Report on the Specific Absorption Rate Testing of the Nuki Home Solutions GmbH

Add value.
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Model: Smart Lock Ultra

In accordance with FCC 47 CFR 2.1093 (2023)

Prepared for: Nuki Home Solutions GmbH
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FCC ID: 2BH6T012518

COMMERCIAL-IN-CONFIDENCE

Document Number: 75964657-01 Issue:01

SIGNATURE			
NAME	**JOB TITLE**	**RESPONSIBLE FOR**	**ISSUE DATE**
Jon Kenny	Technical Director – SAR	Authorised Signatory	10 June 2025

Signatories in this approval box have checked this document in line with the requirements of TÜV SÜD document control rules.

FCC Accreditation
553713/UK2026 Concorde Park, Fareham Test Laboratory

EXECUTIVE SUMMARY
A sample of this product was tested and found to be compliant with FCC 47 CFR 2.1093 (2023) for the tests detailed in section 1.4.

ACCREDITATION
Results of tests covered by our Flexible UKAS Accreditation Schedule are marked FS (Flexible Scope)
Results of tests not covered by our UKAS Accreditation Schedule are marked NUA (Not UKAS Accredited)
Our UKAS Accreditation does not cover opinions and interpretations and any expressed are outside the scope of our UKAS Accreditation.

CONTENTS

SECTION 1

REPORT SUMMARY

Specific Absorption Rate Testing of the Smart Lock Ultra

1.1 REPORT MODIFICATION RECORD

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	10-Jun-2025

Table 1

1.2 INTRODUCTION

The information contained in this report is intended to show verification of the Specific Absorption Rate testing of the Smart Lock Ultra to the requirements of FCC 47 CFR 2.1093 (2023).

Objective	To determine the Equipment Under Test's (EUT) compliance with the requirements specified within FCC 47 CFR 2.1093 (2023).
Applicant	Nuki Home Solutions GmbH
EUT/Sample Identification	Refer to section 1.3
Test Specification/Issue/Date	FCC 47 CFR 2.1093 (2023)
Start of Test	27-May-2025
Finish of Test	30-May-2025
Related Document(s)	FCC 47 CFR 1.1310 (2023) KDB 248227 - D01 v02r02 KDB 447498 - D01 v06 KDB 865664 - D01 v01r04
Name of Engineer(s)	William Jameson

1.3 IDENTIFICATION OF THE EUT

The table below details identification of the EUT(s) that have been used to carry out the testing within this report.

Model: Smart Lock Ultra			
Serial Number	Hardware Version	Software Version	Firmware Version
012.518	11.16	N/A	5.3.7

Table 2

1.4 BRIEF SUMMARY OF RESULTS

The measurements shown in this report were made to the requirements of FCC 47 CFR 2.1093 (2023).

1.4.1 Summary of Maximum Values

The maximum 10g volume averaged stand-alone SAR found during this Assessment:

Max 10g SAR (W/kg) Body	0.039 (Measured)	0.062 (Scaled)
The maximum 10g volume averaged SAR level measured for all the tests performed did not exceed the limits for FCC General Population/Uncontrolled Exposure (W/Kg) extremity of 4.0 W/Kg in accordance with FCC 47 CFR 1.1310 (2023).		

Table 3

The maximum 10g volume averaged stand-alone Reported SAR found during this assessment for each supported mode:

Technology	Band	Test Configuration	Max Reported SAR (W/kg)
WLAN 802.11b	2.4GHz	0mm Front	0.054
WLAN 802.11g	2.4GHz	0mm Front	0.062
The maximum 10g volume averaged SAR level measured for all the tests performed (including simultaneous transmission analysis results) did not exceed the limits for general population/uncontrolled extremity limit of 4.0 W/kg.			

Table 4

1.4.2 Simultaneous Transmission

Thread and Bluetooth qualify for the standalone SAR test exclusion in Clause 4.3.1 in KDB 447498 D01 v06.

Due to this we are using the calculation for estimated SAR found in Clause 4.3.2 in KDB 447498 D01 v06 which is as follows:

$$\boldsymbol{Estimated\ SAR}\ (\frac{\boldsymbol{W}}{\boldsymbol{Kg}}) = \frac{\boldsymbol{Max\ power}(\boldsymbol{mW})}{\boldsymbol{Min\ Seperation\ distance}\ (\boldsymbol{mm})} \cdot \frac{\sqrt{\boldsymbol{Frequency}}(\boldsymbol{GHz})}{\boldsymbol{18.75}}$$

Technology	Max Power (mW)	Min, Separation distance (mm)	Frequency (GHz)	Estimated 10g SAR (W/Kg)	Scaled estimate 10g SAR (W/Kg)
Bluetooth	0.997	5	2.412	0.017	0.027
Thread	0.910	5	2.412	0.015	0.024

Table 5

The simultaneous transmission this EUT can transmit is WLAN, Bluetooth and Thread. The maximum SAR values are then added together to find the total of the simultaneous transmission SAR.

Position	10g WLAN 802.11g SAR (W/Kg)	10g Bluetooth SAR (W/Kg)	10g Thread SAR (W/Kg)	Sum of 10g SAR (W/Kg)
0mm Front	0.062	0.027	0.024	0.113
Limit for general population, extremity (uncontrolled exposure) 4.0 W/Kg (10g)				

Table 6

1.5 TEST RESULTS SUMMARY

1.5.1 Results Summary Tables

WLAN – 802.11b – 1Mbps:
Specific Absorption Rate (SAR) 10g Results

Test Position	Channel Number	Frequency (MHz)	Measured Average Power (dBm)	Tune Up (dBm)	Measured 10g SAR (W/kg)	Scaled 10g SAR (W/kg)	Scan Figure Number
0mm Front	7	2442	8.55	10.55	0.024	0.038	-
0mm Left	7	2442	8.55	10.55	0.000	0.000	-
0mm Right	7	2442	8.55	10.55	0.000	0.000	-
0mm Top	7	2442	8.55	10.55	0.003	0.005	-
0mm Bottom	7	2442	8.55	10.55	0.000	0.000	-
0mm Front	1	2412	8.30	10.30	0.034	0.054	C.1
0mm Front	11	2462	8.45	10.45	0.018	0.029	-
Limit for general population, extremity (uncontrolled exposure) 4.0 W/Kg (10g)							

Table 7

WLAN – 802.11g – 6Mbps:
Specific Absorption Rate (SAR) 10g Results

Test Position	Channel Number	Frequency (MHz)	Measured Average Power (dBm)	Tune Up (dBm)	Measured 10g SAR (W/kg)	Scaled 10g SAR (W/kg)	Scan Figure Number
0mm Front	7	2442	9.78	11.78	0.028	0.044	-
0mm Left	7	2442	9.78	11.78	0.000	0.000	-
0mm Right	7	2442	9.78	11.78	0.000	0.000	-
0mm Top	7	2442	9.78	11.78	0.006	0.010	-
0mm Bottom	7	2442	9.78	11.78	0.000	0.000	-
0mm Front	1	2412	9.40	11.40	0.039	0.062	C.2
0mm Front	11	2462	9.58	11.58	0.026	0.041	-
Limit for general population, extremity (uncontrolled exposure) 4.0 W/Kg (10g)							

Table 8

1.5.2 Technical Description

The equipment under test (EUT) was a Smart Lock.

1.5.3 Test Configuration and Modes of Operation

The testing was performed with an integral battery supplied and manufactured by Yigao Technology.

Supported technologies are 2.4 GHz WLAN (802.11b/g/n), Bluetooth and Thread.

Testing was achieved using a Raspberry Pi and a Serial Connection to configure the EUT to transmit using the technology and channel specified in the test. The Serial Connection was removed as the test was running, however the wires soldered to the PCB stayed attached to the EUT.

Due to the low output power of the Bluetooth and Thread technologies they can be excluded from standalone SAR testing as defined in KDB 447498 D01 v06 clause 4.3.1.

For each scan, the device was configured into a continuous transmission test mode at a maximum power defined by the customer.

Testing was performed in each position at the frequency that gave the highest output power for each band. Testing was then performed on the worst-case face for the two remaining channels.

Conducted power measurements were supplied by the customer and can be found in section 1.6 of this report. It was not possible to verity the output power of the EUT before testing. The measured SAR results were power scaled to the maximum declared tolerance provided by the customer.

For SAR assessment, the Front, Top Edge, Bottom Edge, Left Edge and Right Edge of the device were placed against an Elliptical phantom with a 0mm separation distance. The Back of the EUT was exempt due to being inaccessible to the user in normal operation due to that face of the device being mounted to a door.

The Elliptical Flat Phantom dimensions are 600mm major axis and 400mm minor axis with a shell thickness of 2mm. The phantom was filled to a minimum depth of 150mm with the appropriate liquid. The dielectric properties were in accordance with the requirements specified in KDB 865664 D01 v01r04.

Included in this report are descriptions of the test method; the equipment used and an analysis of the test uncertainties applicable and diagrams indicating the locations of maximum SAR for each relevant test position.

1.5.4 Antenna Location Diagram

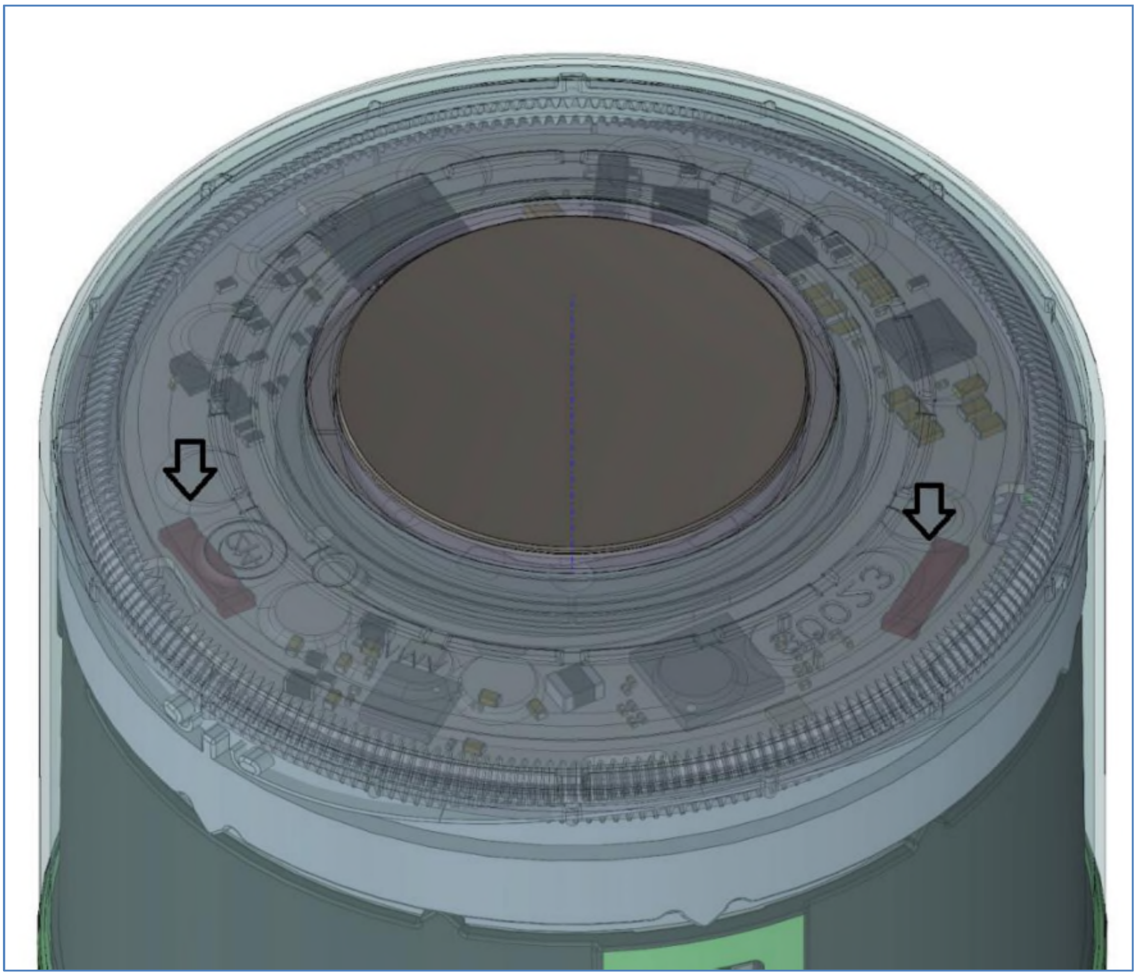


Figure 1

1.5.5 Deviations from Standard

During testing the device has wired attached to the PCB that are not normally present during normal operation and are only there to put the device into a test mode for the SAR testing.

1.6 CONDUCTED POWER MEASUREMENTS

1.6.1 Method

Conducted Power Measurements were supplied by the customer. The WLAN values can be found in report TR-713334509-3. A tune-up value of 2dBm was declared by the customer.

1.6.2 Measured Results

WLAN 2.4GHz

(WLAN 802.11b)

Technology	Channel	Modulation	Duty Cycle (%)	Rate (Mbps)	Frequency (MHz)	Measured Power (dBm)	Tune Up (dBm)
WLAN	1	BPSK	100	1	2412	8.303	10.303
WLAN	7	BPSK	100	1	2442	8.548	10.548
WLAN	11	BPSK	100	1	2462	8.453	10.453

Table 9

(WLAN 802.11g)

Technology	Channel	Modulation	Duty Cycle (%)	Rate (Mbps)	Frequency (MHz)	Measured Power (dBm)	Tune Up (dBm)
WLAN	1	BPSK	100	6	2412	9.399	11.399
WLAN	7	BPSK	100	6	2442	9.775	11.775
WLAN	11	BPSK	100	6	2462	9.578	11.578

Table 10

(WLAN 802.11n)

Technology	Channel	Modulation	Duty Cycle (%)	Rate (Mbps)	Frequency (MHz)	Measured Power (dBm)	Tune Up (dBm)
WLAN	1	BPSK	100	6.5	2412	9.039	11.039
WLAN	7	BPSK	100	6.5	2442	9.328	11.328
WLAN	11	BPSK	100	6.5	2462	9.152	11.152

Table 11

Bluetooth and Thread

Technology	Frequency Band (GHz)	Output power (dBm)	Output power (mW)	Tune up tolerance (dBm)
Thread	2.4	-0.013	0.997	2.00
Bluetooth	2.4	-0.408	0.910	2.00

Table 12

SECTION 2

TEST DETAILS

Specific Absorption Rate Testing of the Smart Lock Ultra

2.1 DASY6 MEASUREMENT SYSTEM

2.1.1 System Description

The DASY6 system for performing compliance tests consists of the following items:

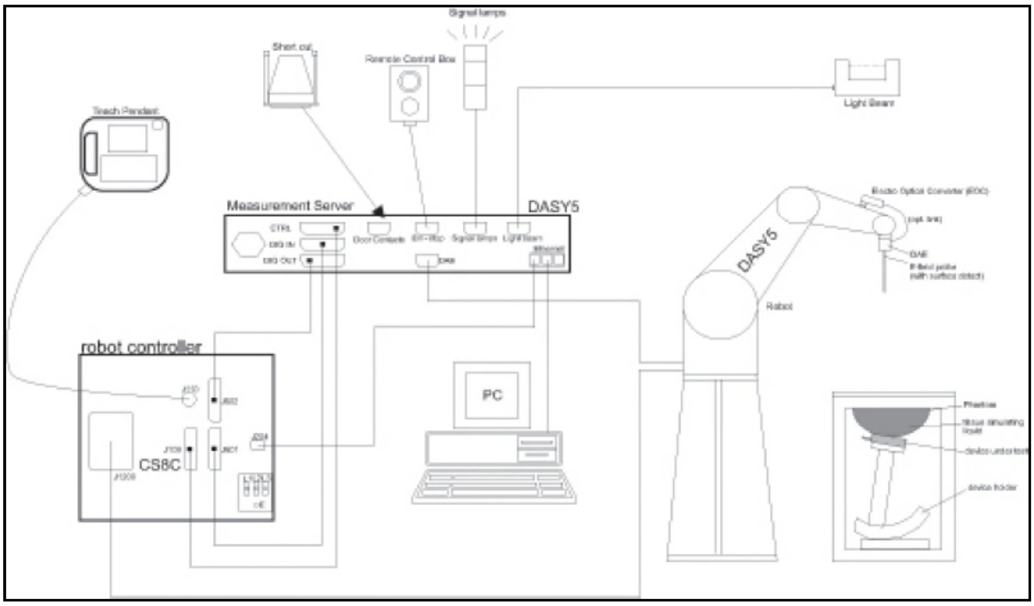


Figure 2 - System Description Diagram

A standard high precision 6-axis robot (Stäubli TX=RX family) with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).

An isotropic field probe optimized and calibrated for the targeted measurement.

A data acquisition electronics (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.

The Electro-optical converter (EOC) performs the conversion from optical to electrical signals for the digital communication to the DAE. To use optical surface detection, a special version of the EOC is required. The EOC signal is transmitted to the measurement server.

The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.

The Light Beam used is for probe alignment. This improves the (absolute) accuracy of the probe positioning.

A computer running the DASY6 software to display and interact with the robot and information.

There is a remote control and a teach pendant as well as additional circuitry for robot safety such as warning lamps, etc.

The phantom, the device holder and other accessories according to the targeted measurement.

2.1.2 Probe Specification

The probes used by the DASY system are isotropic E-field probes, constructed with a symmetric design and a triangular core. The probes have built-in shielding against static charges and are contained within a PEEK enclosure material. These probes are specially designed and calibrated for use in liquids with high permittivity. The frequency range of the probes are from 6 MHz to 6 GHz.

2.1.3 Data Acquisition Electronics

The data acquisition electronics (DAE4 or DAE3) consist 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 with a control logic unit. Transmission to the measurement server is accomplished through an optical downlink for data and status information, as well as an optical uplink for commands and the clock.

The mechanical probe mounting device includes two different sensor systems for frontal and sideways probe contacts. They are used for mechanical surface detection and probe collision detection. The input impedance of both the DAE4 as well as of the DAE3 box is 200MOhm; the inputs are symmetrical and floating. Common mode rejection is above 80dB.

2.1.4 SAR Evaluation Description

The cDASY6 software includes all numerical procedures necessary to evaluate the spatial peak SAR values.

Fast Area Scan:

The Fast Area Scan provides an easy, time efficient and accurate way to define the optimal power reference location. The location of the power reference and power drift measurements for the subsequent Area, Fast Volume and Zoom Scans will be automatically set at the maximum of the Fast Area Scan.

Area Scan:

Area Scans are used to determine the peak location of the measured field before doing a finer measurement around the hotspot. Peak location can be found accurately even on coarse grids using the advanced interpolation routines implemented in cDASY6 Module SAR. Area Scans measure a two dimensional volume covering the full device under test area. cDASY6 Module SAR uses Fast Averaged SAR algorithm to compute the 1g and 10g of simulated tissue from the Area Scan.

Fast Volume Scans:

Fast Volume Scans are 3D scans used to assess the peak spatial SAR values within an averaging volume containing 1g and 10g of simulated tissue. It is compatible with any phantom. For regular phantoms, the measurement grid is generated by projecting a plane onto the phantom surface as for Area and Zoom scans. For specific phantoms, the measurement grid is generated by a conformal offset to the phantom surface at the desired distances. The grid extents can be set by the end user to cover the DUT dimensions or the whole measurable area of the phantom.

Zoom Scan:

Zoom scans are used to assess the peak spatial SAR values within a cubic averaging volume containing 1g and 10g of simulated tissue. Zoom scans measure a three dimensional volume (cube). The bottom face of the cube is Centreed on the maximum of the preceding Area Scan in the same measurement group. For maxima at border of the phantom, the zoom scan can be enabled to automattically extend in order to ensure correct evaluation of peak spatial SAR.

Zoom Scans can be performed in two different modes:

- Smart Mode: the grid settings are adjusted on the fly based on the distribution being measured to fulfill to the IEC 62209-2 Amendment 1 criteria on grid resolution.

- Custom Mode: the user specifies the grid settings to be used. In both modes, Zoom Scans are always anchored to the peak location of the preceding Fast Area / Area / Fast Volume Scan.

SECTION 3

TEST EQUIPMENT USED

3.1 TEST EQUIPMENT USED

The following test equipment was used at TÜV SÜD Product Service:

Instrument Description	Manufacturer	Model Type	TE Number	Cal Period (months)	Calibration Due Date
Hygrometer	Rotronic	A1	2138	12	28-Nov-2025
SAR 2450 MHz dipole	SPEAG	D2450V2	5329	12	14-Jun-2025
Flat phantom (Body)	SPEAG	ELI v8.0	4833	-	TU
Measurement server	SPEAG	DASY 6	4692	-	TU
DASY 6 Robot	SPEAG	TX90 XL	4704	-	TU
Dosimetric SAR Probe	SPEAG	EX3DV4	5330	12	24-Jun-2025
Data Acquisition Electronics	SPEAG	DAE4ip	5327	12	19-Jun-2025
Dielectric Assessment Kit	SPEAG	DAK-3.5	4690	-	TU
Network Analyser	Keysight Technologies	E5063A	5018	12	23-Oct-2025
Validation Source for SAR system	SPEAG	POWERSOURCE1-SE UMS 160 CB	5371	12	04-Dec-2025
Thermometer	Comark	KM14	6946	12	31-Dec-2025
Tissue Simulant Liquid	SPEAG	HBBL600-10000V6	Batch 1	-	Note 1

Table 13

TU - Traceability Unscheduled

Note 1: The calibration dates for the relevant batches of TSL can be found in the fluid parameter tables within this report.

3.2 TEST SOFTWARE

The following software was used to control the TÜV SÜD Product Service DASY System.

Instrument	Version Number
DASY System	cDASY6 Module SAR V16.2.4.2524

Table 14

3.3 TEST VERIFICATION

3.3.1 System Performance Check Results

Prior to formal testing being performed a System Check was performed in accordance with KDB 865664 - D01 v01r04 and the results were compared against the calibration certificates of each corresponding system verification dipole. The following results were obtained and within the ±10% acceptance criteria.

<u>System Performance Check Results</u>

Date	Frequency (MHz)	Fluid Type	Measured Max 10g SAR (W/kg) *	Max 10g SAR Target (W/kg)	Percentage Deviation from Target 10g (%)
27/05/2025	2450	HBBL B1	23.34	24.70	-5.49
29/05/2025	2450	HBBL B1	23.94	24.70	-3.06
30/05/2025	2450	HBBL B1	23.74	24.70	-3.87

Table 15

*Normalised to a forward power of 1W.

3.4 DIELECTRIC PROPERTIES OF SIMULANT LIQUIDS

The fluid properties of the simulant fluids used during routine SAR evaluation meet the dielectric properties required KDB 865664 - D01 v01r04.

The dielectric properties of the tissue simulant liquids used are within the ±10% acceptance criteria for the SAR testing at TÜV SÜD Product Service and are as follows:

Fluid Type and Frequency	Relative Permittivity Measured	Relative Permittivity Target	Conductivity Measured (S/m)	Conductivity Target (S/m)	Date	Fluid Temperature °C
HBBL B1 2450 MHz	39.46	29.20	1.85	1.80	27/05/2025	20.50
HBBL B1 2450 MHz	39.28	39.20	1.85	1.80	29/05/2025	20.30

Table 16

3.5 TEST CONDITIONS

3.5.1 Test Laboratory Conditions

Ambient temperature: Within +18.00°C to +25.00°C.

The actual temperature during the testing ranged from 21.1°C to 21.9°C.

The actual humidity during the testing ranged from 57.8% to 63.8% RH.

The temperature of the fluid during testing does not deviate by more than 2°C for each set of tests.

3.5.2 Test Fluid Temperature Range

Frequency	Body / Head Fluid	Min Temperature °C	Max Temperature °C
2450 MHz	Head	20.3	20.6

Table 17

3.6 MEASUREMENT UNCERTAINTY

Full SAR Measurements, 300 MHz to 3 GHz

Source of Uncertainty	Uncertainty ± %	Probability distribution	Div	c_i (1g)	Standard Uncertainty ± % (1g)
Measurement System Errors					
Probe Calibration	12.0	Normal	2.00	1.00	6.0
Probe Calibration Drift	1.7	Rectangular	1.73	1.00	1.0
Probe Linearity	4.7	Rectangular	1.73	1.00	2.7
Broadband Signal	3.0	Rectangular	1.73	1.00	1.7
Probe Isotropy	7.6	Rectangular	1.73	1.00	4.4
Data Acquisition	0.3	Normal	1.00	1.00	0.3
RF Ambient	1.8	Normal	1.00	1.00	1.8
Probe Positioning	0.2	Normal	1.00	0.14	0.0
Data Processing	1.2	Normal	1.00	1.00	1.2
Phantom and Device errors					
Liquid Conductivity Meas.	2.5	Normal	1.00	0.78	2.0
Liquid Conductivity Temp	3.3	Rectangular	1.73	0.78	1.5
Phantom Permittivity	14.0	Rectangular	1.73	0.00	0.0
Distance DUT - TSL	2.0	Normal	1.00	2.00	4.0
Device Positioning (±0.5mm)	1.0	Normal	1.00	1.00	1.0
Device Holder	3.6	Normal	1.00	1.00	3.6
Device Modulation	2.4	Rectangular	1.73	1.00	1.4
Time-average SAR	2.6	Rectangular	1.73	1.00	1.5
DUT Drift	5.0	Normal	1.00	1.00	5.0
Correction to the SAR results					
Deviation to Target	1.9	Normal	1.00	1.00	1.9
SAR Scaling	0.0	Rectangular	1.73	1.00	0.0
Combined Standard Uncertainty		**RSS**			11.8
Expanded Standard Uncertainty		**K=2**			23.7

Table 18

3.6.1 Decision Rule

Accuracy Method

Determination of conformity with the specification limits is based on the decision rule according to IEC Guide 115: 2007, Clause 4.4.3 and 4.5.1. (Procedure 2). The measurement results are directly compared with the test limit to determine conformance with the requirements of the standard.

Risk: The uncertainty of measurement about the measured result is negligible with regards to the final pass/fail decision. The measurement result can be directly compared with the test limit to determine conformance with the requirement (compare IEC Guide 115). The level of risk to falsely accept and falsely reject items is further described in ILAC-G8.

SECTION 4

ACCREDITATION, DISCLAIMERS AND COPYRIGHT

4.1 ACCREDITATION, DISCLAIMERS AND COPYRIGHT

This non-binding report has been prepared by TÜV SÜD with all reasonable skill and care.

This report relates only to the actual item/items tested.

Results of tests covered by our Flexible UKAS Accreditation Schedule are marked FS (Flexible Scope).

Results of tests not covered by our UKAS Accreditation Schedule are marked NUA (Not UKAS Accredited).

Our UKAS Accreditation does not cover opinions and interpretations and any expressed are outside the scope of our UKAS Accreditation.

ANNEX A

PROBE CALIBRATION REPORT

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

S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
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

Client TüV SÜD
Fareham, United Kingdom

Certificate No. EX-7536_Jun24

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7536
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	June 24, 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
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)	26-Mar-24 (No. 217-04046)	Mar-25
DAE4	SN: 660	23-Feb-24 (No. DAE4-660_Feb24)	Feb-25
Reference Probe EX3DV4	SN: 7349	03-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	Jeton Kastrati	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	

Issued: June 24, 2024

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

S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
 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
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
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:

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 $\vartheta = 0$ ($f \leq 900$ 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 E^2-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. 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 $f \leq 800$ 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 *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).

Parameters of Probe: EX3DV4 - SN:7536

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$) A	0.55	0.61	0.65	±10.1%
DCP (mV) B	96.5	97.3	99.1	±4.7%

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B $dB\sqrt{\mu V}$	C	D dB	VR mV	Max dev.	Max Unc[E] $k = 2$
0	CW	X	0.00	0.00	1.00	0.00	148.3	±3.3%	±4.7%
		Y	0.00	0.00	1.00		142.4		
		Z	0.00	0.00	1.00		140.6		
10352	Pulse Waveform (200Hz, 10%)	X	19.45	87.06	19.15	10.00	60.0	±4.1%	±9.6%
		Y	2.24	63.93	8.97		60.0		
		Z	20.00	90.04	19.86		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	20.00	87.50	18.34	6.99	80.0	±3.5%	±9.6%
		Y	1.53	62.94	7.81		80.0		
		Z	20.00	91.79	19.62		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	20.00	89.01	17.93	3.98	95.0	±2.3%	±9.6%
		Y	1.03	63.03	7.34		95.0		
		Z	20.00	95.70	20.23		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	20.00	91.66	18.14	2.22	120.0	±1.8%	±9.6%
		Y	1.25	67.26	8.83		120.0		
		Z	20.00	100.20	21.15		120.0		
10387	QPSK Waveform, 1 MHz	X	1.65	64.85	14.31	1.00	150.0	±2.0%	±9.6%
		Y	1.69	66.46	15.10		150.0		
		Z	1.58	64.55	14.03		150.0		
10388	QPSK Waveform, 10 MHz	X	2.16	66.79	14.99	0.00	150.0	±1.1%	±9.6%
		Y	2.23	67.95	15.78		150.0		
		Z	2.07	66.28	14.73		150.0		
10396	64-QAM Waveform, 100 kHz	X	2.00	62.00	11.00	3.01	150.0	±4.0%	±9.6%
		Y	2.86	71.20	19.42		150.0		
		Z	2.80	69.68	18.40		150.0		
10399	64-QAM Waveform, 40 MHz	X	3.51	66.70	15.48	0.00	150.0	±0.9%	±9.6%
		Y	3.54	67.18	15.84		150.0		
		Z	3.44	66.43	15.31		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	4.74	64.82	15.06	0.00	150.0	±2.2%	±9.6%
		Y	4.88	65.79	15.63		150.0		
		Z	4.85	65.37	15.31		150.0		

Note: For details on UID parameters see Appendix

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 to 8).
[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:7536

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms V^{-2}$	T2 $ms V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	49.5	372.68	35.99	27.64	0.00	5.06	0.00	0.70	0.95
y	41.4	308.54	35.35	15.46	0.00	4.94	1.66	0.06	1.01
z	46.1	345.10	35.50	12.43	0.00	5.05	1.50	0.15	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	13.8°
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:7536

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[H] (k = 2)
30	55.0	0.75	18.18	18.18	18.18	0.00	1.00	±13.3%
64	54.2	0.75	16.96	16.96	16.96	0.00	1.00	±13.3%
128	52.8	0.76	15.20	15.20	15.20	0.00	1.00	±13.3%
150	52.3	0.76	14.58	14.58	14.58	0.00	1.00	±13.3%
220	49.0	0.81	13.88	13.88	13.88	0.00	1.00	±13.3%
300	45.3	0.87	13.12	13.12	13.12	0.09	1.00	±13.3%
450	43.5	0.87	11.92	11.92	11.92	0.16	1.30	±13.3%
600	42.7	0.88	11.35	11.35	11.35	0.10	1.25	±13.3%
750	41.9	0.89	10.78	10.78	10.78	0.43	0.80	±11.0%
835	41.5	0.90	10.63	10.63	10.63	0.39	0.80	±11.0%
900	41.5	0.97	10.16	10.16	10.16	0.41	0.86	±11.0%
1100	41.2	1.06	9.48	9.48	9.48	0.40	0.80	±11.0%
1300	40.8	1.14	9.19	9.19	9.19	0.39	0.83	±11.0%
1450	40.5	1.20	9.02	9.02	9.02	0.35	0.80	±11.0%
1640	40.2	1.31	8.91	8.91	8.91	0.30	0.86	±11.0%
1750	40.1	1.37	8.85	8.85	8.85	0.27	0.86	±11.0%
1810	40.0	1.40	8.77	8.77	8.77	0.19	0.86	±11.0%
1900	40.0	1.40	8.69	8.69	8.69	0.22	0.86	±11.0%
2000	40.0	1.40	8.54	8.54	8.54	0.24	0.86	±11.0%
2100	39.8	1.49	8.39	8.39	8.39	0.24	0.86	±11.0%
2300	39.5	1.67	8.08	8.08	8.08	0.25	0.90	±11.0%
2450	39.2	1.80	7.88	7.88	7.88	0.24	0.90	±11.0%
2600	39.0	1.96	7.80	7.80	7.80	0.22	0.90	±11.0%
3300	38.2	2.71	7.20	7.20	7.20	0.30	1.35	±13.1%
3500	37.9	2.91	7.14	7.14	7.14	0.30	1.35	±13.1%
3700	37.7	3.12	7.10	7.10	7.10	0.35	1.35	±13.1%
3900	37.5	3.32	6.68	6.68	6.68	0.40	1.60	±13.1%
4100	37.2	3.53	6.63	6.63	6.63	0.40	1.60	±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.
[H] The stated uncertainty is the total calibration uncertainty (k = 2) of Norm·ConvF. Therefore, The uncertainty stated is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

Parameters of Probe: EX3DV4 - SN:7536

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[H] ($k = 2$)
4200	37.1	3.63	6.32	6.32	6.32	0.40	1.70	±13.1%
4400	36.9	3.84	6.16	6.16	6.16	0.40	1.70	±13.1%
4600	36.7	4.04	6.05	6.05	6.05	0.40	1.70	±13.1%
4800	36.4	4.25	5.96	5.96	5.96	0.40	1.80	±13.1%
4950	36.3	4.40	5.85	5.85	5.85	0.40	1.80	±13.1%
5200	36.0	4.66	5.60	5.60	5.60	0.40	1.80	±13.1%
5300	35.9	4.76	5.43	5.43	5.43	0.40	1.80	±13.1%
5500	35.6	4.96	5.03	5.03	5.03	0.40	1.80	±13.1%
5600	35.5	5.07	4.88	4.88	4.88	0.40	1.80	±13.1%
5800	35.3	5.27	4.92	4.92	4.92	0.40	1.80	±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.

[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. Therefore, The uncertainty stated is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

Parameters of Probe: EX3DV4 - SN:7536

Calibration Parameter Determined in Body 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[H] ($k = 2$)
150	61.9	0.80	13.71	13.71	13.71	0.00	1.00	±13.3%
220	60.2	0.86	12.59	12.59	12.59	0.00	1.00	±13.3%
300	58.2	0.92	12.10	12.10	12.10	0.02	1.35	±13.3%
450	56.7	0.94	11.52	11.52	11.52	0.11	1.20	±13.3%
750	55.5	0.96	10.78	10.78	10.78	0.47	0.80	±11.0%
835	55.2	0.97	10.65	10.65	10.65	0.25	1.14	±11.0%
900	55.0	1.05	10.29	10.29	10.29	0.45	0.85	±11.0%
1300	54.3	1.23	9.16	9.16	9.16	0.16	1.88	±11.0%
1450	54.0	1.30	8.97	8.97	8.97	0.26	0.80	±11.0%
1640	53.7	1.42	8.86	8.86	8.86	0.29	0.86	±11.0%
1750	53.4	1.49	8.77	8.77	8.77	0.28	0.86	±11.0%
1810	53.3	1.52	8.70	8.70	8.70	0.32	0.86	±11.0%
1900	53.3	1.52	8.54	8.54	8.54	0.23	0.86	±11.0%
2000	53.3	1.52	8.20	8.20	8.20	0.32	0.86	±11.0%
2100	53.2	1.62	8.12	8.12	8.12	0.25	0.86	±11.0%
2300	52.9	1.81	8.02	8.02	8.02	0.35	0.90	±11.0%
2450	52.7	1.95	7.91	7.91	7.91	0.32	0.90	±11.0%
2600	52.5	2.16	7.78	7.78	7.78	0.17	0.90	±11.0%
3300	51.6	3.08	6.64	6.64	6.64	0.40	1.35	±13.1%
3500	51.3	3.31	6.57	6.57	6.57	0.40	1.35	±13.1%
3700	51.0	3.55	6.47	6.47	6.47	0.40	1.35	±13.1%
4100	50.5	4.01	5.94	5.94	5.94	0.40	1.70	±13.1%
5200	49.0	5.30	5.07	5.07	5.07	0.50	1.90	±13.1%
5300	48.9	5.42	4.96	4.96	4.96	0.50	1.90	±13.1%
5500	48.6	5.65	4.52	4.52	4.52	0.50	1.90	±13.1%
5600	48.5	5.77	4.39	4.39	4.39	0.50	1.90	±13.1%
5800	48.2	6.00	4.37	4.37	4.37	0.50	1.90	±13.1%

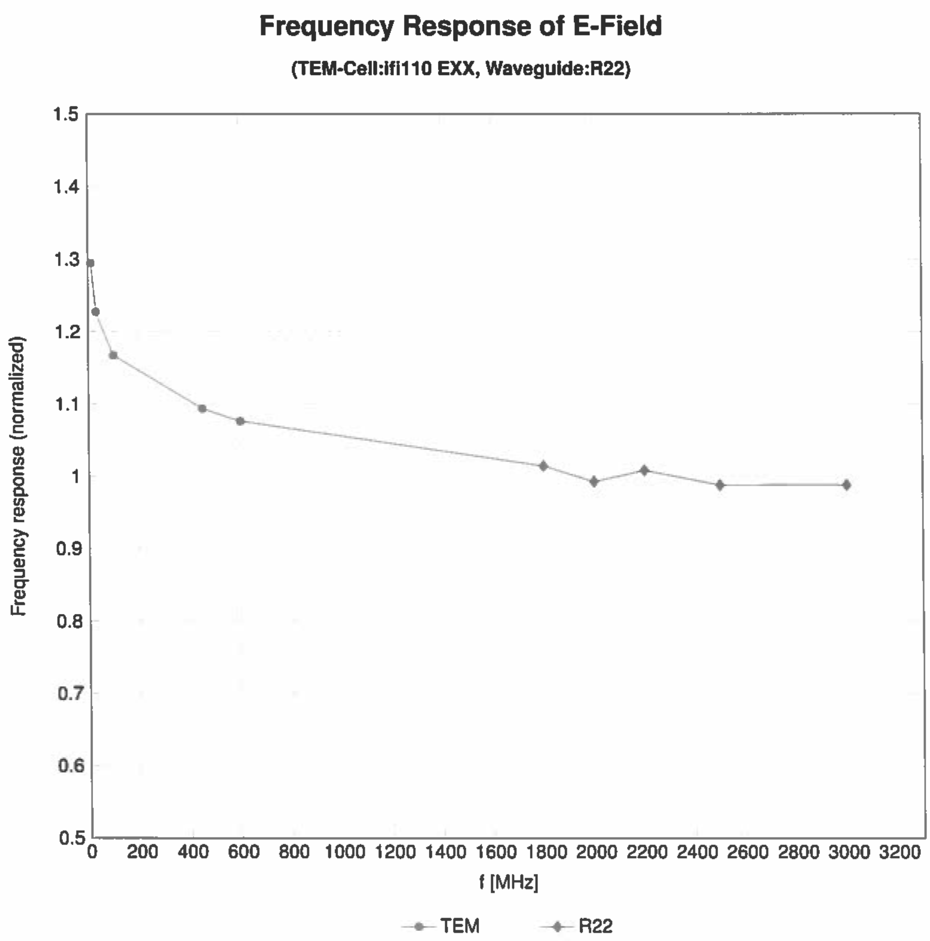
[C] Frequency validity above 300 MHz of ±100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ±50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ±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.
[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. Therefore, The uncertainty stated is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

Parameters of Probe: EX3DV4 - SN:7536

Calibration Parameter Determined in Head Tissue Simulating Media

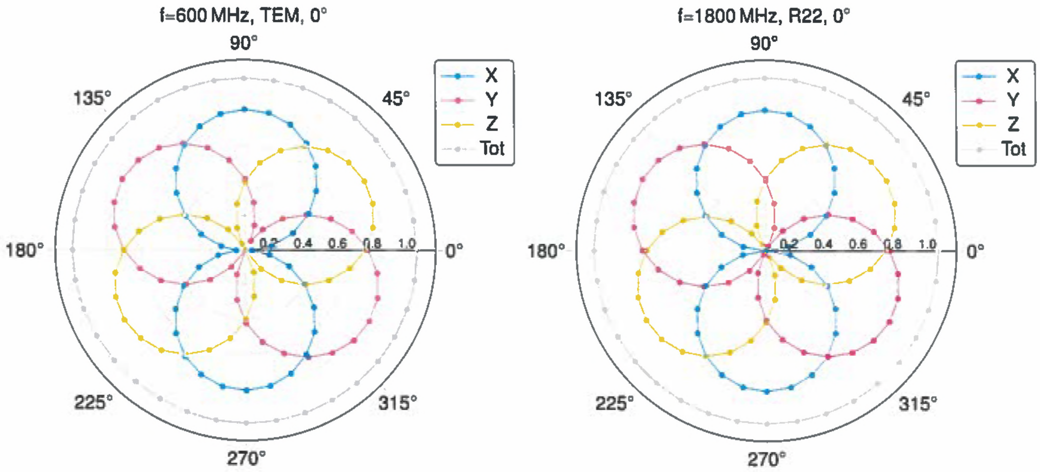
f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] (k = 2)
6500	34.5	6.07	5.50	5.50	5.50	0.20	2.00	±18.6%

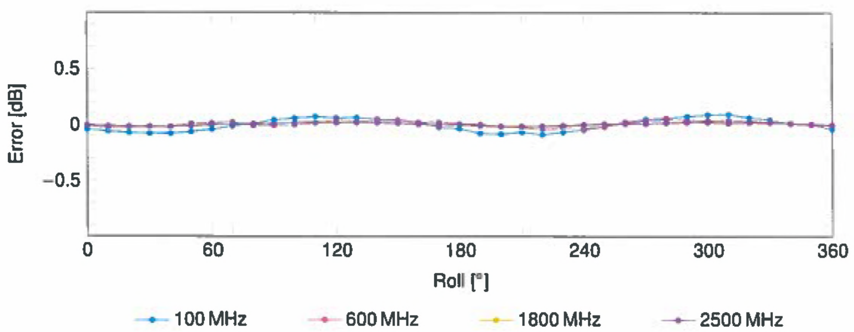
[C] Frequency validity at 6.5 GHz is −600/+700 MHz, and ±700 MHz at or above 7 GHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε 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.
[H] The stated uncertainty is the total calibration uncertainty (k = 2) of Norm·ConvF. Therefore, The uncertainty stated is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.



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

Receiving Pattern (ϕ), $\vartheta = 0°$

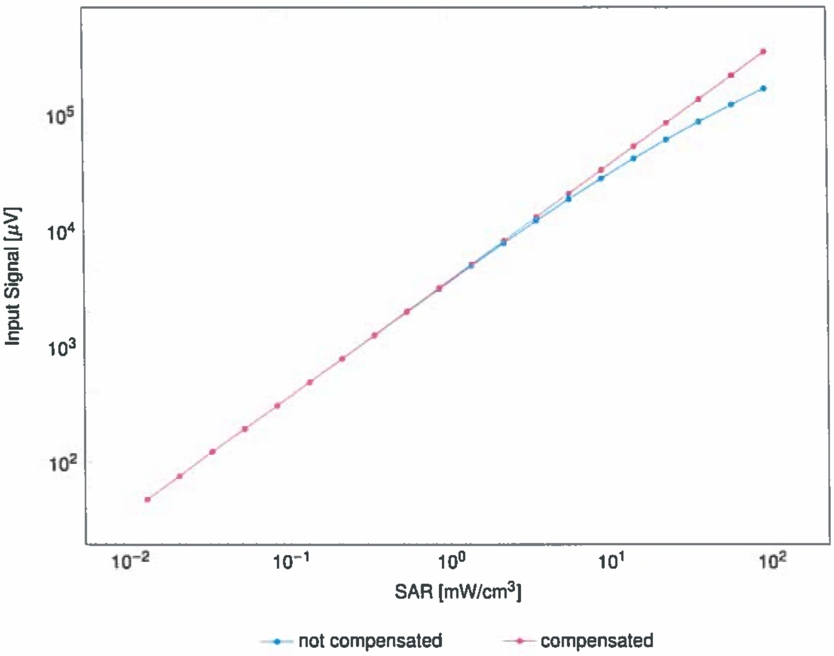


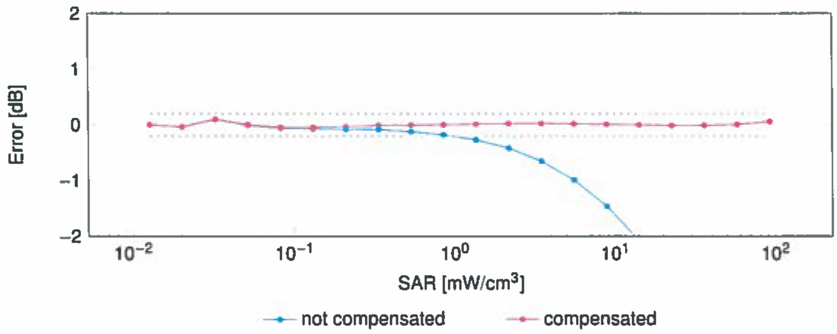


Uncertainty of Axial Isotropy Assessment: ±0.5% (k=2)

Dynamic Range f(SAR_{head})

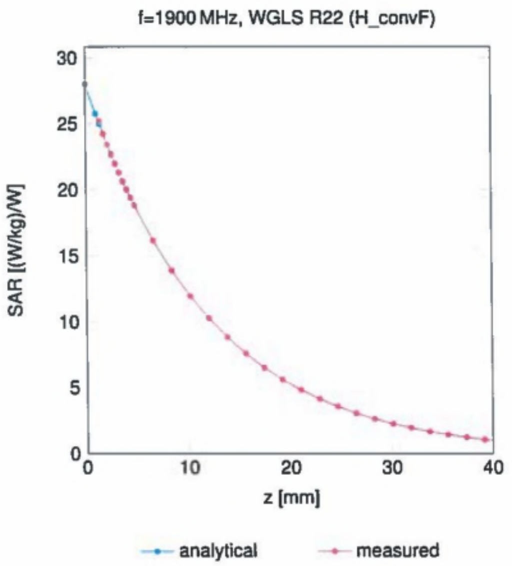
(TEM cell, f_{eval} = 1900 MHz)





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

Conversion Factor Assessment



Deviation from Isotropy in Liquid