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# CERTIFICATE OF COMPLIANCE SAR EVALUATION

Garmin International, Inc.

Dates of Test:

November 7-8, 2022

1200 E. 151<sup>st</sup> Street

Test Report Number:

SAR.20221102

Revision B

Lab Designation Number: US1195(FCC) & US0194(ISED)

FCC ID: IPH-A4624
IC Certificate: 1792A-A4624
Model(s): AA4624

Test Sample: Engineering Unit Same as Production

Serial Number: Eng 1

Equipment Type: Wireless GPS Location Device Classification: Portable Transmitter Next to Body

TX Frequency Range: 1616 – 1626 MHz; 2412 – 2462 MHz, 2402 – 2480 MHz

Frequency Tolerance: ± 2.5 ppm

Maximum RF Output: 1620 MHz – 31.0 dBm; 2450 MHz (b) – 17.0 dBm, 2450 MHz (g) – 16.0 dBm,

2450 MHz (n20) - 15.0 dBm, 2450 MHz (BT) - 3.5 dBm, 2450 MHz (ANT) - 3.5 dBm

Conducted

Signal Modulation: FDMA-FM; DSSS, OFDM, GFSK

Antenna Type: Internal: WiFi/BT/ANT; External Stubby: Satellite

Application Type: Certification FCC Rule Parts: Part 2, 15C, 25

KDB Test Methodology: KDB 447498 D01 v06, KDB 248227 v02r02

Industry Canada: RSS-102 Issue 5, Safety Code 6

Maximum SAR Value: 1.51 W/kg Reported Simultaneous SAR Value: 0.04 Separation Ratio

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 62209-2:2010 (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



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Comment/Revision	Date
Original Release	November 16, 2022
Revision A – Correct model number, FCC ID, IC certificate and change file name	December 20, 2022
Revision B – Correct model number, FCC ID, IC certificate and change file name	December 21, 2022

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 Garmin International, Inc. Model AA4624 FCC ID: IPH-A4624 with FCC Part 2, 1093, ET Docket 93-62 Rules and IC Certificate: 1792A-A4624 with RSS102 Issue 5 & Safety Code 6 for mobile and portable devices. The FCC/ISED have adopted the guidelines for evaluating the environmental effects of radio frequency radiation to protect the public and workers from the potential hazards of RF emissions due to FCC/ISED regulated portable devices. [1], [6]

The test results recorded herein are based on a single type test of Garmin International, Inc. Model AA4624 and therefore apply only to the tested sample.

The test procedures and limits, as described in ANSI C95.1 – 1999 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 [5], 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 table indicates all the wireless technologies operating in the AA4624 Wireless GPS Location Device. The table also shows the tolerance for the power level for each mode.

Band	Modulation	Calibrated Nominal Power dBm	Tolerance dBm	Lower Tolerance dBm	Upper Tolerance dBm
1620 MHz	FDMA-FM	N/A	N/A	N/A	31.0
2450 MHz	802.11b	N/A	N/A	N/A	17.0
2450 MHz	802.11g	N/A	N/A	N/A	16.0
2450 MHz	802.11n20	N/A	N/A	N/A	15.0
2450 MHz	Ant+	N/A	N/A	N/A	3.5
2450 MHz	Bluetooth	N/A	N/A	N/A	3.5



# **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

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

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.

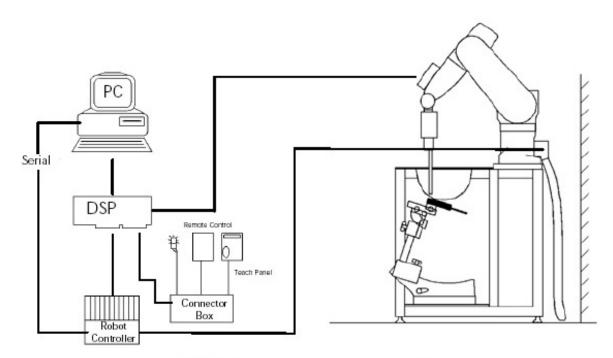


Figure 2.1 SAR Measurement System Setup



## **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:** ±0.2dB (30 MHz to 6 GHz)

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

Range: Linearity: ±0.2dB

**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

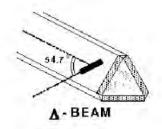


Figure 2.2 Triangular Probe Configurations



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

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

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

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;

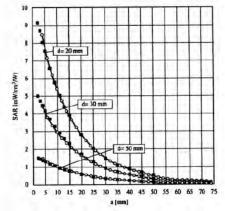


Figure 2.4 E-Field and Temperature Measurements at 900MHz

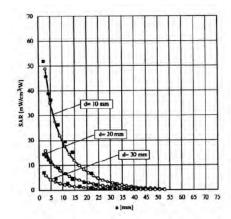


Figure 2.5 E-Field and Temperature Measurements at 1800MHz



#### **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;

with 
$$V_i$$
 = compensated signal of channel i (i=x,y,z)  
 $V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$  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: with 
$$V_i$$
 = compensated signal of channel i (i = x,y,z) Norm<sub>i</sub> = 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<sub>i</sub> = 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 = total field strength in V/m = conductivity in [mho/m] or [Siemens/m] p = 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.

$$P_{pue} = \frac{E_{tot}^2}{3770}$$
 with  $P_{pwe} = \text{equivalent power density of a plane wave in W/cm}^2$  = 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 ≥ 2GHz 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					
≤ 2 GHz	≤ 15 mm				
2 – 4 GHz	≤ 12 mm				
4 – 6 GHz	≤ 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:

Zoom scan grid spacing and volume for different frequency ranges						
Frequency range	Grid spacing	Grid spacing	Minimum zoom			
r requericy range	for x, y axis	for z axis	scan volume			
≤ 2 GHz	≤ 8 mm	≤ 5 mm	≥ 30 mm			
2 – 3 GHz	≤ 5 mm	≤ 5 mm	≥ 28 mm			
3 – 4 GHz	≤ 5 mm	≤ 4 mm	≥ 28 mm			
4 – 5 GHz	≤ 4 mm	≤ 3 mm	≥ 25 mm			
5 – 6 GHz	≤ 4 mm	≤ 2 mm	≥ 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 neighbouring volumes are evaluated until no neighbouring 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 Efield 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:  $2.0 \pm 0.2 \text{ mm}$ 



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 repeat ably be 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			
		1640 MHz Head	2450 MHz Head		
Mixing Percentage					
Water					
Sugar					
Salt		Proprietary Mixture	Proprietary Mixture		
HEC		Procured from Speag	Procured from Speag		
Bactericide					
DGBE			l		
Dielectric Constant	Target	40.20	39.20		
Conductivity (S/m)	Target	1.31	1.80		



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

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

<sup>&</sup>lt;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

## Exposure Assessment Measurement Uncertainty

DAPODUTE HODODOMENTE MEDICALITE ONCE CULTICY											
Re	Relative DASY5 Uncertainty Budget for SAR Tests  According to IEC62209-2/2010 (30 MHz - 6 GHz range)										
				z - 6 GH	Iz range						
Error Description	Uncertainty	Probability	Divisor	Ci	Ci		Jncertainty	v <sub>i</sub> <sup>2</sup> or			
21101 Description	Value	Distribution		(1g)	(10g)	± %, (1g)	± %, (10g)	V <sub>eff</sub>			
Measurement System											
Probe calibration	± 6.6%	Normal	1	1	1	± 6.6%	± 6.6%	∞			
Axial isotropy	± 4.7%	Rectangular	√3	0.7	0.7	± 1.9%	± 1.9%	∞			
Hemispherical isotropy	± 9.6%	Rectangular	√3	0.7	0.7	± 3.9%	± 3.9%	∞			
Boundary effects	± 2.0%	Rectangular	√3	1	1	± 1.2%	± 1.2%	∞			
Probe linearity	± 4.7%	Rectangular	٧3	1	1	± 2.7%	± 2.7%	∞			
System detection limits	± 1.0%	Rectangular	٧3	1	1	± 0.6%	± 0.6%	∞			
Modulation response	± 2.4%	Rectangular	٧3	1	1	± 1.4%	± 1.4%	∞			
Readout electronics	± 0.3%	Normal	1	1	1	± 0.3%	± 0.3%	∞			
Response time	± 0.8%	Rectangular	٧3	1	1	± 0.5%	± 0.5%	∞			
Integration time	± 2.6%	Rectangular	٧3	1	1	± 1.5%	± 1.5%	∞			
RF ambient noise	± 3.0%	Rectangular	٧3	1	1	± 1.7%	± 1.7%	∞			
RF ambient reflections	± 3.0%	Rectangular	٧3	1	1	± 1.7%	± 1.7%	8			
Probe positioner	± 0.8%	Rectangular	٧3	1	1	± 0.5%	± 0.5%	∞			
Probe positioning	± 6.7%	Rectangular	٧3	1	1	± 3.9%	± 3.9%	∞			
Post-processing	± 4.0%	Rectangular	٧3	1	1	± 2.3%	± 2.3%	∞			
Test Sample Related											
Device positioning	± 2.9%	Normal	1	1	1	± 2.9%	± 2.9%	145			
Device holder uncertainty	± 3.6%	Normal	1	1	1	± 3.6%	± 3.6%	5			
Power drift	± 5.0%	Rectangular	٧3	1	1	± 2.9%	± 2.9%	∞			
Phantom and Setup											
Phantom uncertainty	± 7.9%	Rectangular	٧3	1	1	± 4.6%	± 4.6%	∞			
SAR algorithm correction	± 1.9%	Normal	1	1	0.84	± 1.9%	± 1.9%	∞			
Liquid conductivity (meas.)	± 5.0%	Rectangular	٧3	0.78	0.71	± 0.1%	± 0.1%	∞			
Liquid permittivity (meas.)	± 5.0%	Rectangular	٧3	0.26	0.26	± 0.1%	± 0.1%	∞			
Temp. Unc. – Conductivity	± 3.4%	Rectangular	٧3	0.78	0.71	± 1.5%	± 1.5%	∞			
Temp. Unc. – Permittivity	± 0.4%	Rectangular	٧3	0.23	0.26	± 0.1%	± 0.1%	∞			
Combined Uncertainty						± 12.4%	± 12.3%	330			
Expanded Std. Uncertainty						± 24.8%	± 24.6%				

Worst case uncertainty budget for DASY5 assessed according to IEC62209-2/2010 standard. The budget is valid for the frequency range 30 MHz – 6 GHz and represents a worst-case analysis. For specific tests and configurations, the uncertainty could be considerable smaller.



# 7. System Verification

#### **Tissue Verification**

**Table 7.1 Measured Tissue Parameters** 

		1640 N	/IHz Head	2450 MHz Head				
Date(s)		Nov. 7, 2022		Nov. 7, 2022 No		Nov	. 7, 2022	
Liquid Temperature (°C)	20.0	Target	Measured	Target	Measured			
Dielectric Constant: ε		40.23	39.66	39.20	38.57			
Conductivity: σ		1.30	1.32	1.80	1.84			

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 Verification Target & Measured** 

	Test Frequency	Targeted SAR <sub>1g</sub> (W/kg)	Measure SAR <sub>1g</sub> (W/kg)	Tissue Used for Verification	Deviation (%)	Plot Number
07-Nov-2022	1640 MHz	34.40	34.60	Head	+ 0.58	1
07-Nov-2022	2450 MHz	54.10	52.70	Head	- 3.88	2

See Appendix A for data plots.

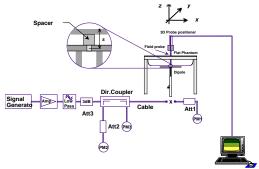


Figure 7.1 Dipole Verification Test Setup



# 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 ((end/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 testing was conducted on the front, back, left and right of the unit with 0 mm gap. The device would only be next to the body. The top and bottom was not tested as it would not be close to the body.

The maximum transmit duty cycle is 25% for the satellite transmitter in 1640 MHz band. The unit was measured at the 25% duty cycle and the SAR value was scaled to the upper end of the tolerance. All measurements were conducted with the device on a minimum of 10 cm of Styrofoam.

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

The BLE and ANT transmitters are excluded due to the low power of the transmitters. Both transmitters maximum Tx power is 3.5 dBm (2.2 mW) which is below the threshold to be excluded for both the FCC and ISED.



1620 MHz						
Freq	Power Measured					
1616.02	1	30.539				
1620.98	2	30.449				
1625.98	3	30.346				

#### **Conduct Power Measurements**

Band	Mode	Bandwidth (MHz)	Channel	Frequency (MHz)	Data Rate	Avg Power (dBm)	Tune-up Pwr (dBm)
			1	2412	1	15.38	17.0
	802.11b	20	6	2437	1 Mbps	15.01	17.0
			11	2462	ivibps	16.74	17.0
		802.11g 20	1	2412	6 Mbps	Not Required	16.0
2450 MHz	802.11g		6	2437			16.0
			11	2462			16.0
			1	2412		Not Required	15.0
8	802.11n	20	6	2437	HT0		15.0
			11	2462			15.0



Figure 8.1 Test Reduction Table - 1640 MHz

Band	Side	Required Channel	Tested/Reduced
		1 – 1616.02 MHz	Reduced <sup>1</sup>
	Back	2 – 1620.98 MHz	Tested
		3 – 1625.98 MHz	Reduced <sup>1</sup>
		1 – 1616.02 MHz	Tested
	Front	2 – 1620.98 MHz	Tested
1640 MHz		3 – 1625.98 MHz	Tested
1640 1/102	Left	1 – 1616.02 MHz	Reduced <sup>1</sup>
		2 – 1620.98 MHz	Tested
		3 – 1625.98 MHz	Reduced <sup>1</sup>
		1 – 1616.02 MHz	Reduced <sup>1</sup>
	Right	2 – 1620.98 MHz	Tested
		3 – 1625.98 MHz	Reduced <sup>1</sup>

Reduced¹ – When the reported SAR is ≤ 0.8 W/kg, SAR is not required for the remaining test configuration per KDB 447498 D01 v06 section 4.4.1 a) page 16.

Figure 8.2 Test Reduction Table – 2.4 GHz

ı ıgur	C O.Z TCSt IX	eduction rabi	6 - 2.4 OHZ
Mode	Side	Required Channel	Tested/Reduced
		1 – 2412 MHz	Reduced <sup>1</sup>
	Back	6 – 2437 MHz	Tested
		11 – 2462 MHz	Reduced <sup>1</sup>
		1 – 2412 MHz	Reduced <sup>1</sup>
	Front	6 – 2437 MHz	Tested
000 445		11 – 2462 MHz	Reduced <sup>1</sup>
802.11b		1 – 2412 MHz	Reduced <sup>1</sup>
	Left	6 – 2437 MHz	Tested
		11 – 2462 MHz	Reduced <sup>1</sup>
		1 – 2412 MHz	Tested
	Right	6 – 2437 MHz	Tested
		11 – 2462 MHz	Tested
		1 – 2412 MHz	Reduced <sup>3</sup>
	Back	6 – 2437 MHz	Reduced <sup>3</sup>
		11 – 2462 MHz	Reduced <sup>3</sup>
		1 – 2412 MHz	Reduced <sup>3</sup>
	Front	6 – 2437 MHz	Reduced <sup>3</sup>
		11 – 2462 MHz	Reduced <sup>3</sup>
802.11g		1 – 2412 MHz	Reduced <sup>3</sup>
	Left	6 – 2437 MHz	Reduced <sup>3</sup>
		11 – 2462 MHz	Reduced <sup>3</sup>
		1 – 2412 MHz	Reduced <sup>3</sup>
	Right	6 – 2437 MHz	Reduced <sup>3</sup>
		11 – 2462 MHz	Reduced <sup>3</sup>
		1 – 2412 MHz	Reduced <sup>3</sup>
	Back	6 – 2437 MHz	Reduced <sup>3</sup>
		11 – 2462 MHz	Reduced <sup>3</sup>
		1 – 2412 MHz	Reduced <sup>3</sup>
	Front	6 – 2437 MHz	Reduced <sup>3</sup>
000.44		11 – 2462 MHz	Reduced <sup>3</sup>
802.11n		1 – 2412 MHz	Reduced <sup>3</sup>
	Left	6 – 2437 MHz	Reduced <sup>3</sup>
		11 – 2462 MHz	Reduced <sup>3</sup>
		1 – 2412 MHz	Reduced <sup>3</sup>
	Right	6 – 2437 MHz	Reduced <sup>3</sup>
		11 – 2462 MHz	Reduced <sup>3</sup>

Reduced¹ – When the reported SAR is ≤ 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.

Reduced² – When the reported SAR is >0.4 W/kg, test the next highest configuration until the SAR value is ≤ 0.8 W/kg per KDB 248227 D01 v02r02 section 5.1.1 2) page 9.

Reduced<sup>3</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 ≤ 1.2 W/kg, SAR is not required per KDB 248227 D01 v02r02 section 5.2.2 2) page 10.



1620.98

1625.98

Report Number: SAR.20221102

# SAR Data Summary - 1640 MHz Body

3

FDMA-FM

FDMA-FM

ME	MEASUREMENT RESULTS										
Gap	Gap Plot Frequency		Modulation	Position	End Power	Measured SAR (W/kg)	Reported SAR (W/kg)				
		MHz	Ch.			(dBm)	(W/Kg)	(WKg)			
	1	1616.02	1	FDMA-FM		30.539	1.36	1.51			
		1620.98	2	FDMA-FM	Front	30.449	1.17	1.33			
0		1625.98	3	FDMA-FM		30.346	1.28	1.49			
_		1620.98	2	FDMA-FM	Back	30.449	0.369	0.42			
mm		1620.98	2	FDMA-FM	Left	30.449	0.399	0.45			

Right

Repeated

30.449

30.539

Body 1.6 W/kg (mW/g) averaged over 1 gram

0.0738

1.34

0.08

1.49

1.	SAR Measurement			
	Phantom Configuration	Left Head	⊠Eli4	Right Head
	SAR Configuration	Head	$\boxtimes$ Body	
2.	Test Signal Call Mode	Test Code	⊠Base Station Sim	ulator
3.	Test Configuration	☐With Belt Clip	Without Belt Cli	p N/A
4	Tissue Denth is at least 15.0	cm	•	-

Jay Moulton Vice President



# SAR Data Summary – 2450 MHz Body 802.11b

ME	MEASUREMENT RESULTS										
Plot	Gap	Position	Frequency		Modulation	End Power	Measured SAR	Reported SAR			
FIOL	Gap	FUSILIOII	MHz	Ch.	Wiodulation	(dBm)	(W/kg)	(W/kg)			
		Back	2437	6	DSSS	15.01	0.127	0.20			
		Front	2437	6	DSSS	15.01	0.157	0.25			
	0 mm	Left	2437	6	DSSS	15.01	0.0920	0.15			
	U IIIIII		2412	1	DSSS	15.38	0.206	0.30			
2		Right	2437	6	DSSS	15.01	0.237	0.38			
			2462	11	DSSS	16.74	0.228	0.24			

Body 1.6 W/kg (mW/g) averaged over 1 gram

1.	Battery is fully charged for all	tests.		
	Power Measured		□ERP	☐EIRP
2.	SAR Measurement			
	Phantom Configuration	Left Head	⊠Eli4	Right Head
	SAR Configuration	Head	$\boxtimes$ Body	
3.	Test Signal Call Mode	⊠Test Code	☐Base Station Simula	ator
4.	Test Configuration	☐With Belt Clip		$\sum N/A$
5.	Tissue Depth is at least 15.0 cn	n		

Jay M. Moulton Vice President



# **SAR Data Summary – Simultaneous Evaluation**

MEASUREMENT RESULTS – Satellite & WiFi Front Side										
Freque	ncy	Modulation	Frequ	Modulation	SAR₁	SAR <sub>2</sub>	SAR Total			
MHz	Ch.	Modulation	MHz	Ch.	Modulation	OAII	OAI12	OAR TOLAI		
1616.02	1	FDMA-FM	2437	6	DSSS	1.51	0.25	1.76		
	Body 1.6 W/kg (mW/g) averaged over 1 gram									

All remaining sides are less than the limit for the WiFi and Satellite combination. See below for the calculation for the SPLSR.

MEASUREMENT RESULTS - Satellite & ANT+										
Frequency Modulation Frequency Modulation SAR <sub>1</sub> SAR <sub>2</sub>								SAR Total		
MHz	Ch.	Modulation	MHz	Ch.	Modulation	OAIN <sub>1</sub>	OAI\2	OAR Total		
1616.02	1	FDMA-FM	2457	N/A	GFSK	1.51	0.09	1.60		
1616.02   1   FDMA-FM   2457   N/A   GFSR   1.51   0.09   1.60										

MEASUREMENT RESULTS – Satellite & BT										
Freque	ncy	Modulation	Frequ	ency	Modulation	SAR₁	SAR <sub>2</sub>	SAR Total		
MHz	Ch.	Modulation	MHz	Ch.	Modulation	SAR <sub>1</sub>				
1616.02	1	FDMA-FM	2480	N/A	GFSK	1.51	0.09	1.60		
	Body   1.6 W/kg (mW/g)   averaged over 1 gram									

The sum of the two transmitters is less than or equal to the limit for the Ant+ and BT combinations; therefore, the simultaneous transmission meets the requirements of KDB447498 D01 v06 section 4.3.2 page 11 for these transmitter combinations.

The estimated SAR value for the BT and ANT+ transmitters are listed below.

[max. power, mW / min. separation distance, mm] \* [ $\sqrt{f_{(GHz)}}$  / x], where x = 7.5 for 1 gram SAR

ВТ

 $[2.2/5] * [\sqrt{2.48} / 7.5] = 0.09$ 

ANT+

 $[2.2/5] * [\sqrt{2.457} / 7.5] = 0.09$ 



-13.74

Report Number: SAR.20221102

-1.48

MEASU	REMEN	NT RE	SULT	S – WW	AN-W	'iFi (Mai	n)						
Position	Freque	ency		Maxima		Frequ	ency		Maxima		SAR₁	SAR <sub>2</sub>	SAR Total
1 03111011	MHz	Ch.	Χ	Υ	7	MHz	Ch.	X	Υ	7	OAN,	OAI12	OAIT TOTAL

23.56

35.81

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

0.38

1.89

1.51

Front – 58.36 mm SPLSR=0.04 See Plot 1 Below

80.69

-1.27

2437

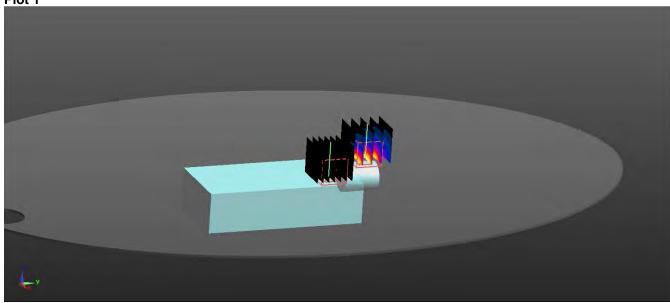
Simultaneous Separation Ratio Calculation

 $(SAR_1 + SAR_2)^{1.5}/R_i \le 0.04$  rounded to two digits

#### Plot 1

1616.02

Front





# 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	02/16/2023	02/16/2022	3662
Speag Validation Dipole D1640V2	02/11/2023	02/11/2022	330
Speag Validation Dipole D2450V2	06/03/2023	06/03/2021	881
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	N/A	N/A	N/A
Attenuator			
MiniCircuits SPL-10.7+ Low Pass Filter	N/A	N/A	R8979513746
Aprel Dielectric Probe Assembly	N/A	N/A	0011
Head Equivalent Matter (1640 MHz)	N/A	N/A	N/A
Head Equivalent Matter (2450 MHz)	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 Verification Plots and Data

```
Test Result for UIM Dielectric Parameter
Mon 07/Nov/2022
Freq Frequency(GHz)
FCC_eH FCC Limits for Head Epsilon
FCC_sH FCC Limits for Head Sigma
Test_e Epsilon of UIM
Test_s Sigma of UIM
**********
Freq FCC_eH FCC_sH Test_e Test_s

      Freq
      FCC_eH FCC_sH Test_e Test_s

      1.6100
      40.29 1.28 39.71 1.29

      1.6160
      40.278 1.286 39.704 1.296*

      1.6200
      40.27 1.29 39.70 1.30

      1.6210
      40.268 1.29 39.697 1.301*

      1.6260
      40.258 1.29 39.682 1.306*

      1.6300
      40.25 1.29 39.67 1.31

      1.6400
      40.23 1.30 39.66 1.32

      1.6500
      40.21 1.31 39.65 1.33

* value interpolated
****************
Test Result for UIM Dielectric Parameter
Mon 07/Nov/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
*****************
            FCC_eH FCC_sH Test_e Test_s
39.26 1.76 38.64 1.79
39.258 1.762 38.636 1.792*
39.25 1.77 38.62 1.80
Freq
```

<sup>\*</sup> value interpolated



# RF Exposure Lab

## Plot 1

DUT: Dipole 1640 MHz D1640V2; Type: Dipole; Serial: 330

Communication System: CW; Frequency: 1640 MHz; Duty Cycle: 1:1

Medium: HSL1640; Medium parameters used: f = 1640 MHz;  $\sigma = 1.32 \text{ S/m}$ ;  $\epsilon_r = 39.66$ ;  $\rho = 1000 \text{ kg/m}^3$ 

Phantom section: Flat Section

Test Date: Date: 11/7/2022; Ambient Temp: 23 °C; Tissue Temp: 21 °C Probe: EX3DV4 – SN3662; ConvF(8.03, 8.03, 8.03); 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:**

**1640 MHz Head/Verification/Area Scan (61x81x1):** Interpolated grid: dx=1.000 mm, dy=1.000 mm Maximum value of SAR (interpolated) = 5.72 W/kg

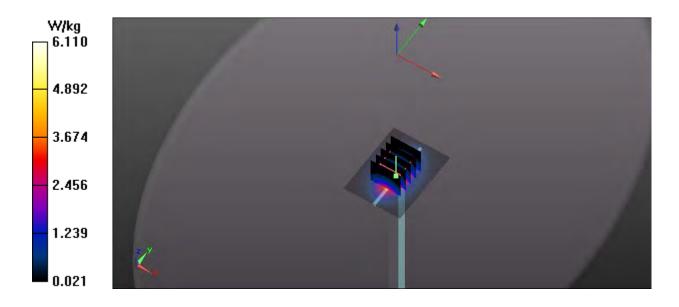
1640 MHz Head/Verification/Zoom Scan (5x5x7)/Cube 0: Measurement grid: dx=8mm, dy=8mm, dz=5mm

Reference Value = 54.367 V/m; Power Drift = -0.03 dB

Peak SAR (extrapolated) = 7.05 W/kg

Pin= 100 mW

SAR(1 g) = 3.46 W/kg; SAR(10 g) = 1.87 W/kg Maximum value of SAR (measured) = 6.11 W/kg





# RF Exposure Lab

## Plot 2

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;  $\sigma = 1.84$  S/m;  $\epsilon_r = 38.57$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

Test Date: Date: 11/7/2022; 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

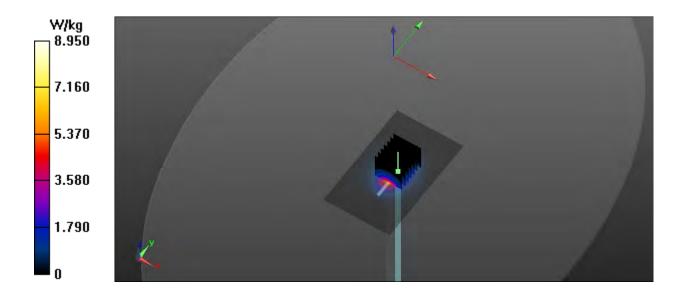
Head Verification/2450 MHz/Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 55.261 V/m; Power Drift = -0.02 dB

Peak SAR (extrapolated) = 11.04 W/kg

Pin= 100 mW

SAR(1 g) = 5.27 W/kg; SAR(10 g) = 2.47 W/kg Maximum value of SAR (measured) = 8.95 W/kg





# **Appendix B – SAR Test Data Plots**



# RF Exposure Lab

## Plot 1

DUT: AA4624; Type: Satellite Location Device; Serial: Eng 1

Communication System: FDMA-FM; Frequency: 1616.02 MHz; Duty Cycle: 1:4.00037

Medium: HSL1640; Medium parameters used (interpolated): f = 1616.02 MHz;  $\sigma = 1.296$  S/m;  $\epsilon_r = 39.704$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

Test Date: Date: 11/7/2022; Ambient Temp: 23 °C; Tissue Temp: 21 °C

Probe: EX3DV4 - SN3662; ConvF(8.03, 8.03, 8.03); 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:**

1640 MHz/Front Low/Area Scan (7x13x1): Measurement grid: dx=15mm, dy=15mm

Info: Interpolated medium parameters used for SAR evaluation.

Maximum value of SAR (measured) = 1.26 W/kg

1640 MHz/Front Low/Zoom Scan (5x5x7)/Cube 0: Measurement grid: dx=8mm, dy=8mm, dz=5mm

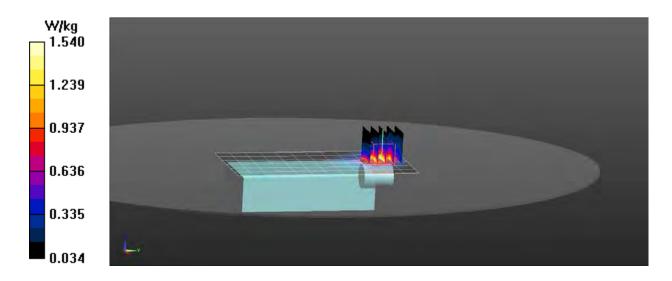
Reference Value = 5.479 V/m; Power Drift = 0.06 dB

Peak SAR (extrapolated) = 2.46 W/kg

SAR(1 g) = 1.36 W/kg; SAR(10 g) = 0.788 W/kg

Info: Interpolated medium parameters used for SAR evaluation.

Maximum value of SAR (measured) = 1.54 W/kg





# RF Exposure Lab

## Plot 2

DUT: AA4624; Type: Satellite Location Device; Serial: Eng 1

Communication System: WiFi 802.11b (DSSS, 1 Mbps); Frequency: 2437 MHz; Duty Cycle: 1:1

Medium: HSL2450; Medium parameters used (interpolated): f = 2437 MHz;  $\sigma = 1.827$  S/m;  $\varepsilon_r = 38.596021$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

Test Date: Date: 11/7/2022; 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:**

2450 MHz/Right Mid/Area Scan (6x16x1): Measurement grid: dx=12mm, dy=12mm

Info: Interpolated medium parameters used for SAR evaluation.

Maximum value of SAR (measured) = 0.312 W/kg

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

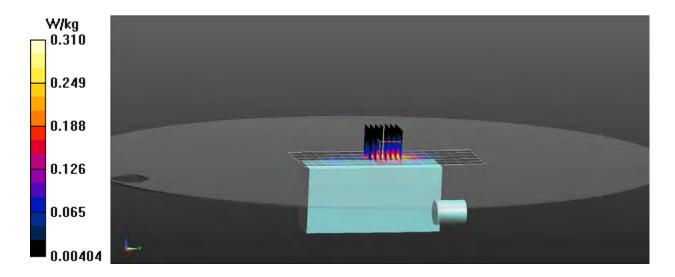
Reference Value = 10.79 V/m; Power Drift = -0.04 dB

Peak SAR (extrapolated) = 0.518 W/kg

SAR(1 g) = 0.237 W/kg; SAR(10 g) = 0.121 W/kg

Info: Interpolated medium parameters used for SAR evaluation.

Maximum value of SAR (measured) = 0.310 W/kg





# **Appendix D – Probe Calibration Data Sheets**

## 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
Swiss Calibration Service

Accreditation No.: SCS 0108

Accredited by the Swiss Accreditation Service (SAS)

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.

OA CAL-25.47

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 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP	SN: 104778	09-Apr-21 (No. 217-03291/03292)	
Power sensor NRP-Z91	SN: 103244	09-Apr-21 (No. 217-03291/03292)	Apr-22 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

Function

Signature

Laboratory Technician

Approved by:

Deputy Manager

S. C.

Issued: February 18, 2022

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## Calibration Laboratory of

Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland





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Glossary:

TSL tissue simulating liquid

NORMx,y,z sensitivity in free space ConvF sensitivity in TSL / NORMx,y,z

DCP diode compression point

CF crest factor (1/duty\_cycle) of the RF signal modulation dependent linearization parameters

Polarization  $\varphi$   $\varphi$  rotation around probe axis

Polarization 9 9 rotation around an axis that is in the plane normal to probe axis (at measurement center),

i.e., 9 = 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:

a) 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.

b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Methods Applied and Interpretation of Parameters:

- NORMx,y,z: Assessed for E-field polarization 9 = 0 (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide).
   NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E²-field uncertainty inside TSL (see below ConvF).
- NORM(f)x,y,z = NORMx,y,z \* 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.
- DCPx,y,z: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- PAR: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: A, B, C, D are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters: Assessed in flat phantom using E-field (or Temperature Transfer Standard for f ≤ 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 NORMx,y,z \* 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 ± 50 MHz to ± 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 NORMx (no uncertainty required).

Certificate No: EX3-3662\_Feb22

EX3DV4 – SN:3662 February 16, 2022

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

#### **Basic Calibration Parameters**

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm (μV/(V/m)²) <sup>A</sup>	0.42	0.49	0.48	± 10.1 %
DCP (mV) <sup>B</sup>	99.8	99.6	98.2	

**Calibration Results for Modulation Response** 

UID	Communication System Name		A dB	B dB√μV	С	D dB	VR mV	Max dev.	Unc <sup>E</sup> (k=2)
0	CW	Х	0.0	0.0	1.0	0.00	147.3	±2.7 %	± 4.7 %
		Υ	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>&</sup>lt;sup>A</sup> The uncertainties of Norm X,Y,Z do not affect the E<sup>2</sup>-field uncertainty inside TSL (see Pages 5 and 6).

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

<sup>&</sup>lt;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.

EX3DV4- SN:3662 February 16, 2022

# 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.

EX3DV4-SN:3662

## 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>&</sup>lt;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.

F At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to  $\pm$  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  $\pm$  5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

G Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is

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.

EX3DV4- SN:3662 February 16, 2022

## 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 %

 $<sup>^{\</sup>rm C}$  Frequency validity above 6GHz is  $\pm$  700 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

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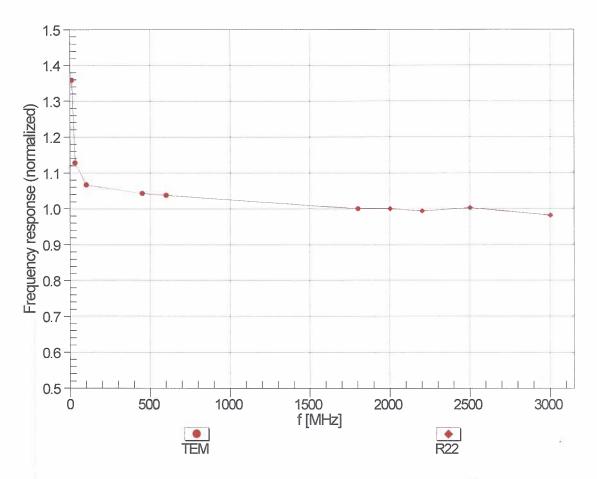
F At frequencies 6-10 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

G Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is

<sup>&</sup>lt;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)

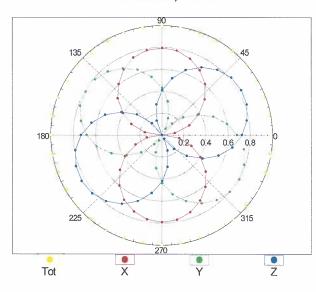


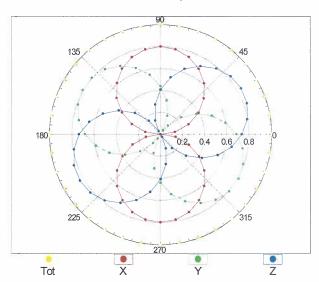
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

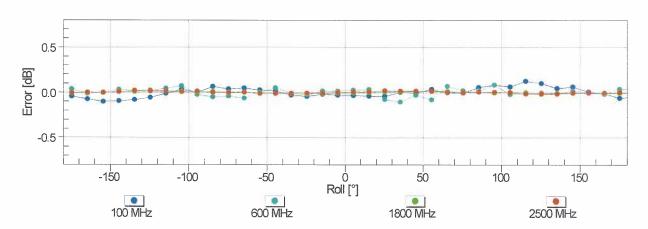
# Receiving Pattern ( $\phi$ ), $\vartheta = 0^{\circ}$



# f=1800 MHz,R22





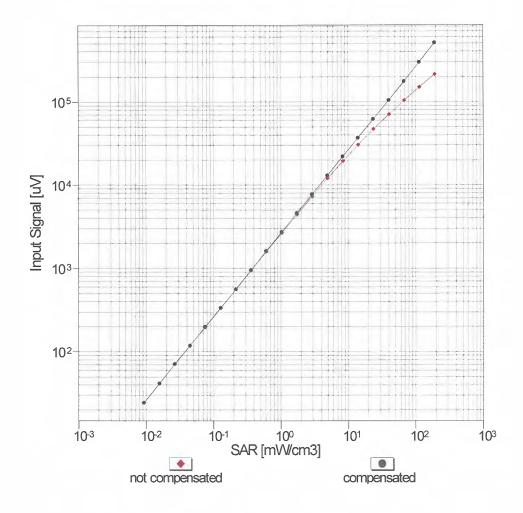


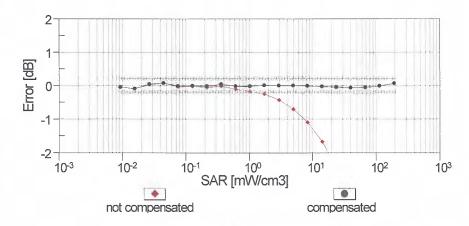
Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

EX3DV4- SN:3662 February 16, 2022

# Dynamic Range f(SAR<sub>head</sub>)

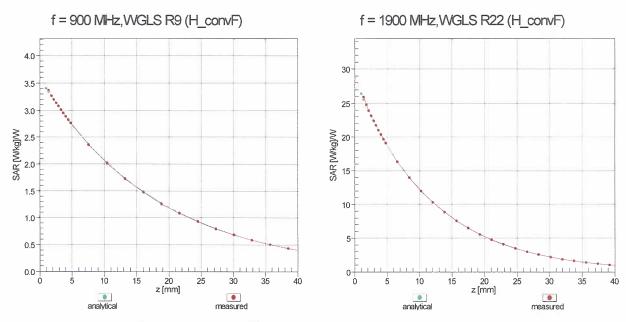
(TEM cell , feval= 1900 MHz)



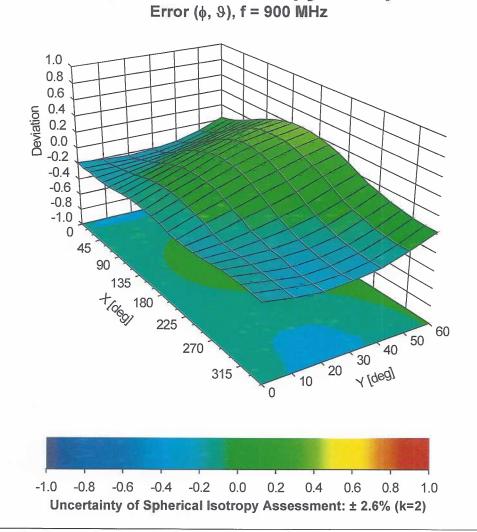


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

## **Conversion Factor Assessment**



# Deviation from Isotropy in Liquid





Report Number: SAR.20221102

# **Appendix E – Dipole Calibration Data Sheets**

# Calibration Laboratory of Schmid & Partner

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Client

RF Exposure Lab

Certificate No: D1640V2-330 Feb22

## CALIBRATION CERTIFICATE

Object **D1640V2 - SN:330** 

Calibration procedure(s) QA CAL-05.vf

Calibration Procedure for SAR Validation Sources between 0.7-3 GHz

Calibration date:

February 11, 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 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID#	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP	SN: 104778	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	31-Dec-21 (No. EX3-7349_Dec21)	Dec-22
DAE4	SN: 601	01-Nov-21 (No. DAE4-601_Nov21)	Nov-22
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: MY41093315	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-22
	Name	Function	Signature
Calibrated by:	Aidonia Georgiadou	Laboratory Technician	Ar .
			Mse
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Approved by:	Sven Kühn	Deputy Manager	
			(10

Issued: February 17, 2022

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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:

- a) 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.
- b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

#### **Additional Documentation:**

c) DASY 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 source is mounted in a touch configuration below the center marking of the flat phantom.
- Return Loss: This parameter is measured with the source positioned under the liquid filled phantom (as described in the measurement condition clause). The Return Loss ensures low reflected power. 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%.

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## **Measurement Conditions**

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

DASY Version	DASY52	V52.10.4
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	1640 MHz ± 1 MHz	

## **Head TSL parameters**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	40.2	1.31 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	40.6 ± 6 %	1.29 mho/m ± 6 %
Head TSL temperature change during test	< 0.5 °C		

#### **SAR** result with Head TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	8.49 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	34.4 W/kg ± 17.0 % (k=2)

SAR averaged over 10 cm³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	4.57 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	18.4 W/kg ± 16.5 % (k=2)

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

#### **Antenna Parameters with Head TSL**

Impedance, transformed to feed point	53.6 Ω + 2.5 jΩ
Return Loss	- 27.5 dB

## **General Antenna Parameters and Design**

Electrical Delay (one direction)	1.232 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

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## **DASY5 Validation Report for Head TSL**

Date: 11.02.2022

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 1640 MHz; Type: D1640V2; Serial: D1640V2 - SN:330** 

Communication System: UID 0 - CW; Frequency: 1640 MHz

Medium parameters used: f = 1640 MHz;  $\sigma = 1.29 \text{ S/m}$ ;  $\varepsilon_r = 40.6$ ;  $\rho = 1000 \text{ kg/m}^3$ 

Phantom section: Flat Section

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

## DASY52 Configuration:

• Probe: EX3DV4 - SN7349; ConvF(8.68, 8.68, 8.68) @ 1640 MHz; Calibrated: 31.12.2021

• Sensor-Surface: 1.4mm (Mechanical Surface Detection)

• Electronics: DAE4 Sn601; Calibrated: 01.11.2021

• Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001

DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

## 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 = 104.6 V/m; Power Drift = 0.01 dB

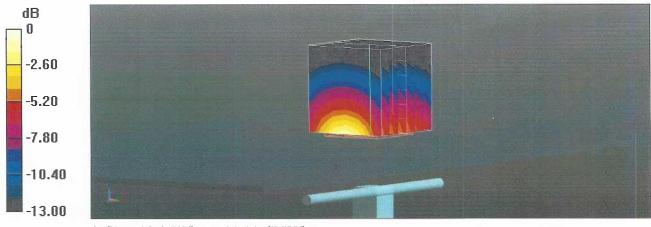
Peak SAR (extrapolated) = 15.4 W/kg

SAR(1 g) = 8.49 W/kg; SAR(10 g) = 4.57 W/kg

Smallest distance from peaks to all points 3 dB below = 10 mm

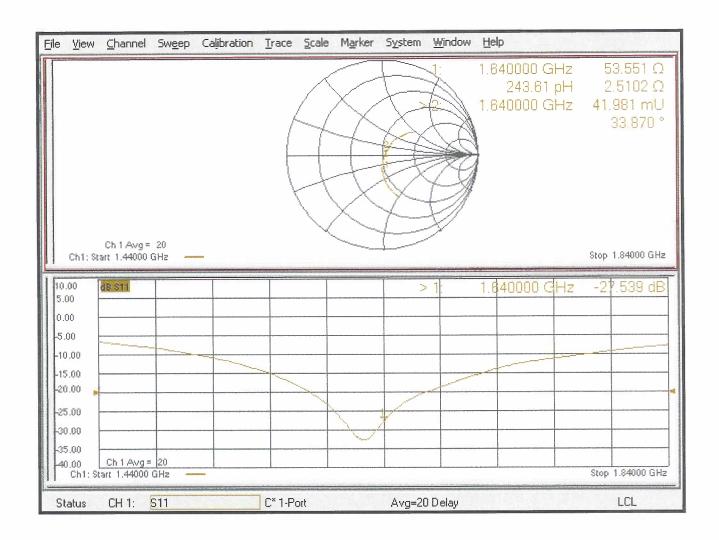
Ratio of SAR at M2 to SAR at M1 = 55.4%

Maximum value of SAR (measured) = 12.9 W/kg



0 dB = 12.9 W/kg = 11.11 dBW/kg

## Impedance Measurement Plot for Head TSL





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





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RF Exposure Lab

Certificate No: D2450V2-881\_Jun21

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CALIBRATION C	ERTIFICATE		
Object	D2450V2 - SN:88	Ħ	
Calibration procedure(s)	QA CAL-05 v11 Calibration Proce	dure for SAR Validation Source	es between 0.7-3 GHz
Calibration date:	June 03, 2021		
		onal standards, which realize the physical robability are given on the following pages	
All calibrations have been conduc	ted in the closed laborator	y facility: environment temperature (22 ± 3	3)°C and humidity < 70%.
Calibration Equipment used (M&T	ΓE 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
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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 E8358/	A SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-21
	Name	Function	Signature
Calibrated by:	Jeffrey Katzman	Laboratory Technician	J. hts
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.

Certificate No: D2450V2-881\_Jun21

## **Calibration Laboratory of**

Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland





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

Accreditation No.: SCS 0108

Accredited by the Swiss Accreditation Service (SAS)

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

#### 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:

- a) 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
- b) 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
- c) 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
- d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

#### **Additional Documentation:**

e) 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%.

Certificate No: D2450V2-881 Jun21 Page 2 of 6

## **Measurement Conditions**

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

DASY Version	DASY5	V52.10.4
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	2450 MHz ± 1 MHz	

## **Head TSL parameters**

The following parameters and calculations were applied.

The following parameters and substantial transfer approximately	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	39.2	1.80 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	37.7 ± 6 %	1.87 mho/m ± 6 %
Head TSL temperature change during test	< 0.5 °C		

## **SAR** result with Head TSL

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

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

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

#### **Antenna Parameters with Head TSL**

Impedance, transformed to feed point	54.3 Ω + 4.3 jΩ
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)	Δ%	Impedance Real (Ω)	ΔΩ	Impedance Imaginary (jΩ)	ΔΩ
6/3/2021	-24.7		54.3		4.3	
6/3/2022	-25.3	2.4	55.2	0.9	4.1	-0.2

Certificate No: D2450V2-881\_Jun21 Page 4 of 6

## **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;  $\varepsilon_r = 37.7$ ;  $\rho = 1000$  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

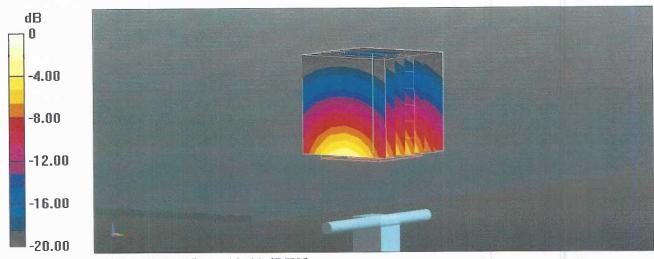
Peak SAR (extrapolated) = 28.0 W/kg

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

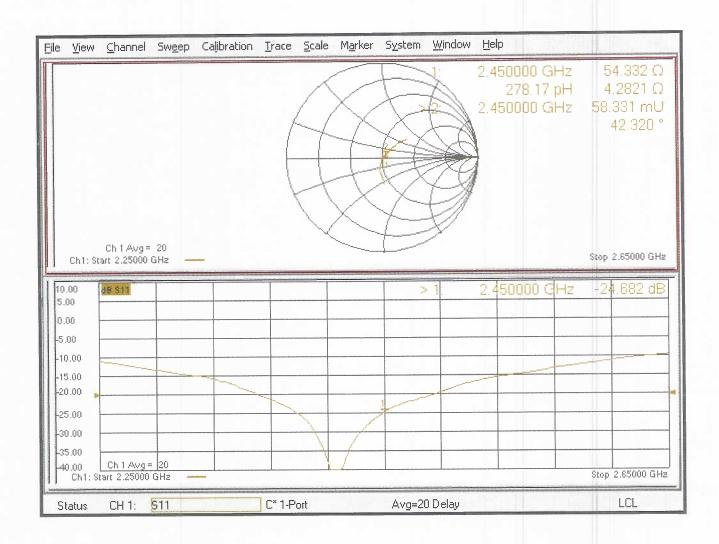
Ratio of SAR at M2 to SAR at M1 = 49.5%

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





Report Number: SAR.20221102

# **Appendix F – DAE Calibration Data Sheets**

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





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Client RF Exposure Lab

Accreditation No.: SCS 0108

S

C

S

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 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

!	1		
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

Name

Function

Calibrated by:

Adrian Gehring

Laboratory Technician

Approved by:

Sven Kühn

Deputy Manager

Issued: April 12, 2022

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Certificate No: DAE4-1416\_Apr22

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





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Swiss Calibration Service

Accreditation No.: SCS 0108

Accredited by the Swiss Accreditation Service (SAS)

The Swiss Accreditation Service is one of the signatories to the EA

Multilateral Agreement for the recognition of calibration certificates

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.

Certificate No: DAE4-1416\_Apr22 Page 2 of 5

## **DC Voltage Measurement**

Low Range:

A/D - Converter Resolution nominal

High Range: 1LSI

1LSB = 1LSB = 6.1μV, 61nV, full range = -100...+300 mV

full range = -1.....+3mV

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

Calibration Factors	X	Υ	Z
High Range	403.562 ± 0.02% (k=2)	403.870 ± 0.02% (k=2)	404.137 ± 0.02% (k=2)
Low Range	3.97865 ± 1.50% (k=2)	3.99513 ± 1.50% (k=2)	3.97046 ± 1.50% (k=2)

## **Connector Angle**

Connector Angle to be used in DASY system	107.5 ° ± 1 °
---	---------------

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

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	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 (μV)	Difference (μV)	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 (μV)	Low Range Average Reading (μV)
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 (μV)	Channel Y (μV)	Channel Z (μV)
Channel X	200	-	2.55	-3.59
Channel Y	200	7.33	-	2.96
Channel Z	200	8.86	6.81	-

Certificate No: DAE4-1416\_Apr22

## 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 (μV)	min. Offset (μV)	max. Offset (μV)	Std. Deviation (μV)
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

Certificate No: DAE4-1416\_Apr22



Report Number: SAR.20221102

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

Zeughausstrasse 43, 8004 Zurich, Switzerland Phone +41 44 245 9700, Fax +41 44 245 9779 info@speag.com, http://www.speag.com

#### 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
	Knebelstrasse 8
	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: 2.0mm +/- 0.2mm	ali
Material parameters	Dielectric parameters for required frequencies	< 6 GHz: Rel. permittivity = 4 +/-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. 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 Depth 190 mm, Shape is within tolerance for filling height up to 155 mm, Eventual sagging is reduced or eliminated by support via DUT	Prototypes, Sample testing

#### Standards

- [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.

Date

28.4.2008

Signature / Stamp

Schmid & Partner Engineering AG Zeughāugstrasse 43, 8004 Zurich, Switzerland Phone +41 44 245 9709, Fax +41,46,245 9779 info@speag.com; http://www.speag.com