



COMOHAC E-Field Probe Calibration Report

Ref : ACR.49.21.22.BES.A

BTF TESTING LAB (SHENZHEN) CO., LTD.
F101,201 AND 301, BUILDING 1, BLOCK 2, TANTOU
INDUSTRIAL PARK, TANTOU COMMUNITY
SONGGANG STREET, BAO'AN DISTRICT, SHENZHEN,
CHINA

MVG COMOHAC E-FIELD PROBE
SERIAL NO.: SN 07/22 EPH50

Calibrated at MVG

Z.I. de la pointe du diable

Technopôle Brest Iroise – 295 avenue Alexis de Rochon

29280 PLOUZANE - FRANCE

Calibration date: 02/06/2024



Accreditations #2-6789

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Summary:

This document presents the method and results from an accredited COMOHAC E-Field Probe calibration performed at MVG, using the CALIPROBE test bench, for use with a MVG COMOHAC 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> |
|----------------------|--------------|---------------------|-------------|---------------------|
| <i>Prepared by :</i> | Jérôme Luc | Technical Manager | 2/6/2024 | <i>JS</i> |
| <i>Checked by :</i> | Jérôme Luc | Technical Manager | 2/6/2024 | <i>JS</i> |
| <i>Approved by :</i> | Yann Toutain | Laboratory Director | 2/6/2024 | <i>Yann TOUTAIN</i> |

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

| <i>Issue</i> | <i>Name</i> | <i>Date</i> | <i>Modifications</i> |
|--------------|-------------|-------------|----------------------|
| A | Jérôme Luc | 2/6/2024 | Initial release |
| | | | |
| | | | |



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1 DEVICE UNDER TEST

| Device Under Test | |
|--|---|
| Device Type | COMOHAC E FIELD PROBE |
| Manufacturer | MVG |
| Model | SCE |
| Serial Number | SN 07/22 EPH50 |
| Product Condition (new / used) | New |
| Frequency Range of Probe | 0.7GHz-2.5GHz |
| Resistance of Three Dipoles at Connector | Dipole 1: R1=0.208 MΩ Dipole 2: R2=0.220 MΩ Dipole 3: R3=0.212 MΩ |

2 PRODUCT DESCRIPTION

2.1 GENERAL INFORMATION

MVG’s COMOHAC E field Probes are built in accordance to the ANSI C63.19 and IEEE 1309 standards.



Figure 1 – MVG COMOHAC E field Probe

| | |
|--|--------|
| Probe Length | 330 mm |
| Length of Individual Dipoles | 3.3 mm |
| Maximum external diameter | 8 mm |
| Probe Tip External Diameter | 5 mm |
| Distance between dipoles / probe extremity | 3 mm |

3 MEASUREMENT METHOD

All methods used to perform the measurements and calibrations comply with the ANSI C63.19 and IEEE 1309 standards.

3.1 LINEARITY

The linearity was determined using a standard dipole with the probe positioned 10 mm above the dipole. The input power of the dipole was adjusted from -15 to 36 dBm using a 1dB step (to cover the range 2V/m to 1000A/m).

3.2 SENSITIVITY

The sensitivity factors of the three dipoles were determined using the waveguide method outlined in the fore mentioned standards.

3.3 ISOTROPY

The axial isotropy was evaluated by exposing the probe to a reference wave from a standard dipole. The probe was rotated along its main axis from 0 - 360 degrees in 15 degree steps.

4 MEASUREMENT UNCERTAINTY

The guidelines outlined in the ANSI C63.19 and IEEE 1309 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 | | | | | 9.6 % |

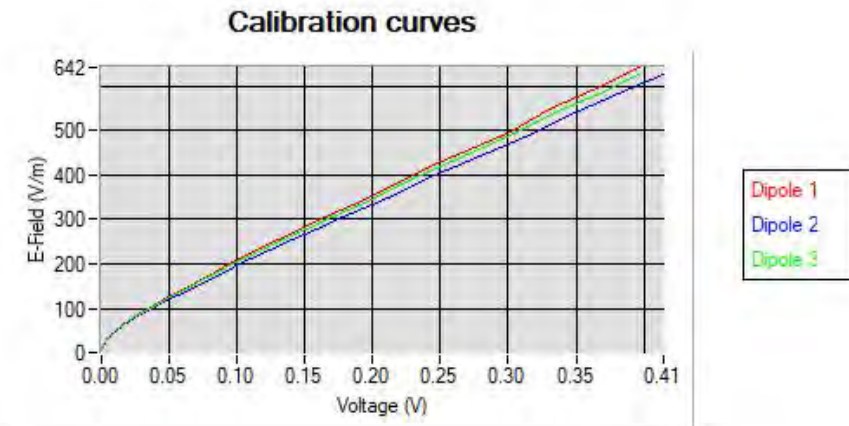
5 CALIBRATION MEASUREMENT RESULTS

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

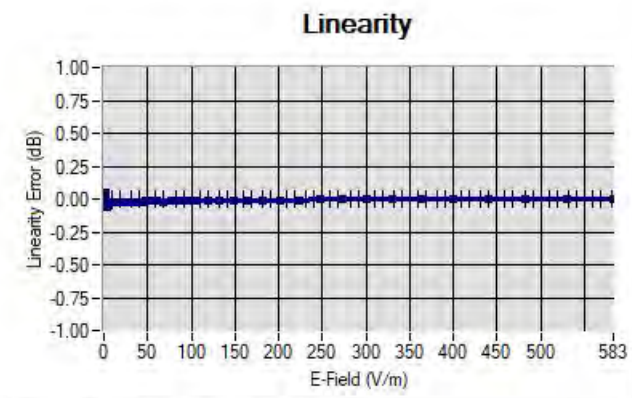
5.1 SENSITIVITY IN AIR

| 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 ($\mu\text{V}/(\text{V}/\text{m})^2$) |
|---|---|---|
| 4.58 | 5.02 | 4.71 |

| DCP dipole 1 (mV) | DCP dipole 2 (mV) | DCP dipole 3 (mV) |
|----------------------|----------------------|----------------------|
| 105 | 110 | 108 |

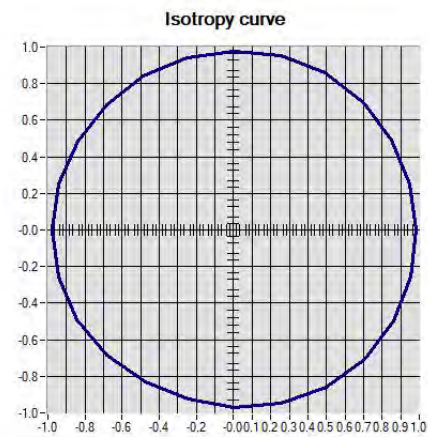


5.2 LINEARITY



Linearity: +/-1.45% (+/-0.06dB)

5.3 ISOTROPY



6 LIST OF EQUIPMENT

| Equipment Summary Sheet | | | | |
|------------------------------------|-------------------------|--------------------|---|---|
| Equipment Description | Manufacturer / Model | Identification No. | Current Calibration Date | Next Calibration Date |
| HAC positioning ruler | MVG | TABH12 SN 42/09 | Validated. No cal required. | Validated. No cal required. |
| COMOHAC Test Bench | Version 2 | NA | Validated. No cal required. | Validated. No cal required. |
| Network Analyzer | Rohde & Schwarz ZVM | 100203 | 05/2021 | 05/2024 |
| 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 | 05/2021 | 05/2024 |
| 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 WG8_1 | Validated. No cal required. | Validated. No cal required. |
| Temperature / Humidity Sensor | Testo 184 H1 | 44225320 | 06/2021 | 06/2024 |



HAC Reference Dipole Calibration Report

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CHINA

MVG COMO HAC REFERENCE DIPOLE

FREQUENCY: 800-950MHZ

SERIAL NO.: SN 07/22 DHA69

Calibrated at MVG

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Summary:

This document presents the method and results from an accredited HAC reference dipole calibration performed at MVG, using the COMO HAC 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>JL</i> |
| <i>Checked by :</i> | Jérôme Luc | Technical Manager | 2/6/2023 | <i>JL</i> |
| <i>Approved by :</i> | Yann Toutain | Laboratory Director | 2/6/2023 | <i>Yann TOUTAIN</i> |

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1 INTRODUCTION

This document contains a summary of the requirements set forth by the ANSI C63.19 standard for reference dipoles used for HAC 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 | COMOHAC 800-950 MHz REFERENCE DIPOLE |
| Manufacturer | MVG |
| Model | SIDB835 |
| Serial Number | SN 07/22 DHA69 |
| Product Condition (new / used) | New |

3 PRODUCT DESCRIPTION

3.1 GENERAL INFORMATION

MVG’s COMOHAC Validation Dipoles are built in accordance to the ANSI C63.19 standard. The product is designed for use with the COMOHAC system only.



Figure 1 – MVG COMOHAC Validation Dipole

4 MEASUREMENT METHOD

The ANSI C63.19 standard outlines the requirements for reference dipoles to be used for system validation measurements. The following measurements were performed to verify that the product complies with the fore mentioned standard.

4.1 RETURN LOSS REQUIREMENTS

The dipole used for HAC system validation measurements and checks must have a return loss of -10 dB or better. The return loss measurement shall be performed in free space. A direct method is used with a network analyser and its calibration kit, both with a valid ISO17025 calibration.

4.1 REFERENCE DIPOLE CALIBRATION

The IEEE ANSI C63-19 standard states that the dipole used for validation measurements and checks must be scanned with the E field probe, with the dipole 10 mm below the probe. The E field strength plots are compared to the simulation results obtained by MVG.

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 Gain |
|----------------|------------------------------|
| 400-6000MHz | 0.08 LIN |

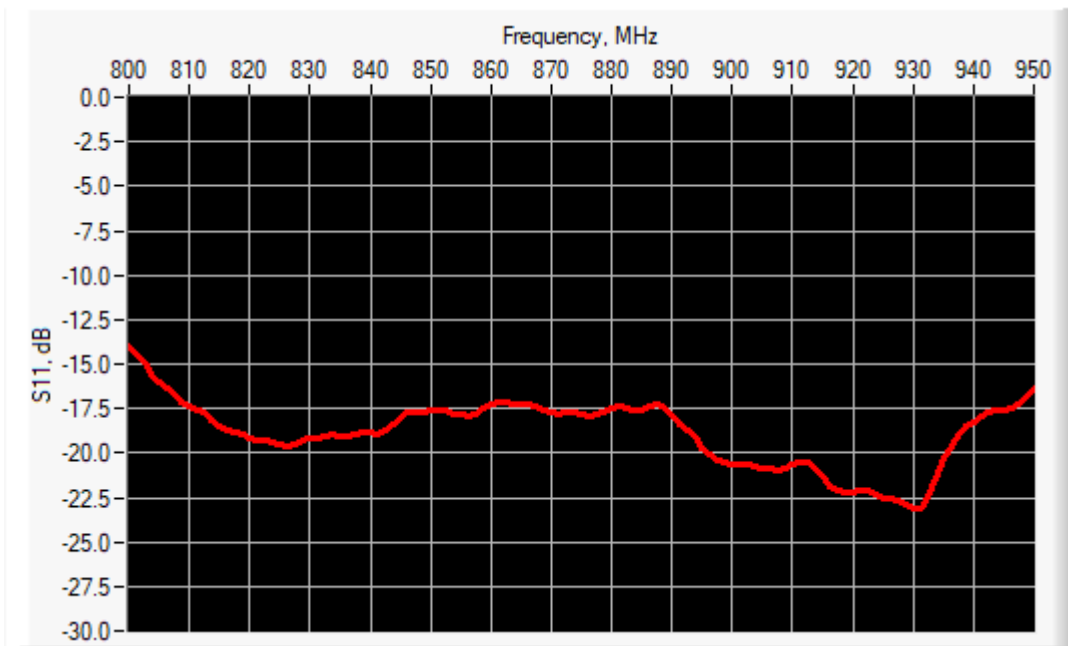
5.2 VALIDATION MEASUREMENT

The guideline outlined in the IEEE ANSI C63.19 standard was followed to generate the measurement uncertainty for validation measurements.

6 CALIBRATION MEASUREMENT RESULTS

| Uncertainty analysis of the probe calibration in waveguide | | | | | |
|--|-----------------------|--------------------------|---------|------------------|--------------------------|
| ERROR SOURCES | Uncertainty value (%) | Probability Distribution | Divisor | Uncertainty (dB) | Standard Uncertainty (%) |
| Expanded uncertainty 95 % confidence level k = 2 | | | | 1.1 | 14 |

6.1 RETURN LOSS



| Frequency (MHz) | Worst Case Return Loss (dB) | Requirement (dB) |
|-----------------|-----------------------------|------------------|
| 800-950 MHz | -13.97 | -10 |

6.2 VALIDATION MEASUREMENT

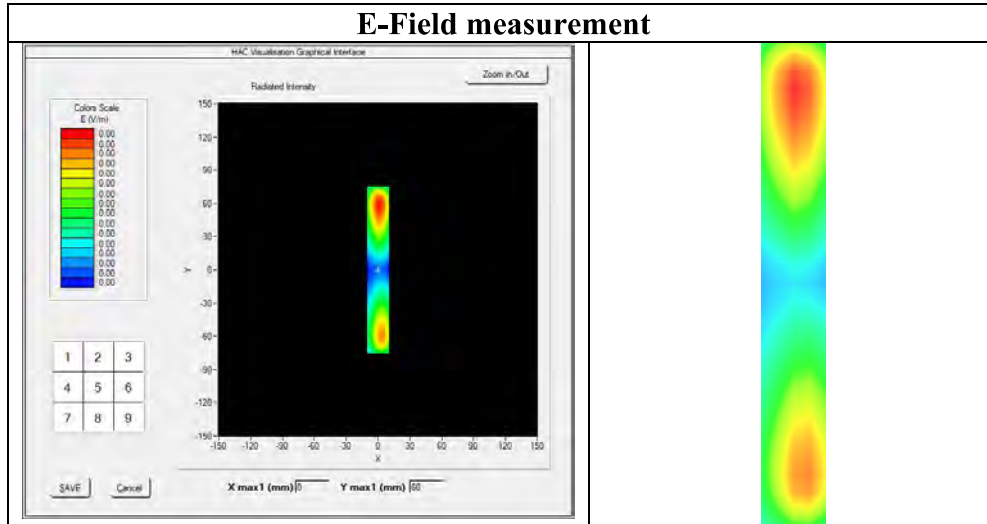
The IEEE ANSI C63.19 standard states that the system validation measurements must be performed using a reference dipole meeting the fore mentioned return loss requirements. The system validations measurement results are then compared to MVG’s simulated results.

Measurement Condition

| | |
|---|-----------------|
| Software Version | OpenHAC V2 |
| HAC positioning ruler | SN 42/09 TABH12 |
| E-Field probe | SN 26/11 EPH32 |
| Distance between dipole and sensor center | 10 mm |
| E-field scan size | X=150mm/Y=20mm |
| H-field scan size | X=40mm/Y=20mm |
| Scan resolution | dx=5mm/dy=5mm |
| Frequency | 835 MHz |
| Input power | 20 dBm |
| Lab Temperature | 20 +/- 1°C |
| Lab Humidity | 30-70% |

Measurement Result

| | Measured | Internal Requirement |
|----------------------|-----------------|-----------------------------|
| E field (V/m) | 216.91 | 210.0 |





7 LIST OF EQUIPMENT

| Equipment Summary Sheet | | | | |
|------------------------------------|-------------------------|--------------------|---|---|
| Equipment Description | Manufacturer / Model | Identification No. | Current Calibration Date | Next Calibration Date |
| HAC positioning ruler | MVG | TABH12 SN 42/09 | Validated. No cal required. | Validated. No cal required. |
| COMOHAC 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 |
| Reference Probe | MVG | EPH32 SN 26/11 | 02/2021 | 02/2024 |
| 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 and Humidity Sensor | Testo 184 H1 | 44225320 | 06/2021 | 06/2024 |



HAC Reference Dipole Calibration Report

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SONGGANG STREET, BAO'AN DISTRICT, SHENZHEN,
CHINA

MVG COMO HAC REFERENCE DIPOLE

FREQUENCY: 1700-2000MHZ

SERIAL NO.: SN 07/22 DHB70

Calibrated at MVG

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| <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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1 INTRODUCTION

This document contains a summary of the requirements set forth by the ANSI C63.19 standard for reference dipoles used for HAC 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 | COMOHAC 1700-2000 MHz REFERENCE DIPOLE |
| Manufacturer | MVG |
| Model | SIDB1900 |
| Serial Number | SN 07/22 DHB70 |
| Product Condition (new / used) | New |

3 PRODUCT DESCRIPTION

3.1 GENERAL INFORMATION

MVG’s COMOHAC Validation Dipoles are built in accordance to the ANSI C63.19 standard. The product is designed for use with the COMOHAC system only.



Figure 1 – MVG COMOHAC Validation Dipole

4 MEASUREMENT METHOD

The ANSI C63.19 standard outlines the requirements for reference dipoles to be used for system validation measurements. The following measurements were performed to verify that the product complies with the fore mentioned standard.

4.1 RETURN LOSS REQUIREMENTS

The dipole used for HAC system validation measurements and checks must have a return loss of -10 dB or better. The return loss measurement shall be performed in free space. A direct method is used with a network analyser and its calibration kit, both with a valid ISO17025 calibration.

4.1 REFERENCE DIPOLE CALIBRATION

The IEEE ANSI C63-19 standard states that the dipole used for validation measurements and checks must be scanned with the E field probe, with the dipole 10 mm below the probe. The E field strength plots are compared to the simulation results obtained by MVG.

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 Gain |
|----------------|------------------------------|
| 400-6000MHz | 0.08 LIN |

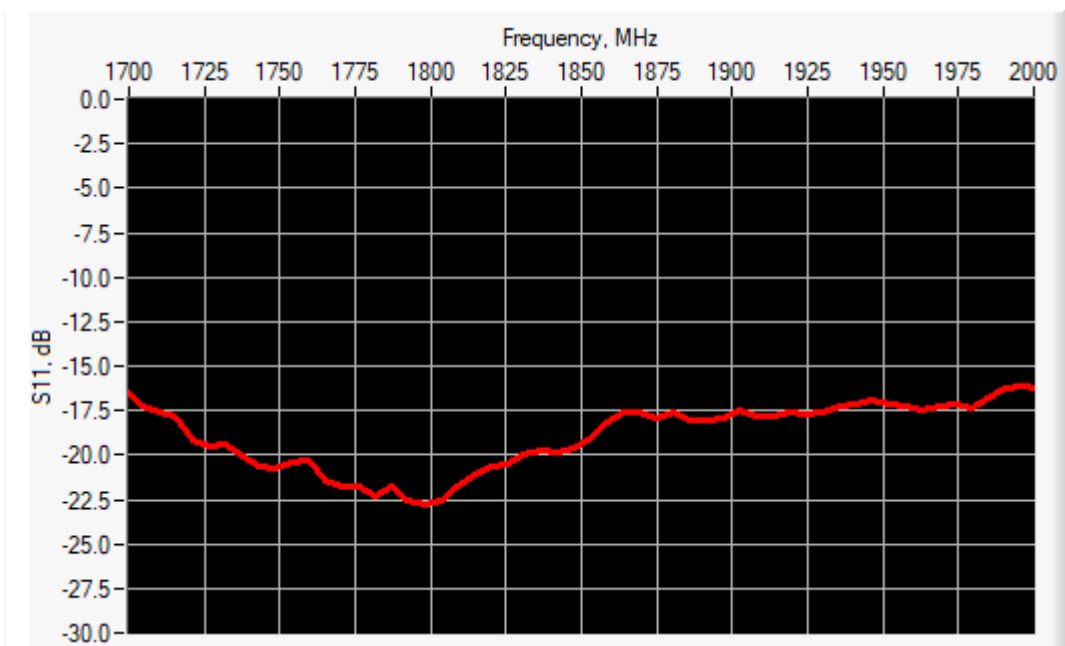
5.2 VALIDATION MEASUREMENT

The guideline outlined in the IEEE ANSI C63.19 standard was followed to generate the measurement uncertainty for validation measurements.

6 **CALIBRATION MEASUREMENT RESULTS**

| Uncertainty analysis of the probe calibration in waveguide | | | | | |
|--|-----------------------|--------------------------|---------|------------------|--------------------------|
| ERROR SOURCES | Uncertainty value (%) | Probability Distribution | Divisor | Uncertainty (dB) | Standard Uncertainty (%) |
| Expanded uncertainty 95 % confidence level k = 2 | | | | 1.1 | 14 |

6.1 RETURN LOSS



| Frequency (MHz) | Worst Case Return Loss (dB) | Requirement (dB) |
|-----------------|-----------------------------|------------------|
| 1700-2000 MHz | -16.23 | -10 |

6.2 VALIDATION MEASUREMENT

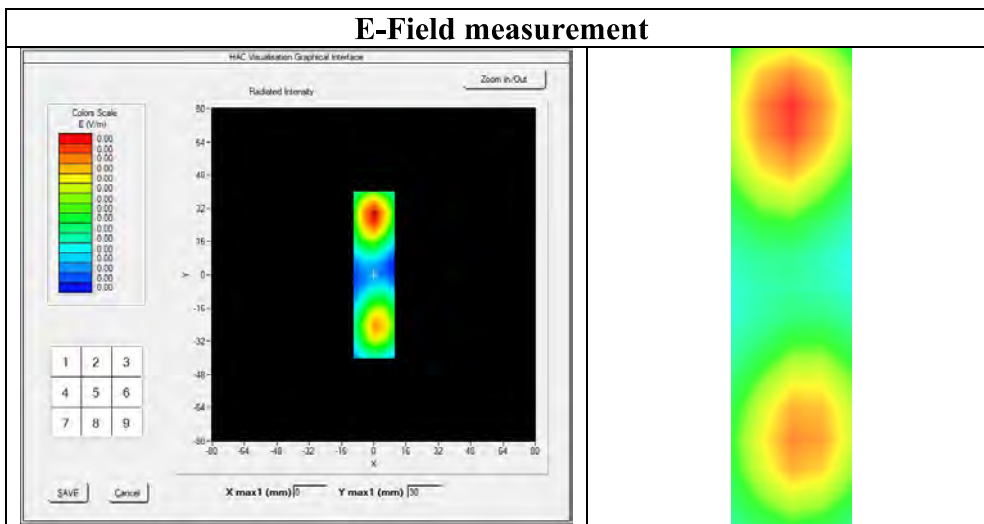
The IEEE ANSI C63.19 standard states that the system validation measurements must be performed using a reference dipole meeting the fore mentioned return loss requirements. The system validations measurement results are then compared to MVG’s simulated results.

Measurement Condition

| | |
|---|-----------------|
| Software Version | OpenHAC V2 |
| HAC positioning ruler | SN 42/09 TABH12 |
| E-Field probe | SN 26/11 EPH32 |
| Distance between dipole and sensor center | 10 mm |
| E-field scan size | X=150mm/Y=20mm |
| H-field scan size | X=40mm/Y=20mm |
| Scan resolution | dx=5mm/dy=5mm |
| Frequency | 1900 MHz |
| Input power | 20 dBm |
| Lab Temperature | 20 +/- 1°C |
| Lab Humidity | 30-70% |

Measurement Result

| | Measured | Internal Requirement |
|----------------------|-----------------|-----------------------------|
| E field (V/m) | 147.01 | 146.1 |





7 LIST OF EQUIPMENT

| Equipment Summary Sheet | | | | |
|------------------------------------|-------------------------|--------------------|---|---|
| Equipment Description | Manufacturer / Model | Identification No. | Current Calibration Date | Next Calibration Date |
| HAC positioning ruler | MVG | TABH12 SN 42/09 | Validated. No cal required. | Validated. No cal required. |
| COMOHAC 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 |
| Reference Probe | MVG | EPH32 SN 26/11 | 02/2021 | 02/2024 |
| 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 and Humidity Sensor | Testo 184 H1 | 44225320 | 06/2021 | 06/2024 |