



COMOSAR E-Field Probe Calibration Report

Ref : ACR.49.1.22.BES.A

BTF TESTING LAB (SHENZHEN) CO., LTD.
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INDUSTRIAL PARK, TANTOU COMMUNITY
SONGGANG STREET, BAO'AN DISTRICT, SHENZHEN,
CHINA
MVG COMOSAR DOSIMETRIC E-FIELD PROBE
SERIAL NO.: SN 04/22 EPGO365

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



Accreditations #2-6789
Scope available on www.cofrac.fr

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Summary:

This document presents the method and results from an accredited COMOSAR E-Field Probe calibration performed at MVG, using the CALIPROBE test bench, for use with a MVG COMOSAR system only. The test results covered by accreditation are traceable to the International System of Units (SI).

| | <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 DEVICE UNDER TEST

| Device Under Test | |
|--|---|
| Device Type | COMOSAR DOSIMETRIC E FIELD PROBE |
| Manufacturer | MVG |
| Model | SSE2 |
| Serial Number | SN 04/22 EPGO365 |
| Product Condition (new / used) | New |
| Frequency Range of Probe | 0.15 GHz-6GHz |
| Resistance of Three Dipoles at Connector | Dipole 1: R1=0.204 MΩ Dipole 2: R2=0.212 MΩ Dipole 3: R3=0.187 MΩ |

2 PRODUCT DESCRIPTION

2.1 GENERAL INFORMATION

MVG’s COMOSAR E field Probes are built in accordance to the IEC/IEEE 62209-1528 and FCC KDB865664 D01 standards.



Figure 1 – MVG COMOSAR Dosimetric E field Probe

| | |
|--|--------|
| 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 IEC/IEEE 62209-1528 and FCC KDB865664 D01 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 to 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°).

3.1 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.

The boundary effect uncertainty can be estimated according to the following uncertainty approximation formula based on linear and exponential extrapolations between the surface and $d_{be} + d_{step}$ along lines that are approximately normal to the surface:

$$SAR_{uncertainty} [\%] = \Delta SAR_{be} \frac{(d_{be} + d_{step})^2}{2d_{step}} \frac{(e^{-d_{be}/(\delta/2)})}{\delta/2} \quad \text{for } (d_{be} + d_{step}) < 10 \text{ mm}$$

where

- $SAR_{uncertainty}$ is the uncertainty in percent of the probe boundary effect
- d_{be} is the distance between the surface and the closest *zoom-scan* measurement point, in millimetre
- Δ_{step} is the separation distance between the first and second measurement points that are closest to the phantom surface, in millimetre, assuming the boundary effect at the second location is negligible
- δ is the minimum penetration depth in millimetres of the head tissue-equivalent liquids defined in this standard, i.e., $\delta \approx 14$ mm at 3 GHz;
- ΔSAR_{be} in percent of SAR is the deviation between the measured SAR value, at the distance d_{be} from the boundary, and the analytical SAR value.

The measured worst case boundary effect $SAR_{uncertainty}[\%]$ for scanning distances larger than 4mm is 1.0% Limit ,2%).

4 MEASUREMENT UNCERTAINTY

The guidelines outlined in the IEC/IEEE 62209-1528 and FCC KDB865664 D01 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 (%) |
| Expanded uncertainty 95 % confidence level k = 2 | | | | | 14 % |

5 CALIBRATION MEASUREMENT RESULTS

| Calibration Parameters | |
|------------------------|-------------|
| Liquid Temperature | 20 +/- 1 °C |
| Lab Temperature | 20 +/- 1 °C |
| Lab Humidity | 30-70 % |

5.1 SENSITIVITY IN AIR

| Normx dipole 1 (µV/(V/m) ²) | Normy dipole 2 (µV/(V/m) ²) | Normz dipole 3 (µV/(V/m) ²) |
|--|--|--|
| 0.79 | 0.94 | 0.85 |

| DCP dipole 1 (mV) | DCP dipole 2 (mV) | DCP dipole 3 (mV) |
|----------------------|----------------------|----------------------|
| 106 | 110 | 107 |

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

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

Calibration curves



5.2 LINEARITY

Linearity



Linearity: +/-1.77% (+/-0.08dB)



5.3 SENSITIVITY IN LIQUID

| Liquid | Frequency (MHz +/- 100MHz) | ConvF |
|--------|----------------------------------|-------|
| HL450* | 450 | 1.82 |
| BL450* | 450 | 1.74 |
| HL750 | 750 | 1.65 |
| BL750 | 750 | 1.68 |
| HL850 | 835 | 1.68 |
| BL850 | 835 | 1.69 |
| HL1800 | 1800 | 1.96 |
| BL1800 | 1800 | 2.01 |
| HL1900 | 1900 | 2.24 |
| BL1900 | 1900 | 2.20 |
| HL2000 | 2000 | 2.33 |
| BL2000 | 2000 | 2.29 |
| HL2100 | 2100 | 2.35 |
| BL2100 | 2100 | 2.40 |
| HL2300 | 2300 | 2.36 |
| BL2300 | 2300 | 2.44 |
| HL2450 | 2450 | 2.36 |
| BL2450 | 2450 | 2.28 |
| HL2600 | 2600 | 2.40 |
| BL2600 | 2600 | 2.27 |
| HL3500 | 3500 | 2.00 |
| BL3500 | 3500 | 2.13 |
| HL3700 | 3700 | 2.02 |
| BL3700 | 3700 | 2.10 |
| HL3900 | 3900 | 1.99 |
| BL3900 | 3900 | 2.19 |
| HL4200 | 4200 | 2.27 |
| BL4200 | 4200 | 2.39 |
| HL4600 | 4600 | 2.27 |
| BL4600 | 4600 | 2.37 |
| HL4900 | 4900 | 2.16 |
| BL4900 | 4900 | 2.05 |
| HL5200 | 5200 | 2.24 |
| BL5200 | 5200 | 2.26 |
| HL5400 | 5400 | 2.12 |
| BL5400 | 5400 | 2.08 |
| HL5600 | 5600 | 2.18 |
| BL5600 | 5600 | 2.05 |
| HL5800 | 5800 | 2.04 |
| BL5800 | 5800 | 2.01 |

* Frequency not covered by COFRAC scope, calibration not accredited

LOWER DETECTION LIMIT: 7mW/kg

5.4 ISOTROPY

HL1800 MHz



6 LIST OF EQUIPMENT

| Equipment Summary Sheet | | | | |
|------------------------------------|-------------------------|-------------------------|---|---|
| Equipment Description | Manufacturer / Model | Identification No. | Current Calibration Date | Next Calibration Date |
| CALIPROBE Test Bench | Version 2 | 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 |
| 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. |
| Waveguide | MVG | SN 32/16 WG4_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_0G900_1 | Validated. No cal required. | Validated. No cal required. |
| Waveguide | MVG | SN 32/16 WG6_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_1G500_1 | Validated. No cal required. | Validated. No cal required. |
| Waveguide | MVG | SN 32/16 WG8_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_1G800B_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_1G800H_1 | Validated. No cal required. | Validated. No cal required. |
| Waveguide | MVG | SN 32/16 WG10_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_3G500_1 | Validated. No cal required. | Validated. No cal required. |



COMOSAR E-FIELD PROBE CALIBRATION REPORT

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| | | | | |
|-------------------------------|--------------|---------------------------|-----------------------------|-----------------------------|
| Waveguide | MVG | SN 32/16 WG12_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_5G000_1 | Validated. No cal required. | Validated. No cal required. |
| Temperature / Humidity Sensor | Testo 184 H1 | 44225320 | 06/2021 | 06/2024 |



Dielectric Probe Calibration Report

Ref : ACR.49.20.22.BES.A

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SONGGANG STREET, BAO'AN DISTRICT, SHENZHEN,
CHINA

MVG LIMESAR DIELECTRIC PROBE

FREQUENCY: 0.4-6 GHZ

SERIAL NO.: SN 06/22 OCPG 88

Calibrated at MVG

Z.I. de la pointe du diable

Technopôle Brest Iroise – 295 avenue Alexis de Rochon

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Calibration date: 02/06/2023



Accreditations #2-6789
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Summary:

This document presents the method and results from an accredited Dielectric Probe calibration performed at MVG, using the LIMESAR test bench. The test results covered by accreditation are traceable to the International System of Units (SI).

| | <i>Name</i> | <i>Function</i> | <i>Date</i> | <i>Signature</i> |
|----------------------|--------------|---------------------|-------------|---------------------|
| <i>Prepared by :</i> | Jérôme Luc | Technical Manager | 2/6/2023 | <i>JLS</i> |
| <i>Checked by :</i> | Jérôme Luc | Technical Manager | 2/6/2023 | <i>JLS</i> |
| <i>Approved by :</i> | Yann Toutain | Laboratory Director | 2/6/2023 | <i>Yann TOUTAIN</i> |

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| | <i>Customer Name</i> |
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| <i>Distribution :</i> | BTF Testing Lab (Shenzhen) Co., Ltd. |

| <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 suggested methods and requirements set forth by the IEC/IEEE 62209-1528 and FCC KDB865664 D01 standards for liquid permittivity measurements 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 | LIMESAR DIELECTRIC PROBE |
| Manufacturer | MVG |
| Model | SCLMP |
| Serial Number | SN 06/22 OCPG 88 |
| Product Condition (new / used) | New |

3 PRODUCT DESCRIPTION

3.1 GENERAL INFORMATION

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



Figure 1 – MVG LIMESAR Dielectric Probe

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.49.4.22.BES.A

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SONGGANG STREET, BAO'AN DISTRICT, SHENZHEN,
CHINA

MVG COMOSAR REFERENCE DIPOLE
FREQUENCY: 750 MHZ
SERIAL NO.: SN 07/22 DIP 0G750-655

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.