

## CALIBRATION DATA PROBE CALIBRATION DATA



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Certificate No: **Z17-97111**

### CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3953**

Calibration Procedure(s) **FF-Z11-004-01**  
**Calibration Procedures for Dosimetric E-field Probes**

Calibration date: **August 31, 2017**

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)°C and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards       | ID #        | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
|-------------------------|-------------|------------------------------------------|-----------------------|
| Power Meter NRP2        | 101919      | 27-Jun-17 (CTTL, No.J17X05857)           | Jun-18                |
| Power sensor NRP-Z91    | 101547      | 27-Jun-17 (CTTL, No.J17X05857)           | Jun-18                |
| Power sensor NRP-Z91    | 101548      | 27-Jun-17 (CTTL, No.J17X05857)           | Jun-18                |
| Reference10dBAttenuator | 18N50W-10dB | 13-Mar-16(CTTL,No.J16X01547)             | Mar-18                |
| Reference20dBAttenuator | 18N50W-20dB | 13-Mar-16(CTTL, No.J16X01548)            | Mar-18                |
| Reference Probe EX3DV4  | SN 7433     | 26-Sep-16(SPEAG,No.EX3-7433_Sep16)       | Sep-17                |
| DAE4                    | SN 549      | 13-Dec-16(SPEAG, No.DAE4-549_Dec16)      | Dec -17               |
| Secondary Standards     | ID #        | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
| SignalGeneratorMG3700A  | 6201052605  | 27-Jun-17 (CTTL, No.J17X05858)           | Jun-18                |
| Network Analyzer E5071C | MY46110673  | 13-Jan-17 (CTTL, No.J17X00285)           | Jan -18               |

|                | Name        | Function           | Signature |
|----------------|-------------|--------------------|-----------|
| Calibrated by: | Yu Zongying | SAR Test Engineer  |           |
| Reviewed by:   | Lin Hao     | SAR Test Engineer  |           |
| Approved by:   | Qi Dianyuan | SAR Project Leader |           |

Issued: September 01, 2017

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**Glossary:**

|                       |                                                                                                                                             |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| TSL                   | tissue simulating liquid                                                                                                                    |
| NORM <sub>x,y,z</sub> | sensitivity in free space                                                                                                                   |
| ConvF                 | sensitivity in TSL / NORM <sub>x,y,z</sub>                                                                                                  |
| DCP                   | diode compression point                                                                                                                     |
| CF                    | crest factor (1/duty_cycle) of the RF signal                                                                                                |
| A,B,C,D               | modulation dependent linearization parameters                                                                                               |
| Polarization $\Phi$   | $\Phi$ rotation around probe axis                                                                                                           |
| Polarization $\theta$ | $\theta$ rotation around an axis that is in the plane normal to probe axis (at measurement center), i<br>$\theta=0$ is normal to probe axis |

Connector Angle information used in DASY system to align probe sensor X to the robot coordinate system

**Calibration is Performed According to the Following Standards:**

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

**Methods Applied and Interpretation of Parameters:**

- NORM<sub>x,y,z</sub>:** Assessed for E-field polarization  $\theta=0$  ( $f \leq 900\text{MHz}$  in TEM-cell;  $f > 1800\text{MHz}$ : waveguide). NORM<sub>x,y,z</sub> are only intermediate values, i.e., the uncertainties of NORM<sub>x,y,z</sub> does not effect the  $E^2$ -field uncertainty inside TSL (see below ConvF).
- NORM( $f$ )<sub>x,y,z</sub> = NORM<sub>x,y,z</sub> \* frequency\_response** (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCP<sub>x,y,z</sub>:** DCP are numerical linearization parameters assessed based on the data of power sweep (no uncertainty required). DCP does not depend on frequency nor media.
- PAR:** PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics.
- A<sub>x,y,z</sub>; B<sub>x,y,z</sub>; C<sub>x,y,z</sub>; VR<sub>x,y,z</sub>; A,B,C** are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters:** Assessed in flat phantom using E-field (or Temperature Transfer Standard for  $f \leq 800\text{MHz}$ ) and inside waveguide using analytical field distributions based on power measurements for  $f > 800\text{MHz}$ . The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty valued are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM<sub>x,y,z</sub> \* ConvF whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from  $\pm 50\text{MHz}$  to  $\pm 100\text{MHz}$ .
- Spherical isotropy (3D deviation from isotropy):** in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset:** The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle:** The angle is assessed using the information gained by determining the NORM<sub>x</sub> (no uncertainty required).



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# Probe EX3DV4

## SN: 3953

Calibrated: August 31, 2017

Calibrated for DASY/EASY Systems

(Note: non-compatible with DASY2 system!)

Certificate No: Z17-97111

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## DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3953

### Basic Calibration Parameters

|                                      | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|--------------------------------------|----------|----------|----------|-----------|
| Norm( $\mu V/(V/m)^2$ ) <sup>A</sup> | 0.54     | 0.55     | 0.48     | ±10.0%    |
| DCP(mV) <sup>B</sup>                 | 100.9    | 102.7    | 100.5    |           |

### Modulation Calibration Parameters

| UID | Communication System Name |   | A dB | B dB $\mu V$ | C   | D dB | VR mV | Unc <sup>E</sup> (k=2) |
|-----|---------------------------|---|------|--------------|-----|------|-------|------------------------|
| 0   | CW                        | X | 0.0  | 0.0          | 1.0 | 0.00 | 169.4 | ±2.2%                  |
|     |                           | Y | 0.0  | 0.0          | 1.0 |      | 172.1 |                        |
|     |                           | Z | 0.0  | 0.0          | 1.0 |      | 160.5 |                        |

The reported uncertainty of measurement is stated as the standard uncertainty of Measurement multiplied by the coverage factor k=2, which for a normal distribution Corresponds to a coverage probability of approximately 95%.

<sup>A</sup> The uncertainties of Norm X, Y, Z do not affect the E<sup>2</sup>-field uncertainty inside TSL (see Page 5 and Page 6).

<sup>B</sup> Numerical linearization parameter: uncertainty not required.

<sup>E</sup> Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

## DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3953

### Calibration Parameter Determined in Head Tissue Simulating Media

| f [MHz] <sup>C</sup> | Relative Permittivity <sup>F</sup> | Conductivity (S/m) <sup>F</sup> | ConvF X | ConvF Y | ConvF Z | Alpha <sup>G</sup> | Depth <sup>G</sup> (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 750                  | 41.9                               | 0.89                            | 10.10   | 10.10   | 10.10   | 0.30               | 0.80                    | ±12.1%      |
| 835                  | 41.5                               | 0.90                            | 10.01   | 10.01   | 10.01   | 0.15               | 1.34                    | ±12.1%      |
| 900                  | 41.5                               | 0.97                            | 9.84    | 9.84    | 9.84    | 0.12               | 1.52                    | ±12.1%      |
| 1750                 | 40.1                               | 1.37                            | 8.45    | 8.45    | 8.45    | 0.25               | 1.02                    | ±12.1%      |
| 1810                 | 40.0                               | 1.40                            | 8.16    | 8.16    | 8.16    | 0.30               | 0.91                    | ±12.1%      |
| 1900                 | 40.0                               | 1.40                            | 8.08    | 8.08    | 8.08    | 0.23               | 1.09                    | ±12.1%      |
| 2100                 | 39.8                               | 1.49                            | 8.02    | 8.02    | 8.02    | 0.27               | 0.99                    | ±12.1%      |
| 2300                 | 39.5                               | 1.67                            | 8.05    | 8.05    | 8.05    | 0.59               | 0.65                    | ±12.1%      |
| 2450                 | 39.2                               | 1.80                            | 7.61    | 7.61    | 7.61    | 0.61               | 0.70                    | ±12.1%      |
| 2600                 | 39.0                               | 1.96                            | 7.28    | 7.28    | 7.28    | 0.43               | 0.91                    | ±12.1%      |

<sup>C</sup> Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

<sup>F</sup> At frequency below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ±5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

<sup>G</sup> Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

## DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3953

### Calibration Parameter Determined in Body Tissue Simulating Media

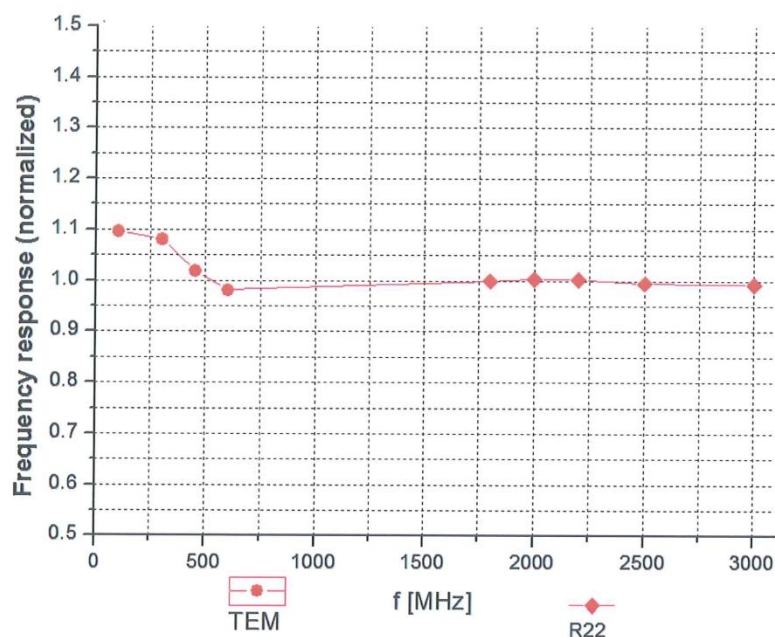
| f [MHz] <sup>C</sup> | Relative Permittivity <sup>F</sup> | Conductivity (S/m) <sup>F</sup> | ConvF X | ConvF Y | ConvF Z | Alpha <sup>G</sup> | Depth <sup>G</sup> (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 750                  | 55.5                               | 0.96                            | 10.26   | 10.26   | 10.26   | 0.30               | 0.90                    | ±12.1%      |
| 835                  | 55.2                               | 0.97                            | 10.00   | 10.00   | 10.00   | 0.18               | 1.38                    | ±12.1%      |
| 900                  | 55.0                               | 1.05                            | 9.93    | 9.93    | 9.93    | 0.21               | 1.18                    | ±12.1%      |
| 1750                 | 53.4                               | 1.49                            | 8.19    | 8.19    | 8.19    | 0.25               | 1.06                    | ±12.1%      |
| 1810                 | 53.3                               | 1.52                            | 8.12    | 8.12    | 8.12    | 0.18               | 1.39                    | ±12.1%      |
| 1900                 | 53.3                               | 1.52                            | 8.02    | 8.02    | 8.02    | 0.20               | 1.00                    | ±12.1%      |
| 2100                 | 53.2                               | 1.62                            | 8.18    | 8.18    | 8.18    | 0.20               | 1.28                    | ±12.1%      |
| 2300                 | 52.9                               | 1.81                            | 8.00    | 8.00    | 8.00    | 0.31               | 1.26                    | ±12.1%      |
| 2450                 | 52.7                               | 1.95                            | 7.73    | 7.73    | 7.73    | 0.42               | 0.96                    | ±12.1%      |
| 2600                 | 52.5                               | 2.16                            | 7.35    | 7.35    | 7.35    | 0.44               | 0.91                    | ±12.1%      |

<sup>C</sup> Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

<sup>F</sup> At frequency below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ±5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

<sup>G</sup> Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

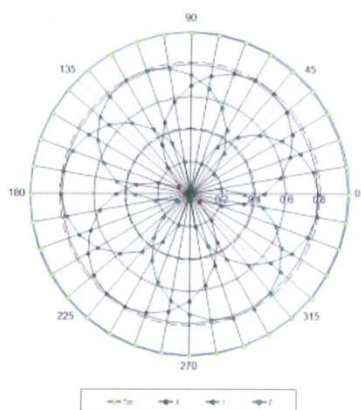
### Frequency Response of E-Field (TEM-Cell: ifi110 EXX, Waveguide: R22)



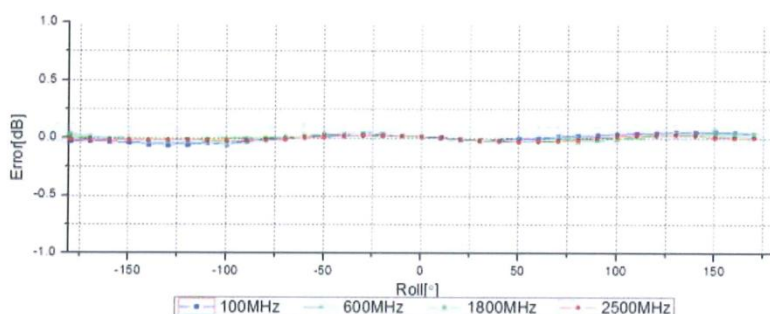
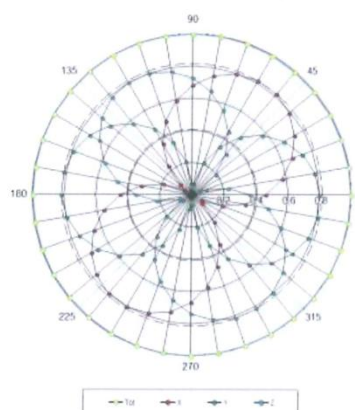
Uncertainty of Frequency Response of E-field:  $\pm 7.4\%$  (k=2)

## Receiving Pattern ( $\Phi$ ), $\theta=0^\circ$

**f=600 MHz, TEM**

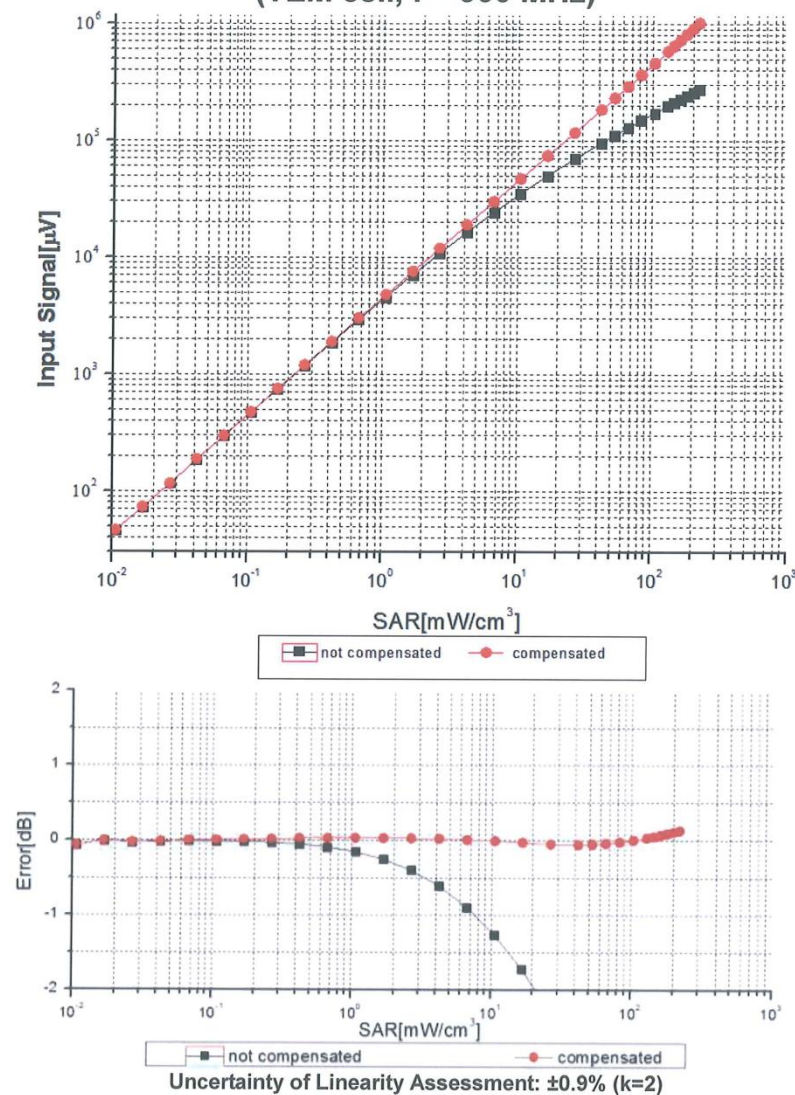


**f=1800 MHz, R22**



Uncertainty of Axial Isotropy Assessment:  $\pm 1.2\%$  ( $k=2$ )

### Dynamic Range f(SAR<sub>head</sub>) (TEM cell, f = 900 MHz)



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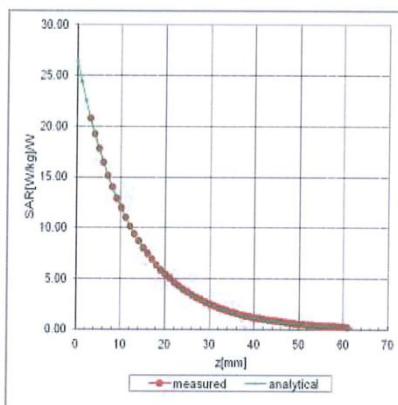
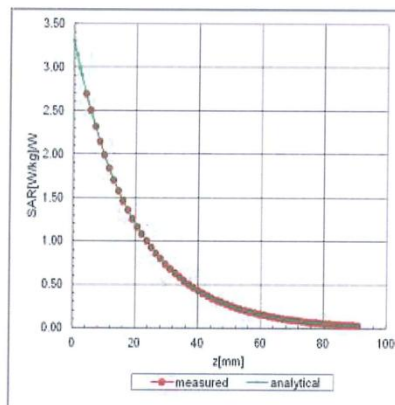
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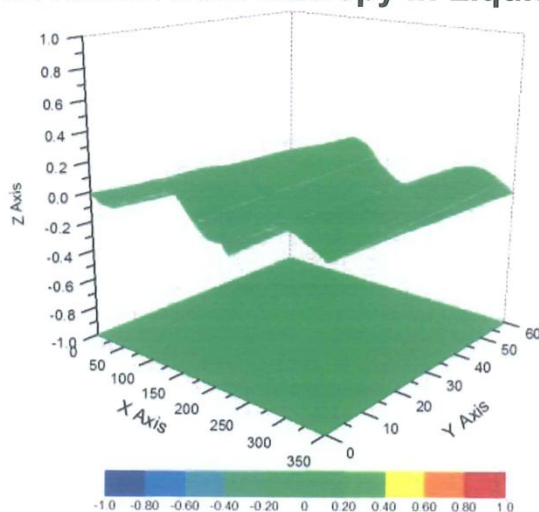
## Conversion Factor Assessment

f=835 MHz, WGLS R9(H\_convF)

f=1750 MHz, WGLS R22(H\_convF)



## Deviation from Isotropy in Liquid



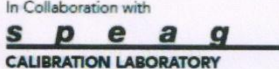
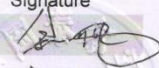
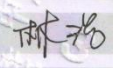
Uncertainty of Spherical Isotropy Assessment:  $\pm 3.2\%$  (K=2)

## DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3953

### Other Probe Parameters

|                                               |            |
|-----------------------------------------------|------------|
| Sensor Arrangement                            | Triangular |
| Connector Angle (°)                           | 33.2       |
| Mechanical Surface Detection Mode             | enabled    |
| Optical Surface Detection Mode                | disable    |
| Probe Overall Length                          | 337mm      |
| Probe Body Diameter                           | 10mm       |
| Tip Length                                    | 9mm        |
| Tip Diameter                                  | 2.5mm      |
| Probe Tip to Sensor X Calibration Point       | 1mm        |
| Probe Tip to Sensor Y Calibration Point       | 1mm        |
| Probe Tip to Sensor Z Calibration Point       | 1mm        |
| Recommended Measurement Distance from Surface | 1.4mm      |

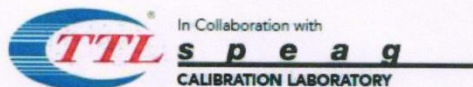
**DAE CALIBRATION DATA**

|                                                                                                                                                                                                                                                                           |  |                                                                                    |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|------------------------------------------------------------------------------------|------------------------------------------|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--|-------------------------------------------------------------|--|
|                                                                                                                                                                                          |  | In Collaboration with                                                              |                                          |  |                                                                                       |  |  | 中国认可<br>国际互认<br>校准<br>CALIBRATION<br>CNAS L0570             |  |
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| <b>CALIBRATION CERTIFICATE</b>                                                                                                                                                                                                                                            |  |                                                                                    |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
| Object                                                                                                                                                                                                                                                                    |  | DAE4 - SN: 1398                                                                    |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
| Calibration Procedure(s)                                                                                                                                                                                                                                                  |  | FF-Z11-002-01<br>Calibration Procedure for the Data Acquisition Electronics (DAEx) |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
| Calibration date:                                                                                                                                                                                                                                                         |  | February 08, 2018                                                                  |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
| This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate. |  |                                                                                    |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
| All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)°C and humidity<70%.                                                                                                                                                 |  |                                                                                    |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
| Calibration Equipment used (M&T critical for calibration)                                                                                                                                                                                                                 |  |                                                                                    |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
| Primary Standards                                                                                                                                                                                                                                                         |  | ID #                                                                               | Cal Date(Calibrated by, Certificate No.) |                                                                                   | Scheduled Calibration                                                                 |                                                                                    |  |                                                             |  |
| Process Calibrator 753                                                                                                                                                                                                                                                    |  | 1971018                                                                            | 27-Jun-17 (CTTL, No.J17X05859)           |                                                                                   | June-18                                                                               |                                                                                    |  |                                                             |  |
| Calibrated by:                                                                                                                                                                                                                                                            |  | Name                                                                               | Function                                 |                                                                                   | Signature                                                                             |                                                                                    |  |                                                             |  |
|                                                                                                                                                                                                                                                                           |  | Yu Zongying                                                                        | SAR Test Engineer                        |                                                                                   |  |                                                                                    |  |                                                             |  |
| Reviewed by:                                                                                                                                                                                                                                                              |  | Lin Hao                                                                            | SAR Test Engineer                        |                                                                                   |  |                                                                                    |  |                                                             |  |
| Approved by:                                                                                                                                                                                                                                                              |  | Qi Dianyuan                                                                        | SAR Project Leader                       |                                                                                   |  |                                                                                    |  |                                                             |  |
| Issued: February 09, 2018                                                                                                                                                                                                                                                 |  |                                                                                    |                                          |                                                                                   |                                                                                       |                                                                                    |  |                                                             |  |
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**Glossary:**

DAE data acquisition electronics  
Connector angle information used in DASY system to align probe sensor X to the robot coordinate system.

**Methods Applied and Interpretation of Parameters:**

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle:* The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The report provide only calibration results for DAE, it does not contain other performance test results.



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#### DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB =  $6.1\mu\text{V}$ , full range =  $-100\dots+300\text{ mV}$   
Low Range: 1LSB =  $61\text{nV}$ , full range =  $-1\dots\dots+3\text{mV}$

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| Calibration Factors | X                          | Y                          | Z                          |
|---------------------|----------------------------|----------------------------|----------------------------|
| High Range          | $404.218 \pm 0.15\% (k=2)$ | $404.199 \pm 0.15\% (k=2)$ | $403.661 \pm 0.15\% (k=2)$ |
| Low Range           | $3.97526 \pm 0.7\% (k=2)$  | $3.99340 \pm 0.7\% (k=2)$  | $3.97096 \pm 0.7\% (k=2)$  |

#### Connector Angle

|                                           |                           |
|-------------------------------------------|---------------------------|
| Connector Angle to be used in DASY system | $196.5^\circ \pm 1^\circ$ |
|-------------------------------------------|---------------------------|

Certificate No: Z18-97028

Page 3 of 3

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**DIPOLE CALIBRATION DATA**



**SAR Reference Dipole Calibration Report**

Ref : ACR.216.9.16.SATU.A

**ATTESTATION OF GLOBAL COMPLIANCE CO.  
LTD.**

**1&2F, NO.2 BUILDING, HUAFENG NO.1 INDUSTRIAL  
PARK, GUSHU COMMUNITY XIXIANG STREET  
BAOAN DISTRICT, SHENZHEN, P.R. CHINA  
MVG COMOSAR REFERENCE DIPOLE  
FREQUENCY: 2450 MHZ  
SERIAL NO.: SN 29/15 DIP 2G450-393**

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



**Calibration Date: 07/05/2016**

*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.

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**SAR REFERENCE DIPOLE CALIBRATION REPORT**

Ref: ACR.216.9.16.SATU.A

|               | Name          | Function        | Date     | Signature            |
|---------------|---------------|-----------------|----------|----------------------|
| Prepared by : | Jérôme LUC    | Product Manager | 8/3/2016 | <i>JS</i>            |
| Checked by :  | Jérôme LUC    | Product Manager | 8/3/2016 | <i>JS</i>            |
| Approved by : | Kim RUTKOWSKI | Quality Manager | 8/3/2016 | <i>Kim Rutkowski</i> |

|                | Customer Name                                      |
|----------------|----------------------------------------------------|
| Distribution : | ATTESTATION<br>OF GLOBAL<br>COMPLIANCE<br>CO. LTD. |

| Issue | Date     | Modifications   |
|-------|----------|-----------------|
| A     | 8/3/2016 | 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 29/15 DIP 2G450-393            |
| Product Condition (new / used) | New                               |

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

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#### 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 %               |

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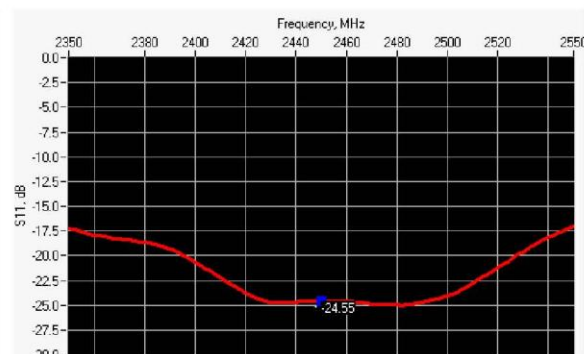
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|      |        |
|------|--------|
| 10 g | 20.1 % |
|------|--------|

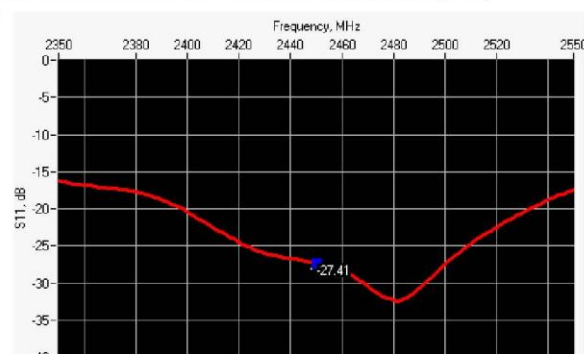
## 6 CALIBRATION MEASUREMENT RESULTS

### 6.1 RETURN LOSS AND IMPEDANCE IN HEAD LIQUID



| Frequency (MHz) | Return Loss (dB) | Requirement (dB) | Impedance                   |
|-----------------|------------------|------------------|-----------------------------|
| 2450            | -24.55           | -20              | $47.5 \Omega + 5.4 j\Omega$ |

### 6.2 RETURN LOSS AND IMPEDANCE IN BODY LIQUID



| Frequency (MHz) | Return Loss (dB) | Requirement (dB) | Impedance                   |
|-----------------|------------------|------------------|-----------------------------|
| 2450            | -27.41           | -20              | $50.5 \Omega + 4.2 j\Omega$ |

### 6.3 MECHANICAL DIMENSIONS

| Frequency MHz | L mm       |          | h mm       |          | d mm      |          |
|---------------|------------|----------|------------|----------|-----------|----------|
|               | required   | measured | required   | measured | required  | measured |
| 300           | 420.0 ±1 % |          | 250.0 ±1 % |          | 6.35 ±1 % |          |

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

## 7 VALIDATION MEASUREMENT

The IEEE Std. 1528, FCC KDBs and CE/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<br>MHz | Relative permittivity ( $\epsilon_r$ ) |          | Conductivity ( $\sigma$ ) S/m |          |
|------------------|----------------------------------------|----------|-------------------------------|----------|
|                  | required                               | measured | required                      | measured |
| 300              | 45.3 ±5 %                              |          | 0.87 ±5 %                     |          |
| 450              | 43.5 ±5 %                              |          | 0.87 ±5 %                     |          |
| 750              | 41.9 ±5 %                              |          | 0.89 ±5 %                     |          |
| 835              | 41.5 ±5 %                              |          | 0.90 ±5 %                     |          |
| 900              | 41.5 ±5 %                              |          | 0.97 ±5 %                     |          |
| 1450             | 40.5 ±5 %                              |          | 1.20 ±5 %                     |          |
| 1500             | 40.4 ±5 %                              |          | 1.23 ±5 %                     |          |
| 1640             | 40.2 ±5 %                              |          | 1.31 ±5 %                     |          |
| 1750             | 40.1 ±5 %                              |          | 1.37 ±5 %                     |          |

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|      |           |      |           |      |
|------|-----------|------|-----------|------|
| 1800 | 40.0 ±5 % |      | 1.40 ±5 % |      |
| 1900 | 40.0 ±5 % |      | 1.40 ±5 % |      |
| 1950 | 40.0 ±5 % |      | 1.40 ±5 % |      |
| 2000 | 40.0 ±5 % |      | 1.40 ±5 % |      |
| 2100 | 39.8 ±5 % |      | 1.49 ±5 % |      |
| 2300 | 39.5 ±5 % |      | 1.67 ±5 % |      |
| 2450 | 39.2 ±5 % | PASS | 1.80 ±5 % | PASS |
| 2600 | 39.0 ±5 % |      | 1.96 ±5 % |      |
| 3000 | 38.5 ±5 % |      | 2.40 ±5 % |      |
| 3500 | 37.9 ±5 % |      | 2.91 ±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: eps' : 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<br>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              |          |

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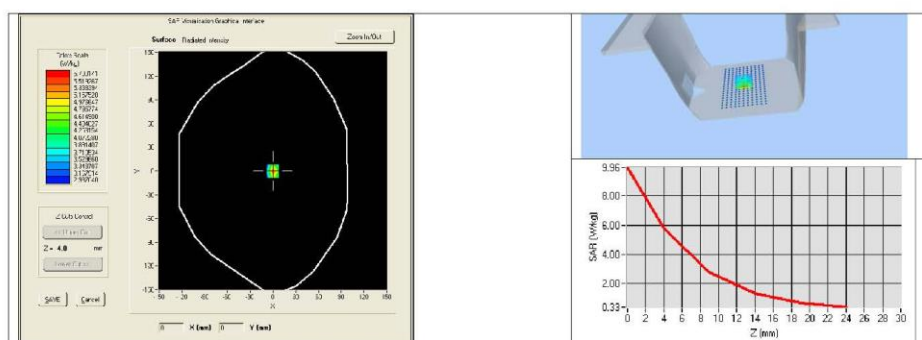
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|      |      |              |      |              |
|------|------|--------------|------|--------------|
| 1900 | 39.7 |              | 20.5 |              |
| 1950 | 40.5 |              | 20.9 |              |
| 2000 | 41.1 |              | 21.1 |              |
| 2100 | 43.6 |              | 21.9 |              |
| 2300 | 48.7 |              | 23.3 |              |
| 2450 | 52.4 | 54.53 (5.45) | 24   | 24.30 (2.43) |
| 2600 | 55.3 |              | 24.6 |              |
| 3000 | 63.8 |              | 25.7 |              |
| 3500 | 67.1 |              | 25   |              |



**7.3 BODY LIQUID MEASUREMENT**

| Frequency<br>MHz | Relative permittivity ( $\epsilon_r$ ) |          | Conductivity ( $\sigma$ ) 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     |

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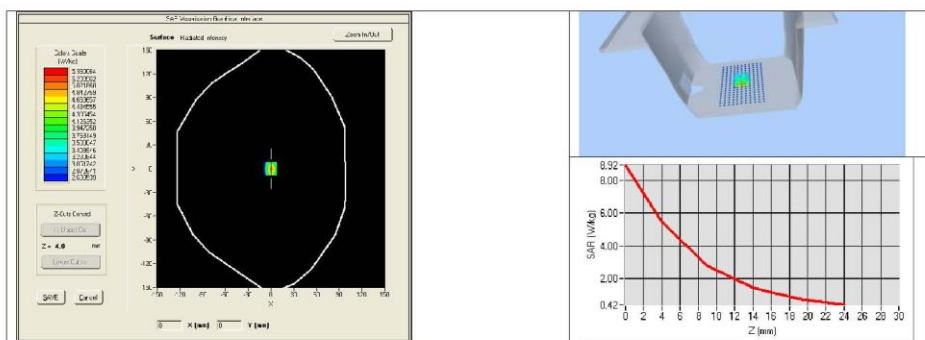
Ref: ACR.216.9.16.SATU.A

|      |            |  |            |  |
|------|------------|--|------------|--|
| 2600 | 52.5 ±5 %  |  | 2.16 ±5 %  |  |
| 3000 | 52.0 ±5 %  |  | 2.73 ±5 %  |  |
| 3500 | 51.3 ±5 %  |  | 3.31 ±5 %  |  |
| 5200 | 49.0 ±10 % |  | 5.30 ±10 % |  |
| 5300 | 48.9 ±10 % |  | 5.42 ±10 % |  |
| 5400 | 48.7 ±10 % |  | 5.53 ±10 % |  |
| 5500 | 48.6 ±10 % |  | 5.65 ±10 % |  |
| 5600 | 48.5 ±10 % |  | 5.77 ±10 % |  |
| 5800 | 48.2 ±10 % |  | 6.00 ±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: $\epsilon_{ps}$ : 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<br>MHz | 1 g SAR (W/kg/W) | 10 g SAR (W/kg/W) |
|------------------|------------------|-------------------|
|                  | measured         | measured          |
| 2450             | 49.92 (4.99)     | 23.16 (2.32)      |



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## 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         | 12/2013                                       | 12/2016                                       |
| Reference Probe                 | MVG                  | EPG122 SN 18/11    | 10/2015                                       | 10/2016                                       |
| Multimeter                      | Keithley 2000        | 1188656            | 12/2013                                       | 12/2016                                       |
| Signal Generator                | Agilent E4438C       | MY49070581         | 12/2013                                       | 12/2016                                       |
| Amplifier                       | Aethercomm           | SN 046             | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Power Meter                     | HP E4418A            | US38261498         | 12/2013                                       | 12/2016                                       |
| Power Sensor                    | HP ECP-E26A          | US37181460         | 12/2013                                       | 12/2016                                       |
| 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                                       |

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