

# RF Exposure Lab

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## CERTIFICATE OF COMPLIANCE SAR EVALUATION

Lennox Industries Inc.  
1600 Metrocrest Dr.  
Carrollton, TX 75006

Dates of Test:  
Test Report Number:

June 17, 2022  
SAR.20220618

|                           |                                                                                                                                                                              |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FCC ID:                   | 2A6F9-S4022A                                                                                                                                                                 |
| IC Certificate:           | 28687-S4022A                                                                                                                                                                 |
| Model(s):                 | Lennox S40 Smart Thermostat                                                                                                                                                  |
| Test Sample:              | Engineering Unit Same as Production                                                                                                                                          |
| Serial Number:            | Eng 1                                                                                                                                                                        |
| Equipment Type:           | Wireless Thermostat                                                                                                                                                          |
| Classification:           | Portable Transmitter Next to Body                                                                                                                                            |
| TX Frequency Range:       | 2402 – 2480 MHz, 2412 – 2462 MHz; 5150 – 5250 MHz                                                                                                                            |
| Frequency Tolerance:      | ± 2.5 ppm                                                                                                                                                                    |
| Maximum RF Output:        | 2450 MHz (BT) – 19 dBm, 2450 MHz (b) – 17.00 dBm, 2450 MHz (g) – 14.00 dBm,<br>2450 MHz (n20) – 15.00 dBm, 5250 MHz (a) – 15.00 dBm, 5250 MHz (n20) – 15.00 dBm<br>Conducted |
| Signal Modulation:        | DSSS, OFDM, GFSK                                                                                                                                                             |
| Antenna Type:             | Internal Antenna                                                                                                                                                             |
| Application Type:         | Certification                                                                                                                                                                |
| FCC Rule Parts:           | Part 2, 15C, 15E                                                                                                                                                             |
| KDB Test Methodology:     | KDB 447498 D01 v07, KDB 248227 v02r02                                                                                                                                        |
| Industry Canada:          | RSS-102 Issue 5, Safety Code 6                                                                                                                                               |
| Maximum SAR Value:        | 0.33 W/kg Reported                                                                                                                                                           |
| Maximum Simultaneous SAR: | 0.52 W/kg Reported                                                                                                                                                           |
| Separation Distance:      | 0 mm                                                                                                                                                                         |

This wireless mobile and/or portable device has been shown to be compliant for localized specific absorption rate (SAR) for uncontrolled environment/general exposure limits specified in ANSI/IEEE Std. C95.1-1992 and had been tested in accordance with the measurement procedures specified in IEEE 1528-2013 and IEC 62209-1528:2020 (See test report).

I attest to the accuracy of the data. All measurements were performed by myself or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

RF Exposure Lab, LLC certifies that no party to this application is subject to a denial of Federal benefits that includes FCC benefits pursuant to Section 5301 of the Anti-Drug Abuse Act of 1988, 21 U.S.C. 853(a).



Jay M. Moulton  
Vice President



Testing Cert. # 2387.01

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| Comment/Revision | Date          |
|------------------|---------------|
| Original Release | June 29, 2022 |
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**Note: The latest version supersedes all previous versions listed in the above table. The latest version shall be used.**

## 1. Introduction

This measurement report shows compliance of the Lennox Industries Inc. Model Lennox S40 Smart Thermostat FCC ID: 2A6F9-S4022A with FCC Part 2, 1093, ET Docket 93-62 Rules for mobile and portable devices and IC Certificate: 28687-S4022A with RSS102 Issue 5 & Safety Code 6. The FCC have adopted the guidelines for evaluating the environmental effects of radio frequency radiation in ET Docket 93-62 on August 6, 1996 to protect the public and workers from the potential hazards of RF emissions due to FCC regulated portable devices. [1], [6]

The test results recorded herein are based on a single type test of Lennox Industries Inc. Model Lennox S40 Smart Thermostat and therefore apply only to the tested sample.

The test procedures and limits, as described in ANSI C95.1 – 1992 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz [2], ANSI C95.3 – 2002 Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields [3], IEEE Std.1528 – 2013 Recommended Practice [4], and Industry Canada Safety Code 6 Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3kHz to 300 GHz were employed.

The following tables indicates all the wireless technologies operating in the Lennox S40 Smart Thermostat Wireless Thermostat. The tables also show the tolerance for the power level for each mode.

| Band                | Technology | 3GPP Nominal Power dBm | Setpoint Nominal Power dBm | Tolerance dBm | Lower Tolerance dBm | Upper Tolerance dBm |
|---------------------|------------|------------------------|----------------------------|---------------|---------------------|---------------------|
| WLAN – 2.4 GHz      | 802.11b    | N/A                    | N/A                        | N/A           | N/A                 | 18.0                |
| WLAN – 2.4 GHz      | 802.11g    | N/A                    | N/A                        | N/A           | N/A                 | 20.0                |
| WLAN – 2.4 GHz      | 802.11n20  | N/A                    | N/A                        | N/A           | N/A                 | 20.0                |
| WLAN – 5 GHz Band I | 802.11a    | N/A                    | N/A                        | N/A           | N/A                 | 13.0                |
| WLAN – 5 GHz Band I | 802.11n20  | N/A                    | N/A                        | N/A           | N/A                 | 12.0                |
| BT – EDR & BT – LE  | Bluetooth  | N/A                    | N/A                        | N/A           | N/A                 | 17.0                |

## SAR Definition [5]

Specific Absorption Rate is defined as the time derivative (rate) of the incremental energy ( $dW$ ) absorbed by (dissipated in) an incremental mass ( $dm$ ) contained in a volume element ( $dV$ ) of a given density ( $\rho$ ).

$$SAR = \frac{d}{dt} \left( \frac{dW}{dm} \right) = \frac{d}{dt} \left( \frac{dW}{\rho dV} \right)$$

SAR is expressed in units of watts per kilogram (W/kg). SAR can be related to the electric field at a point by

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

where:

$\sigma$  = conductivity of the tissue (S/m)

$\rho$  = mass density of the tissue (kg/m<sup>3</sup>)

$E$  = rms electric field strength (V/m)

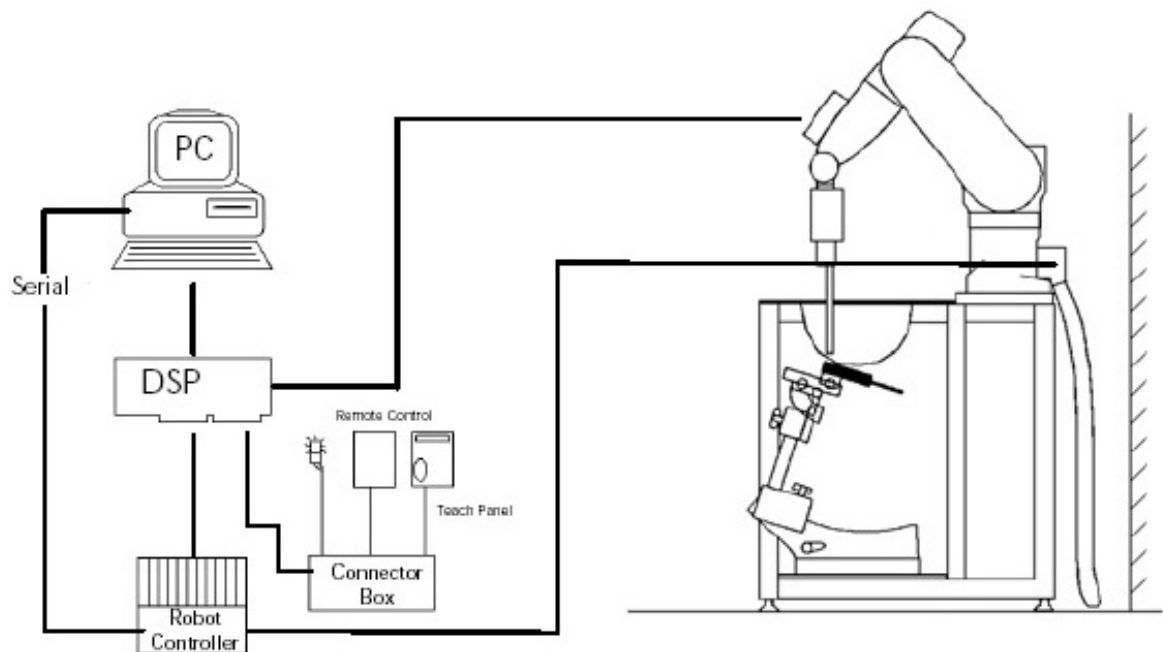
## 2. SAR Measurement Setup

### Robotic System

These measurements are performed using the DASY52 automated dosimetric assessment system. The DASY52 is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland and consists of high precision robotics system (Staubli), robot controller, Intel Core2 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. 2.1).

### System Hardware

A cell controller system contains the power supply, robot controller teach pendant (Joystick), and a remote control used to drive the robot motors. The PC consists of the HP Intel Core2 computer with Windows XP system and SAR Measurement Software DASY52, 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 2.1 SAR Measurement System Setup**

## System Electronics

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 in.

## Probe Measurement System

The SAR measurements were conducted with the dosimetric probe EX3DV4, designed in the classical triangular configuration (see Fig. 2.2) 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 multi fiber line ending at the front of the probe tip. (see Fig. 2.3) 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 DASY52 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.



**DAE System**

**Probe Specifications**

**Calibration:** In air from 10 MHz to 6.0 GHz  
In brain and muscle simulating tissue at Frequencies of 450 MHz, 835 MHz, 1750 MHz, 1900 MHz, 2450 MHz, 2600 MHz, 3500 MHz, 5200 MHz, 5300 MHz, 5600 MHz, 5800 MHz

**Frequency:** 10 MHz to 6 GHz

**Linearity:**  $\pm 0.2\text{dB}$  (30 MHz to 6 GHz)

**Dynamic:** 10 mW/kg to 100 W/kg

**Range:** Linearity:  $\pm 0.2\text{dB}$

**Dimensions:** Overall length: 330 mm

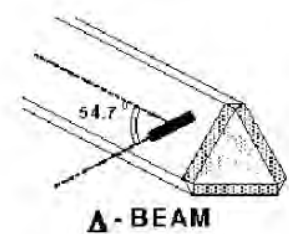
**Tip length:** 20 mm

**Body diameter:** 12 mm

**Tip diameter:** 2.5 mm

**Distance from probe tip to sensor center:** 1 mm

**Application:** SAR Dosimetry Testing  
Compliance tests of wireless device



**Figure 2.2 Triangular Probe Configurations**



**Figure 2.3 Probe Thick-Film Technique**

## Probe Calibration Process

### Dosimetric Assessment Procedure

Each probe is calibrated according to a dosimetric assessment procedure described in with accuracy better than +/- 10%. The spherical isotropy was evaluated with the procedure described in 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 until the three channels show the maximum reading. The power density readings equates to 1 mW/cm<sup>2</sup>.

### 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 thermistor based temperature probe is used in conjunction with the E-field probe

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

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

where:

where:

$\Delta t$  = exposure time (30 seconds),

$\sigma$  = simulated tissue conductivity,

$C$  = heat capacity of tissue (brain or muscle),

$\rho$  = Tissue density (1.25 g/cm<sup>3</sup> for brain tissue)

$\Delta T$  = temperature increase due to RF exposure.

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;

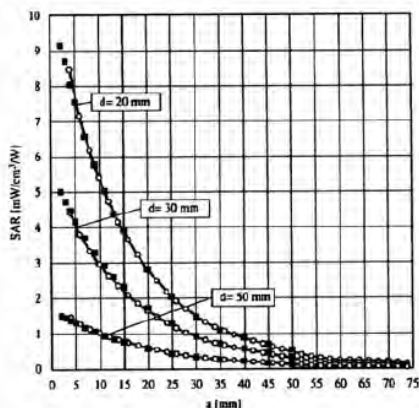


Figure 2.4 E-Field and Temperature Measurements at 900MHz

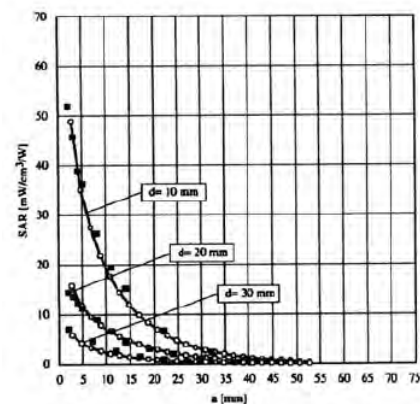


Figure 2.5 E-Field and Temperature Measurements at 1800MHz

## Data Extrapolation

The DASY52 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  $P_{free}$  = equivalent power density of a plane wave in W/cm<sup>2</sup>  
 $E_{tot}$  = total electric field strength in V/m

## Scanning procedure

- The DASY installation includes predefined files with recommended procedures for measurements and system check. They are read-only document files and destined as fully defined but unmeasured masks. All test positions (head or body-worn) are tested with the same configuration of test steps differing only in the grid definition for the different test positions.
- The „reference“ and „drift“ measurements are located at the beginning and end of the batch process. They measure the field drift at one single point in the liquid over the complete procedure. The indicated drift is mainly the variation of the DUT's output power and should vary max. +/- 5 %.
- The highest integrated SAR value is the main concern in compliance test applications. These values can mostly be found at the inner surface of the phantom and cannot be measured directly due to the sensor offset in the probe. To extrapolate the surface values, the measurement distances to the surface must be known accurately. A distance error of 0.5mm could produce SAR errors of 6% at 1800 MHz. Using predefined locations for measurements is not accurate enough. Any shift of the phantom (e.g., slight deformations after filling it with liquid) would produce high uncertainties. For an automatic and accurate detection of the phantom surface, the DASY5 system uses the mechanical surface detection. The detection is always at touch, but the probe will move backward from the surface the indicated distance before starting the measurement.
- The „area scan“ measures the SAR above the DUT or verification dipole on a parallel plane to the surface. It is used to locate the approximate location of the peak SAR with 2D spline interpolation. The robot performs a stepped movement along one grid axis while the local electrical field strength is measured by the probe. The probe is touching the surface of the SAM during acquisition of measurement values. The scan uses different grid spacings for different frequency measurements. Standard grid spacing for head measurements in frequency ranges  $\leq 2$ GHz is 15 mm in x - and y- dimension. For higher frequencies a finer resolution is needed, thus for the grid spacing is reduced according the following table:

| Area scan grid spacing for different frequency ranges |              |
|-------------------------------------------------------|--------------|
| Frequency range                                       | Grid spacing |
| $\leq 2$ GHz                                          | $\leq 15$ mm |
| 2 – 4 GHz                                             | $\leq 12$ mm |
| 4 – 6 GHz                                             | $\leq 10$ mm |

Grid spacing and orientation have no influence on the SAR result. For special applications where the standard scan method does not find the peak SAR within the grid, e.g. mobile phones with flip cover, the grid can be adapted in orientation. Results of this coarse scan are shown in annex B.

- A „zoom scan” measures the field in a volume around the 2D peak SAR value acquired in the previous „coarse” scan. It uses a fine meshed grid where the robot moves the probe in steps along all the 3 axis (x,y and z-axis) starting at the bottom of the Phantom. The grid spacing for the cube measurement is varied according to the measured frequency range, the dimensions are given in the following table:

| <b>Zoom scan grid spacing and volume for different frequency ranges</b> |                            |                         |                          |
|-------------------------------------------------------------------------|----------------------------|-------------------------|--------------------------|
| Frequency range                                                         | Grid spacing for x, y axis | Grid spacing for z axis | Minimum zoom scan volume |
| $\leq 2$ GHz                                                            | $\leq 8$ mm                | $\leq 5$ mm             | $\geq 30$ mm             |
| 2 – 3 GHz                                                               | $\leq 5$ mm                | $\leq 5$ mm             | $\geq 28$ mm             |
| 3 – 4 GHz                                                               | $\leq 5$ mm                | $\leq 4$ mm             | $\geq 28$ mm             |
| 4 – 5 GHz                                                               | $\leq 4$ mm                | $\leq 3$ mm             | $\geq 25$ mm             |
| 5 – 6 GHz                                                               | $\leq 4$ mm                | $\leq 2$ mm             | $\geq 22$ mm             |

DASY is also able to perform repeated zoom scans if more than 1 peak is found during area scan. In this document, the evaluated peak 1g and 10g averaged SAR values are shown in the 2D-graphics in annex B. Test results relevant for the specified standard (see section 3) are shown in table form in section 7.

## Spatial Peak SAR Evaluation

The spatial peak SAR - value for 1 and 10 g is evaluated after the Cube measurements have been done. The basis of the evaluation are the SAR values measured at the points of the fine cube grid consisting of all points in the three directions x, y and z. The algorithm that finds the maximal averaged volume is separated into three different stages.

- The data between the dipole center of the probe and the surface of the phantom are extrapolated. This data cannot be measured since the center of the dipole is 1 to 2.7 mm away from the tip of the probe and the distance between the surface and the lowest measuring point is about 1 mm (see probe calibration sheet). The extrapolated data from a cube measurement can be visualized by selecting 'Graph Evaluated'.
- The maximum interpolated value is searched with a straight-forward algorithm. Around this maximum the SAR - values averaged over the spatial volumes (1g or 10 g) are computed using the 3d-spline interpolation algorithm. If the volume cannot be evaluated (i.e., if a part of the grid was cut off by the boundary of the measurement area) the evaluation will be started on the corners of the bottom plane of the cube.
- All neighboring volumes are evaluated until no neighboring volume with a higher average value is found.

## Extrapolation

The extrapolation is based on a least square algorithm [W. Gander, Computermathematik, p.168-180]. Through the points in the first 3 cm along the z-axis, polynomials of order four are calculated. These polynomials are then used to evaluate the points between the surface and the probe tip. The points, calculated from the surface, have a distance of 1 mm from each other.

## Interpolation

The interpolation of the points is done with a 3d-Spline. The 3d-Spline is composed of three one-dimensional splines with the "Not a knot"-condition [W. Gander, Computermathematik, p.141-150] (x, y and z -direction) [Numerical Recipes in C, Second Edition, p.123ff].

## Volume Averaging

At First the size of the cube is calculated. Then the volume is integrated with the trapezoidal algorithm. 8000 points (20x20x20) are interpolated to calculate the average.

## Advanced Extrapolation

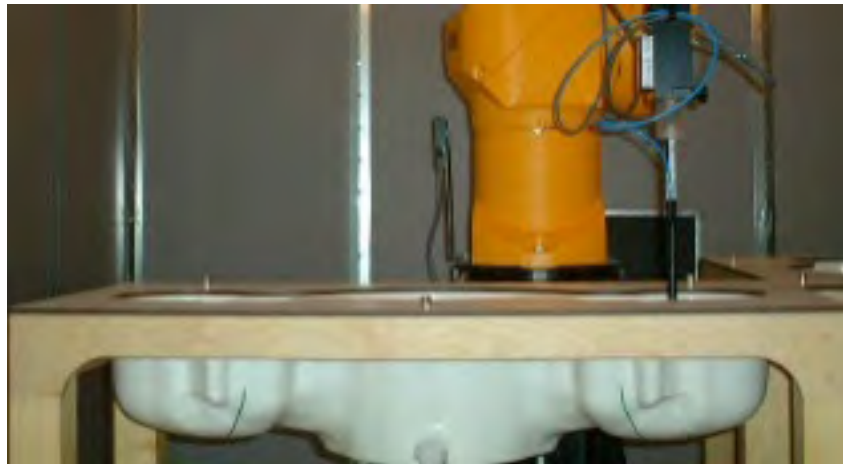
DASY uses the advanced extrapolation option which is able to compensate boundary effects on E-field probes.

**SAM PHANTOM**

The SAM Twin Phantom V4.0 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. 2.6)

**Phantom Specification**

**Phantom:** SAM Twin Phantom (V4.0)  
**Shell Material:** Vivac Composite  
**Thickness:**  $2.0 \pm 0.2$  mm



**Figure 2.6 SAM Twin Phantom**

**Device Holder for Transmitters**

In combination with the SAM Twin Phantom V4.0 the Mounting Device (see Fig. 2.7), enables the rotation of the mounted transmitter in spherical coordinates whereby the rotation point is the ear opening. The devices can be easily, accurately, and repeatedly positioned according to the FCC, CENELEC, IEC and IEEE specifications. The device holder can be locked at different phantom locations (left head, right head, flat phantom).



**Figure 2.7 Mounting Device**

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.

### **3. Probe and Dipole Calibration**

**See Appendix D and E.**

## 4. Phantom & Simulating Tissue Specifications

### Head & Body Simulating Mixture Characterization

The head and body mixtures consist of the material based on the table listed below. The mixture is calibrated to obtain proper dielectric constant (permittivity) and conductivity of the desired tissue. Body tissue parameters that have not been specified in IEEE1528-2013 are derived from the issue dielectric parameters computed from the 4-Cole-Cole equations.

**Table 4.1 Typical Composition of Ingredients for Tissue**

| Ingredients         |        | Simulating Tissue                          |               |
|---------------------|--------|--------------------------------------------|---------------|
|                     |        | 2450 MHz Head                              | 5250 MHz Head |
| Mixing Percentage   |        |                                            |               |
| Water               |        | Proprietary Mixture<br>Procured from Speag |               |
| Sugar               |        |                                            |               |
| Salt                |        |                                            |               |
| HEC                 |        |                                            |               |
| Bactericide         |        |                                            |               |
| DGBE                |        |                                            |               |
| Dielectric Constant | Target | 39.20                                      | 35.93         |
| Conductivity (S/m)  | Target | 1.80                                       | 4.71          |

## 5. ANSI/IEEE C95.1 – 1992 RF Exposure Limits [2]

### Uncontrolled Environment

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure. The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity.

### Controlled Environment

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation). In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. This exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

**Table 5.1 Human Exposure Limits**

|                                                              | UNCONTROLLED ENVIRONMENT<br>General Population<br>(W/kg) or (mW/g) | CONTROLLED ENVIROMENT<br>Professional Population<br>(W/kg) or (mW/g) |
|--------------------------------------------------------------|--------------------------------------------------------------------|----------------------------------------------------------------------|
| SPATIAL PEAK SAR <sup>1</sup><br>Head                        | 1.60                                                               | 8.00                                                                 |
| SPATIAL AVERAGE SAR <sup>2</sup><br>Whole Body               | 0.08                                                               | 0.40                                                                 |
| SPATIAL PEAK SAR <sup>3</sup><br>Hands, Feet, Ankles, Wrists | 4.00                                                               | 20.00                                                                |

<sup>1</sup> The Spatial Peak value of the SAR averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

<sup>2</sup> The Spatial Average value of the SAR averaged over the whole body.

<sup>3</sup> The Spatial Peak value of the SAR averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

## 6. Measurement Uncertainty

Measurement uncertainty table is not required per KDB 865664 D01 v01 section 2.8.2 page 12. SAR measurement uncertainty analysis is required in the SAR report only when the highest measured SAR in a frequency band is  $\geq 1.5$  W/kg for 1-g SAR. The equivalent ratio (1.5/1.6) should be applied to extremity and occupational exposure conditions. The highest reported value is less than 1.5 W/kg. Therefore, the measurement uncertainty table is not required.

## 7. System Validation

### Tissue Verification

**Table 7.1 Measured Tissue Parameters**

|                                 |      | 2450 MHz Head |          | 5250 MHz Head |          |
|---------------------------------|------|---------------|----------|---------------|----------|
| Date(s)                         |      | Jun. 17, 2022 |          | Jun 17, 2022  |          |
| Liquid Temperature (°C)         | 20.0 | Target        | Measured | Target        | Measured |
| Dielectric Constant: $\epsilon$ |      | 39.20         | 38.57    | 35.93         | 34.94    |
| Conductivity: $\sigma$          |      | 1.80          | 1.82     | 4.71          | 4.75     |

See Appendix A for data printout.

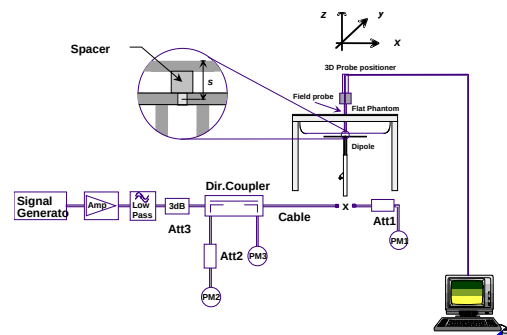
### Test System Verification

Prior to assessment, the system is verified to the  $\pm 10\%$  of the specifications at the test frequency by using the system kit. Power is normalized to 1 watt. (Graphic Plots Attached)

**Table 7.2 System Dipole Validation Target & Measured**

|             | Test Frequency | Targeted SAR <sub>1g</sub> (W/kg) | Measure SAR <sub>1g</sub> (W/kg) | Tissue Used for Verification | Deviation Target and Fast SAR to SAR (%) | Plot Number |
|-------------|----------------|-----------------------------------|----------------------------------|------------------------------|------------------------------------------|-------------|
| 17-Jun-2022 | 2450 MHz       | 54.10                             | 55.30                            | Head                         | + 2.22                                   | 1           |
| 17-Jun-2022 | 5250 MHz       | 79.50                             | 81.90                            | Head                         | + 3.02                                   | 2           |

See Appendix A for data plots.



**Figure 7.1 Dipole Validation Test Setup**

## 8. SAR Test Data Summary

### See Measurement Result Data Pages

See Appendix B for SAR Test Data Plots.  
See Appendix C for SAR Test Setup Photos.

### Procedures Used To Establish Test Signal

The device was either placed into simulated transmit mode using the manufacturer's test codes or the actual transmission is activated through a base station simulator or similar equipment. See data pages for actual procedure used in measurement.

### Device Test Condition

In order to verify that the device was tested at full power, conducted output power measurements were performed before and after each SAR measurement to confirm the output power unless otherwise noted. If a conducted power deviation of more than 5% occurred, the test was repeated. The power drift of each test is measured at the start of the test and again at the end of the test. The drift percentage is calculated by the formula  $((\text{end}/\text{start})-1)*100$  and rounded to three decimal places. The drift percentage is calculated into the resultant SAR value on the data sheet for each test.

The EUT was tested on the front of the device. All remaining sides were excluded due to the installation and use of the device. The device is either wall mounted or sitting on a counter. See the exclusions on pages 22-23. All measurements were conducted with the side of the device in direct contact with the phantom.

The WiFi transmit signal was set at an 85% duty cycle. The reported SAR value was first scaled to 100% duty cycle and then to the upper end of the tolerance for each WiFi transmitter test.

The data rates used when evaluating the WiFi transmitter were the lowest data rates with the highest power for each mode. The device was operating at its maximum output power at the lowest data rate for all measurements.

The antenna was on a minimum of 10 cm of Styrofoam during each test. The following is a picture of the antenna location.

## Power Measurements

| Band          | Mode    | Bandwidth (MHz) | Channel | Frequency (MHz) | Data Rate | Avg Power (dBm) | Tune-up Pwr (dBm) |
|---------------|---------|-----------------|---------|-----------------|-----------|-----------------|-------------------|
| 2450 MHz      | 802.11b | 20              | 1       | 2412            | 1 Mbps    | 18.11           | 19.00             |
|               |         |                 | 6       | 2437            |           | 17.95           | 19.00             |
|               |         |                 | 11      | 2462            |           | 17.80           | 19.00             |
|               | 802.11g | 20              | 1       | 2412            | 6 Mbps    | Not Required    | 20.00             |
|               |         |                 | 6       | 2437            |           |                 | 20.00             |
|               |         |                 | 11      | 2462            |           |                 | 20.00             |
|               | 802.11n | 20              | 1       | 2412            | MCS0      |                 | 20.00             |
|               |         |                 | 6       | 2437            |           |                 | 20.00             |
|               |         |                 | 11      | 2462            |           |                 | 20.00             |
|               | 802.11n | 40              | 3       | 2422            | MCS0      |                 | 19.00             |
|               |         |                 | 6       | 2437            |           |                 | 19.00             |
|               |         |                 | 9       | 2452            |           |                 | 19.00             |
| 5.15-5.25 GHz | 802.11a | 20              | 36      | 5180            | 6 Mbps    | 11.64           | 13.00             |
|               |         |                 | 40      | 5200            |           | 12.56           | 13.00             |
|               |         |                 | 44      | 5240            |           | 12.51           | 13.00             |
|               |         |                 | 48      | 5230            |           | 12.21           | 13.00             |
|               | 802.11n | 20              | 36      | 5180            | MCS0      | Not Required    | 12.00             |
|               |         |                 | 40      | 5200            |           |                 | 12.00             |
|               |         |                 | 44      | 5240            |           |                 | 12.00             |
|               |         |                 | 48      | 5230            |           |                 | 12.00             |
|               | 802.11n | 40              | 38      | 5190            | MCS0      |                 | 11.00             |
|               |         |                 | 46      | 5230            |           |                 | 11.00             |

**Figure 8.1 Test Reduction Table – 2.4 GHz**

| Mode    | Side                           | Required Channel | Tested/Reduced       |
|---------|--------------------------------|------------------|----------------------|
| 802.11b | Front                          | 1 – 2412 MHz     | Reduced <sup>2</sup> |
|         |                                | 6 – 2437 MHz     | Reduced <sup>2</sup> |
|         |                                | 11 – 2462 MHz    | Reduced <sup>2</sup> |
|         | Left, Right, Back, Top, Bottom | 1 – 2412 MHz     | Reduced <sup>3</sup> |
|         |                                | 6 – 2437 MHz     | Reduced <sup>3</sup> |
|         |                                | 11 – 2462 MHz    | Reduced <sup>3</sup> |
| 802.11g | Front                          | 1 – 2412 MHz     | Reduced <sup>2</sup> |
|         |                                | 6 – 2437 MHz     | Reduced <sup>2</sup> |
|         |                                | 11 – 2462 MHz    | Reduced <sup>2</sup> |
|         | Left, Right, Back, Top, Bottom | 1 – 2412 MHz     | Reduced <sup>3</sup> |
|         |                                | 6 – 2437 MHz     | Reduced <sup>3</sup> |
|         |                                | 11 – 2462 MHz    | Reduced <sup>3</sup> |
| 802.11n | Front                          | 1 – 2412 MHz     | Reduced <sup>2</sup> |
|         |                                | 6 – 2437 MHz     | Reduced <sup>2</sup> |
|         |                                | 11 – 2462 MHz    | Reduced <sup>2</sup> |
|         | Left, Right, Back, Top, Bottom | 1 – 2412 MHz     | Reduced <sup>3</sup> |
|         |                                | 6 – 2437 MHz     | Reduced <sup>3</sup> |
|         |                                | 11 – 2462 MHz    | Reduced <sup>3</sup> |

Reduced<sup>1</sup> – When the reported SAR is  $\leq 0.4$  W/kg, SAR is not required for the remaining test configuration per KDB 248227 D01 v02r02 section 5.1.1 1) page 9.

Reduced<sup>2</sup> – When the highest reported SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and the adjusted SAR is  $\leq 1.2$  W/kg, SAR is not required per KDB 248227 D01 v02r02 section 5.2.2 2) page 10.

Reduced<sup>3</sup> – These sides are not required based on the use case described on page 20.

**Figure 8.2 Test Reduction Table – 5.1 GHz**

| Mode                | Side                              | Required Channel | Tested/Reduced       |
|---------------------|-----------------------------------|------------------|----------------------|
| 802.11a<br>5150 MHz | Front                             | 36 – 5180 MHz    | Tested               |
|                     |                                   | 40 – 5200 MHz    | Reduced <sup>1</sup> |
|                     |                                   | 44 – 5220 MHz    | Tested               |
|                     |                                   | 48 – 5240 MHz    | Tested               |
|                     | Left, Right, Back,<br>Top, Bottom | 36 – 5180 MHz    | Reduced <sup>2</sup> |
|                     |                                   | 40 – 5200 MHz    | Reduced <sup>2</sup> |
|                     |                                   | 44 – 5220 MHz    | Reduced <sup>2</sup> |
|                     |                                   | 48 – 5240 MHz    | Reduced <sup>2</sup> |
| 802.11n<br>5150 MHz | Front                             | 36 – 5180 MHz    | Reduced <sup>1</sup> |
|                     |                                   | 40 – 5200 MHz    | Reduced <sup>1</sup> |
|                     |                                   | 44 – 5220 MHz    | Reduced <sup>1</sup> |
|                     |                                   | 48 – 5240 MHz    | Reduced <sup>1</sup> |
|                     | Left, Right, Back,<br>Top, Bottom | 36 – 5180 MHz    | Reduced <sup>2</sup> |
|                     |                                   | 40 – 5200 MHz    | Reduced <sup>2</sup> |
|                     |                                   | 44 – 5220 MHz    | Reduced <sup>2</sup> |
|                     |                                   | 48 – 5240 MHz    | Reduced <sup>2</sup> |

Reduced<sup>1</sup> – When the reported SAR is  $\leq 0.4$  W/kg, SAR is not required for the remaining test configuration per KDB 248227 D01 v02r02 section 5.1.1 1) page 9.

Reduced<sup>2</sup> – These sides are not required based on the use case described on page 20.

## SAR Data Summary – 2450 MHz Body 802.11b & BLE

### MEASUREMENT RESULTS

| Plot  | Gap  | Mode | Position | Frequency |     | Modulation | End Power | Measured SAR (W/kg) | Reported SAR (W/kg) |
|-------|------|------|----------|-----------|-----|------------|-----------|---------------------|---------------------|
|       |      |      |          | MHz       | Ch. |            | (dBm)     |                     |                     |
| ----- | 0 mm | WiFi | Front    | 2412      | 1   | DSSS       | 18.11     | 0.231               | 0.30                |
| 1     |      |      |          | 2437      | 6   | DSSS       | 17.95     | 0.239               | 0.33                |
| ----- |      |      |          | 2462      | 11  | DSSS       | 17.80     | 0.226               | 0.32                |
| ----- |      | BLE  | Front    | 2440      | 19  | GMSK       | 16.53     | 0.167               | 0.19                |

**Head Tissue**  
**1.6 W/kg (mW/g)**  
averaged over 1 gram

- Battery is fully charged for all tests.  
Power Measured ☒ Conducted ☐ ERP ☐ EIRP
- SAR Measurement  
Phantom Configuration ☐ Left Head ☒ Eli4 ☐ Right Head  
SAR Configuration ☐ Head ☒ Body
- Test Signal Call Mode ☒ Test Code ☐ Base Station Simulator
- Test Configuration ☐ With Belt Clip ☐ Without Belt Clip ☒ N/A
- Tissue Depth is at least 15.0 cm



Jay M. Moulton  
Vice President

## SAR Data Summary – 5250 MHz Body 802.11n

### MEASUREMENT RESULTS

| Plot  | Gap  | Mode | Position | Frequency |      | Modulation | End Power | Measured SAR (W/kg) | Reported SAR (W/kg) |
|-------|------|------|----------|-----------|------|------------|-----------|---------------------|---------------------|
|       |      |      |          | MHz       | Ch.  |            | (dBm)     |                     |                     |
| ----- | 0 mm | WiFi | Front    | 36        | 5180 | OFDM       | 11.64     | 0.101               | 0.15                |
| 2     |      |      | Front    | 44        | 5220 | OFDM       | 12.51     | 0.144               | 0.17                |
| ----- |      |      | Front    | 48        | 5240 | OFDM       | 12.21     | 0.116               | 0.15                |

**Head Tissue**  
**1.6 W/kg (mW/g)**  
 averaged over 1 gram

- Battery is fully charged for all tests.  
 Power Measured ☒ Conducted ☐ ERP ☐ EIRP
- SAR Measurement  
 Phantom Configuration ☐ Left Head ☒ Eli4 ☐ Right Head  
 SAR Configuration ☐ Head ☒ Body
- Test Signal Call Mode ☒ Test Code ☐ Base Station Simulator
- Test Configuration ☐ With Belt Clip ☐ Without Belt Clip ☒ N/A
- Tissue Depth is at least 15.0 cm



Jay M. Moulton  
 Vice President

## SAR Data Summary – Simultaneous Evaluation

| MEASUREMENT RESULTS – WiFi & BT |     |            |           |     |            |                                                               |                  |           |
|---------------------------------|-----|------------|-----------|-----|------------|---------------------------------------------------------------|------------------|-----------|
| Frequency                       |     | Modulation | Frequency |     | Modulation | SAR <sub>1</sub>                                              | SAR <sub>2</sub> | SAR Total |
| MHz                             | Ch. |            | MHz       | Ch. |            |                                                               |                  |           |
| 2437                            | 6   | DSSS       | 2440      | 19  | GFSK       | 0.33                                                          | 0.19             | 0.52      |
|                                 |     |            |           |     |            | <b>Body</b><br><b>1.6 W/kg (mW/g)</b><br>averaged over 1 gram |                  |           |

The sum of the two transmitters is less than the limit; therefore, the simultaneous transmission meets the requirements.

## 9. Test Equipment List

**Table 9.1 Equipment Specifications**

| Type                                          | Calibration Due Date | Calibration Done Date | Serial Number   |
|-----------------------------------------------|----------------------|-----------------------|-----------------|
| Staubli Robot TX60L                           | N/A                  | N/A                   | F07/55M6A1/A/01 |
| Measurement Controller CS8c                   | N/A                  | N/A                   | 1012            |
| ELI5 Flat Phantom                             | N/A                  | N/A                   | 2037            |
| Device Holder                                 | N/A                  | N/A                   | N/A             |
| Data Acquisition Electronics 4                | 04/12/2023           | 04/12/2022            | 1416            |
| SPEAG E-Field Probe EX3DV4                    | 02/16/2022           | 02/16/2022            | 3662            |
| Speag Validation Dipole D2450V2               | 06/03/2023           | 06/03/2021            | 881             |
| Speag Validation Dipole D5GHzV2               | 06/08/2023           | 06/08/2021            | 1119            |
| Agilent N1911A Power Meter                    | 03/16/2023           | 03/16/2022            | GB45100254      |
| Agilent N1922A Power Sensor                   | 03/17/2023           | 03/17/2022            | MY45240464      |
| Agilent (HP) 8561E Spectrum Analyzer          | 03/17/2023           | 03/17/2022            | 31720068        |
| Agilent (HP) 83752A Synthesized Sweeper       | 03/17/2023           | 03/17/2022            | 3610A01048      |
| Agilent (HP) 8753C Vector Network Analyzer    | 03/17/2023           | 03/17/2022            | 3135A01724      |
| Agilent (HP) 85047A S-Parameter Test Set      | 03/16/2023           | 03/16/2022            | 2904A00595      |
| Agilent 778D Dual Directional Coupler         | N/A                  | N/A                   | MY48220184      |
| MiniCircuits BW-N20W5+ Fixed 20 dB Attenuator | N/A                  | N/A                   | N/A             |
| MiniCircuits SPL-10.7+ Low Pass Filter        | N/A                  | N/A                   | R8979513746     |
| Apriel Dielectric Probe Assembly              | N/A                  | N/A                   | 0011            |
| Head Equivalent Matter (2450 MHz)             | N/A                  | N/A                   | N/A             |
| Head Equivalent Matter (5 GHz)                | N/A                  | N/A                   | N/A             |

## 10. Conclusion

The SAR measurement indicates that the EUT complies with the RF radiation exposure limits of the FCC/IC. These measurements are taken to simulate the RF effects exposure under worst-case conditions. Precise laboratory measures were taken to assure repeatability of the tests. The tested device complies with the requirements in respect to all parameters subject to the test. The test results and statements relate only to the item(s) tested.

Please note that the absorption and distribution of electromagnetic energy in the body is a very complex phenomena that depends on the mass, shape, and size of the body; the orientation of the body with respect to the field vectors; and, the electrical properties of both the body and the environment. Other variables that may play a substantial role in possible biological effects are those that characterize the environment (e.g. ambient temperature, air velocity, relative humidity, and body insulation) and those that characterize the individual (e.g. age, gender, activity level, debilitation, or disease). Because innumerable factors may interact to determine the specific biological outcome of an exposure to electromagnetic fields, any protection guide shall consider maximal amplification of biological effects as a result of field-body interactions, environmental conditions, and physiological variables.

## 11. References

- [1] Federal Communications Commission, ET Docket 93-62, Guidelines for Evaluating the Environmental Effects of Radio Frequency Radiation, August 1996
- [2] ANSI/IEEE C95.1 – 1992, American National Standard Safety Levels with respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300kHz to 100GHz, New York: IEEE, 1992.
- [3] ANSI/IEEE C95.3 – 2002, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields – RF and Microwave, New York: IEEE, 2002.
- [4] International Electrotechnical Commission, IEC 62209-2 (Edition 1.0), Human Exposure to radio frequency fields from hand-held and body mounted wireless communication devices – Human models, instrumentation, and procedures – Part 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.
- [5] IEEE Standard 1528 – 2013, IEEE Recommended Practice for Determining the Peak-Spatial Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communication Devices: Measurement Techniques, June 2013.
- [6] Industry Canada, RSS – 102 Issue 5, Radio Frequency Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands), March 2015.
- [7] Health Canada, Safety Code 6, Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3kHz to 300 GHz, 2009.

## Appendix A – System Validation Plots and Data

\*\*\*\*\*

Test Result for UIM Dielectric Parameter

Fri 17/Jun/2022

Freq Frequency(GHz)

FCC\_eH Limits for Head Epsilon

FCC\_sH Limits for Head Sigma

Test\_e Epsilon of UIM

Test\_s Sigma of UIM

\*\*\*\*\*

| Freq   | FCC_eH | FCC_sH | Test_e | Test_s |
|--------|--------|--------|--------|--------|
| 2.4000 | 39.27  | 1.75   | 38.69  | 1.76   |
| 2.4020 | 39.268 | 1.752  | 38.686 | 1.762* |
| 2.4100 | 39.26  | 1.76   | 38.67  | 1.77   |
| 2.4120 | 39.258 | 1.762  | 38.666 | 1.772* |
| 2.4200 | 39.25  | 1.77   | 38.65  | 1.78   |
| 2.4300 | 39.24  | 1.78   | 38.63  | 1.79   |
| 2.4370 | 39.226 | 1.787  | 38.623 | 1.804* |
| 2.4400 | 39.22  | 1.79   | 38.62  | 1.81   |
| 2.4420 | 39.216 | 1.792  | 38.61  | 1.812* |
| 2.4500 | 39.20  | 1.80   | 38.57  | 1.82   |
| 2.4600 | 39.19  | 1.81   | 38.57  | 1.83   |
| 2.4620 | 39.186 | 1.812  | 38.566 | 1.832* |
| 2.4700 | 39.17  | 1.82   | 38.55  | 1.84   |
| 2.4720 | 39.168 | 1.822  | 38.546 | 1.846* |
| 2.4800 | 39.16  | 1.83   | 38.53  | 1.87   |

\* value interpolated

\*\*\*\*\*

Test Result for UIM Dielectric Parameter

Fri 17/Jun/2022

Freq Frequency(GHz)

FCC\_eH Limits for Head Epsilon

FCC\_sH Limits for Head Sigma

Test\_e Epsilon of UIM

Test\_s Sigma of UIM

\*\*\*\*\*

| Freq   | FCC_eH | FCC_sH | Test_e | Test_s |
|--------|--------|--------|--------|--------|
| 5.1000 | 36.10  | 4.55   | 35.11  | 4.58   |
| 5.1200 | 36.08  | 4.57   | 35.09  | 4.60   |
| 5.1400 | 36.05  | 4.59   | 35.06  | 4.62   |
| 5.1600 | 36.03  | 4.61   | 35.04  | 4.65   |
| 5.1800 | 36.01  | 4.63   | 35.02  | 4.67   |
| 5.2000 | 35.99  | 4.65   | 34.99  | 4.69   |
| 5.2200 | 35.96  | 4.68   | 34.97  | 4.71   |
| 5.2400 | 35.94  | 4.70   | 34.95  | 4.73   |
| 5.2500 | 35.93  | 4.71   | 34.935 | 4.745* |
| 5.2600 | 35.92  | 4.72   | 34.92  | 4.76   |
| 5.2800 | 35.89  | 4.74   | 34.89  | 4.78   |

\* value interpolated

# RF Exposure Lab

## Plot 1

**DUT: Dipole 2450 MHz D2450V2; Type: D2450V2; Serial: D2450V2 - SN: 881**

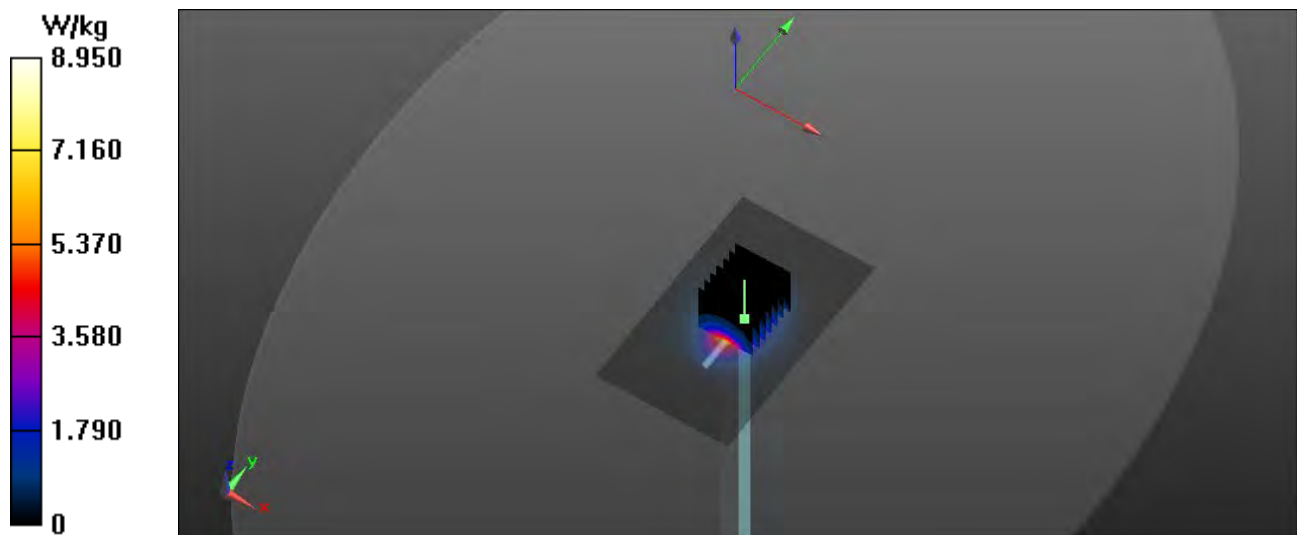
Communication System: CW; Frequency: 2450 MHz; Duty Cycle: 1:1  
Medium: HSL2450; Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.82$  S/m;  $\epsilon_r = 38.57$ ;  $\rho = 1000$  kg/m<sup>3</sup>  
Phantom section: Flat Section

Test Date: Date: 6/17/2022; Ambient Temp: 23 °C; Tissue Temp: 21 °C  
Probe: EX3DV4 – SN3662; ConvF(7.28, 7.28, 7.28); Calibrated: 2/16/2022;  
Sensor-Surface: 2mm (Mechanical Surface Detection)  
Electronics: DAE4 Sn1416; Calibrated: 4/12/2022  
Phantom: ELI v5.0; Type: QDOVA002AA; Serial: 2037  
Measurement SW: DASY52, Version 52.10 (0); SEMCAD X Version 14.6.10 (7417)

### Procedure Notes:

**Head Verification/2450 MHz/Area Scan (61x101x1):** Interpolated grid: dx=1.200 mm, dy=1.200 mm  
Maximum value of SAR (interpolated) = 8.42 W/kg

**Head Verification/2450 MHz/Zoom Scan (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm  
Reference Value = 52.487 V/m; Power Drift = -0.01 dB  
Peak SAR (extrapolated) = 10.95 W/kg  
 $P_{in} = 100$  mW  
**SAR(1 g) = 5.53 W/kg; SAR(10 g) = 2.52 W/kg**  
Maximum value of SAR (measured) = 8.94 W/kg



# RF Exposure Lab

## Plot 2

**DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1119**

Communication System: CW; Frequency: 5250 MHz; Duty Cycle: 1:1  
Medium: HSL 3-6 GHz; Medium parameters used (interpolated):  $f = 5250$  MHz;  $\sigma = 4.745$  S/m;  $\epsilon_r = 34.935$ ;  $\rho = 1000$  kg/m<sup>3</sup>  
Phantom section: Flat Section

Test Date: Date: 6/17/2022; Ambient Temp: 23 °C; Tissue Temp: 21 °C  
Probe: EX3DV4 – SN3662; ConvF(4.95, 4.95, 4.95); Calibrated 2/16/2022;  
Sensor-Surface: 2mm (Mechanical Surface Detection)  
Electronics: DAE4 Sn1416; Calibrated: 4/12/2022  
Phantom: ELI v5.0; Type: QDOVA002AA; Serial: 2037  
Measurement SW: DASY52, Version 52.10 (0); SEMCAD X Version 14.6.10 (7417)

### Procedure Notes:

**Head Verification/5250 MHz/Area Scan (61x81x1):** Interpolated grid: dx=1.000 mm, dy=1.000 mm

[Info: Interpolated medium parameters used for SAR evaluation.](#)

Maximum value of SAR (interpolated) = 1.51 W/kg

**Head Verification/5250 MHz/Zoom Scan (7x7x12)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=2mm

Reference Value = 14.357 V/m; Power Drift = -0.01 dB

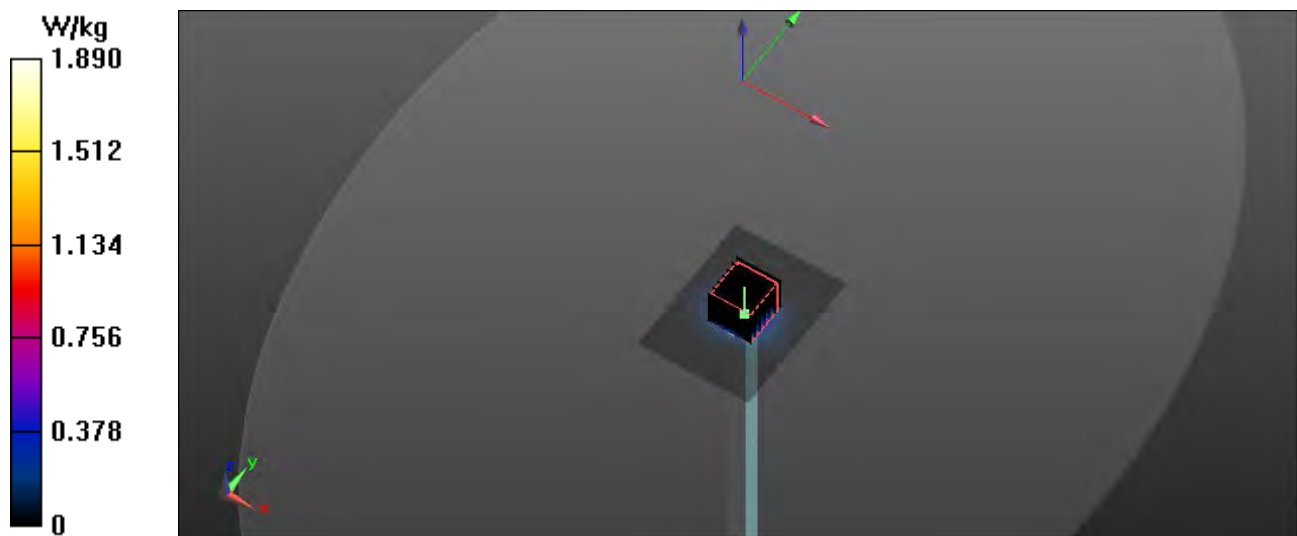
Peak SAR (extrapolated) = 3.41 W/kg

Pin=10 mW

**SAR(1 g) = 0.819 W/kg; SAR(10 g) = 0.234 W/kg**

[Info: Interpolated medium parameters used for SAR evaluation.](#)

Maximum value of SAR (measured) = 1.89 W/kg



## Appendix B – SAR Test Data Plots

# RF Exposure Lab

## Plot 1

**DUT: Lennox; Type: Thermostat; Serial: Eng 1**

Communication System: WiFi 802.11b (DSSS, 1 Mbps) 85% DC; Frequency: 2437 MHz; Duty Cycle: 1:1.1749  
Medium: HSL2450; Medium parameters used (interpolated):  $f = 2437$  MHz;  $\sigma = 1.804$  S/m;  $\epsilon_r = 38.623$ ;  $\rho = 1000$  kg/m<sup>3</sup>  
Phantom section: Flat Section

Test Date: Date: 6/17/2022; Ambient Temp: 23 °C; Tissue Temp: 21 °C

Probe: EX3DV4 - SN3662; ConvF(7.28, 7.28, 7.28); Calibrated: 2/16/2022  
Sensor-Surface: 2mm (Mechanical Surface Detection)  
Electronics: DAE4 Sn1416; Calibrated: 4/22/2021  
Phantom: ELI v5.0; Type: QDOVA002AA; Serial: 2037  
Measurement SW: DASY52, Version 52.10 (0); SEMCAD X Version 14.6.14 (7483)

### Procedure Notes:

**2450 MHz WiFi/Front Mid/Area Scan (15x11x1):** Measurement grid: dx=10mm, dy=10mm

[Info: Interpolated medium parameters used for SAR evaluation.](#)

Maximum value of SAR (measured) = 0.401 W/kg

**2450 MHz WiFi/Front Mid/Zoom Scan (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm

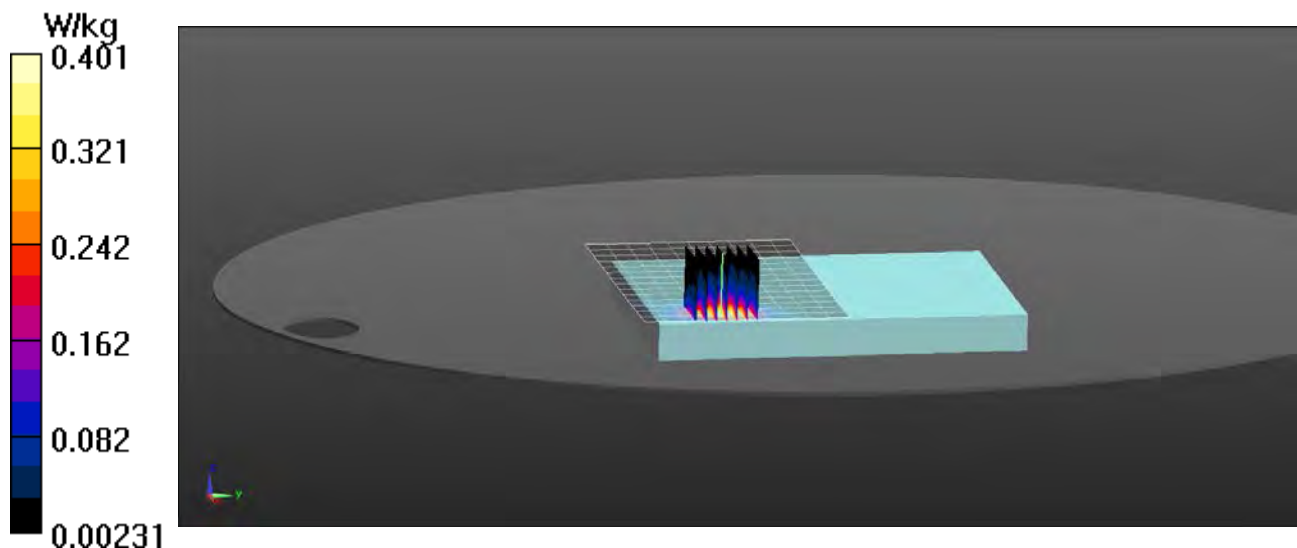
Reference Value = 3.222 V/m; Power Drift = -0.02 dB

Peak SAR (extrapolated) = 0.630 W/kg

**SAR(1 g) = 0.239 W/kg; SAR(10 g) = 0.102 W/kg**

[Info: Interpolated medium parameters used for SAR evaluation.](#)

Maximum value of SAR (measured) = 0.401 W/kg



# RF Exposure Lab

## Plot 2

**DUT: Lennox; Type: Thermostat; Serial: Eng 1**

Communication System: WiFi 802.11b (DSSS, 1 Mbps) 85% DC; Frequency: 5220 MHz; Duty Cycle: 1:1.1749  
Medium: HSL3-6GHz; Medium parameters used:  $f = 5220$  MHz;  $\sigma = 4.71$  S/m;  $\epsilon_r = 34.97$ ;  $\rho = 1000$  kg/m<sup>3</sup>  
Phantom section: Flat Section

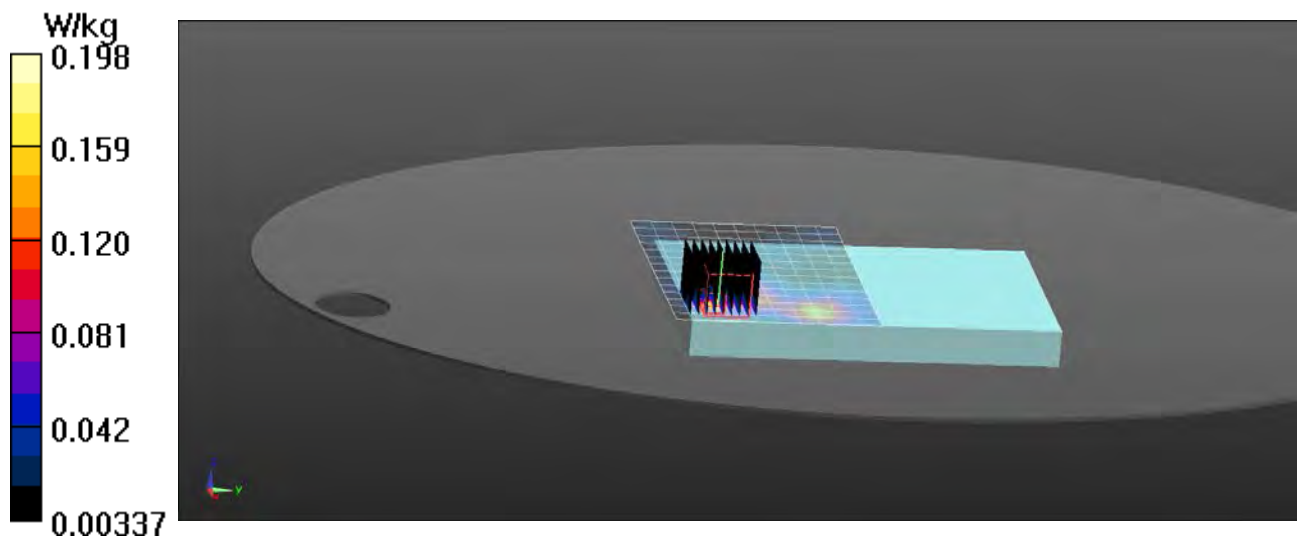
Test Date: Date: 6/17/2022; Ambient Temp: 23 °C; Tissue Temp: 21 °C

Probe: EX3DV4 - SN3662; ConvF(4.95, 4.95, 4.95); Calibrated: 2/16/2022  
Sensor-Surface: 2mm (Mechanical Surface Detection)  
Electronics: DAE4 Sn1416; Calibrated: 4/22/2021  
Phantom: ELI v5.0; Type: QDOVA002AA; Serial: 2037  
Measurement SW: DASY52, Version 52.10 (0); SEMCAD X Version 14.6.14 (7483)

### Procedure Notes:

**5200 MHz/Front 44/Area Scan (15x11x1):** Measurement grid: dx=10mm, dy=10mm  
Maximum value of SAR (measured) = 0.199 W/kg

**5200 MHz/Front 44/Zoom Scan (9x9x16)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=2mm  
Reference Value = 1.134 V/m; Power Drift = 0.03 dB  
Peak SAR (extrapolated) = 0.244 W/kg  
**SAR(1 g) = 0.144 W/kg; SAR(10 g) = 0.080 W/kg**  
Maximum value of SAR (measured) = 0.198 W/kg



## Appendix D – Probe Calibration Data Sheets



Accredited by the Swiss Accreditation Service (SAS)

Accreditation No.: **SCS 0108**

The Swiss Accreditation Service is one of the signatories to the EA  
Multilateral Agreement for the recognition of calibration certificates

Client **RF Exposure Lab**

Certificate No: **EX3-3662\_Feb22**

## CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3662**

Calibration procedure(s) **QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v6, QA CAL-23.v5,  
QA CAL-25.v7  
Calibration procedure for dosimetric E-field probes**

Calibration date: **February 16, 2022**

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       | 09-Apr-21 (No. 217-03291/03292)   | Apr-22                 |
| Power sensor NRP-Z91       | SN: 103244       | 09-Apr-21 (No. 217-03291)         | Apr-22                 |
| Power sensor NRP-Z91       | SN: 103245       | 09-Apr-21 (No. 217-03292)         | Apr-22                 |
| Reference 20 dB Attenuator | SN: CC2552 (20x) | 09-Apr-21 (No. 217-03343)         | Apr-22                 |
| DAE4                       | SN: 660          | 13-Oct-21 (No. DAE4-660_Oct21)    | Oct-22                 |
| Reference Probe ES3DV2     | SN: 3013         | 27-Dec-21 (No. ES3-3013_Dec21)    | Dec-22                 |
| Secondary Standards        | ID               | Check Date (in house)             | Scheduled Check        |
| Power meter E4419B         | SN: GB41293874   | 06-Apr-16 (in house check Jun-20) | In house check: Jun-22 |
| Power sensor E4412A        | SN: MY41498087   | 06-Apr-16 (in house check Jun-20) | In house check: Jun-22 |
| Power sensor E4412A        | SN: 000110210    | 06-Apr-16 (in house check Jun-20) | In house check: Jun-22 |
| RF generator HP 8648C      | SN: US3642U01700 | 04-Aug-99 (in house check Jun-20) | In house check: Jun-22 |
| Network Analyzer E8358A    | SN: US41080477   | 31-Mar-14 (in house check Oct-20) | In house check: Oct-22 |

|                |                               |                                          |               |
|----------------|-------------------------------|------------------------------------------|---------------|
| Calibrated by: | Name<br><b>Jeton Kastrati</b> | Function<br><b>Laboratory Technician</b> | Signature<br> |
| Approved by:   | Name<br><b>Sven Kuhn</b>      | Function<br><b>Deputy Manager</b>        | Signature<br> |

Issued: February 18, 2022

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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 $\varphi$   | $\varphi$ rotation around probe axis                                                                                                                    |
| Polarization $\vartheta$ | $\vartheta$ rotation around an axis that is in the plane normal to probe axis (at measurement center),<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:

- 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 (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).

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3662

## Basic Calibration Parameters

|                                                           | Sensor X | Sensor Y | Sensor Z | Unc (k=2)     |
|-----------------------------------------------------------|----------|----------|----------|---------------|
| Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup> | 0.42     | 0.49     | 0.48     | $\pm 10.1 \%$ |
| DCP (mV) <sup>B</sup>                                     | 99.8     | 99.6     | 98.2     |               |

## 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    | 147.3    | $\pm 2.7 \%$ | $\pm 4.7 \%$              |
|     |                           | Y | 0.0     | 0.0                          | 1.0 |         | 161.3    |              |                           |
|     |                           | Z | 0.0     | 0.0                          | 1.0 |         | 168.0    |              |                           |

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  $E^2$ -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.

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3662

### Other Probe Parameters

|                                               |            |
|-----------------------------------------------|------------|
| Sensor Arrangement                            | Triangular |
| 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                                    | 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.

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3662

### 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) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-----------|
| 150                  | 52.3                               | 0.76                            | 11.58   | 11.58   | 11.58   | 0.00               | 1.00                    | ± 13.3 %  |
| 220                  | 49.0                               | 0.81                            | 11.43   | 11.43   | 11.43   | 0.00               | 1.00                    | ± 13.3 %  |
| 300                  | 45.3                               | 0.87                            | 11.15   | 11.15   | 11.15   | 0.09               | 1.00                    | ± 13.3 %  |
| 450                  | 43.5                               | 0.87                            | 10.72   | 10.72   | 10.72   | 0.16               | 1.30                    | ± 13.3 %  |
| 750                  | 41.9                               | 0.89                            | 9.23    | 9.23    | 9.23    | 0.52               | 0.80                    | ± 12.0 %  |
| 900                  | 41.5                               | 0.97                            | 8.76    | 8.76    | 8.76    | 0.44               | 0.80                    | ± 12.0 %  |
| 1450                 | 40.5                               | 1.20                            | 8.18    | 8.18    | 8.18    | 0.37               | 0.80                    | ± 12.0 %  |
| 1640                 | 40.2                               | 1.31                            | 8.03    | 8.03    | 8.03    | 0.35               | 0.86                    | ± 12.0 %  |
| 1750                 | 40.1                               | 1.37                            | 7.87    | 7.87    | 7.87    | 0.32               | 0.86                    | ± 12.0 %  |
| 1900                 | 40.0                               | 1.40                            | 7.66    | 7.66    | 7.66    | 0.27               | 0.86                    | ± 12.0 %  |
| 2300                 | 39.5                               | 1.67                            | 7.54    | 7.54    | 7.54    | 0.34               | 0.90                    | ± 12.0 %  |
| 2450                 | 39.2                               | 1.80                            | 7.28    | 7.28    | 7.28    | 0.38               | 0.90                    | ± 12.0 %  |
| 2600                 | 39.0                               | 1.96                            | 7.10    | 7.10    | 7.10    | 0.38               | 0.90                    | ± 12.0 %  |
| 3500                 | 37.9                               | 2.91                            | 6.73    | 6.73    | 6.73    | 0.35               | 1.30                    | ± 13.1 %  |
| 3700                 | 37.7                               | 3.12                            | 6.53    | 6.53    | 6.53    | 0.35               | 1.30                    | ± 13.1 %  |
| 5250                 | 35.9                               | 4.71                            | 4.95    | 4.95    | 4.95    | 0.40               | 1.80                    | ± 13.1 %  |
| 5600                 | 35.5                               | 5.07                            | 4.66    | 4.66    | 4.66    | 0.40               | 1.80                    | ± 13.1 %  |
| 5750                 | 35.4                               | 5.22                            | 4.80    | 4.80    | 4.80    | 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.

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3662

### Calibration Parameter Determined in Head Tissue Simulating Media

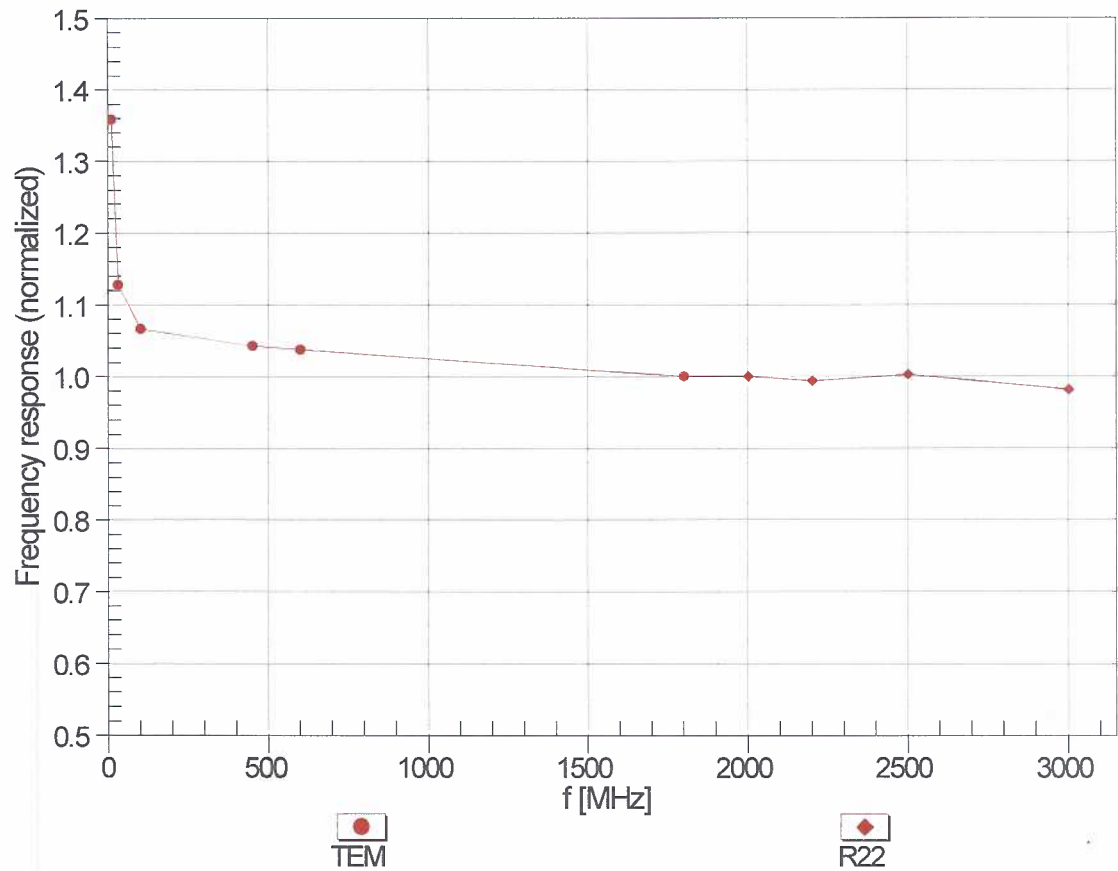
| f (MHz) <sup>C</sup> | Relative Permittivity <sup>F</sup> | Conductivity (S/m) <sup>F</sup> | ConvF X | ConvF Y | ConvF Z | Alpha <sup>G</sup> | Depth <sup>G</sup> (mm) | Unc (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-----------|
| 6500                 | 34.5                               | 6.07                            | 5.50    | 5.50    | 5.50    | 0.20               | 2.00                    | ± 18.6 %  |

<sup>C</sup> Frequency validity above 6GHz is ± 700 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

<sup>F</sup> At frequencies 6-10 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. 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; below ± 2% for frequencies between 3-6 GHz; and below ± 4% for frequencies between 6-10 GHz at any distance larger than half the probe tip diameter from the boundary.

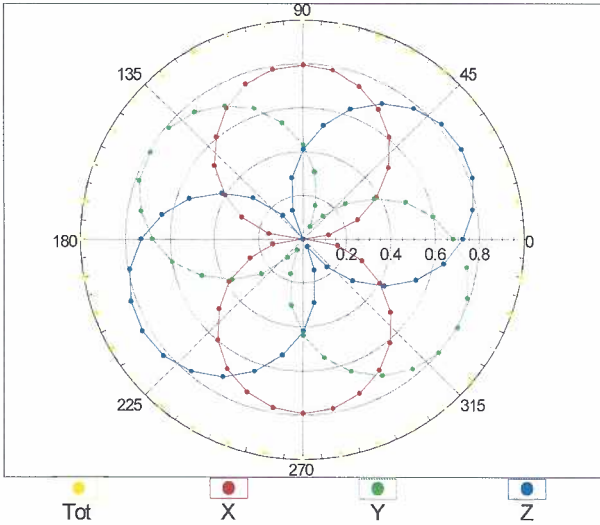
**Frequency Response of E-Field**  
(TEM-Cell:ifi110 EXX, Waveguide: R22)



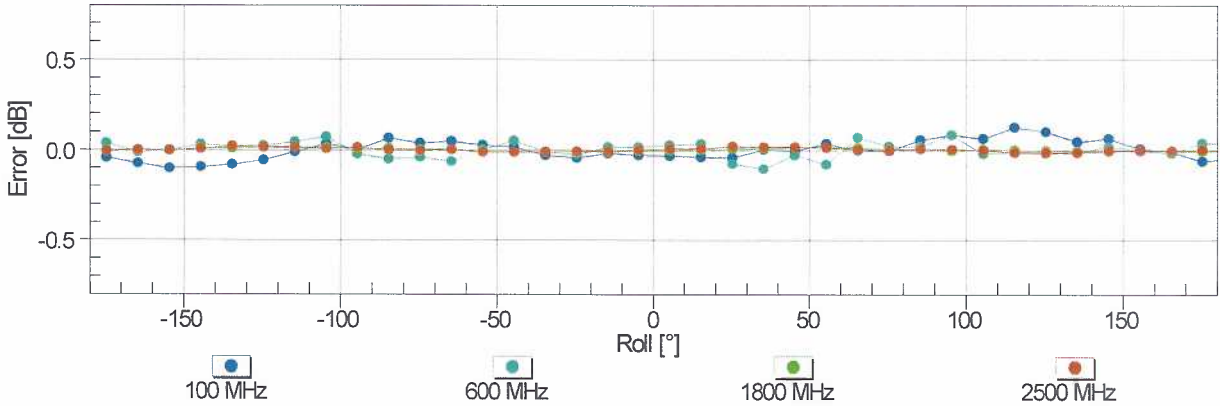
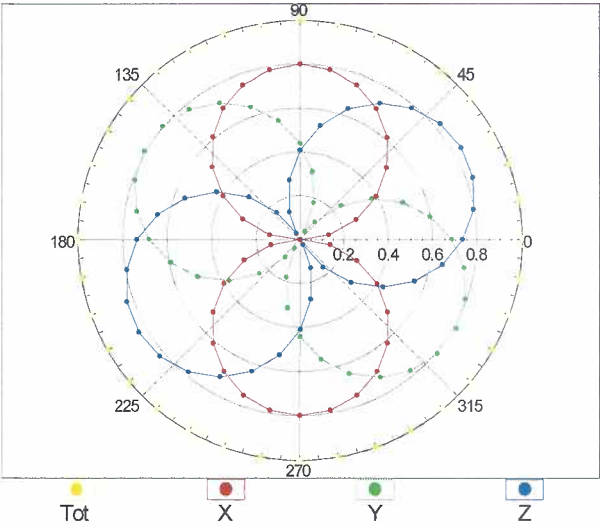
Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  ( $k=2$ )

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

f=600 MHz,TEM

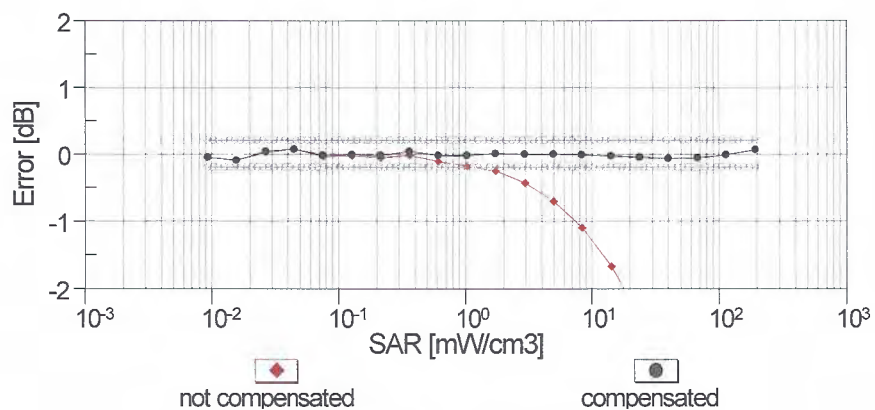
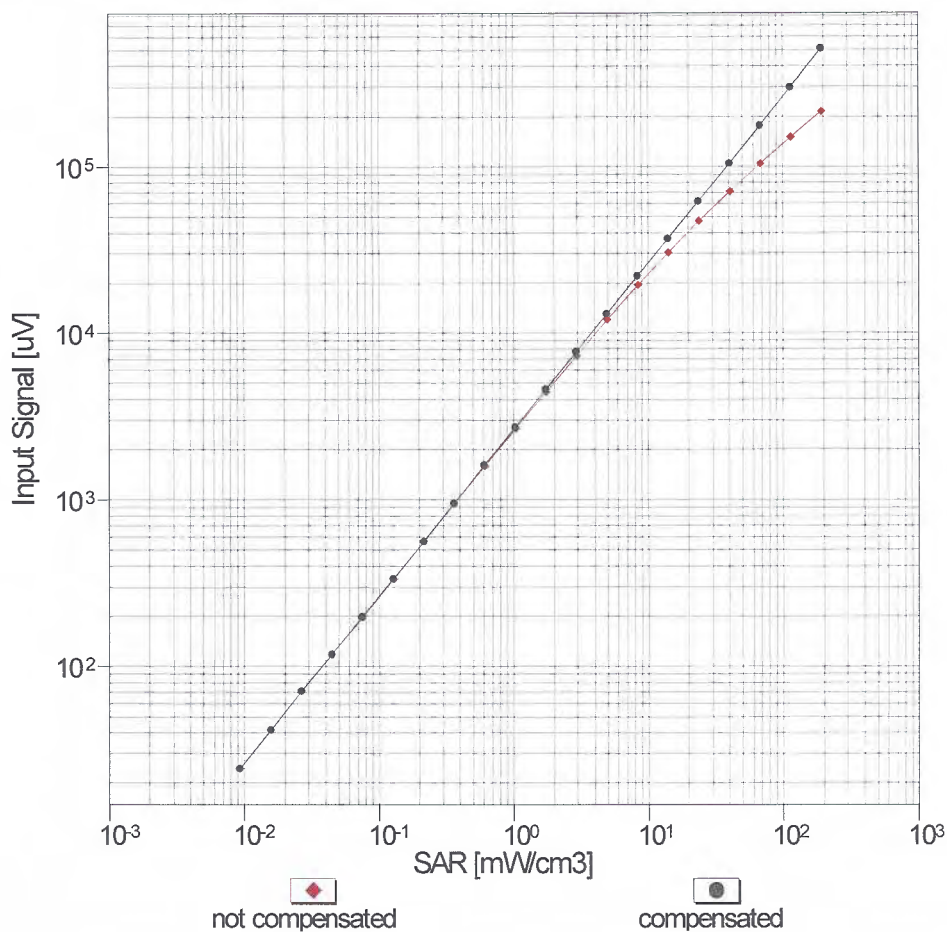


f=1800 MHz,R22



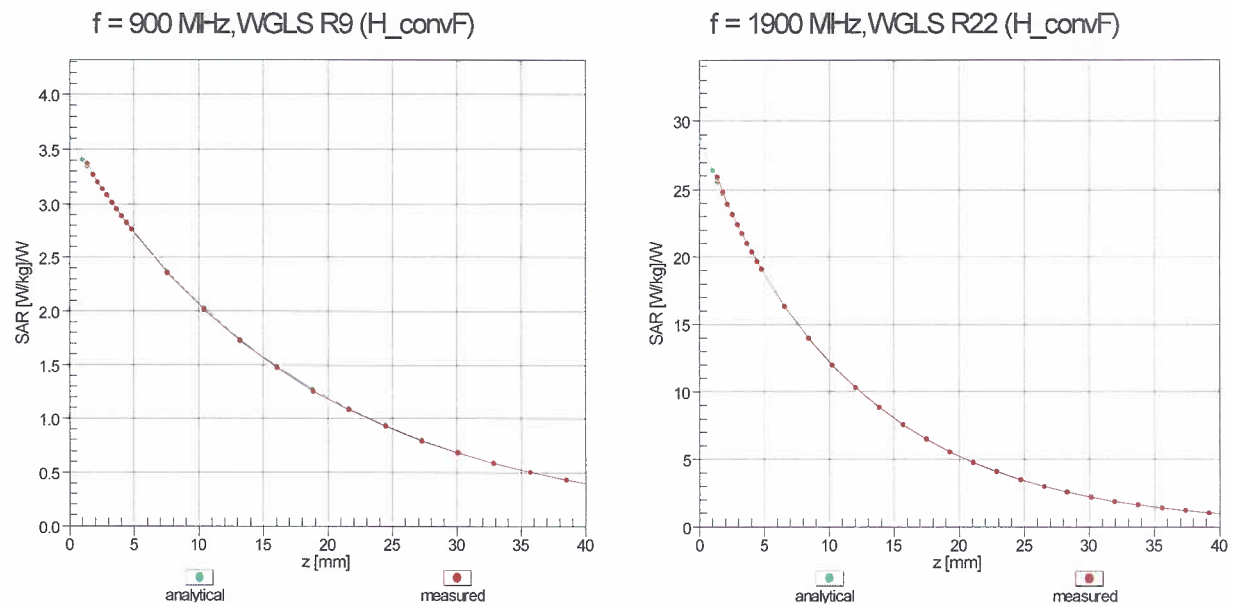
Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  (k=2)

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



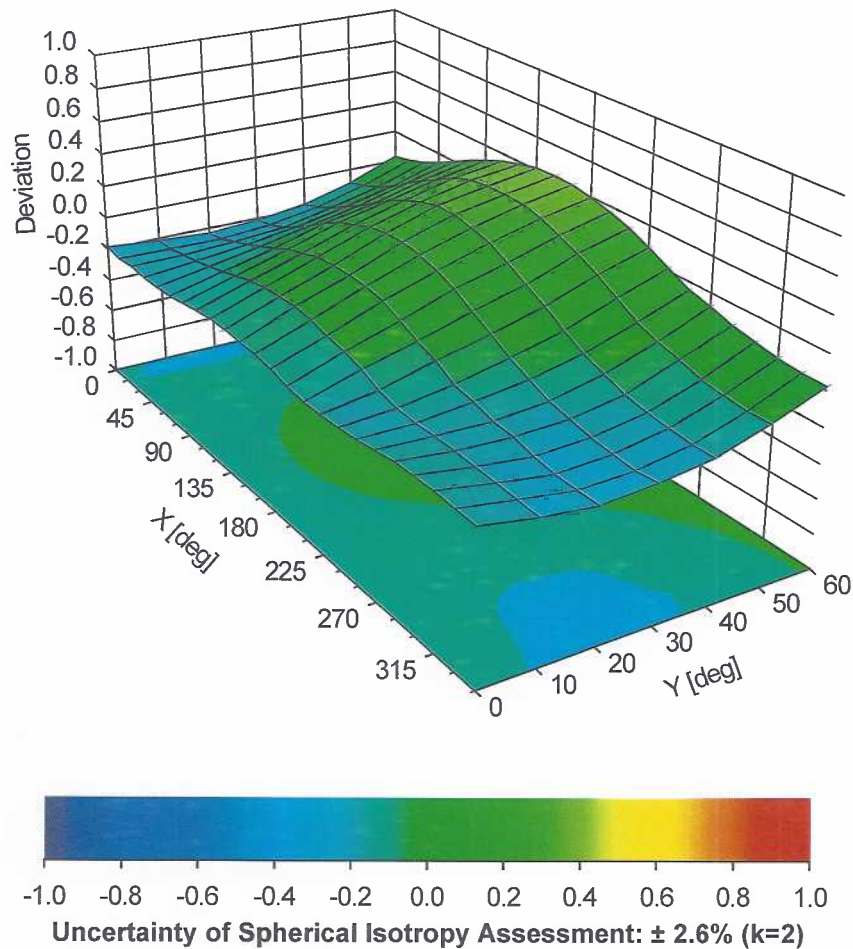
Uncertainty of Linearity Assessment:  $\pm 0.6\%$  ( $k=2$ )

## Conversion Factor Assessment



## Deviation from Isotropy in Liquid

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



## Appendix E – Dipole Calibration Data Sheets

*gm*

**Calibration Laboratory of**  
**Schmid & Partner**  
**Engineering AG**  
 Zeughausstrasse 43, 8004 Zurich, Switzerland



**S** Schweizerischer Kalibrierdienst  
**C** Service suisse d'étalonnage  
**S** Servizio svizzero di taratura  
**S** Swiss Calibration Service

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Client **RF Exposure Lab**

Certificate No: **D2450V2-881\_Jun21**

## CALIBRATION CERTIFICATE

Object **D2450V2 - SN:881**

Calibration procedure(s) **QA CAL-05 v11**  
**Calibration Procedure for SAR Validation Sources between 0.7-3 GHz**

Calibration date: **June 03, 2021**

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         | 09-Apr-21 (No. 217-03291/03292)   | Apr-22                 |
| Power sensor NRP-Z91            | SN: 103244         | 09-Apr-21 (No. 217-03291)         | Apr-22                 |
| Power sensor NRP-Z91            | SN: 103245         | 09-Apr-21 (No. 217-03292)         | Apr-22                 |
| Reference 20 dB Attenuator      | SN: BH9394 (20k)   | 09-Apr-21 (No. 217-03343)         | Apr-22                 |
| Type-N mismatch combination     | SN: 310982 / 06327 | 09-Apr-21 (No. 217-03344)         | Apr-22                 |
| Reference Probe EX3DV4          | SN: 7349           | 28-Dec-20 (No. EX3-7349_Dec20)    | Dec-21                 |
| DAE4                            | SN: 601            | 02-Nov-20 (No. DAE4-601_Nov20)    | Nov-21                 |
| Secondary Standards             | ID #               | Check Date (in house)             | Scheduled Check        |
| Power meter E4419B              | SN: GB39512475     | 30-Oct-14 (in house check Oct-20) | In house check: Oct-22 |
| Power sensor HP 8481A           | SN: US37292783     | 07-Oct-15 (in house check Oct-20) | In house check: Oct-22 |
| Power sensor HP 8481A           | SN: MY41092317     | 07-Oct-15 (in house check Oct-20) | In house check: Oct-22 |
| RF generator R&S SMT-06         | SN: 100972         | 15-Jun-15 (in house check Oct-20) | In house check: Oct-22 |
| Network Analyzer Agilent E8358A | SN: US41080477     | 31-Mar-14 (in house check Oct-20) | In house check: Oct-21 |

|                |                 |                       |           |
|----------------|-----------------|-----------------------|-----------|
|                | Name            | Function              | Signature |
| Calibrated by: | Jeffrey Katzman | Laboratory Technician |           |
| Approved by:   | Katja Pokovic   | Technical Manager     |           |

Issued: June 8, 2021

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### Glossary:

|       |                                 |
|-------|---------------------------------|
| TSL   | tissue simulating liquid        |
| ConvF | sensitivity in TSL / NORM x,y,z |
| N/A   | not applicable or not measured  |

### 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"

### Additional Documentation:

- DASY4/5 System Handbook

### Methods Applied and Interpretation of Parameters:

- Measurement Conditions:** Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- Antenna Parameters with TSL:** The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- Feed Point Impedance and Return Loss:** These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- Electrical Delay:** One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- SAR measured:** SAR measured at the stated antenna input power.
- SAR normalized:** SAR as measured, normalized to an input power of 1 W at the antenna connector.
- SAR for nominal TSL parameters:** The measured TSL parameters are used to calculate the nominal SAR result.

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%.

## Measurement Conditions

DASY system configuration, as far as not given on page 1.

|                                     |                        |             |
|-------------------------------------|------------------------|-------------|
| <b>DASY Version</b>                 | DASY5                  | V52.10.4    |
| <b>Extrapolation</b>                | Advanced Extrapolation |             |
| <b>Phantom</b>                      | Modular Flat Phantom   |             |
| <b>Distance Dipole Center - TSL</b> | 10 mm                  | with Spacer |
| <b>Zoom Scan Resolution</b>         | dx, dy, dz = 5 mm      |             |
| <b>Frequency</b>                    | 2450 MHz $\pm$ 1 MHz   |             |

## Head TSL parameters

The following parameters and calculations were applied.

|                                                | Temperature         | Permittivity   | Conductivity         |
|------------------------------------------------|---------------------|----------------|----------------------|
| <b>Nominal Head TSL parameters</b>             | 22.0 °C             | 39.2           | 1.80 mho/m           |
| <b>Measured Head TSL parameters</b>            | (22.0 $\pm$ 0.2) °C | 37.7 $\pm$ 6 % | 1.87 mho/m $\pm$ 6 % |
| <b>Head TSL temperature change during test</b> | < 0.5 °C            | ----           | ----                 |

## SAR result with Head TSL

|                                                             |                    |                                                |
|-------------------------------------------------------------|--------------------|------------------------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Head TSL</b> | Condition          |                                                |
| SAR measured                                                | 250 mW input power | 13.9 W/kg                                      |
| SAR for nominal Head TSL parameters                         | normalized to 1W   | <b>54.1 W/kg <math>\pm</math> 17.0 % (k=2)</b> |

|                                                               |                    |                                                |
|---------------------------------------------------------------|--------------------|------------------------------------------------|
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Head TSL</b> | condition          |                                                |
| SAR measured                                                  | 250 mW input power | 6.34 W/kg                                      |
| SAR for nominal Head TSL parameters                           | normalized to 1W   | <b>25.0 W/kg <math>\pm</math> 16.5 % (k=2)</b> |

## Appendix (Additional assessments outside the scope of SCS 0108)

### Antenna Parameters with Head TSL

|                                      |                                |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 54.3 $\Omega$ + 4.3 j $\Omega$ |
| Return Loss                          | - 24.7 dB                      |

### General Antenna Parameters and Design

|                                  |          |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.156 ns |
|----------------------------------|----------|

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.

No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

### Additional EUT Data

|                 |       |
|-----------------|-------|
| Manufactured by | SPEAG |
|-----------------|-------|

#### Extended Calibration

Usage of SAR dipoles calibrated less than 3 years ago but more than 1 year ago were confirmed in maintaining return loss (<-20 dB, within 20% of prior calibration) and impedance (within 5 ohm from prior calibration) requirements per extended calibrations in KDB Publication 865664 D01 v01r04.

| D2450V2 SN: 829 - Head |                  |            |                             |                |                                   |                |
|------------------------|------------------|------------|-----------------------------|----------------|-----------------------------------|----------------|
| Date of Measurement    | Return Loss (dB) | $\Delta\%$ | Impedance Real ( $\Omega$ ) | $\Delta\Omega$ | Impedance Imaginary (j $\Omega$ ) | $\Delta\Omega$ |
| 6/3/2021               | -24.7            |            | 54.3                        |                | 4.3                               |                |
| 6/3/2022               | -25.3            | 2.4        | 55.2                        | 0.9            | 4.1                               | -0.2           |
|                        |                  |            |                             |                |                                   |                |

## DASY5 Validation Report for Head TSL

Date: 03.06.2021

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN:881**

Communication System: UID 0 - CW; Frequency: 2450 MHz

Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.87$  S/m;  $\epsilon_r = 37.7$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.96, 7.96, 7.96) @ 2450 MHz; Calibrated: 28.12.2020
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 02.11.2020
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.4(1527); SEMCAD X 14.6.14(7483)

### Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 119.0 V/m; Power Drift = 0.05 dB

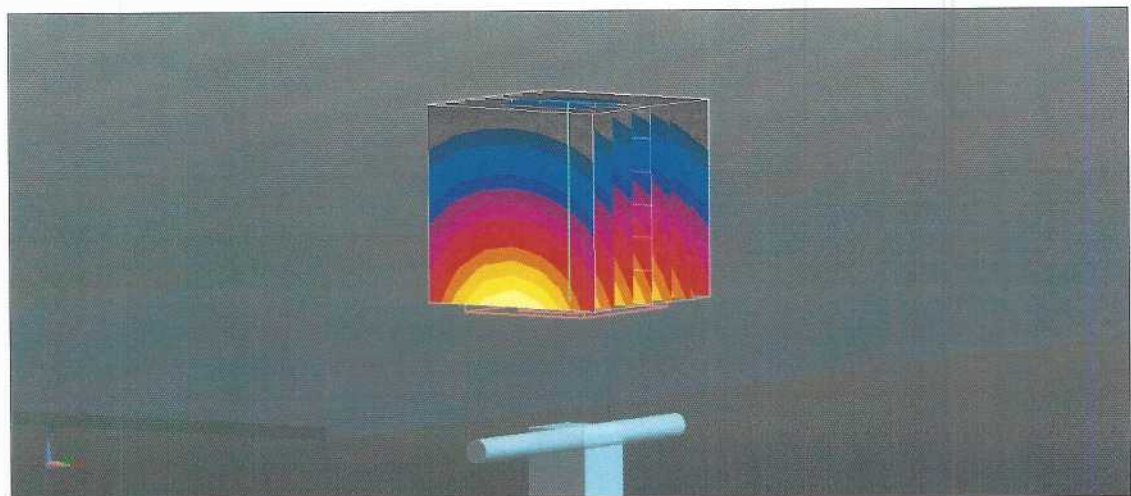
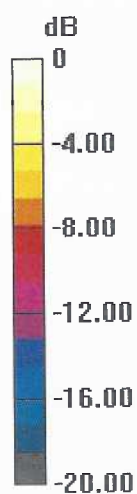
Peak SAR (extrapolated) = 28.0 W/kg

**SAR(1 g) = 13.9 W/kg; SAR(10 g) = 6.34 W/kg**

Smallest distance from peaks to all points 3 dB below = 9 mm

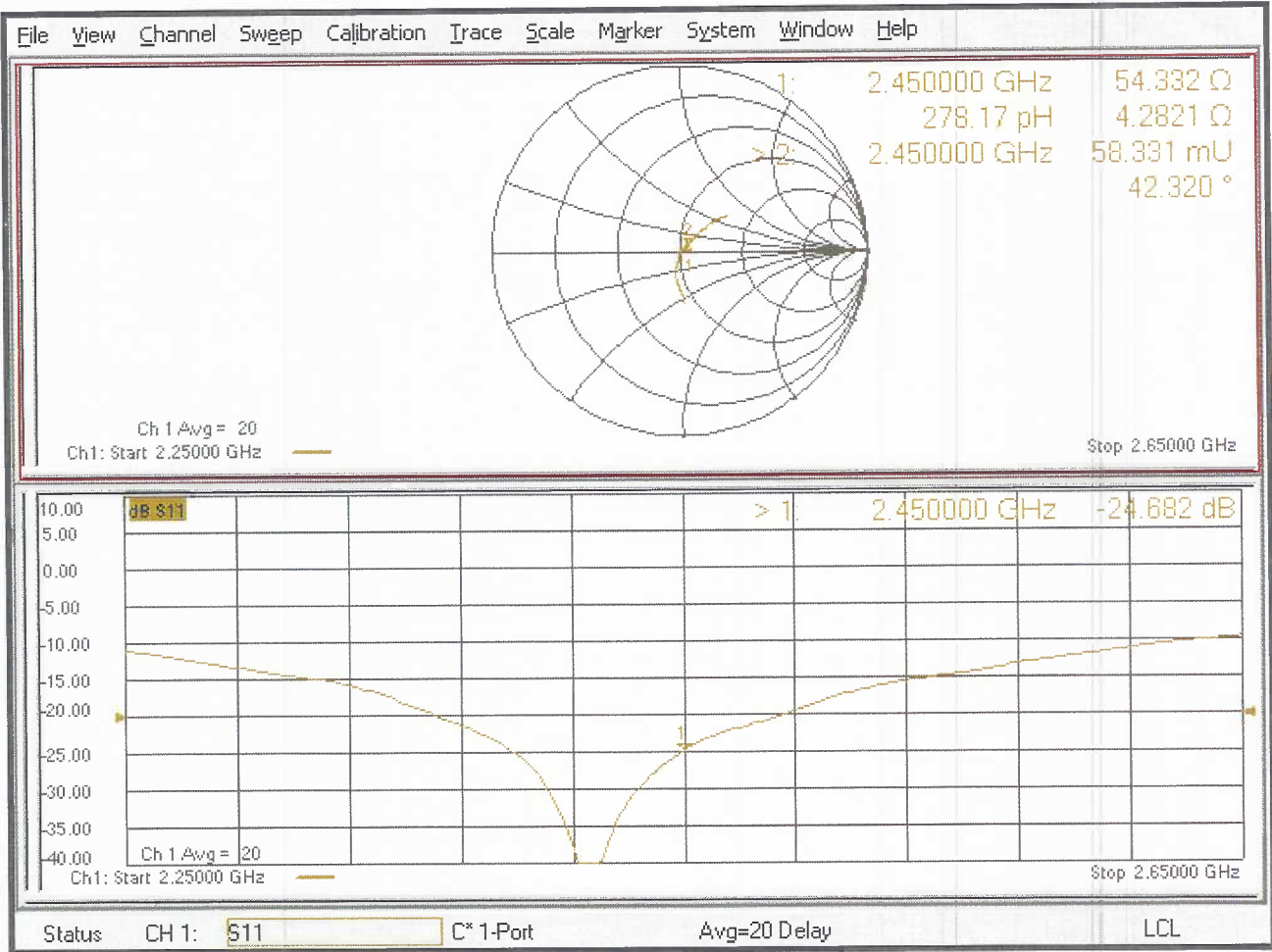
Ratio of SAR at M2 to SAR at M1 = 49.5%

Maximum value of SAR (measured) = 23.1 W/kg



0 dB = 23.1 W/kg = 13.64 dBW/kg

Impedance Measurement Plot for Head TSL





Accredited by the Swiss Accreditation Service (SAS)

Accreditation No.: **SCS 0108**

The Swiss Accreditation Service is one of the signatories to the EA  
 Multilateral Agreement for the recognition of calibration certificates

Client **RF Exposure Lab**

Certificate No: **D5GHzV2-1119\_Jun21**

## CALIBRATION CERTIFICATE

Object **D5GHzV2 - SN:1119**

Calibration procedure(s) **QA CAL-22.v6**  
**Calibration Procedure for SAR Validation Sources between 3-10 GHz**

Calibration date: **June 08, 2021**

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         | 09-Apr-21 (No. 217-03291/03292)   | Apr-22                 |
| Power sensor NRP-Z91            | SN: 103244         | 09-Apr-21 (No. 217-03291)         | Apr-22                 |
| Power sensor NRP-Z91            | SN: 103245         | 09-Apr-21 (No. 217-03292)         | Apr-22                 |
| Reference 20 dB Attenuator      | SN: BH9394 (20k)   | 09-Apr-21 (No. 217-03343)         | Apr-22                 |
| Type-N mismatch combination     | SN: 310982 / 06327 | 09-Apr-21 (No. 217-03344)         | Apr-22                 |
| Reference Probe EX3DV4          | SN: 3503           | 30-Dec-20 (No. EX3-3503_Dec20)    | Dec-21                 |
| DAE4                            | SN: 601            | 02-Nov-20 (No. DAE4-601_Nov20)    | Nov-21                 |
| Secondary Standards             | ID #               | Check Date (in house)             | Scheduled Check        |
| Power meter E4419B              | SN: GB39512475     | 30-Oct-14 (in house check Oct-20) | In house check: Oct-22 |
| Power sensor HP 8481A           | SN: US37292783     | 07-Oct-15 (in house check Oct-20) | In house check: Oct-22 |
| Power sensor HP 8481A           | SN: MY41092317     | 07-Oct-15 (in house check Oct-20) | In house check: Oct-22 |
| RF generator R&S SMT-06         | SN: 100972         | 15-Jun-15 (in house check Oct-20) | In house check: Oct-22 |
| Network Analyzer Agilent E8358A | SN: US41080477     | 31-Mar-14 (in house check Oct-20) | In house check: Oct-21 |

Calibrated by: **Michael Weber** **Laboratory Technician**

Signature

Approved by: **Katja Pokovic** **Technical Manager**

Issued: June 8, 2021

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



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

### Glossary:

|       |                                 |
|-------|---------------------------------|
| TSL   | tissue simulating liquid        |
| ConvF | sensitivity in TSL / NORM x,y,z |
| N/A   | not applicable or not measured  |

### 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"

### Additional Documentation:

- DASY4/5 System Handbook

### Methods Applied and Interpretation of Parameters:

- Measurement Conditions:** Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- Antenna Parameters with TSL:** The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- Feed Point Impedance and Return Loss:** These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- Electrical Delay:** One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- SAR measured:** SAR measured at the stated antenna input power.
- SAR normalized:** SAR as measured, normalized to an input power of 1 W at the antenna connector.
- SAR for nominal TSL parameters:** The measured TSL parameters are used to calculate the nominal SAR result.

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%.

## Measurement Conditions

DASY system configuration, as far as not given on page 1.

|                                     |                                                                      |                                  |
|-------------------------------------|----------------------------------------------------------------------|----------------------------------|
| <b>DASY Version</b>                 | DASY5                                                                | V52.10.4                         |
| <b>Extrapolation</b>                | Advanced Extrapolation                                               |                                  |
| <b>Phantom</b>                      | Modular Flat Phantom V5.0                                            |                                  |
| <b>Distance Dipole Center - TSL</b> | 10 mm                                                                | with Spacer                      |
| <b>Zoom Scan Resolution</b>         | dx, dy = 4.0 mm, dz = 1.4 mm                                         | Graded Ratio = 1.4 (Z direction) |
| <b>Frequency</b>                    | 5250 MHz $\pm$ 1 MHz<br>5600 MHz $\pm$ 1 MHz<br>5750 MHz $\pm$ 1 MHz |                                  |

## Head TSL parameters at 5250 MHz

The following parameters and calculations were applied.

|                                                | Temperature         | Permittivity   | Conductivity         |
|------------------------------------------------|---------------------|----------------|----------------------|
| <b>Nominal Head TSL parameters</b>             | 22.0 °C             | 35.9           | 4.71 mho/m           |
| <b>Measured Head TSL parameters</b>            | (22.0 $\pm$ 0.2) °C | 34.6 $\pm$ 6 % | 4.59 mho/m $\pm$ 6 % |
| <b>Head TSL temperature change during test</b> | < 0.5 °C            | ---            | ---                  |

## SAR result with Head TSL at 5250 MHz

|                                                             |                    |                                                |
|-------------------------------------------------------------|--------------------|------------------------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Head TSL</b> | Condition          |                                                |
| SAR measured                                                | 100 mW input power | 8.02 W/kg                                      |
| SAR for nominal Head TSL parameters                         | normalized to 1W   | <b>79.5 W/kg <math>\pm</math> 19.9 % (k=2)</b> |

|                                                               |                    |                                                |
|---------------------------------------------------------------|--------------------|------------------------------------------------|
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Head TSL</b> | condition          |                                                |
| SAR measured                                                  | 100 mW input power | 2.32 W/kg                                      |
| SAR for nominal Head TSL parameters                           | normalized to 1W   | <b>22.9 W/kg <math>\pm</math> 19.5 % (k=2)</b> |

## Head TSL parameters at 5600 MHz

The following parameters and calculations were applied.

|                                                | Temperature         | Permittivity   | Conductivity         |
|------------------------------------------------|---------------------|----------------|----------------------|
| <b>Nominal Head TSL parameters</b>             | 22.0 °C             | 35.5           | 5.07 mho/m           |
| <b>Measured Head TSL parameters</b>            | (22.0 $\pm$ 0.2) °C | 34.1 $\pm$ 6 % | 4.95 mho/m $\pm$ 6 % |
| <b>Head TSL temperature change during test</b> | < 0.5 °C            | ---            | ---                  |

## SAR result with Head TSL at 5600 MHz

|                                                             |                    |                                                |
|-------------------------------------------------------------|--------------------|------------------------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Head TSL</b> | Condition          |                                                |
| SAR measured                                                | 100 mW input power | 8.40 W/kg                                      |
| SAR for nominal Head TSL parameters                         | normalized to 1W   | <b>83.2 W/kg <math>\pm</math> 19.9 % (k=2)</b> |

|                                                               |                    |                                                |
|---------------------------------------------------------------|--------------------|------------------------------------------------|
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Head TSL</b> | condition          |                                                |
| SAR measured                                                  | 100 mW input power | 2.41 W/kg                                      |
| SAR for nominal Head TSL parameters                           | normalized to 1W   | <b>23.8 W/kg <math>\pm</math> 19.5 % (k=2)</b> |

## Head TSL parameters at 5750 MHz

The following parameters and calculations were applied.

|                                         | Temperature     | Permittivity | Conductivity     |
|-----------------------------------------|-----------------|--------------|------------------|
| Nominal Head TSL parameters             | 22.0 °C         | 35.4         | 5.22 mho/m       |
| Measured Head TSL parameters            | (22.0 ± 0.2) °C | 33.9 ± 6 %   | 5.10 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C        | ----         | ----             |

## SAR result with Head TSL at 5750 MHz

|                                                             |                    |                                 |
|-------------------------------------------------------------|--------------------|---------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Head TSL</b> | Condition          |                                 |
| SAR measured                                                | 100 mW input power | 8.13 W/kg                       |
| SAR for nominal Head TSL parameters                         | normalized to 1W   | <b>80.5 W/kg ± 19.9 % (k=2)</b> |

|                                                               |                    |                                 |
|---------------------------------------------------------------|--------------------|---------------------------------|
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Head TSL</b> | condition          |                                 |
| SAR measured                                                  | 100 mW input power | 2.33 W/kg                       |
| SAR for nominal Head TSL parameters                           | normalized to 1W   | <b>23.0 W/kg ± 19.5 % (k=2)</b> |

## Appendix (Additional assessments outside the scope of SCS 0108)

### Antenna Parameters with Head TSL at 5250 MHz

|                                      |                                |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 51.9 $\Omega$ - 7.3 j $\Omega$ |
| Return Loss                          | - 22.6 dB                      |

### Antenna Parameters with Head TSL at 5600 MHz

|                                      |                                |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 56.8 $\Omega$ - 1.3 j $\Omega$ |
| Return Loss                          | - 23.8 dB                      |

### Antenna Parameters with Head TSL at 5750 MHz

|                                      |                                |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 56.9 $\Omega$ - 1.8 j $\Omega$ |
| Return Loss                          | - 23.5 dB                      |

### General Antenna Parameters and Design

|                                  |          |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.206 ns |
|----------------------------------|----------|

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.

No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

### Additional EUT Data

|                 |       |
|-----------------|-------|
| Manufactured by | SPEAG |
|-----------------|-------|

#### Extended Calibration

Usage of SAR dipoles calibrated less than 3 years ago but more than 1 year ago were confirmed in maintaining return loss (<-20 dB, within 20% of prior calibration) and impedance (within 5 ohm from prior calibration) requirements per extended calibrations in KDB Publication 865664 D01 v01r04.

| D5GHzV2 SN: 1085 - Head |           |                  |            |                             |                |                                   |                |
|-------------------------|-----------|------------------|------------|-----------------------------|----------------|-----------------------------------|----------------|
| Date of Measurement     | Frequency | Return Loss (dB) | $\Delta\%$ | Impedance Real ( $\Omega$ ) | $\Delta\Omega$ | Impedance Imaginary (j $\Omega$ ) | $\Delta\Omega$ |
| 6/8/2021                | 5250 MHz  | -22.6            |            | 51.9                        |                | -7.3                              |                |
| 6/5/2022                |           | -22.9            | 1.3        | 52.6                        | 0.7            | -7.7                              | -0.4           |
|                         |           |                  |            |                             |                |                                   |                |
| 6/8/2021                | 5600 MHz  | -23.8            |            | 56.8                        |                | -1.3                              |                |
| 6/5/2022                |           | -24.6            | 3.4        | 55.2                        | -1.6           | -1.6                              | -0.3           |
|                         |           |                  |            |                             |                |                                   |                |
| 6/8/2021                | 5750 MHz  | -23.5            |            | 56.9                        |                | -1.8                              |                |
| 6/5/2022                |           | -24.8            | 5.5        | 56.2                        | -0.7           | -2.5                              | -0.7           |
|                         |           |                  |            |                             |                |                                   |                |

## DASY5 Validation Report for Head TSL

Date: 08.06.2021

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN:1119**

Communication System: UID 0 - CW; Frequency: 5250 MHz, Frequency: 5600 MHz, Frequency: 5750 MHz

Medium parameters used:  $f = 5250$  MHz;  $\sigma = 4.59$  S/m;  $\epsilon_r = 34.6$ ;  $\rho = 1000$  kg/m<sup>3</sup>,

Medium parameters used:  $f = 5600$  MHz;  $\sigma = 4.95$  S/m;  $\epsilon_r = 34.1$ ;  $\rho = 1000$  kg/m<sup>3</sup>,

Medium parameters used:  $f = 5750$  MHz;  $\sigma = 5.1$  S/m;  $\epsilon_r = 33.9$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.5, 5.5, 5.5) @ 5250 MHz, ConvF(5.1, 5.1, 5.1) @ 5600 MHz, ConvF(5.08, 5.08, 5.08) @ 5750 MHz; Calibrated: 30.12.2020
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 02.11.2020
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.4(1527); SEMCAD X 14.6.14(7483)

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5250 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 76.83 V/m; Power Drift = 0.07 dB

Peak SAR (extrapolated) = 27.1 W/kg

**SAR(1 g) = 8.02 W/kg; SAR(10 g) = 2.32 W/kg**

Smallest distance from peaks to all points 3 dB below = 7.2 mm

Ratio of SAR at M2 to SAR at M1 = 70.7%

Maximum value of SAR (measured) = 17.7 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 76.09 V/m; Power Drift = 0.05 dB

Peak SAR (extrapolated) = 30.6 W/kg

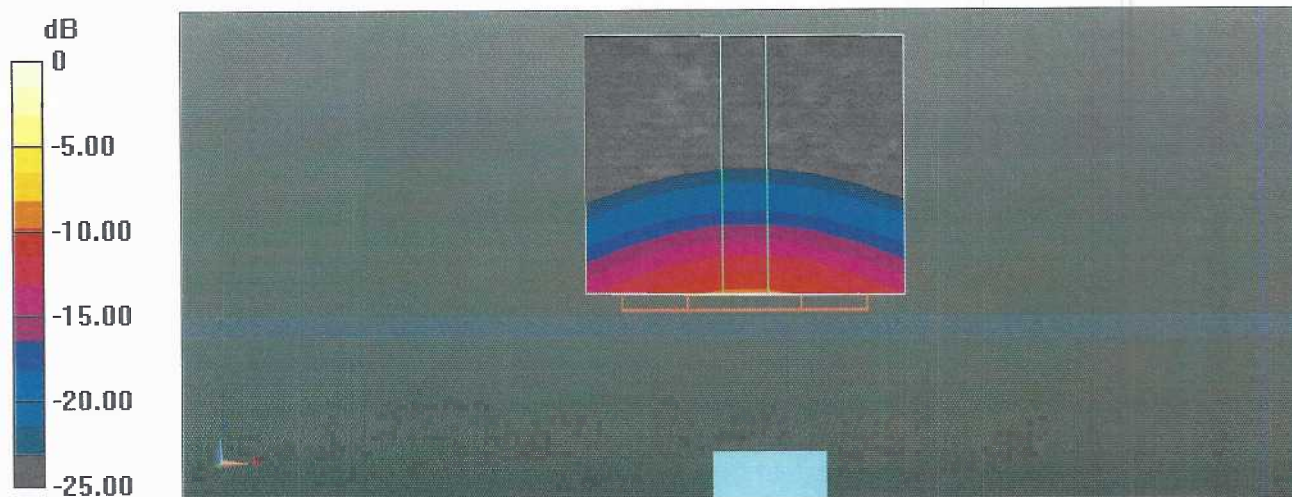
**SAR(1 g) = 8.4 W/kg; SAR(10 g) = 2.41 W/kg**

Smallest distance from peaks to all points 3 dB below = 7.5 mm

Ratio of SAR at M2 to SAR at M1 = 68.4%

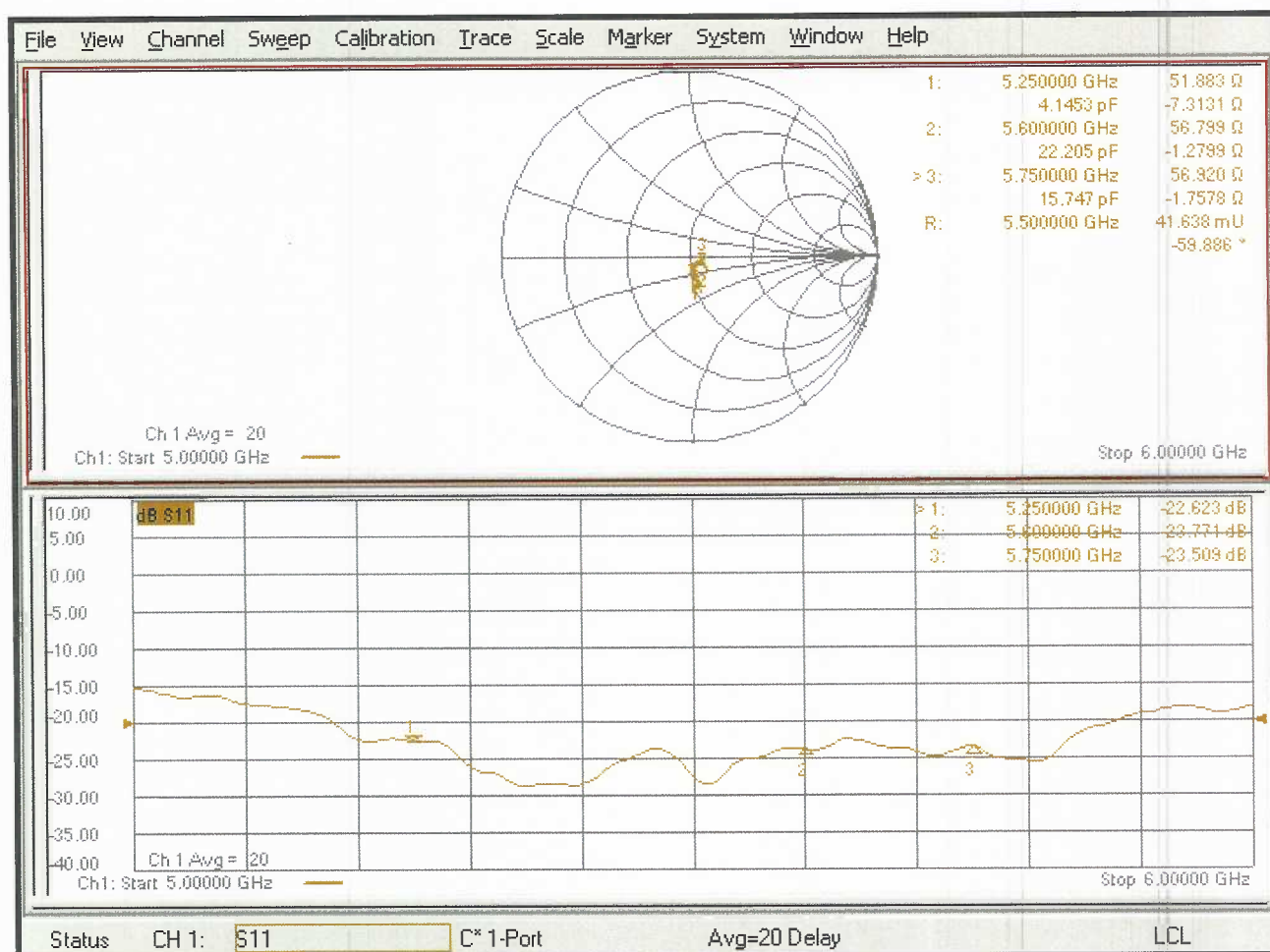
Maximum value of SAR (measured) = 19.1 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5750 MHz/Zoom Scan,  
dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 75.64 V/m; Power Drift = 0.02 dB  
Peak SAR (extrapolated) = 31.8 W/kg  
**SAR(1 g) = 8.13 W/kg; SAR(10 g) = 2.33 W/kg**  
Smallest distance from peaks to all points 3 dB below = 7.4 mm  
Ratio of SAR at M2 to SAR at M1 = 65.4%  
Maximum value of SAR (measured) = 19.3 W/kg



0 dB = 19.3 W/kg = 12.86 dBW/kg

## Impedance Measurement Plot for Head TSL



## Appendix F – DAE Calibration Data Sheets



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **RF Exposure Lab**

Certificate No: **DAE4-1416\_Apr22**

## CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 1416**

Calibration procedure(s) **QA CAL-06.v30**  
**Calibration procedure for the data acquisition electronics (DAE)**

Calibration date: **April 12, 2022**

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  |
|-------------------------------|--------------------|----------------------------|------------------------|
| Keithley Multimeter Type 2001 | SN: 0810278        | 31-Aug-21 (No:31368)       | Aug-22                 |
| Secondary Standards           | ID #               | Check Date (in house)      | Scheduled Check        |
| Auto DAE Calibration Unit     | SE UWS 053 AA 1001 | 24-Jan-22 (in house check) | In house check: Jan-23 |
| Calibrator Box V2.1           | SE UMS 006 AA 1002 | 24-Jan-22 (in house check) | In house check: Jan-23 |

Calibrated by: **Name**  
**Adrian Gehring** **Function**  
**Laboratory Technician**

Approved by: **Sven Kühn** **Deputy Manager**

Signature

Issued: April 12, 2022

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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

## 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 $\mu$ 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          | 403.562 $\pm$ 0.02% (k=2) | 403.870 $\pm$ 0.02% (k=2) | 404.137 $\pm$ 0.02% (k=2) |
| Low Range           | 3.97865 $\pm$ 1.50% (k=2) | 3.99513 $\pm$ 1.50% (k=2) | 3.97046 $\pm$ 1.50% (k=2) |

## Connector Angle

|                                           |                   |
|-------------------------------------------|-------------------|
| Connector Angle to be used in DASY system | 107.5 ° $\pm$ 1 ° |
|-------------------------------------------|-------------------|

## Appendix (Additional assessments outside the scope of SCS0108)

### 1. DC Voltage Linearity

| High Range        | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 199993.69                 | 0.39                         | 0.00      |
| Channel X + Input | 20001.91                  | 0.04                         | 0.00      |
| Channel X - Input | -20001.32                 | 0.29                         | -0.00     |
| Channel Y + Input | 199995.49                 | 2.37                         | 0.00      |
| Channel Y + Input | 20001.59                  | -0.18                        | -0.00     |
| Channel Y - Input | -20002.90                 | -1.28                        | 0.01      |
| Channel Z + Input | 199997.14                 | 3.84                         | 0.00      |
| Channel Z + Input | 20000.35                  | -1.29                        | -0.01     |
| Channel Z - Input | -20003.32                 | -1.40                        | 0.01      |

| Low Range         | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 2001.25                   | 0.20                         | 0.01      |
| Channel X + Input | 201.83                    | 0.41                         | 0.20      |
| Channel X - Input | -198.42                   | 0.20                         | -0.10     |
| Channel Y + Input | 2000.98                   | -0.02                        | -0.00     |
| Channel Y + Input | 200.80                    | -0.47                        | -0.23     |
| Channel Y - Input | -199.14                   | -0.51                        | 0.25      |
| Channel Z + Input | 2000.99                   | 0.08                         | 0.00      |
| Channel Z + Input | 200.25                    | -0.91                        | -0.45     |
| Channel Z - Input | -200.06                   | -1.29                        | 0.65      |

### 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 ( $\mu\text{V}$ ) | Low Range Average Reading ( $\mu\text{V}$ ) |
|-----------|--------------------------------|----------------------------------------------|---------------------------------------------|
| Channel X | 200                            | -3.28                                        | -4.95                                       |
|           | - 200                          | 6.21                                         | 4.15                                        |
| Channel Y | 200                            | -6.92                                        | -7.58                                       |
|           | - 200                          | 6.27                                         | 6.10                                        |
| Channel Z | 200                            | -23.61                                       | -23.40                                      |
|           | - 200                          | 21.76                                        | 21.65                                       |

### 3. Channel separation

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

|           | Input Voltage (mV) | Channel X ( $\mu\text{V}$ ) | Channel Y ( $\mu\text{V}$ ) | Channel Z ( $\mu\text{V}$ ) |
|-----------|--------------------|-----------------------------|-----------------------------|-----------------------------|
| Channel X | 200                | -                           | 2.55                        | -3.59                       |
| Channel Y | 200                | 7.33                        | -                           | 2.96                        |
| Channel Z | 200                | 8.86                        | 6.81                        | -                           |

#### 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 | 15996            | 17631           |
| Channel Y | 16152            | 16767           |
| Channel Z | 16134            | 15846           |

#### 5. Input Offset Measurement

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

Input 10M $\Omega$

|           | Average ( $\mu$ V) | min. Offset ( $\mu$ V) | max. Offset ( $\mu$ V) | Std. Deviation ( $\mu$ V) |
|-----------|--------------------|------------------------|------------------------|---------------------------|
| Channel X | 0.76               | -0.27                  | 1.42                   | 0.33                      |
| Channel Y | -0.76              | -2.04                  | 0.57                   | 0.45                      |
| Channel Z | -0.41              | -1.10                  | 0.34                   | 0.30                      |

#### 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                |

## **Appendix G – Phantom Calibration Data Sheets**

**Certificate of Conformity / First Article Inspection**

|              |                                                                           |
|--------------|---------------------------------------------------------------------------|
| Item         | Oval Flat Phantom ELI 4.0                                                 |
| Type No      | QD OVA 001 B                                                              |
| Series No    | 1003 and higher                                                           |
| Manufacturer | Untersee Composites<br>Knebelstrasse 8<br>CH-8268 Mannenbach, Switzerland |

**Tests**

Complete tests were made on the prototype units QD OVA 001 AA 1001, QD OVA 001 AB 1002, pre-series units QD OVA 001 BA 1003-1005 as well as on the series units QD OVA 001 BB, 1006 ff.

| Test                 | Requirement                                                                                                                                   | Details                                                                                                                                                                       | Units tested                         |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| Material thickness   | Compliant with the standard requirements                                                                                                      | Bottom plate:<br>2.0mm +/- 0.2mm                                                                                                                                              | all                                  |
| Material parameters  | Dielectric parameters for required frequencies                                                                                                | < 6 GHz: Rel. permittivity = 4<br>+/-1, Loss tangent ≤ 0.05                                                                                                                   | Material sample                      |
| Material resistivity | The material has been tested to be compatible with the liquids defined in the standards if handled and cleaned according to the instructions. | DGBE based simulating liquids.<br>Observe Technical Note for material compatibility.                                                                                          | Equivalent phantoms, Material sample |
| Shape                | Thickness of bottom material, Internal dimensions, Sagging compatible with standards from minimum frequency                                   | Bottom elliptical 600 x 400 mm<br>Depth 190 mm,<br>Shape is within tolerance for filling height up to 155 mm,<br>Eventual sagging is reduced or eliminated by support via DUT | Prototypes, Sample testing           |

**Standards**

- [1] CENELEC EN 50361-2001, « Basic standard for the measurement of the Specific Absorption Rate related to human exposure to electromagnetic fields from mobile phones (300 MHz – 3 GHz) », July 2001
- [2] IEEE 1528-2003, "Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques, December 2003
- [3] IEC 62209 – 1, "Specific Absorption Rate (SAR) in the frequency range of 300 MHz to 3 GHz – Measurement Procedure, Part 1: Hand-held mobile wireless communication devices", February 2005
- [4] IEC 62209 – 2, Draft, "Human Exposure to Radio Frequency Fields from Handheld and Body-Mounted Wireless Communication Devices – Human models, Instrumentation and Procedures – Part 2: Procedure to determine the Specific Absorption Rate (SAR) in the head and body for 30 MHz to 6 GHz Handheld and Body-Mounted Devices used in close proximity to the Body.", February 2005
- [5] OET Bulletin 65, Supplement C, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", Edition January 2001

Based on the tests above, we certify that this item is in compliance with the standards [1] to [5] if operated according to the specific requirements and considering the thickness. The dimensions are fully compliant with [4] from 30 MHz to 6 GHz. For the other standards, the minimum lower frequency limit is limited due to the dimensional requirements ([1]: 450 MHz, [2]: 300 MHz, [3]: 800 MHz, [5]: 375 MHz) and possibly further by the dimensions of the DUT.

**s p e a g**

Date 28.4.2008

Signature / Stamp

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