	39.0

Simulating Liquid for 5GHz

Ingredients	(% by weight)
Water	64~78%
Mineral oil	11~18%
Emulsifiers	9~15%
Additives and Salt	2~3%

Note: Please refer to the validation results for dielectric parameters of each frequency band.



The dielectric properties of the tissue simulating liquids were verified prior to the SAR evaluation using an Agilent 85033E Dielectric Probe Kit and an Agilent Network Analyzer.

Table 1: Dielectric Performance of Tissue Simulating Liquid

Frequency (MHz)	Tissue Type	Liquid Temp. (°C)	Conductivity (σ)	Conductivity Target (σ)	Delta (σ) (%)	Limit (%)	Date
2450	MSL	21.8	1.970	1.95	1.03	±5	2018.3.20
5200	MSL	22.1	5.240	5.30	-1.13	±5	2018.3.19
5800	MSL	22.1	5.960	6.00	-0.67	±5	2018.3.19

Frequency (MHz)	Tissue Type	Liquid Temp. (°C)	Permittivity (ϵ_r)	Permittivity Target (ϵ_r)	Delta (ϵ_r) (%)	Limit (%)	Date
2450	MSL	21.8	52.880	52.70	0.34	±5	2018.3.20
5200	MSL	22.1	48.870	49.00	-0.27	±5	2018.3.19
5800	MSL	22.1	48.090	48.20	-0.23	±5	2018.3.19

6. Uncertainty Assessment

The component of uncertainty may generally be categorized according to the methods used to evaluate them. The evaluation of uncertainty by the statistical analysis of a series of observations is termed a Type A evaluation of uncertainty. The evaluation of uncertainty by means other than the statistical analysis of a series of observation is termed a Type B evaluation of uncertainty. Each component of uncertainty, however evaluated, is represented by an estimated standard deviation, termed standard uncertainty, which is determined by the positive square root of the estimated variance.

A Type A evaluation of standard uncertainty may be based on any valid statistical method for treating data. This includes calculating the standard deviation of the mean of a series of independent observations; using the method of least squares to fit a curve to the data in order to estimate the parameter of the curve and their standard deviations; or carrying out an analysis of variance in order to identify and quantify random effects in certain kinds of measurement.

A type B evaluation of standard uncertainty is typically based on scientific judgment using all of the relevant information available. These may include previous measurement data, experience, and knowledge of the behavior and properties of relevant materials and instruments, manufacturer's specification, data provided in calibration reports and uncertainties assigned to reference data taken from handbooks. Broadly speaking, the uncertainty is either obtained from an outdoor source or obtained from an assumed distribution, such as the normal distribution, rectangular or triangular distributions indicated in table below.

Uncertainty	Normal	Rectangular	Triangular	U-Shape
Multi-plying Factor ^(a)	$1/\kappa^{(b)}$	$1/\sqrt{3}$	$1/\sqrt{6}$	$1/\sqrt{2}$

(a) standard uncertainty is determined as the product of the multiplying factor and the estimated range of variations in the measured quantity
(b) κ is the coverage factor

(c) Table 6.1. Standard Uncertainty for Assumed Distribution

The combined standard uncertainty of the measurement result represents the estimated standard deviation of the result. It is obtained by combining the individual standard uncertainties of both Type A and Type B evaluation using the usual "root-sum-squares" (RSS) methods of combining standard deviations by taking the positive square root of the estimated variances.

Expanded uncertainty is a measure of uncertainty that defines an interval about the measurement result within which the measured value is confidently believed to lie. It is obtained by multiplying the combined standard uncertainty by a coverage factor. Typically, the coverage factor ranges from 2 to 3. Using a coverage factor allows the true value of a measured quantity to be specified with a defined probability within the specified uncertainty range. For purpose of this document, a coverage factor two is used, which



corresponds to confidence interval of about 95 %. The DASY uncertainty Budget is shown in the following tables.

a	b	c	d	e= f(d,k)	f	g	h= c*f/e	i= c*g/e	k
Uncertainty Component	Sec.	Tol (+- %)	Prob. Dist.	Div.	Ci (1g)	Ci (10g)	1g Ui (+-%)	10g Ui (+-%)	Vi
Measurement System									
Probe calibration	E.2.1	5.83	N	1	1	1	5.83	5.83	∞
Axial Isotropy	E.2.2	3.5	R	$\sqrt{3}$	1	1	2.02	2.02	∞
Hemispherical Isotropy	E.2.2	5.9	R	$\sqrt{3}$	1	1	3.41	3.41	∞
Boundary effect	E.2.3	1.0	R	$\sqrt{3}$	1	1	0.58	0.58	∞
Linearity	E.2.4	4.7	R	$\sqrt{3}$	1	1	2.71	2.71	∞
System detection limits	E.2.5	1.0	R	$\sqrt{3}$	1	1	0.58	0.58	∞
Readout Electronics	E.2.6	0.5	N	1	1	1	0.5	0.5	∞
Reponse Time	E.2.7	3.0	R	$\sqrt{3}$	1	1	3.0	3.0	∞
Integration Time	E.2.8	1.4	R	$\sqrt{3}$	1	1	0.81	0.81	∞
RF ambient Conditions	E.6.1	3.0	R	$\sqrt{3}$	1	1	1.73	1.73	∞
Probe positioner Mechanical Tolerance	E.6.2	1.4	R	$\sqrt{3}$	1	1	0.81	0.81	∞
Probe positioning with respect to Phantom Shell	E.6.3	1.4	R	$\sqrt{3}$	1	1	0.81	0.81	∞
Extrapolation, interpolation and integration Algoritms for Max. SAR Evaluation	E.5.2	2.3	R	$\sqrt{3}$	1	1	1.33	1.33	∞
Test sample Related									
Test sample positioning	E.4.2.1	2.6	N	1	1	1	2.6	2.6	N-1
Device Holder Uncertainty	E.4.1.1	3.0	N	1	1	1	3.0	3.0	N-1
Output power Power drift - SAR drift measurement	6.6.2	5.0	R	$\sqrt{3}$	1	1	2.89	2.89	∞
Phantom and Tissue Parameters									
Phantom Uncertainty (Shape and thickness tolerances)	E.3.1	4.0	R	$\sqrt{3}$	1	1	2.31	2.31	∞
Liquid conductivity - deviation from target value	E.3.2	2.0	R	$\sqrt{3}$	0.64	0.43	1.69	1.13	∞
Liquid conductivity - measurement uncertainty	E.3.3	2.5	N	1	0.64	0.43	3.20	2.15	M
Liquid permittivity - deviation	E.3.2	2.5	R	$\sqrt{3}$	0.6	0.49	1.28	1.04	∞



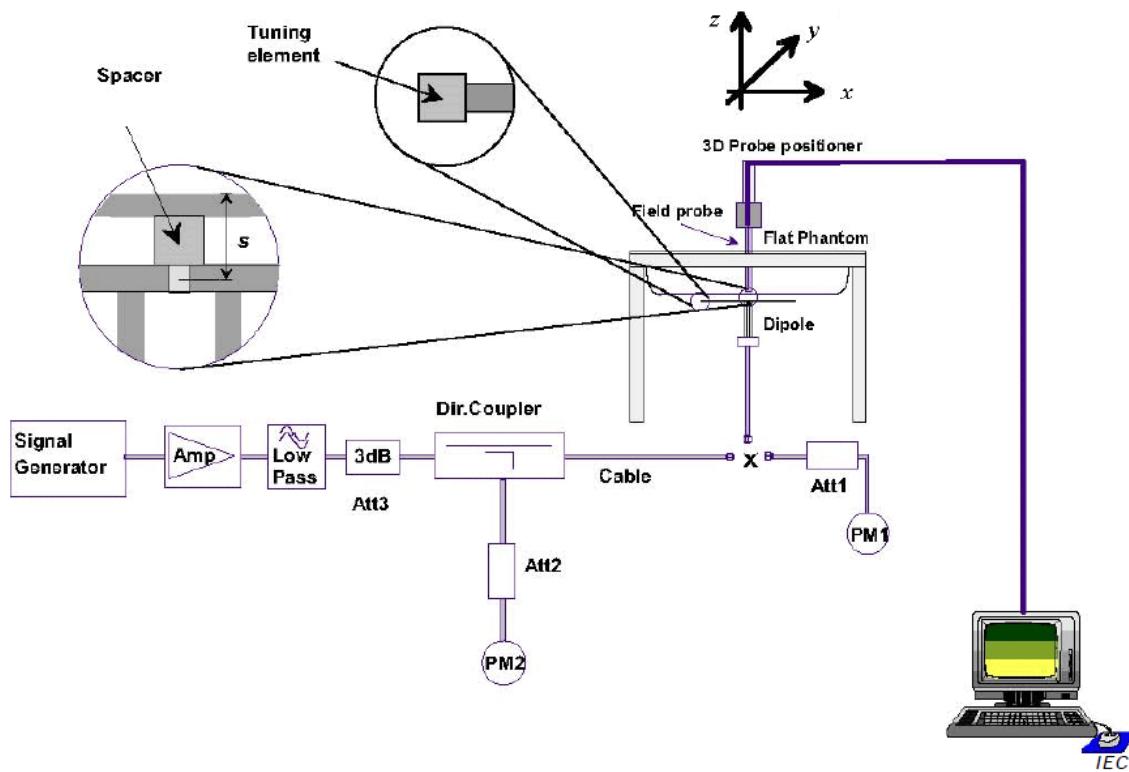
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from target value									
Liquid permittivity - measurement uncertainty	E.3.3	5.0	N	1	0.6	0.49	6.00	4.90	M
Liquid conductivity -temperature uncertainty	E.3.4		R	$\sqrt{3}$	0.78	0.41			∞
Liquid permittivity -temperature uncertainty	E.3.4		R	$\sqrt{3}$	0.23	0.26			∞
Combined Standard Uncertainty			RSS				11.55	12.07	
Expanded Uncertainty (95% Confidence interval)			K=2				± 23.20	± 24.17	

7. SAR Measurement Evaluation

7.1. System Setup

In the simplified setup for system evaluation, the DUT is replaced by a calibrated dipole and the power source is replaced by a continuous wave which comes from a signal generator. The calibrated dipole must be placed beneath the flat phantom section of the SAM twin phantom with the correct distance holder. The distance holder should touch the phantom surface with a light pressure at the reference marking and be oriented parallel to the long side of the phantom. The system check verifies that the system operates within its specifications. It is performed daily or before every SAR measurement. The system check uses normal SAR measurements in the flat section of the phantom with a matched dipole at a specified distance. The system verification setup is shown as below



The validation dipole is placed beneath the flat phantom with the specific spacer in place. The distance spacer is touch the phantom surface with a light pressure at the reference marking and be oriented parallel to the long side of the phantom. The power meter PM1 measures the forward power at the location of the system check dipole connector. The signal generator is adjusted for the desired forward power (250mW is used for 700MHz to 3GHz, 100mW is used for 3.5GHz to 6 GHz) at the dipole connector and the power meter PM2 is read at that level. After connecting the cable to the dipole, the signal generator is readjusted for the same reading at power meter.



7.2. Validation Results

After system check testing, the SAR result will be normalized to 1W forward input power and compared with the reference SAR value derived from validation dipole certificate report. The deviation of system check should be within 10 %.

<1g SAR>

Date	Frequency (MHz)	Tissue Type	Input Power (mW)	Probe S/N	Measured 1g SAR (W/kg)	Targeted 1g SAR (W/kg)	Normalized 1g SAR (W/kg)	Deviation (%)
2018.3.20	2450	MSL	100	37/08 EP80	5.08	50.93	50.8	-0.26
2018.3.19	5200	MSL	100	37/13 EPG193	16.28	163.36	162.8	-0.34
2018.3.19	5800	MSL	100	37/13 EPG193	17.70	177.10	177	-0.06

<10g SAR>

Date	Frequency (MHz)	Tissue Type	Input Power (mW)	Probe S/N	Measured 10g SAR (W/kg)	Targeted 10g SAR (W/kg)	Normalized 10g SAR (W/kg)	Deviation (%)
2018.3.20	2450	MSL	100	37/08 EP80	2.37	23.26	23.7	1.89
2018.3.19	5200	MSL	100	37/13 EPG193	5.96	57.09	59.6	4.40
2018.3.19	5800	MSL	100	37/13 EPG193	5.98	59.95	59.8	-0.25

Note: System checks the specific test data please see Annex C

8. Operational Conditions During Test

8.1. Body-worn Configurations

The body-worn configurations shall be tested with the supplied accessories (belt-clips, holsters, etc.) attached to the device in normal use configuration.

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.

Remark: Please refer to Appendix B for the test setup photos.

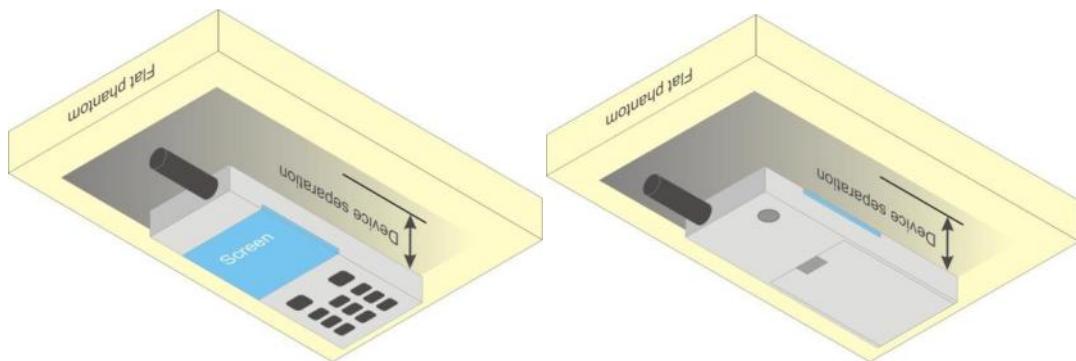
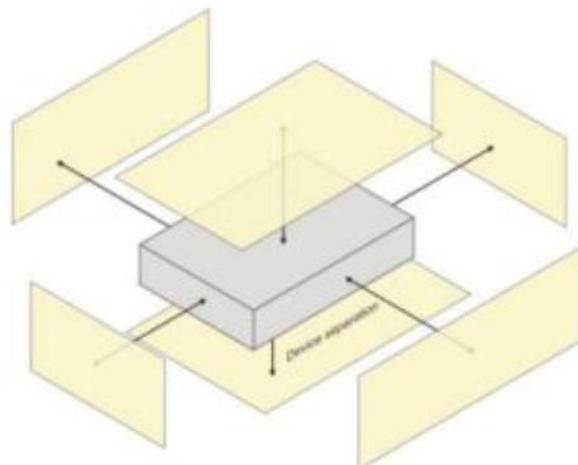


Illustration for Body-Worn Position

8.2. Hotspot Mode Exposure Position Conditions

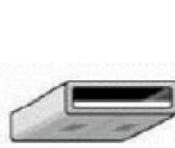
For handsets that support hotspot mode operations, with wireless router capabilities and various web browsing functions, the relevant hand and body exposure conditions are tested according to the hotspot SAR procedures in KDB 941225. A test separation distance of 10 mm is required between the phantom and all surfaces and edges with a transmitting antenna located within 25 mm from that surface or edge. When the form factor of a handset is smaller than 9 cm x 5 cm, a test separation distance of 5 mm (instead of 10 mm) is required for testing hotspot mode. When the separation distance required for body-worn accessory testing is larger than or equal to that tested for hotspot mode, in the same wireless mode and for the same surface of the phone, the hotspot mode SAR data may be used to support body-worn accessory SAR compliance for that particular configuration (surface).



8.3. USB Connector Orientations Implemented on Laptop Computers



(A)
Horizontal-Up



(B)
Horizontal-Down



(C)
Vertical-Front



(D)
Vertical-Back

Note: These are USB connector orientations on laptop computers; USB dongles have the reverse configuration for plugging into the corresponding laptop computers.

8.4. Simple Dongle Test Procedures

Test all USB orientations [see figure below: (A) Horizontal-Up, (B) Horizontal-Down, (C) Vertical-Front, and (D) Vertical-Back] with a device-to-phantom separation distance of 10mm as op.des described. These test orientations are intended for the exposure conditions found in typical laptop/notebook/netbook or tablet computers with either horizontal or vertical USB connector configurations at various locations in the keyboard section of the computer. Current generation portable host computers should be used to establish the required SAR measurement separation distance. The same test separation distance must be used to test all frequency bands and modes in each USB orientation. The typical Horizontal-Up USB connection (A), found in the majority of host computers, must be tested using an appropriate host computer. A host computer with either Vertical-Front (C) or Vertical-Back (D) USB connection should be used to test one of the vertical USB orientations. If a suitable host computer is not available for testing the Horizontal-Down (B) or the remaining Vertical



USB orientation, a high quality USB cable, 12 inches or less, may be used for testing these other orientations. It must be documented that the USB cable does not influence the radiating characteristics and output power of the transmitter.

8.5. Dongles with Swivel or Rotating Connectors

A swivel or rotating USB connector may enable the dongle to connect in different orientations to host computers. When the antenna is built-in within the housing of a dongle, a swivel or rotating connector may allow the antenna to assume different positions. The combination of these possible configurations must be considered to determine the SAR test requirements. When the antenna is located near the tip of a dongle, it may operate at closer proximity to users in certain connector orientations where dongle tip testing may be required.

The 5 mm test separation distance used for testing simple dongles has been established based on the overall host platform (laptop/notebook/netbook) and device variations, and varying user operating configurations and exposure conditions expected for a peripheral device. The same test distance should generally apply to dongles with swivel or rotating connectors. The procedures described for simple dongles should be used to position the four surfaces of the dongle at 5 mm from the phantom to evaluate SAR. At least one of the horizontal and one of the vertical positions should be tested using an applicable host computer. If the antenna is within 1 cm from the tip of the dongle (the end without the USB connector), the tip of the dongle should also be tested at 5 mm perpendicular to the phantom. For antennas located within 2.5 cm from the USB connector and if the dongle can be positioned at 45° to 90° from the horizontal position [(A) or (B)], testing in one or more of these configurations may need to be considered. A KDB inquiry should be submitted to determine the applicable test configurations.

9. SAR Measurement Procedure

9.1. General scan Requirements

Probe boundary effect error compensation is required for measurements with the probe tip closer than half a probe tip diameter to the phantom surface. Both the probe tip diameter and sensor offset distance must satisfy measurement protocols; to ensure probe boundary effect errors are minimized and the higher fields closest to the phantom surface can be correctly measured and extrapolated to the phantom surface for computing 1-g SAR. Tolerances of the post-processing algorithms must be verified by the test laboratory for the scan resolutions used in the SAR measurements, according to the reference distribution functions specified in IEEE Std 1528-2013.

		≤ 3 GHz	> 3 GHz
Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface		$5 \text{ mm} \pm 1 \text{ mm}$	$\frac{1}{2} \cdot \delta \cdot \ln(2) \text{ mm} \pm 0.5 \text{ mm}$
Maximum probe angle from probe axis to phantom surface normal at the measurement location		$30^\circ \pm 1^\circ$	$20^\circ \pm 1^\circ$
		$\leq 2 \text{ GHz: } \leq 15 \text{ mm}$ $2 - 3 \text{ GHz: } \leq 12 \text{ mm}$	$3 - 4 \text{ GHz: } \leq 12 \text{ mm}$ $4 - 6 \text{ GHz: } \leq 10 \text{ mm}$
Maximum area scan spatial resolution: $\Delta x_{\text{Area}}, \Delta y_{\text{Area}}$		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 \leq the corresponding x or y dimension of the test device with at least one measurement point on the test device.	
Maximum zoom scan spatial resolution: $\Delta x_{\text{Zoom}}, \Delta y_{\text{Zoom}}$		$\leq 2 \text{ GHz: } \leq 8 \text{ mm}$ $2 - 3 \text{ GHz: } \leq 5 \text{ mm}^*$	$3 - 4 \text{ GHz: } \leq 5 \text{ mm}^*$ $4 - 6 \text{ GHz: } \leq 4 \text{ mm}^*$
Maximum zoom scan spatial resolution, normal to phantom surface	uniform grid: $\Delta z_{\text{Zoom}}(n)$	$\leq 5 \text{ mm}$	$3 - 4 \text{ GHz: } \leq 4 \text{ mm}$ $4 - 5 \text{ GHz: } \leq 3 \text{ mm}$ $5 - 6 \text{ GHz: } \leq 2 \text{ mm}$
	graded grid	$\Delta z_{\text{Zoom}}(1): \text{ between } 1^{\text{st}} \text{ two points closest to phantom surface}$ $\Delta z_{\text{Zoom}}(n>1): \text{ between subsequent points}$	$\leq 4 \text{ mm}$ $\leq 1.5 \cdot \Delta z_{\text{Zoom}}(n-1) \text{ mm}$
Minimum zoom scan volume	x, y, z	$\geq 30 \text{ mm}$	$3 - 4 \text{ GHz: } \geq 28 \text{ mm}$ $4 - 5 \text{ GHz: } \geq 25 \text{ mm}$ $5 - 6 \text{ GHz: } \geq 22 \text{ mm}$
Note: δ is the penetration depth of a plane-wave at normal incidence to the tissue medium; see IEEE Std 1528-2013 for details.			
* When zoom scan is required and the <i>reported</i> SAR from the <i>area scan based 1-g SAR estimation</i> procedures of KDB Publication 447498 is $\leq 1.4 \text{ W/kg}$, $\leq 8 \text{ mm}$, $\leq 7 \text{ mm}$ and $\leq 5 \text{ mm}$ zoom scan resolution may be applied, respectively, for 2 GHz to 3 GHz, 3 GHz to 4 GHz and 4 GHz to 6 GHz.			



9.2. Measurement procedure

The following steps are used for each test position:

1. Establish a call with the maximum output power with a base station simulator. The connection between the mobile and the base station simulator is established via air interface.
2. Measurement of the local E-field value at a fixed location. This value serves as a reference value for calculating a possible power drift.
3. Measurement of the SAR distribution with a grid of 8 to 16mm * 8 to 16 mm and a constant distance to the inner surface of the phantom. Since the sensors cannot directly measure at the inner phantom surface, the values between the sensors and the inner phantom surface are extrapolated. With these values the area of the maximum SAR is calculated by an interpolation scheme.
4. Around this point, a cube of 30 * 30 * 30 mm or 32 * 32 * 32 mm is assessed by measuring 5 or 8 * 5 or 8 * 4 or 5 mm. With these data, the peak spatial-average SAR value can be calculated.

9.3. Description of interpolation/extrapolation scheme

The local SAR inside the phantom is measured using small dipole sensing elements inside a probe body. The probe tip must not be in contact with the phantom surface in order to minimize measurements errors, but the highest local SAR will occur at the surface of the phantom.

An extrapolation is used to determine these highest local SAR values. The extrapolation is based on a fourth-order least-square polynomial fit of measured data. The local SAR value is then extrapolated from the liquid surface with a 1mm step.

The measurements have to be performed over a limited time (due to the duration of the battery) so the step of measurement is high. It could vary between 5 and 8 mm. To obtain an accurate assessment of the maximum SAR averaged over 10 grams and 1 gram requires a very fine resolution in the three dimensional scanned data array.



10. Measurement of Conducted output power

1. Conducted average output power

	Mode	Channel	Frequency (MHz)	Average power (dBm)	Tune-Up Limit	Power Setting	Duty cycle %
WLAN 2.4GHz	802.11b 1Mbps	CH 1	2412	23.12	23.50	6	100
		CH 6	2437	23.03	23.50	6	100
		CH 11	2462	21.63	23.50	3	100
	802.11g 6Mbps	CH 1	2412	19.91	20.50	0B	100
		CH 6	2437	20.08	20.50	0B	100
		CH 11	2462	19.74	20.50	7.00	100
	802.11n-HT20 MCS0	CH 1	2412	18.00	18.50	7	100
		CH 6	2437	17.95	18.50	7	100
		CH 11	2462	17.77	18.50	7	100
	802.11n-HT40 MCS0	CH 3	2422	16.90	17.50	3.00	100
		CH 6	2437	16.38	17.50	3.00	100
		CH 9	2452	16.06	17.50	1.00	100

	Mode	Channel	Frequency (MHz)	Average power (dBm)	Tune-Up Limit	Power Setting	Duty cycle %
WLAN 5.2GHz	802.11a 6Mbps	CH 36	5180	14.98	15.50	17	100
		CH 44	5220	15.85	16.00	15	100
		CH 48	5240	13.19	13.50	15	100
	802.11n-HT20 MCS0	CH 36	5180	14.47	15.00	17	100
		CH 44	5220	16.40	16.50	18	100
		CH 48	5240	15.65	16.00	15	100
	802.11n-HT40 MCS0	CH 38	5190	10.22	10.50	0D	100
		CH 46	5230	16.45	17.00	17.00	100
	802.11ac-VHT80 MCS0	CH 42	5210	12.24	12.50	1A	100



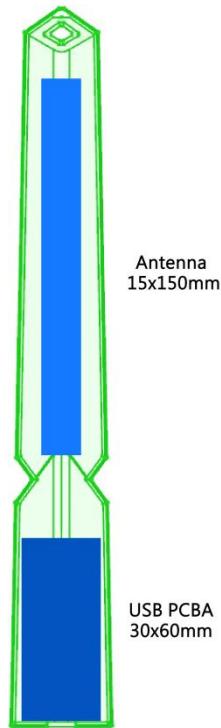
WLAN 5.8GHz	Mode	Channel	Frequency (MHz)	Average power (dBm)	Tune-Up Limit	Power Setting	Duty cycle %
	802.11a MCS0	CH 149	5745	19.09	19.50	0F	100
		CH 157	5785	18.58	19.00	0C	100
		CH 165	5825	19.58	20.00	0E	100
	802.11n-HT20 MCS0	CH 149	5745	18.78	19.00	0F	100
		CH 157	5785	18.09	18.50	0C	100
		CH 165	5825	19.33	20.00	0F	100
	802.11n-HT40 MCS0	CH 151	5755	18.99	19.50	0F	100
		CH 159	5795	18.64	19.00	17.00	100
	802.11ac-VHT80 MCS0	CH 155	5775	20.70	21.00	1C	100

Scaling Factor calculation

Band	Tune-up power tolerance(dBm)
WLAN 2.4GHz	Max output power = 13.0 ± 0.5
WLAN 5.2 GHz	Max output power = 16.5 ± 0.5
WLAN 5.8 GHz	Max output power = 20.5 ± 0.5

11. Hotspot Evaluation

10.1 EUT Antenna Location



10.2 SAR Test Exclusion Consider Table

According with FCC KDB 447498 D01, Appendix A, <SAR Test Exclusion Thresholds for 100 MHz –6 GHz and ≤50 mm> Table, this Device SAR test configurations consider as following:

Band	Horizontal-Up	Horizontal-Down	Vertical-Front	Vertical-Back
Distance	<10mm	<10mm	<10mm	<10mm
WLAN 2.4GHz	Yes	Yes	Yes	Yes
WLAN 5GHz	Yes	Yes	Yes	Yes

Note:

1. Maximum power is the source-based time-average power and represents the maximum RF output



power among production units.

2. Per KDB 447498 D01, for larger devices, the test separation distance of adjacent edge configuration is determined by the closest separation between the antenna and the user.
3. Per KDB 447498 D01, standalone SAR test exclusion threshold is applied; If the distance of the antenna to the user is < 5mm, 5mm is used to determine SAR exclusion threshold
4. Per KDB 447498 D01, the 1-g and 10-g SAR test exclusion thresholds for 100 MHz to 6 GHz at test separation distances \leq 50 mm are determined by:

$[(\text{max. power of channel, including tune-up tolerance, mW}) / (\text{min. test separation distance, mm})] \cdot [\sqrt{f(\text{GHz})}] \leq 3.0 \text{ for 1-g SAR and } \leq 7.5 \text{ for 10-g extremity SAR}$

- a. $f(\text{GHz})$ is the RF channel transmit frequency in GHz
- b. Power and distance are rounded to the nearest mW and mm before calculation
- c. The result is rounded to one decimal place for comparison
- d. For < 50 mm distance, we just calculate mW of the exclusion threshold value (3.0) to do compare.

This formula is $[3.0] / [\sqrt{f(\text{GHz})}] \cdot (\text{min. test separation distance, mm}) = \text{exclusion threshold of mW}$.

5. Per KDB 447498 D01, at 100 MHz to 6 GHz and for test separation distances > 50 mm, the SAR test exclusion threshold is determined according to the following:

- a. $[\text{Threshold at 50 mm in step 1} + (\text{test separation distance} - 50 \text{ mm}) \cdot (f(\text{MHz})/150)] \text{ mW}$, at 100 MHz to 1500 MHz
- b. $[\text{Threshold at 50 mm in step 1} + (\text{test separation distance} - 50 \text{ mm}) \cdot 10] \text{ mW}$ at > 1500 MHz and ≤ 6 GHz

6. Per KDB 248227 D01 SAR is not required for the following 2.4 GHz OFDM conditions.

- a. When the reported SAR of the highest measured maximum output power channel for the exposure configuration is ≤ 0.8 W/kg, no further SAR testing is required for 802.11b DSSS in that exposure configuration.
- b. When the reported SAR is > 0.8 W/kg, SAR is required for that exposure configuration using the next highest measured output power channel. When any reported SAR is > 1.2 W/kg, SAR is required for the third channel

7. Per KDB 248227 D01SAR is not required for the following 2.4 GHz OFDM conditions.

- a. When KDB Publication 447498 D01 SAR test exclusion applies to the OFDM configuration.
- b. When the highest reported SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output



12. Test Results List

Summary of Measurement Results

Plot No.	Band	Mode	Test Position	Gap (mm)	Ch.	Freq. (MHz)	Average Power (dBm)	Tune-Up Limit (dBm)	Tune-up Scaling Factor	Measured 1g SAR (W/kg)	Reported 1g SAR (W/kg)
1#	WLAN2.4GHz	802.11b 1Mbps	Front	10mm	1	2412	23.12	23.5	1.091	0.711	0.776
	WLAN2.4GHz	802.11b 1Mbps	Back	10mm	1	2412	23.12	23.5	1.091	0.442	0.482
	WLAN2.4GHz	802.11b 1Mbps	Right	10mm	1	2412	23.12	23.5	1.091	0.212	0.231
	WLAN2.4GHz	802.11b 1Mbps	Left	10mm	1	2412	23.12	23.5	1.091	0.278	0.303
<hr/>											
2#	WLAN5GHz	802.11n-HT40 MCS0	Front	10mm	46	5230	16.45	17	1.135	0.692	0.785
	WLAN5GHz	802.11n-HT40 MCS0	Back	10mm	46	5230	16.45	17	1.135	0.601	0.682
	WLAN5GHz	802.11n-HT40 MCS0	Right	10mm	46	5230	16.45	17	1.135	0.680	0.772
	WLAN5GHz	802.11n-HT40 MCS0	Left	10mm	46	5230	16.45	17	1.135	0.287	0.326
<hr/>											
	WLAN5GHz	802.11ac-VHT80 MCS0	Front	10mm	155	5775	20.70	21	1.072	0.106	0.114
	WLAN5GHz	802.11ac-VHT80 MCS0	Back	10mm	155	5775	20.70	21	1.072	0.113	0.121
3#	WLAN5GHz	802.11ac-VHT80 MCS0	Right	10mm	155	5775	20.70	21	1.072	0.186	0.199
	WLAN5GHz	802.11ac-VHT80 MCS0	Left	10mm	155	5775	20.70	21	1.072	0.065	0.07

Note:

1. The attaching "cable" is positioned flatly, and stretched so as not to influence radiating characteristics during testing
2. The product is used with cable and far away from users in general condition, so it is tested below 10mm for distance. (See PAG procedure)



13. Repeated SAR Measurement

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.

Repeated measurement is not required when the original highest measured SAR is $< 0.80 \text{ W/kg}$; steps 2) through 4) do not apply.

1. Per KDB 865664 D01v01r04, for each frequency band, repeated SAR measurement is required only when the measured SAR is $\geq 0.8 \text{ W/kg}$. When the original highest measured SAR is $\geq 0.80 \text{ W/kg}$, repeat that measurement once.
2. 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 $\geq 1.45 \text{ W/kg}$ ($\sim 10\%$ from the 1-g SAR limit).
3. Perform a third repeated measurement only if the original, first or second repeated measurement is $\geq 1.5 \text{ W/kg}$ and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20 .
4. Per KDB 865664 D01v01r04, if the extremity repeated SAR is necessary, the same procedures should be adapted for measurements according to extremity and occupational exposure limits by applying a factor of 2.5 for extremity exposure and a factor of 5 for occupational exposure to the corresponding SAR thresholds.
5. The ratio is the difference in percentage between original and repeated measured SAR.
6. All measurement SAR result is scaled-up to account for tune-up tolerance and is compliant.



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14. Simultaneous SAR

According to the EUT character, WLAN 2.4GHz and WLAN 5GHz share the same antenna, and cannot transmit simultaneously, so the simultaneous transmission is not required in this report.

— END OF REPORT —



Annex A General Information

1. Identification of the Responsible Testing Laboratory

Company Name:	Shenzhen Morlab Communications Technology Co., Ltd.
Department:	Morlab Laboratory
Address:	FL.3, Building A, FeiYang Science Park, No.8 LongChang Road, Block 67, BaoAn District, ShenZhen, GuangDong Province, P. R. China
Responsible Test Lab Manager:	Mr. Su Feng
Telephone:	+86 755 36698555
Facsimile:	+86 755 36698525

2. Identification of the Responsible Testing Location

Name:	Shenzhen Morlab Communications Technology Co., Ltd. Morlab Laboratory
Address:	FL.3, Building A, FeiYang Science Park, No.8 LongChang Road, Block 67, BaoAn District, ShenZhen, GuangDong Province, P. R. China

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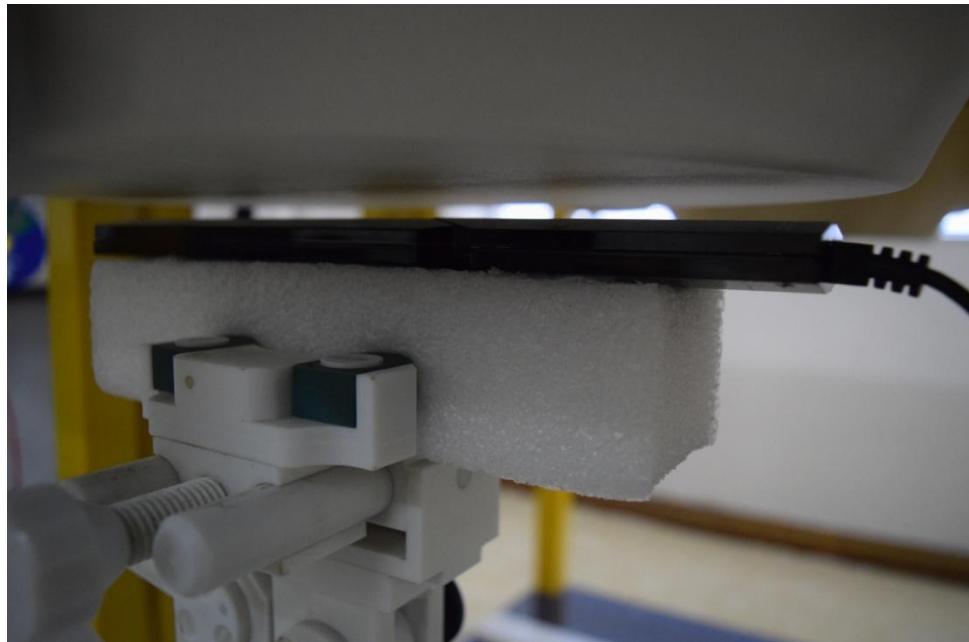
**3. List of Test Equipments**

No.	Instrument	Type	Cal. Date	Cal. Due
1	PC	Dell (Pentium IV 2.4GHz, SN:X10-23533)	(n.a)	(n.a)
2	Network Emulator	Agilent (8960, SN:10752)	2017-5-24	1year
3	Network Emulator	Rohde&Schwarz (CMW500,SN:124534)	2017-5-25	1year
4	Network Analyzer	Agilent(E5071B ,SN:MY42404762)	2017-5-25	1year
5	Voltmeter	Keithley (2000, SN:1000572)	2017-7-8	1year
6	Synthetizer	Rohde&Schwarz (SML_03, SN:101868)	2017-8-24	1year
7	Signal Generator	Rohde&Schwarz (SMP_02)	2017-7-8	1year
8	Power Amplifier	PRANA (Ap32 SV125AZ)	2017-7-8	1year
9	Power Meter	Agilent (E4416A, SN:MY45102093)	2017-7-8	1year
10	Power Sensor	Agilent (N8482A, SN:MY41091706)	2017-7-8	1year
11	Power Meter	Rohde&Schwarz (NRVD, SN:101066)	2017-7-8	1year
12	Power Sensor	MA2411B	2017-7-8	1year
13	Directional coupler	Giga-tronics(SN:1829112)	2017-7-24	1year
14	Probe	Satimo (SN:SN 37/08 EP80)	2017-7-5	1year
15	Probe	Satimo (SN:SN 37/13 EPG193)	2017-7-5	1year
16	Dielectric Probe Kit	Agilent (85033E)	2017-7-5	1year
17	Phantom	Satimo (SN:SN_36_08_SAM62)	N/A	N/A
18	Liquid	Satimo(Last Calibration: 2018-03-19 to 2018-03-20)	N/A	N/A
19	Dipole 2450MHz	Satimo (SN 30/13 DIP2G450-263)	2017-7-5	1year
20	Dipole 5-6GHz	Satimo (SN 41/12 WGA21)	2017-7-5	1year
21	Thermo meter	KTJ(mode-01)	2017-5-10	1year

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Annex B Test Setup Photos

1. Face Side_10mm

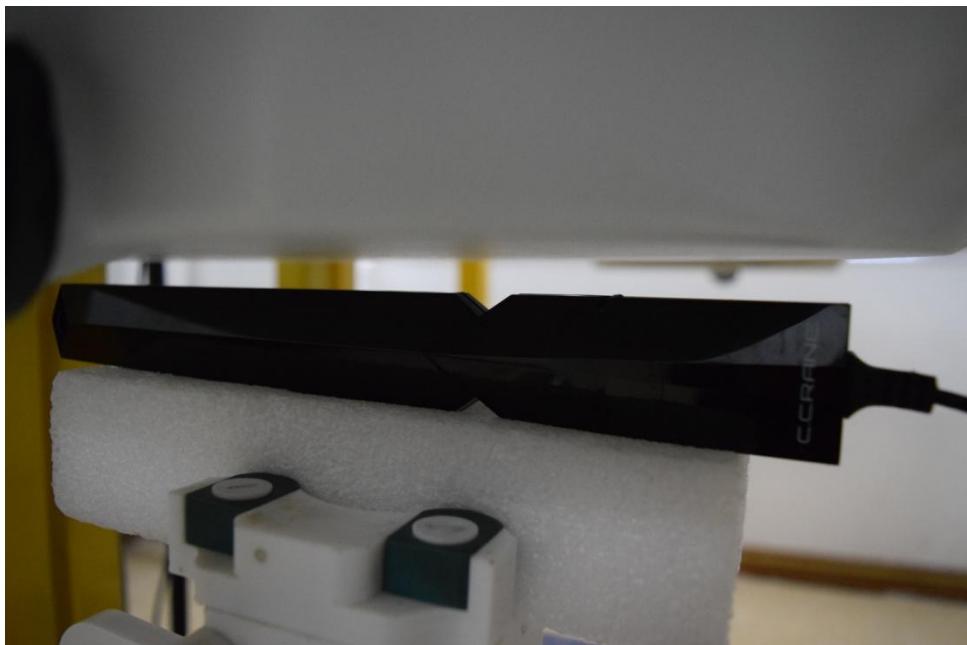


2. Back Side_10mm

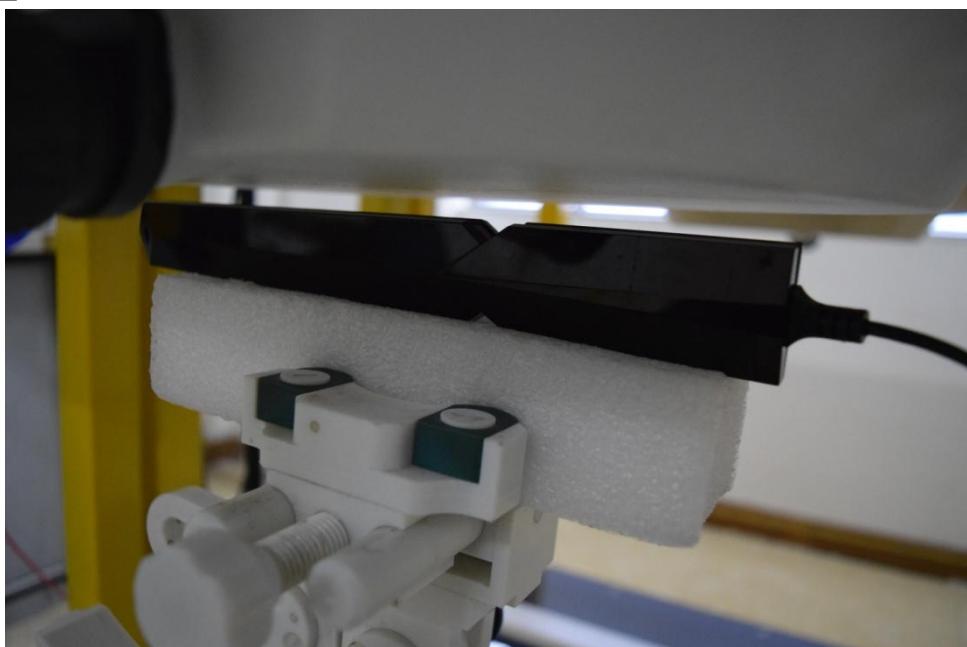


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3. Right Side_10mm



4. Left Side_10mm



5. Test Setup Photos



Annex C Plots of System Performance Check

System Performance Check Data(2450MHz Body)

Type: Phone measurement (Complete)

Area scan resolution: dx=8mm,dy=8mm

Zoom scan resolution: dx=8mm, dy=8mm, dz=5mm

Date of measurement: 2018.03.20

Measurement duration: 13 minutes 31 seconds

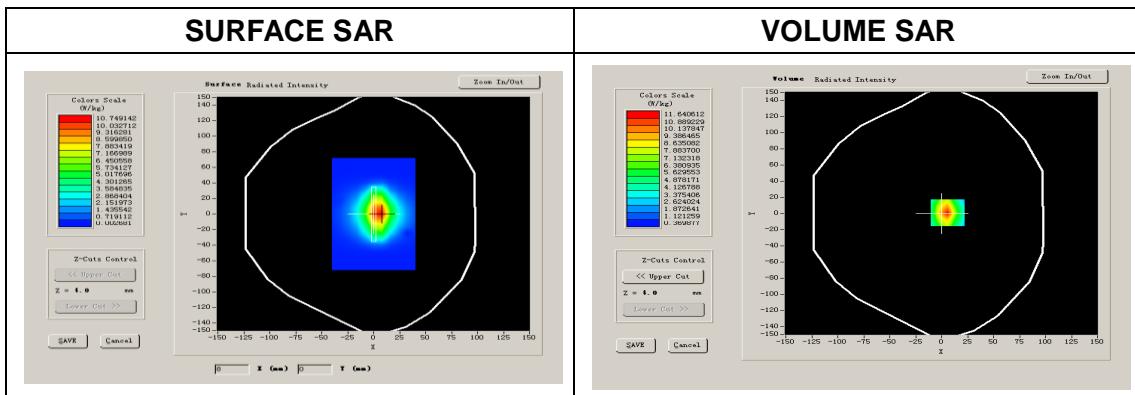
A. Experimental conditions.

Phantom File	surf_sam_plan.txt
Phantom	Flat
Device Position	
Band	2450MHz
Channels	
Signal	CW

B. SAR Measurement Results

Band SAR

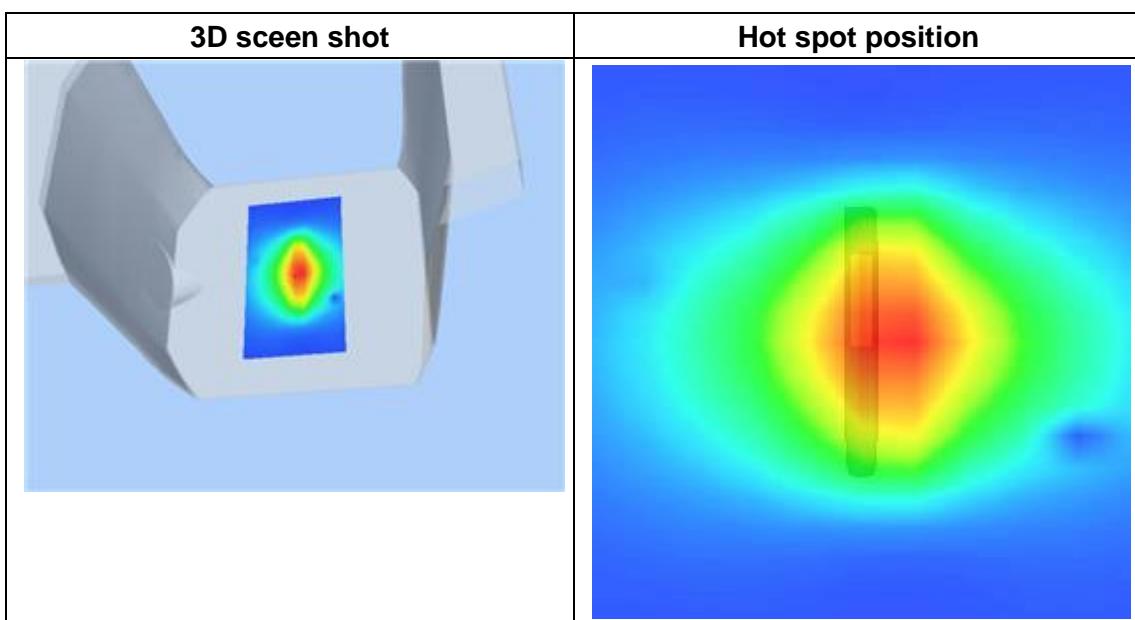
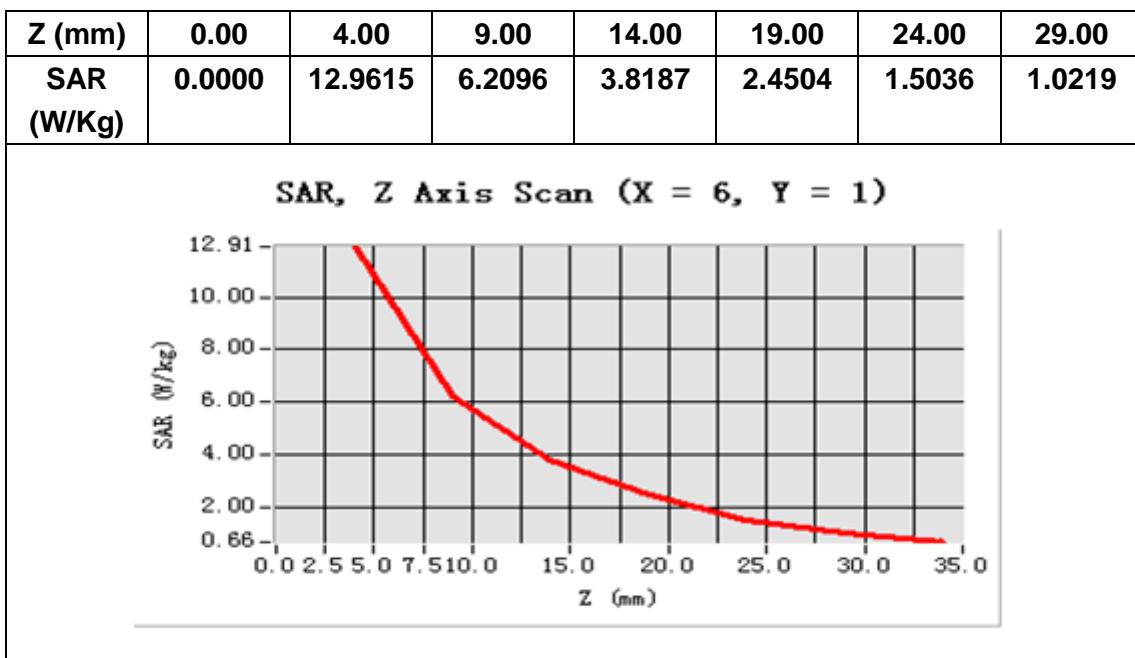
Frequency (MHz)	2450.000000
Relative permittivity (real part)	52.884446
Conductivity (S/m)	1.966143
Power Drift (%)	1.080000
Ambient Temperature:	22.0°C
Liquid Temperature:	21.8°C
ConvF:	4.93
Crest factor:	1:1



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Maximum location: X=6.00, Y=1.00

SAR 10g (W/Kg)	2.377250
SAR 1g (W/Kg)	5.081074

Z Axis Scan


**System Performance Check Data(5200MHz Body)**

Type: Phone measurement (Complete)

Area scan resolution: dx=8mm,dy=8mm

Zoom scan resolution: dx=4mm, dy=4mm, dz=2mm

Date of measurement: 2018.03.19

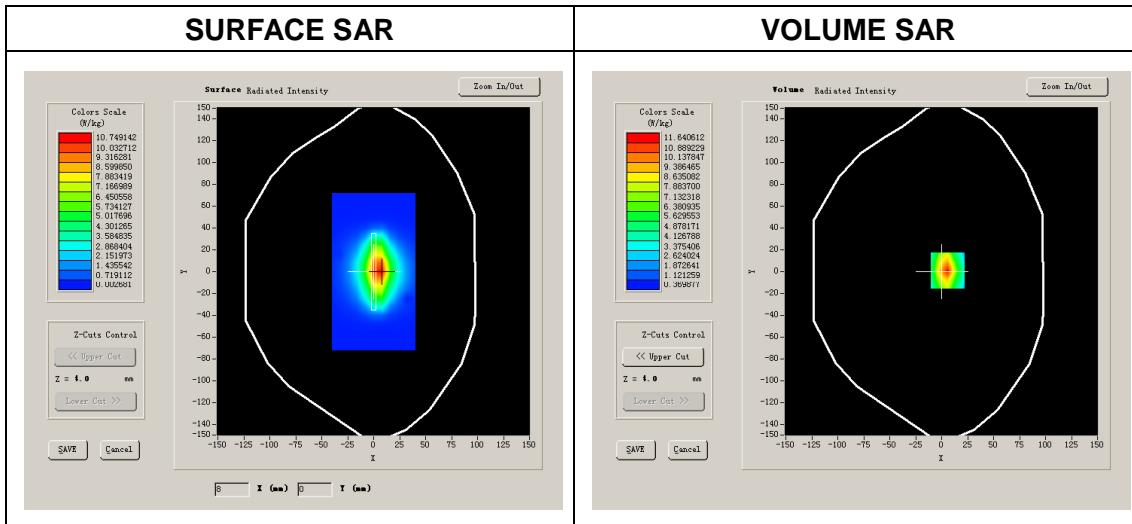
Measurement duration: 13 minutes 27 seconds

A. Experimental conditions.

Phantom File	surf_sam_plan.txt
Phantom	Validation plane
Device Position	
Band	5200MHz
Channels	
Signal	CW

B. SAR Measurement Results**Band SAR**

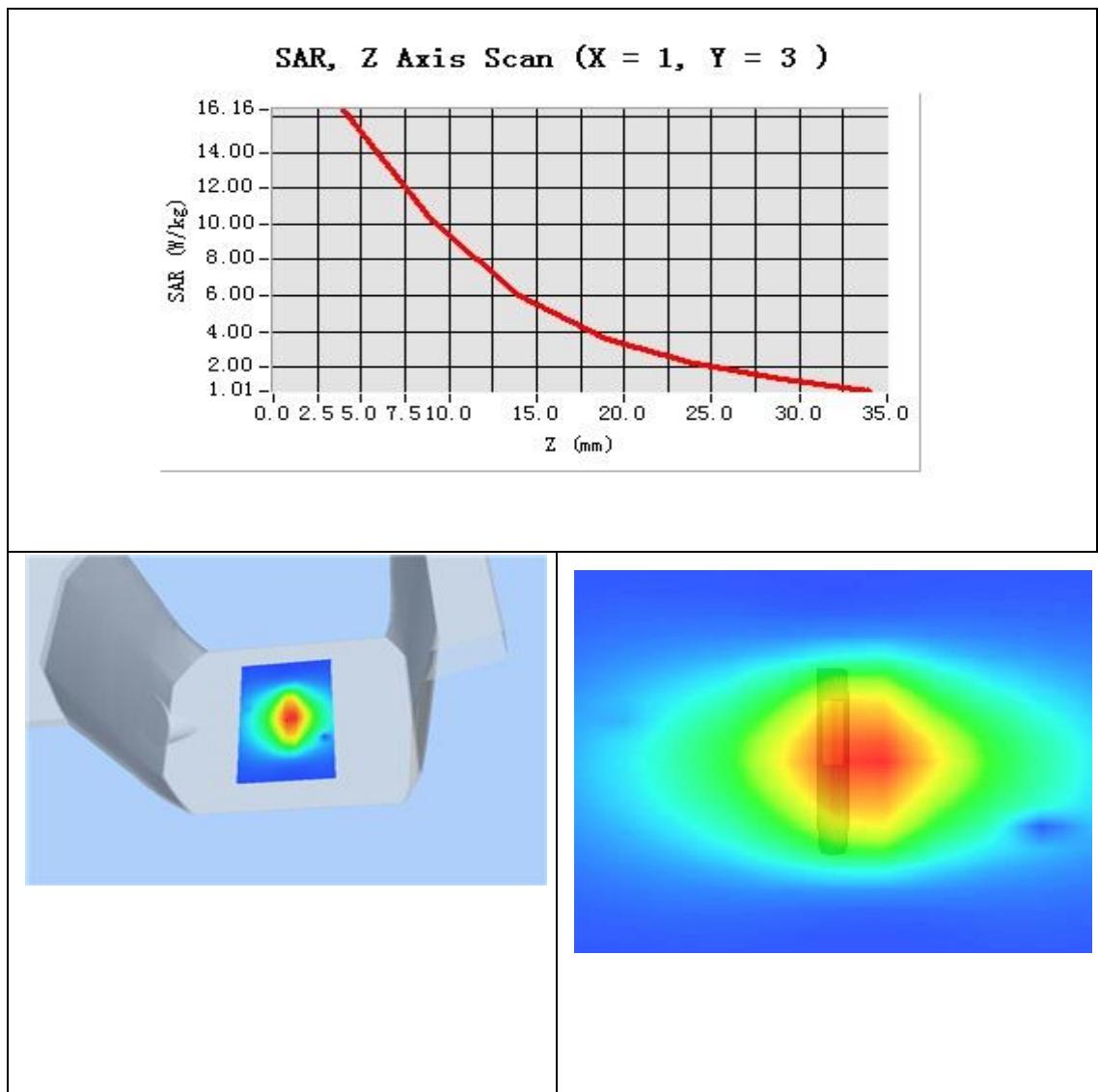
Frequency (MHz)	5200.000000
Relative permittivity (real part)	48.873014
Conductivity (S/m)	5.243260
Power Drift (%)	2.310000
Ambient Temperature:	22.9°C
Liquid Temperature:	22.1°C
ConvF:	22.11
Crest factor:	1:1



Maximum location: X=1.00, Y=3.00

SAR 10g (W/Kg)	5.694355
SAR 1g (W/Kg)	16.28442

Z Axis Scan



**System Performance Check Data(5800MHz Body)**

Type: Phone measurement (Complete)

Area scan resolution: dx=8mm,dy=8mm

Zoom scan resolution: dx=4mm, dy=4mm, dz=2mm

Date of measurement: 2018.03.20

Measurement duration: 13 minutes 27 seconds

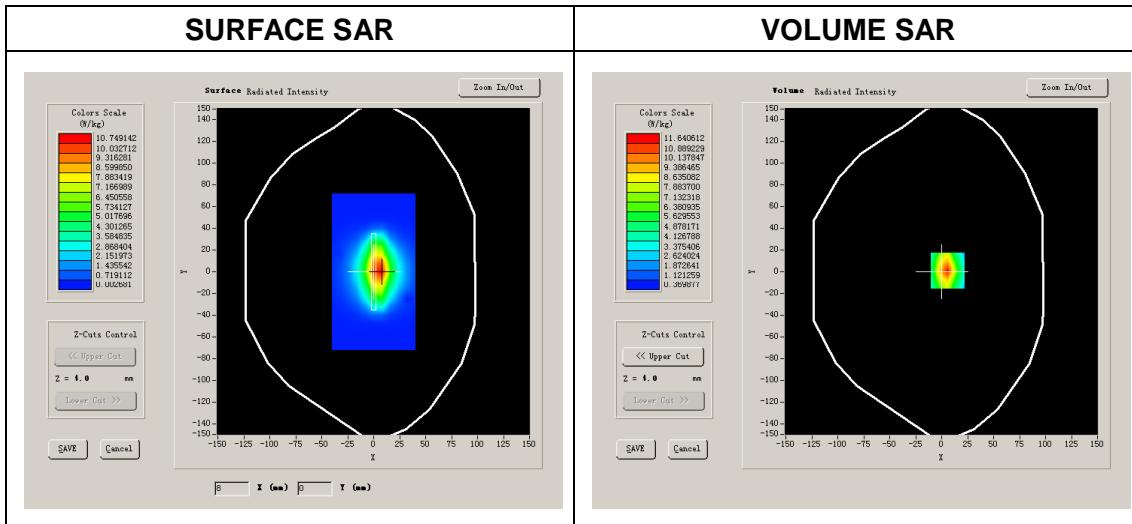
A. Experimental conditions.

Phantom File	surf_sam_plan.txt
Phantom	Validation plane
Device Position	
Band	5800MHz
Channels	
Signal	CW

B. SAR Measurement Results

Band SAR

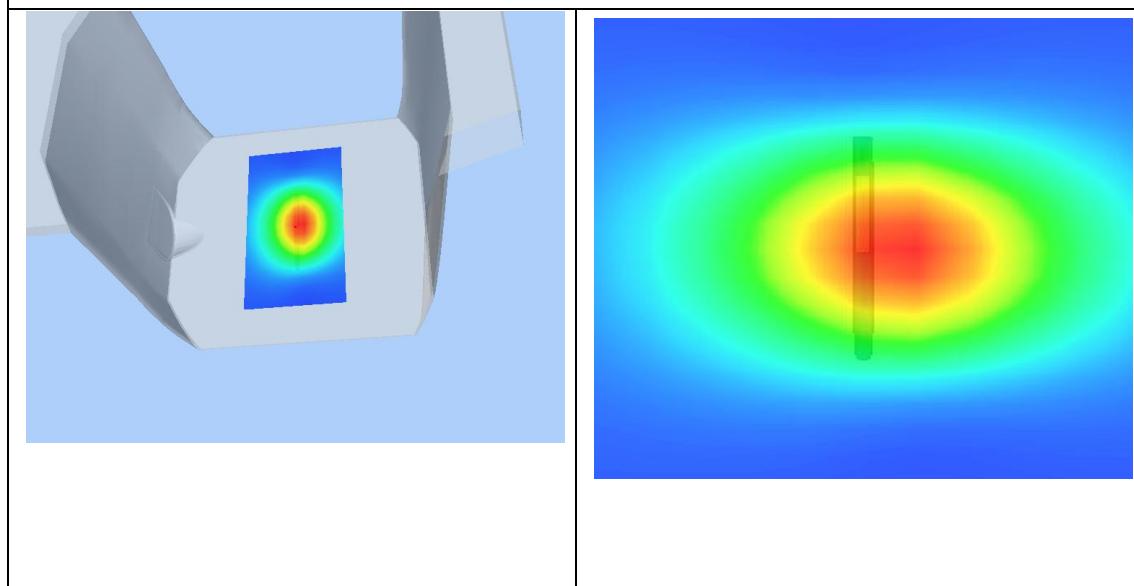
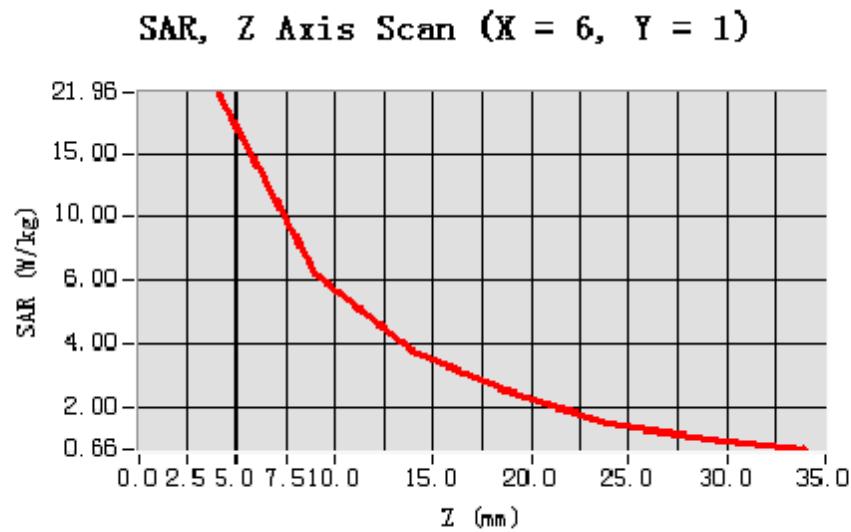
Frequency (MHz)	5800.000000
Relative permittivity (real part)	48.093428
Conductivity (S/m)	5.960716
Power Drift (%)	1.260000
Ambient Temperature:	22.9°C
Liquid Temperature:	22.1°C
ConvF:	23.02
Crest factor:	1:1



Maximum location: X=-6.00, Y=-1.00

SAR 10g (W/Kg)	5.9824634
SAR 1g (W/Kg)	17.695290

Z Axis Scan



Annex D Plots of Maximum SAR Test Results

MEASUREMENT 1

Type: Phone measurement (Complete)

Area scan resolution: $dx=10\text{mm}, dy=10\text{mm}$

Zoom scan resolution: $dx=4\text{mm}, dy=4\text{mm}, dz=2\text{mm}$

Date of measurement: 2018.03.19

Measurement duration: 17 minutes 8 seconds

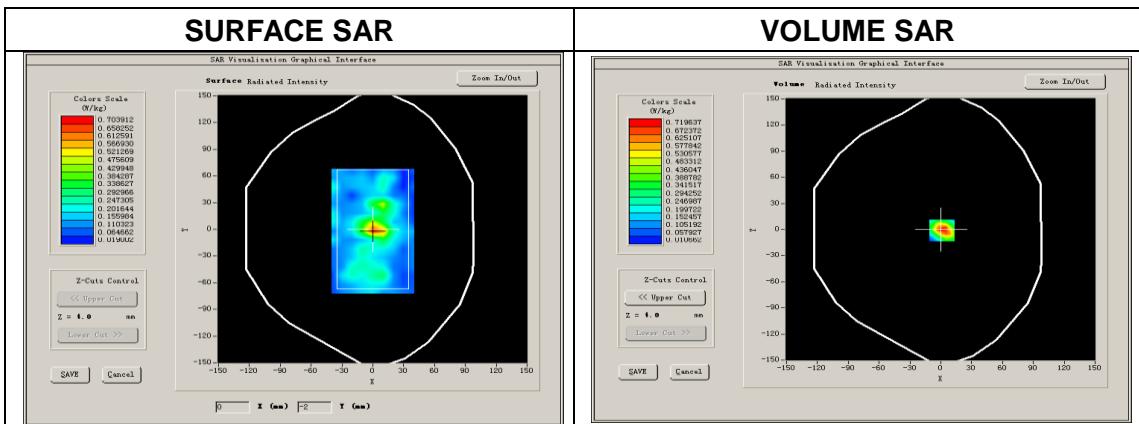
A. Experimental conditions.

<u>Phantom File</u>	<u>surf_sam_plan.txt</u>
<u>Phantom</u>	<u>Flat</u>
<u>Device Position</u>	<u>Body</u>
<u>Band</u>	<u>IEEE 802.11n-HT40 U-NII</u>
<u>Channels</u>	<u>High</u>
<u>Signal</u>	<u>OFDM</u>

B. SAR Measurement Results

Middle Band SAR (Channel 46):

Frequency (MHz)	5230.000000
Relative permittivity (real part)	48.680000
Conductivity (S/m)	5.302130
Power drift (%)	-1.330000
Ambient Temperature:	22.9°C
Liquid Temperature:	22.1°C
ConvF:	22.11
Crest factor:	1:1

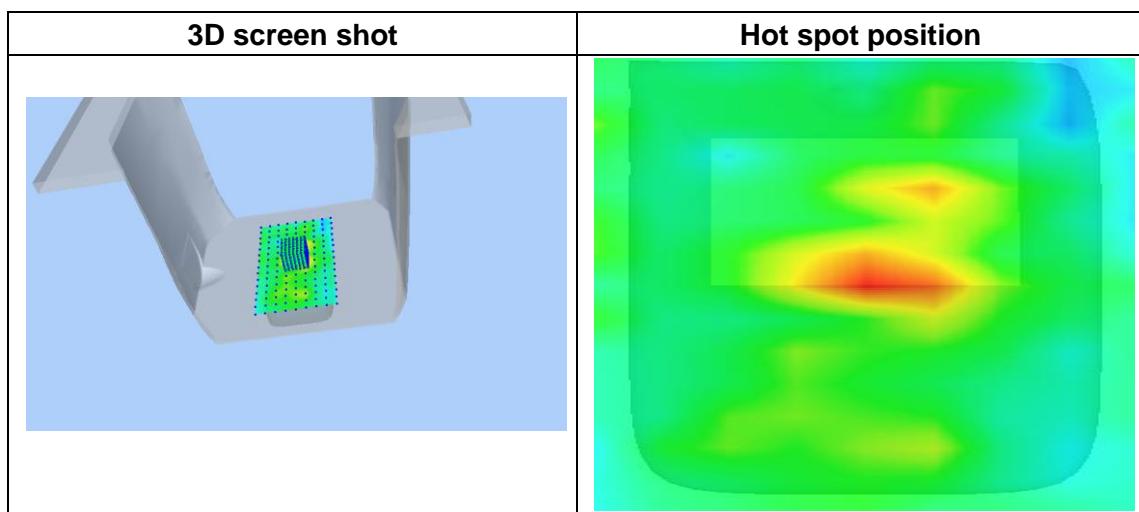
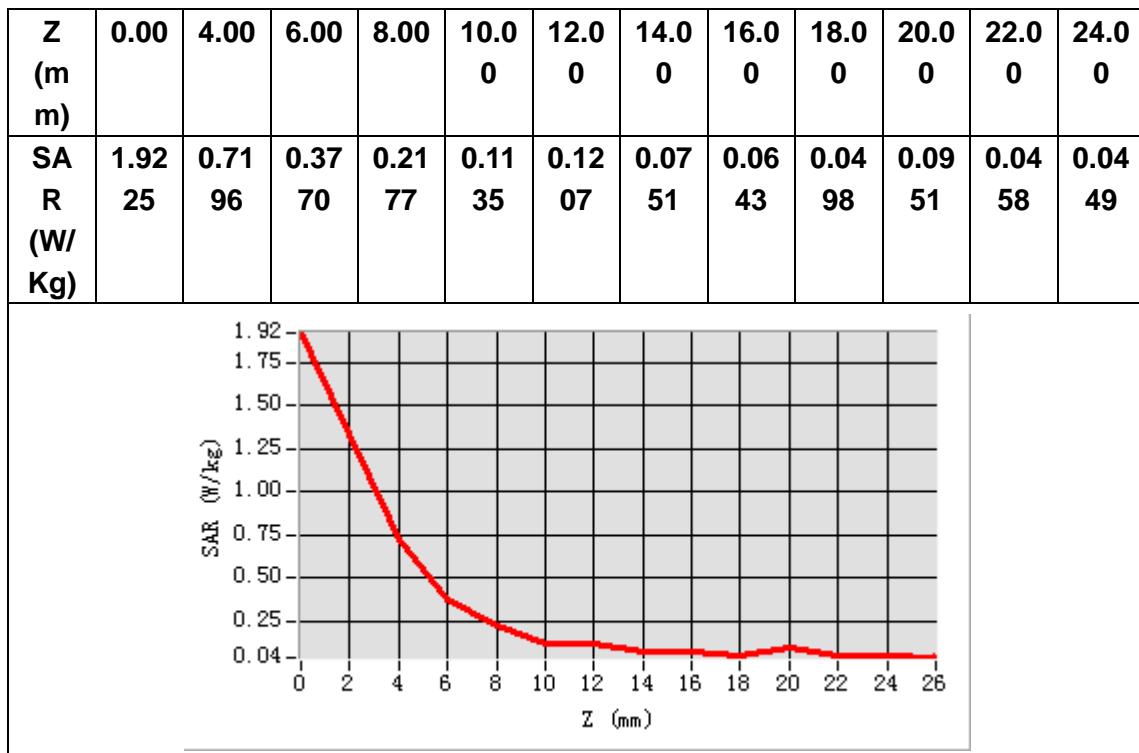


NOTE: This document is issued by MORLAB, the test report shall not be reproduced except in full without prior written permission of the company. The test results apply only to the particular sample(s) tested and to the specific tests carried out which is available on request for validation and information confirmed at our website.

Maximum location: X=1.00, Y=-1.00

SAR Peak: 1.91 W/kg

SAR 10g (W/Kg)	0.292048
SAR 1g (W/Kg)	0.691708



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MEASUREMENT 2

Type: Phone measurement (Complete)

Area scan resolution: dx=8mm,dy=8mm

Zoom scan resolution: dx=4mm, dy=4mm, dz=2mm

Date of measurement: 2018.03.19

Measurement duration: 17 minutes 9 seconds

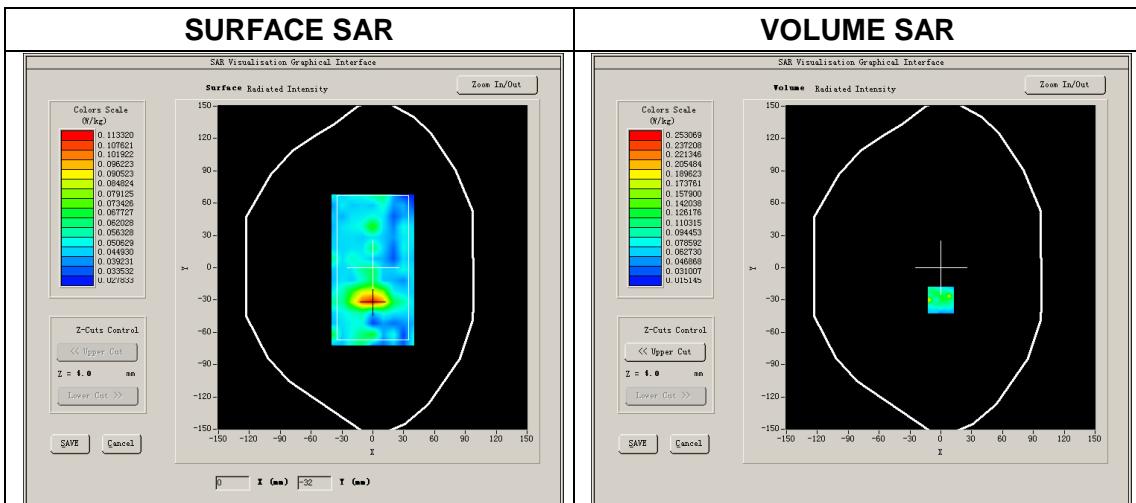
A. Experimental conditions.

<u>Phantom File</u>	<u>surf sam plan.txt</u>
<u>Phantom</u>	<u>Flat</u>
<u>Device Position</u>	<u>Body</u>
<u>Band</u>	<u>IEEE 802.11ac-VHT80 U-NII</u>
<u>Channels</u>	<u>High</u>
<u>Signal</u>	<u>OFDM</u>

B. SAR Measurement Results

Higher Band SAR (Channel 155):

Frequency (MHz)	5775.000000
Relative permittivity (real part)	48.275002
Conductivity (S/m)	5.957514
Power drift (%)	1.580000
Ambient Temperature:	22.9°C
Liquid Temperature:	22.1°C
ConvF:	23.02
Crest factor:	1:1

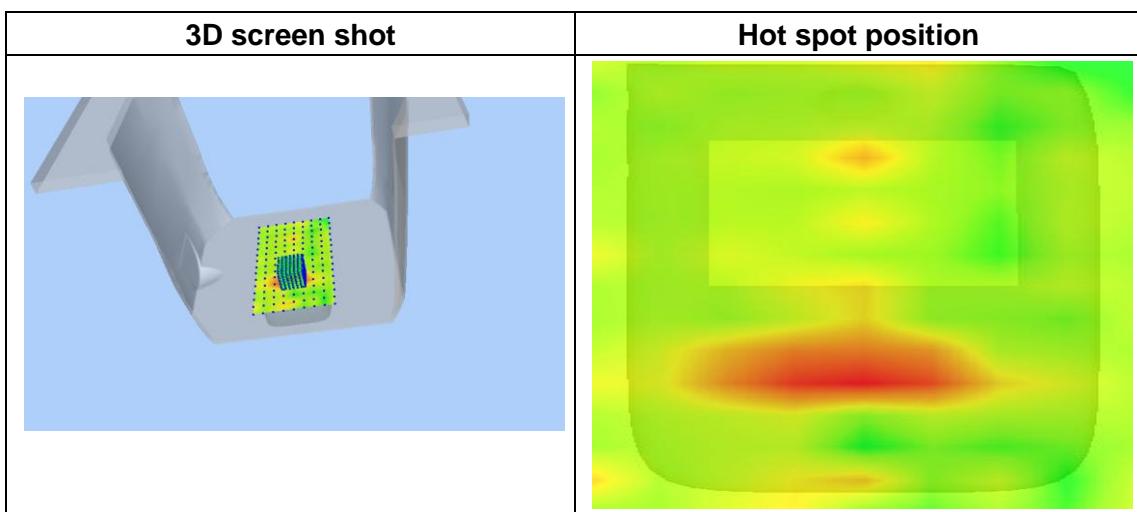
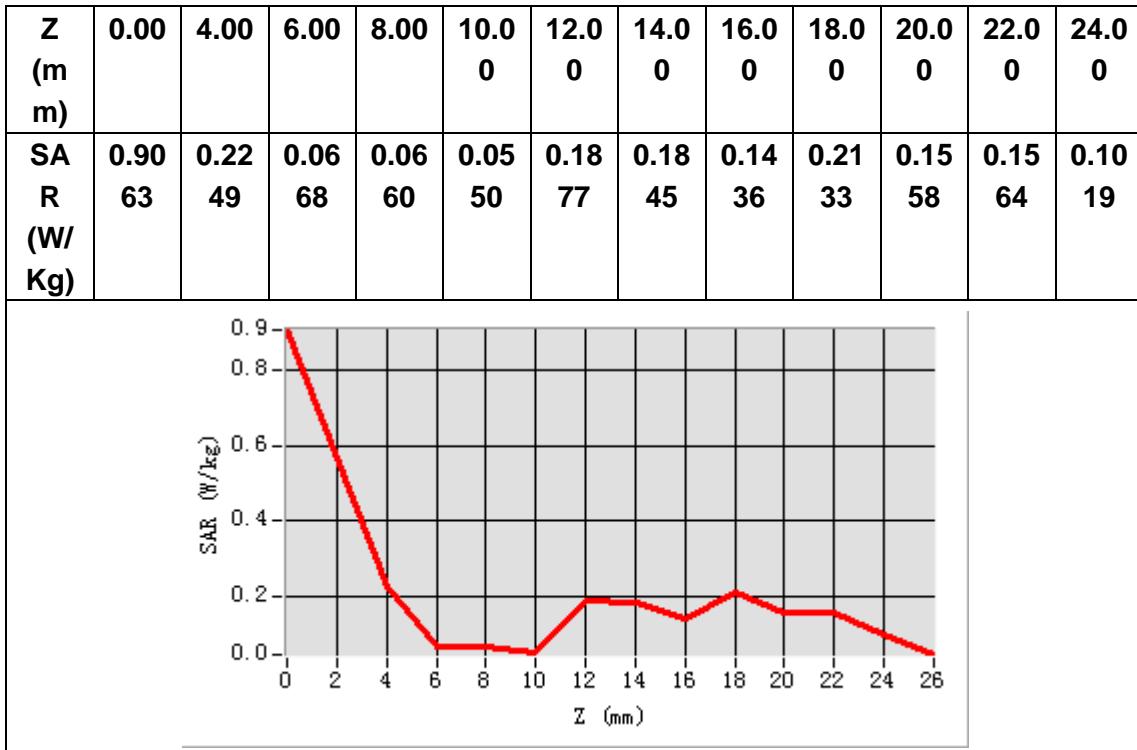


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Maximum location: X=0.00, Y=-30.00

SAR Peak: 0.70 W/kg

SAR 10g (W/Kg)	0.147476
SAR 1g (W/Kg)	0.186342



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MEASUREMENT 3

Type: Phone measurement (Complete)

Area scan resolution: dx=10mm,dy=10mm

Zoom scan resolution: dx=4mm, dy=4mm, dz=2mm

Date of measurement: 2018.03.20

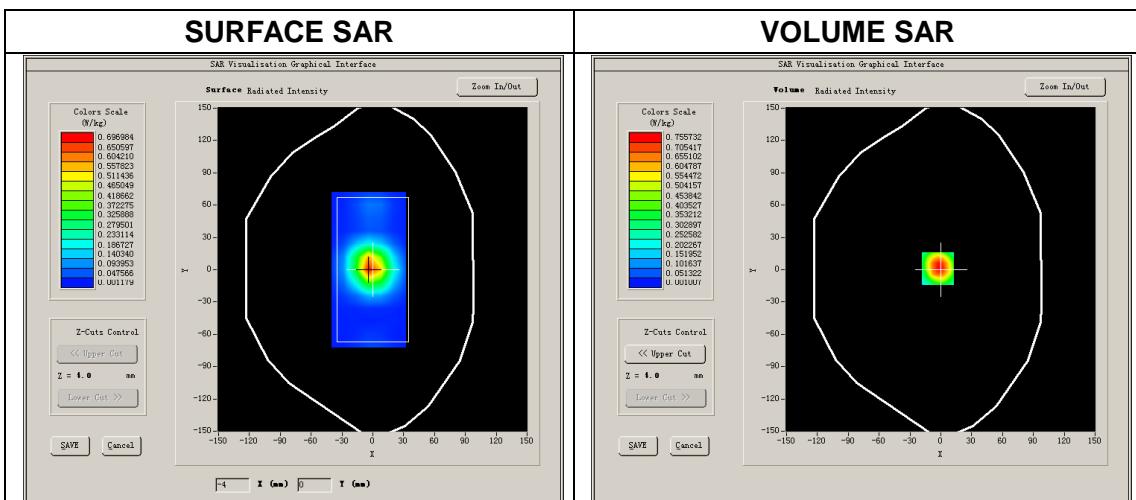
Measurement duration: 16 minutes 43 seconds

A. Experimental conditions.

<u>Phantom File</u>	<u>surf sam plan.txt</u>
<u>Phantom</u>	<u>Flat</u>
<u>Device Position</u>	<u>Body</u>
<u>Band</u>	<u>IEEE 802.11b ISM</u>
<u>Channels</u>	<u>Low</u>
<u>Signal</u>	<u>DSSS</u>

B. SAR Measurement Results
Lower Band SAR (Channel 1):

Frequency (MHz)	2412.000000
Relative permittivity (real part)	52.993668
Conductivity (S/m)	1.912865
Power drift (%)	0.480000
Ambient Temperature:	22.0°C
Liquid Temperature:	21.8°C
ConvF:	4.93
Crest factor:	1:1

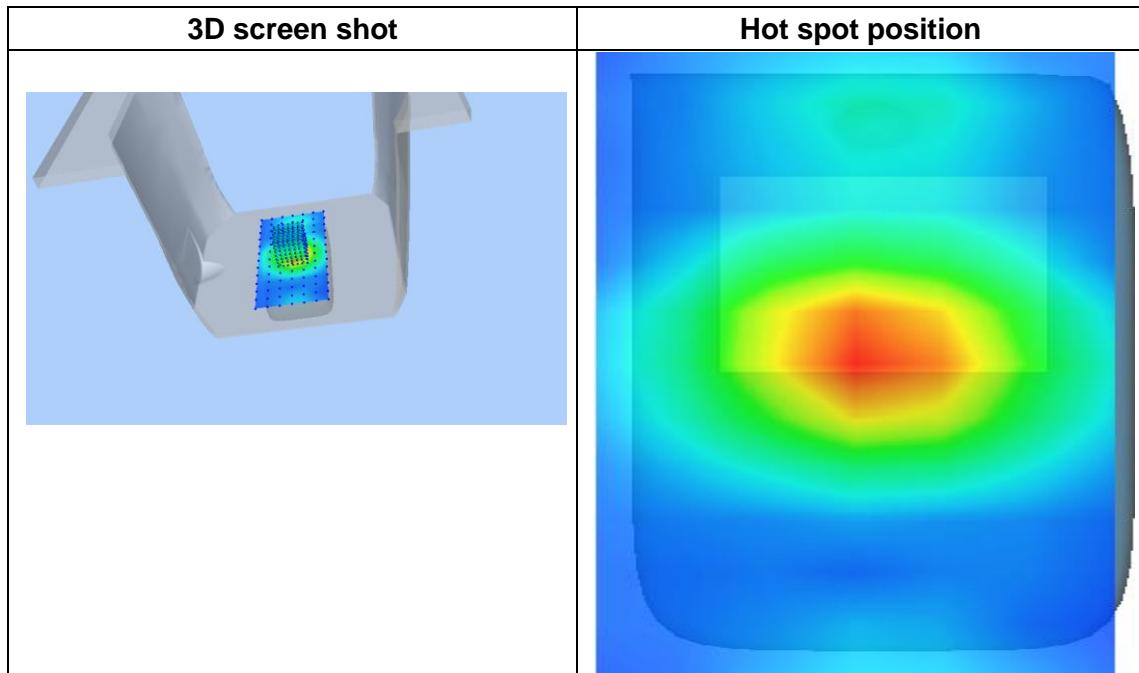
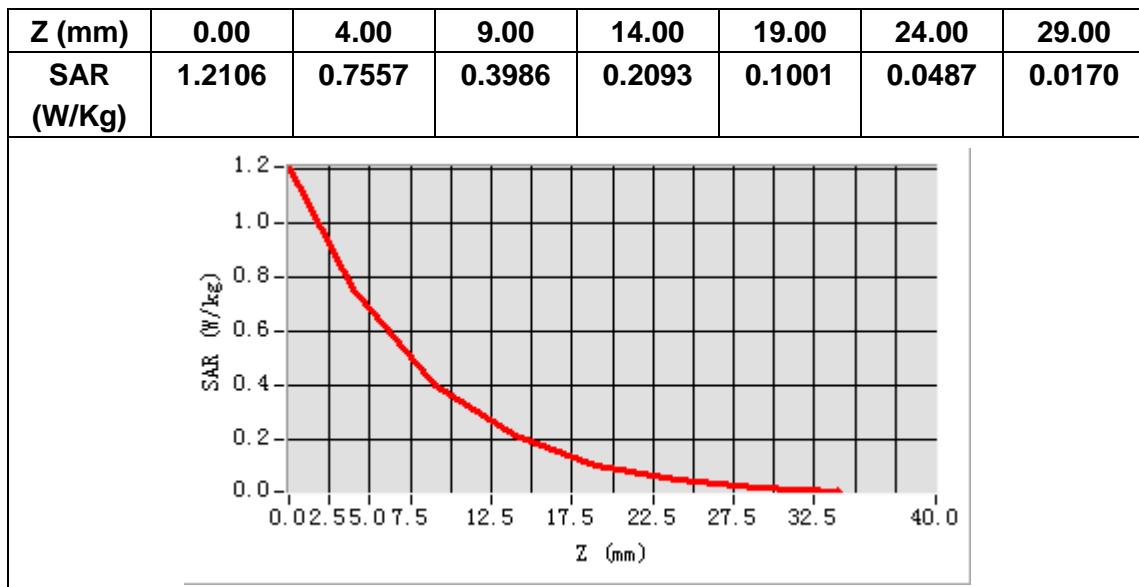


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Maximum location: X=-3.00, Y=1.00

SAR Peak: 1.21 W/kg

SAR 10g (W/Kg)	0.353992
SAR 1g (W/Kg)	0.711122



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REPORT No. : SZ18030025S01

Annex E SATIMO Calibration Certificate

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MORLAB

SHENZHEN MORLAB COMMUNICATIONS TECHNOLOGY Co., Ltd.
FL1-3, Building A, FeiYang Science Park, No.8 LongChang Road,
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Tel: 86-755-36698555 Fax: 86-755-36698525
[Http://www.morlab.cn](http://www.morlab.cn) E-mail: service@morlab.cn



COMOSAR E-Field Probe Calibration Report

Ref : ACR.189.1.16.SATU.A

**SHENZHEN MORLAB COMMUNICATIONS
TECHNOLOGY CO., LTD**
**FL3, BUILDING A, FEIYANG SCIENCE PARK, NO.8
LONGCHANG ROAD,**
**BLOCK 67, BAOAN DISTRICT, SHENZHEN, GUANGDONG
PROVINCE, P.R. CHINA**
MVG COMOSAR DOSIMETRIC E-FIELD PROBE
SERIAL NO.: SN 37/08 EP80

Calibrated at MVG US
2105 Barrett Park Dr. - Kennesaw, GA 30144



Calibration Date: 07/05/2017

Summary:

This document presents the method and results from an accredited COMOSAR Dosimetric E-Field Probe calibration performed in MVG USA using the CALISAR / CALIBAIR test bench, for use with a COMOSAR system only. All calibration results are traceable to national metrology institutions.

	<i>Name</i>	<i>Function</i>	<i>Date</i>	<i>Signature</i>
<i>Prepared by :</i>	Jérôme LUC	Product Manager	7/7/2017	
<i>Checked by :</i>	Jérôme LUC	Product Manager	7/7/2017	
<i>Approved by :</i>	Kim RUTKOWSKI	Quality Manager	7/7/2017	

	<i>Customer Name</i>
<i>Distribution :</i>	Shenzhen Morlab Communications Technology Co., Ltd

<i>Issue</i>	<i>Date</i>	<i>Modifications</i>
A	7/7/2017	Initial release

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1 DEVICE UNDER TEST

Device Under Test	
Device Type	COMOSAR DOSIMETRIC E FIELD PROBE
Manufacturer	MVG
Model	SSE5
Serial Number	SN 37/08 EP80
Product Condition (new / used)	Used
Frequency Range of Probe	0.7 GHz-3GHz
Resistance of Three Dipoles at Connector	Dipole 1: R1=1.445 MΩ Dipole 2: R2=1.467 MΩ Dipole 3: R3=1.477 MΩ

A yearly calibration interval is recommended.

2 PRODUCT DESCRIPTION

2.1 GENERAL INFORMATION

MVG's COMOSAR E field Probes are built in accordance to the IEEE 1528, OET 65 Bulletin C and CEI/IEC 62209 standards.



Figure 1 – MVG COMOSAR Dosimetric E field Dipole

Probe Length	330 mm
Length of Individual Dipoles	4.5 mm
Maximum external diameter	8 mm
Probe Tip External Diameter	5 mm
Distance between dipoles / probe extremity	2.7 mm

3 MEASUREMENT METHOD

The IEEE 1528, OET 65 Bulletin C, CENELEC EN50361 and CEI/IEC 62209 standards provide recommended practices for the probe calibrations, including the performance characteristics of interest and methods by which to assess their affect. All calibrations / measurements performed meet the fore mentioned standards.

3.1 LINEARITY

The evaluation of the linearity was done in free space using the waveguide, performing a power sweep to cover the SAR range 0.01W/kg to 100W/kg.

3.2 SENSITIVITY

The sensitivity factors of the three dipoles were determined using a two step calibration method (air and tissue simulating liquid) using waveguides as outlined in the standards.

3.3 LOWER DETECTION LIMIT

The lower detection limit was assessed using the same measurement set up as used for the linearity measurement. The required lower detection limit is 10 mW/kg.

3.4 ISOTROPY

The axial isotropy was evaluated by exposing the probe to a reference wave from a standard dipole with the dipole mounted under the flat phantom in the test configuration suggested for system validations and checks. The probe was rotated along its main axis from 0 - 360 degrees in 15 degree steps. The hemispherical isotropy is determined by inserting the probe in a thin plastic box filled with tissue-equivalent liquid, with the plastic box illuminated with the fields from a half wave dipole. The dipole is rotated about its axis (0°–180°) in 15° increments. At each step the probe is rotated about its axis (0°–360°).

3.5 BOUNDARY EFFECT

The boundary effect is defined as the deviation between the SAR measured data and the expected exponential decay in the liquid when the probe is oriented normal to the interface. To evaluate this effect, the liquid filled flat phantom is exposed to fields from either a reference dipole or waveguide. With the probe normal to the phantom surface, the peak spatial average SAR is measured and compared to the analytical value at the surface.

4 MEASUREMENT UNCERTAINTY

The guidelines outlined in the IEEE 1528, OET 65 Bulletin C, CENELEC EN50361 and CEI/IEC 62209 standards were followed to generate the measurement uncertainty associated with an E-field probe calibration using the waveguide technique. All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of $k=2$, traceable to the Internationally Accepted Guides to Measurement Uncertainty.

Uncertainty analysis of the probe calibration in waveguide					
ERROR SOURCES	Uncertainty value (%)	Probability Distribution	Divisor	ci	Standard Uncertainty (%)
Incident or forward power	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Reflected power	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Liquid conductivity	5.00%	Rectangular	$\sqrt{3}$	1	2.887%
Liquid permittivity	4.00%	Rectangular	$\sqrt{3}$	1	2.309%
Field homogeneity	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Field probe positioning	5.00%	Rectangular	$\sqrt{3}$	1	2.887%

Field probe linearity	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Combined standard uncertainty					5.831%
Expanded uncertainty 95 % confidence level $k = 2$					12.0%

5 CALIBRATION MEASUREMENT RESULTS

Calibration Parameters	
Liquid Temperature	21 °C
Lab Temperature	21 °C
Lab Humidity	45 %

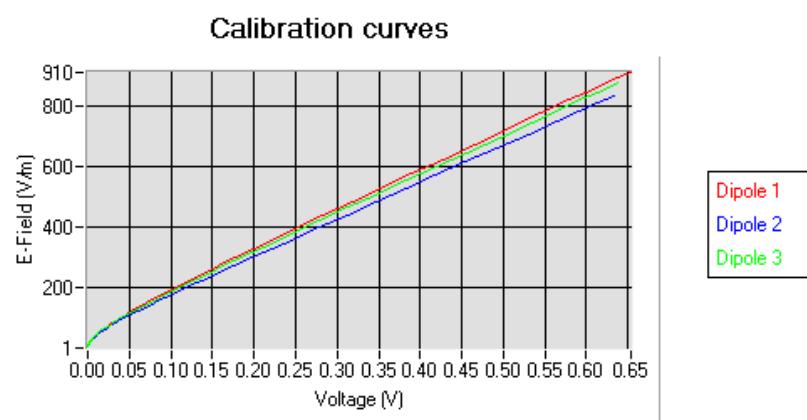
5.1 SENSITIVITY IN AIR

Normx dipole 1 ($\mu\text{V}/(\text{V}/\text{m})^2$)	Normy dipole 2 ($\mu\text{V}/(\text{V}/\text{m})^2$)	Normz dipole 3 ($\mu\text{V}/(\text{V}/\text{m})^2$)
5.13	5.62	5.15

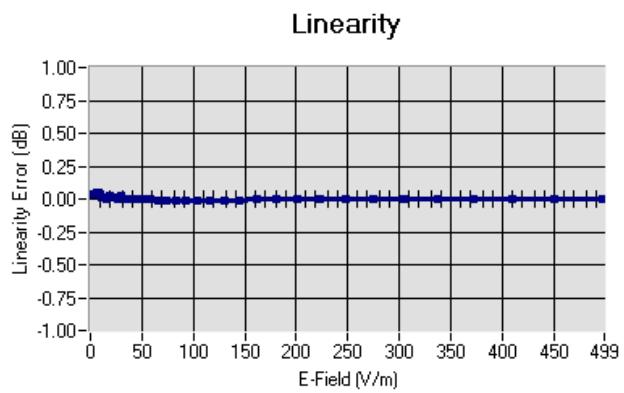
DCP dipole 1 (mV)	DCP dipole 2 (mV)	DCP dipole 3 (mV)
129	109	123

Calibration curves $e_i=f(V)$ ($i=1,2,3$) allow to obtain H-field value using the formula:

$$E = \sqrt{E_1^2 + E_2^2 + E_3^2}$$



5.2 LINEARITY



Linearity: +/-1.11% (+/-0.05dB)

5.3 SENSITIVITY IN LIQUID

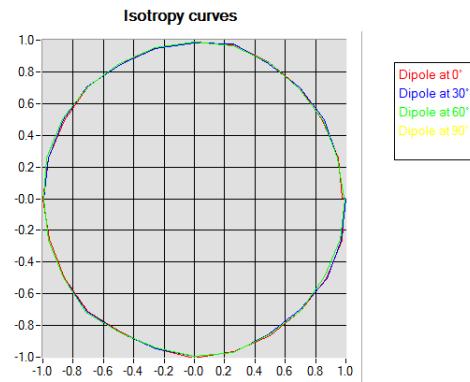
<u>Liquid</u>	<u>Frequency (MHz +/- 100MHz)</u>	<u>Permittivity</u>	<u>Epsilon (S/m)</u>	<u>ConvF</u>
HL450	450	42.17	0.86	7.55
BL450	450	57.65	0.95	7.77
HL750	750	40.03	0.93	6.44
BL750	750	56.83	1.00	6.68
HL900	900	42.08	1.01	6.13
BL900	900	55.25	1.08	6.37
HL1800	1800	41.68	1.46	5.21
BL1800	1800	53.86	1.46	5.38
HL1900	1900	38.45	1.45	5.61
BL1900	1900	53.32	1.56	5.71
HL2450	2450	37.50	1.80	4.82
BL2450	2450	53.22	1.89	4.96
HL2600	2600	39.80	1.99	4.74
BL2600	2600	52.52	2.23	4.93

LOWER DETECTION LIMIT: 8mW/kg

5.4 ISOTROPY

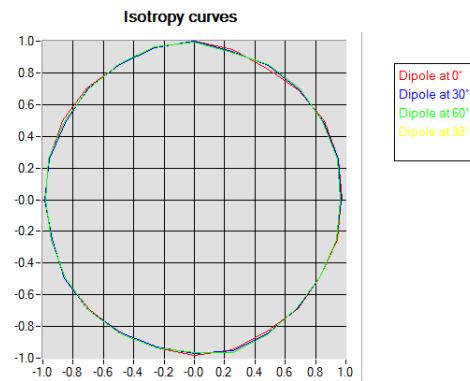
HL900 MHz

- Axial isotropy: 0.04 dB
- Hemispherical isotropy: 0.05 dB



HL1800 MHz

- Axial isotropy: 0.04 dB
- Hemispherical isotropy: 0.07 dB



6 LIST OF EQUIPMENT

Equipment Summary Sheet				
Equipment Description	Manufacturer / Model	Identification No.	Current Calibration Date	Next Calibration Date
Flat Phantom	MVG	SN-20/09-SAM71	Validated. No cal required.	Validated. No cal required.
COMOSAR Test Bench	Version 3	NA	Validated. No cal required.	Validated. No cal required.
Network Analyzer	Rhode & Schwarz ZVA	SN100132	02/2016	02/2019
Reference Probe	MVG	EP 94 SN 37/08	10/2016	10/2017
Multimeter	Keithley 2000	1188656	12/2016	12/2019
Signal Generator	Agilent E4438C	MY49070581	12/2016	12/2019
Amplifier	Aethercomm	SN 046	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Power Meter	HP E4418A	US38261498	12/2016	12/2019
Power Sensor	HP ECP-E26A	US37181460	12/2016	12/2019
Directional Coupler	Narda 4216-20	01386	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Waveguide	Mega Industries	069Y7-158-13-712	Validated. No cal required.	Validated. No cal required.
Waveguide Transition	Mega Industries	069Y7-158-13-701	Validated. No cal required.	Validated. No cal required.
Waveguide Termination	Mega Industries	069Y7-158-13-701	Validated. No cal required.	Validated. No cal required.
Temperature / Humidity Sensor	Control Company	150798832	10/2015	10/2017



COMOSAR E-Field Probe Calibration Report

Ref : ACR.189.2.16.SATU.A

**SHENZHEN MORLAB COMMUNICATIONS
TECHNOLOGY CO., LTD**
**FL3, BUILDING A, FEIYANG SCIENCE PARK, NO.8
LONGCHANG ROAD,**
**BLOCK 67, BAOAN DISTRICT, SHENZHEN, GUANGDONG
PROVINCE, P.R. CHINA**

**MVG COMOSAR DOSIMETRIC E-FIELD PROBE
SERIAL NO.: SN 27/13 EPG193**

**Calibrated at MVG US
2105 Barrett Park Dr. - Kennesaw, GA 30144**



Calibration Date: 07/05/2017

Summary:

This document presents the method and results from an accredited COMOSAR Dosimetric E-Field Probe calibration performed in MVG USA using the CALISAR / CALIBAIR test bench, for use with a COMOSAR system only. All calibration results are traceable to national metrology institutions.

	<i>Name</i>	<i>Function</i>	<i>Date</i>	<i>Signature</i>
<i>Prepared by :</i>	Jérôme LUC	Product Manager	7/7/2017	
<i>Checked by :</i>	Jérôme LUC	Product Manager	7/7/2017	
<i>Approved by :</i>	Kim RUTKOWSKI	Quality Manager	7/7/2017	

	<i>Customer Name</i>
<i>Distribution :</i>	Shenzhen Morlab Communications Technology Co., Ltd

<i>Issue</i>	<i>Date</i>	<i>Modifications</i>
A	7/7/2017	Initial release

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3.3	Lower Detection Limit	5
3.4	Isotropy	5
3.5	Boundary Effect	5
4	Measurement Uncertainty	5
5	Calibration Measurement Results	6
5.1	Sensitivity in air	6
5.2	Linearity	7
5.3	Sensitivity in liquid	7
5.4	Isotropy	8
6	List of Equipment	9

1 DEVICE UNDER TEST

Device Under Test	
Device Type	COMOSAR DOSIMETRIC E FIELD PROBE
Manufacturer	MVG
Model	SSE2
Serial Number	SN 27/13 EPG193
Product Condition (new / used)	Used
Frequency Range of Probe	0.7 GHz-6GHz
Resistance of Three Dipoles at Connector	Dipole 1: R1=0.205 MΩ Dipole 2: R2=0.175 MΩ Dipole 3: R3=0.213 MΩ

A yearly calibration interval is recommended.

2 PRODUCT DESCRIPTION

2.1 GENERAL INFORMATION

MVG's COMOSAR E field Probes are built in accordance to the IEEE 1528, OET 65 Bulletin C and CEI/IEC 62209 standards.



Figure 1 – MVG COMOSAR Dosimetric E field Dipole

Probe Length	330 mm
Length of Individual Dipoles	2 mm
Maximum external diameter	8 mm
Probe Tip External Diameter	2.5 mm
Distance between dipoles / probe extremity	1 mm

3 MEASUREMENT METHOD

The IEEE 1528, OET 65 Bulletin C, CENELEC EN50361 and CEI/IEC 62209 standards provide recommended practices for the probe calibrations, including the performance characteristics of interest and methods by which to assess their affect. All calibrations / measurements performed meet the fore mentioned standards.

3.1 LINEARITY

The evaluation of the linearity was done in free space using the waveguide, performing a power sweep to cover the SAR range 0.01W/kg to 100W/kg.

3.2 SENSITIVITY

The sensitivity factors of the three dipoles were determined using a two step calibration method (air and tissue simulating liquid) using waveguides as outlined in the standards.

3.3 LOWER DETECTION LIMIT

The lower detection limit was assessed using the same measurement set up as used for the linearity measurement. The required lower detection limit is 10 mW/kg.

3.4 ISOTROPY

The axial isotropy was evaluated by exposing the probe to a reference wave from a standard dipole with the dipole mounted under the flat phantom in the test configuration suggested for system validations and checks. The probe was rotated along its main axis from 0 - 360 degrees in 15 degree steps. The hemispherical isotropy is determined by inserting the probe in a thin plastic box filled with tissue-equivalent liquid, with the plastic box illuminated with the fields from a half wave dipole. The dipole is rotated about its axis (0°–180°) in 15° increments. At each step the probe is rotated about its axis (0°–360°).

3.5 BOUNDARY EFFECT

The boundary effect is defined as the deviation between the SAR measured data and the expected exponential decay in the liquid when the probe is oriented normal to the interface. To evaluate this effect, the liquid filled flat phantom is exposed to fields from either a reference dipole or waveguide. With the probe normal to the phantom surface, the peak spatial average SAR is measured and compared to the analytical value at the surface.

4 MEASUREMENT UNCERTAINTY

The guidelines outlined in the IEEE 1528, OET 65 Bulletin C, CENELEC EN50361 and CEI/IEC 62209 standards were followed to generate the measurement uncertainty associated with an E-field probe calibration using the waveguide technique. All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of $k=2$, traceable to the Internationally Accepted Guides to Measurement Uncertainty.

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ERROR SOURCES	Uncertainty value (%)	Probability Distribution	Divisor	ci	Standard Uncertainty (%)
Incident or forward power	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Reflected power	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Liquid conductivity	5.00%	Rectangular	$\sqrt{3}$	1	2.887%
Liquid permittivity	4.00%	Rectangular	$\sqrt{3}$	1	2.309%
Field homogeneity	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Field probe positioning	5.00%	Rectangular	$\sqrt{3}$	1	2.887%

Field probe linearity	3.00%	Rectangular	$\sqrt{3}$	1	1.732%
Combined standard uncertainty					5.831%
Expanded uncertainty 95 % confidence level k = 2					12.0%

5 CALIBRATION MEASUREMENT RESULTS

Calibration Parameters	
Liquid Temperature	21 °C
Lab Temperature	21 °C
Lab Humidity	45 %

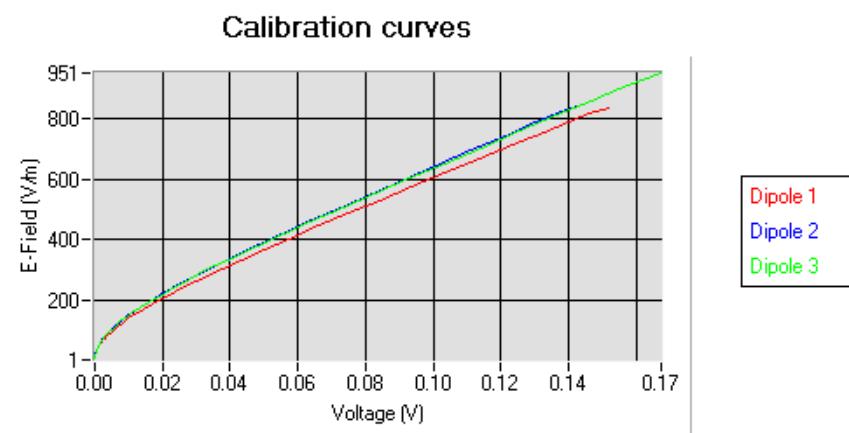
5.1 SENSITIVITY IN AIR

Normx dipole 1 ($\mu\text{V}/(\text{V}/\text{m})^2$)	Normy dipole 2 ($\mu\text{V}/(\text{V}/\text{m})^2$)	Normz dipole 3 ($\mu\text{V}/(\text{V}/\text{m})^2$)
0.53	0.49	0.60

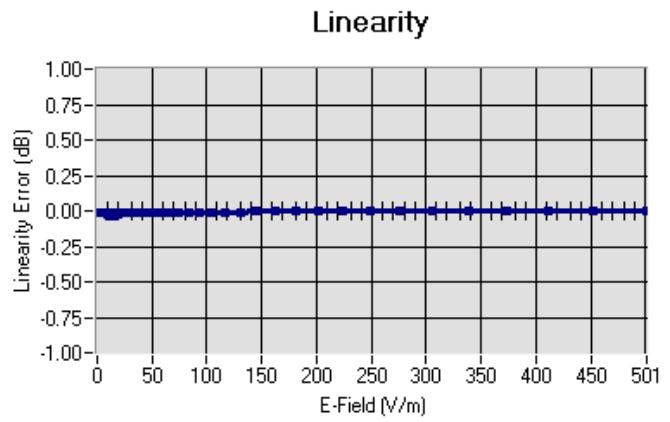
DCP dipole 1 (mV)	DCP dipole 2 (mV)	DCP dipole 3 (mV)
90	99	97

Calibration curves $e_i=f(V)$ ($i=1,2,3$) allow to obtain H-field value using the formula:

$$E = \sqrt{E_1^2 + E_2^2 + E_3^2}$$



5.2 LINEARITY



Linearity: +/-0.86% (+/-0.04dB)

5.3 SENSITIVITY IN LIQUID

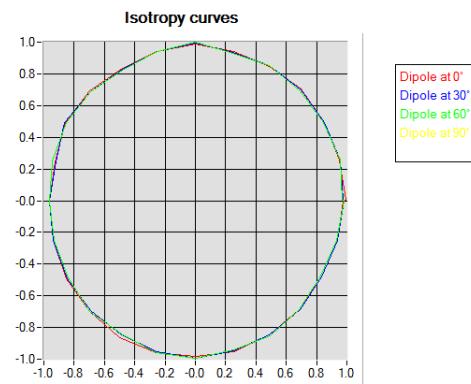
<u>Liquid</u>	<u>Frequency (MHz +/- 100MHz)</u>	<u>Permittivity</u>	<u>Epsilon (S/m)</u>	<u>ConvF</u>
HL5200	5200	35.64	4.67	21.61
BL5200	5200	48.64	5.51	22.11
HL5400	5400	36.44	4.87	22.47
BL5400	5400	46.52	5.77	23.20
HL5600	5600	36.66	5.17	22.92
BL5600	5600	46.79	5.77	23.69
HL5800	5800	35.31	5.31	22.42
BL5800	5800	47.04	6.10	23.02

LOWER DETECTION LIMIT: 9mW/kg

5.4 ISOTROPY

HL5600 MHz

- Axial isotropy: 0.06 dB
- Hemispherical isotropy: 0.08 dB



6 LIST OF EQUIPMENT

Equipment Summary Sheet				
Equipment Description	Manufacturer / Model	Identification No.	Current Calibration Date	Next Calibration Date
Flat Phantom	MVG	SN-20/09-SAM71	Validated. No cal required.	Validated. No cal required.
COMOSAR Test Bench	Version 3	NA	Validated. No cal required.	Validated. No cal required.
Network Analyzer	Rhode & Schwarz ZVA	SN100132	02/2016	02/2019
Reference Probe	MVG	EP 94 SN 37/08	10/2016	10/2017
Multimeter	Keithley 2000	1188656	12/2016	12/2019
Signal Generator	Agilent E4438C	MY49070581	12/2016	12/2019
Amplifier	Aethercomm	SN 046	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Power Meter	HP E4418A	US38261498	12/2016	12/2019
Power Sensor	HP ECP-E26A	US37181460	12/2016	12/2019
Directional Coupler	Narda 4216-20	01386	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Waveguide	Mega Industries	069Y7-158-13-712	Validated. No cal required.	Validated. No cal required.
Waveguide Transition	Mega Industries	069Y7-158-13-701	Validated. No cal required.	Validated. No cal required.
Waveguide Termination	Mega Industries	069Y7-158-13-701	Validated. No cal required.	Validated. No cal required.
Temperature / Humidity Sensor	Control Company	150798832	10/2015	10/2017



SAR Reference Dipole Calibration Report

Ref : ACR.189.9.16.SATU.A

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MVG COMOSAR REFERENCE DIPOLE
FREQUENCY: 2450 MHZ
SERIAL NO.: SN 30/13 DIP2G450-263

Calibrated at MVG US
2105 Barrett Park Dr. - Kennesaw, GA 30144



Calibration Date: 07/05/2017

Summary:

This document presents the method and results from an accredited SAR reference dipole calibration performed in MVG USA using the COMOSAR test bench. All calibration results are traceable to national metrology institutions.

	<i>Name</i>	<i>Function</i>	<i>Date</i>	<i>Signature</i>
<i>Prepared by :</i>	Jérôme LUC	Product Manager	7/7/2017	
<i>Checked by :</i>	Jérôme LUC	Product Manager	7/7/2017	
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<i>Distribution :</i>	<i>Customer Name</i>
	Shenzhen Morlab Communications Technology Co., Ltd

<i>Issue</i>	<i>Date</i>	<i>Modifications</i>
A	7/7/2017	Initial release

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1 INTRODUCTION

This document contains a summary of the requirements set forth by the IEEE 1528, FCC KDBs and CEI/IEC 62209 standards for reference dipoles used for SAR measurement system validations and the measurements that were performed to verify that the product complies with the fore mentioned standards.

2 DEVICE UNDER TEST

Device Under Test	
Device Type	COMOSAR 2450 MHz REFERENCE DIPOLE
Manufacturer	MVG
Model	SID2450
Serial Number	SN 30/13 DIP2G450-263
Product Condition (new / used)	Used

A yearly calibration interval is recommended.

3 PRODUCT DESCRIPTION

3.1 GENERAL INFORMATION

MVG's COMOSAR Validation Dipoles are built in accordance to the IEEE 1528, FCC KDBs and CEI/IEC 62209 standards. The product is designed for use with the COMOSAR test bench only.



Figure 1 – MVG COMOSAR Validation Dipole

4 MEASUREMENT METHOD

The IEEE 1528, FCC KDBs and CEI/IEC 62209 standards provide requirements for reference dipoles used for system validation measurements. The following measurements were performed to verify that the product complies with the fore mentioned standards.

4.1 RETURN LOSS REQUIREMENTS

The dipole used for SAR system validation measurements and checks must have a return loss of -20 dB or better. The return loss measurement shall be performed against a liquid filled flat phantom, with the phantom constructed as outlined in the fore mentioned standards.

4.2 MECHANICAL REQUIREMENTS

The IEEE Std. 1528 and CEI/IEC 62209 standards specify the mechanical components and dimensions of the validation dipoles, with the dimensions frequency and phantom shell thickness dependent. The COMOSAR test bench employs a 2 mm phantom shell thickness therefore the dipoles sold for use with the COMOSAR test bench comply with the requirements set forth for a 2 mm phantom shell thickness.

5 MEASUREMENT UNCERTAINTY

All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of $k=2$, traceable to the Internationally Accepted Guides to Measurement Uncertainty.

5.1 RETURN LOSS

The following uncertainties apply to the return loss measurement:

Frequency band	Expanded Uncertainty on Return Loss
400-6000MHz	0.1 dB

5.2 DIMENSION MEASUREMENT

The following uncertainties apply to the dimension measurements:

Length (mm)	Expanded Uncertainty on Length
3 - 300	0.05 mm

5.3 VALIDATION MEASUREMENT

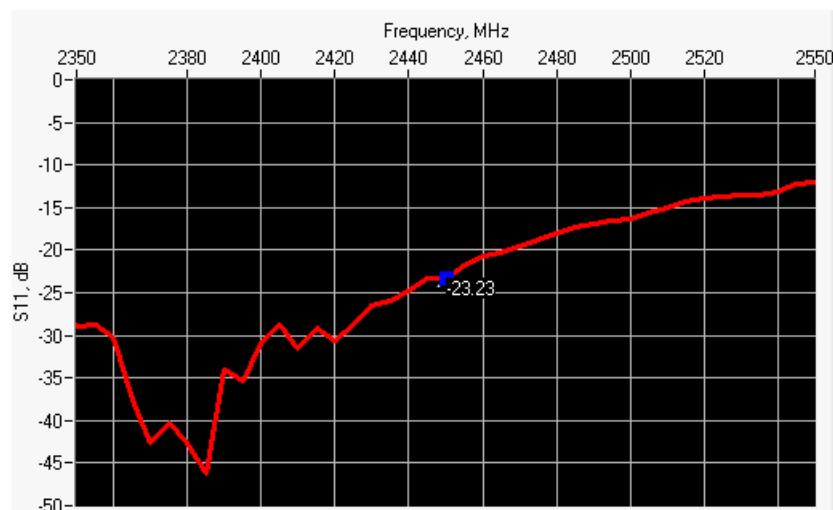
The guidelines outlined in the IEEE 1528, FCC KDBs, CENELEC EN50361 and CEI/IEC 62209 standards were followed to generate the measurement uncertainty for validation measurements.

Scan Volume	Expanded Uncertainty
1 g	20.3 %

10 g	20.1 %
------	--------

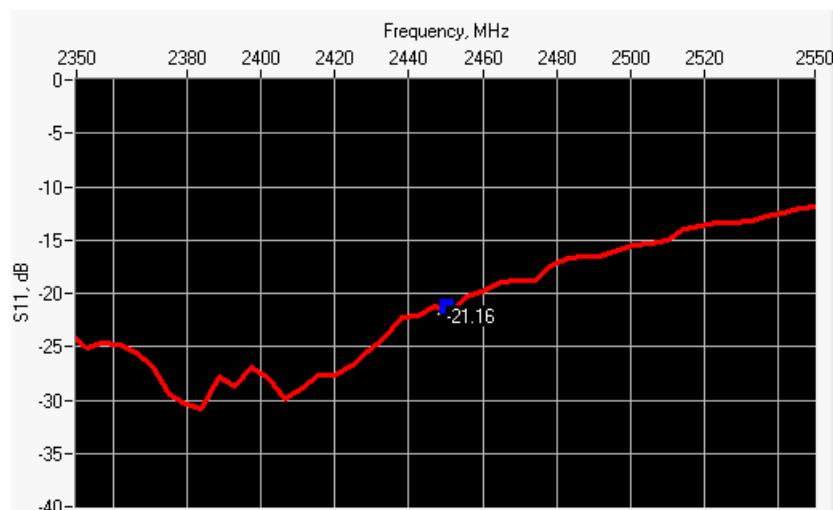
6 CALIBRATION MEASUREMENT RESULTS

6.1 RETURN LOSS AND IMPEDANCE IN HEAD LIQUID



Frequency (MHz)	Return Loss (dB)	Requirement (dB)	Impedance
2450	-23.23	-20	$47.7 \Omega - 6.4 j\Omega$

6.2 RETURN LOSS AND IMPEDANCE IN BODY LIQUID



Frequency (MHz)	Return Loss (dB)	Requirement (dB)	Impedance
2450	-21.16	-20	$53.7 \Omega - 8.3 j\Omega$

6.3 MECHANICAL DIMENSIONS

Frequency MHz	L mm		h mm		d mm	
	required	measured	required	measured	required	measured
300	$420.0 \pm 1 \%$.		$250.0 \pm 1 \%$.		$6.35 \pm 1 \%$.	

450	290.0 \pm 1 %.		166.7 \pm 1 %.		6.35 \pm 1 %.	
750	176.0 \pm 1 %.		100.0 \pm 1 %.		6.35 \pm 1 %.	
835	161.0 \pm 1 %.		89.8 \pm 1 %.		3.6 \pm 1 %.	
900	149.0 \pm 1 %.		83.3 \pm 1 %.		3.6 \pm 1 %.	
1450	89.1 \pm 1 %.		51.7 \pm 1 %.		3.6 \pm 1 %.	
1500	80.5 \pm 1 %.		50.0 \pm 1 %.		3.6 \pm 1 %.	
1640	79.0 \pm 1 %.		45.7 \pm 1 %.		3.6 \pm 1 %.	
1750	75.2 \pm 1 %.		42.9 \pm 1 %.		3.6 \pm 1 %.	
1800	72.0 \pm 1 %.		41.7 \pm 1 %.		3.6 \pm 1 %.	
1900	68.0 \pm 1 %.		39.5 \pm 1 %.		3.6 \pm 1 %.	
1950	66.3 \pm 1 %.		38.5 \pm 1 %.		3.6 \pm 1 %.	
2000	64.5 \pm 1 %.		37.5 \pm 1 %.		3.6 \pm 1 %.	
2100	61.0 \pm 1 %.		35.7 \pm 1 %.		3.6 \pm 1 %.	
2300	55.5 \pm 1 %.		32.6 \pm 1 %.		3.6 \pm 1 %.	
2450	51.5 \pm 1 %.	PASS	30.4 \pm 1 %.	PASS	3.6 \pm 1 %.	PASS
2600	48.5 \pm 1 %.		28.8 \pm 1 %.		3.6 \pm 1 %.	
3000	41.5 \pm 1 %.		25.0 \pm 1 %.		3.6 \pm 1 %.	
3500	37.0 \pm 1 %.		26.4 \pm 1 %.		3.6 \pm 1 %.	
3700	34.7 \pm 1 %.		26.4 \pm 1 %.		3.6 \pm 1 %.	

7 VALIDATION MEASUREMENT

The IEEE Std. 1528, FCC KDBs and CEI/IEC 62209 standards state that the system validation measurements must be performed using a reference dipole meeting the fore mentioned return loss and mechanical dimension requirements. The validation measurement must be performed against a liquid filled flat phantom, with the phantom constructed as outlined in the fore mentioned standards. Per the standards, the dipole shall be positioned below the bottom of the phantom, with the dipole length centered and parallel to the longest dimension of the flat phantom, with the top surface of the dipole at the described distance from the bottom surface of the phantom.

7.1 HEAD LIQUID MEASUREMENT

Frequency MHz	Relative permittivity (ϵ_r')		Conductivity (σ) S/m	
	required	measured	required	measured
300	45.3 \pm 5 %		0.87 \pm 5 %	
450	43.5 \pm 5 %		0.87 \pm 5 %	
750	41.9 \pm 5 %		0.89 \pm 5 %	
835	41.5 \pm 5 %		0.90 \pm 5 %	
900	41.5 \pm 5 %		0.97 \pm 5 %	
1450	40.5 \pm 5 %		1.20 \pm 5 %	
1500	40.4 \pm 5 %		1.23 \pm 5 %	
1640	40.2 \pm 5 %		1.31 \pm 5 %	
1750	40.1 \pm 5 %		1.37 \pm 5 %	

1800	40.0 \pm 5 %		1.40 \pm 5 %	
1900	40.0 \pm 5 %		1.40 \pm 5 %	
1950	40.0 \pm 5 %		1.40 \pm 5 %	
2000	40.0 \pm 5 %		1.40 \pm 5 %	
2100	39.8 \pm 5 %		1.49 \pm 5 %	
2300	39.5 \pm 5 %		1.67 \pm 5 %	
2450	39.2 \pm 5 %	PASS	1.80 \pm 5 %	PASS
2600	39.0 \pm 5 %		1.96 \pm 5 %	
3000	38.5 \pm 5 %		2.40 \pm 5 %	
3500	37.9 \pm 5 %		2.91 \pm 5 %	

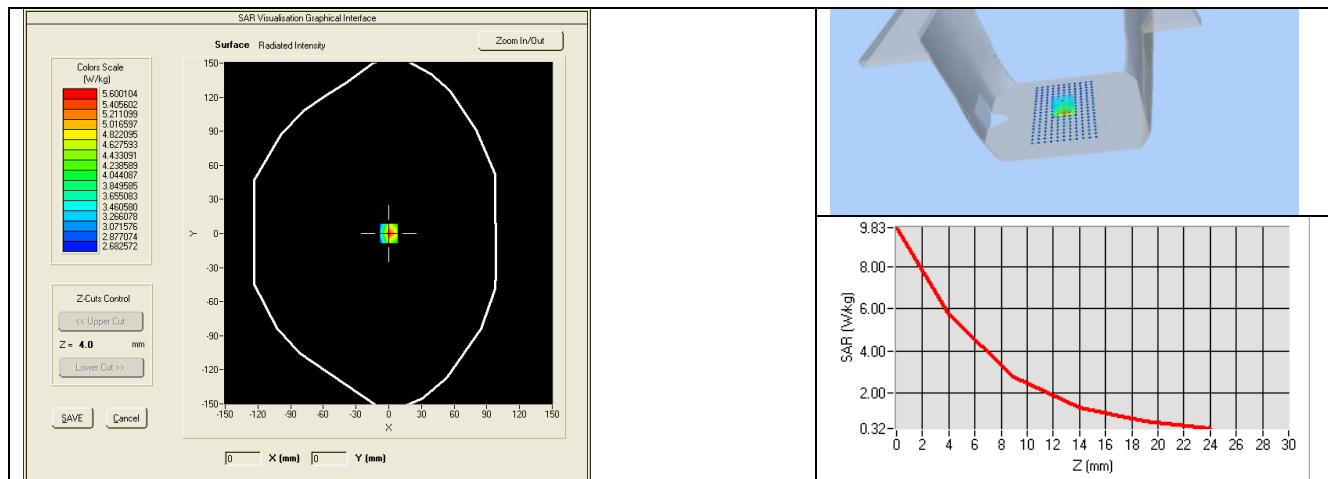
7.2 SAR MEASUREMENT RESULT WITH HEAD LIQUID

The IEEE Std. 1528 and CEI/IEC 62209 standards state that the system validation measurements should produce the SAR values shown below (for phantom thickness of 2 mm), within the uncertainty for the system validation. All SAR values are normalized to 1 W forward power. In bracket, the measured SAR is given with the used input power.

Software	OPENSAR V4
Phantom	SN 20/09 SAM71
Probe	SN 18/11 EPG122
Liquid	Head Liquid Values: ϵ s' : 37.5 sigma : 1.80
Distance between dipole center and liquid	10.0 mm
Area scan resolution	dx=8mm/dy=8mm
Zoon Scan Resolution	dx=5mm/dy=5mm/dz=5mm
Frequency	2450 MHz
Input power	20 dBm
Liquid Temperature	21 °C
Lab Temperature	21 °C
Lab Humidity	45 %

Frequency MHz	1 g SAR (W/kg/W)		10 g SAR (W/kg/W)	
	required	measured	required	measured
300	2.85		1.94	
450	4.58		3.06	
750	8.49		5.55	
835	9.56		6.22	
900	10.9		6.99	
1450	29		16	
1500	30.5		16.8	
1640	34.2		18.4	
1750	36.4		19.3	
1800	38.4		20.1	

1900	39.7		20.5	
1950	40.5		20.9	
2000	41.1		21.1	
2100	43.6		21.9	
2300	48.7		23.3	
2450	52.4	53.34 (5.33)	24	24.22 (2.42)
2600	55.3		24.6	
3000	63.8		25.7	
3500	67.1		25	



7.3 BODY LIQUID MEASUREMENT

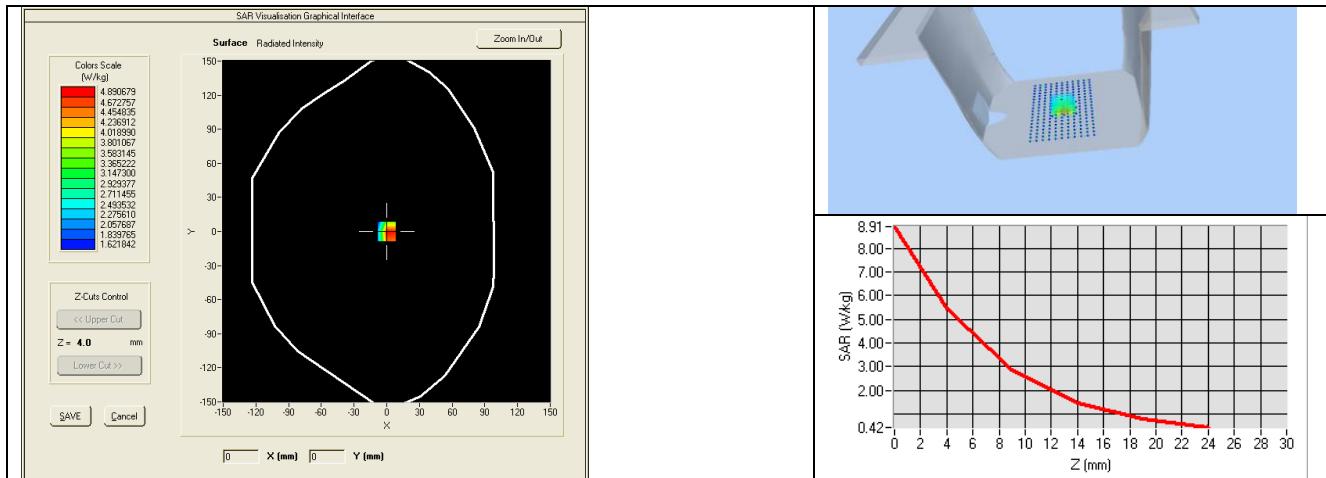
Frequency MHz	Relative permittivity (ϵ_r')		Conductivity (σ) S/m	
	required	measured	required	measured
150	61.9 \pm 5 %		0.80 \pm 5 %	
300	58.2 \pm 5 %		0.92 \pm 5 %	
450	56.7 \pm 5 %		0.94 \pm 5 %	
750	55.5 \pm 5 %		0.96 \pm 5 %	
835	55.2 \pm 5 %		0.97 \pm 5 %	
900	55.0 \pm 5 %		1.05 \pm 5 %	
915	55.0 \pm 5 %		1.06 \pm 5 %	
1450	54.0 \pm 5 %		1.30 \pm 5 %	
1610	53.8 \pm 5 %		1.40 \pm 5 %	
1800	53.3 \pm 5 %		1.52 \pm 5 %	
1900	53.3 \pm 5 %		1.52 \pm 5 %	
2000	53.3 \pm 5 %		1.52 \pm 5 %	
2100	53.2 \pm 5 %		1.62 \pm 5 %	
2450	52.7 \pm 5 %	PASS	1.95 \pm 5 %	PASS

2600	52.5 \pm 5 %		2.16 \pm 5 %	
3000	52.0 \pm 5 %		2.73 \pm 5 %	
3500	51.3 \pm 5 %		3.31 \pm 5 %	
5200	49.0 \pm 10 %		5.30 \pm 10 %	
5300	48.9 \pm 10 %		5.42 \pm 10 %	
5400	48.7 \pm 10 %		5.53 \pm 10 %	
5500	48.6 \pm 10 %		5.65 \pm 10 %	
5600	48.5 \pm 10 %		5.77 \pm 10 %	
5800	48.2 \pm 10 %		6.00 \pm 10 %	

7.4 SAR MEASUREMENT RESULT WITH BODY LIQUID

Software	OPENSAR V4
Phantom	SN 20/09 SAM71
Probe	SN 18/11 EPG122
Liquid	Body Liquid Values: ϵ' : 53.2 sigma : 1.89
Distance between dipole center and liquid	10.0 mm
Area scan resolution	$dx=8mm/dy=8mm$
Zoon Scan Resolution	$dx=5mm/dy=5mm/dz=5mm$
Frequency	2450 MHz
Input power	20 dBm
Liquid Temperature	21 °C
Lab Temperature	21 °C
Lab Humidity	45 %

Frequency MHz	1 g SAR (W/kg/W)	10 g SAR (W/kg/W)
	measured	measured
2450	50.93 (5.09)	23.26 (2.33)



8 LIST OF EQUIPMENT

Equipment Summary Sheet				
Equipment Description	Manufacturer / Model	Identification No.	Current Calibration Date	Next Calibration Date
SAM Phantom	MVG	SN-20/09-SAM71	Validated. No cal required.	Validated. No cal required.
COMOSAR Test Bench	Version 3	NA	Validated. No cal required.	Validated. No cal required.
Network Analyzer	Rhode & Schwarz ZVA	SN100132	02/2016	02/2019
Calipers	Carrera	CALIPER-01	12/2016	12/2019
Reference Probe	MVG	EPG122 SN 18/11	10/2016	10/2017
Multimeter	Keithley 2000	1188656	12/2016	12/2019
Signal Generator	Agilent E4438C	MY49070581	12/2016	12/2019
Amplifier	Aethercomm	SN 046	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Power Meter	HP E4418A	US38261498	12/2016	12/2019
Power Sensor	HP ECP-E26A	US37181460	12/2016	12/2019
Directional Coupler	Narda 4216-20	01386	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Temperature and Humidity Sensor	Control Company	150798832	10/2015	10/2017



SAR Reference Waveguide Calibration Report

Ref : ACR.189.11.16.SATU.A

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CHINAMVG COMOSAR REFERENCE WAVEGUIDE
FREQUENCY: 5000-6000 MHZ
SERIAL NO.: SN 41/12 WGA21

Calibrated at MVG US
2105 Barrett Park Dr. - Kennesaw, GA 30144



Calibration Date: 07/05/2017

Summary:

This document presents the method and results from an accredited SAR reference waveguide calibration performed in MVG USA using the COMOSAR test bench. All calibration results are traceable to national metrology institutions.

	<i>Name</i>	<i>Function</i>	<i>Date</i>	<i>Signature</i>
<i>Prepared by :</i>	Jérôme LUC	Product Manager	7/7/2017	
<i>Checked by :</i>	Jérôme LUC	Product Manager	7/7/2017	
<i>Approved by :</i>	Kim RUTKOWSKI	Quality Manager	7/7/2017	

	<i>Customer Name</i>
<i>Distribution :</i>	Shenzhen Morlab Communications Technology Co., Ltd

<i>Issue</i>	<i>Date</i>	<i>Modifications</i>
A	7/7/2017	Initial release

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1 INTRODUCTION

This document contains a summary of the requirements set forth by the IEEE 1528 and CEI/IEC 62209 standards for reference waveguides used for SAR measurement system validations and the measurements that were performed to verify that the product complies with the fore mentioned standards.

2 DEVICE UNDER TEST

Device Under Test	
Device Type	COMOSAR 5000-6000 MHz REFERENCE WAVEGUIDE
Manufacturer	MVG
Model	SWG5500
Serial Number	SN 41/12 WGA21
Product Condition (new / used)	Used

A yearly calibration interval is recommended.

3 PRODUCT DESCRIPTION

3.1 GENERAL INFORMATION

MVG's COMOSAR Validation Waveguides are built in accordance to the IEEE 1528 and CEI/IEC 62209 standards.

4 MEASUREMENT METHOD

The IEEE 1528 and CEI/IEC 62209 standards provide requirements for reference waveguides used for system validation measurements. The following measurements were performed to verify that the product complies with the fore mentioned standards.

4.1 RETURN LOSS REQUIREMENTS

The waveguide used for SAR system validation measurements and checks must have a return loss of -8 dB or better. The return loss measurement shall be performed with matching layer placed in the open end of the waveguide, with the waveguide and matching layer in direct contact with the phantom shell as outlined in the fore mentioned standards.

4.2 MECHANICAL REQUIREMENTS

The IEEE 1528 and CEI/IEC 62209 standards specify the mechanical dimensions of the validation waveguide, the specified dimensions are as shown in Section 6.2. Figure 1 shows how the dimensions relate to the physical construction of the waveguide.

5 MEASUREMENT UNCERTAINTY

All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of $k=2$, traceable to the Internationally Accepted Guides to Measurement Uncertainty.

5.1 RETURN LOSS

The following uncertainties apply to the return loss measurement:

Frequency band	Expanded Uncertainty on Return Loss
400-6000MHz	0.1 dB

5.2 DIMENSION MEASUREMENT

The following uncertainties apply to the dimension measurements:

Length (mm)	Expanded Uncertainty on Length
3 - 300	0.05 mm

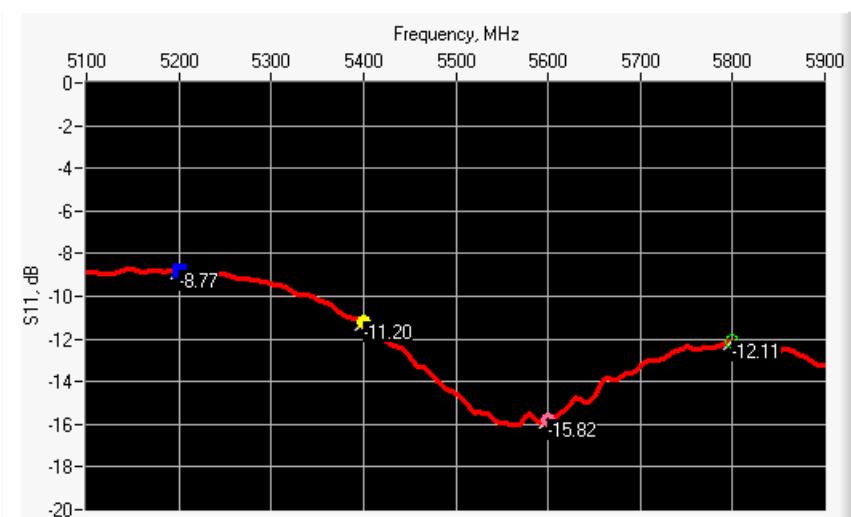
5.3 VALIDATION MEASUREMENT

The guidelines outlined in the IEEE 1528 and CEI/IEC 62209 standards were followed to generate the measurement uncertainty for validation measurements.

Scan Volume	Expanded Uncertainty
1 g	20.3 %
10 g	20.1 %

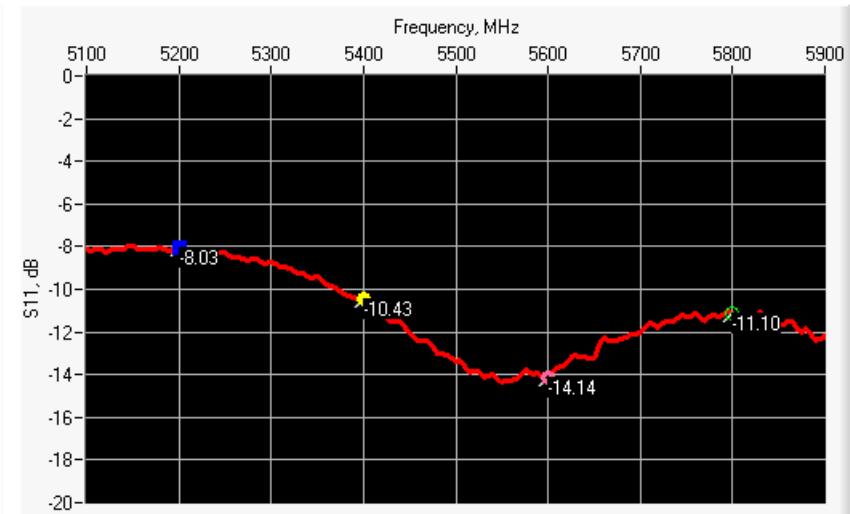
6 CALIBRATION MEASUREMENT RESULTS

6.1 RETURN LOSS IN HEAD LIQUID



Frequency (MHz)	Return Loss (dB)	Requirement (dB)	Impedance
5200	-8.77	-8	$25.52 \Omega + 13.34 j\Omega$
5400	-11.20	-8	$85.09 \Omega + 12.81 j\Omega$
5600	-15.82	-8	$36.65 \Omega - 4.32 j\Omega$
5800	-12.11	-8	$53.20 \Omega + 26.19 j\Omega$

6.2 RETURN LOSS IN BODY LIQUID



Frequency (MHz)	Return Loss (dB)	Requirement (dB)	Impedance
5200	-8.03	-8	$24.31 \Omega + 15.75 j\Omega$
5400	-10.43	-8	$92.67 \Omega + 5.39 j\Omega$
5600	-14.14	-8	$33.81 \Omega - 2.99 j\Omega$
5800	-11.10	-8	$57.11 \Omega + 30.17 j\Omega$

6.3 MECHANICAL DIMENSIONS

Frequency (MHz)	L (mm)		W (mm)		L _f (mm)		W _f (mm)		T (mm)	
	Require d	Measure d	Require d	Measure d	Require d	Measure d	Require d	Measure d	Require d	Measure d
5200	40.39 ± 0.13	PASS	20.19 ± 0.13	PASS	81.03 ± 0.13	PASS	61.98 ± 0.13	PASS	5.3*	PASS
5800	40.39 ± 0.13	PASS	20.19 ± 0.13	PASS	81.03 ± 0.13	PASS	61.98 ± 0.13	PASS	4.3*	PASS

* The tolerance for the matching layer is included in the return loss measurement.

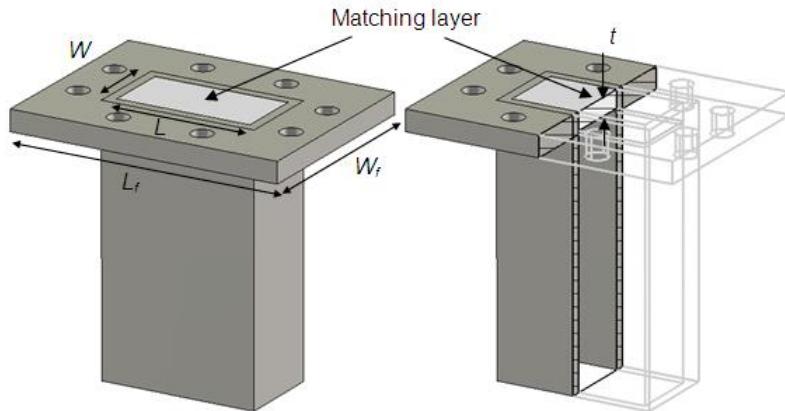


Figure 1: Validation Waveguide Dimensions

7 VALIDATION MEASUREMENT

The IEEE Std. 1528 and CEI/IEC 62209 standards state that the system validation measurements must be performed using a reference waveguide meeting the fore mentioned return loss and mechanical dimension requirements. The validation measurement must be performed with the matching layer placed in the open end of the waveguide, with the waveguide and matching layer in direct contact with the phantom shell.

7.1 HEAD LIQUID MEASUREMENT

Frequency MHz	Relative permittivity (ϵ_r')		Conductivity (σ) S/m	
	required	measured	required	measured
5000	$36.2 \pm 10\%$		$4.45 \pm 10\%$	
5100	$36.1 \pm 10\%$		$4.56 \pm 10\%$	
5200	$36.0 \pm 10\%$	PASS	$4.66 \pm 10\%$	PASS
5300	$35.9 \pm 10\%$		$4.76 \pm 10\%$	
5400	$35.8 \pm 10\%$	PASS	$4.86 \pm 10\%$	PASS
5500	$35.6 \pm 10\%$		$4.97 \pm 10\%$	
5600	$35.5 \pm 10\%$	PASS	$5.07 \pm 10\%$	PASS
5700	$35.4 \pm 10\%$		$5.17 \pm 10\%$	
5800	$35.3 \pm 10\%$	PASS	$5.27 \pm 10\%$	PASS
5900	$35.2 \pm 10\%$		$5.38 \pm 10\%$	
6000	$35.1 \pm 10\%$		$5.48 \pm 10\%$	

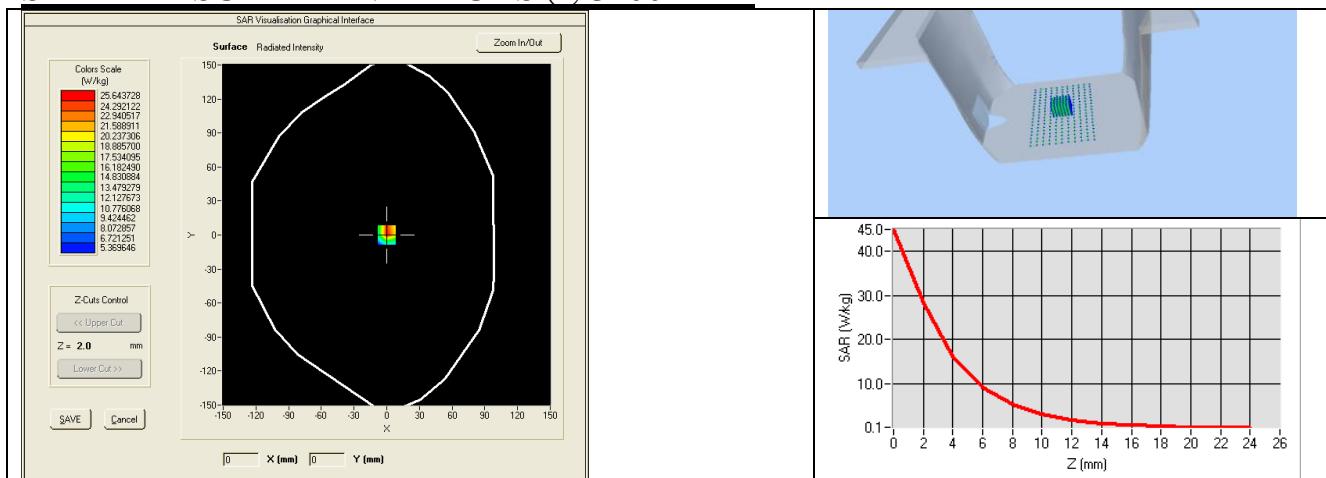
7.2 SAR MEASUREMENT RESULT WITH HEAD LIQUID

At those frequencies, the target SAR value can not be generic. Hereunder is the target SAR value defined by MVG, within the uncertainty for the system validation. All SAR values are normalized to 1 W net power. In bracket, the measured SAR is given with the used input power.

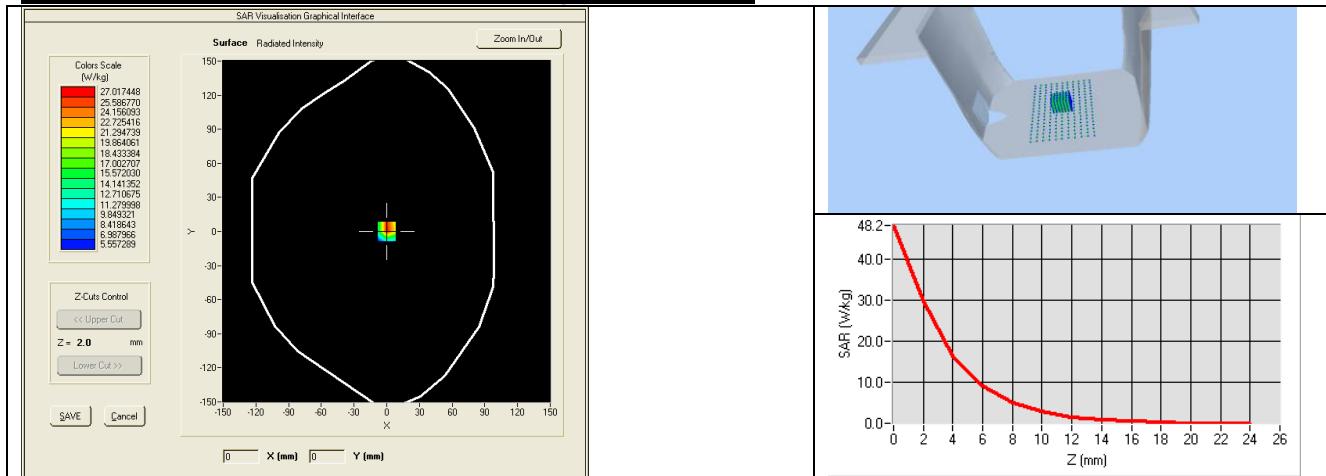
Software	OPENSAR V4
Phantom	SN 20/09 SAM71
Probe	SN 18/11 EPG122
Liquid	Head Liquid Values 5200 MHz: $\epsilon' = 35.64$ sigma : 4.67 Head Liquid Values 5400 MHz: $\epsilon' = 36.44$ sigma : 4.87 Head Liquid Values 5600 MHz: $\epsilon' = 36.66$ sigma : 5.17 Head Liquid Values 5800 MHz: $\epsilon' = 35.31$ sigma : 5.31
Distance between dipole waveguide and liquid	0 mm
Area scan resolution	$dx = 8\text{ mm}/dy = 8\text{ mm}$
Zoon Scan Resolution	$dx = 4\text{ mm}/dy = 4\text{ m}/dz = 2\text{ mm}$
Frequency	5200 MHz 5400 MHz 5600 MHz 5800 MHz
Input power	20 dBm
Liquid Temperature	21 °C
Lab Temperature	21 °C
Lab Humidity	45 %

Frequency (MHz)	1 g SAR (W/kg)		10 g SAR (W/kg)	
	required	measured	required	measured
5200	159.00	164.05 (16.41)	56.90	57.03 (5.70)
5400	166.40	171.66 (17.17)	58.43	59.33 (5.93)
5600	173.80	177.81 (17.78)	59.97	60.90 (6.09)
5800	181.20	185.02 (18.50)	61.50	62.43 (6.24)

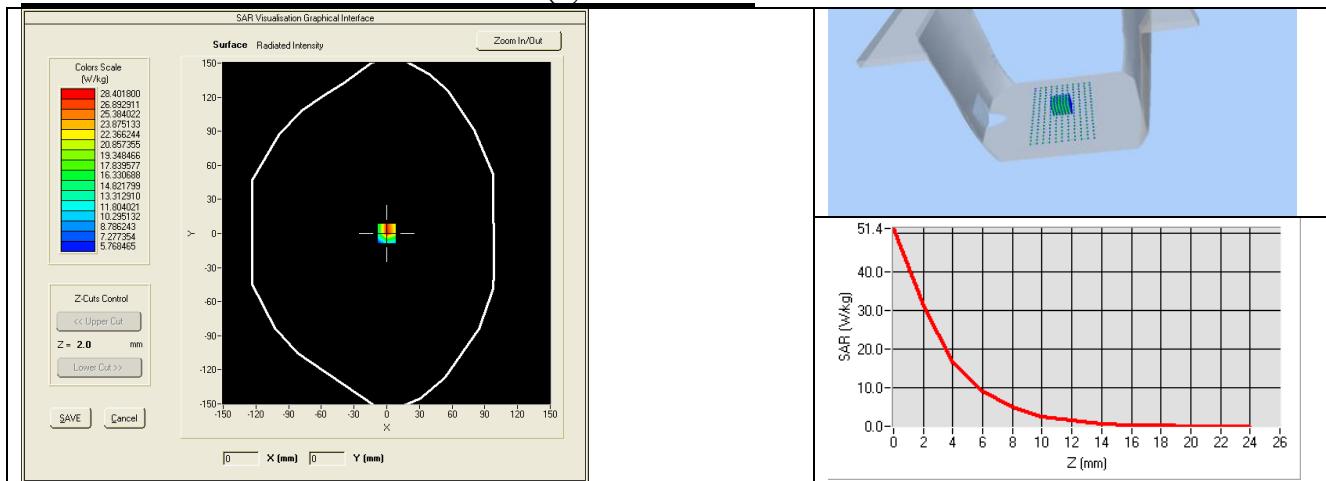
SAR MEASUREMENT PLOTS @ 5200 MHz



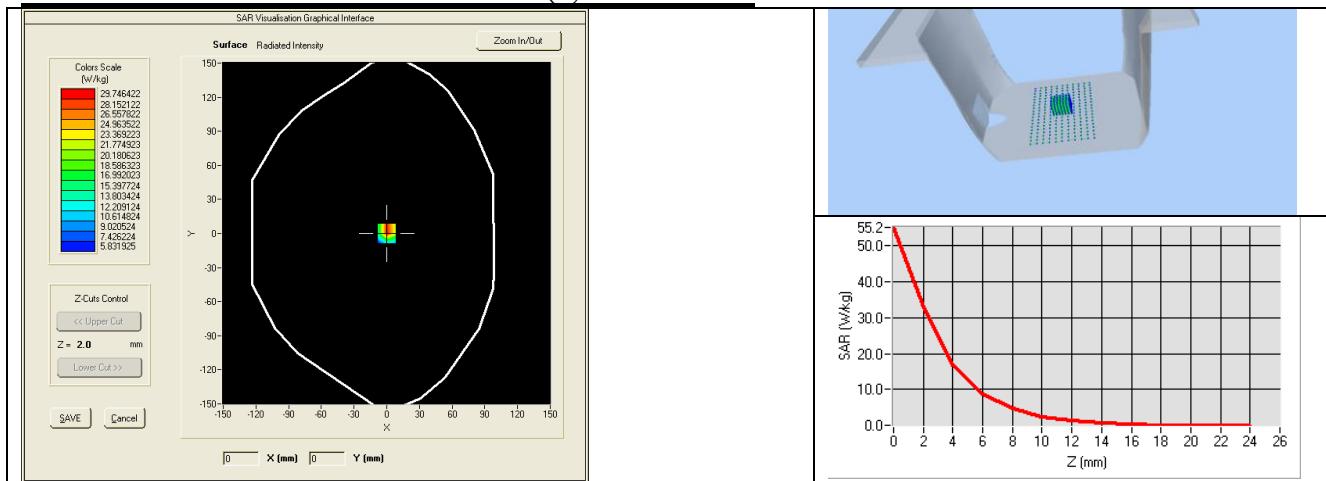
SAR MEASUREMENT PLOTS @ 5400 MHz



SAR MEASUREMENT PLOTS @ 5600 MHz



SAR MEASUREMENT PLOTS @ 5800 MHz



7.3 BODY LIQUID MEASUREMENT

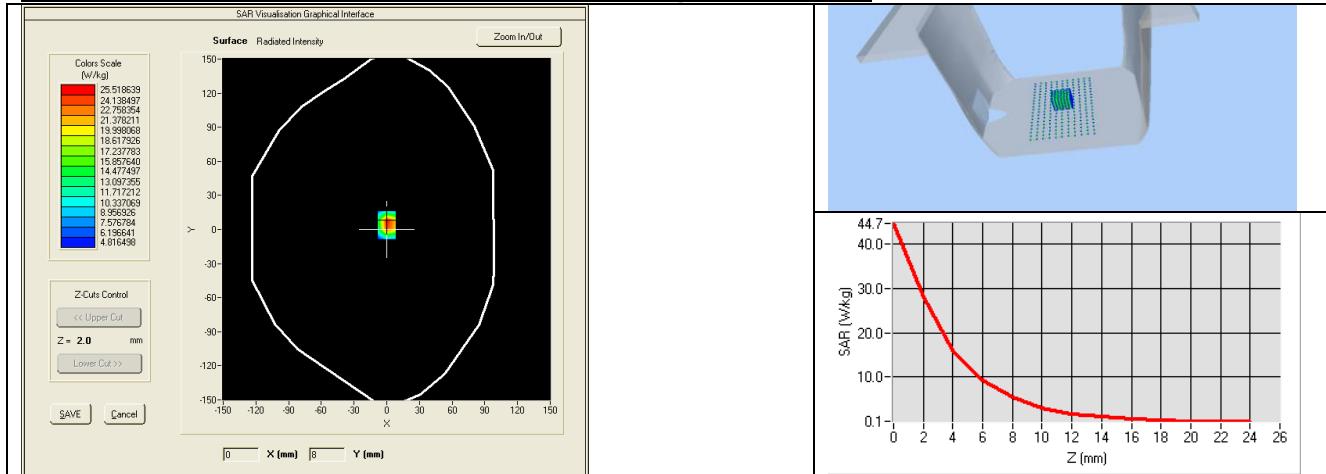
Frequency MHz	Relative permittivity (ϵ_r')		Conductivity (σ) S/m	
	required	measured	required	measured
5200	49.0 \pm 10 %	PASS	5.30 \pm 10 %	PASS
5300	48.9 \pm 10 %		5.42 \pm 10 %	
5400	48.7 \pm 10 %	PASS	5.53 \pm 10 %	PASS
5500	48.6 \pm 10 %		5.65 \pm 10 %	
5600	48.5 \pm 10 %	PASS	5.77 \pm 10 %	PASS
5800	48.2 \pm 10 %	PASS	6.00 \pm 10 %	PASS

7.4 SAR MEASUREMENT RESULT WITH BODY LIQUID

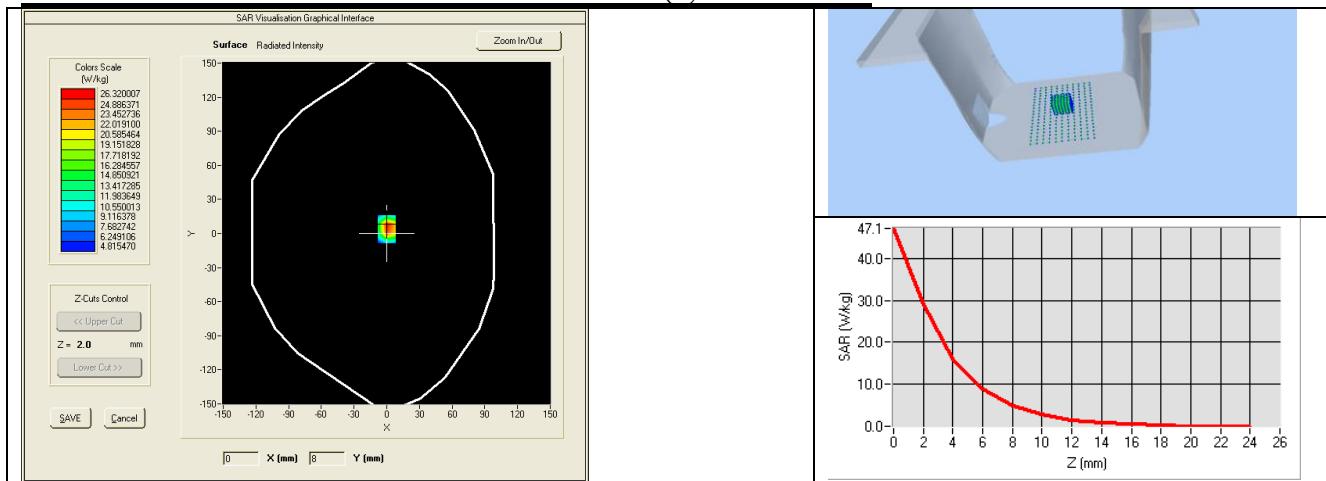
Software	OPENSAR V4
Phantom	SN 20/09 SAM71
Probe	SN 18/11 EPG122
Liquid	Body Liquid Values 5200 MHz: ϵ_r' :48.64 sigma : 5.51 Body Liquid Values 5400 MHz: ϵ_r' :46.52 sigma : 5.77 Body Liquid Values 5600 MHz: ϵ_r' :46.79 sigma : 5.77 Body Liquid Values 5800 MHz: ϵ_r' :47.04 sigma : 6.10
Distance between dipole waveguide and liquid	0 mm
Area scan resolution	dx=8mm/dy=8mm
Zoon Scan Resolution	dx=4mm/dy=4m/dz=2mm
Frequency	5200 MHz 5400 MHz 5600 MHz 5800 MHz
Input power	20 dBm
Liquid Temperature	21 °C
Lab Temperature	21 °C
Lab Humidity	45 %

Frequency (MHz)	1 g SAR (W/kg)	10 g SAR (W/kg)
	measured	measured
5200	163.36 (16.34)	57.09 (5.71)
5400	166.22 (16.62)	57.22 (5.72)
5600	172.11 (17.21)	58.61 (5.86)
5800	177.10 (17.71)	59.95 (5.99)

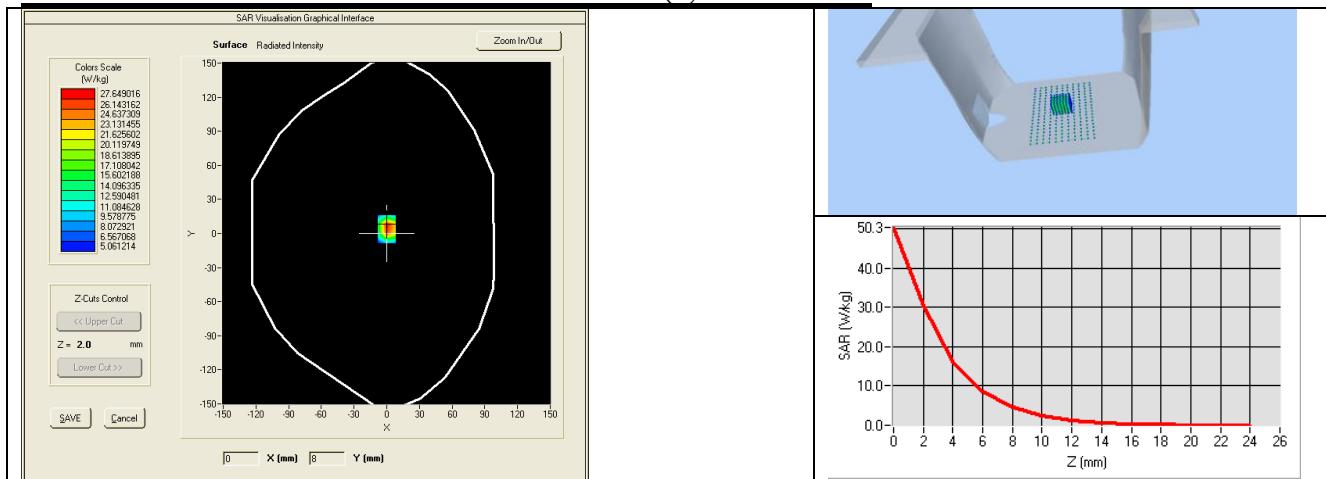
BODY SAR MEASUREMENT PLOTS @ 5200 MHz



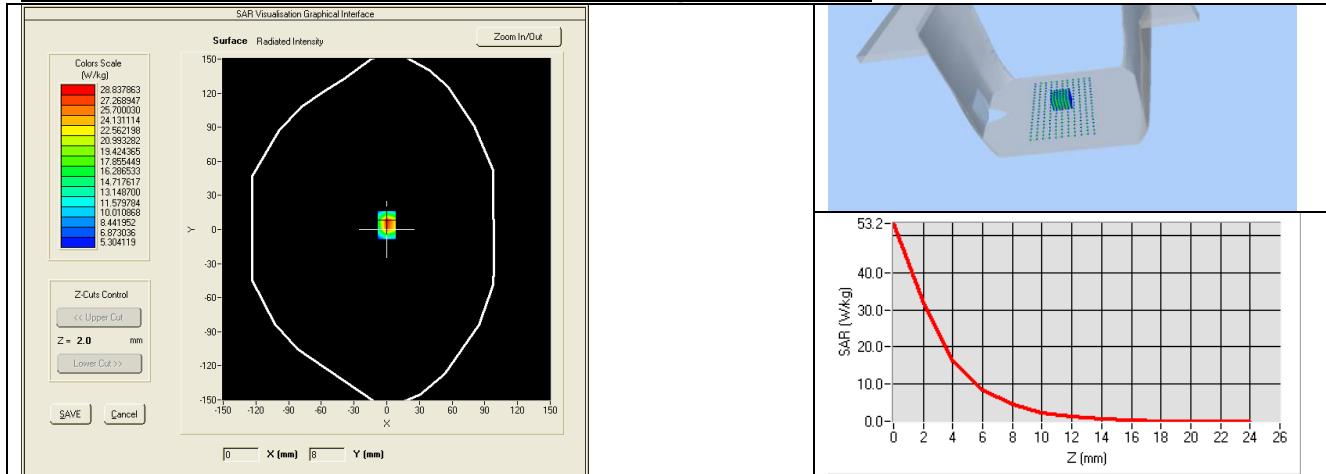
BODY SAR MEASUREMENT PLOTS @ 5400 MHz



BODY SAR MEASUREMENT PLOTS @ 5600 MHz



BODY SAR MEASUREMENT PLOTS @ 5800 MHz



8 LIST OF EQUIPMENT

Equipment Summary Sheet				
Equipment Description	Manufacturer / Model	Identification No.	Current Calibration Date	Next Calibration Date
Flat Phantom	MVG	SN-20/09-SAM71	Validated. No cal required.	Validated. No cal required.
COMOSAR Test Bench	Version 3	NA	Validated. No cal required.	Validated. No cal required.
Network Analyzer	Rhode & Schwarz ZVA	SN100132	02/2016	02/2019
Calipers	Carrera	CALIPER-01	12/2016	12/2019
Reference Probe	MVG	EPG122 SN 18/11	10/2016	10/2017
Multimeter	Keithley 2000	1188656	12/2016	12/2019
Signal Generator	Agilent E4438C	MY49070581	12/2016	12/2019
Amplifier	Aethercomm	SN 046	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Power Meter	HP E4418A	US38261498	12/2016	12/2019
Power Sensor	HP ECP-E26A	US37181460	12/2016	12/2019
Directional Coupler	Narda 4216-20	01386	Characterized prior to test. No cal required.	Characterized prior to test. No cal required.
Temperature and Humidity Sensor	Control Company	150798832	10/2015	10/2017