

## **Appendix D. Probe Calibration**



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Client

DEKRA  
Taoyuan City

Certificate No.

EX-3979\_Nov24

## CALIBRATION CERTIFICATE

Object EX3DV4 - SN:3979

Calibration procedure(s) QA CAL-01.v10, QA CAL-12.v10, QA CAL-14.v7, QA CAL-23.v6,  
QA CAL-25.v8  
Calibration procedure for dosimetric E-field probes

Calibration date November 20, 2024

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  $(22 \pm 3)^\circ\text{C}$  and humidity  $< 70\%$ .

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards          | ID               | Cal Date (Certificate No.)        | Scheduled Calibration |
|----------------------------|------------------|-----------------------------------|-----------------------|
| Power meter NRP2           | SN: 104778       | 26-Mar-24 (No. 217-04036/04037)   | Mar-25                |
| Power sensor NRP-Z91       | SN: 103244       | 26-Mar-24 (No. 217-04036)         | Mar-25                |
| OCP DAK-3.5 (weighted)     | SN: 1249         | 23-Sep-24 (OCP-DAK3.5-1249_Sep24) | Sep-25                |
| OCP DAK-12                 | SN: 1016         | 24-Sep-24 (OCP-DAK12-1016_Sep24)  | Sep-25                |
| Reference 20 dB Attenuator | SN: CC2552 (20x) | 26-Mar-24 (No. 217-04046)         | Mar-25                |
| DAE4                       | SN: 660          | 23-Feb-24 (No. DAE4-660_Feb24)    | Feb-25                |
| Reference Probe EX3DV4     | SN: 7349         | 03-Jun-24 (No. EX3-7349_Jun24)    | Jun-25                |

| Secondary Standards     | ID               | Check Date (in house)             | Scheduled Check        |
|-------------------------|------------------|-----------------------------------|------------------------|
| Power meter E4419B      | SN: GB41293874   | 06-Apr-16 (in house check Jun-24) | In house check: Jun-26 |
| Power sensor E4412A     | SN: MY41498087   | 06-Apr-16 (in house check Jun-24) | In house check: Jun-26 |
| Power sensor E4412A     | SN: 000110210    | 06-Apr-16 (in house check Jun-24) | In house check: Jun-26 |
| RF generator HP 8648C   | SN: US3642U01700 | 04-Aug-99 (in house check Jun-24) | In house check: Jun-26 |
| Network Analyzer E8358A | SN: US41080477   | 31-Mar-14 (in house check Sep-24) | In house check: Sep-26 |

|               | Name               | Function              | Signature |
|---------------|--------------------|-----------------------|-----------|
| Calibrated by | Aidonia Georgiadou | Laboratory Technician |           |
| Approved by   | Sven Kühn          | Technical Manager     |           |

Issued: November 20, 2024

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

## Calibration Laboratory of

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S Schweizerischer Kalibrierdienst  
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Accreditation No.: **SCS 0108**

## 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 $\varphi$   | $\varphi$ rotation around probe axis                                                                                                                 |
| Polarization $\vartheta$ | $\vartheta$ 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:

- IEC/IEEE 62209-1528, "Measurement Procedure For The Assessment Of Specific Absorption Rate Of Human Exposure To Radio Frequency Fields From Hand-Held And Body-Worn Wireless Communication Devices – Part 1528: Human Models, Instrumentation And Procedures (Frequency Range of 4 MHz to 10 GHz)", October 2020.
- 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  $\vartheta = 0$  ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide). NORM<sub>x,y,z</sub> are only intermediate values, i.e., the uncertainties of NORM<sub>x,y,z</sub> does not affect the E<sup>2</sup>-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 with CW signal. 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>; D<sub>x,y,z</sub>; VR<sub>x,y,z</sub>**: 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.
- ConvF and Boundary Effect Parameters**: Assessed in flat phantom using E-field (or Temperature Transfer Standard for  $f \leq 800$  MHz) and inside waveguide using analytical field distributions based on power measurements for  $f > 800$  MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values 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  $\pm 50$  MHz to  $\pm 100$  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).



Parameters of Probe: EX3DV4 - SN:3979

Basic Calibration Parameters

|                                       | Sensor X | Sensor Y | Sensor Z | Unc (k = 2) |
|---------------------------------------|----------|----------|----------|-------------|
| Norm ( $\mu V/(V/m)^2$ ) <sup>A</sup> | 0.49     | 0.49     | 0.48     | ±10.1%      |
| DCP (mV) <sup>B</sup>                 | 100.0    | 101.8    | 102.1    | ±4.7%       |

Calibration Results for Modulation Response

| UID | Communication System Name |   | A<br>dB | B<br>dB $\sqrt{\mu V}$ | C    | D<br>dB | VR<br>mV | Max<br>dev. | Max<br>Unc <sup>E</sup><br>k = 2 |
|-----|---------------------------|---|---------|------------------------|------|---------|----------|-------------|----------------------------------|
| 0   | CW                        | X | 0.00    | 0.00                   | 1.00 | 0.00    | 119.9    | ±1.0%       | ±4.7%                            |
|     |                           | Y | 0.00    | 0.00                   | 1.00 |         | 133.0    |             |                                  |
|     |                           | Z | 0.00    | 0.00                   | 1.00 |         | 118.4    |             |                                  |

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).  
<sup>B</sup> Linearization parameter uncertainty for maximum specified field strength.  
<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.

**Parameters of Probe: EX3DV4 - SN:3979****Other Probe Parameters**

|                                               |            |
|-----------------------------------------------|------------|
| Sensor Arrangement                            | Triangular |
| Connector Angle                               | -51.0°     |
| Mechanical Surface Detection Mode             | enabled    |
| Optical Surface Detection Mode                | disabled   |
| Probe Overall Length                          | 337 mm     |
| Probe Body Diameter                           | 10 mm      |
| Tip Length                                    | 9 mm       |
| Tip Diameter                                  | 2.5 mm     |
| Probe Tip to Sensor X Calibration Point       | 1 mm       |
| Probe Tip to Sensor Y Calibration Point       | 1 mm       |
| Probe Tip to Sensor Z Calibration Point       | 1 mm       |
| Recommended Measurement Distance from Surface | 1.4 mm     |

**Note:** Measurement distance from surface can be increased to 3–4 mm for an *Area Scan* job.

## Parameters of Probe: EX3DV4 - SN:3979

### Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) <sup>C</sup> | Relative Permittivity <sup>F</sup> | Conductivity <sup>F</sup> (S/m) | ConvF X | ConvF Y | ConvF Z | Alpha <sup>G</sup> | Depth <sup>G</sup> (mm) | Unc <sup>H</sup> (k = 2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|--------------------------|
| 450                  | 43.5                               | 0.87                            | 10.63   | 10.63   | 10.63   | 0.16               | 1.30                    | ±13.3%                   |
| 750                  | 41.9                               | 0.89                            | 8.47    | 10.75   | 8.97    | 0.36               | 1.27                    | ±11.0%                   |
| 835                  | 41.5                               | 0.90                            | 8.22    | 10.43   | 8.70    | 0.36               | 1.27                    | ±11.0%                   |
| 900                  | 41.5                               | 0.97                            | 8.06    | 10.23   | 8.54    | 0.36               | 1.27                    | ±11.0%                   |
| 1450                 | 40.5                               | 1.20                            | 7.19    | 9.12    | 7.61    | 0.36               | 1.27                    | ±11.0%                   |
| 1640                 | 40.2                               | 1.31                            | 7.03    | 8.92    | 7.44    | 0.36               | 1.27                    | ±11.0%                   |
| 1750                 | 40.1                               | 1.37                            | 6.92    | 8.78    | 7.33    | 0.36               | 1.27                    | ±11.0%                   |
| 1950                 | 40.0                               | 1.40                            | 6.74    | 8.55    | 7.13    | 0.35               | 1.27                    | ±11.0%                   |
| 2300                 | 39.5                               | 1.67                            | 6.54    | 8.30    | 6.92    | 0.35               | 1.27                    | ±11.0%                   |
| 2450                 | 39.2                               | 1.80                            | 6.39    | 8.11    | 6.76    | 0.35               | 1.27                    | ±11.0%                   |
| 2600                 | 39.0                               | 1.96                            | 6.25    | 7.93    | 6.62    | 0.35               | 1.27                    | ±11.0%                   |
| 3300                 | 38.2                               | 2.71                            | 6.10    | 7.74    | 6.46    | 0.34               | 1.27                    | ±13.1%                   |
| 3500                 | 37.9                               | 2.91                            | 6.06    | 7.69    | 6.42    | 0.34               | 1.27                    | ±13.1%                   |
| 3700                 | 37.7                               | 3.12                            | 5.93    | 7.52    | 6.28    | 0.34               | 1.27                    | ±13.1%                   |
| 5250                 | 35.9                               | 4.71                            | 4.53    | 5.75    | 4.80    | 0.30               | 1.27                    | ±13.1%                   |
| 5600                 | 35.5                               | 5.07                            | 4.33    | 5.49    | 4.58    | 0.27               | 1.27                    | ±13.1%                   |
| 5800                 | 35.3                               | 5.27                            | 4.23    | 5.36    | 4.47    | 0.26               | 1.27                    | ±13.1%                   |

<sup>C</sup> Frequency validity above 300 MHz of ±100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ±50 MHz. The uncertainty is the RSS of the 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. Validity of ConvF assessed at 6 MHz is 4–9 MHz, and ConvF assessed at 13 MHz is 9–19 MHz. Above 5 GHz frequency validity can be extended to ±110 MHz.

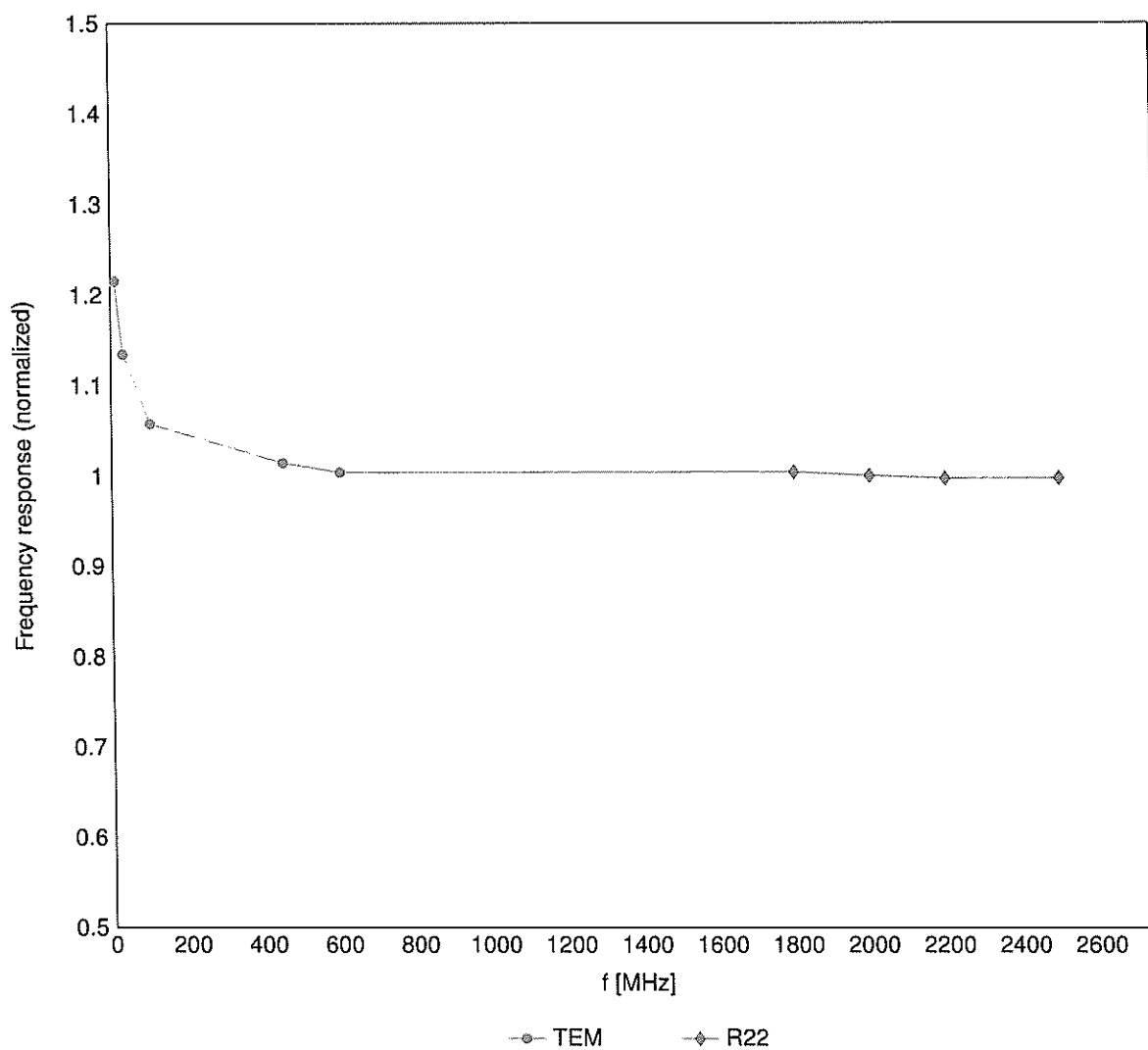
<sup>F</sup> The probes are calibrated using tissue simulating liquids (TSL) that deviate for  $\epsilon$  and  $\sigma$  by less than ±5% from the target values (typically better than ±3%) and are valid for TSL with deviations of up to ±10% if SAR correction is applied.

<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 frequencies between 3–6 GHz at any distance larger than half the probe tip diameter from the boundary.

<sup>H</sup> The stated uncertainty is the total calibration uncertainty (k = 2) of Norm-ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

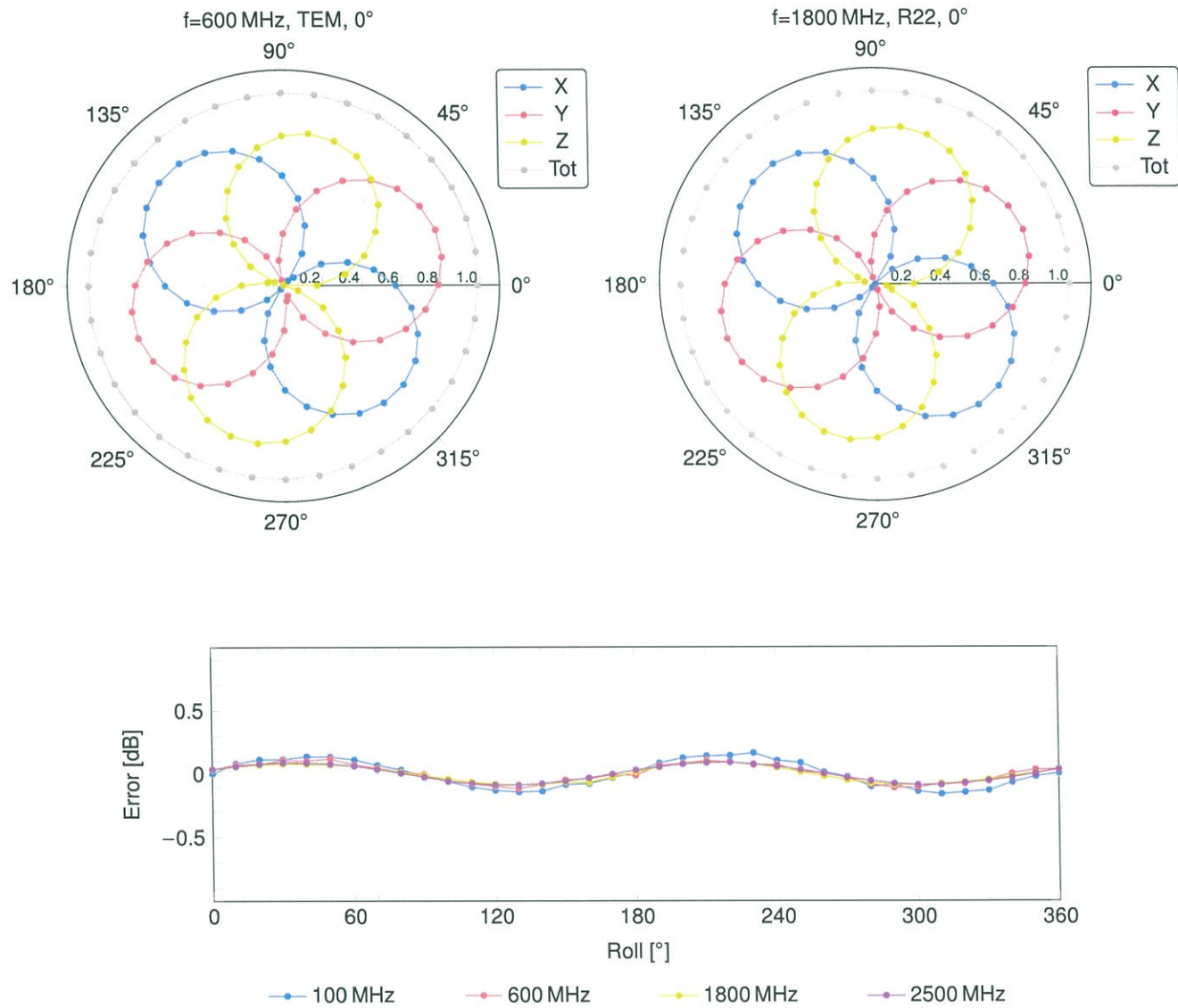
## Frequency Response of E-Field

(TEM-Cell:ifi110 EXX, Waveguide:R22)

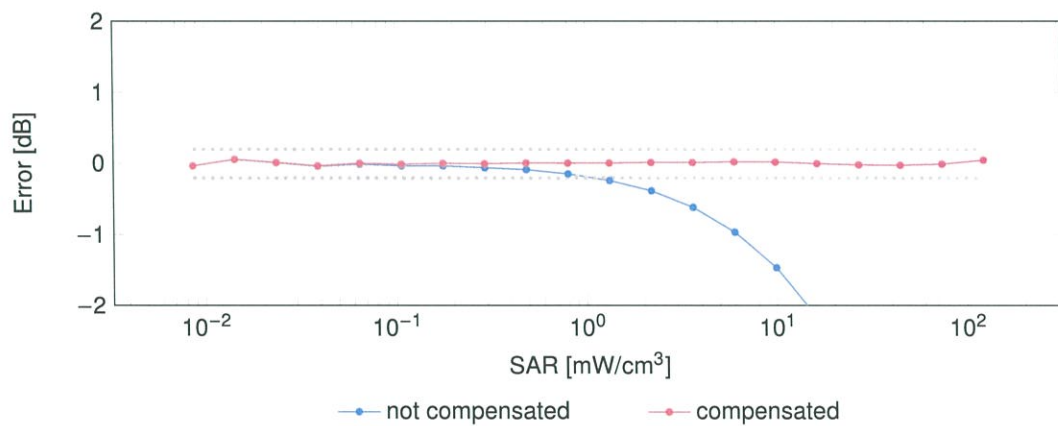
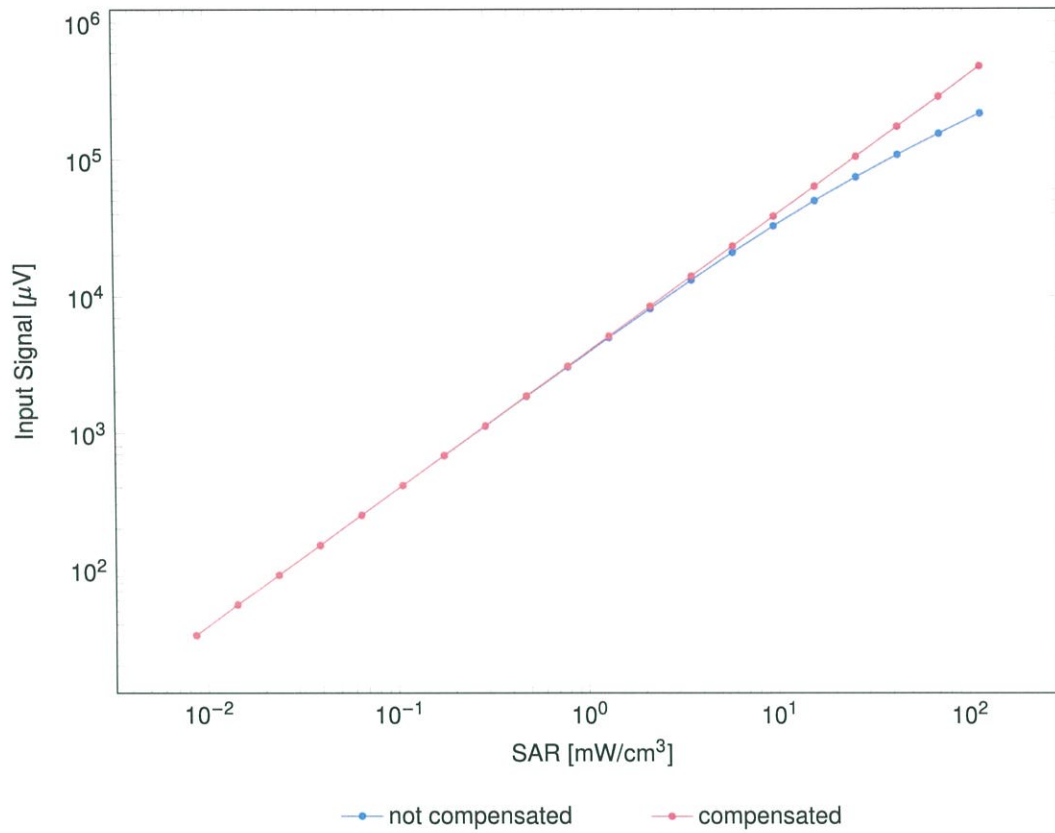


Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  ( $k=2$ )

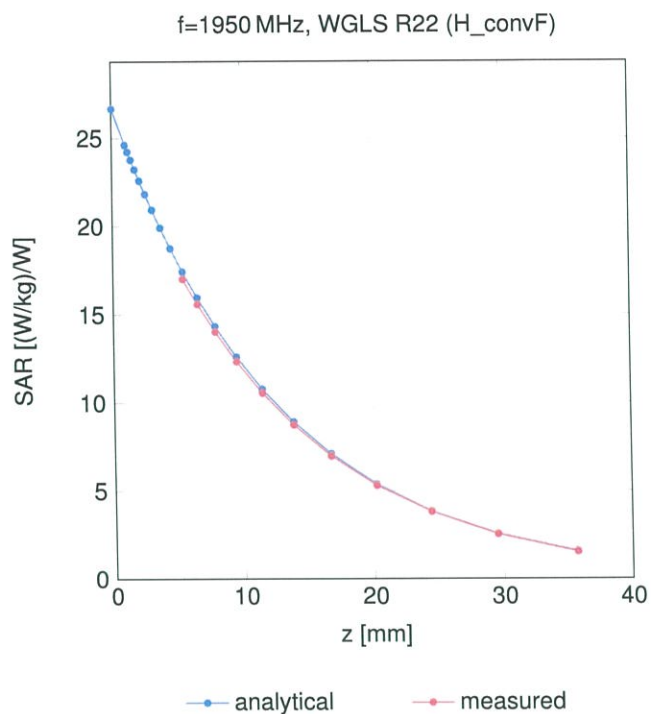
Receiving Pattern ( $\phi$ ),  $\vartheta = 0^\circ$





**Dynamic Range  $f(\text{SAR}_{\text{head}})$** (TEM cell,  $f_{\text{eval}} = 1900\text{MHz}$ )Uncertainty of Linearity Assessment:  $\pm 0.6\%$  ( $k=2$ )

## Conversion Factor Assessment



## Deviation from Isotropy in Liquid

Error ( $\phi, \theta$ ),  $f = 900\text{ MHz}$

