

4 MEASUREMENT METHOD

The IEC/IEEE 62209-1528 and FCC KDB865664 D01 standards outline techniques for dielectric property measurements. The LIMESAR test bench employs one of the methods outlined in the standards, using a contact probe or open-ended coaxial transmission-line probe and vector network analyzer. The standards recommend the measurement of two reference materials that have well established and stable dielectric properties to validate the system, one for the calibration and one for checking the calibration. The LIMESAR test bench uses De-ionized water as the reference for the calibration and either DMS or Methanol as the reference for checking the calibration. The following measurements were performed to verify that the product complies with the fore mentioned standards.

4.1 LIQUID PERMITTIVITY MEASUREMENTS

The permittivity of a liquid with well established dielectric properties was measured and the measurement results compared to the values provided in the fore mentioned standards.

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 DIELECTRIC PERMITTIVITY MEASUREMENT

The following uncertainties apply to the Dielectric Permittivity measurement:

| Uncertainty analysis of Permittivity Measurement | | | | | |
|---|--------------------------|--------------------------|---------|----|-----------------------------|
| ERROR SOURCES | Uncertainty value (+/-%) | Probability Distribution | Divisor | ci | Standard Uncertainty (+/-%) |
| Expanded uncertainty (confidence level of 95%, k = 2) | | | | | 10 % |

| Uncertainty analysis of Conductivity Measurement | | | | | |
|---|--------------------------|--------------------------|---------|----|-----------------------------|
| ERROR SOURCES | Uncertainty value (+/-%) | Probability Distribution | Divisor | ci | Standard Uncertainty (+/-%) |
| Expanded uncertainty (confidence level of 95%, k = 2) | | | | | 8.2% |

6 CALIBRATION MEASUREMENT RESULTS

Measurement Condition

| | |
|--------------------|-------------|
| Software | LIMESAR |
| Liquid Temperature | 20 +/- 1 °C |
| Lab Temperature | 20 +/- 1 °C |
| Lab Humidity | 30-70 % |

6.1 LIQUID PERMITTIVITY MEASUREMENT

A liquid of known characteristics (methanol or ethanediol) is measured with the probe and the results (complex permittivity $\epsilon' + j\epsilon''$) are compared with the reference values for this liquid.





7 LIST OF EQUIPMENT

| Equipment Summary Sheet | | | | |
|------------------------------------|-------------------------|--------------------|-----------------------------|-----------------------------|
| Equipment Description | Manufacturer / Model | Identification No. | Current Calibration Date | Next Calibration Date |
| LIMESAR Test Bench | Version 3 | NA | Validated. No cal required. | Validated. No cal required. |
| Liquid measurement probe | MVG | SN 35/10 OCPG37 | 11/2022 | 11/2023 |
| Network Analyzer | Rohde & Schwarz ZVM | 100203 | 08/2021 | 08/2024 |
| Network Analyzer | Agilent 8753ES | MY40003210 | 10/2021 | 10/2024 |
| Network Analyzer – Calibration kit | Rohde & Schwarz ZV-Z235 | 101223 | 05/2021 | 05/2024 |
| Network Analyzer – Calibration kit | HP 85033D | 3423A08186 | 06/2021 | 06/2027 |
| Temperature / Humidity Sensor | Testo 184 H1 | 44225320 | 06/2021 | 06/2024 |



SAR Reference Dipole Calibration Report

Ref : ACR.49.11.22.BES.A

BTF TESTING LAB (SHENZHEN) CO., LTD.
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MVG COMOSAR REFERENCE DIPOLE

FREQUENCY: 2450 MHZ

SERIAL NO.: SN 07/22 DIP2G450-662

Calibrated at MVG

Z.I. de la pointe du diable

Technopôle Brest Iroise – 295 avenue Alexis de Rochon

29280 PLOUZANE - FRANCE

Calibration date: 02/06/2023



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Summary:

This document presents the method and results from an accredited SAR reference dipole calibration performed in MVG 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> |
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| <i>Issue</i> | <i>Name</i> | <i>Date</i> | <i>Modifications</i> |
|--------------|-------------|-------------|----------------------|
| A | Jérôme Luc | 2/6/2023 | Initial release |
| | | | |
| | | | |



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1 INTRODUCTION

This document contains a summary of the requirements set forth by the IEC/IEEE 62209-1528 and FCC KDB865664 D01 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 07/22 DIP2G450-662 |
| Product Condition (new / used) | New |

3 PRODUCT DESCRIPTION

3.1 GENERAL INFORMATION

MVG’s COMOSAR Validation Dipoles are built in accordance to the IEC/IEEE 62209-1528 and FCC KDB865664 D01 standards. The product is designed for use with the COMOSAR test bench only.



Figure 1 – MVG COMOSAR Validation Dipole

4 MEASUREMENT METHOD

The IEC/IEEE 62209-1528 and FCC KDB865664 D01 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. A direct method is used with a network analyser and its calibration kit, both with a valid ISO17025 calibration.

4.2 MECHANICAL REQUIREMENTS

The IEC/IEEE 62209-1528 and FCC KDB865664 D01 standards specify the mechanical components and dimensions of the validation dipoles, with the dimension's 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. A direct method is used with a ISO17025 calibrated caliper.

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 | 0.08 LIN |

5.2 DIMENSION MEASUREMENT

The following uncertainties apply to the dimension measurements:

| Length (mm) | Expanded Uncertainty on Length |
|-------------|--------------------------------|
| 0 - 300 | 0.20 mm |
| 300 - 450 | 0.44 mm |

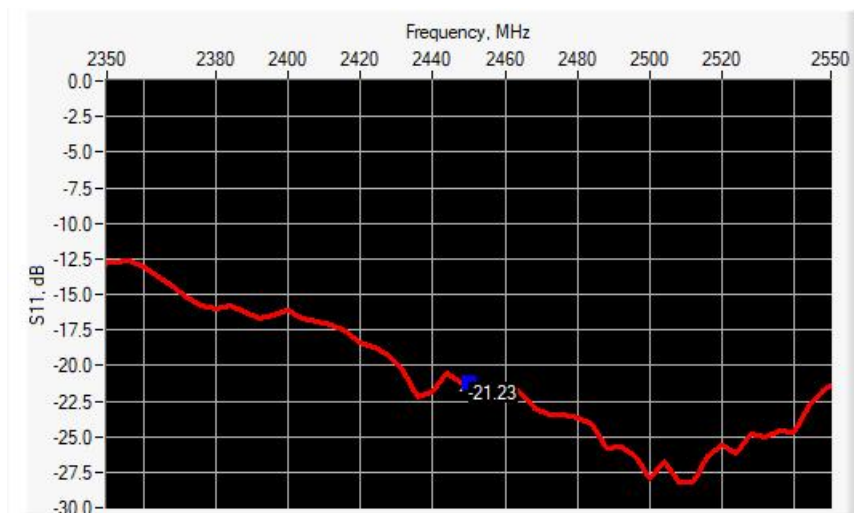
5.3 VALIDATION MEASUREMENT

The guidelines outlined in the IEC/IEEE 62209-1528 and FCC KDB865664 D01 standards were followed to generate the measurement uncertainty for validation measurements.

| Scan Volume | Expanded Uncertainty |
|-------------|----------------------|
| 1 g | 19 % (SAR) |
| 10 g | 19 % (SAR) |

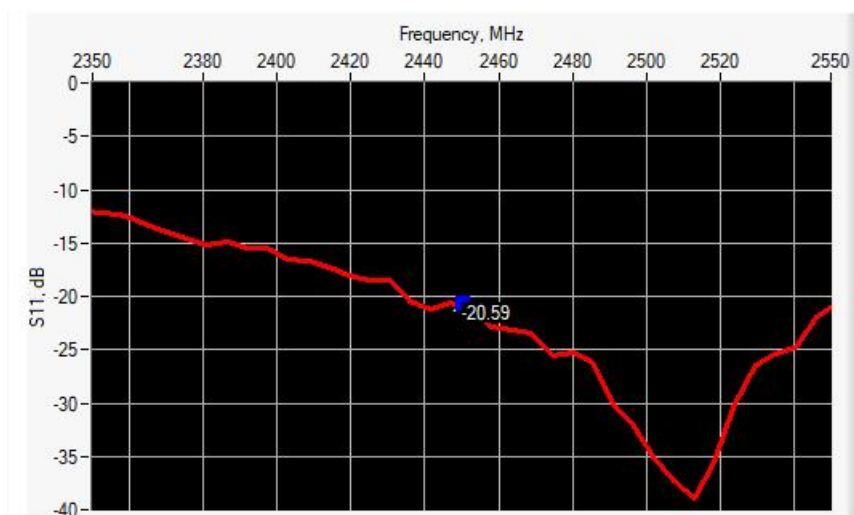
6 CALIBRATION MEASUREMENT RESULTS

6.1 RETURN LOSS AND IMPEDANCE IN HEAD LIQUID



| Frequency (MHz) | Return Loss (dB) | Requirement (dB) | Impedance |
|-----------------|------------------|------------------|-----------------|
| 2450 | -21.23 | -20 | 49.4 Ω + 8.6 jΩ |

6.2 RETURN LOSS AND IMPEDANCE IN BODY LIQUID



| Frequency (MHz) | Return Loss (dB) | Requirement (dB) | Impedance |
|-----------------|------------------|------------------|-----------------|
| 2450 | -20.59 | -20 | 53.5 Ω + 8.6 jΩ |

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 %. | |
| 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 | 86.2 ±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 %. | 51.49 | 30.4 ±1 %. | 30.37 | 3.6 ±1 %. | 3.60 |
| 2600 | 48.5 ±1 %. | | 28.8 ±1 %. | | 3.6 ±1 %. | |
| 3000 | 41.5 ±1 %. | | 25.0 ±1 %. | | 3.6 ±1 %. | |
| 3300 | - | | - | | - | |
| 3500 | 37.0±1 %. | | 26.4 ±1 %. | | 3.6 ±1 %. | |
| 3700 | 34.7±1 %. | | 26.4 ±1 %. | | 3.6 ±1 %. | |
| 3900 | - | | - | | - | |
| 4200 | - | | - | | - | |
| 4600 | - | | - | | - | |
| 4900 | - | | - | | - | |

7 VALIDATION MEASUREMENT

The IEC/IEEE 62209-1528 and FCC KDB865664 D01 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 ±10 % | | 0.87 ±10 % | |
| 450 | 43.5 ±10 % | | 0.87 ±10 % | |
| 750 | 41.9 ±10 % | | 0.89 ±10 % | |
| 835 | 41.5 ±10 % | | 0.90 ±10 % | |
| 900 | 41.5 ±10 % | | 0.97 ±10 % | |
| 1450 | 40.5 ±10 % | | 1.20 ±10 % | |
| 1500 | 40.4 ±10 % | | 1.23 ±10 % | |
| 1640 | 40.2 ±10 % | | 1.31 ±10 % | |
| 1750 | 40.1 ±10 % | | 1.37 ±10 % | |
| 1800 | 40.0 ±10 % | | 1.40 ±10 % | |
| 1900 | 40.0 ±10 % | | 1.40 ±10 % | |
| 1950 | 40.0 ±10 % | | 1.40 ±10 % | |
| 2000 | 40.0 ±10 % | | 1.40 ±10 % | |
| 2100 | 39.8 ±10 % | | 1.49 ±10 % | |
| 2300 | 39.5 ±10 % | | 1.67 ±10 % | |
| 2450 | 39.2 ±10 % | 36.4 | 1.80 ±10 % | 1.96 |
| 2600 | 39.0 ±10 % | | 1.96 ±10 % | |
| 3000 | 38.5 ±10 % | | 2.40 ±10 % | |
| 3300 | 38.2 ±10 % | | 2.71 ±10 % | |
| 3500 | 37.9 ±10 % | | 2.91 ±10 % | |
| 3700 | 37.7 ±10 % | | 3.12 ±10 % | |
| 3900 | 37.5 ±10 % | | 3.32 ±10 % | |
| 4200 | 37.1 ±10 % | | 3.63 ±10 % | |
| 4600 | 36.7 ±10 % | | 4.04 ±10 % | |
| 4900 | 36.3 ±10 % | | 4.35 ±10 % | |

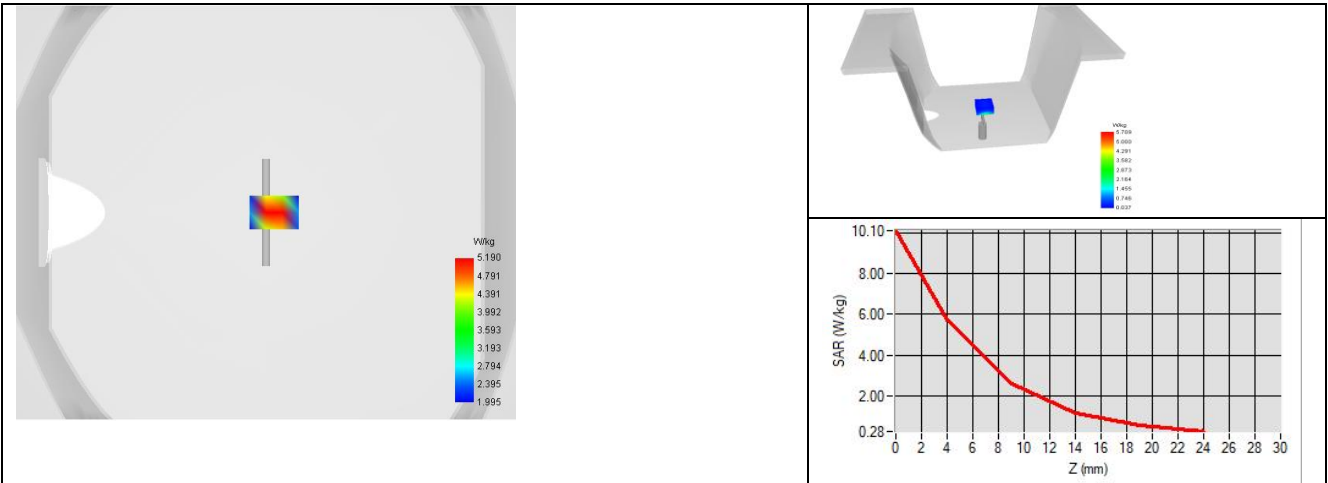
7.2 SAR MEASUREMENT RESULT WITH HEAD LIQUID

The IEC/IEEE 62209-1528 and FCC KDB865664 D01 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 V5 |
| Phantom | SN 13/09 SAM68 |
| Probe | SN 41/18 EPGO333 |
| Liquid | Head Liquid Values: eps' : 36.4 sigma : 1.96 |
| 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 | 20 +/- 1 °C |
| Lab Temperature | 20 +/- 1 °C |
| Lab Humidity | 30-70 % |

| 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 | 54.40 (5.44) | 24 | 23.86 (2.39) |
| 2600 | 55.3 | | 24.6 | |
| 3000 | 63.8 | | 25.7 | |
| 3300 | - | | - | |
| 3500 | 67.1 | | 25 | |
| 3700 | 67.4 | | 24.2 | |
| 3900 | - | | - | |
| 4200 | - | | - | |
| 4600 | - | | - | |
| 4900 | - | | - | |



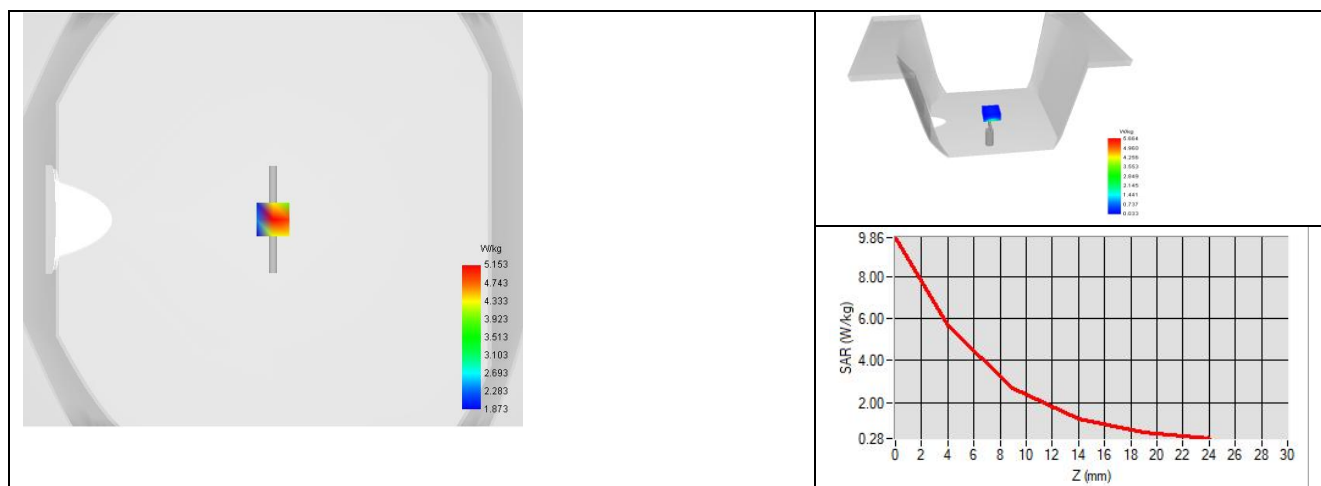
7.3 BODY LIQUID MEASUREMENT

| Frequency MHz | Relative permittivity (ϵ_r') | | Conductivity (σ) S/m | |
|------------------|---|----------|-------------------------------|----------|
| | required | measured | required | measured |
| 150 | 61.9 ±10 % | | 0.80 ±10 % | |
| 300 | 58.2 ±10 % | | 0.92 ±10 % | |
| 450 | 56.7 ±10 % | | 0.94 ±10 % | |
| 750 | 55.5 ±10 % | | 0.96 ±10 % | |
| 835 | 55.2 ±10 % | | 0.97 ±10 % | |
| 900 | 55.0 ±10 % | | 1.05 ±10 % | |
| 915 | 55.0 ±10 % | | 1.06 ±10 % | |
| 1450 | 54.0 ±10 % | | 1.30 ±10 % | |
| 1610 | 53.8 ±10 % | | 1.40 ±10 % | |
| 1800 | 53.3 ±10 % | | 1.52 ±10 % | |
| 1900 | 53.3 ±10 % | | 1.52 ±10 % | |
| 2000 | 53.3 ±10 % | | 1.52 ±10 % | |
| 2100 | 53.2 ±10 % | | 1.62 ±10 % | |
| 2300 | 52.9 ±10 % | | 1.81 ±10 % | |
| 2450 | 52.7 ±10 % | 53.4 | 1.95 ±10 % | 2.14 |
| 2600 | 52.5 ±10 % | | 2.16 ±10 % | |
| 3000 | 52.0 ±10 % | | 2.73 ±10 % | |
| 3300 | 51.6 ±10 % | | 3.08 ±10 % | |
| 3500 | 51.3 ±10 % | | 3.31 ±10 % | |
| 3700 | 51.0 ±10 % | | 3.55 ±10 % | |
| 3900 | 50.8 ±10 % | | 3.78 ±10 % | |
| 4200 | 50.4 ±10 % | | 4.13 ±10 % | |
| 4600 | 49.8 ±10 % | | 4.60 ±10 % | |
| 4900 | 49.4 ±10 % | | 4.95 ±10 % | |
| 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 V5 |
| Phantom | SN 13/09 SAM68 |
| Probe | SN 41/18 EPGO333 |
| Liquid | Body Liquid Values: ϵ_p : 53.4 σ : 2.14 |
| 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 | 20 +/- 1 °C |
| Lab Temperature | 20 +/- 1 °C |
| Lab Humidity | 30-70 % |

| Frequency MHz | 1 g SAR (W/kg/W) | 10 g SAR (W/kg/W) |
|---------------|------------------|-------------------|
| | measured | measured |
| 2450 | 53.84 (5.38) | 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 13/09 SAM68 | Validated. No cal required. | Validated. No cal required. |
| COMOSAR Test Bench | Version 3 | NA | Validated. No cal required. | Validated. No cal required. |
| Network Analyzer | Rohde & Schwarz ZVM | 100203 | 08/2021 | 08/2024 |
| Network Analyzer | Agilent 8753ES | MY40003210 | 10/2021 | 10/2024 |
| Network Analyzer – Calibration kit | Rohde & Schwarz ZV-Z235 | 101223 | 05/2021 | 05/2024 |
| Network Analyzer – Calibration kit | HP 85033D | 3423A08186 | 06/2021 | 06/2027 |
| Calipers | Mitutoyo | SN 0009732 | 10/2021 | 10/2024 |
| Reference Probe | MVG | SN 41/18 EPGO333 | 10/2021 | 10/2024 |
| Multimeter | Keithley 2000 | 1160271 | 02/2021 | 02/2024 |
| Signal Generator | Rohde & Schwarz SMB | 106589 | 04/2021 | 04/2024 |
| Amplifier | MVG | MODU-023-C-0002 | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Power Meter | NI-USB 5680 | 170100013 | 06/2021 | 06/2024 |
| Power Meter | Rohde & Schwarz NRVD | 832839-056 | 11/2021 | 11/2024 |
| Directional Coupler | Krytar 158020 | 131467 | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Temperature / Humidity Sensor | Testo 184 H1 | 44225320 | 06/2021 | 06/2024 |