SAR Compliance Test Report

Date of Report	4/07/2024	**Client's Contact person:**	Martin Zeiner
Number of pages:	27	**Responsible Test engineer:**	Kalle Orava
Testing laboratory:	**Verkotan Oy** Elektroniikkatie 17 90590 Oulu Finland	**Client:**	**ekey biometric systems GmbH** Lunzerstraße 89 4030 Linz Austria
Tested devices:	**sLine, xLine**		
Related reports:	-		
Testing has been carried out in accordance with:	**47CFR §2.1093** Radiofrequency Radiation Exposure Evaluation: Portable Devices **FCC published RF exposure KDB procedures** **IEC/IEEE 62209-1528, 2020** Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices		
Documentation:	The test report must always be reproduced in full; reproduction of an excerpt only is subject to written approval of the testing laboratory		
Test Results:	**The EUT complies with the requirements in respect of all parameters subject to the test.** The test results relate only to devices specified in this document		
Date and signatures:	04.07.2024 **Laboratory Manager** Miia Nurkkala		

TABLE OF CONTENTS

1. SUMMARY OF SAR TEST REPORT

1.1 Test Details

Equipment under Test (DUT):

Product:	Fingerprint sensor
Manufacturer:	ekey biometric systems GmbH
Model:	sLine, xLine
Serial Number:	sLine: serial number base: 850459C317062400539, serial number fingerprint module: 850460A407062400437 xLine: serial number base: 850310C317112400818, serial number fingerprint module: 850311A407202400109
FCC ID Number:	2AC7Z-ESP32WROVERE
DUT Number:	20432 (sLine), 20433 (xLine)
Battery Type used in testing:	N/A
State of the Sample:	Production sample

Testing information:

Testing performed:	26.06.2024
Notes:	-
Document history:	-
Document ID:	FCC_SAR report_sLine xLine_ID6188_04072024.docx
Temperature °C	22±2 / Controlled
Humidity RH%	30±20 / Controlled
Measurement performed by:	Kalle Orava
FCC Test Firm Designation Number:	FI0005

1.2 Maximum Results

The maximum reported* SAR values for Body-worn for transmitting systems are shown in a table below. The device conforms to the requirements of the standards when the maximum reported SAR value is less than or equal to the limit. The SAR limit specified in FCC 47 CFR part 2 (2.1093) for Head/Body SAR_{1g} is 1.6 W/kg.

1.2.1 Standalone SAR

System	Highest Reported* SAR_{1g} in Body-Worn Exposure Condition, 0mm separation distance [W/kg]	Result
2.4GHz WLAN	0.73	**PASS**
Bluetooth	0.00495	**PASS**

* Reported SAR Values are scaled to upper limit of power tuning tolerance.

1.2.2 Maximum Drift

Maximum Drift During Measurements	1.1 dB*

*Larger than 5% drifts included to scaling factors

1.2.3 Measurement Uncertainty

SAR 1g: 0.3 – 3 GHz:

Expanded Uncertainty (k=2) 95 %	±22.1 %

2. DESCRIPTION OF THE DEVICE UNDER TEST (DUT)

The DUTs is a fingerprint sensor supporting 2.4GHz WLAN and Bluetooth. This report covers both models sLine and xLine. In terms of electronic components, schematics and PCB layout, both device families are 100% identical. Within each device family there are different options for the optical design (colors etc.), but this has no influence on the underlying technology. There is only one major difference between sLine and xLine. In the sLine, the two printed circuit boards are slightly closer together. Full SAR testing was done for sLine due to antenna being at closer user separation distance of 20.94mm. xLine has a user separation distance of 22.33mm.

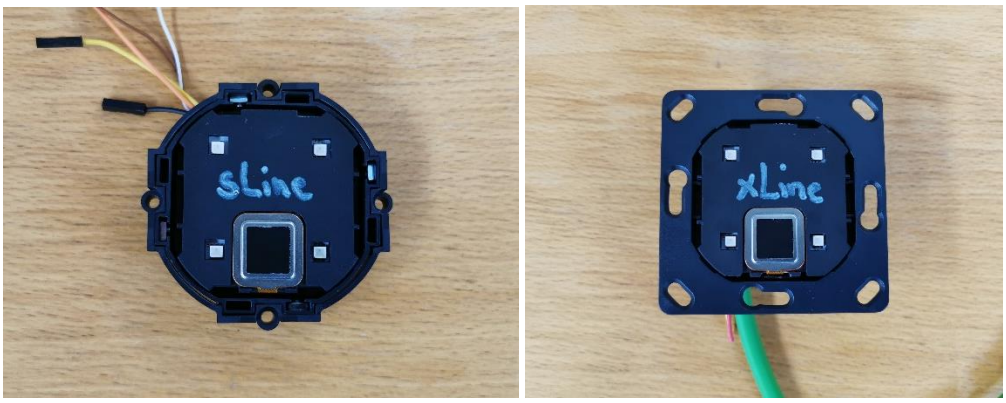


Figure 1. Overview of the DUTs

Device Category	Portable
Exposure Environment	General population uncontrolled

2.1 Supported Frequency Bands and Operational Modes

TX Frequency bands	Modes of Operation	Transmitter Frequency Range [MHz]
	2.4 GHz WLAN	2412 – 2462
	Bluetooth	2402 – 2480

3. OUTPUT POWER

3.1 Maximum specified conducted output power

From the customer, including tune-up tolerances;

2.4GHz WLAN	Max Output Power [dBm]
802.11b	20.5
802.11n	14

Bluetooth	Max Output Power [dBm]
	9

3.2 Tested conducted power

Measured conducted output power at transmitting antenna connector;

3.2.1 sLine

2.4 GHz WLAN:

Standard	Transmission mode	Data rate [Mbps]	Output power [dBm]		
			CH 1 2412 MHz	CH 6 2437 MHz	CH 11 2462 MHz
802.11b	DSSS	1	17	17.31	17.56

Bluetooth:

Packet Type	Output power [dBm]		
	CH 0 2402 MHz	CH 39 2441 MHz	CH 78 2480 MHz
DH5	6.29	7.2	7.56

3.2.2 xLine

2.4 GHz WLAN:

Standard	Transmission mode	Data rate [Mbps]	Output power [dBm]		
			CH 1 2412 MHz	CH 6 2437 MHz	CH 11 2462 MHz
802.11b	DSSS	1	17.07	17	17.39

Bluetooth:

Packet Type	Output power [dBm]		
	CH 0 2402 MHz	CH 39 2441 MHz	CH 78 2480 MHz
DH5	8.24	8.7	8.82

4. TEST EQUIPMENT

Dasy near field scanning system, manufactured by SPEAG was used for SAR testing. The test system consists of high precision robotics system (Staubli), robot controller, computer, near-field probe, probe alignment sensor, and a phantom containing the tissue equivalent material. The robot is a six-axis industrial robot performing precise movements to position the probe to the location of maximum electromagnetic field.

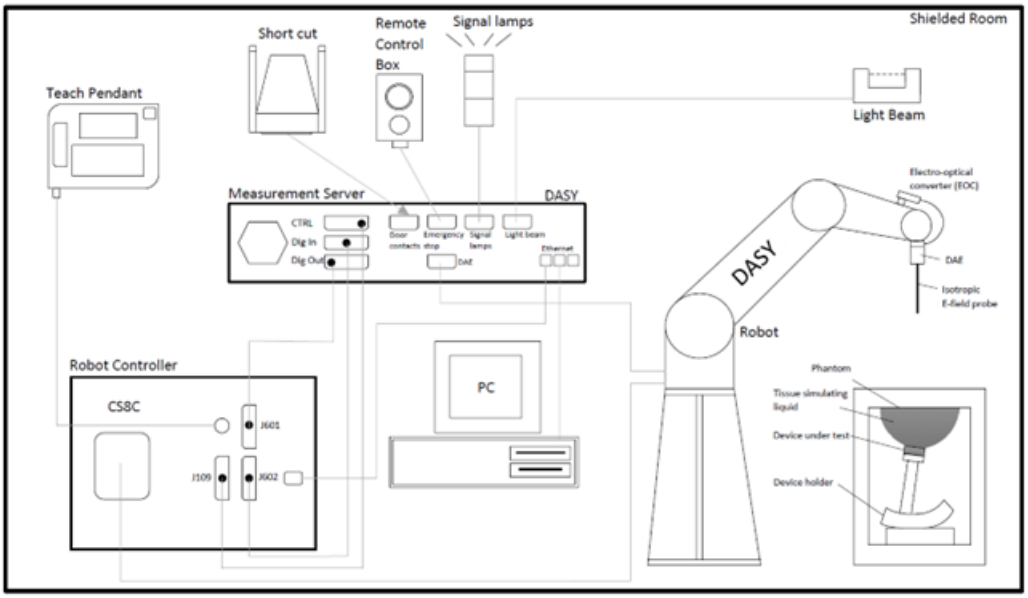


Figure 2 Schematic Laboratory Picture

4.1 Test Equipment List

Main used test system components are listed below. For a full equipment list and calibration intervals, please contact the testing laboratory.

Test Equipment	Model	Serial Number	Calibration Date	Interval [years]
Amplifier, 800MHz-4200MHz, 10W	10S1G4A	320421	NA	NA
DAE4, converter	DAE4	710	10/2023	1
Inline Peak Power Sensor	MA24105A	2102058	10/2023	1
Isotropic DOS probe	EX3DV4	3852	10/2023	1
Power Sensor	NRP8S	1419.0006K02-108509-Zh	03/2024	2
System validation dipole	D2450V2	729	07/2022	3
Vector Network Analyzer	P5008A	MY58100258	05/2024	1
Vector Signal Generator	MG3710A	6201502519	NA	1
DASY5 Software	52.8.8.1258	-	NA	NA

Dipole calibration period supporting data:

		Measured on 09/2023			Calibrated		
Dipole and serial number	Frequency [MHz]	Return loss [dB]	Impedance [Ω]		Return loss [dB]	Impedance [Ω]	
D2450V2-729	2450	-30.1	53.1	0.8	-24.7	54.3	4.3

4.1.1 Isotropic E-field Probe Type EX3DV4

Construction	Symmetrical design with triangular core Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)
Calibration	Calibration certificate in Appendix D
Frequency	4 MHz to 10 GHz (dosimetry) Linearity: ± 0.2 dB (30 MHz to 10 GHz)
Directivity (typical)	±0.1 dB in TSL (rotation around probe axis) ±0.3 dB in TSL (rotation normal to probe axis)
Dynamic Range	10 µW/g – >100 mW/g Linearity: ±0.2 dB (noise: typically <1 µW/g)
Dimensions	Overall length: 337 mm (tip: 20 mm) Tip diameter: 2.5 mm (body: 12 mm) Typical distance from probe tip to dipole centers: 1 mm
Application	General dosimetry up to 6 GHz Compliance tests of mobile phones Fast automatic scanning in arbitrary phantoms

4.2 Phantoms

Modular flat phantom:

The Triple Modular Phantom consists of three identical modules that can be installed and removed separately without emptying the liquid. It is used for compliance testing of small wireless devices in body-worn configurations. The phantom conforms to the requirements of IEC/IEEE 62209-1528 and FCC published RF Exposure KDB Procedures.

4.3 Tissue Simulants

Recommended values for the dielectric parameters of the tissue simulants are given in IEC/IEEE 62209-1528 and FCC published RF Exposure KDB Procedures. The dielectric parameters of the used tissue simulants were within ±10% of the recommended values at frequencies under 3GHz. A liquid compensation algorithm was used in DASY with which measured peak average SAR values were corrected for the deviation of used liquid. Depth of the tissue simulant was at least 15.0 cm from the inner surface of the flat phantom.

Tissue simulant liquid Ingredients
Deionized Water, tween, salt

4.4 System Validation Status

Frequency [MHz]	Dipole Type / SN	Probe Type / SN	Calibrated Signal Type	DAE Unit / SN	Dielectric Constant [ε']	Conductivity σ [S/m]	Date
2450	D2450V2 - SN: 758	EX3DV4 - SN: 3852	CW	DAE 4 / 710	38.16	1.68	11/2023

4.5 System Check

Date	Tissue Type	Tissue Temp. [°C]	Frequency [MHz]	Input Power [mW]	Measured SAR_{1g} [W/kg]	1 W Target SAR_{1g} [W/kg]	1 W Normalized SAR_{1g} [W/kg]	Deviation [%]	Plot #
26.06.2024	WB Head	22	2450	250	12.4	52.3	49.6	-5.16	1

4.5.1 Tissue Simulant Verification

				Measured		Target		Deviation	
Date	Tissue Type	Tissue Temp [°C]	Frequency [MHz]	Dielectric Constant [ε]	Conductivity σ [S/m]	Dielectric Constant [ε] Target	Conductivity σ [S/m] Target	ε [%]	σ [%]
26.06.2024	WB Head	22.3	2402	38.31	1.73	39.28	1.76	-2.5	-1.3
26.06.2024	WB Head	22.3	2412	38.29	1.74	39.27	1.77	-2.5	-1.5
26.06.2024	WB Head	22.3	2437	38.24	1.76	39.22	1.79	-2.5	-1.7
26.06.2024	WB Head	22.3	2441	38.24	1.76	39.22	1.79	-2.5	-1.8
26.06.2024	WB Head	22.3	2450	38.22	1.77	39.2	1.8	-2.5	-1.9
26.06.2024	WB Head	22.3	2462	38.2	1.77	39.18	1.81	-2.5	-2.2
26.06.2024	WB Head	22.3	2480	38.19	1.79	39.16	1.83	-2.5	-2.5

5. TEST PROCEDURE

Testing was carried out in accordance with FCC KDB Publications 447498 D04 Interim General RF Exposure Guidance v01, 248227 D01 802.11 Wi-Fi SAR. The DUT was set to transmit at maximum power and duty cycle using test software. A control software for WLAN was used to set the DUT to transmit at maximum power.

The WLAN transmission modes for testing were selected according to largest channel bandwidth configuration, lowest order modulation and lowest data rate.
2.4GHz WLAN was tested with 802.11b standard with data rate of 1Mbit/s. Bluetooth was tested using packet type DH5 with a data rate of 1Mbit/s.

5.1 Device Holder

The device was placed in the device holder (illustrated below) that is supplied by SPEAG as an integral part of the Dasy system.

Device holder supplied by SPEAG

5.2 Test Positions

5.2.1 Body-worn Configuration, 0mm separation distance

Body SAR was tested from the front of the device. The device was placed in the SPEAG holder and lifted towards the phantom until the distance between the phantom and the device was 0mm.

Photos of the test positions are presented in appendix A

5.3 Scan Procedures

First, area scans were used for determination of the field distribution. Next, a zoom scan was performed around the highest E-field value to determine the averaged SAR value. Drift was determined by measuring the same point at the start of the area scan and again at the end of the zoom scan.

5.4 SAR Averaging Methods

The maximum SAR value was averaged over a cube of tissue using interpolation and extrapolation.

The interpolation, extrapolation and maximum search routines within Dasy are all based on the modified Quadratic Shepard's method (Robert J. Renka," Multivariate Interpolation of Large Sets of Scattered Data", University of North Texas ACM Transactions on Mathematical Software, vol. 14, no. 2, June 1988, pp. 139-148).
The interpolation scheme combines a least-square fitted function method with a weighted average method. A trivariate 3-D / bivariate 2-D quadratic function is computed for each measurement point and fitted to neighboring points by a least-square method. For the zoom scan, inverse distance weighting is incorporated to fit distant points more accurately. The interpolating function is finally calculated as a weighted average of the quadratics.

In the zoom scan, the interpolation function is used to extrapolate the Peak SAR from the deepest measurement points to the inner surface of the phantom.

6. MEASUREMENT UNCERTAINTY

DASY5 Uncertainty Budget
According to IEC/IEEE 62209-1528
(Frequency band: 300MHz - 3GHz range)

Symbol	Error Description	Uncert. value	Prob. Dist.	Div.	(ci) 1g	(ci) 10g	Std. Unc. (1g)	Std. Unc. (10g)
Measurement System Errors								
CF	Probe Calibration	±12.0%	N	√2	1	1	±6.0%	±6.0%
CF_{drift}	Probe Calibration Drift	±1.7%	R	√3	1	1	±1.0%	±1.0%
LIN	Probe Linearity	±4.7%	R	√3	1	1	±2.7%	±2.7%
BBS	Broadband Signal	±3.0%	R	√3	1	1	±1.7%	±1.7%
ISO	Probe Isotropy	±7.6%	R	3	1	1	±4.4%	±4.4%
DAE	Data Acquisition	±0.3%	N	1	1	1	±0.3%	±0.3%
AMB	RF Ambient	±1.8%	N	1	1	1	±1.8%	±1.8%
Δ_{syz}	Probe Positioning	±3.9%	N	1	0.14	0.14	±0.5%	±0.5%
DAT	Data Processing	±1.2%	N	1	1	1	±1.2%	±1.2%
Phantom and Device Errors								
LIQ(σ)	Conductivity (meas.)[DAK]	±2.5%	N	√1	0.78	0.71	±2.0%	±1.8%
$LIQ(T_\sigma)$	Conductivity (temp.)[BB]	±3.3%	R	√3	0.78	0.71	±1.5%	±1.4%
EPS	Phantom Permittivity	±14.0%	R	3	0	0	±0%	±0%
DIS	Distance DUT - TSL	±2.0%	N	1	2	2	±4.0%	±4.0%
D_{xyz}	Device Positioning (±0.5mm)	±1.0%	N	1	1	1	±1.0%	±1.0%
H	Device Holder	±3.6%	N	√1	1	1	±3.6%	±3.6%
MOD	DUT Modulation[m]	±2.4%	R	√3	1	1	±1.4%	±1.4%
TAS	Time-average SAR	±2.6%	R	3	1	1	±1.5%	±1.5%
RF_{drift}	DUT drift	±2.5%	N	1	1	1	±2.5%	±2.5%
VAL	Val Antenna Unc.[val]	±0.0%	N	1	1	1	±0%	±0%
RF_{in}	Unc. Input Power[val]	±0.0%	N	1	1	1	±0%	±0%
Correction to the SAR results								
C(ε, σ)	Deviation to Target	±1.9%	N	√1	1	0.84	±1.9%	±1.6%
C(R)	SAR scaling[p]	±0%	R	3	1	1	±0%	±0%
u(ΔSAR)	Combined Uncertainty						±11.0%	±10.9%
U	**Expanded Uncertainty**						±22.1%	±21.9%

7. TEST RESULTS

7.1 SAR Results for Body Condition with 0mm separation

2.4GHz WLAN:

Band	Standard	Data Rate [Mbps]	Channel	Frequency [MHz]	Maximum Power [dBm]	Conducted Power [dBm]	Test position	Measured SAR1g [W/kg]	Power Drift* [dB]	Duty Cycle [%]	Scaling Factor	Reported SAR1g [W/kg]	Plot #
2.4 GHz WLAN	802.11b	1	1	2412	20.5	17	Front, 0mm	0.28	-0.64	100	2.59	0.73	2
2.4 GHz WLAN	802.11b	1	6	2437	20.5	17.31	Front, 0mm	0.23	0.63	100	2.41	0.55	-
2.4 GHz WLAN	802.11b	1	11	2462	20.5	17.56	Front, 0mm	0.20	0.84	100	2.39	0.48	-

*Larger than 5% drifts included to scaling factors

2.4GHz WLAN xLine spot-check:

Band	Standard	Data Rate [Mbps]	Channel	Frequency [MHz]	Maximum Power [dBm]	Conducted Power [dBm]	Test position	Measured SAR1g [W/kg]	Power Drift* [dB]	Duty Cycle [%]	Scaling Factor	Reported SAR1g [W/kg]	Plot #
2.4 GHz WLAN	802.11b	1	1	2412	20.5	17	Front, 0mm	0.0941	1.10	100	2.88	0.27	-

*Larger than 5% drifts included to scaling factors

Bluetooth:

Band	Packet Type	Data Rate [Mbps]	Channel	Frequency [MHz]	Maximum Power [dBm]	Conducted Power [dBm]	Test position	Measured SAR1g** [W/kg]	Power Drift* [dB]	Duty Cycle [%]	Scaling Factor	Reported SAR1g** [W/kg]	Plot #
Bluetooth	DH5	1	0	2402	9	6.29	Front, 0mm	0.00211	0	77	1.87	0.00394	-
Bluetooth	DH5	1	39	2441	9	7.20	Front, 0mm	0.00327	0	77	1.51	0.00495	3
Bluetooth	DH5	1	78	2480	9	7.56	Front, 0mm	0.0000801	0	77	1.39	0.000112	-

*Due to low e-field generated by DUT at the location of drift measurement, the measurements are not applicable.
**Measured result of the area scan was below the dynamic range of the E-field Probe Type EX3DV4 thus zoom scan could not be measured. Area scan result was presented.

Bluetooth xLine spot-check:

Band	Packet Type	Data Rate [Mbps]	Channel	Frequency [MHz]	Maximum Power [dBm]	Conducted Power [dBm]	Test position	Measured SAR1g** [W/kg]	Power Drift* [dB]	Duty Cycle [%]	Scaling Factor	Reported SAR1g** [W/kg]	Plot #
Bluetooth	DH5	1	39	2441	9	7.20	Front, 0mm	0.00000443	0	77	1.51	0.00000671	-

*Due to low e-field generated by the DUT at the location of drift measurement, the measurements are not applicable.
**Measured result of the area scan was below the dynamic range of the E-field Probe Type EX3DV4 thus zoom scan could not be measured. Area scan result was presented.

APPENDIX A: PHOTOS OF THE DUT

Size of the sLine and xLine are 60 x 60 x 15 mm and 70 x 70 x 25 mm respectively.

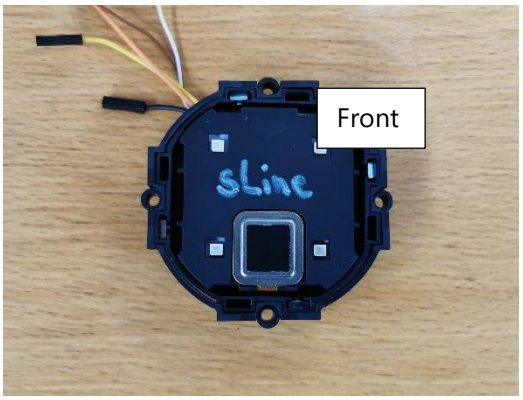


Figure 3. Overview of the sLine

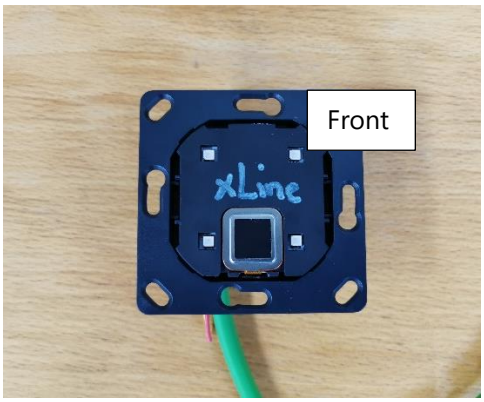


Figure 4. Overview of the xLine

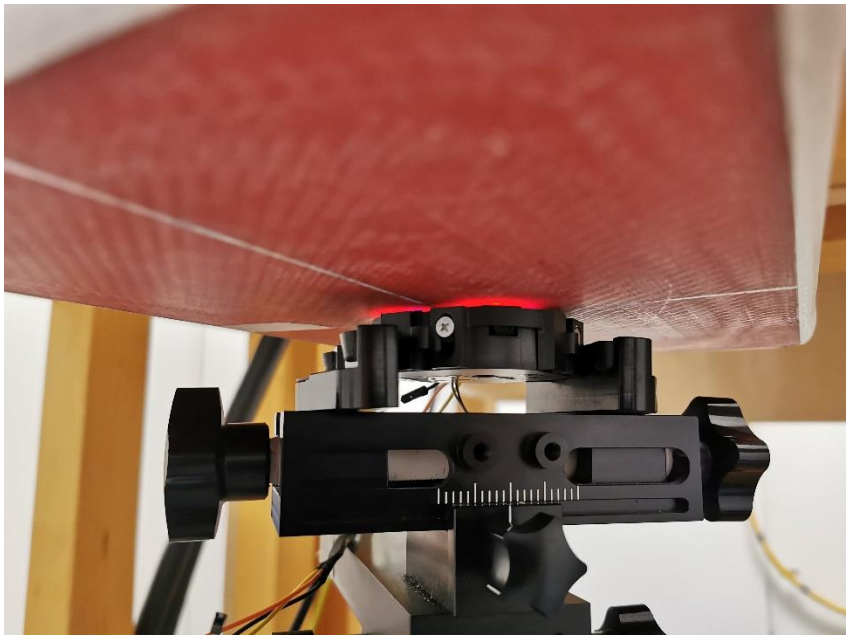


Figure 5. sLine, front, 0 mm separation distance

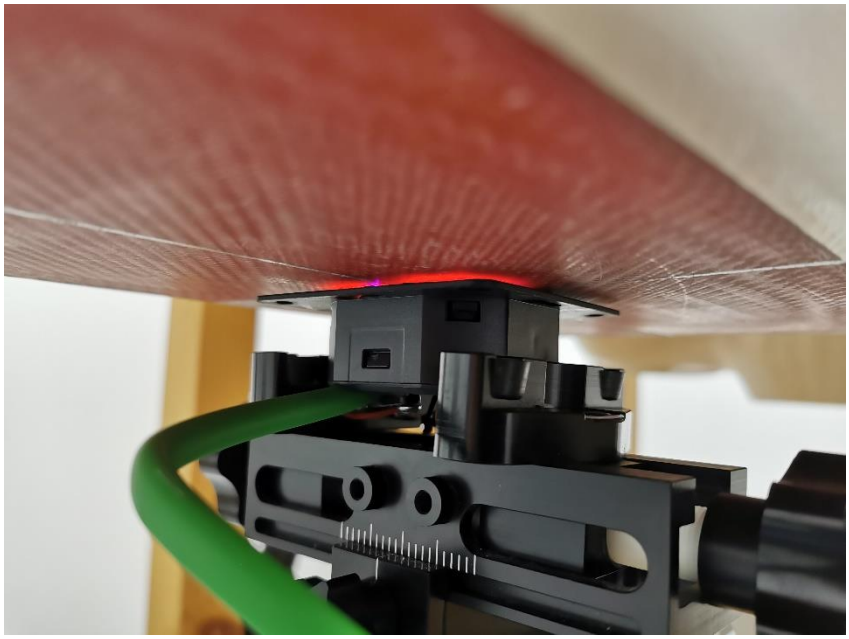


Figure 6. xLine, front, 0mm separation distance

APPENDIX B: SYSTEM CHECK SCAN

Plot 1

Date/Time: 26/06/2024 11:21:17

Test Laboratory: Verkotan Oy

DUT: D2450V2 - SN729; Type: D2450V2; Serial: SN729

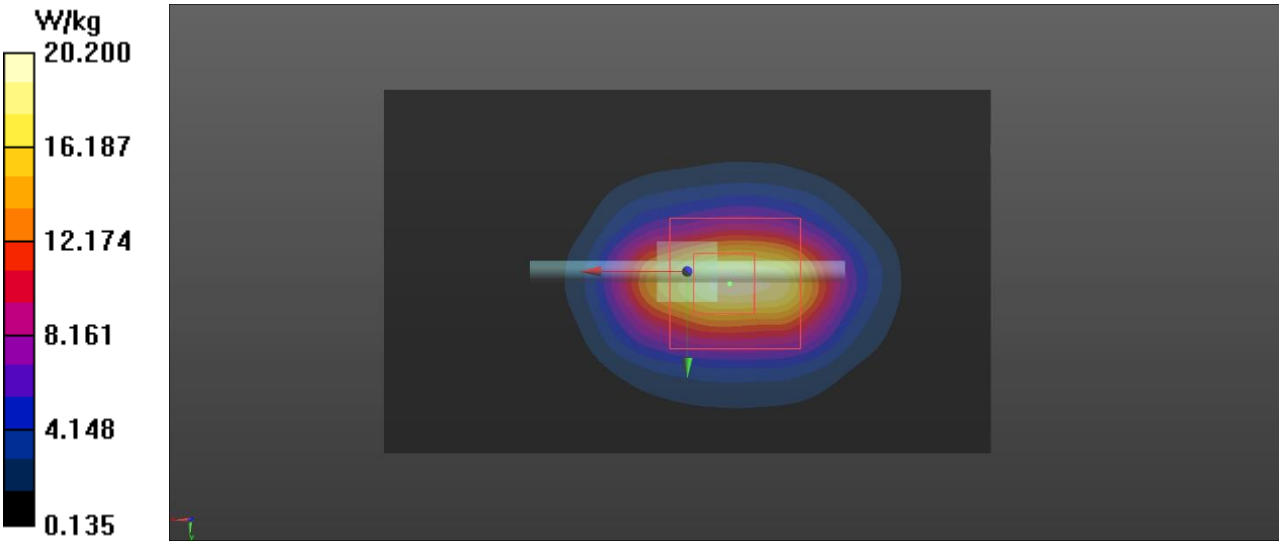
Communication System: UID 0, CW (0); Communication System Band: D2450 (2450.0 MHz); Frequency: 2450 MHz;
Communication System PAR: 0 dB;
Medium parameters used: f = 2450 MHz; σ = 1.766 S/m; ε_r = 38.222; ρ = 1000 kg/m^3
Phantom section: Center Section
Measurement Standard: DASY5 (IEEE/IEC)

DASY Configuration:

- Probe: EX3DV4 - SN3852; ConvF(7.07, 7.09, 7.16) @ 2450 MHz; Calibrated: 23/10/2023
  - Sensor-Surface: 1.4mm (Mechanical Surface Detection), z = -4.0, 31.0
  - Electronics: DAE4 Sn710; Calibrated: 24/10/2023
  - Phantom: MFP_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx;
  - DASY52 52.10.4(1527); SEMCAD X 14.6.14(7483)

Configuration/System check 2450MHz/Area Scan (101x61x1): Interpolated grid: dx=1.000 mm, dy=1.000 mm
Maximum value of SAR (interpolated) = 19.7 W/kg

Configuration/System check 2450MHz/Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 103.8 V/m; Power Drift = -0.20 dB
Peak SAR (extrapolated) = 24.4 W/kg
SAR(1 g) = 12.4 W/kg; SAR(10 g) = 5.82 W/kg (SAR corrected for target medium)
Smallest distance from peaks to all points 3 dB below = 9 mm
Ratio of SAR at M2 to SAR at M1 = 51%
Maximum value of SAR (measured) = 20.2 W/kg



APPENDIX C: MEASUREMENT SCANS

Plot 2

Date/Time: 26/06/2024 12:17:46

Test Laboratory: Verkotan Oy

DUT: sLine

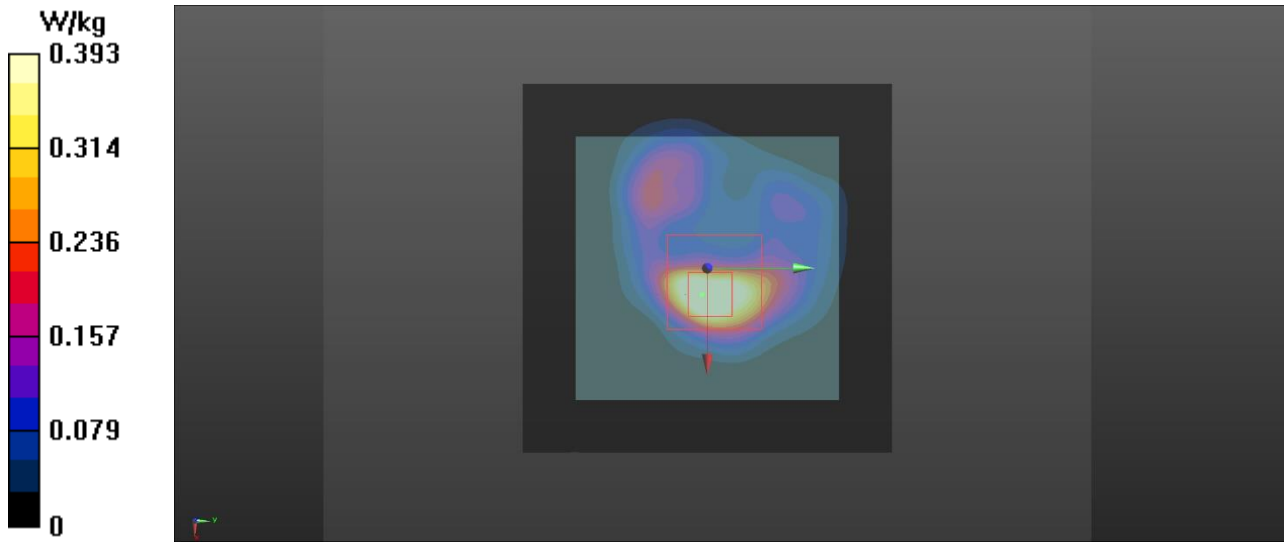
Communication System: UID 0, WLAN 2.4 (0); Communication System Band: WLAN2.4GHz; Frequency: 2412 MHz;
Communication System PAR: 0 dB;
Medium parameters used: f = 2412 MHz; σ = 1.74 S/m; ε_r = 38.292; ρ = 1000 kg/m^3
Phantom section: Center Section
Measurement Standard: DASY5 (IEEE/IEC)

DASY Configuration:

- Probe: EX3DV4 - SN3852; ConvF(7.07, 7.09, 7.16) @ 2412 MHz; Calibrated: 23/10/2023
  - Sensor-Surface: 1.4mm (Mechanical Surface Detection), z = -4.0, 31.0
  - Electronics: DAE4 Sn710; Calibrated: 24/10/2023
  - Phantom: MFP_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx;
  - DASY52 52.10.4(1527); SEMCAD X 14.6.14(7483)

Configuration/2.4 GHz WLAN, 802.11b, 1Mbps, CH1, front 0mm/Area Scan (71x71x1): Interpolated grid: dx=1.200 mm, dy=1.200 mm
Maximum value of SAR (interpolated) = 0.527 W/kg

Configuration/2.4 GHz WLAN, 802.11b, 1Mbps, CH1, front 0mm/Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 16.58 V/m; Power Drift = -0.64 dB
Peak SAR (extrapolated) = 0.513 W/kg
SAR(1 g) = 0.280 W/kg; SAR(10 g) = 0.095 W/kg (SAR corrected for target medium)
Smallest distance from peaks to all points 3 dB below = 5 mm
Ratio of SAR at M2 to SAR at M1 = 63.7%
Maximum value of SAR (measured) = 0.393 W/kg



Plot 3

Date/Time: 26/06/2024 13:38:04

Test Laboratory: Verkotan Oy

DUT: sLine

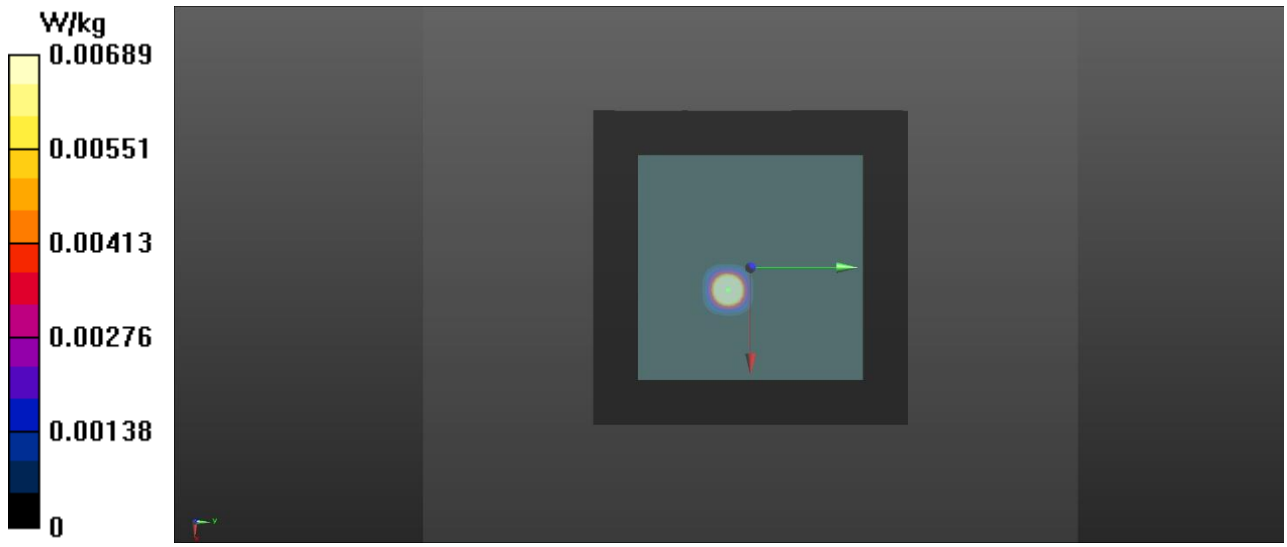
Communication System: UID 0, Bluetooth (0); Communication System Band: Bluetooth; Frequency: 2441 MHz;
Communication System PAR: 4.771 dB;
Medium parameters used: f = 2441 MHz; σ = 1.759 S/m; ε_r = 38.238; ρ = 1000 kg/m^3
Phantom section: Center Section
Measurement Standard: DASY5 (IEEE/IEC)

DASY Configuration:

- Probe: EX3DV4 - SN3852; ConvF(7.07, 7.09, 7.16) @ 2441 MHz; Calibrated: 23/10/2023
  - Sensor-Surface: 1.4mm (Mechanical Surface Detection (Locations From Previous Scan Used)), Sensor-Surface: 1.4mm (Mechanical Surface Detection), z = -4.0, 31.0
  - Electronics: DAE4 Sn710; Calibrated: 24/10/2023
  - Phantom: MFP_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx;
  - DASY52 52.10.4(1527); SEMCAD X 14.6.14(7483)

Configuration/Bluetooth, DH5, 1Mbps, CH39, front 0mm/Area Scan (71x71x1): Interpolated grid: dx=1.200 mm, dy=1.200 mm
Maximum value of SAR (interpolated) = 0.0183 W/kg

Configuration/Bluetooth, DH5, 1Mbps, CH39, front 0mm/Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 0 V/m; Power Drift = N/A
Peak SAR (extrapolated) = 0 W/kg
SAR(1 g) = n.a. ; SAR(10 g) = n.a. (SAR corrected for target medium)
Smallest distance from peaks to all points 3 dB below: Larger than measurement grid
Ratio of SAR at M2 to SAR at M1 = 12.8%
Maximum value of SAR (measured) = 0.00689 W/kg



APPENDIX D: RELEVANT PAGES FROM PROBE CALIBRATION REPORTS

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

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Accreditation No.: **SCS 0108**

Client	Verkotan Oulu, Finland	Certificate No.	EX-3852_Oct23

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3852
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	October 23, 2023

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 ES3DV2	SN: 3013	06-Jan-23 (No. ES3-3013_Jan23)	Jan-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	Joanna Lleshaj	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	

Issued: October 23, 2023

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

Certificate No: EX-3852_Oct23 Page 1 of 21

Parameters of Probe: EX3DV4 - SN:3852

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$) [A]	0.42	0.40	0.47	±10.1%
DCP (mV) [B]	102.6	101.5	101.2	±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	148.1	±1.2%	±4.7%
		Y	0.00	0.00	1.00		135.0		
		Z	0.00	0.00	1.00		125.7		
10352	Pulse Waveform (200Hz, 10%)	X	20.00	88.23	18.81	10.00	60.0	±2.9%	±9.6%
		Y	15.83	86.04	18.58		60.0		
		Z	20.00	89.60	19.58		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	20.00	89.81	18.49	6.99	80.0	±1.6%	±9.6%
		Y	20.00	89.05	18.11		80.0		
		Z	20.00	91.94	19.69		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	20.00	94.09	19.25	3.98	95.0	±1.2%	±9.6%
		Y	20.00	88.35	16.15		95.0		
		Z	20.00	93.97	19.35		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	20.00	100.39	20.91	2.22	120.0	±1.2%	±9.6%
		Y	2.38	71.76	9.70		120.0		
		Z	20.00	97.37	19.68		120.0		
10387	QPSK Waveform, 1 MHz	X	1.64	66.74	15.13	1.00	150.0	±2.8%	±9.6%
		Y	1.57	65.66	14.38		150.0		
		Z	1.68	66.38	15.01		150.0		
10388	QPSK Waveform, 10 MHz	X	2.18	68.09	15.84	0.00	150.0	±0.9%	±9.6%
		Y	2.13	67.56	15.26		150.0		
		Z	2.26	68.28	15.80		150.0		
10396	64-QAM Waveform, 100 kHz	X	2.80	70.45	18.83	3.01	150.0	±0.7%	±9.6%
		Y	2.67	68.53	17.69		150.0		
		Z	2.75	69.32	18.17		150.0		
10399	64-QAM Waveform, 40 MHz	X	3.46	67.10	15.80	0.00	150.0	±2.2%	±9.6%
		Y	3.46	66.99	15.61		150.0		
		Z	3.55	67.36	15.87		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	4.78	65.65	15.56	0.00	150.0	±4.1%	±9.6%
		Y	4.86	65.73	15.56		150.0		
		Z	4.73	65.20	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 Page 5).
[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:3852

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 msV^{-2}	T2 msV^{-1}	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	40.1	298.39	35.39	12.42	0.00	5.06	1.30	0.18	1.01
y	45.2	342.83	36.51	8.80	0.45	5.06	0.00	0.49	1.01
z	44.9	336.32	35.73	13.60	0.00	5.08	0.53	0.35	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	-56.9°
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	9 mm
Tip Diameter	2.5 mm
Probe Tip to Sensor X Calibration Point	1 mm
Probe Tip to Sensor Y Calibration Point	1 mm
Probe Tip to Sensor Z Calibration Point	1 mm
Recommended Measurement Distance from Surface	1.4 mm

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

Parameters of Probe: EX3DV4 - SN:3852

Calibration Parameter Determined in Head Tissue Simulating Media

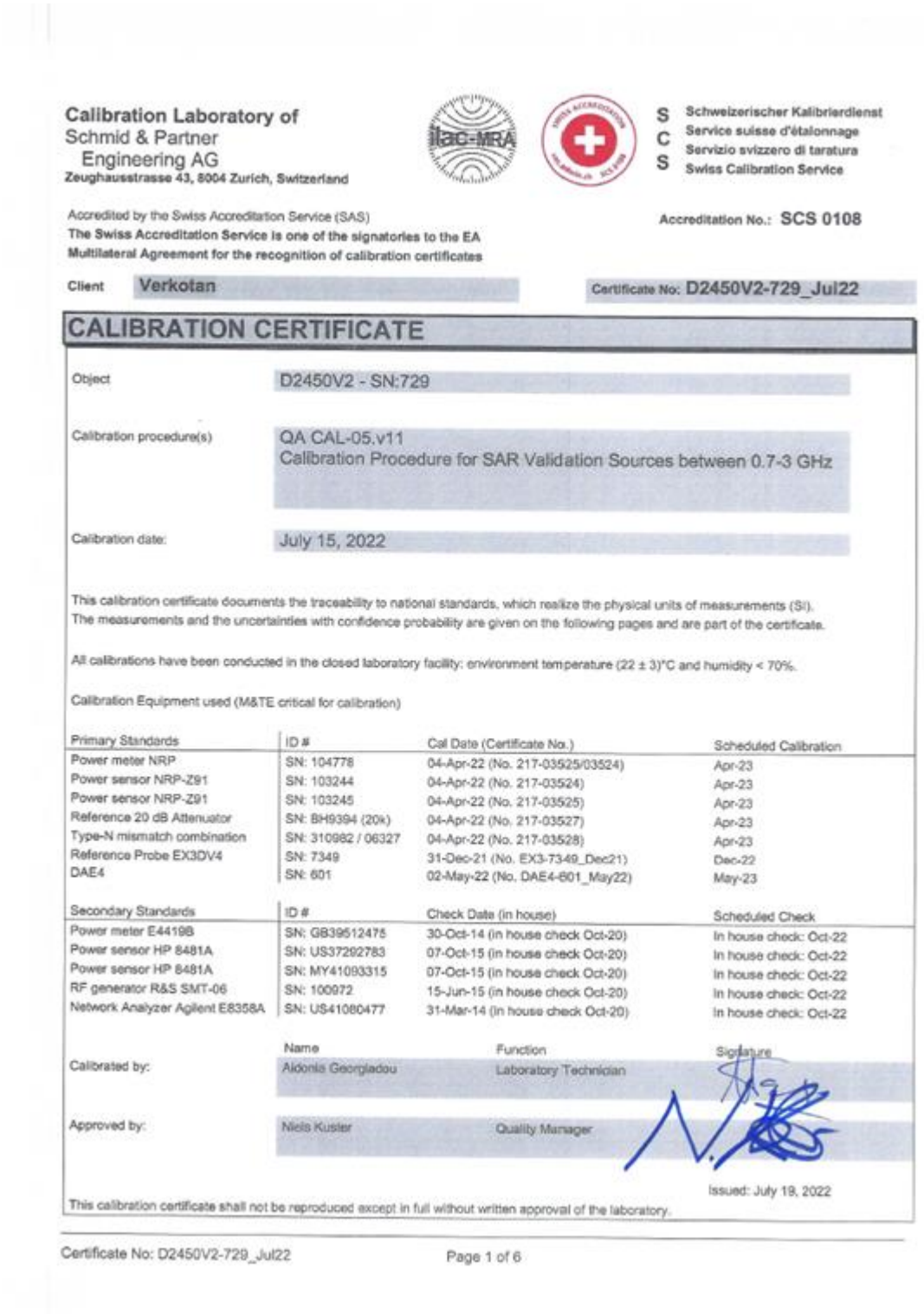
f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc ($k = 2$)
6	55.0	0.75	14.87	14.87	14.87	0.00	1.25	±13.3%
13	55.0	0.75	13.94	13.94	13.94	0.00	1.25	±13.3%
30	55.0	0.75	12.97	12.97	12.97	0.00	1.25	±13.3%
64	54.2	0.75	11.54	11.54	11.54	0.00	1.25	±13.3%
128	52.8	0.76	11.14	11.14	11.14	0.00	1.25	±13.3%
220	49.0	0.81	10.56	10.56	10.56	0.00	1.25	±13.3%
450	43.5	0.87	9.99	9.99	9.99	0.16	1.30	±13.3%
1300	40.8	1.14	8.19	7.92	8.28	0.48	1.27	±12.0%
1450	40.5	1.20	8.04	7.77	8.01	0.46	1.27	±12.0%
1640	40.2	1.31	8.04	7.69	8.00	0.43	1.27	±12.0%
1810	40.0	1.40	7.69	7.64	7.66	0.28	1.27	±12.0%
1900	40.0	1.40	7.75	7.66	7.73	0.28	1.27	±12.0%
2450	39.2	1.80	7.07	7.09	7.16	0.31	1.27	±12.0%
3300	38.2	2.71	6.76	6.56	6.80	0.32	1.27	±14.0%
3500	37.9	2.91	6.75	6.56	6.76	0.33	1.27	±14.0%
3700	37.7	3.12	6.56	6.40	6.58	0.34	1.27	±14.0%
3900	37.5	3.32	6.52	6.37	6.54	0.34	1.27	±14.0%
4100	37.2	3.53	6.23	6.14	6.27	0.35	1.27	±14.0%
5250	35.9	4.71	4.99	4.95	5.05	0.37	1.53	±14.0%
5600	35.5	5.07	4.54	4.50	4.60	0.37	1.75	±14.0%
5750	35.4	5.22	4.62	4.57	4.67	0.36	1.84	±14.0%

[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 TSL with deviations from the target of less than ±5% are used, the calibration uncertainties are 11.1% for 0.7 - 3 GHz and 13.1% for 3 - 6 GHz.

[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.

APPENDIX E: RELEVANT PAGES FROM DIPOLE CALIBRATION REPORTS



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

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Accreditation No.: SCS 0108

Client Verkotan

Certificate No: D2450V2-729_Jul22

CALIBRATION CERTIFICATE

Object	D2450V2 - SN:729
Calibration procedure(s)	QA CAL-05.v11 Calibration Procedure for SAR Validation Sources between 0.7-3 GHz
Calibration date:	July 15, 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	04-Apr-22 (No. 217-03525/03524)	Apr-23
Power sensor NRP-Z91	SN: 103244	04-Apr-22 (No. 217-03524)	Apr-23
Power sensor NRP-Z91	SN: 103245	04-Apr-22 (No. 217-03525)	Apr-23
Reference 20 dB Attenuator	SN: BH9394 (20k)	04-Apr-22 (No. 217-03527)	Apr-23
Type-N mismatch combination	SN: 310982 / 06327	04-Apr-22 (No. 217-03528)	Apr-23
Reference Probe EX3DV4	SN: 7349	31-Dec-21 (No. EX3-7349_Dec21)	Dec-22
DAE4	SN: 601	02-May-22 (No. DAE4-601_May22)	May-23

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:	Aldonia Georgiadou	Laboratory Technician	
Approved by:	Niels Kuster	Quality Manager	

Issued: July 19, 2022

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

Certificate No: D2450V2-729_Jul22 Page 1 of 6

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 ± 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 ± 0.2) °C	37.9 ± 6 %	1.85 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	13.4 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	**52.3 W/kg ± 17.0 % (k=2)**

SAR averaged over 10 cm³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	6.21 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	**24.5 W/kg ± 16.5 % (k=2)**

