

EX3DV4- SN:3866

May 28, 2019

|       |     |                                                |      |      |         |
|-------|-----|------------------------------------------------|------|------|---------|
| 10728 | AAA | IEEE 802.11ax (80MHz, MCS9, 90pc duty cycle)   | WLAN | 8.65 | ± 9.6 % |
| 10729 | AAA | IEEE 802.11ax (80MHz, MCS10, 90pc duty cycle)  | WLAN | 8.64 | ± 9.6 % |
| 10730 | AAA | IEEE 802.11ax (80MHz, MCS11, 90pc duty cycle)  | WLAN | 8.67 | ± 9.6 % |
| 10731 | AAA | IEEE 802.11ax (80MHz, MCS0, 99pc duty cycle)   | WLAN | 8.42 | ± 9.6 % |
| 10732 | AAA | IEEE 802.11ax (80MHz, MCS1, 99pc duty cycle)   | WLAN | 8.46 | ± 9.6 % |
| 10733 | AAA | IEEE 802.11ax (80MHz, MCS2, 99pc duty cycle)   | WLAN | 8.40 | ± 9.6 % |
| 10734 | AAA | IEEE 802.11ax (80MHz, MCS3, 99pc duty cycle)   | WLAN | 8.25 | ± 9.6 % |
| 10735 | AAA | IEEE 802.11ax (80MHz, MCS4, 99pc duty cycle)   | WLAN | 8.33 | ± 9.6 % |
| 10736 | AAA | IEEE 802.11ax (80MHz, MCS5, 99pc duty cycle)   | WLAN | 8.27 | ± 9.6 % |
| 10737 | AAA | IEEE 802.11ax (80MHz, MCS6, 99pc duty cycle)   | WLAN | 8.36 | ± 9.6 % |
| 10738 | AAA | IEEE 802.11ax (80MHz, MCS7, 99pc duty cycle)   | WLAN | 8.42 | ± 9.6 % |
| 10739 | AAA | IEEE 802.11ax (80MHz, MCS8, 99pc duty cycle)   | WLAN | 8.29 | ± 9.6 % |
| 10740 | AAA | IEEE 802.11ax (80MHz, MCS9, 99pc duty cycle)   | WLAN | 8.48 | ± 9.6 % |
| 10741 | AAA | IEEE 802.11ax (80MHz, MCS10, 99pc duty cycle)  | WLAN | 8.40 | ± 9.6 % |
| 10742 | AAA | IEEE 802.11ax (80MHz, MCS11, 99pc duty cycle)  | WLAN | 8.43 | ± 9.6 % |
| 10743 | AAA | IEEE 802.11ax (160MHz, MCS0, 90pc duty cycle)  | WLAN | 8.94 | ± 9.6 % |
| 10744 | AAA | IEEE 802.11ax (160MHz, MCS1, 90pc duty cycle)  | WLAN | 9.16 | ± 9.6 % |
| 10745 | AAA | IEEE 802.11ax (160MHz, MCS2, 90pc duty cycle)  | WLAN | 8.93 | ± 9.6 % |
| 10746 | AAA | IEEE 802.11ax (160MHz, MCS3, 90pc duty cycle)  | WLAN | 9.11 | ± 9.6 % |
| 10747 | AAA | IEEE 802.11ax (160MHz, MCS4, 90pc duty cycle)  | WLAN | 9.04 | ± 9.6 % |
| 10748 | AAA | IEEE 802.11ax (160MHz, MCS5, 90pc duty cycle)  | WLAN | 8.93 | ± 9.6 % |
| 10749 | AAA | IEEE 802.11ax (160MHz, MCS6, 90pc duty cycle)  | WLAN | 8.90 | ± 9.6 % |
| 10750 | AAA | IEEE 802.11ax (160MHz, MCS7, 90pc duty cycle)  | WLAN | 8.79 | ± 9.6 % |
| 10751 | AAA | IEEE 802.11ax (160MHz, MCS8, 90pc duty cycle)  | WLAN | 8.82 | ± 9.6 % |
| 10752 | AAA | IEEE 802.11ax (160MHz, MCS9, 90pc duty cycle)  | WLAN | 8.81 | ± 9.6 % |
| 10753 | AAA | IEEE 802.11ax (160MHz, MCS10, 90pc duty cycle) | WLAN | 9.00 | ± 9.6 % |
| 10754 | AAA | IEEE 802.11ax (160MHz, MCS11, 90pc duty cycle) | WLAN | 8.94 | ± 9.6 % |
| 10755 | AAA | IEEE 802.11ax (160MHz, MCS0, 99pc duty cycle)  | WLAN | 8.64 | ± 9.6 % |
| 10756 | AAA | IEEE 802.11ax (160MHz, MCS1, 99pc duty cycle)  | WLAN | 8.77 | ± 9.6 % |
| 10757 | AAA | IEEE 802.11ax (160MHz, MCS2, 99pc duty cycle)  | WLAN | 8.77 | ± 9.6 % |
| 10758 | AAA | IEEE 802.11ax (160MHz, MCS3, 99pc duty cycle)  | WLAN | 8.69 | ± 9.6 % |
| 10759 | AAA | IEEE 802.11ax (160MHz, MCS4, 99pc duty cycle)  | WLAN | 8.58 | ± 9.6 % |
| 10760 | AAA | IEEE 802.11ax (160MHz, MCS5, 99pc duty cycle)  | WLAN | 8.49 | ± 9.6 % |
| 10761 | AAA | IEEE 802.11ax (160MHz, MCS6, 99pc duty cycle)  | WLAN | 8.58 | ± 9.6 % |
| 10762 | AAA | IEEE 802.11ax (160MHz, MCS7, 99pc duty cycle)  | WLAN | 8.49 | ± 9.6 % |
| 10763 | AAA | IEEE 802.11ax (160MHz, MCS8, 99pc duty cycle)  | WLAN | 8.53 | ± 9.6 % |
| 10764 | AAA | IEEE 802.11ax (160MHz, MCS9, 99pc duty cycle)  | WLAN | 8.54 | ± 9.6 % |
| 10765 | AAA | IEEE 802.11ax (160MHz, MCS10, 99pc duty cycle) | WLAN | 8.54 | ± 9.6 % |
| 10766 | AAA | IEEE 802.11ax (160MHz, MCS11, 99pc duty cycle) | WLAN | 8.51 | ± 9.6 % |

<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.

Calibration Laboratory of  
Schmid & Partner  
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Accreditation No.: SCS 0108

Client DT&C (Dymstec)

Certificate No: EX3-3916\_Apr19

## CALIBRATION CERTIFICATE

Object EX3DV4 - SN:3916

Calibration procedure(s) QA CAL-01.v9, QA CAL-14.v5, QA CAL-23.v5, QA CAL-25.v7  
Calibration procedure for dosimetric E-field probes

Calibration date: April 25, 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  $(22 \pm 3)^\circ\text{C}$  and humidity  $< 70\%$ .

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards          | ID               | Cal Date (Certificate No.)        | Scheduled Calibration  |
|----------------------------|------------------|-----------------------------------|------------------------|
| Power meter 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: 660          | 19-Dec-18 (No. DAE4-660_Dec18)    | Dec-19                 |
| Reference Probe ES3DV2     | SN: 3013         | 31-Dec-18 (No. ES3-3013_Dec18)    | Dec-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 |

|                        | Name          | Function              | Signature |
|------------------------|---------------|-----------------------|-----------|
| Calibrated by:         | Leif Klysner  | Laboratory Technician |           |
| Approved by:           | Katja Pokovic | Technical Manager     |           |
| Issued: April 27, 2019 |               |                       |           |

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

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### 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 $\phi$      | $\phi$ rotation around probe axis                                                                                                                       |
| Polarization $\vartheta$ | $\vartheta$ rotation around an axis that is in the plane normal to probe axis (at measurement center),<br>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 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- 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  $E^2$ -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 (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<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).

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## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3916

### Basic Calibration Parameters

|                                                    | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|----------------------------------------------------|----------|----------|----------|-----------|
| Norm ( $\mu\text{V}/(\text{V/m})^2$ ) <sup>A</sup> | 0.56     | 0.48     | 0.52     | ± 10.1 %  |
| DCP (mV) <sup>B</sup>                              | 101.7    | 96.9     | 104.5    |           |

### Calibration Results for Modulation Response

| UID | Communication System Name |   | A<br>dB | B<br>dB $\sqrt{\mu\text{V}}$ | C   | D<br>dB | VR<br>mV | Max<br>dev. | Unc <sup>E</sup><br>(k=2) |
|-----|---------------------------|---|---------|------------------------------|-----|---------|----------|-------------|---------------------------|
| 0   | CW                        | X | 0.0     | 0.0                          | 1.0 | 0.00    | 146.1    | ±3.8 %      | ± 4.7 %                   |
|     |                           | Y | 0.0     | 0.0                          | 1.0 |         | 139.8    |             |                           |
|     |                           | Y | 0.0     | 0.0                          | 1.0 |         | 143.5    |             |                           |

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 Pages 5 and 6).

<sup>B</sup> Numerical linearization parameter: uncertainty not required.

<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.

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## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3916

### Other Probe Parameters

|                                               |            |
|-----------------------------------------------|------------|
| Sensor Arrangement                            | Triangular |
| Connector Angle (°)                           | 90.9       |
| 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     |

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## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3916

### Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) <sup>c</sup> | Relative Permittivity <sup>f</sup> | Conductivity (S/m) <sup>f</sup> | ConvF X | ConvF Y | ConvF Z | Alpha <sup>g</sup> | Depth <sup>g</sup> (mm) | Unc (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-----------|
| 2450                 | 39.2                               | 1.80                            | 7.66    | 7.66    | 7.66    | 0.39               | 0.85                    | ± 12.0 %  |
| 2600                 | 39.0                               | 1.96                            | 7.46    | 7.46    | 7.46    | 0.36               | 0.86                    | ± 12.0 %  |
| 5200                 | 36.0                               | 4.66                            | 5.14    | 5.14    | 5.14    | 0.40               | 1.80                    | ± 13.1 %  |
| 5300                 | 35.9                               | 4.76                            | 4.94    | 4.94    | 4.94    | 0.40               | 1.80                    | ± 13.1 %  |
| 5500                 | 35.6                               | 4.96                            | 4.89    | 4.89    | 4.89    | 0.40               | 1.80                    | ± 13.1 %  |
| 5600                 | 35.5                               | 5.07                            | 4.75    | 4.75    | 4.75    | 0.40               | 1.80                    | ± 13.1 %  |
| 5800                 | 35.3                               | 5.27                            | 4.82    | 4.82    | 4.82    | 0.40               | 1.80                    | ± 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> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

<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.

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## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3916

### Calibration Parameter Determined in Body Tissue Simulating Media

| f (MHz) <sup>c</sup> | Relative Permittivity <sup>f</sup> | Conductivity (S/m) <sup>f</sup> | ConvF X | ConvF Y | ConvF Z | Alpha <sup>g</sup> | Depth <sup>g</sup> (mm) | Unc (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-----------|
| 2450                 | 52.7                               | 1.95                            | 7.62    | 7.62    | 7.62    | 0.34               | 0.85                    | ± 12.0 %  |
| 2600                 | 52.5                               | 2.16                            | 7.42    | 7.42    | 7.42    | 0.22               | 1.03                    | ± 12.0 %  |
| 5200                 | 49.0                               | 5.30                            | 4.56    | 4.56    | 4.56    | 0.50               | 1.90                    | ± 13.1 %  |
| 5300                 | 48.9                               | 5.42                            | 4.37    | 4.37    | 4.37    | 0.50               | 1.90                    | ± 13.1 %  |
| 5500                 | 48.6                               | 5.65                            | 4.14    | 4.14    | 4.14    | 0.50               | 1.90                    | ± 13.1 %  |
| 5600                 | 48.5                               | 5.77                            | 4.00    | 4.00    | 4.00    | 0.50               | 1.90                    | ± 13.1 %  |
| 5800                 | 48.2                               | 6.00                            | 4.23    | 4.23    | 4.23    | 0.50               | 1.90                    | ± 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.

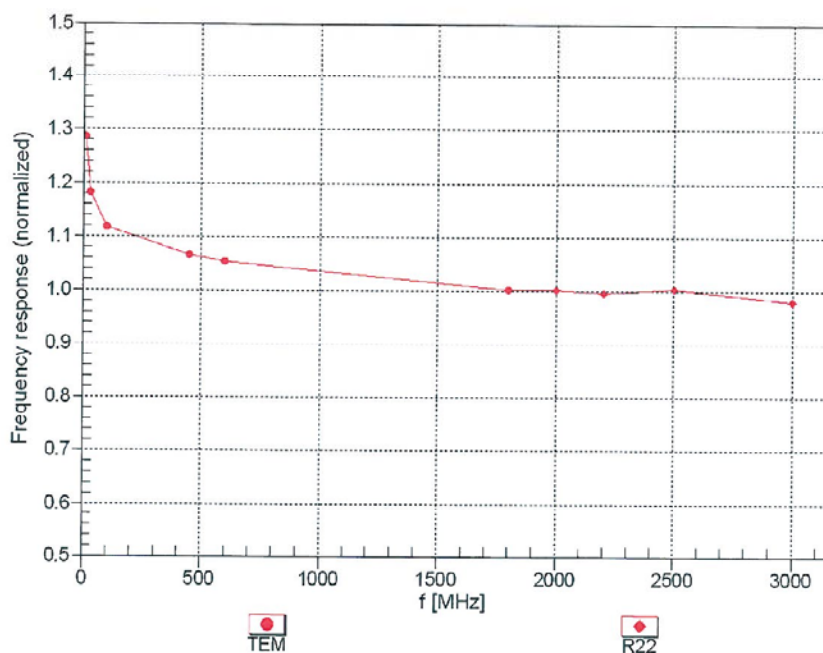
<sup>f</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

<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.

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### Frequency Response of E-Field (TEM-Cell:ifi110 EXX, Waveguide: R22)

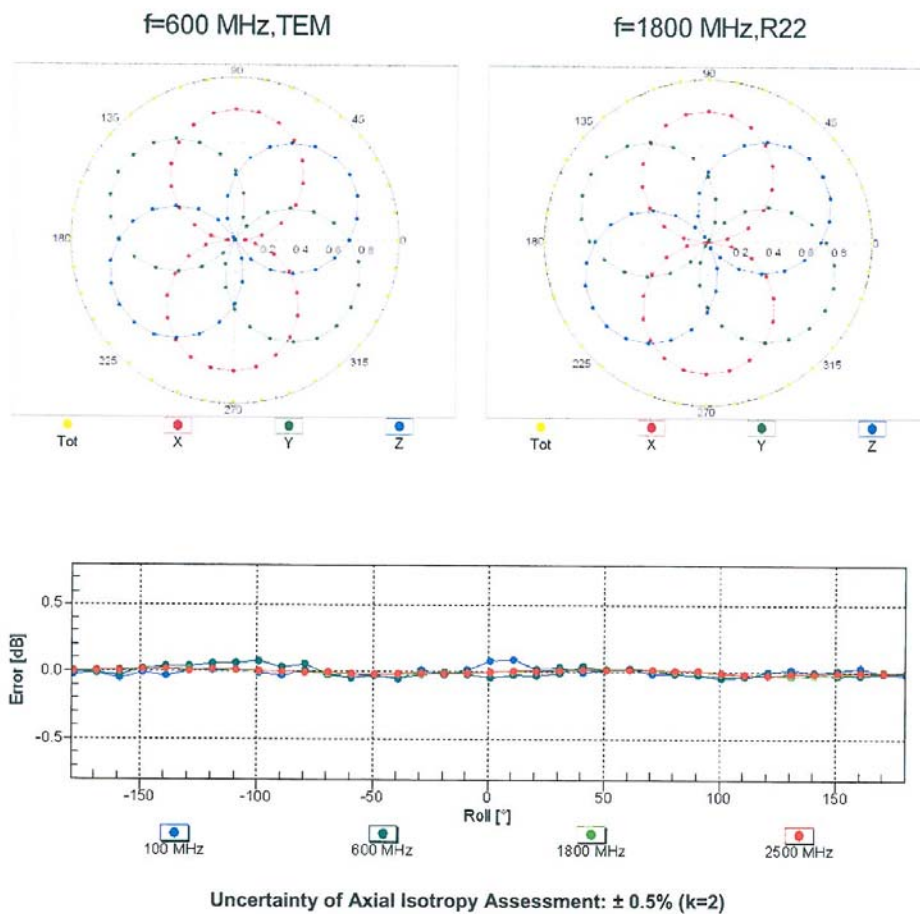


Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  ( $k=2$ )

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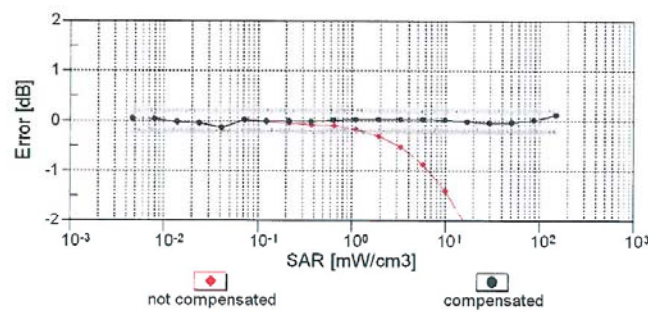
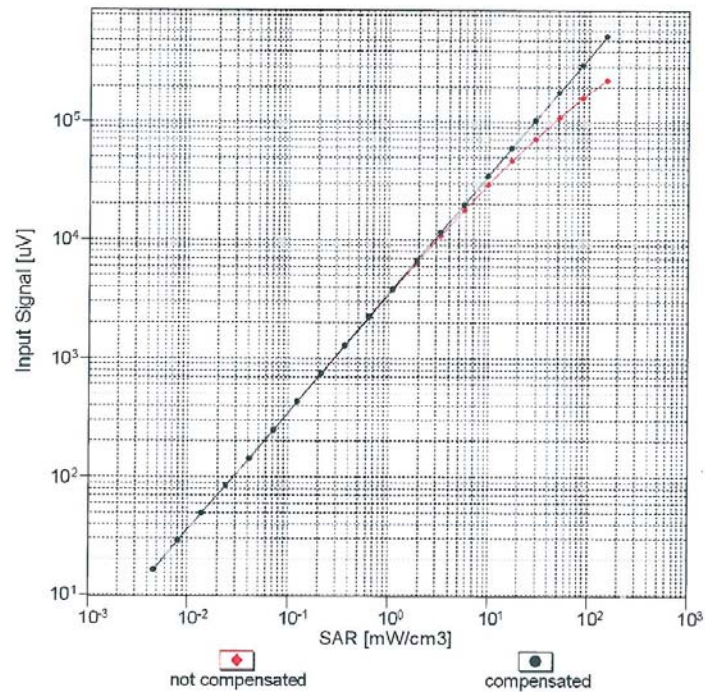
## Receiving Pattern ( $\phi$ ), $\theta = 0^\circ$



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### Dynamic Range $f(\text{SAR}_{\text{head}})$ (TEM cell, $f_{\text{eval}} = 1900 \text{ MHz}$ )

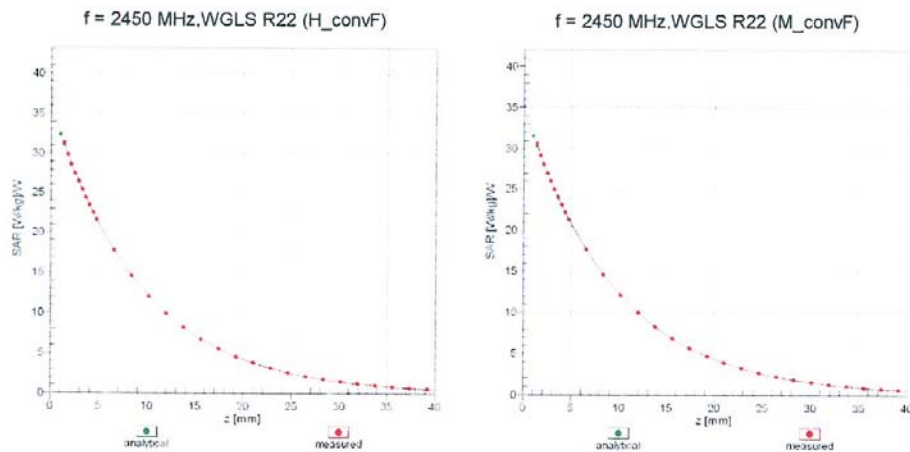


Uncertainty of Linearity Assessment:  $\pm 0.6\%$  ( $k=2$ )

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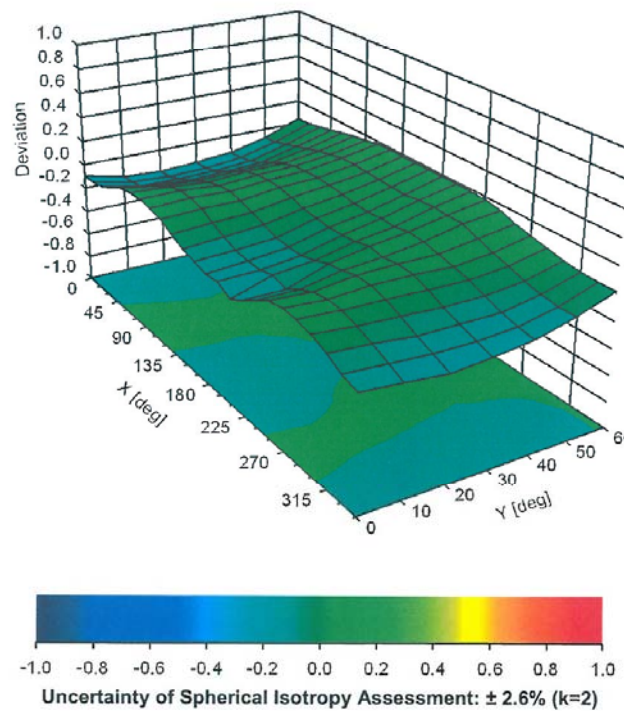
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## Conversion Factor Assessment



## Deviation from Isotropy in Liquid

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



## **APPENDIX C. – SAR Tissue Specifications**

The brain and muscle mixtures consist of a viscous gel using hydrox-ethylcellulose (HEC) gelling agent and saline solution (see Table C.1). Preservation with a bactericide is added and visual inspection is made to make sure air bubbles are not trapped during the mixing process. The mixture is calibrated to obtain proper dielectric constant (permittivity) and conductivity of the desired tissue. The mixture characterizations used for the brain and muscle tissue simulating liquids are according to the data by C. Gabriel and G. Harts grove.



Figure C.1 Simulated Tissue

Table C.1 Composition of the Tissue Equivalent Matter

| Ingredients<br>(% by weight)   | Frequency (MHz) |       |       |       |       |       |             |       |
|--------------------------------|-----------------|-------|-------|-------|-------|-------|-------------|-------|
|                                | 835             |       | 1900  |       | 2450  |       | 5200 – 5800 |       |
| Tissue Type                    | Head            | Body  | Head  | Body  | Head  | Body  | Head        | Body  |
| Water                          | 40.19           | 50.75 | 55.24 | 70.23 | 71.88 | 73.40 | 65.52       | 80.00 |
| Salt (NaCl)                    | 1.480           | 0.940 | 0.310 | 0.290 | 0.160 | 0.060 | -           | -     |
| Sugar                          | 57.90           | 48.21 | -     | -     | -     | -     | -           | -     |
| HEC                            | 0.250           | -     | -     | -     | -     | -     | -           | -     |
| Bactericide                    | 0.180           | 0.100 | -     | -     | -     | -     | -           | -     |
| Triton X-100                   | -               | -     | -     | -     | 19.97 | -     | 17.24       | -     |
| DGBE                           | -               | -     | 44.45 | 29.48 | 7.990 | 26.54 | -           | -     |
| Diethylene glycol hexyl ether  | -               | -     | -     | -     | -     | -     | 17.24       | -     |
| Polysorbate (Tween) 80         | -               | -     | -     | -     | -     | -     | -           | 20.00 |
| Target for Dielectric Constant | 41.5            | 55.2  | 40.0  | 53.3  | 39.2  | 52.7  | -           | -     |
| Target for Conductivity (S/m)  | 0.90            | 0.97  | 1.40  | 1.52  | 1.80  | 1.95  | -           | -     |

Salt: 99 % Pure Sodium Chloride      Sugar: 98 % Pure Sucrose  
 Water: De-ionized, 16M resistivity      HEC: Hydroxyethyl Cellulose  
 DGBE: 99 % Di(ethylene glycol) butyl ether,[2-(2-butoxyethoxy) ethanol]  
 Triton X-100(ultra pure): Polyethylene glycol mono[4-(1,1,3,3-tetramethylbutyl)phenyl] ether

Table C.2 HSL/MSL750 (Head and Body liquids for 700 – 800 MHz)

| Item                                               | Head Tissue Simulation Liquids HSL750                                                                                                               |
|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                    | Muscle (body) Tissue Simulation Liquids MSL750                                                                                                      |
| Type No                                            | SL AAH 075, SL AAM 075                                                                                                                              |
| Manufacturer                                       | SPEAG                                                                                                                                               |
| The item is composed of the following ingredients: |                                                                                                                                                     |
| H <sub>2</sub> O                                   | Water, 35 – 58%                                                                                                                                     |
| Sucrose                                            | Sucrose, 40 – 60%                                                                                                                                   |
| NaCl                                               | Sodium Chloride, 0 – 6%                                                                                                                             |
| Hydroxyethyl-cellulose                             | Medium Viscosity (CAS# 9004-62-0), < 0.3%                                                                                                           |
| Preventol-D7                                       | Preservative: aqueous preparation, (CAS# 55965-84-9), containing 5-chloro-2-methyl-3(2H)-isothiazolone and 2-methyl-3(2H)-isothiazolone, 0.1 – 0.6% |

Table C.3 HSL/MSL1750 (Head and Body liquids for 1700 – 1800 MHz)

| Item                                               | Head Tissue Simulation Liquids HSL1750             |
|----------------------------------------------------|----------------------------------------------------|
|                                                    | Muscle (body) Tissue Simulation Liquids MSL1750    |
| Type No                                            | SL AAH 175, SL AAM 175                             |
| Manufacturer                                       | SPEAG                                              |
| The item is composed of the following ingredients: |                                                    |
| H <sub>2</sub> O                                   | Water, 52 – 75%                                    |
| C8H18O3                                            | Diethylene glycol monobutyl ether (DGBE), 25 – 48% |
| NaCl                                               | Sodium Chloride, < 1.0%                            |

## **APPENDIX D. – SAR SYSTEM VALIDATION**

## SAR System Validation

Per FCC KDB 865664 D02v01r02, SAR system validation status should be documented to confirm measurement accuracy. The SAR systems (including SAR probes, system components and software versions) used for this device were validated against its performance specifications prior to the SAR measurements. Reference dipoles were used with the required tissue- equivalent media for system validation, according to the procedures outlined in FCC KDB 865664 D01v01r04 and IEEE 1528-2013. Since SAR probe calibrations are frequency dependent, each probe calibration point was validated at a frequency within the valid frequency range of the probe calibration point, using the system that normally operates with the probe for routine SAR measurements and according to the required tissue-equivalent media.

A tabulated summary of the system validation status including the validation date(s), measurement frequencies, SAR probes and tissue dielectric parameters has been included.

**Table D.1 SAR System Validation Summary**

| SAR System | Freq. [MHz] | Date       | Probe SN | Probe Type | Probe CAL. Point |      | PERM.            | COND.        | CW Validation    |                    |                    | MOD. Validation |                |      |
|------------|-------------|------------|----------|------------|------------------|------|------------------|--------------|------------------|--------------------|--------------------|-----------------|----------------|------|
|            |             |            |          |            |                  |      | ( $\epsilon_r$ ) | ( $\sigma$ ) | Sensi-<br>tivity | Probe<br>Linearity | Probe<br>Isortropy | MOD. Type       | Duty<br>Factor | PAR  |
| C          | 750         | 2019.06.18 | 3866     | EX3DV4     | 750              | Head | 42.172           | 0.891        | PASS             | PASS               | PASS               | N/A             | N/A            | N/A  |
| C          | 835         | 2019.06.19 | 3866     | EX3DV4     | 835              | Head | 40.982           | 0.921        | PASS             | PASS               | PASS               | GMSK            | PASS           | N/A  |
| C          | 1900        | 2019.06.20 | 3866     | EX3DV4     | 1900             | Head | 39.568           | 1.363        | PASS             | PASS               | PASS               | GMSK            | PASS           | N/A  |
| D          | 2450        | 2019.05.20 | 3916     | EX3DV4     | 2450             | Head | 38.923           | 1.816        | PASS             | PASS               | PASS               | OFDM/TDD        | PASS           | PASS |
| D          | 5300        | 2019.05.21 | 3916     | EX3DV4     | 5300             | Head | 34.822           | 4.832        | PASS             | PASS               | PASS               | OFDM            | N/A            | PASS |
| D          | 5500        | 2019.05.22 | 3916     | EX3DV4     | 5500             | Head | 34.613           | 5.124        | PASS             | PASS               | PASS               | OFDM            | N/A            | PASS |
| D          | 5600        | 2019.05.22 | 3916     | EX3DV4     | 5600             | Head | 34.248           | 5.226        | PASS             | PASS               | PASS               | OFDM            | N/A            | PASS |

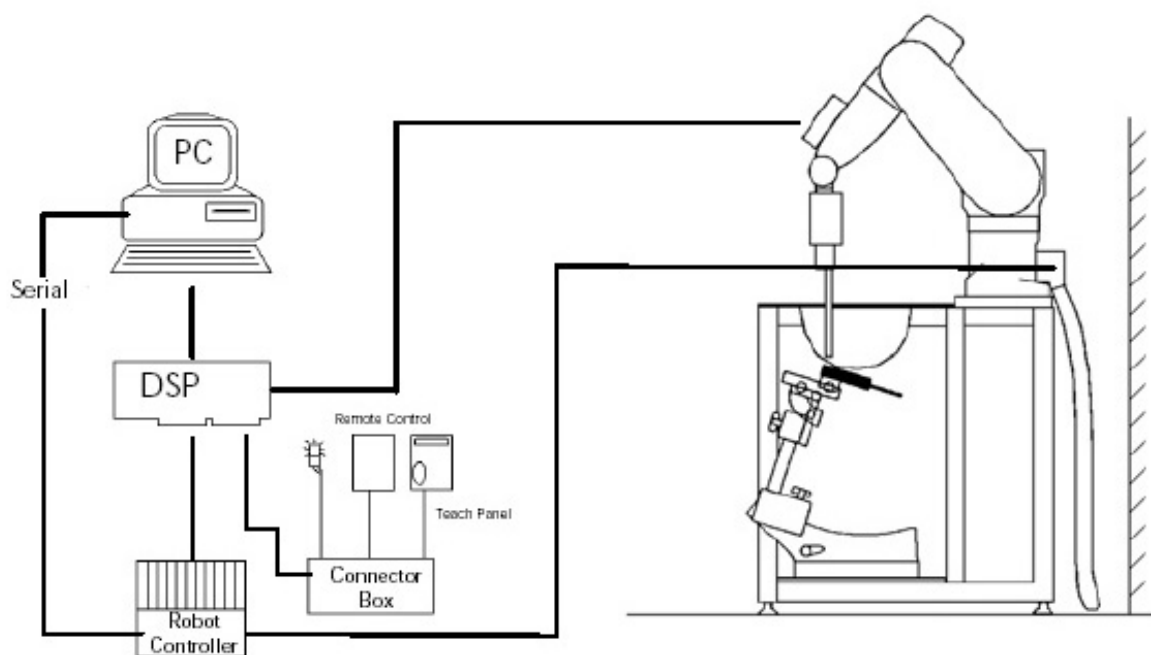
NOTE: While the probes have been calibrated for both a CW and modulated signals, all measurements were performed using communication systems calibrated for CW signals only. Modulations in the table above represent test configurations for which the measurement system has been validated per FCC KDB Publication 865664 D01v01r04 for scenarios when CW probe calibrations are used with other signal types. SAR systems were validated for modulated signals with a periodic duty cycle, such as GMSK, or with a high peak to average ratio (>5 dB), such as OFDM according to KDB 865664.

## **APPENDIX F. – Description of Test Equipment**

## F.1 SAR Measurement Setup

Measurements are performed using the DASY5 automated dosimetric assessment system. The DASY5 is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland and consists of high precision robotics system (Staubli), robot controller, desktop computer, near-field probe, probe alignment sensor, and the generic twin phantom containing the brain equivalent material. The robot is a six-axis industrial robot performing precise movements to position the probe to the location (points) of maximum electromagnetic field (EMF) (see Fig. F.1.1).

A cell controller system contains the power supply, robot controller each pendant (Joystick), and a remote control used to drive the robot motors. The PC consists of the Intel Core i7-3770 3.40 GHz desktop computer with Windows 7 system and SAR Measurement Software DASY5, A/D interface card, monitor, mouse, and keyboard. The Staubli Robot is connected to the cell controller to allow software manipulation of the robot. A data acquisition electronic (DAE) circuit that performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. is connected to the Electro-optical coupler (EOC). The EOC performs the conversion from the optical into digital electric signal of the DAE and transfers data to the PC plug-in card.



**Figure F.1.1 SAR Measurement System Setup**

The DAE4 consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the PC-card is accomplished through an optical downlink for data and status information and an optical uplink for commands and clock lines. The mechanical probe mounting device includes two different sensor systems for frontal and sidewise probe contacts. They are also used for mechanical surface detection and probe collision detection. The robot uses its own controller with a built in VME-bus computer. The system is described in detail.

## F.2 Probe Specification

|                                          |                                                                                                                                                                                                                                                                                                                                                                                         |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Calibration                              | In air from 10 MHz to 6 GHz                                                                                                                                                                                                                                                                                                                                                             |
|                                          | In brain and muscle simulating tissue at Frequencies of<br>750 MHz, 835 MHz, 900 MHz, 1750 MHz, 1900 MHz, 2300 MHz, 2450 MHz, 2600 MHz,<br>3500 MHz, 3700 MHz, 5200 MHz, 5300 MHz, 5500 MHz, 5600 MHz, 5800 MHz /<br>2450 MHz, 2600 MHz, 5200 MHz, 5300 MHz, 5500 MHz, 5600 MHz, 5800 MHz /<br>2450 MHz, 2600 MHz, 3500 MHz, 3700 MHz, 5200 MHz, 5300 MHz, 5500 MHz, 5600 MHz, 5800 MHz |
| Frequency                                | 10 MHz to 6 GHz                                                                                                                                                                                                                                                                                                                                                                         |
| Linearity                                | $\pm 0.2$ dB(30 MHz to 6 GHz)                                                                                                                                                                                                                                                                                                                                                           |
| Dynamic                                  | 10 $\mu$ W/g to > 100 mW/g                                                                                                                                                                                                                                                                                                                                                              |
| Range                                    | Linearity : $\pm 0.2$ dB                                                                                                                                                                                                                                                                                                                                                                |
| Dimensions                               | Overall length : 337 mm                                                                                                                                                                                                                                                                                                                                                                 |
| Tip length                               | 20 mm                                                                                                                                                                                                                                                                                                                                                                                   |
| Body diameter                            | 12 mm                                                                                                                                                                                                                                                                                                                                                                                   |
| Tip diameter                             | 2.5 mm                                                                                                                                                                                                                                                                                                                                                                                  |
| Distance from probe tip to sensor center | 1.0 mm                                                                                                                                                                                                                                                                                                                                                                                  |
| Application                              | SAR Dosimetry Testing<br>Compliance tests of mobile phones                                                                                                                                                                                                                                                                                                                              |

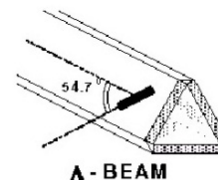


Figure F.2.1 Triangular Probe Configurations



Figure F.2.2 Probe Thick-Film Technique



DAE System

The SAR measurements were conducted with the dosimetric probe EX3DV4 designed in the classical triangular configuration(see F.2.1) and optimized for dosimetric evaluation. The probe is constructed using the thick film technique; with printed resistive lines on ceramic substrates. The probe is equipped with an optical multitier line ending at the front of the probe tip. It is connected to the EOC box on the robot arm and provides an automatic detection of the phantom surface. Half of the fibers are connected to a pulsed infrared transmitter, the other half to a synchronized receiver. As the probe approaches the surface, the reflection from the surface produces a coupling from the transmitting to the receiving fibers. This reflection increases first during the approach, reaches maximum and then decreases. If the probe is flatly touching the surface, the coupling is zero. The distance of the coupling maximum to the surface is independent of the surface reflectivity and largely independent of the surface to probe angle. The DASY5 software reads the reflection during a software approach and looks for the maximum using a 2nd order fitting. The approach is stopped at reaching the maximum.

### F.3 E-Probe Calibration Process

#### Dosimetric Assessment Procedure

Each probe is calibrated according to a dosimetric assessment procedure with accuracy better than +/- 10%. The spherical isotropy was evaluated with the procedure and found to be better than +/-0.25dB. The sensitivity parameters (Norm X, Norm Y, Norm Z), the diode compression parameter (DCP) and the conversion factor (Conv F) of the probe is tested.

#### Free Space Assessment

The free space E-field from amplified probe outputs is determined in a test chamber. This is performed in a TEM cell for frequencies below 1 GHz, and in a waveguide above 1GHz for free space. For the free space calibration, the probe is placed in the volumetric center of the cavity at the proper orientation with the field. The probe is then rotated 360 degrees.

#### Temperature Assessment \*

E-field temperature correlation calibration is performed in a flat phantom filled with the appropriate simulated brain tissue. The measured free space E-field in the medium, correlates to temperature rise in a dielectric medium. For temperature correlation calibration a RF transparent the remits or based temperature probe is used in conjunction with the E-field probe.

$$SAR = C \frac{\Delta T}{\Delta t}$$

where:

- $\Delta t$  = exposure time (30 seconds),  
 $C$  = heat capacity of tissue (brain or muscle),  
 $\Delta T$  = temperature increase due to RF exposure.

$$SAR = \frac{|E|^2 \cdot \sigma}{\rho}$$

where:

- $\sigma$  = simulated tissue conductivity,  
 $\rho$  = Tissue density (1.25 g/cm<sup>3</sup> for brain tissue)

SAR is proportional to  $\Delta T / \Delta t$ , the initial rate of tissue heating, before thermal diffusion takes place. Now it's possible to quantify the electric field in the simulated tissue by equating the thermally derived SAR to the E- field;

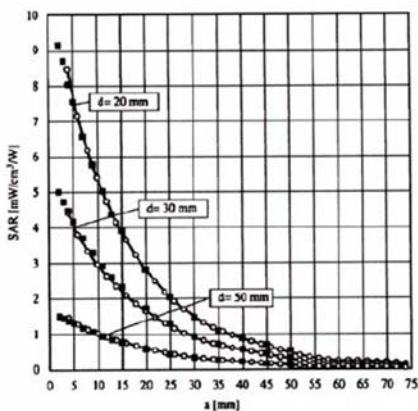


Figure F.3.1 E-Field and Temperature Measurements at 900MHz

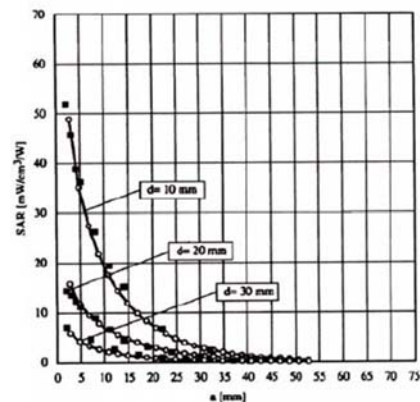


Figure F.3.2 E-Field and Temperature Measurements at 1800MHz

## F.4 Data Extrapolation

The DASY5 software automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC-transmission factor from the diode to the evaluation electronics. If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given like below;

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

with  $V_i$  = compensated signal of channel i (i=x,y,z)  
 $U_i$  = input signal of channel i (i=x,y,z)  
 $cf$  = crest factor of exciting field (DASY parameter)  
 $dcp_i$  = diode compression point (DASY parameter)

From the compensated input signals the primary field data for each channel can be evaluated:

E-field probes:

$$E_i = \sqrt{\frac{V_i}{Norm_i \cdot ConvF}}$$

with  $V_i$  = compensated signal of channel i (i = x,y,z)  
 $Norm_i$  = sensor sensitivity of channel i (i = x,y,z)  
 $\mu V/(V/m)^2$  for E-field probes  
 $ConvF$  = sensitivity of enhancement in solution  
 $E_i$  = electric field strength of channel i in V/m

The RSS value of the field components gives the total field strength (Hermetian magnitude):

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

The primary field data are used to calculate the derived field units.

$$SAR = E_{tot}^2 \cdot \frac{\sigma}{\rho \cdot 1000}$$

with  $SAR$  = local specific absorption rate in W/g  
 $E_{tot}$  = total field strength in V/m  
 $\sigma$  = conductivity in [mho/m] or [Siemens/m]  
 $\rho$  = equivalent tissue density in g/cm<sup>3</sup>

The power flow density is calculated assuming the excitation field to be a free space field.

$$P_{free} = \frac{E_{tot}^2}{3770}$$

with  $P_{pwe}$  = equivalent power density of a plane wave in W/cm<sup>2</sup>  
 $E_{tot}$  = total electric field strength in V/m

## F.5 SAM Twin Phantom

The SAM Twin Phantom V5.0 is constructed of a fiberglass shell integrated in a wooden table. The shape of the shell is based on data from an anatomical study designed to determine the maximum exposure in at least 90% of all users. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. A cover prevents the evaporation of the liquid.

Reference markings on the Phantom allow the complete setup of all predefined phantom positions and measurement grids by manually teaching three points in the robot. (see Fig. F.5.1)



**Figure F.5.1 SAM Twin Phantom**

### SAM Twin Phantom Specification:

#### Construction

The shell corresponds to the specifications of the Specific Anthropomorphic Mannequin (SAM) phantom defined in IEEE 1528 and IEC 62209-1. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. A cover prevents evaporation of the liquid. Reference markings on the phantom allow the complete setup of all predefined phantom positions and measurement grids by teaching three points with the robot.

Twin SAM V5.0 has the same shell geometry and is manufactured from the same material as Twin SAM V4.0, but has reinforced top structure.

#### Shell Thickness

$2 \pm 0.2$  mm

#### Filling Volume

Approx. 25 liters

#### Dimensions

Length: 1000 mm

Width: 500 mm

Height: adjustable feet

### Specific Anthropomorphic Mannequin (SAM) Specifications:

The phantom for handset SAR assessment testing is a low-loss dielectric shell, with shape and dimensions derived from the anthropometric data of the 90th percentile adult male head dimensions as tabulated by the US Army. The SAM Twin Phantom shell is bisected along the mid-sagittal plane into right and left halves (see Fig. F.5.2). The perimeter sidewalls of each phantom halves are extended to allow filling with liquid to a depth that is sufficient to minimized reflections from the upper surface. The liquid depth is maintained at a minimum depth of 15cm to minimize reflections from the upper surface.



**Figure F.5.2 Sam Twin Phantom shell**

## F.6 Device Holder for Transmitters

In combination with the Twin SAM Phantom V4.0/V4.0c, V5.0 or ELI4, the Mounting Device enables the rotation of the mounted transmitter device in spherical coordinates. Rotation point is the ear opening point. Transmitter devices can be easily and accurately positioned according to IEC, IEEE, FCC or other specifications. The device holder can be locked for positioning at different phantom sections (left head, right head, flat).

Note: A simulating human hand is not used due to the complex anatomical and geometrical structure of the hand that may produce infinite number of configurations. To produce the worst-case condition (the hand absorbs antenna output power), the hand is omitted during the tests.



**Figure F.6.1 Mounting Device**

## F.7 Automated Test System Specifications

### Positioner

|                      |                                             |
|----------------------|---------------------------------------------|
| <b>Robot</b>         | Stäubli Unimation Corp. Robot Model: TX90XL |
| <b>Repeatability</b> | 0.02 mm                                     |
| <b>No. of axis</b>   | 6                                           |

### Data Acquisition Electronic (DAE) System

#### Cell Controller

|                         |                                                           |
|-------------------------|-----------------------------------------------------------|
| <b>Processor</b>        | Intel Core i7-2600/ Intel Core i7-3770/Intel Core i7-4770 |
| <b>Clock Speed</b>      | 3.40 GHz                                                  |
| <b>Operating System</b> | Windows 7 Professional                                    |
| <b>Data Card</b>        | DASY5 PC-Board                                            |

#### Data Converter

|                         |                                                                                    |
|-------------------------|------------------------------------------------------------------------------------|
| <b>Features</b>         | Signal, multiplexer, A/D converter. & control logic                                |
| <b>Software</b>         | DASY5                                                                              |
| <b>Connecting Lines</b> | Optical downlink for data and status info<br>Optical uplink for commands and clock |

#### PC Interface Card

|                 |                                                                                                                                                                                      |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Function</b> | 24 bit (64 MHz) DSP for real time processing<br>Link to DAE 4<br>16 bit A/D converter for surface detection system<br>serial link to robot<br>direct emergency stop output for robot |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

#### E-Field Probes

|                     |                                              |
|---------------------|----------------------------------------------|
| <b>Model</b>        | EX3DV4 S/N: 3933, 3916, 3930                 |
| <b>Construction</b> | Triangular core fiber optic detection system |
| <b>Frequency</b>    | 10 MHz to 6 GHz                              |
| <b>Linearity</b>    | $\pm 0.2$ dB (30 MHz to 6 GHz)               |

#### Phantom

|                       |                         |
|-----------------------|-------------------------|
| <b>Phantom</b>        | SAM Twin Phantom (V5.0) |
| <b>Shell Material</b> | Composite               |
| <b>Thickness</b>      | $2.0 \pm 0.2$ mm        |



Figure F.7.1 DASY5 Test System