

RF Exposure Lab

802 N. Twin Oaks Valley Road, Suite 105 • San Marcos, CA 92069 • U.S.A.

TEL (760) 471-2100 • FAX (760) 471-2121

<http://www.rfexposurelab.com>

CERTIFICATE OF COMPLIANCE SAR EVALUATION

Garmin International, Inc.
1200 E. 151st Street
Olathe, KS 66062

Dates of Test:
Test Report Number:

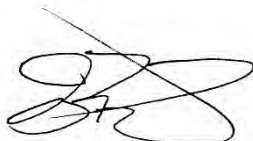
June 5-6, 2024
SAR.20240603
Revision A
Lab Designation Number: US1195

FCC ID:	IPH-04746
Contains FCC ID:	IPH-04349
Model(s):	A04746
Test Sample:	Engineering Unit Same as Production
Serial No.:	16977296
Equipment Type:	Digital Transmission System Transceiver
Classification:	Portable Transmitter Next to Body
TX Frequency Range:	1616 – 1626 MHz; 2400 – 2480 MHz
Frequency Tolerance:	± 2.5 ppm
Maximum RF Output:	1640 MHz – 35.7 dBm, 2450 MHz (BT) – 6.0 dBm, 2450 MHz (ANT) – 4.0 dBm Conducted
Signal Modulation:	DE-QPSK, QPSK, GFSK, GMSK
Antenna Type:	Internal Antenna
Application Type:	Certification
FCC Rule Parts:	Part 2, 15C, 25
KDB Test Methodology:	KDB 447498 D01 v06, KDB 865664 D01 v01r04, KDB 865664 D02 v01r02
Max. Stand Alone SAR Value:	1.35 W/kg Reported
Max. Simultaneous SAR Value:	1.45 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 C95.1 – 1999 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, ANSI C95.3 – 2002 Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields, IEEE Std.1528 – 2013 Recommended Practice and had been tested in accordance with the measurement procedures specified in KDB 447498 (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

Table of Contents

1. Introduction	4
SAR Definition [5].....	5
2. SAR Measurement Setup.....	6
Robotic System.....	6
System Hardware.....	6
System Electronics.....	7
Probe Measurement System.....	7
3. Probe and Dipole Calibration.....	15
4. Phantom & Simulating Tissue Specifications.....	16
Head Simulating Mixture Characterization.....	16
5. ANSI/IEEE C95.1 – 1999 RF Exposure Limits [2].....	17
Uncontrolled Environment.....	17
Controlled Environment.....	17
6. Measurement Uncertainty	18
7. System Verification.....	19
Tissue Verification.....	19
Test System Verification.....	19
8. SAR Test Data Summary	20
Procedures Used To Establish Test Signal	20
Device Test Condition	20
SAR Data Summary – 1640 MHz Body.....	23
SAR Data Summary – 2450 MHz Body.....	24
SAR Data Summary – Simultaneous Evaluation	Error! Bookmark not defined.
9. Test Equipment List.....	26
10. Conclusion	27
11. References.....	28
Appendix A – System Validation Plots and Data	29
Appendix B – SAR Test Data Plots	32
Appendix C – SAR Test Setup Photos.....	35
Appendix D – Probe Calibration Data Sheets.....	44
Appendix E – Dipole Calibration Data Sheets	55
Appendix F – DAE Calibration Data Sheets	68
Appendix G – Phantom Calibration Data Sheets.....	74
Appendix H – Validation Summary.....	76

Comment/Revision	Date
Original Release	June 7, 2024
Revision A – Corrected tune-up tolerance and modulations	August 1, 2024

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 the Garmin International, Inc. Model A04746 FCC ID: IPH-04746, which contains FCC ID: IPH-04349 to be compliant to FCC Part 2, 1093, ET Docket 93-62 Rules for mobile and portable devices. The FCC has 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 regulated portable devices. [1]

The test results recorded herein are based on a single type test of Garmin International, Inc. Model A04746 and therefore apply only to the tested sample.

The test procedures, 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, ANSI C95.3 – 2002 Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields, IEEE Std.1528 – 2013 Recommended Practice and KDB 447498 were employed.

The following table indicates all the wireless technologies operating in the A04746 Digital Transmission System Transceiver. The table also shows the tolerance for the power level for each mode.

Band	Technology	Rel.	Class	3GPP Nominal Power dBm	Setpoint Nominal Power dBm	Tolerance dBm	Lower Tolerance dBm	Upper Tolerance dBm
1640 MHz	DE-QPSK/MES	N/A	N/A	N/A	N/A	N/A	N/A	35.7
Bluetooth	BLE	N/A	N/A	N/A	N/A	N/A	N/A	6.0
Ant	Ant	N/A	N/A	N/A	N/A	N/A	N/A	4.0

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 (ρ).

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

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:

σ = conductivity of the tissue (S/m)

ρ = mass density of the tissue (kg/m³)

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.

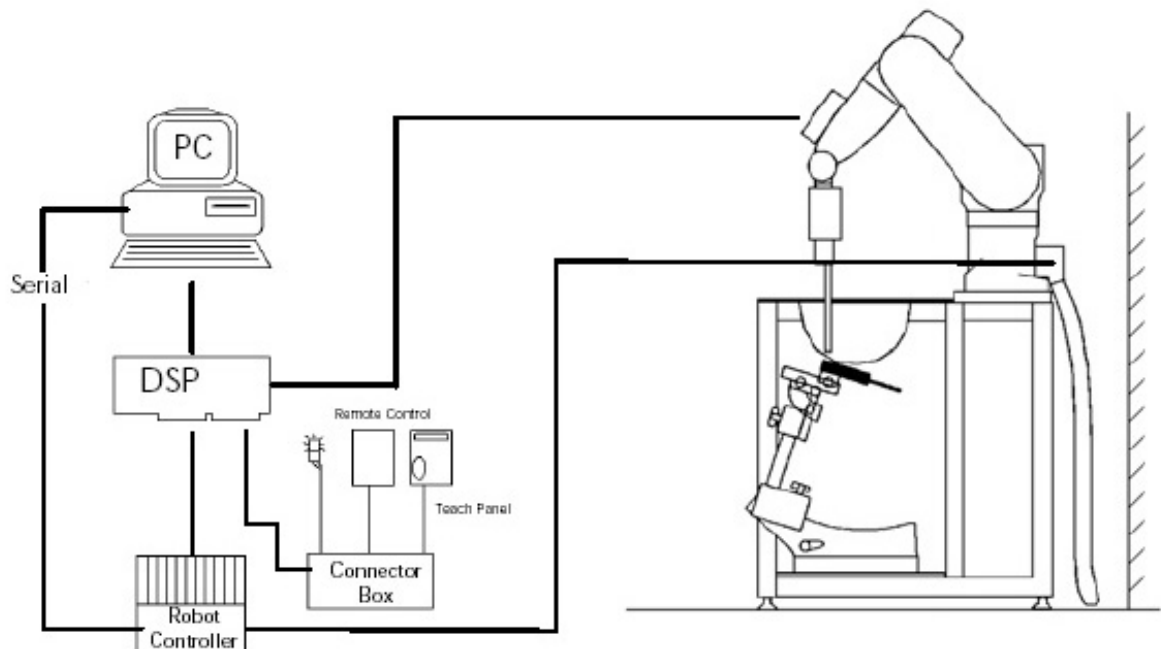


Figure 2.1 SAR Measurement System Setup

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: ± 0.2 dB (30 MHz to 6 GHz)

Dynamic: 10 mW/kg to 100 W/kg

Range: Linearity: ± 0.2 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

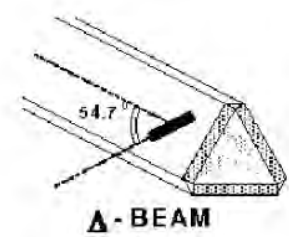


Figure 2.2 Triangular Probe Configurations



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/cm².

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:

Δt = exposure time (30 seconds),

σ = simulated tissue conductivity,

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

ρ = Tissue density (1.25 g/cm³ for brain tissue)

ΔT = 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;

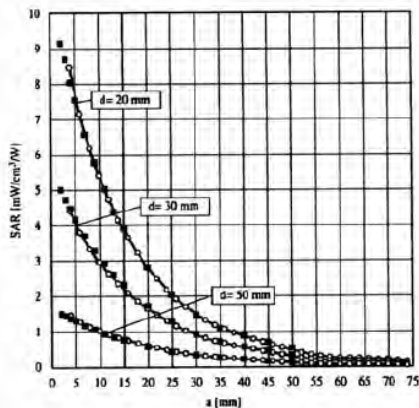


Figure 2.4 E-Field and Temperature Measurements at 900MHz

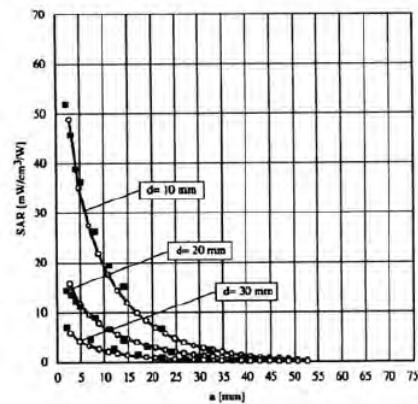


Figure 2.5 E-Field and Temperature Measurements at 1800MHz

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)
μV/(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
- σ = conductivity in [mho/m] or [Siemens/m]
- ρ = equivalent tissue density in g/cm³

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

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

with

- P_{pwc} = equivalent power density of a plane wave in W/cm²
- 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 ≤ 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 for x, y axis	Grid spacing for z axis	Minimum zoom 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 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 ± 0.2 mm

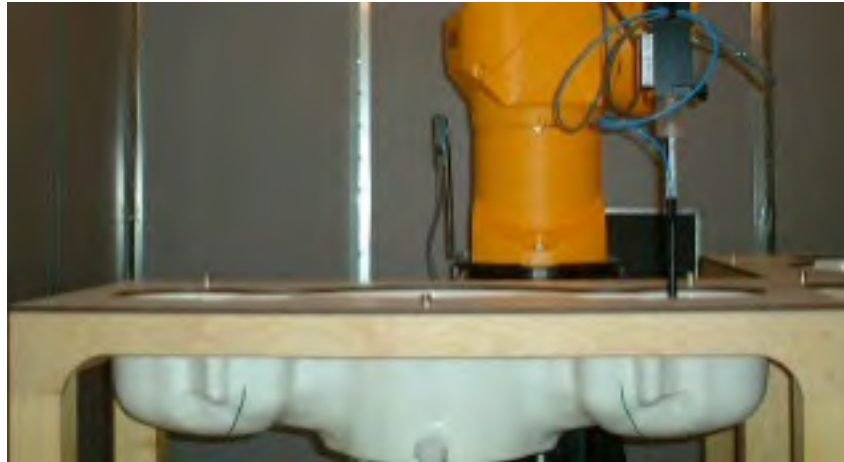


Figure 2.6 SAM Twin Phantom

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 Simulating Mixture Characterization

The head mixture consists 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.

Table 4.1 Typical Composition of Ingredients for Tissue

Ingredients		Simulating Tissue	
		1640 MHz Head	2450 MHz Head
Mixing Percentage			
Water		Proprietary Purchased From Speag	Proprietary Purchased From Speag
Sugar			
Salt			
HEC			
Bactericide			
DGBE			
Dielectric Constant	Target	40.23	39.20
Conductivity (S/m)	Target	1.30	1.80

5. ANSI/IEEE C95.1 – 1999 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 ¹ Brain	1.60	8.00
SPATIAL AVERAGE SAR ² Whole Body	0.08	0.40
SPATIAL PEAK SAR ³ Hands, Feet, Ankles, Wrists	4.00	20.00

¹ 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.

² The Spatial Average value of the SAR averaged over the whole body.

³ 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 ≥ 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 Verification

Tissue Verification

Table 7.1 Measured Tissue Parameters

		1640 MHz Head		2450 MHz Head	
Date(s)		Jun. 5, 2024		Jun. 6, 2024	
Liquid Temperature (°C)	20.0	Target	Measured	Target	Measured
Dielectric Constant: ϵ		40.23	39.61	39.20	38.21
Conductivity: σ		1.30	1.53	1.80	1.81

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 extrapolated to 1 watt. (Graphic Plots Attached)

Table 7.2 System Dipole Validation Target & Measured

	Test Frequency	Targeted SAR _{1g} (W/kg)	Measure SAR _{1g} (W/kg)	Tissue Used for Verification	Deviation (%)	Plot Number
05-Jun-2024	1640 MHz	34.40	35.00	Head	+ 1.74	1
06-Jun-2024	2450 MHz	53.30	54.20	Head	+ 1.69	2

See Appendix A for data plots.

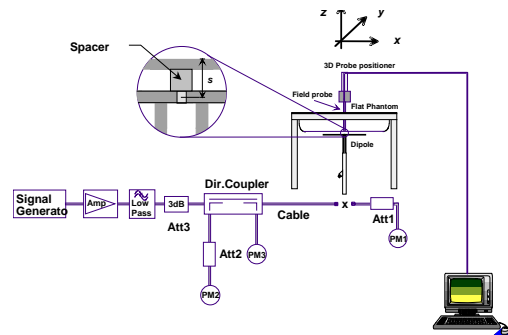


Figure 7.1 Dipole Validation Test Setup

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 placed into simulated transmit mode using the manufacturer's test codes. Such test signals offer a consistent means for testing SAR and are recommended for evaluating SAR. When test modes are not available or inappropriate for testing a device, 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 all six sides of the device in contact with the ELI Flat phantom for measurements. All measurements were conducted with the side of the device in direct contact with the phantom. All further test reductions are shown on page 21. The device does allow for simultaneous Tx with the BT or ANT but not both. See the photo in Appendix C for a pictorial of the setups.

The transmitter has a maximum duty cycle of 9.3%. The measured values were first scaled to the upper end of the tolerance and then scaled to 9.3% duty cycle for the final reported SAR value. A screen shot of the duty cycle on a spectrum analyzer is included in appendix C.

The ANT transmitter is excluded from SAR testing. The antenna has a minimum separation distance of 5 mm. The transmitter is in the same band as the BLE and the maximum power for BLE is 6.0 dBm and for ANT is 4.0 dBm. The ANT transmitter has a lower power and in the same band and modulation as the BLE; therefore, the ANT would be excluded.

The device was on a minimum of 10 cm of Styrofoam during each test.

Table 8.1 Test Reduction Table

Mode	Side	Required Channel	Tested/Reduced
1620 MHz	Back	1 – 2412 MHz	Reduced ¹
		125 – 2437 MHz	Tested
		240 – 2462 MHz	Reduced ¹
	Front	1 – 2412 MHz	Tested
		125 – 2437 MHz	Tested
		240 – 2462 MHz	Tested
	Left	1 – 2412 MHz	Reduced ¹
		125 – 2437 MHz	Tested
		240 – 2462 MHz	Reduced ¹
	Right	1 – 2412 MHz	Reduced ¹
		125 – 2437 MHz	Tested
		240 – 2462 MHz	Reduced ¹
	Top	1 – 2412 MHz	Reduced ¹
		125 – 2437 MHz	Tested
		240 – 2462 MHz	Reduced ¹
Bottom	1 – 2412 MHz	Reduced ¹	
	125 – 2437 MHz	Tested	
	240 – 2462 MHz	Reduced ¹	

Reduced¹ – When the reported SAR is >0.8 W/kg, the remaining channels are excluded based on KDB447498 v06.

Table 8.2 Test Reduction Table

Mode	Side	Required Channel	Tested/Reduced
BLE	Back	0 – 2404 MHz	Reduced ¹
		17 – 2440 MHz	Tested
		36 – 2478 MHz	Reduced ¹
	Front	0 – 2404 MHz	Reduced ¹
		17 – 2440 MHz	Tested
		36 – 2478 MHz	Reduced ¹
	Left	0 – 2404 MHz	Reduced ¹
		17 – 2440 MHz	Tested
		36 – 2478 MHz	Reduced ¹
	Right	0 – 2404 MHz	Reduced ¹
		17 – 2440 MHz	Tested
		36 – 2478 MHz	Reduced ¹
	Top	0 – 2404 MHz	Tested
		17 – 2440 MHz	Tested
		36 – 2478 MHz	Tested
Bottom	0 – 2404 MHz	Reduced ¹	
	17 – 2440 MHz	Tested	
	36 – 2478 MHz	Reduced ¹	

Reduced¹ – When the reported SAR is >0.8 W/kg, the remaining channels are excluded based on KDB447498 v06.

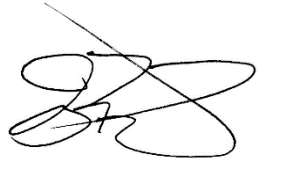
Band	Mode	Channel	Frequency (MHz)	Avg Power (dBm)	Tune-up Pwr (dBm)
1640 MHz	DE-QPSK	1	1616.02	32.16	35.7
		125	1620.98	31.85	35.7
		240	1625.98	31.62	35.7

Band	Mode	Channel	Frequency (MHz)	Avg Power (dBm)	Tune-up Pwr (dBm)
2450 MHz	BLE	0	2404	3.376	6.0
		17	2440	3.096	6.0
		36	2478	2.776	6.0
	ANT	1	2402	3.555	4.0
		39	2440	3.445	4.0
		78	2480	3.105	4.0

SAR Data Summary – 1640 MHz Body

MEASUREMENT RESULTS								
Plot	Gap	Position/ Device	Frequency		Modulation	End Power (dBm)	Measured SAR (W/kg)	Reported SAR (W/kg)
			MHz	Ch.				
----	0 mm	Back	1620.98	125	DE-QPSK	31.85	0.755	0.17
----		Front	1616.02	1	DE-QPSK	32.16	5.23	1.10
1			1620.98	125	DE-QPSK	31.85	5.84	1.32
----			1625.98	240	DE-QPSK	31.62	5.68	1.35
----			Left	1620.98	125	DE-QPSK	31.85	1.35
----		Right	1620.98	125	DE-QPSK	31.85	0.963	0.22
----		Top	1620.98	125	DE-QPSK	31.85	1.02	0.23
----		Bottom	1620.98	125	DE-QPSK	31.85	0.534	0.12
----		Repeat	1620.98	125	DE-QPSK	31.85	5.82	1.31
Body						1.6 W/kg (mW/g) averaged over 1 gram		

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



Jay M. Moulton
Vice President

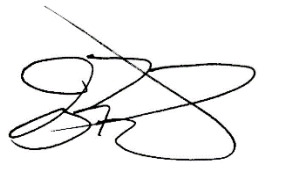
Note: The reports SAR was calculated by first scaling to the upper end of the tolerance and then scaled by the 9.3% duty cycle.

SAR Data Summary – 2450 MHz Body

MEASUREMENT RESULTS									
Plot	Gap	Position/ Device	Frequency		Modulation	End Power (dBm)	Measured SAR (W/kg)	Reported SAR (W/kg)	
			MHz	Ch.					
-----	0 mm	Back	2440	17	GMSK	3.096	0.000148	<0.01	
-----		Front	2440	17	GMSK	3.096	0.00803	0.02	
-----		Left	2440	17	GMSK	3.096	0.000168	<0.01	
-----		Right	2440	17	GMSK	3.096	0.00413	0.01	
-----		Top		2402	37	GMSK	3.376	0.00842	0.02
2				2440	17	GMSK	3.096	0.00910	0.02
-----				2480	39	GMSK	2.779	0.00738	0.02
-----		Bottom	2440	17	GMSK	3.096	0.000539	<0.01	

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

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



Jay M. Moulton
 Vice President

SAR Data Summary – Simultaneous Evaluation

MEASUREMENT RESULTS – Satellite & ANT+								
Frequency		Modulation	Frequency		Modulation	SAR ₁	SAR ₂	SAR Total
MHz	Ch.		MHz	Ch.				
1620.98	125	DE-QPSK	2457	N/A	GMSK	1.35	0.10	1.45
Body 1.6 W/kg (mW/g) averaged over 1 gram								

MEASUREMENT RESULTS – Satellite & BT								
Frequency		Modulation	Frequency		Modulation	SAR ₁	SAR ₂	SAR Total
MHz	Ch.		MHz	Ch.				
1620.98	125	DE-QPSK	2440	17	GMSK	1.35	0.02	1.37
Body 1.6 W/kg (mW/g) averaged over 1 gram								

The sum of the two transmitters are less than the limit; therefore, the simultaneous transmission meets the requirements of KDB447498 D01 v06 section 4.3.2 page 11 and RSS-102 Issue 6.

The estimated SAR value for the ANT+ transmitter is listed below.

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

ANT+

$$[2.5/5] * [\sqrt{2.457} / 7.5] = 0.10$$

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
ELI4 Flat Phantom	N/A	N/A	1065
Device Holder	N/A	N/A	N/A
Data Acquisition Electronics 4	01/15/2025	01/15/2024	1321
SPEAG E-Field Probe EX3DV4	02/14/2025	02/14/2024	3662
Speag Validation Dipole D1640V2	02/11/2025	02/11/2022	330
Speag Validation Dipole D2450V2	05/06/2025	05/06/2024	829
Agilent N1911A Power Meter	03/08/2025	03/08/2024	GB45100254
Agilent N1922A Power Sensor	03/08/2025	03/08/2024	MY45240464
Agilent (HP) 8596E Spectrum Analyzer	03/08/2025	03/08/2024	3826A01468
Agilent (HP) 83752A Synthesized Sweeper	03/08/2025	03/08/2024	3610A01048
Agilent (HP) 8753C Vector Network Analyzer	03/08/2025	03/08/2024	3135A01724
Agilent (HP) 85047A S-Parameter Test Set	03/07/2025	03/07/2024	2904A00595
Copper Mountain R140 Vector Reflectometer	03/08/2025	03/08/2024	21390004
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 (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. 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. [3]

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] 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.

Appendix A – System Validation Plots and Data

Test Result for UIM Dielectric Parameter

Wed 05/Jun/2024

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
1.6100	40.29	1.28	39.66	1.50
1.6160	40.278	1.286	39.654	1.506*
1.6200	40.27	1.29	39.65	1.51
1.6210	40.268	1.29	39.647	1.511*
1.6260	40.258	1.29	39.632	1.516*
1.6300	40.25	1.29	39.62	1.52
1.6400	40.23	1.30	39.61	1.53
1.6500	40.21	1.31	39.60	1.54
1.6600	40.21	1.32	39.58	1.55
1.6700	40.22	1.33	39.56	1.56

* value interpolated

Test Result for UIM Dielectric Parameter

Thu 06/Jun/2024

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	38.30	1.75
2.4020	39.268	1.752	38.302	1.752*
2.4100	39.26	1.76	38.31	1.76
2.4200	39.25	1.77	38.29	1.77
2.4300	39.24	1.78	38.27	1.78
2.4400	39.22	1.79	38.26	1.80
2.4500	39.20	1.80	38.21	1.81
2.4600	39.19	1.81	38.21	1.82
2.4700	39.17	1.82	38.19	1.83
2.4800	39.16	1.83	38.17	1.86
2.4900	39.15	1.84	38.15	1.87

* value interpolated

RF Exposure Lab

Plot 1

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

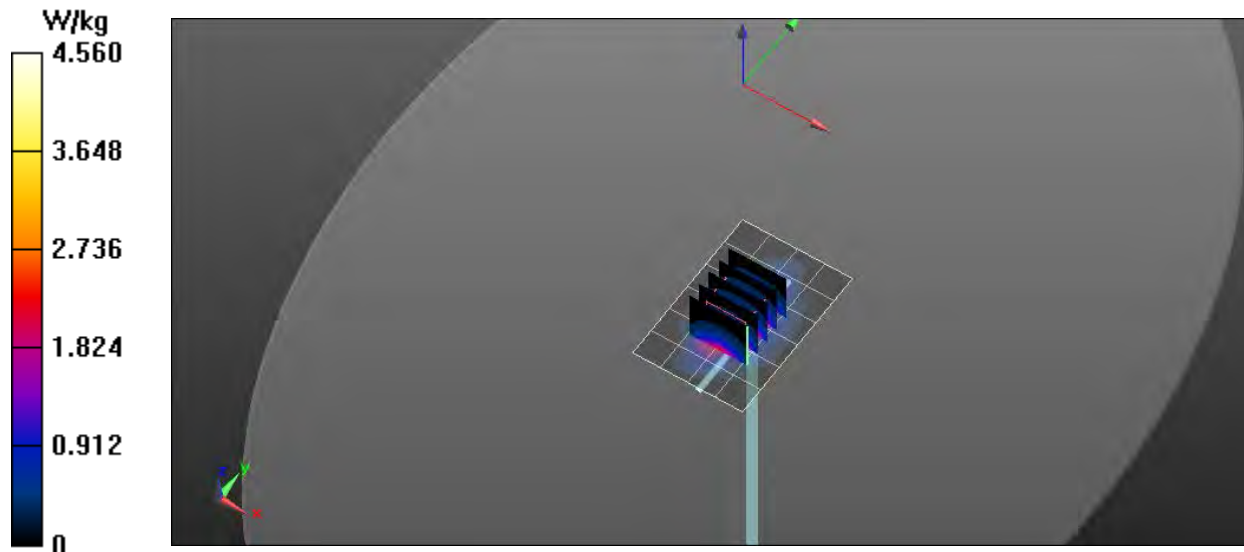
Communication System: CW; Frequency: 1640 MHz; Duty Cycle: 1:1
Medium: HSL1640; Medium parameters used: $f = 1640$ MHz; $\sigma = 1.53$ mho/m; $\epsilon_r = 39.61$; $\rho = 1000$ kg/m³
Phantom section: Flat Section

Test Date: Date: 6/5/2024; Ambient Temp: 23 °C; Tissue Temp: 21 °C
Probe: EX3DV4 - SN3662; ConvF(7.61, 8.12, 6.82); Calibrated: 2/14/2024;
Sensor-Surface: 2mm (Mechanical Surface Detection)
Electronics: DAE4 Sn1321; Calibrated: 1/15/2024
Phantom: ELI v4.0; Type: QDOVA001BB; Serial: 1065
Measurement SW: DASY52, Version 52.10 (0); SEMCAD X Version 14.6.10 (7417)

Procedure Notes:

1640 MHz Verification/Head/Area Scan (61x81x1): Interpolated grid: dx=1.500 mm, dy=1.500 mm
Maximum value of SAR (interpolated) = 3.96 W/kg

1640 MHz Verification/Head/Zoom Scan (5x5x7)/Cube 0: Measurement grid: dx=8mm, dy=8mm, dz=5mm
Reference Value = 55.926 V/m; Power Drift = -0.02 dB
Peak SAR (extrapolated) = 7.21 mW/g
 $P_{IN}=100$ mW
SAR(1 g) = 3.50 W/kg; SAR(10 g) = 1.87 W/kg
Maximum value of SAR (measured) = 4.56 W/kg



RF Exposure Lab

Plot 2

DUT: Dipole 2450 MHz D2450V2; Type: D2450V2; Serial: D2450V2 - SN: 829

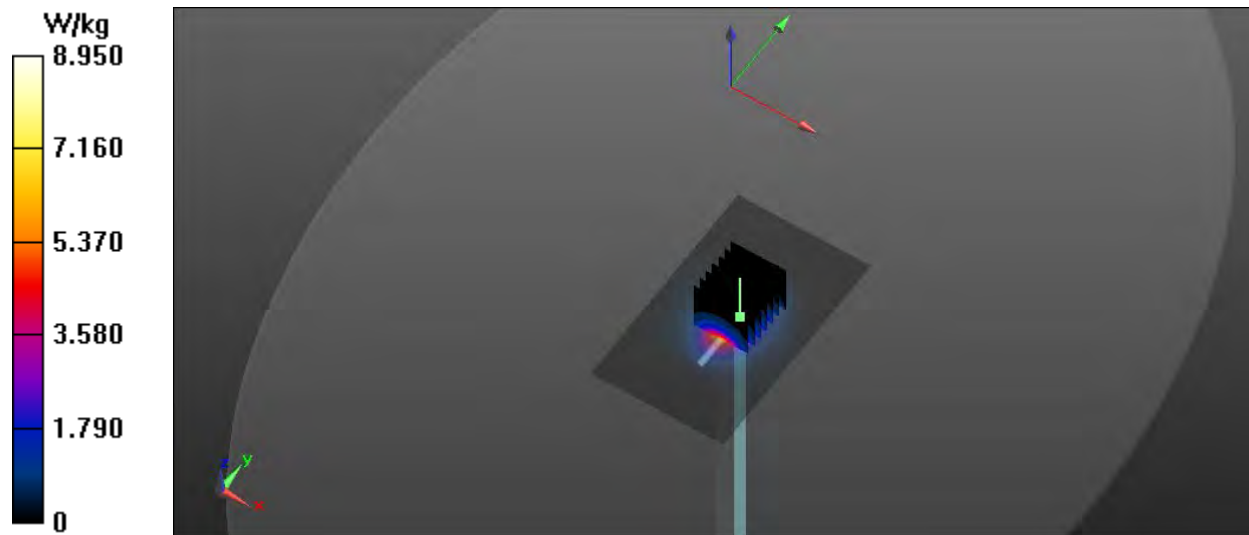
Communication System: CW; Frequency: 2450 MHz; Duty Cycle: 1:1
Medium: HSL2450; Medium parameters used: $f = 2450$ MHz; $\sigma = 1.81$ S/m; $\epsilon_r = 38.21$; $\rho = 1000$ kg/m³
Phantom section: Flat Section

Test Date: Date: 6/6/2024; Ambient Temp: 23 °C; Tissue Temp: 21 °C
Probe: EX3DV4 – SN3662; ConvF(6.93, 7.49, 6.22); Calibrated: 2/14/2024;
Sensor-Surface: 2mm (Mechanical Surface Detection)
Electronics: DAE4 Sn1321; Calibrated: 1/15/2024
Phantom: ELI v4.0; Type: QDOVA001BB; Serial: 1065
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) = 8.41 W/kg

Head Verification/2450 MHz/Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 59.112 V/m; Power Drift = -0.03 dB
Peak SAR (extrapolated) = 11.06 W/kg
 $P_{in} = 100$ mW
SAR(1 g) = 5.42 W/kg; SAR(10 g) = 2.53 W/kg
Maximum value of SAR (measured) = 8.94 W/kg



Appendix B – SAR Test Data Plots

RF Exposure Lab

Plot 1

DUT: A04746; Type: Digital Transmission System Transceiver; Serial: 16977296

Communication System: DE-QPSK; Frequency: 1620.98 MHz; Duty Cycle: 1:1
Medium: HSL1640; Medium parameters used (interpolated): $f = 1620.98$ MHz; $\sigma = 1.511$ S/m; $\epsilon_r = 39.647$; $\rho = 1000$ kg/m³
Phantom section: Flat Section

Test Date: Date: 6/6/2024; Ambient Temp: 23 °C; Tissue Temp: 21 °C

Probe: EX3DV4 - SN3662; ConvF(7.61, 8.12, 6.82); Calibrated: 2/14/2024
Sensor-Surface: 2mm (Mechanical Surface Detection)
Electronics: DAE4 Sn1321; Calibrated: 1/15/2024
Phantom: ELI v4.0; Type: QDOVA001BB; Serial: 1065
Measurement SW: DASY52, Version 52.10 (0); SEMCAD X Version 14.6.10 (7417)

Procedure Notes:

1640 MHz/Front Mid/Area Scan (7x9x1): Measurement grid: dx=15mm, dy=15mm

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

Maximum value of SAR (measured) = 6.57 W/kg

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

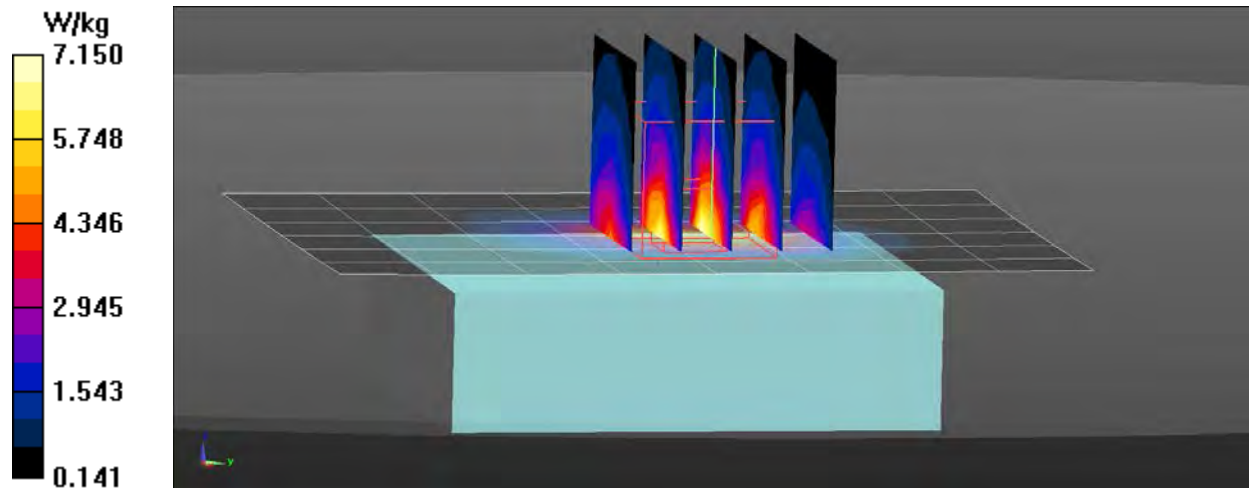
Reference Value = 70.70 V/m; Power Drift = -0.08 dB

Peak SAR (extrapolated) = 7.83 W/kg

SAR(1 g) = 5.84 W/kg; SAR(10 g) = 3.53 W/kg

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

Maximum value of SAR (measured) = 7.15 W/kg



RF Exposure Lab

Plot 2

DUT: A04746; Type: Digital Transmission System Transceiver; Serial: 16977296

Communication System: Bluetooth; Frequency: 2440 MHz; Duty Cycle: 1:1
Medium: HSL2450; Medium parameters used: $f = 2440$ MHz; $\sigma = 1.8$ S/m; $\epsilon_r = 38.26$; $\rho = 1000$ kg/m³
Phantom section: Flat Section

Test Date: Date: 6/6/2024; Ambient Temp: 23 °C; Tissue Temp: 21 °C

Probe: EX3DV4 - SN3662; ConvF(6.93, 7.49, 6.22); Calibrated: 2/14/2024
Sensor-Surface: 2mm (Mechanical Surface Detection)
Electronics: DAE4 Sn1321; Calibrated: 1/15/2024
Phantom: ELI v4.0; Type: QDOVA001BB; Serial: 1065
Measurement SW: DASY52, Version 52.10 (0); SEMCAD X Version 14.6.10 (7417)

Procedure Notes:

2450 MHz/Top Mid/Area Scan (10x13x1): Measurement grid: dx=10mm, dy=10mm

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

Maximum value of SAR (measured) = 0.00978 W/kg

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

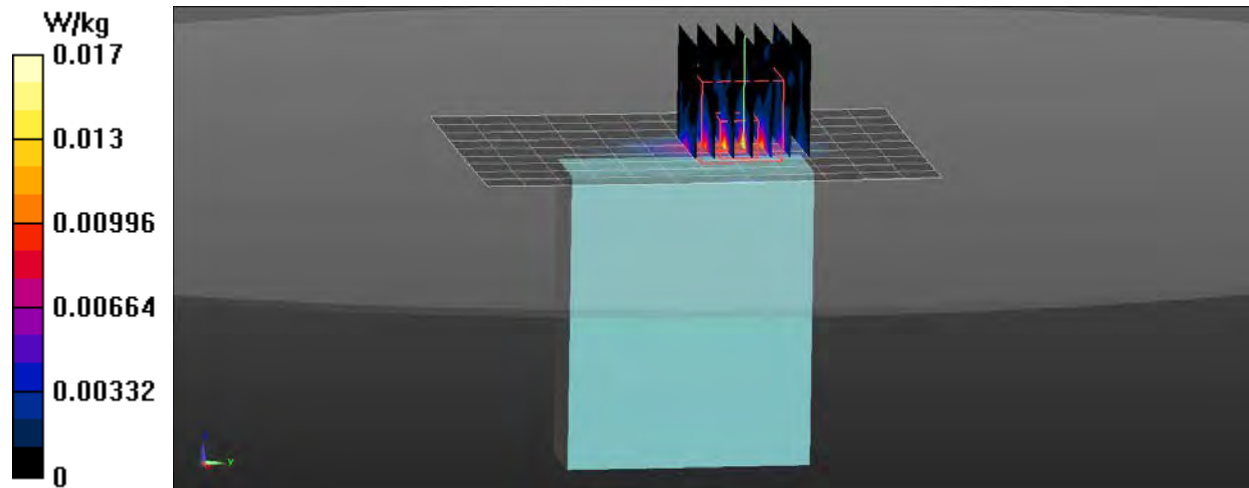
Reference Value = 1.738 V/m; Power Drift = -0.04 dB

Peak SAR (extrapolated) = 0.0200 W/kg

SAR(1 g) = 0.0091 W/kg; SAR(10 g) = 0.00267 W/kg

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

Maximum value of SAR (measured) = 0.0166 W/kg



Appendix D – Probe Calibration Data Sheets



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**

Accreditation No.: SCS 0108

Client **RF Exposure Lab**
San Marcos, USA

Certificate No. **EX-3662_Feb24**

CALIBRATION CERTIFICATE

Object EX3DV4 - SN:3662

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

Calibration date February 14, 2024

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.
All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3) °C and humidity < 70%.
Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP2	SN: 104778	30-Mar-23 (No. 217-03804/03805)	Mar-24
Power sensor NRP-Z91	SN: 103244	30-Mar-23 (No. 217-03804)	Mar-24
OCP DAK-3.5 (weighted)	SN: 1249	05-Oct-23 (OCP-DAK3.5-1249_Oct23)	Oct-24
OCP DAK-12	SN: 1016	05-Oct-23 (OCP-DAK12-1016_Oct23)	Oct-24
Reference 20 dB Attenuator	SN: CC2552 (20x)	30-Mar-23 (No. 217-03809)	Mar-24
DAE4	SN: 660	16-Mar-23 (No. DAE4-660_Mar23)	Mar-24
Reference Probe EX3DV4	SN: 7349	03-Nov-23 (No. EX3-7349_Nov23)	Nov-24

Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-22)	In house check: Jun-24
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-22)	In house check: Jun-24
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-22)	In house check: Jun-24
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-22)	In house check: Jun-24
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-22)	In house check: Oct-24

	Name	Function	Signature
Calibrated by	Jeffrey Katzman	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	

Issued: February 14, 2024

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

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

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

Accreditation No.: SCS 0108

Glossary

TSL	tissue simulating liquid
NORM _{x,y,z}	sensitivity in free space
ConvF	sensitivity in TSL / NORM _{x,y,z}
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C, D	modulation dependent linearization parameters
Polarization φ	φ rotation around probe axis
Polarization ϑ	ϑ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., $\vartheta = 0$ is normal to probe axis
Connector Angle	information used in DASY system to align probe sensor X to the robot coordinate system

Calibration is Performed According to the Following Standards:

- 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_{x,y,z}**: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not affect the E²-field uncertainty inside TSL (see below ConvF).
- NORM(f)_{x,y,z}** = NORM_{x,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.
- DCP_{x,y,z}**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal. DCP does not depend on frequency nor media.
- PAR**: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- A_{x,y,z}; B_{x,y,z}; C_{x,y,z}; D_{x,y,z}; VR_{x,y,z}**: A, B, C, D are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- 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_{x,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 NORM_x (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:3662

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.41	0.49	0.51	$\pm 10.1\%$
DCP (mV) ^B	100.0	100.2	97.8	$\pm 4.7\%$

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B $\text{dB}\sqrt{\mu\text{V}}$	C	D dB	VR mV	Max dev.	Max Unc ^E $k = 2$
0	CW	X	0.00	0.00	1.00	0.00	142.1	$\pm 2.6\%$	$\pm 4.7\%$
		Y	0.00	0.00	1.00		135.7		
		Z	0.00	0.00	1.00		122.6		

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%.

^A The uncertainties of Norm X,Y,Z do not affect the E^2 -field uncertainty inside TSL (see Pages 5 and 6).

^B Linearization parameter uncertainty for maximum specified field strength.

^E Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Parameters of Probe: EX3DV4 - SN:3662**Other Probe Parameters**

Sensor Arrangement	Triangular
Connector Angle	80.8°
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	9 mm
Tip Diameter	2.5 mm
Probe Tip to Sensor X Calibration Point	1 mm
Probe Tip to Sensor Y Calibration Point	1 mm
Probe Tip to Sensor Z Calibration Point	1 mm
Recommended Measurement Distance from Surface	1.4 mm

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

Parameters of Probe: EX3DV4 - SN:3662**Calibration Parameter Determined in Head Tissue Simulating Media**

f (MHz) ^C	Relative Permittivity ^F	Conductivity ^F (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha ^G	Depth ^G (mm)	Unc (k = 2)
150	52.3	0.76	11.37	11.37	11.37	0.00	1.25	±13.3%
220	49.0	0.81	11.10	11.10	11.10	0.00	1.25	±13.3%
300	45.3	0.87	10.56	10.56	10.56	0.09	1.00	±13.3%
450	43.5	0.87	10.11	10.11	10.11	0.16	1.30	±13.3%
600	42.7	0.88	9.72	9.72	9.72	0.10	1.25	±13.3%
750	41.9	0.89	8.69	9.23	7.72	0.38	1.27	±11.0%
900	41.5	0.97	8.07	8.67	7.35	0.37	1.27	±11.0%
1450	40.5	1.20	7.68	8.23	6.89	0.36	1.27	±11.0%
1640	40.2	1.31	7.61	8.12	6.82	0.32	1.27	±11.0%
1750	40.1	1.37	7.65	8.01	6.62	0.28	1.27	±11.0%
1900	40.0	1.40	7.37	7.91	6.59	0.30	1.27	±11.0%
2300	39.5	1.67	7.08	7.67	6.36	0.32	1.27	±11.0%
2450	39.2	1.80	6.93	7.49	6.22	0.30	1.27	±11.0%
2600	39.0	1.96	6.81	7.33	6.11	0.30	1.27	±11.0%
5250	35.9	4.71	5.12	5.37	4.57	0.33	1.72	±13.1%
5600	35.5	5.07	4.70	4.92	4.17	0.41	1.67	±13.1%
5750	35.4	5.22	4.83	5.08	4.30	0.41	1.75	±13.1%

^C 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 The probes are calibrated using tissue simulating liquids (TSL) that deviate for ϵ and σ by less than ±5% from the target values (typically better than ±3%) and are valid for TSL with deviations of up to ±10% if SAR correction is applied.

^G 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.

Parameters of Probe: EX3DV4 - SN:3662

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) ^C	Relative Permittivity ^F	Conductivity ^F (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha ^G	Depth ^G (mm)	Unc (k = 2)
6500	34.5	6.07	5.53	5.80	5.00	0.20	2.00	±18.6%

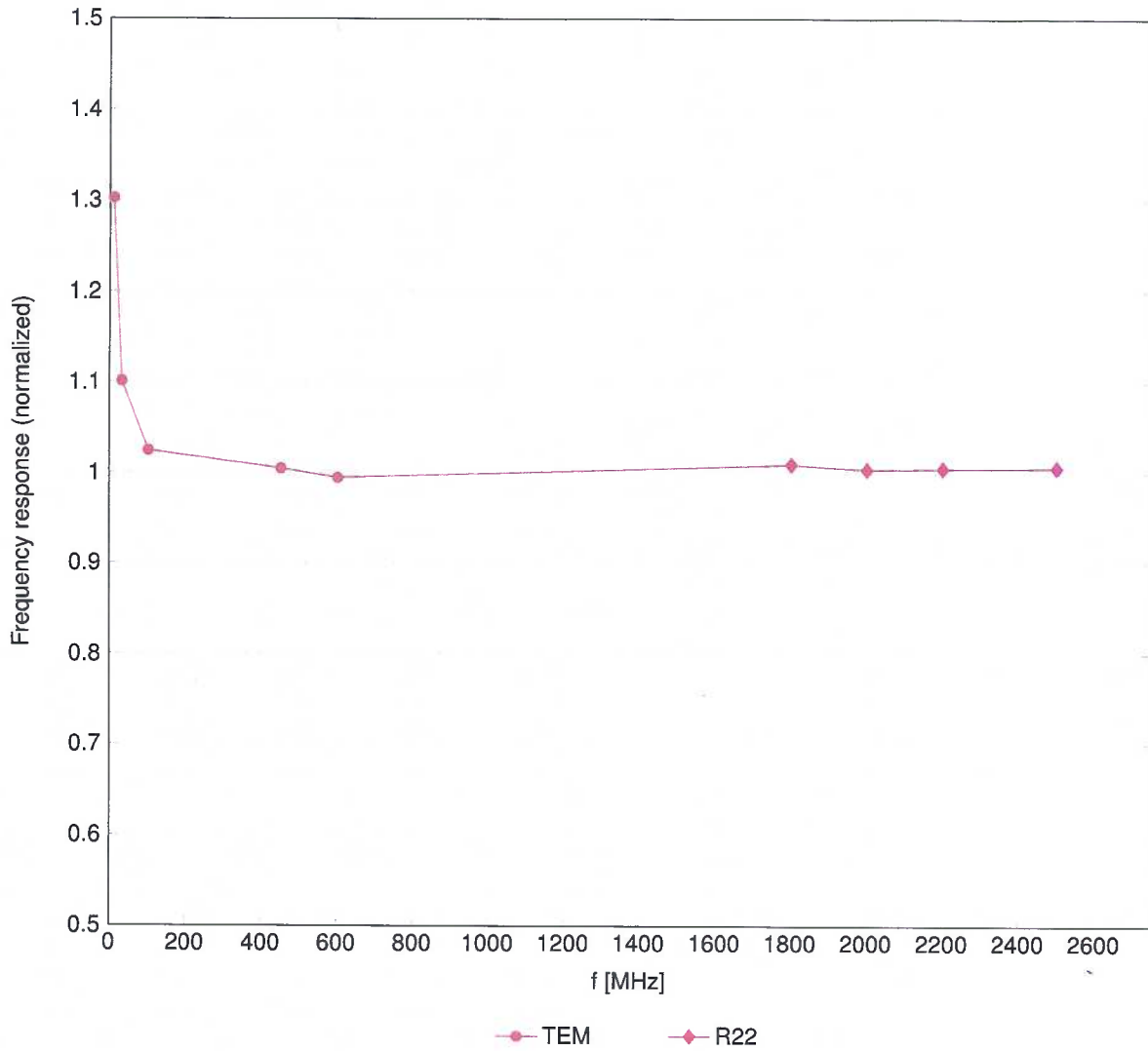
^C Frequency validity at 6.5 GHz is -600/+700 MHz, and ±700 MHz at or above 7 GHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

^F The probes are calibrated using tissue simulating liquids (TSL) that deviate for ϵ and σ by less than ±10% from the target values (typically better than ±6%) and are valid for TSL with deviations of up to ±10%.

^G 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.

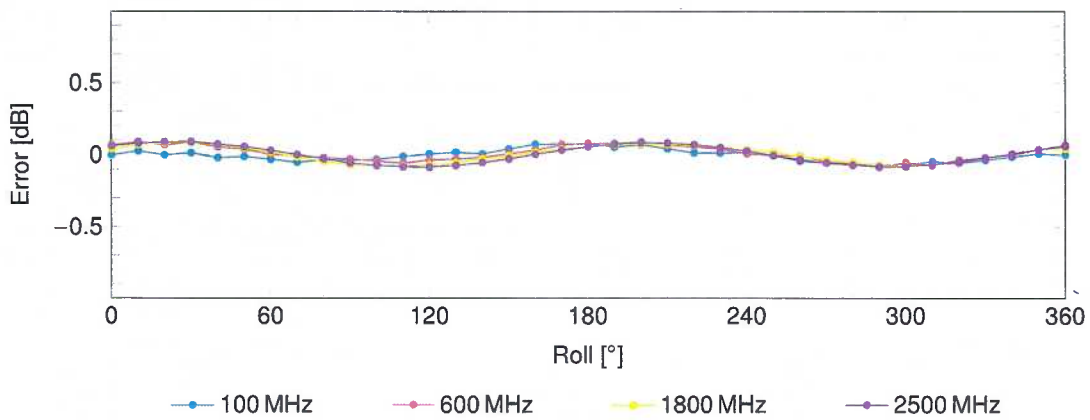
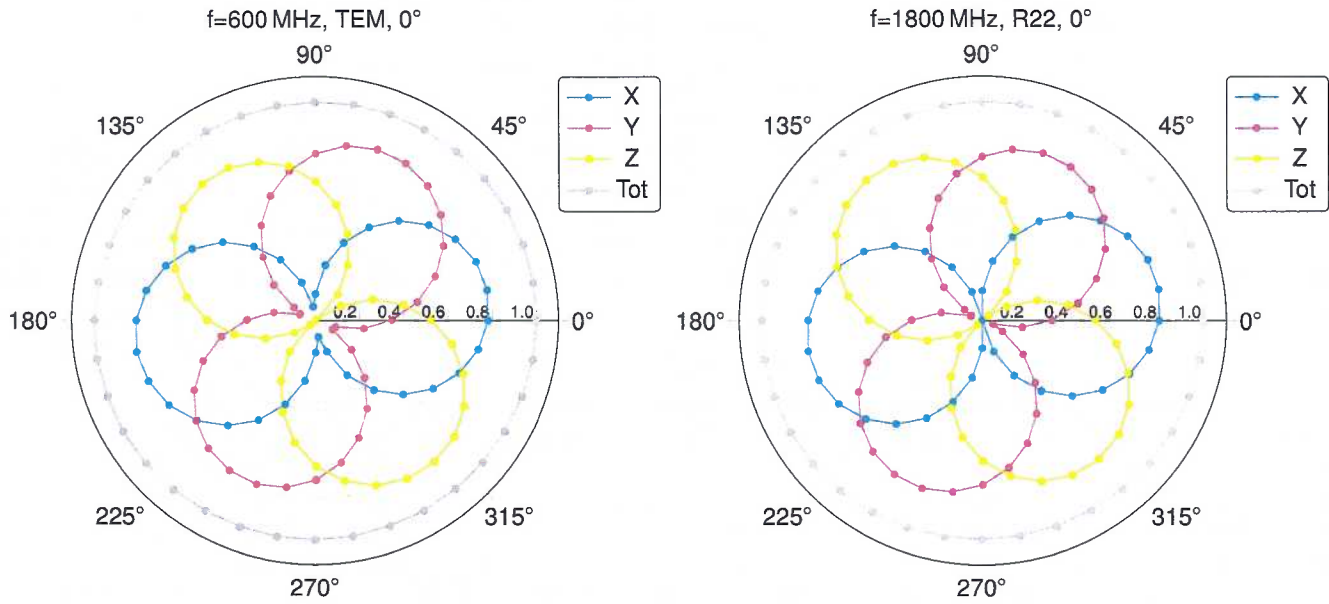
Frequency Response of E-Field

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



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

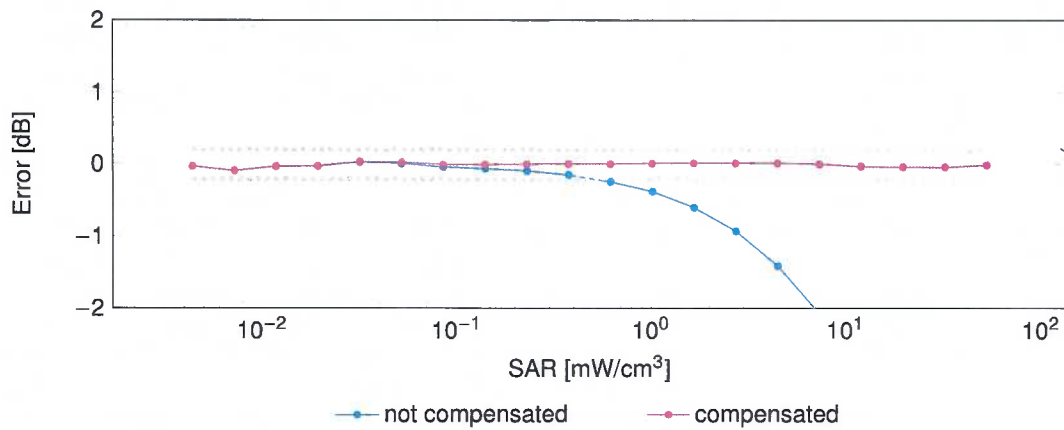
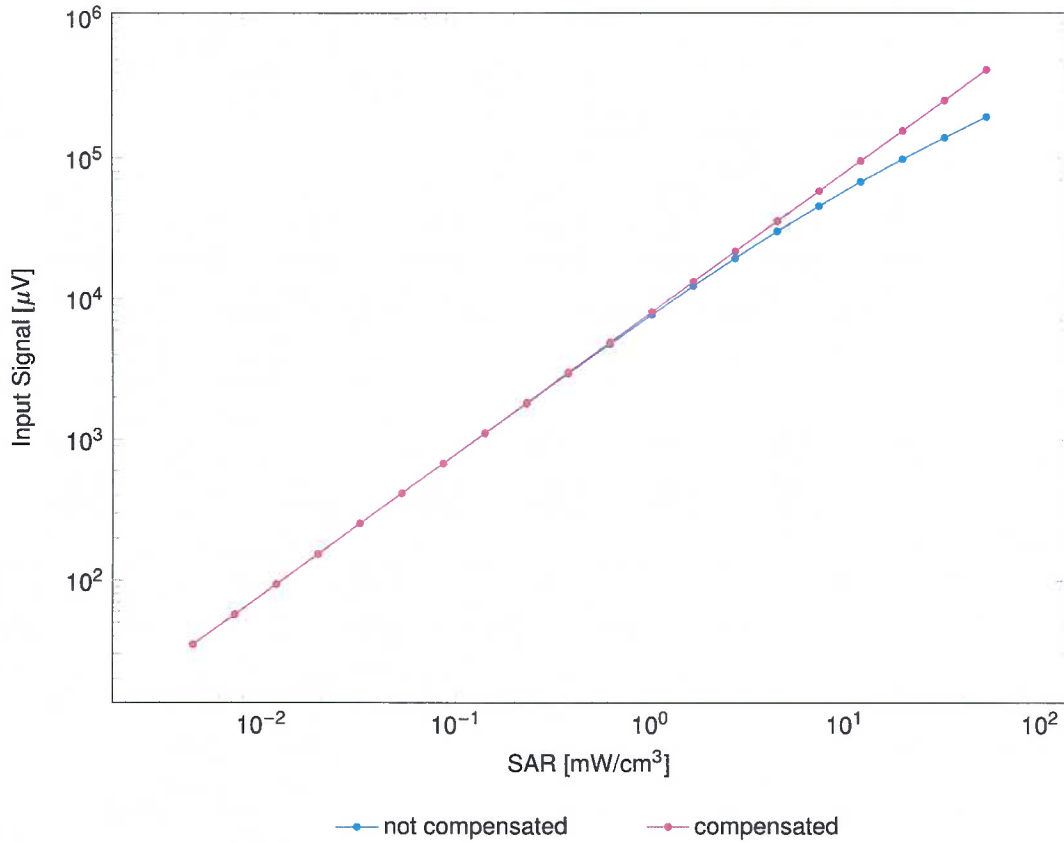
Receiving Pattern (ϕ), $\vartheta = 0^\circ$



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

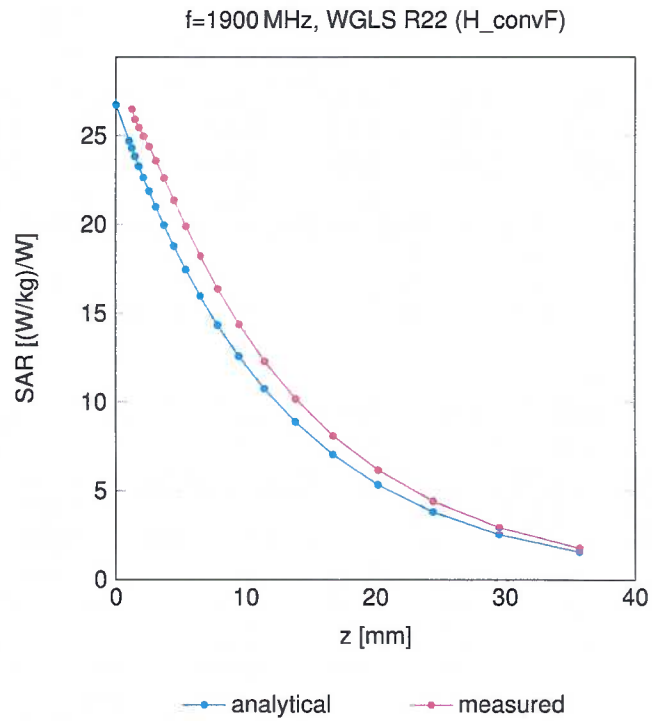
Dynamic Range f(SAR_{head})

(TEM cell, f_{eval} = 1900MHz)



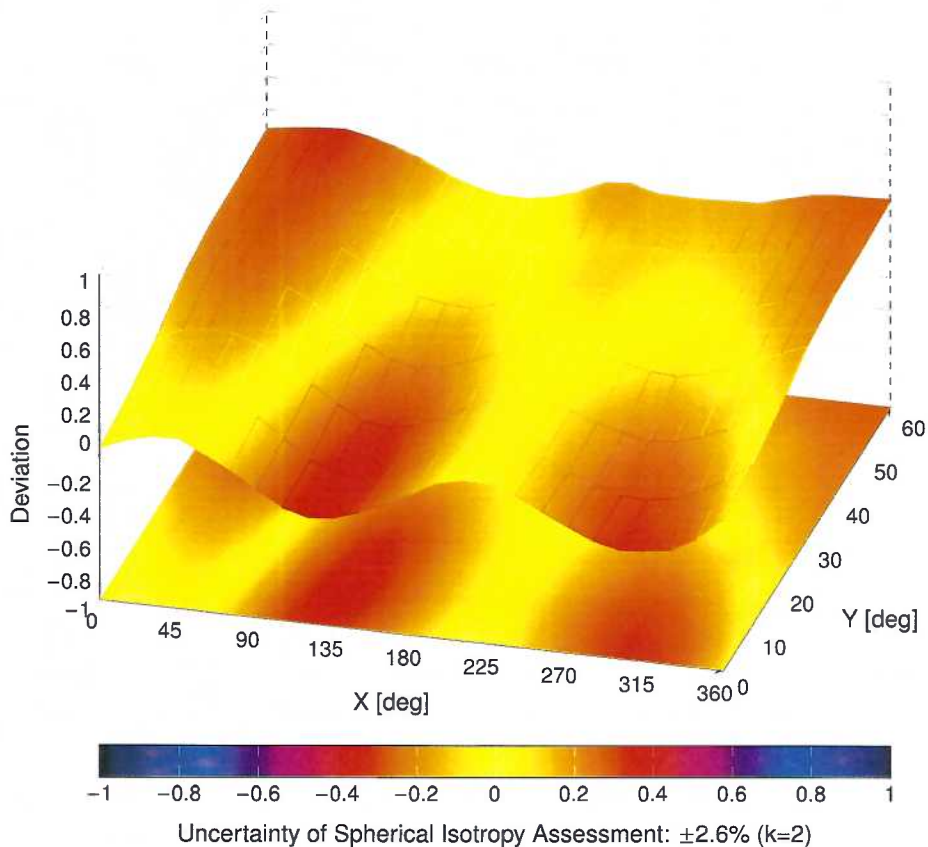
Uncertainty of Linearity Assessment: ±0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid

Error (ϕ, θ), f = 900 MHz



Appendix E – Dipole Calibration Data Sheets



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

Accreditation No.: **SCS 0108**

Client **RF Exposure Lab**

Certificate No: **D1640V2-330_Feb22**

CALIBRATION CERTIFICATE

Object **D1640V2 - SN:330**

Calibration procedure(s) **QA CAL-05.v11
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	

	Name	Function
Approved by:	Sven Kühn	Deputy Manager

Issued: February 17, 2022

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



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

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:

- 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%.

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 cm³ (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)

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	53.6 Ω + 2.5 j Ω
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
-----------------	-------

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.

D1640V2 SN: 330 - Head						
Date of Measurement	Return Loss (dB)	$\Delta\%$	Impedance (Ω)	$\Delta\Omega$	Impedance Imaginary (j Ω)	$\Delta\Omega$
2/11/2022	-27.5		53.6		2.5	
2/13/2023	-26.8	-2.5	52.4	-1.2	2.6	0.1
2/13/2024	-26.2	-4.7	53.9	0.3	2.3	-0.2

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; $\sigma = 1.29$ S/m; $\epsilon_r = 40.6$; $\rho = 1000$ kg/m³

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

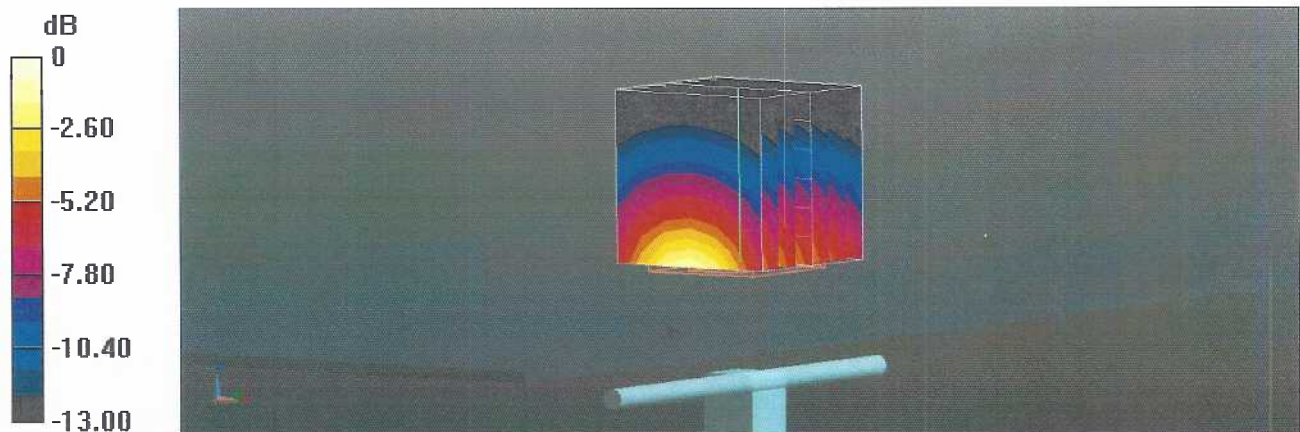
Peak SAR (extrapolated) = 15.4 W/kg

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

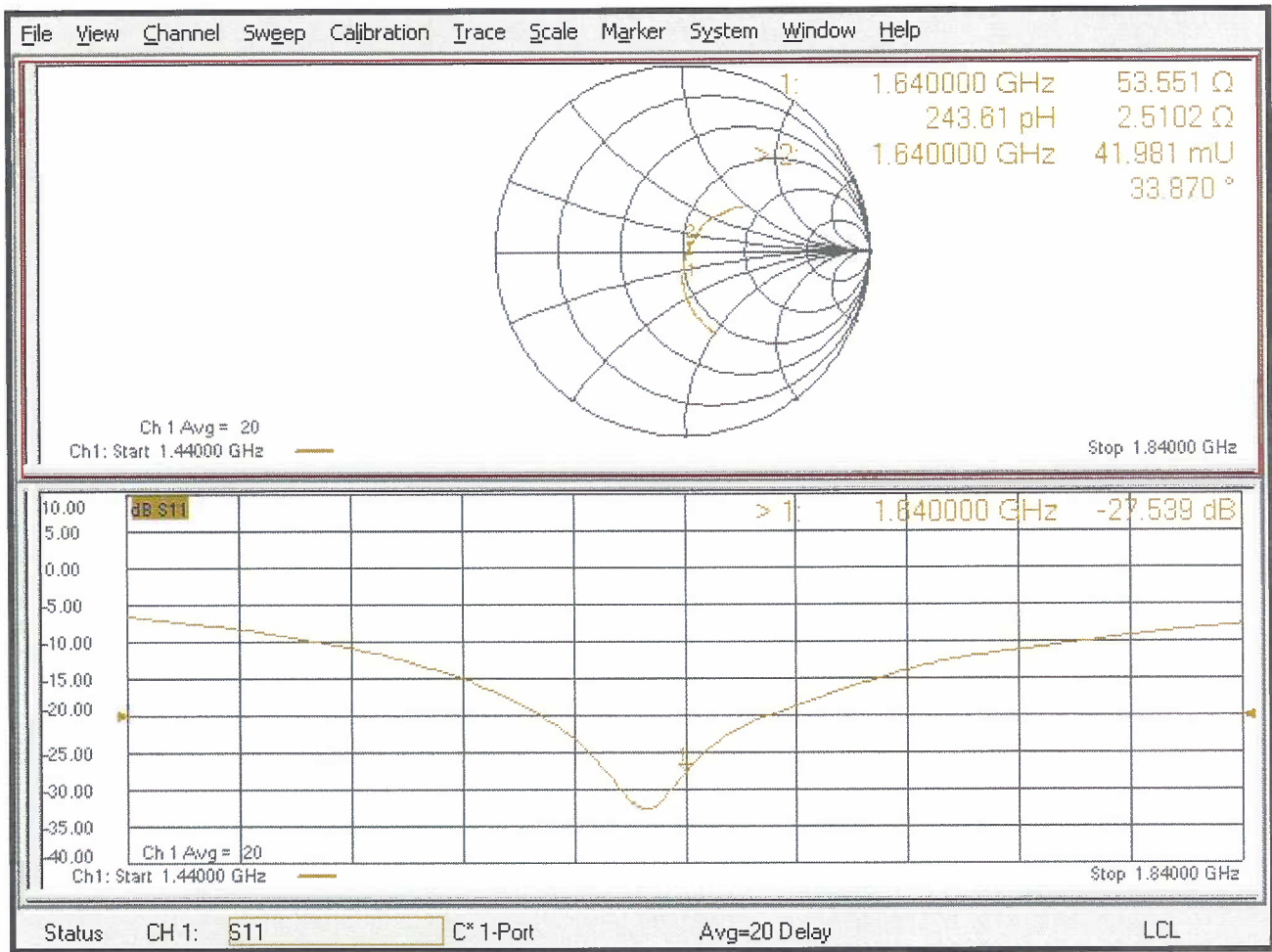
Smallest distance from peaks to all points 3 dB below = 10 mm

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

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



Impedance Measurement Plot for Head TSL





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**
San Marcos, USA

Certificate No. **D2450V2-829_May24**

CALIBRATION CERTIFICATE

Object **D2450V2 - SN:829**

Calibration procedure(s) **QA CAL-05.v12**
Calibration Procedure for SAR Validation Sources between 0.7-3 GHz

Calibration date: **May 06, 2024**

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP2	SN: 104778	26-Mar-24 (No. 217-04036/04037)	Mar-25
Power sensor NRP-Z91	SN: 103244	26-Mar-24 (No. 217-04036)	Mar-25
Power sensor NRP-Z91	SN: 103245	26-Mar-24 (No. 217-04037)	Mar-25
Reference 20 dB Attenuator	SN: BH9394 (20k)	26-Mar-24 (No. 217-04046)	Mar-25
Type-N mismatch combination	SN: 310982 / 06327	26-Mar-24 (No. 217-04047)	Mar-25
Reference Probe EX3DV4	SN: 7349	03-Nov-23 (No. EX3-7349_Nov23)	Nov-24
DAE4	SN: 601	30-Jan-24 (No. DAE4-601_Jan24)	Jan-25

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB39512475	30-Oct-14 (in house check Oct-22)	In house check: Oct-24
Power sensor HP 8481A	SN: US37292783	07-Oct-15 (in house check Oct-22)	In house check: Oct-24
Power sensor HP 8481A	SN: MY41093315	07-Oct-15 (in house check Oct-22)	In house check: Oct-24
RF generator R&S SMT-06	SN: 100972	15-Jun-15 (in house check Oct-22)	In house check: Oct-24
Network Analyzer Agilent E8358A	SN: US41080477	31-Mar-14 (in house check Oct-22)	In house check: Oct-24

Calibrated by: **Leif Klysner** Name: **Leif Klysner** Function: **Laboratory Technician**

Approved by: **Sven Kühn** Name: **Sven Kühn** Function: **Technical Manager**

Signature

Issued: May 7, 2024

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



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:

- 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"

Additional Documentation:

- 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%.

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	2450 MHz \pm 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	39.2	1.80 mho/m
Measured Head TSL parameters	(22.0 \pm 0.2) °C	37.9 \pm 6 %	1.88 mho/m \pm 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	13.7 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	53.3 W/kg \pm 17.0 % (k=2)

SAR averaged over 10 cm³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	6.36 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	25.0 W/kg \pm 16.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	53.9 Ω + 4.1 j Ω
Return Loss	- 25.4 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
-----------------	-------

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN:829

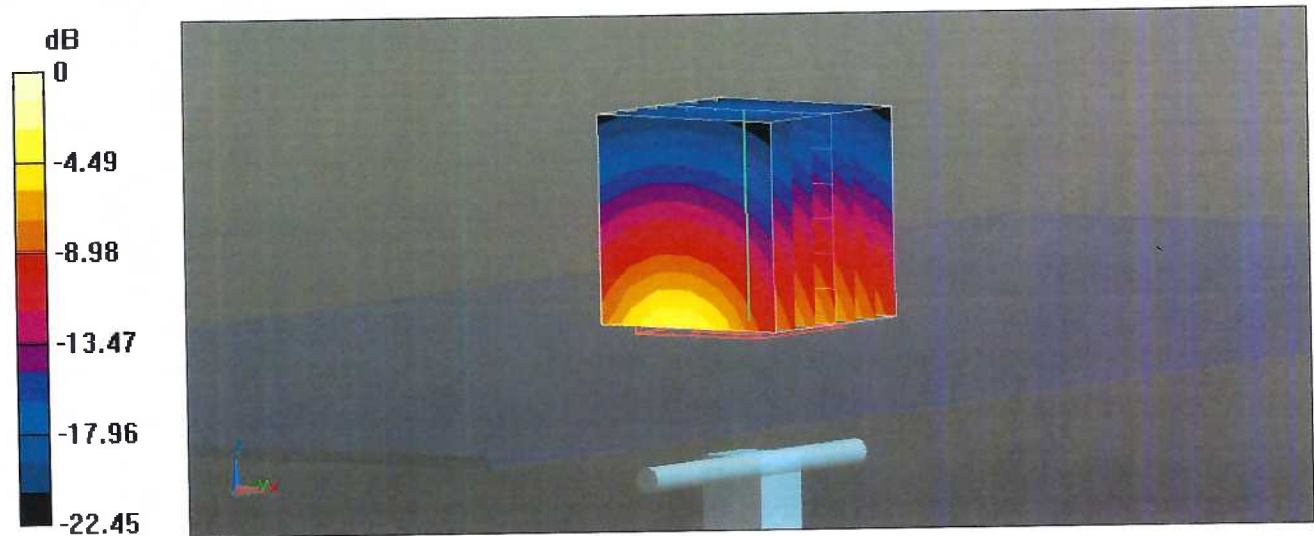
Communication System: UID 0 - CW; Frequency: 2450 MHz
Medium parameters used: $f = 2450$ MHz; $\sigma = 1.88$ S/m; $\epsilon_r = 37.9$; $\rho = 1000$ kg/m³
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.96, 7.96, 7.96) @ 2450 MHz; Calibrated: 03.11.2023
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.01.2024
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

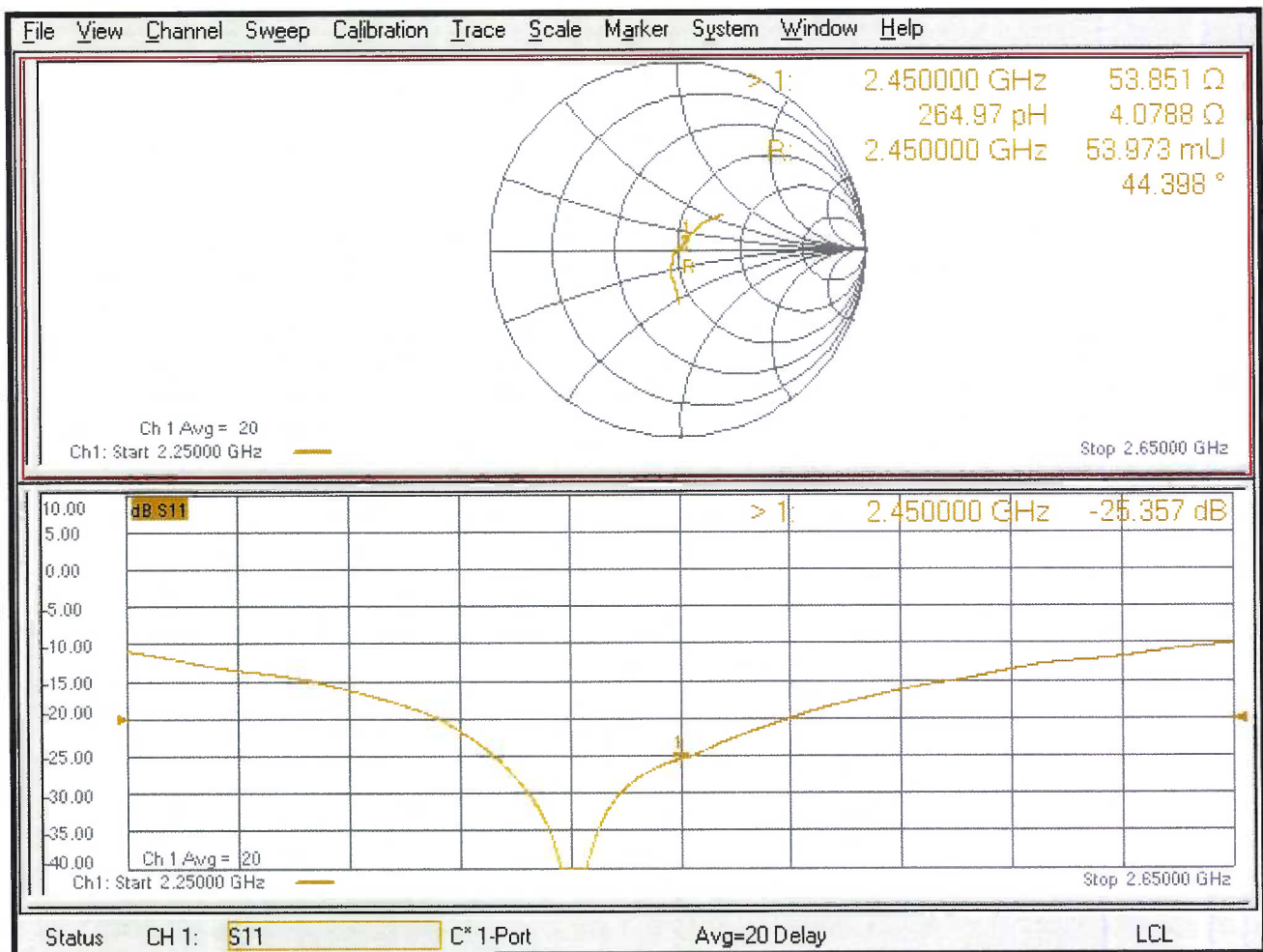
Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 116.7 V/m; Power Drift = 0.10 dB
Peak SAR (extrapolated) = 27.4 W/kg
SAR(1 g) = 13.7 W/kg; SAR(10 g) = 6.36 W/kg
Smallest distance from peaks to all points 3 dB below = 9 mm
Ratio of SAR at M2 to SAR at M1 = 50.6%
Maximum value of SAR (measured) = 21.9 W/kg



0 dB = 21.9 W/kg = 13.40 dBW/kg

Impedance Measurement Plot for Head TSL



Appendix F – DAE Calibration Data Sheets



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

Accreditation No.: **SCS 0108**

Client **RF Exposure Lab**
San Marcos, USA

Certificate No: **DAE4-1321_Jan24**

CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 1321**

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

Calibration date: **January 15, 2024**

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Keithley Multimeter Type 2001	SN: 0810278	29-Aug-23 (No:37421)	Aug-24
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	27-Jan-23 (in house check)	In house check: Jan-24
Calibrator Box V2.1	SE UMS 006 AA 1002	27-Jan-23 (in house check)	In house check: Jan-24

Calibrated by: **Dominique Steffen** Function: **Laboratory Technician**

Signature

Approved by: **Sven Kühn** Technical Manager

Issued: January 15, 2024

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



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.

DC Voltage Measurement

A/D - Converter Resolution nominal

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

Low Range: 1LSB = 61nV, full range = -1.....+3mV

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

Calibration Factors	X	Y	Z
High Range	405.047 \pm 0.02% (k=2)	404.878 \pm 0.02% (k=2)	405.288 \pm 0.02% (k=2)
Low Range	3.96649 \pm 1.50% (k=2)	3.99492 \pm 1.50% (k=2)	4.00458 \pm 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	0.0 $^{\circ}$ \pm 1 $^{\circ}$
---	-----------------------------------

Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	199997.21	-1.47	-0.00
Channel X + Input	20008.61	2.50	0.01
Channel X - Input	-19994.36	3.87	-0.02
Channel Y + Input	200000.32	1.62	0.00
Channel Y + Input	20004.55	-1.53	-0.01
Channel Y - Input	-19999.08	-0.94	0.00
Channel Z + Input	199998.68	-0.04	-0.00
Channel Z + Input	20004.02	-1.95	-0.01
Channel Z - Input	-19999.80	-1.59	0.01

Low Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	2004.42	-0.44	-0.02
Channel X + Input	205.99	0.90	0.44
Channel X - Input	-193.79	1.03	-0.53
Channel Y + Input	2005.19	0.20	0.01
Channel Y + Input	204.01	-1.22	-0.60
Channel Y - Input	-194.77	-0.20	0.10
Channel Z + Input	2004.45	-0.55	-0.03
Channel Z + Input	204.73	-0.48	-0.24
Channel Z - Input	-195.71	-1.10	0.56

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	17.56	15.38
	- 200	-14.31	-15.72
Channel Y	200	1.48	1.39
	- 200	-3.35	-3.61
Channel Z	200	-13.82	-13.62
	- 200	13.53	13.05

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	-	1.85	-4.18
Channel Y	200	8.99	-	2.84
Channel Z	200	10.54	5.70	-

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	15471	15013
Channel Y	15577	15348
Channel Z	16351	15583

5. Input Offset Measurement

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

Input 10M Ω

	Average (μ V)	min. Offset (μ V)	max. Offset (μ V)	Std. Deviation (μ V)
Channel X	1.25	-0.30	2.44	0.59
Channel Y	-0.60	-1.95	0.58	0.57
Channel Z	-0.27	-1.85	1.20	0.58

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 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	all
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

- [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.

Date 28.4.2008 Signature / Stamp

s p e a g
Schmid & Partner Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland
Phone +41 44 245 9700, Fax +41 44 245 9779
info@speag.com; http://www.speag.com

Appendix H – Validation Summary

Per FCC KDB 865664 D02 v01r02, SAR system validation status should be documented to confirm measurement accuracy. The SAR systems (including SAR probes, system components and software versions) used for this device were validated against its performance specifications prior to the SAR measurements. Reference dipoles were used with the required tissue equivalent media for system validation according to the procedures outlined in FCC KDB 865664 D01 v01r04 and IEEE 1528-2013. Since SAR probe calibrations are frequency dependent, each probe calibration point was validated at a frequency within the valid frequency range of the probe calibration point using the system that normally operates with the probe for routine SAR measurements and according to the required tissue equivalent media.

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

**Table H-1
SAR System Validation Summary**

SAR System #	Freq. (MHz)	Date	Probe S/N	Probe Type	Probe Cal. Point	Cond. (σ)	Perm. (ϵ_r)	CW Validation			Modulation Validation			
								Sensitivity	Probe Linearity	Probe Isotropy	Modulation Type	Duty Factor	PAR	
2	1640	03/07/2024	3662	EX3DV4	1640	Head	1.33	39.85	Pass	Pass	Pass	DE-QPSK	Pass	Pass
2	2450	03/13/2024	3662	EX3DV4	2450	Head	1.84	38.65	Pass	Pass	Pass	GMSK	Pass	Pass