

DASY5 E-field Result

Date: 17.09.2019

Test Laboratory: SPEAG Lab2

DUT: HAC Dipole 2450 MHz; Type: CD2450V3; Serial: CD2450V3 - SN: 1069

Communication System: UID 0 - CW; Frequency: 2450 MHz
 Medium parameters used: $\sigma = 0$ S/m, $\epsilon_r = 1$; $\rho = 0$ kg/m³
 Phantom section: RF Section
 Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

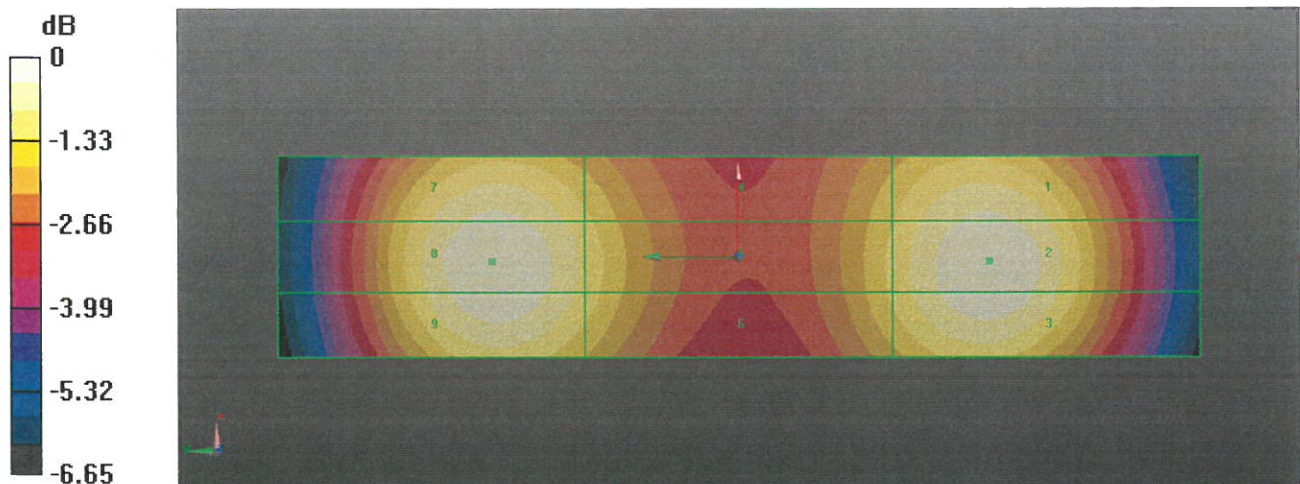
- Probe: EF3DV3 - SN4013; ConvF(1, 1, 1) @ 2450 MHz; Calibrated: 03.01.2019
- Sensor-Surface: (Fix Surface)
- Electronics: DAE4 Sn781; Calibrated: 09.01.2019
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA; Serial: 1070
- DASY52 52.10.2(1504); SEMCAD X 14.6.12(7470)

Dipole E-Field measurement @ 2450MHz/E-Scan - 2450MHz d=15mm/Hearing Aid Compatibility Test (41x181x1):

Interpolated grid: dx=0.5000 mm, dy=0.5000 mm
 Device Reference Point: 0, 0, -6.3 mm
 Reference Value = 74.77 V/m; Power Drift = 0.02 dB
 Applied MIF = 0.00 dB
 RF audio interference level = 38.59 dBV/m
Emission category: M2

MIF scaled E-field

| | | |
|--------------------------|--------------------------|--------------------------|
| Grid 1 M2 38.27 dBV/m | Grid 2 M2 38.58 dBV/m | Grid 3 M2 38.49 dBV/m |
| Grid 4 M2 37.4 dBV/m | Grid 5 M2 37.61 dBV/m | Grid 6 M2 37.54 dBV/m |
| Grid 7 M2 38.29 dBV/m | Grid 8 M2 38.59 dBV/m | Grid 9 M2 38.49 dBV/m |



0 dB = 85.00 V/m = 38.59 dBV/m



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **SRTC (Auden)**

Certificate No: **DAE4-546_Aug19**

CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 546**

Calibration procedure(s) **QA CAL-06.v29
Calibration procedure for the data acquisition electronics (DAE)**

Calibration date: **August 28, 2019**

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 (Certificate No.) | Scheduled Calibration |
|-------------------------------|--------------------|----------------------------|------------------------|
| Keithley Multimeter Type 2001 | SN: 0810278 | 03-Sep-18 (No:23488) | Sep-19 |
| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
| Auto DAE Calibration Unit | SE UWS 053 AA 1001 | 07-Jan-19 (in house check) | In house check: Jan-20 |
| Calibrator Box V2.1 | SE UMS 006 AA 1002 | 07-Jan-19 (in house check) | In house check: Jan-20 |

| | | | |
|----------------|---------------|-----------------------|-----------|
| Calibrated by: | Name | Function | Signature |
| | Eric Hainfeld | Laboratory Technician | |
| Approved by: | Name | Function | Signature |
| | Sven Kühn | Deputy Manager | |

Issued: August 28, 2019

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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 following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
 - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
 - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
 - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
 - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
 - *Input Offset Measurement:* Output voltage and statistical results over a large number of zero voltage measurements.
 - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
 - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
 - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
 - *Power consumption:* Typical value for information. Supply currents in various operating modes.

DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1 μ V, full range = -100...+300 mV
Low Range: 1LSB = 61nV, full range = -1.....+3mV

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

| Calibration Factors | X | Y | Z |
|---------------------|---------------------------|---------------------------|---------------------------|
| High Range | 405.352 \pm 0.02% (k=2) | 404.098 \pm 0.02% (k=2) | 404.222 \pm 0.02% (k=2) |
| Low Range | 3.98830 \pm 1.50% (k=2) | 3.95641 \pm 1.50% (k=2) | 3.97961 \pm 1.50% (k=2) |

Connector Angle

| | |
|---|-------------------------------------|
| Connector Angle to be used in DASY system | 237.0 $^{\circ}$ \pm 1 $^{\circ}$ |
|---|-------------------------------------|

Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

| High Range | | Reading (μV) | Difference (μV) | Error (%) |
|------------|---------|---------------------------|------------------------------|-----------|
| Channel X | + Input | 199995.19 | -1.38 | -0.00 |
| Channel X | + Input | 20000.83 | -0.80 | -0.00 |
| Channel X | - Input | -19997.26 | 4.75 | -0.02 |
| Channel Y | + Input | 199989.47 | -7.29 | -0.00 |
| Channel Y | + Input | 20002.52 | 0.88 | 0.00 |
| Channel Y | - Input | -20001.62 | 0.45 | -0.00 |
| Channel Z | + Input | 199996.94 | 0.28 | 0.00 |
| Channel Z | + Input | 19998.55 | -3.07 | -0.02 |
| Channel Z | - Input | -20002.95 | -0.90 | 0.00 |

| Low Range | | Reading (μV) | Difference (μV) | Error (%) |
|-----------|---------|---------------------------|------------------------------|-----------|
| Channel X | + Input | 2001.48 | 0.50 | 0.03 |
| Channel X | + Input | 201.14 | -0.15 | -0.07 |
| Channel X | - Input | -198.97 | -0.38 | 0.19 |
| Channel Y | + Input | 2000.52 | -0.41 | -0.02 |
| Channel Y | + Input | 200.95 | -0.13 | -0.07 |
| Channel Y | - Input | -199.00 | -0.30 | 0.15 |
| Channel Z | + Input | 2000.96 | -0.05 | -0.00 |
| Channel Z | + Input | 200.01 | -1.11 | -0.55 |
| Channel Z | - Input | -199.97 | -1.27 | 0.64 |

2. Common mode sensitivity

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

| | Common mode Input Voltage (mV) | High Range Average Reading (μV) | Low Range Average Reading (μV) |
|-----------|--------------------------------|--|---|
| Channel X | 200 | 2.12 | -0.11 |
| | - 200 | 0.79 | -0.91 |
| Channel Y | 200 | 1.96 | 0.12 |
| | - 200 | -0.90 | -1.27 |
| Channel Z | 200 | 1.15 | 1.74 |
| | - 200 | -4.83 | -4.14 |

3. Channel separation

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

| | Input Voltage (mV) | Channel X (μV) | Channel Y (μV) | Channel Z (μV) |
|-----------|--------------------|-----------------------------|-----------------------------|-----------------------------|
| Channel X | 200 | - | -2.05 | -3.29 |
| Channel Y | 200 | 9.27 | - | -0.65 |
| Channel Z | 200 | 4.64 | 6.99 | - |

4. AD-Converter Values with inputs shorted

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

| | High Range (LSB) | Low Range (LSB) |
|-----------|------------------|-----------------|
| Channel X | 15840 | 15900 |
| Channel Y | 16134 | 12789 |
| Channel Z | 15911 | 16844 |

5. Input Offset Measurement

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

Input 10M Ω

| | Average (μ V) | min. Offset (μ V) | max. Offset (μ V) | Std. Deviation (μ V) |
|-----------|--------------------|------------------------|------------------------|---------------------------|
| Channel X | 1.16 | 0.11 | 3.01 | 0.45 |
| Channel Y | 0.12 | -0.83 | 1.50 | 0.46 |
| Channel Z | -0.42 | -1.81 | 0.51 | 0.42 |

6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

7. Input Resistance (Typical values for information)

| | Zeroing (kOhm) | Measuring (MOhm) |
|-----------|----------------|------------------|
| Channel X | 200 | 200 |
| Channel Y | 200 | 200 |
| Channel Z | 200 | 200 |

8. Low Battery Alarm Voltage (Typical values for information)

| Typical values | Alarm Level (VDC) |
|----------------|-------------------|
| Supply (+ Vcc) | +7.9 |
| Supply (- Vcc) | -7.6 |

9. Power Consumption (Typical values for information)

| Typical values | Switched off (mA) | Stand by (mA) | Transmitting (mA) |
|----------------|-------------------|---------------|-------------------|
| Supply (+ Vcc) | +0.01 | +6 | +14 |
| Supply (- Vcc) | -0.01 | -8 | -9 |



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **SRTC (Auden)**

Certificate No: **ER3-2368_Sep19**

CALIBRATION CERTIFICATE

Object **ER3DV6- SN:2368**

Calibration procedure(s) **QA CAL-02.v9, QA CAL-25.v7
Calibration procedure for E-field probes optimized for close near field
evaluations in air**

Calibration date: **September 23, 2019**

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 (Certificate No.) | Scheduled Calibration |
|----------------------------|------------------|-----------------------------------|------------------------|
| Power meter NRP | SN: 104778 | 03-Apr-19 (No. 217-02892/02893) | Apr-20 |
| Power sensor NRP-Z91 | SN: 103244 | 03-Apr-19 (No. 217-02892) | Apr-20 |
| Power sensor NRP-Z91 | SN: 103245 | 03-Apr-19 (No. 217-02893) | Apr-20 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-19 (No. 217-02894) | Apr-20 |
| DAE4 | SN: 789 | 14-Jan-19 (No. DAE4-789_Jan19) | Jan-20 |
| Reference Probe ER3DV6 | SN: 2328 | 09-Oct-18 (No. ER3-2328_Oct18) | Oct-19 |
| Secondary Standards | ID | Check Date (in house) | Scheduled Check |
| Power meter E4419B | SN: GB41293874 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: MY41498087 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: 000110210 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| RF generator HP 8648C | SN: US3642U01700 | 04-Aug-99 (in house check Jun-18) | In house check: Jun-20 |
| Network Analyzer E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-18) | In house check: Oct-19 |

| | | | |
|----------------|-------------------------------|--|---------------|
| Calibrated by: | Name Jeton Kastrati | Function Laboratory Technician | Signature |
| Approved by: | Name Katja Pokovic | Function Technical Manager | Signature |

Issued: September 24, 2019

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Glossary:

| | |
|--------------------------|---|
| NORM _{x,y,z} | sensitivity in free space |
| DCP | diode compression point |
| CF | crest factor (1/duty_cycle) of the RF signal |
| A, B, C, D | modulation dependent linearization parameters |
| En | incident E-field orientation normal to probe axis |
| Ep | incident E-field orientation parallel to probe axis |
| Polarization φ | φ rotation around probe axis |
| Polarization ϑ | ϑ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., $\vartheta = 0$ 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 1309-2005, "IEEE Standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz", December 2005
- CTIA Test Plan for Hearing Aid Compatibility, Rev 3.1.1, May 2017

Methods Applied and Interpretation of Parameters:

- NORM_{x,y,z}*: Assessed for E-field polarization $\vartheta = 0$ for XY sensors and $\vartheta = 90$ for Z sensor ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide).
- NORM(f)_{x,y,z}* = *NORM_{x,y,z}* * *frequency_response* (see Frequency Response Chart).
- DCP_{x,y,z}*: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (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_{x,y,z}; B_{x,y,z}; C_{x,y,z}; D_{x,y,z}; VR_{x,y,z}*: A, B, C, D 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.
- Spherical isotropy (3D deviation from isotropy)*: in a locally homogeneous field realized using an open waveguide setup.
- 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_x* (no uncertainty required).

DASY/EASY - Parameters of Probe: ER3DV6 - SN:2368

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|--|----------|----------|----------|--------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) | 1.71 | 1.61 | 1.82 | $\pm 10.1\%$ |
| DCP (mV) ^B | 99.0 | 99.6 | 102.0 | |

Calibration results for Frequency Response (30 MHz – 3 GHz)

| Frequency MHz | Target E-Field V/m | Measured E-field (En) V/m | Deviation E-normal in % | Measured E-field (Ep) V/m | Deviation E-normal in % | Unc (k=2) % |
|---------------|--------------------|---------------------------|-------------------------|---------------------------|-------------------------|-------------|
| 30 | 77.4 | 76.6 | -1.0% | 77.7 | 0.3% | $\pm 5.1\%$ |
| 100 | 77.2 | 78.7 | 1.9% | 77.5 | 0.4% | $\pm 5.1\%$ |
| 450 | 77.1 | 78.7 | 2.0% | 77.9 | 1.0% | $\pm 5.1\%$ |
| 600 | 77.2 | 78.4 | 1.6% | 77.7 | 0.8% | $\pm 5.1\%$ |
| 750 | 77.1 | 78.2 | 1.4% | 77.7 | 0.7% | $\pm 5.1\%$ |
| 1800 | 143.3 | 141.7 | -1.1% | 141.2 | -1.5% | $\pm 5.1\%$ |
| 2000 | 135.3 | 134.4 | -0.6% | 133.6 | -1.3% | $\pm 5.1\%$ |
| 2200 | 128.0 | 126.4 | -1.3% | 127.8 | -0.2% | $\pm 5.1\%$ |
| 2500 | 125.4 | 125.8 | 0.3% | 127.1 | 1.4% | $\pm 5.1\%$ |
| 3000 | 79.5 | 78.2 | -1.7% | 81.3 | 2.3% | $\pm 5.1\%$ |

Calibration Results for Modulation Response

| UID | Communication System Name | | A dB | B dB $\sqrt{\mu\text{V}}$ | C | D dB | VR mV | Max dev. | Unc ^E (k=2) |
|-----------|---|---|-------|---------------------------|-------|------|-------|-------------|------------------------|
| 0 | CW | X | 0.0 | 0.0 | 1.0 | 0.00 | 202.5 | $\pm 3.5\%$ | $\pm 4.7\%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 209.0 | | |
| | | Z | 0.0 | 0.0 | 1.0 | | 197.7 | | |
| 10021-DAC | GSM-FDD (TDMA, GMSK) | X | 8.62 | 84.20 | 22.70 | 9.39 | 106.3 | $\pm 3.5\%$ | $\pm 4.7\%$ |
| | | Y | 19.00 | 99.60 | 27.80 | | 148.4 | | |
| | | Z | 12.69 | 88.90 | 24.60 | | 111.1 | | |
| 10172-CAG | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 8.82 | 79.80 | 29.50 | 9.21 | 129.1 | $\pm 3.8\%$ | $\pm 4.7\%$ |
| | | Y | 8.36 | 79.20 | 29.40 | | 131.6 | | |
| | | Z | 9.17 | 79.60 | 28.50 | | 127.8 | | |
| 10173-CAG | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, 16-QAM) | X | 9.31 | 80.60 | 29.90 | 9.48 | 129.6 | $\pm 3.8\%$ | $\pm 4.7\%$ |
| | | Y | 8.79 | 79.90 | 29.70 | | 131.8 | | |
| | | Z | 9.74 | 80.90 | 29.20 | | 128.1 | | |

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%.

^B Numerical linearization parameter: uncertainty not required.

^E 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: ER3DV6 - SN:2368

Sensor Frequency Model Parameters

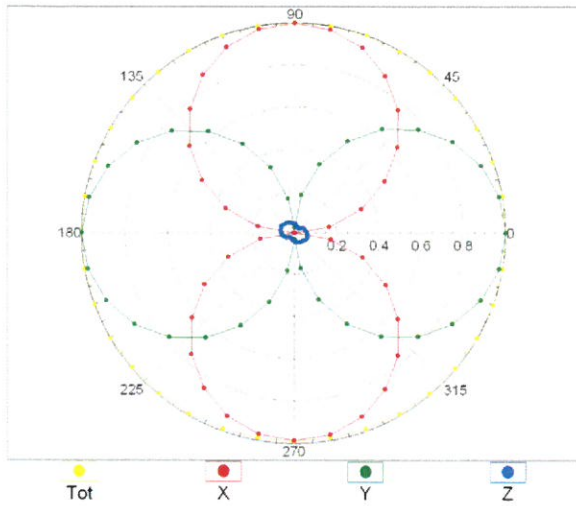
| | Sensor X | Sensor Y | Sensor Z |
|----------------------|----------|----------|----------|
| Frequency Corr. (LF) | -1.72 | -1.39 | 0.36 |
| Frequency Corr. (HF) | 0.00 | 0.00 | 0.00 |

Other Probe Parameters

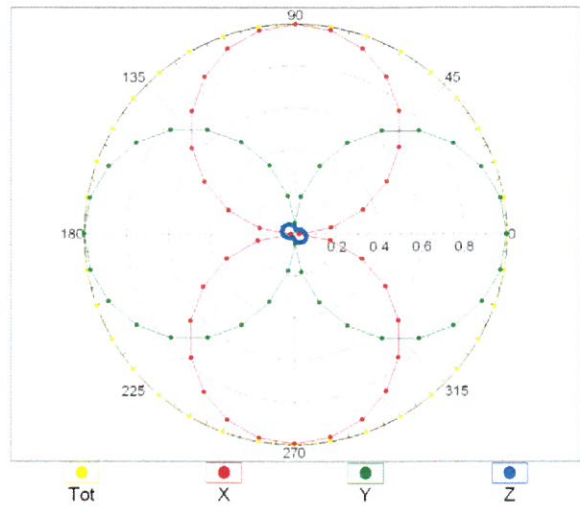
| | |
|---|-------------|
| Sensor Arrangement | Rectangular |
| Connector Angle (°) | 94.7 |
| Mechanical Surface Detection Mode | enabled |
| Optical Surface Detection Mode | disabled |
| Probe Overall Length | 337 mm |
| Probe Body Diameter | 10 mm |
| Tip Length | 10 mm |
| Tip Diameter | 8 mm |
| Probe Tip to Sensor X Calibration Point | 2.5 mm |
| Probe Tip to Sensor Y Calibration Point | 2.5 mm |
| Probe Tip to Sensor Z Calibration Point | 2.5 mm |

Receiving Pattern (ϕ), $\vartheta = 0^\circ$

f=600 MHz, TEM, 0°

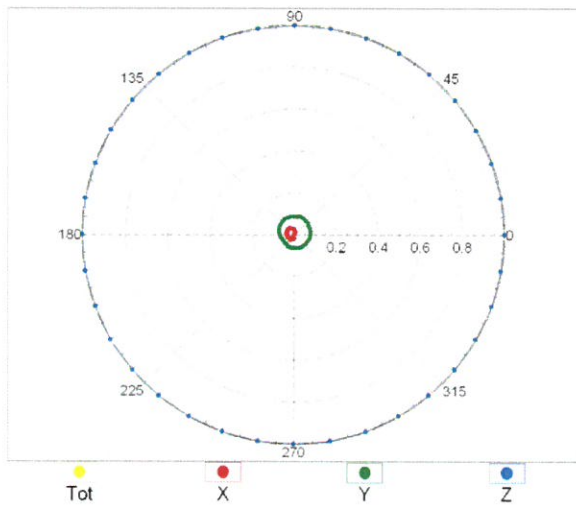


f=2500 MHz, R22, 0°

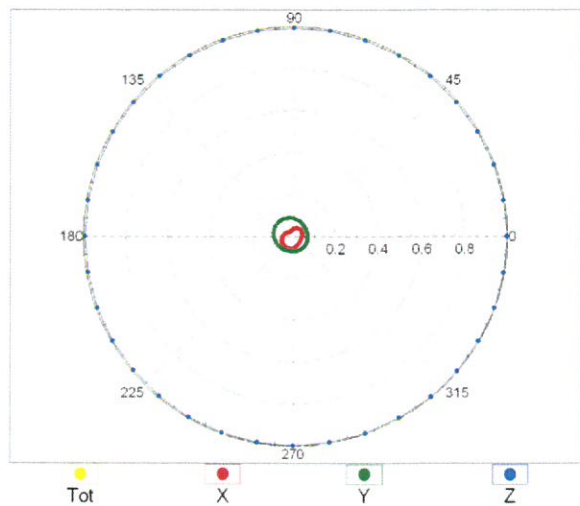


Receiving Pattern (ϕ), $\vartheta = 90^\circ$

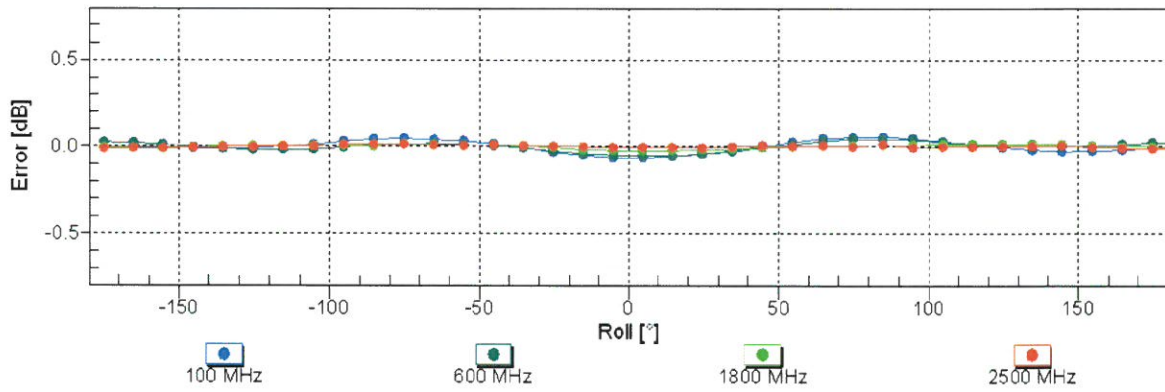
f=600 MHz, TEM, 90°



f=2500 MHz, R22, 90°

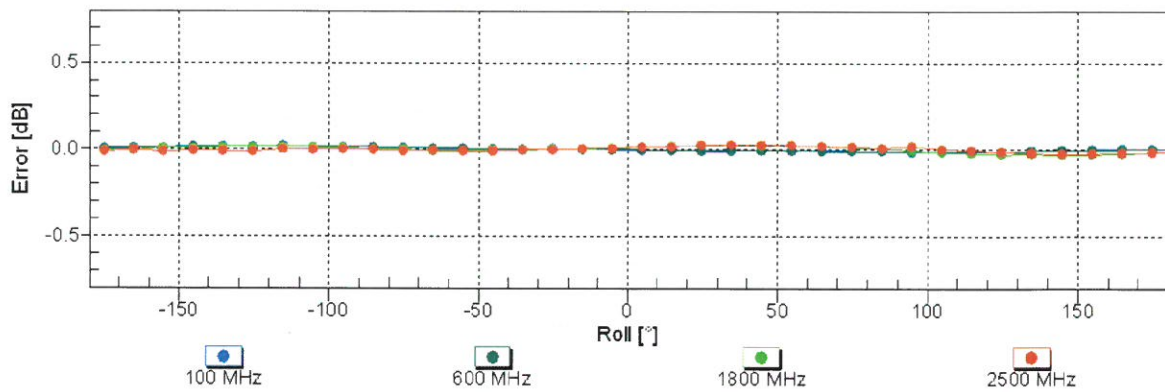


Receiving Pattern (ϕ), $\vartheta = 0^\circ$



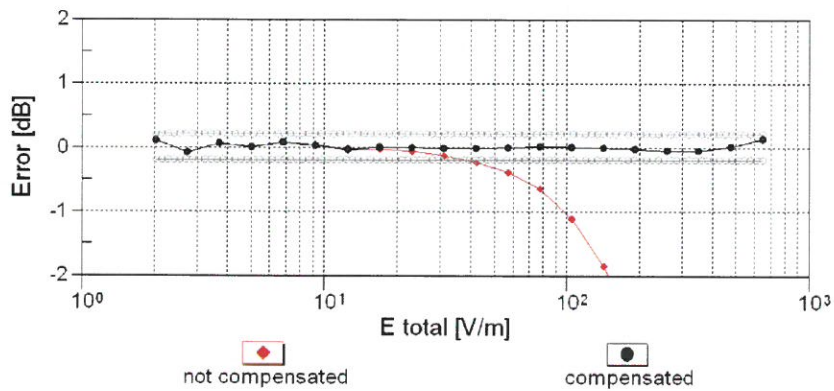
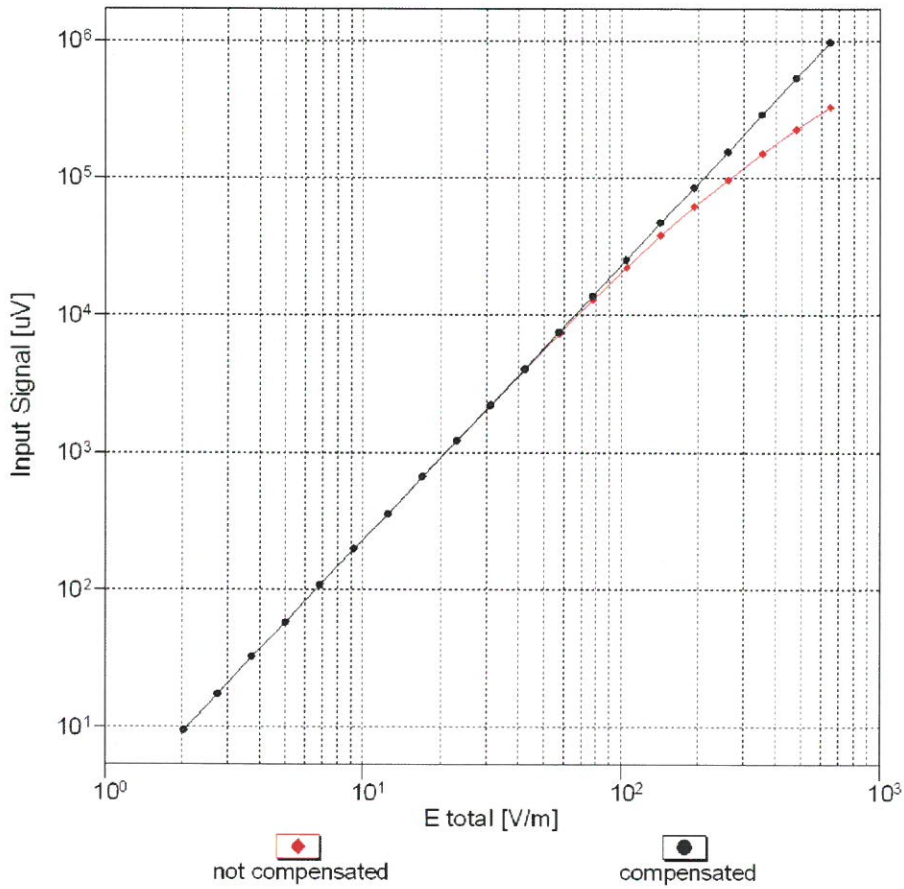
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

Receiving Pattern (ϕ), $\vartheta = 90^\circ$



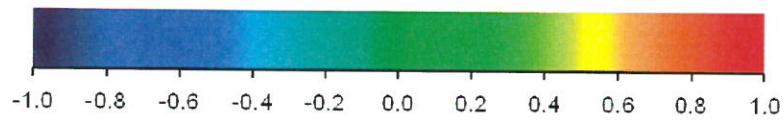
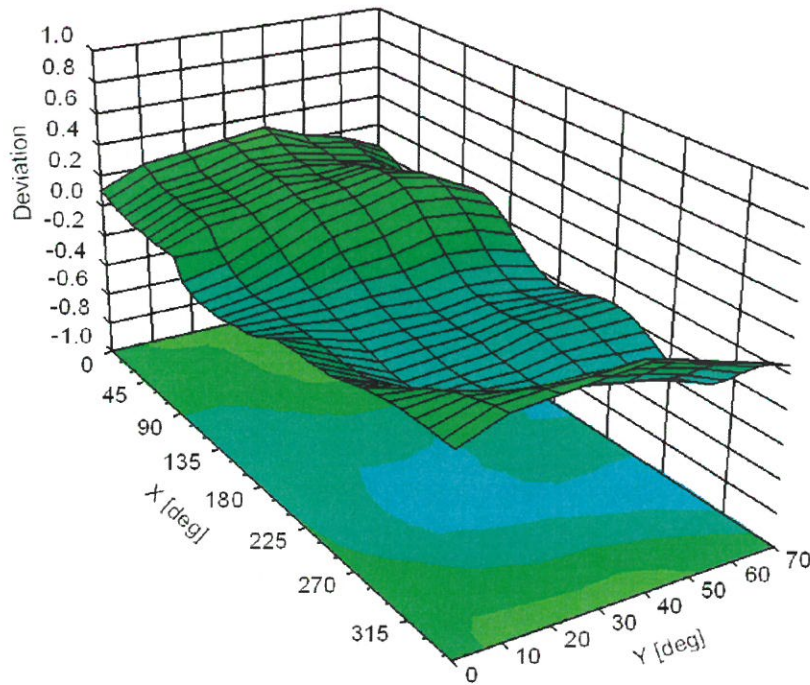
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

Dynamic Range f(E-field) (TEM cell, f = 900 MHz)



Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Deviation from Isotropy in Air Error (ϕ, θ), $f = 900$ MHz



Uncertainty of Spherical Isotropy Assessment: $\pm 2.6\%$ ($k=2$)