



TEST REPORT

Test Report No.: 1-8581-24-01-17_TR2-R01



Deutsche
Akkreditierungsstelle
D-PL-12047-01-00

BNetzA-CAB-02/21-102

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Accredited Testing Laboratory:

The testing laboratory (area of testing) is accredited according to DIN EN ISO/IEC 17025 (2018-03) by the Deutsche Akkreditierungsstelle GmbH (DAkkS).

The accreditation is valid for the scope of testing procedures as stated in the accreditation certificate with the registration number: D-PL-12047-01-00.

FCC designation number: DE0002

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Manufacturer

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Test Standard/s

KDB 447498D01v06

Mobile and Portable Devices RF Exposure Procedures and Equipment Authorization Policies

KDB 680106 D01v04

Equipment Authorization of Wireless Power Transfer devices

IEC PAS 63184

Assessment methods of the human exposure to electric and magnetic fields from wireless power transfer systems – Models, instrumentation, measurement and numerical methods and procedures (frequency range of 1 kHz to 30 MHz)

CFR 47 – Part 1, §1.1310

RF exposure limits (100 kHz to 6 GHz) for SAR (BR)

For further applied test standards please refer to section 3 of this test report.

Test Item

Kind of test item:

nivia 3D finder

Device type:

portable device

Model name:

Avalanche Bacon

FCC ID:

2BG4V-MI1LVS-001-WW

Serial number:

8

Hardware status:

300

Software status:

1.14

Frequency:

Avalanche Beacon 457 kHz, ± 80 Hz

BT LE 2450 MHz

Antenna:

Integrated antenna

Power supply:

3.7 V DC by Li Ion battery

Test sample status:

identical prototype

Exposure category:

general population / uncontrolled environment

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Test Report authorised:



Alexander Hnatovskiy
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Radio Lab

Test performed:



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2 General information

2.1 Notes and disclaimer

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2.2 Application details

Date of receipt of order:	2024-09-04
Date of receipt of test item:	2024-09-30
Start of test:	2024-10-22
End of test:	2024-12-13

2.3 Statement of compliance

The EMF values found for the Avalanche Bacon nivia 3D finder are below the maximum allowed levels according to the standards listed in section 3.

3 Test standard/s:

Test Standard	Version	Test Standard Description
IEEE Std. C95-3	2021	IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields – RF and Microwave
IEC PAS 63184	May 2021	Assessment methods of the human exposure to electric and magnetic fields from wireless power transfer systems – Models, instrumentation, measurement and numerical methods and procedures (frequency range of 1 kHz to 30 MHz)
IEC TR 62905	01.02.2018	IEC/TR 62905:2018(E) is a Technical Report. It describes general exposure assessment methods for wireless power transfer (WPT) at frequency up to 10 MHz considering thermal and stimulus effects. Exposure assessment procedures and experimental results are shown as examples such as electric vehicles (EVs) and mobile devices.
IEEE Std. C95-3	2002	IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields – RF and Microwave
IEC/IEEE 62209-1528-2020	2020-10-19	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 – Part 1528: Human models, instrumentation, and procedures (Frequency range of 4 MHz to 10 GHz)
FCC KDBs:		
KDB 865664D01v01	August 7, 2015	FCC OET SAR measurement requirements 100 MHz to 6 GHz
KDB 865664D02v01	October 23, 2015	RF Exposure Compliance Reporting and Documentation Considerations
KDB 447498D01v06	October 23, 2015	Mobile and Portable Devices RF Exposure Procedures and Equipment Authorization Policies
KDB 680106 D01v04	October 24, 2023	Equipment Authorization of Wireless Power Transfer devices
KDB 648474D04v01	October 23, 2015	SAR Evaluation Considerations for Wireless Handsets

APPLICATION NOTE:

Testing WPT Devices with DASY8/6 Modules WPT and SAR for Compliance with FCC KDB 447498/680106 (Chapter 5 Test System and Procedures for Frequencies from 100 kHz to 4 MHz, by SPEAG, R2, 05/24)

3.1 RF exposure limits according CFR 47 – Part 1, §1.1310

RF Exposure levels according CFR 47 – Part 1, §1.1310:

Human Exposure	Uncontrolled Environment General Population	Controlled Environment Occupational
Spatial Peak SAR* (Brain and Trunk)	1.60 W/kg	8.00 W/kg
Spatial Average SAR** (Whole Body)	0.08 W/kg	0.40 W/kg
Spatial Peak SAR*** (Hands/Feet/Ankle/Wrist)	4.00 W/kg	20.00 W/kg

Table 1: RF exposure limits (100 kHz to 6 GHz)

The limit applied in this test report is shown in bold letters

Notes:

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

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure.

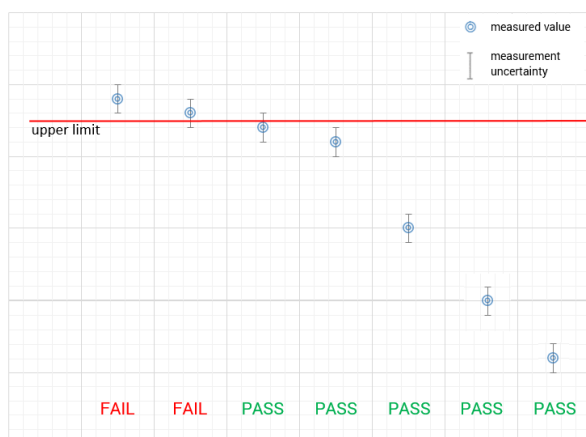
Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation).

4 Reporting statements of conformity – decision rule

Only the measured values related to their corresponding limits will be used to decide whether the equipment under test meets the requirements of the test standards listed in chapter 3.

The measurement uncertainty is mentioned in this test report, see chapter 9, but is not taken into account - neither to the limits nor to the measurement results. Measurement results with a smaller margin to the corresponding limits than the measurement uncertainty have a potential risk of more than 5% that the decision might be wrong."

measured value, measurement uncertainty, verdict



5 Summary of Measurement Results

☒	No deviations from the technical specifications ascertained	
☐	Deviations from the technical specifications ascertained	
Maximum SAR value (W/kg)		
	reported	limit
body worn 0 mm distance for 1g	0.052	1.6
extremity 0 mm distance for 10g	0.023	4.0
Collocated Σ SAR: 457 kHz Avalanche Bacon + 2.4 GHz BT LE	0.055	1.6

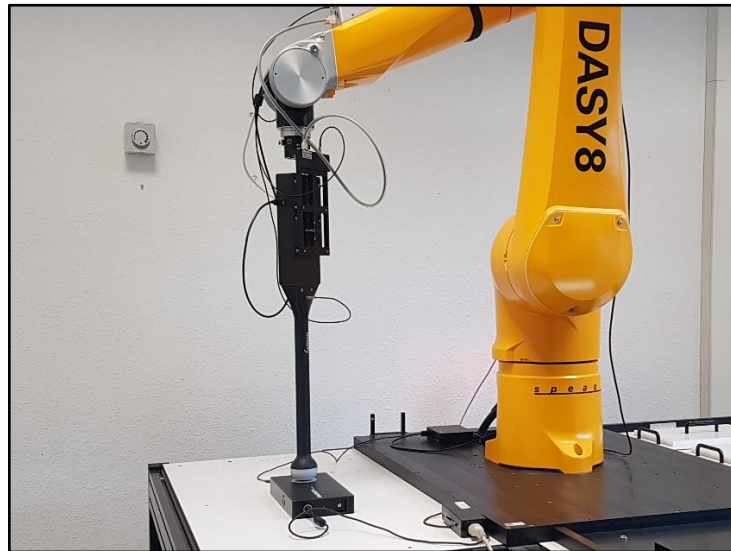
6 Test Environment

Ambient temperature:	20 – 24 °C
Relative humidity content:	40 – 50 %
Air pressure:	not relevant for this kind of testing
Power supply:	230 V / 50 Hz

7 Test Set-up for WPT measurements (SAR evaluation 3kHz to 4MHz)

7.1 Measurement system

7.1.1 Measurement with MAGPy-H3D probe / DASY 8 WPT-System



The DASY8 WPT-System is a complete high precision robot-based evaluation platform for demonstrating compliance of wireless power transfer (WPT) devices according to IEC PAS 63184:2021(Chapter 8 "Measurement and numerical combination methods") and enables fully automated compliance testing. [1]

It is composed of the isotropic probe MAGPy-8H3D+E3D V2, the reference amplitude and phase probe (MAGPy-RAφ V2), and the data acquisition system (MAGPy-DAS V2) mounted to the DASY8 robot via the emergency stop (MAGPy-ES). The induced electric (E-) fields and specific absorption rate (SAR) are assessed with Sim4Life's Quasi-Static EM Solver (P-EM-QS) using only the measured data. The dedicated graphical user interface (GUI) fully automates the testing workflow.

This allows for Laboratory evaluation of WPT devices and any other local electromagnetic source not requiring magnetic (H-) field volume scans exceeding 2000 x 1000 x 1500 mm³ with a precision of ±2.0mm.

The H-field distributions can be analyzed directly, and the values are compared to the reference level, or they are converted into Maxwell field and used as excitations for determining the basic restriction quantities for further dosimetric analysis with the Magneto Quasi-Static (MQS) solver [2].

This specific solution is optimized for:

- Evaluation of E & H-field (3 kHz – 10 MHz)
- Demonstration of compliance (3 kHz and 4 MHz) according to IEC PAS 63184:2021 [3]

References:

[1] Assessment methods of the human exposure to electric and magnetic fields from wireless power transfer systems. Models, instrumentation, measurement and numerical methods and procedures (frequency range of 1 kHz to 30MHz), IEC PAS 63184:2021.

[2] The MQS conditions are violated above 4MHz and SPEAG recommends to use IEC/IEEE 62209-1528 for the frequency range above 4 MHz.

[3] Sim4Life, V7.2, ZMT Zurich MedTech AG, Zurich, Switzerland.

7.1.1.1 Workflow for Tier-4 Compliance Testing of IEC PAS 63184:2021

Compliance testing according to Tier-4 of IEC PAS 63184:2021 is the most accurate method ensuring no overestimation of the exposure. The workflow implemented in DASY8 Module WPT consists of the following steps:

1. probe alignment,
2. teaching of the DUT position,
3. 3D scan with automated grid optimization,
4. vector potential reconstruction (Sim4Life),
5. solving the MQS equation in the muscle half-space,
6. applying coverage factors (pre-determined by the IT'IS Foundation),
7. advanced evaluations in various posed Sim4Life ViP phantoms.

Additionally, the system performance is routinely verified using the standard verification sources as DUT's.

7.1.1.2 Compatibility with IEC PAS 63184:2021

DASY8 Module WPT is fully compliant with IEC PAS 63184:2021 and evaluates the reference values and basic restrictions according to:

- ICNIRP 2020
- ICNIRP 2010
- ICNIRP 1998
- IEEE 2019
- CFR 47 – Part 1, §1.1310
- FCC 2020
- FCC KDB 680106 D01
- FCC KDB 447498 D01
- HC Code 6
- ISED SPR-002 ISSUE 2

7.1.1.3 MAGPy-Probes

MAGPy-8H3D+E3D V2

The MAGPy-8H3D+E3D V2 probe consists of eight isotropic H-field subprobes and one isotropic E-field subprobe that are all integrated inside the probe head with a flat tip. Each isotropic H-field subprobe is comprised of three concentric orthogonal loop coil sensors. The isotropic E-field subprobe is composed of three orthogonal sensors (x and y sensors are dipoles, and the sensor measuring the z component is a monopole).

In total, the MAGPy-8H3D+E3D V2 probe contains 27 sensors that measure in the time domain. The specifications of the probe are provided in the table below.

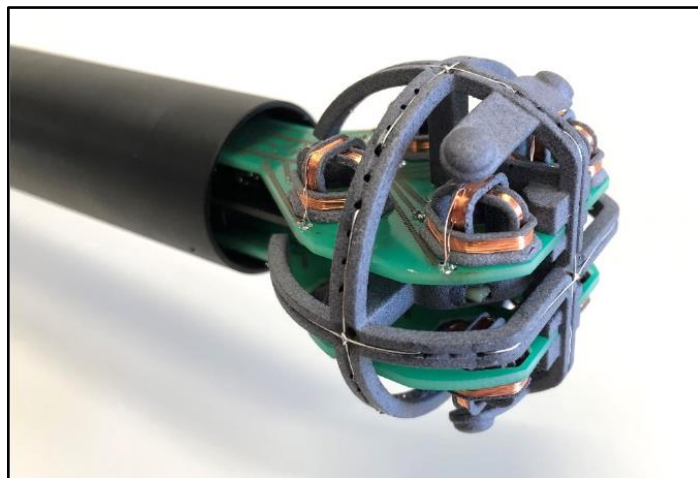
The MAGPy-8H3D+E3D V2 probe measures the isotropic H-field and E-field, and is compatible with DASY8 Module WPT V2.2 and MAGPy V2.2.



Probe design	
Probe head diameter	60mm
H-field sub-probes	8 isotropic H-field sub-probes Concentric loops of 1 cm ² arranged at the corners of a 22mm cube
E-field sub-probes	1 isotropic E-field sub-probe Orthogonal dipole/monopole (arm length: 50mm)
Temperature range	0–40 °C
Dimensions	110mm×635mm×35mm (MAGPy-8H3D+E3D V2 & MAGPy-DAS V2)
H-field measurement specifications	
Frequency range	3 kHz–10MHz
Dynamic range	0.1–3200A/m (0.12 µT–4 mT)
E-field measurement specifications	
Frequency range	3 kHz–10MHz
Dynamic range	0.08–2000V/m

The sensor offset, i.e., the distance from the outer surface (tip) of the probe to the center of the closest H-field sensors inside, is 7.5 mm. The distance to the virtual measuring point is 19 mm (The center of the 8 sub-field probes)

The following picture shows The MAGPy-8H3D+E3D V2 probe with the probe-head cap removed, showing the eight isotropic H-field sub-probes and one isotropic E-field sub-probe:



MAGPy-RAφ V2

The MAGPy-RAφ V2 probe is a pick-up coil to serve as a phase and amplitude reference, composed of one loop with the specifications shown in following table.

It is connected to the MAGPy-8H3D+E3D V2 probe and should be placed near the DUT during the spatial scan to ensure a sufficient signal-to-noise ratio.

Frequency range	3 kHz - 10 MHz
Dynamic range	0.1 – 3200 A/m (0.12 μ T – 4 mT)
Loop coil size	50 × 50mm ²



7.1.1.4 MAGPy-DAS: Data Acquisition System

Description of MAGPy-DAS V2

The MAGPy-DAS V2 is a speed-optimized unit that can process up to 27 input channels in real-time with a sampling rate of 25 MHz. The specifications of the MAGPy-DAS are:

- 27 x 14 Bit ADC Channels with 25 MSPs
- peak detection stage
- hardware supervising unit
- data transfer to backend
- 22 tap FIR filter

The measured analog signals from the MAGPy probes are firstly transferred to the analog input stage, which comprises filters, amplifiers, and attenuators. The analog signal is then transformed into a digital signal through the analog to digital converter (ADC) and treated in the field programmable gate arrays (FPGA) controller. The FPGA firmware consists of:

- FIR filter
- peak detection
- AGC (Automatic gain control unit)
- scaling unit

The controller communicates with the MAGPy software installed on the desktop or tablet PC across USB 2.0.

7.1.2 Uncertainties

The probe uncertainties stated by the manufacturer are considered to be the main relevant and dominant issues.

7.1.2.1 Typical uncertainty of Module WPT

DASY8 Uncertainty Budget for Peak <i>H</i> -field according to IEC/IEEE 63184						
Item	Error Description	Unc. Value (±dB)	Probab. Distr.	Div.	(c_i)	Std. Unc. (±dB)
Measurement system						
1	Amplitude calibration uncertainty	0.35	N	1	1	0.35
2	Probe anisotropy	0.6	R	$\sqrt{3}$	1	0.35
3	Probe dynamic linearity	0.2	R	$\sqrt{3}$	1	0.12
4	Probe frequency domain response	0.3	R	$\sqrt{3}$	1	0.17
5	Probe frequency linear interp. fit	0.15	R	$\sqrt{3}$	1	0.09
6	Gradient uncertainty	0.1	R	$\sqrt{3}$	1	0.06
7	Parasitic E-field sensitivity	0.1	R	$\sqrt{3}$	1	0.06
8	Detection limit	0.15	R	$\sqrt{3}$	1	0.09
9	Readout electronics	0	N	1	1	0
10	Probe positioning	0.19	N	1	1	0.19
11	Repeatability	0.1	N	1	1	0.10
12	Surface field reconstruction	0.3	N	1	1	0.3
Combined uncertainty ($k = 1$)						0.59
Expanded uncertainty ($k = 2$)						1.33 (16.6%)

Uncertainty budget for peak incident H-field measured with DASY8 Module WPT assessed according to IEC/IEEE 63184

DASY8 Uncertainty Budget for Incident <i>E</i> -field according to IEC/IEEE 63184						
Item	Error Description	Unc. Value (±dB)	Probab. Distr.	Div.	(c_i)	Std. Unc. (±dB)
Measurement system						
1	Amplitude calibration uncertainty	0.53	N	1	1	0.53
2	Probe anisotropy	0.8	R	$\sqrt{3}$	1	0.46
3	Probe dynamic linearity	1	R	$\sqrt{3}$	1	0.58
4	Probe frequency domain response	0.3	R	$\sqrt{3}$	1	0.17
5	Probe frequency linear interp. fit	0.15	R	$\sqrt{3}$	1	0.09
6	Parasitic H-field sensitivity	0.2	R	$\sqrt{3}$	1	0.12
7	Detection limit	0.15	R	$\sqrt{3}$	1	0.09
8	Readout electronics	0	N	1	1	0
9	Repeatability	0.1	N	1	1	0.10
Combined uncertainty ($k = 1$)						0.95
Expanded uncertainty ($k = 2$)						1.89 (24.4%)

Uncertainty budget for incident E-field measured with DASY8 Module WPT with linear gradients across the probe.

DASY8 Uncertainty Budget for Peak $2 \times 2 \times 2 \text{ mm}^3$ Cube-Average E_{ind} according to IEC/IEEE 63184						
Item	Error Description	Unc. Value ($\pm \text{dB}$)	Probab. Distr.	Div.	(c_i)	Std. Unc. ($\pm \text{dB}$)
Measurement system						
1	Amplitude calibration uncertainty	0.35	N	1	1	0.35
2	Probe anisotropy	0.6	R	$\sqrt{3}$	1	0.35
3	Probe dynamic linearity	0.2	R	$\sqrt{3}$	1	0.12
4	Probe frequency domain response	0.3	R	$\sqrt{3}$	1	0.17
5	Probe frequency linear interp. fit	0.15	R	$\sqrt{3}$	1	0.09
6	Spatial averaging	0.1	R	$\sqrt{3}$	1	0.06
7	Parasitic E -field sensitivity	0.1	R	$\sqrt{3}$	1	0.06
8	Detection limit	0.15	R	$\sqrt{3}$	1	0.09
9	Readout electronics	0	N	1	1	0
10	Probe positioning	0.19	N	1	1	0.19
11	Repeatability	0.1	N	1	1	0.1
12	Surface field reconstruction	0.3	N	1	1	0.3
Numerical simulations						
13	Grid resolution	0.18	R	$\sqrt{3}$	1	0.10
14	Tissue parameters	0	R	$\sqrt{3}$	1	0
15	Exposure position	0	R	$\sqrt{3}$	1	0
16	Source representation	0.24	N	1	1	0.24
17	Convergence and power budget	0	R	$\sqrt{3}$	1	0
18	Boundary conditions	0.1	R	$\sqrt{3}$	1	0.06
19	Phantom loading/backscattering	0.1	R	$\sqrt{3}$	1	0.06
Combined uncertainty ($k = 1$)						0.72
Expanded uncertainty ($k = 2$)						1.44 (18.0%)

Uncertainty budget for peak $2 \times 2 \times 2 \text{ mm}^3$ cube-average induced E-field measured with DASY8 Module WPT assessed according to IEC/IEEE 63184.

DASY8 Uncertainty Budget for Peak 5 mm Line-Average E_{ind} according to IEC/IEEE 63184						
Item	Error Description	Unc. Value ($\pm$ dB)	Probab. Distr.	Div.	(c_i)	Std. Unc. ($\pm$ dB)
Measurement system						
1	Amplitude calibration uncertainty	0.35	N	1	1	0.35
2	Probe anisotropy	0.6	R	$\sqrt{3}$	1	0.35
3	Probe dynamic linearity	0.2	R	$\sqrt{3}$	1	0.12
4	Probe frequency domain response	0.3	R	$\sqrt{3}$	1	0.17
5	Probe frequency linear interp. fit	0.15	R	$\sqrt{3}$	1	0.09
6	Spatial averaging	0.1	R	$\sqrt{3}$	1	0.06
7	Parasitic E -field sensitivity	0.1	R	$\sqrt{3}$	1	0.06
8	Detection limit	0.15	R	$\sqrt{3}$	1	0.09
9	Readout electronics	0	N	1	1	0
10	Probe positioning	0.19	N	1	1	0.19
11	Repeatability	0.1	N	1	1	0.1
12	Surface field reconstruction	0.3	N	1	1	0.3
Numerical simulations						
13	Grid resolution	0.25	R	$\sqrt{3}$	1	0.14
14	Tissue parameters	0	R	$\sqrt{3}$	1	0
15	Exposure position	0	R	$\sqrt{3}$	1	0
16	Source representation	0.27	N	1	1	0.27
17	Convergence and power budget	0	R	$\sqrt{3}$	1	0
18	Boundary conditions	0.1	R	$\sqrt{3}$	1	0.06
19	Phantom loading/backscattering	0.1	R	$\sqrt{3}$	1	0.06
Combined uncertainty ($k = 1$)						0.74
Expanded uncertainty ($k = 2$)						1.48 (18.5%)

Uncertainty budget for peak 5 mm line-average induced E-field measured with DASY8 Module WPT assessed according to IEC/IEEE 63184.

DASY8 Uncertainty Budget for Peak Local E_{ind} according to IEC/IEEE 63184						
Item	Error Description	Unc. Value ($\pm$ dB)	Probab. Distr.	Div.	(c_1)	Std. Unc. ($\pm$ dB)
Measurement system						
1	Amplitude calibration uncertainty	0.35	N	1	1	0.35
2	Probe anisotropy	0.6	R	$\sqrt{3}$	1	0.35
3	Probe dynamic linearity	0.2	R	$\sqrt{3}$	1	0.12
4	Probe frequency domain response	0.3	R	$\sqrt{3}$	1	0.17
5	Probe frequency linear interp. fit	0.15	R	$\sqrt{3}$	1	0.09
6	Spatial averaging	0.1	R	$\sqrt{3}$	1	0.06
7	Parasitic E -field sensitivity	0.1	R	$\sqrt{3}$	1	0.06
8	Detection limit	0.15	R	$\sqrt{3}$	1	0.09
9	Readout electronics	0	N	1	1	0
10	Probe positioning	0.19	N	1	1	0.19
11	Repeatability	0.1	N	1	1	0.1
12	Surface field reconstruction	0.3	N	1	1	0.3
Numerical simulations						
13	Grid resolution	0.09	R	$\sqrt{3}$	1	0.05
14	Tissue parameters	0	R	$\sqrt{3}$	1	0
15	Exposure position	0	R	$\sqrt{3}$	1	0
16	Source representation	0.27	N	1	1	0.27
17	Convergence and power budget	0	R	$\sqrt{3}$	1	0
18	Boundary conditions	0.1	R	$\sqrt{3}$	1	0.06
19	Phantom loading/backscattering	0.1	R	$\sqrt{3}$	1	0.06
Combined uncertainty ($k = 1$)						0.73
Expanded uncertainty ($k = 2$)						1.45 (18.2%)

Uncertainty budget for peak local (i.e., not spatial averaged) induced E-field measured with DASY8 Module WPT assessed according to IEC/IEEE 63184.

DASY8 Uncertainty Budget for Peak 1 cm ² Area-Average J _{ind} according to IEC/IEEE 63184						
Item	Error Description	Unc. Value (±dB)	Probab. Distr.	Div.	(c _i)	Std. Unc. (±dB)
Measurement system						
1	Amplitude calibration uncertainty	0.35	N	1	1	0.35
2	Probe anisotropy	0.6	R	√3	1	0.35
3	Probe dynamic linearity	0.2	R	√3	1	0.12
4	Probe frequency domain response	0.3	R	√3	1	0.17
5	Probe frequency linear interp. fit	0.15	R	√3	1	0.09
6	Spatial averaging	0.1	R	√3	1	0.06
7	Parasitic E-field sensitivity	0.1	R	√3	1	0.06
8	Detection limit	0.15	R	√3	1	0.09
9	Readout electronics	0	N	1	1	0
10	Probe positioning	0.19	N	1	1	0.19
11	Repeatability	0.1	N	1	1	0.1
12	Surface field reconstruction	0.3	N	1	1	0.3
Numerical simulations						
13	Grid resolution	0.12	R	√3	1	0.07
14	Tissue parameters	0	R	√3	1	0
15	Exposure position	0	R	√3	1	0
16	Source representation	0.1	N	1	1	0.1
17	Convergence and power budget	0	R	√3	1	0
18	Boundary conditions	0.1	R	√3	1	0.06
19	Phantom loading/backscattering	0.1	R	√3	1	0.06
Combined uncertainty (k = 1)						0.68
Expanded uncertainty (k = 2)						1.36 (17.0%)

Uncertainty budget for peak 1 cm² area-average induced current density measured with DASY8 Module WPT assessed according to IEC/IEEE 63184.

DASY8 Uncertainty Budget for psSAR1 g according to IEC/IEEE 63184						
Item	Error Description	Unc. Value (±dB)	Probab. Distr.	Div.	(c_1)	Std. Unc. (±dB)
Measurement system						
1	Amplitude calibration uncertainty	0.35	N	1	1	0.35
2	Probe anisotropy	0.6	R	$\sqrt{3}$	1	0.35
3	Probe dynamic linearity	0.2	R	$\sqrt{3}$	1	0.12
4	Probe frequency domain response	0.3	R	$\sqrt{3}$	1	0.17
5	Probe frequency linear interp. fit	0.15	R	$\sqrt{3}$	1	0.09
6	Spatial averaging	0.1	R	$\sqrt{3}$	1	0.06
7	Parasitic <i>E</i> -field sensitivity	0.1	R	$\sqrt{3}$	1	0.06
8	Detection limit	0.15	R	$\sqrt{3}$	1	0.09
9	Readout electronics	0	N	1	1	0
10	Probe positioning	0.19	N	1	1	0.19
11	Repeatability	0.1	N	1	1	0.1
12	Surface field reconstruction	0.2	N	1	1	0.2
Numerical simulations						
13	Grid resolution	0.02	R	$\sqrt{3}$	1	0.01
14	Tissue parameters	0	R	$\sqrt{3}$	1	0
15	Exposure position	0	R	$\sqrt{3}$	1	0
16	Source representation	0.09	N	1	1	0.09
17	Convergence and power budget	0	R	$\sqrt{3}$	1	0
18	Boundary conditions	0.1	R	$\sqrt{3}$	1	0.06
19	Phantom loading/backscattering	0.1	R	$\sqrt{3}$	1	0.06
Combined uncertainty ($k = 1$)						0.63
Expanded uncertainty ($k = 2$)						1.27 (33.0%)

Uncertainty budget for peak 1 gram mass-average induced SAR measured with DASY8 Module WPT assessed according to IEC/IEEE 63184.

NOTE: SAR Upscaling to compensate for the unfulfilled Uncertainty budget

As all other uncertainties fulfil the <30% Budget, upscaling of the SAR Value by 3% ($1.339/1.3=1.03$) for both 1g and 10g SAR is sufficient to offset the expanded by SAR measurements to ensure a reasonable overestimation.

DASY8 Uncertainty Budget for psSAR10 g according to IEC/IEEE 63184						
Item	Error Description	Unc. Value (±dB)	Probab. Distr.	Div.	(c_1)	Std. Unc. (±dB)
Measurement system						
1	Amplitude calibration uncertainty	0.35	N	1	1	0.35
2	Probe anisotropy	0.6	R	$\sqrt{3}$	1	0.35
3	Probe dynamic linearity	0.2	R	$\sqrt{3}$	1	0.12
4	Probe frequency domain response	0.3	R	$\sqrt{3}$	1	0.17
5	Probe frequency linear interp. fit	0.15	R	$\sqrt{3}$	1	0.09
6	Spatial averaging	0.1	R	$\sqrt{3}$	1	0.06
7	Parasitic <i>E</i> -field sensitivity	0.1	R	$\sqrt{3}$	1	0.06
8	Detection limit	0.15	R	$\sqrt{3}$	1	0.09
9	Readout electronics	0	N	1	1	0
10	Probe positioning	0.19	N	1	1	0.19
11	Repeatability	0.1	N	1	1	0.1
12	Surface field reconstruction	0.2	N	1	1	0.2
Numerical simulations						
13	Grid resolution	0	R	$\sqrt{3}$	1	0
14	Tissue parameters	0	R	$\sqrt{3}$	1	0
15	Exposure position	0	R	$\sqrt{3}$	1	0
16	Source representation	0.04	N	1	1	0.04
17	Convergence and power budget	0	R	$\sqrt{3}$	1	0
18	Boundary conditions	0.1	R	$\sqrt{3}$	1	0.06
19	Phantom loading/backscattering	0.1	R	$\sqrt{3}$	1	0.06
Combined uncertainty ($k = 1$)						0.63
Expanded uncertainty ($k = 2$)						1.25 (33.4%)

Uncertainty budget for peak 10 gram mass-average induced SAR measured with DASY8 Module WPT assessed according to IEC/IEEE 63184.

NOTE: SAR Upscaling to compensate for the unfulfilled Uncertainty budget

As all other uncertainties fulfil the <30% Budget, upscaling of the SAR Value by 3% ($1.339/1.3=1.03$) for both 1g and 10g SAR is sufficient to offset the expanded by SAR measurements to ensure a reasonable overestimation.

7.1.3 Definition of test position and distances

In absence of an equipment specific regulation with given test distances, all not further noted test positions were measured in “touched” mode, the probe radome touching the DUT at the defined test position. Due to the mechanical concept of the used probe a distance between DUT surface and electrical centre of the probe antennas remains.

Probe type	Closest physical Test distance (cm)	
	Magnetic Field	Electrical Field
MAGPy-8H3D+E3D V2	0.75 (Sub @ lowest plane)	5.0

7.1.3.1 System Check and Validation

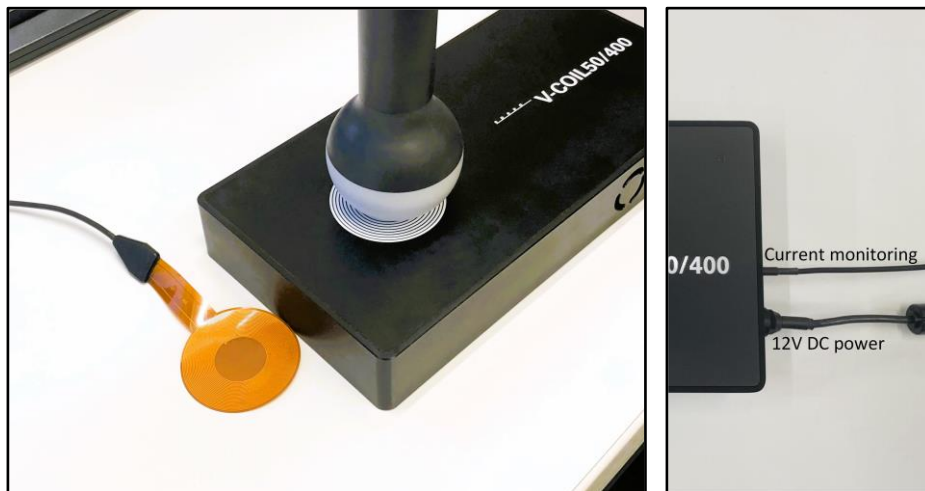
Overview

Verification and Validation (V&V) sources are designed as well-defined sources with target values to verify that the system works within its specification. A system check is typically performed prior to any compliance evaluation.

For the DASY8 Module WPT, a set of four system validation sources (3 kHz, 85 kHz, 400 kHz and 6.78 MHz) are available. These sources consist of series resonant spiral coils, fed with an integrated current source. The current source consists of an oscillator and an amplifier at the appropriate frequency.

A monitoring port in the form of a SMB connector is available on the device to monitor the current through the coil. The port offers the voltage across a 1 Ohm resistor connected in series with the coil, therefore the current I corresponds to the measured voltage V_{testport} ($I = V_{\text{testport}}$). The voltage on the port can thus be monitored with an oscilloscope and this should be equal to the current through the coil.

Target values ($H_{\text{inc;max}}$, $E_{\text{ind;max}}$, $J_{\text{ind;max}}$) for each source have been determined for several distances through simulations using the MQS solver in Sim4Life. The details of the evaluation are available at Application Notes, for each source.



The picture above shows a 400 kHz system check and validation device, with the power cable and the current monitoring cable connected.

Specifications

The specifications of the sources are as follows:

Item	V-Coil500/3	V-Coil350/85	V-Coil50/400	V-Coil25/6780
Frequency (kHz)	3	85	400	6780
Coil Dimension (mm)	500 x 500	350 x 200	50 x 50	25 x 25
No. of Turns	11	13	11	10
Current Source	I500/3	I350/85	I50/400	I25/6780
Current Monitor Port	SMB	SMB	SMB	SMB
Device Dimensions (mm)	500 x 500 x 35	250 x 500 x 35	125 x 250 x 35	125 x 250 x 35

7.2 Test results

7.2.1 System Check 400kHz source

WPT 2.6 - measurement - 22/10/2024		Peak Eind (V/m, rms)		Peak Jind (A/m ² , rms)	psSAR (mW/kg)	
Spacing (mm)	Peak Hinc (A/m, rms)	Cube avg.	Line avg.	Surface avg.	1g avg.	10g avg.
0	250	3.91	4.03	2.40	5.50	2.88

target values		Peak Eind (V/m, rms)		Peak Jind (A/m ² , rms)	psSAR (mW/kg)	
Spacing (mm)	Peak Hinc (A/m, rms)	Cube avg.	Line avg.	Surface avg.	1g avg.	10g avg.
0	280	4.42	4.53	2.79	7.67	3.79

Comparison (in dB)		Peak Eind (V/m, rms)		Peak Jind (A/m ² , rms)	psSAR (mW/kg)	
Spacing (mm)	Peak Hinc (A/m, rms)	Cube avg.	Line avg.	Surface avg.	1g avg.	10g avg.
0	-0.98	-1.06	-0.99	-1.31	-1.44	-1.19

7.2.2 cDASY8 Module WPT Measurement Report

Device under test

- Model / Manufacturer: nivia
- Serial number: 8
- Dimensions: 130 x 65 x 45 mm
- Measurement scenario: Touch position for backside

Hardware setup

- DASY version DASY8 Module WPT 2.6.0.5002
- Software version: 2.0.61, backend: 2.2.22
- Probe model, serial no. and configuration date: MAGPy-8H3D+E3Dv2, WP000009, 2023/11/02

Scan setup

- Center location: X: 50.00 mm, Y: -65.00 mm, Z: 64.00 mm
- Dimensions: X: 169.0 mm, Y: 256.7 mm, Z: 124.5 mm
- Resolution: X: 7.33 mm, Y: 7.33 mm, Z: 7.33 mm
- Completed on: 2024/10/22 15:58:19

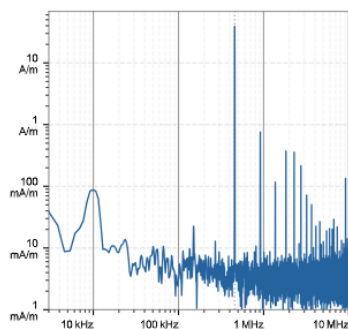
Measurement results

- Maximum H-field_[RMS]: 32.98 A/m
X: 5.04 A/m, Y: 24.40 A/m, Z: 21.61 A/m
- Maximum H-Field location relative to DUT: X: 25.67 mm, Y: -25.67 mm, Z: 8.50 mm
- Maximum E-field_[RMS]: 136.73 V/m
X: 34.66 V/m, Y: 9.64 V/m, Z: 131.92 V/m
- Maximum E-field location relative to DUT: X: 14.67 mm, Y: -29.33 mm, Z: 0.00 mm
- Distance to -20.0 dB boundary: 57.28 mm
- Offset relative to DUT: X: 0.00 mm, Y: 0.00 mm, Z: 1.00 mm

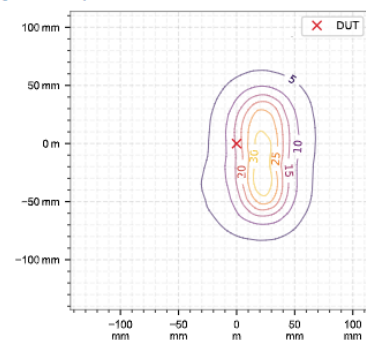
H-field magnitude at maximum, H-field magnitude at lowest plane, Post-processing setup

- Sim4Life version: 8.0.1.15446
- Sim4Life solver: Low Frequency Magneto Quasi Static
- Conductivity: 0.750 S/m
- Tissue density: 1000 kg/m³
- Frequency: 457.02 kHz
- Resolution: X: 1.00 mm, Y: 1.00 mm, Z: 1.00 mm
- Simulation date: 2024/10/23 09:27:34

H-field magnitude [RMS] at maximum location



H-field magnitude [RMS] at lowest plane



7.2.3 Incident fields and induced quantities in the anatomical model

$f = 457.02 \text{ kHz}$, $\sigma = 0.750 \text{ S/m}$, tissue density = $1,000 \text{ kg/m}^3$

			Peak E_{ind} (V/m, rms)		Peak J_{ind} (A/m ² , rms)	psSAR (mW/kg, rms)				H-field extent
Distance (mm)	Peak H_{inc} (A/m, rms)	Peak E_{inc} (V/m, rms)	Cube avg.	Line avg.	Surface avg.	LIMIT: 1600 1g avg.		Limit: 4000 10g avg.		-20 dB radius (mm)
						Meas.	Rep.*	Meas.	Rep.*	
0.0	65.3	137	2.44	2.49	1.62	2.67	2.75	1.42	1.46	59.3

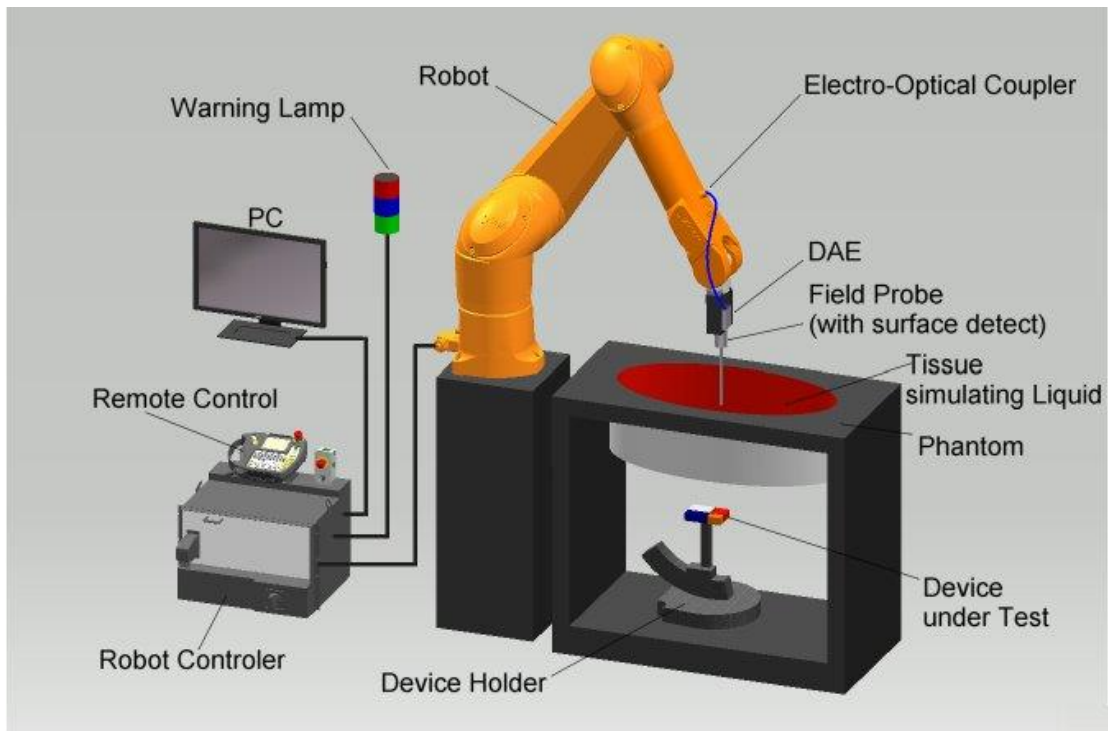
*) SAR values were up-scaled to compensate for the unfulfilled Uncertainty budget by factor 1.03

NOTE: Detailed test results are shown in the additional document: 1-8581-24-01-17_TR2-A201-R01.

8 Test Set-up for SAR measurements (30MHz to 6GHz)

8.1 SAR System Description

8.1.1 Overview



- The DASY system for performing compliance tests consists of the following items:
- A standard high precision 6-axis robot (Stäubli RX/TX family) with controller and software. An arm extension for accommodating the data acquisition electronics (DAE).
- A dosimetric probe, i.e. an isotropic E-field probe optimized and calibrated for usage in tissue simulating liquid.
- A data acquisition electronic (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 Coupler (EOC) performs the conversion from the optical into a digital electric signal of the DAE. The EOC is connected to the DASY measurement server.
- The DASY measurement server, which performs all real-time data evaluation for field measurements and surface detection, controls robot movements and handles safety operation. A computer operating Windows.
- DASY software and SEMCAD data evaluation software.
- Remote control with teach panel and additional circuitry for robot safety such as warning lamps, etc.
- The generic twin phantom enabling the testing of left-hand and right-hand usage.
- The triple flat and eli phantom for the testing of handheld and body-mounted wireless devices.
- The device holder for handheld mobile phones and mounting device adaptor for laptops
- Tissue simulating liquid mixed according to the given recipes.
- System check dipoles allowing to validate the proper functioning of the system.

8.1.2 Test environment

The DASY measurement system is placed in a laboratory room within an environment which avoids influence on SAR measurements by ambient electromagnetic fields and any reflection from the environment. The pictures at the beginning of the photo documentation show a complete view of the test environment. The system allows the measurement of SAR values larger than 0.005 W/kg.

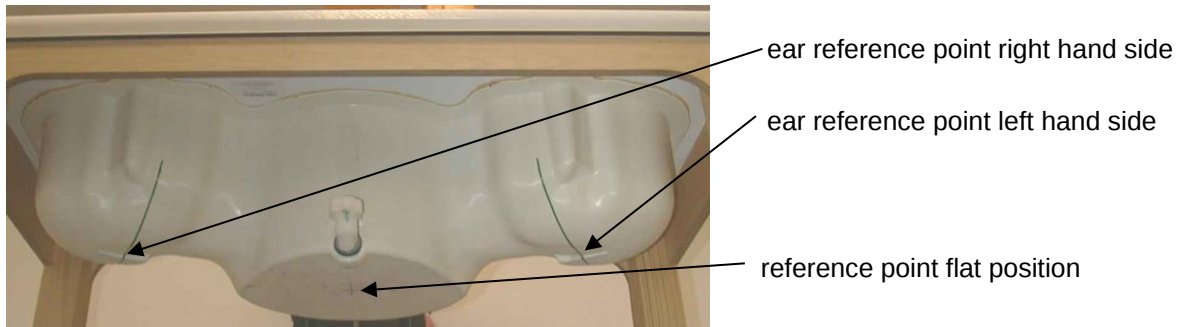
8.1.3 Probe description

Isotropic E-Field Probe EX3DV4 for Dosimetric Measurements	
Technical data according to manufacturer information	
Construction	Symmetrical design with triangular core Interleaved sensors Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)
Calibration	ISO/IEC 17025 calibration service available.
Frequency	10 MHz to >6 GHz (dosimetry); Linearity: ± 0.2 dB (30 MHz to 6 GHz)
Directivity	± 0.3 dB in HSL (rotation around probe axis) ± 0.5 dB in tissue material (rotation normal to probe axis)
Dynamic range	10 μ W/g to > 100 W/kg; Linearity: ± 0.2 dB (noise: typically <1 μ W/g)
Dimensions	Overall length: 337 mm (Tip: 20mm) Tip length: 2.5 mm (Body: 12mm) Typical distance from probe tip to dipole centers: 1mm
Application	High precision dosimetric measurements in any exposure scenario (e.g., very strong gradient fields). Only probe which enables compliance testing for frequencies up to 6 GHz with precision of better 30%.

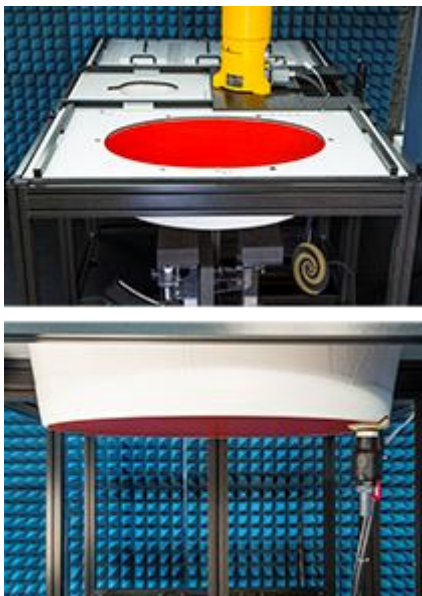
8.1.4 Phantom description

The used SAM Phantom meets the requirements specified in FCC KDB865664 D01 for Specific Absorption Rate (SAR) measurements.

The phantom consists of a fibreglass shell integrated in a wooden table. It allows left-hand and right-hand head as well as body-worn measurements with a maximum liquid depth of 18 cm in head position and 22 cm in planar position (body measurements). The thickness of the Phantom shell is 2 mm +/- 0.1 mm.



Triple Modular Phantom consists of three identical modules which can be installed and removed separately without emptying the liquid. It includes three reference points for phantom installation. Covers prevent evaporation of the liquid. Phantom material is resistant to DGBE based tissue simulating liquids.



The used ELI Phantom is fully compatible with the IEC/IEEE 62209-1528 and all known tissue stimulating liquids. It meets the requirements specified in KDB865664 D01 for Specific Absorption Rate (SAR) measurements and is fully compatible with the standard IEC 62209-2. The phantom consists of a fibreglass shell integrated in a wooden table. The ELI phantom is intended for compliance testing of handheld and body-mounted wireless devices in the frequency range of 4MHz to 10 GHz.

8.1.5 Device holder description

The DASY device holder has two scales for device rotation (with respect to the body axis) and the device inclination (with respect to the line between the ear openings). The plane between the ear openings and the mouth tip has a rotation angle of 65°. The bottom plate contains three pair of bolts for locking the device holder. The device holder positions are adjusted to the standard measurement positions in the three sections. This device holder is used for standard mobile phones or PDA's only. If necessary an additional support of polystyrene material is used.



Larger DUT's (e.g. notebooks) cannot be tested using this device holder. Instead a support of bigger polystyrene cubes and thin polystyrene plates is used to position the DUT in all relevant positions to find and measure spots with maximum SAR values.

Therefore those devices are normally only tested at the flat part of the SAM.

8.1.6 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. Measurements can be performed in a fixed plane or by following an arbitrary surface.
- For an automatic and accurate detection of the phantom surface, the DASY system uses Mechanical Surface Detection:

Mechanical Surface Detection

Mechanical surface detection uses the probe collision detector built into the DAE. It is extremely accurate if the probe is normal to the surface (0.05 mm). For angled probes, the distance increases, because the detection is at the edge of the probe tip. It can be used in any liquid with any kind of probe. If the surface is strongly angled with respect to the probe, the probe slides along the surface and is deflected sideways. The second switch system in the DAE will detect this situation and the probe will move backward until the touch condition is cleared. However, there will be some remaining uncertainty in the final probe position. In the job description, the desired distance from the probe sensors to the phantom surface can be entered. The detection is always at touch, but the probe will move backward from the surface the indicated distance before starting the measurement.

Mother Scan in cDASY6/DASY8 Module SAR

While the DASY5 V5.2 SAR system uses the mechanical surface detection at each point of the Area Scan / Zoom Scan, the cDASY6/DASY8 Module SAR provides the possibility to do a Mother Scan in which a high resolution Area Scan is done in the phantom filled with liquid to a fixed level using a special teaching probe. This mother scan data is used to recreate the phantom inner surface in software, and all future area and/or zoom scans, and a surface detection check is no longer required.

- 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 ≤ 2 GHz is 15 mm in x- and y-dimension. For higher frequencies a finer resolution is needed, thus for the grid spacing is reduced according the following table:

Area scan grid spacing for different frequency ranges	
Frequency range	Grid spacing
≤ 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

* When zoom scan is required and the reported SAR from the area scan based 1-g SAR estimation procedures of KDB Publication 447498 is ≤ 1.4 W/kg, ≤ 8 mm, ≤ 7 mm and ≤ 5 mm zoom scan resolution may be applied, respectively, for 2 GHz to 3 GHz, 3 GHz to 4 GHz and 4 GHz to 6 GHz.

- DASY provides an auto-extending feature to expand the size of the measurement area of the zoom scan as long as the maximum is found too close to the edge of the measured range, which eliminates the need to re-measure cubes whose maximum is found on the boundary of the defined measurement cube.
- To meet the requirements of **IEC 62209-2 AMD1 from 2019** it is necessary to perform graded grid measurements to avoid measurement mistakes.

Below 3 GHz it defines:

Horizontal grid step ≤ 8 mm

Vertical grid step ≤ 5 mm for uniform spacing

For variable spacing in vertical direction the maximum distance between the two closest measured points to the phantom shell (M1 and M2) shall be ≤ 4 mm and the spacing between farther points shall increase by a factor ≤ 1.5 . Zoom Scan size ≤ 30 mm by 30 mm by 30 mm.

Above 3 GHz it defines:

Horizontal grid step $\leq (24/f \text{ [GHz]})$ mm

Vertical grid step $\leq (10/(f \text{ [GHz]} - 1))$ mm for uniform spacing

For variable spacing in vertical direction the maximum distance between the two closest measured points to the phantom shell (M1 and M2) shall be $\leq (12/f \text{ [GHz]})$ mm and the spacing between farther points shall increase by a factor ≤ 1.5 . Zoom Scan size ≤ 22 mm by 22 mm by 22 mm.

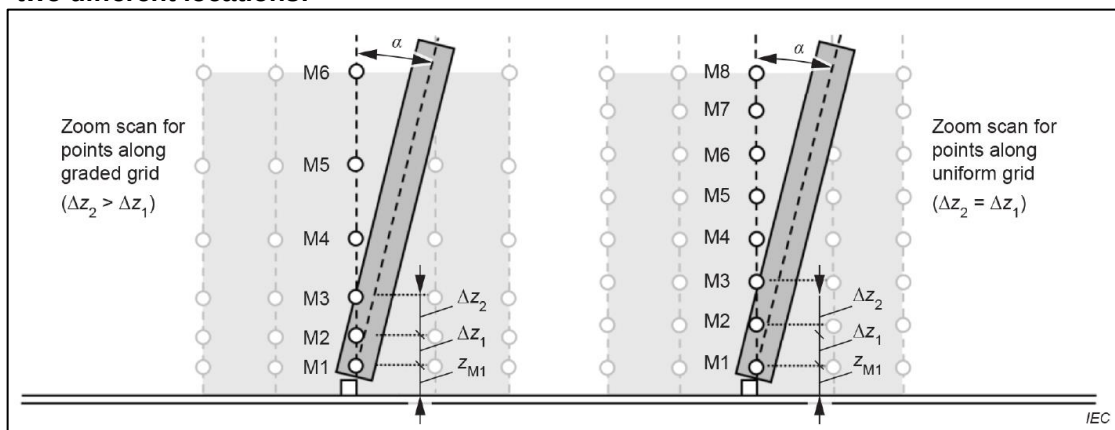
If the zoom scan measured as defined above complies with both of the following criteria, or if the peak spatial-average SAR is below 0.1 W/kg, no additional measurements are needed:

- the smallest horizontal distance from the local SAR peaks to all points 3 dB below the SAR peak shall be larger than the horizontal grid steps in both x and y directions (Δx , Δy). This shall be checked for the measured zoom scan plane conformal to the phantom at the distance z_{M1} . The minimum distance shall be recorded in the SAR test report;
- the ratio of the SAR at the second measured point (M2) to the SAR at the closest measured point (M1) at the x-y location of the measured maximum SAR value shall be at least 30 %. This ratio (in %) shall be recorded in the SAR test report.

If one or both of the above criteria are not met, the zoom scan measurement shall be repeated using a finer resolution while keeping the other zoom scan parameters compatible with the basic requirements for zoom scans.

New horizontal and vertical grid steps shall be determined from the measured SAR distribution so that the above criteria are met. Compliance with the above two criteria shall be demonstrated for the new measured zoom scan. The size of the higher resolution zoom scan and all other parameters shall apply. The closest point to the phantom shell shall be 2 mm or less for graded grids and the grading factor shall be 1.5 or less. Uncertainties due to field distortion between the media boundary and the dielectric enclosure of the probe should also be minimized, which is achieved if the distance between the phantom surface and physical tip of the probe is larger than the probe tip diameter. Other methods may utilize correction procedures to compensate for boundary effects that enable high precision measurements closer than half the probe tip diameter. For all measurement points, the angle of the probe normal to the flat phantom surface shall be less than 5° . If this cannot be achieved, an additional uncertainty evaluation is required.

Orientation of the probe with respect to the line normal to the phantom surface, shown at two different locations:



NOTE M1 to M8 are example measurement points used for extrapolation to the surface. The maximum of the angle α between the evaluation axis and the surface normal line is called the probe angle. The distance z_{M1} is from the phantom shell to the first measurement point M1, and its maximum value is 1.4mm fixed for the DASY system equipped with an EX-Probe. The distances Δz_i ($i = 1, 2, 3, \dots$) are the distances from measurement points M_i to M_{i-1} . For uniform grids, Δz_i are equal. For graded grids, $\Delta z_{i+1} > \Delta z_i$. $R_z = \Delta z_{i+1}/\Delta z_i$ is a ratio with a maximum value (defined in the table below). The z direction corresponds to the vertical direction, the x direction is horizontal and the y direction is horizontal into the page.

NOTE 1: The evaluation of the zoom scan is typically done by the post-processor by interpolation and extrapolation and without reconstruction of the field. More focused induced SAR distributions (e.g., for more localized sources such as capacitively coupled sources) require a more dense grid such that the same integration and extrapolation algorithms can be used for the same assessment uncertainty.

NOTE 2: The minimum ratio of 30 % is derived from the plane wave penetration depth at 6 GHz.

Detailed parameters can be seen in the following table:

Table 8 – Zoom scan parameters

Parameter	DUT transmit frequency being tested	
	$f \leq 3 \text{ GHz}$	$3 \text{ GHz} < f \leq 6 \text{ GHz}$
Maximum distance between the closest measured points and the phantom surface (z_{M1} in Figure 14 and Table 2, in mm)	5	$\delta \ln(2)/2^a$
Maximum angle between the probe axis and the flat phantom surface normal (α in Figure 14)	5°	5°
Maximum spacing between measured points in the x- and y-directions (Δx and Δy , in mm)	8	$24/f^{b,c}$
For uniform grids: Maximum spacing between measured points in the direction normal to the phantom shell (Δz_1 in Figure 14, in mm)	5	$10/(f - 1)$
For graded grids: Maximum spacing between the two closest measured points in the direction normal to the phantom shell (Δz_1 in Figure 14, in mm)	4	$12/f$
For graded grids: Maximum incremental increase in the spacing between measured points in the direction normal to the phantom shell ($R_z = \Delta z_2/\Delta z_1$ in Figure 14)	1,5	1,5
Minimum edge length of the zoom scan volume in the x- and y-directions (L_x in 7.2.5.3, in mm)	30	22
Minimum edge length of the zoom scan volume in the direction normal to the phantom shell (L_h in 7.2.5.3, in mm)	30	22
Tolerance in the probe angle	1°	1°

^a δ is the penetration depth for a plane-wave incident normally on a planar half-space.
^b This is the maximum spacing allowed, which may not work for all circumstances.
^c f is the frequency in GHz.

Table M.1 – Minimum probe requirements as a function of frequency and parameters of the tissue equivalent liquid

1	2	3	4	5	6	7	8
Frequency MHz	Relative permittivity	Conduc- tivity S/m	Wavelength in the medium (λ) mm	Plane wave Skin Depth (δ) mm	Maximum Diameter mm	50 % Distance for M1 ($z_{50\%} =$ $\delta \ln(2)/2$) mm	Min. distance for M1 (z_{M1}) mm
300	45,3	0,87	148,6	46,1	8,0	16,0	5,0
450	43,5	0,87	101,1	42,9	8,0	14,9	5,0
750	41,9	0,89	61,8	39,8	8,0	13,8	5,0
835	41,5	0,9	55,8	38,9	8,0	13,5	5,0
900	41,5	0,97	51,7	36,1	8,0	12,5	5,0
1 450	40,5	1,20	32,5	28,6	8,0	9,9	5,0
1 800	40,0	1,40	26,4	24,3	8,0	8,4	5,0
2 000	40,0	1,40	23,7	24,2	8,0	8,4	5,0
2 450	39,2	1,80	19,6	18,7	6,5	6,5	5,0
2 600	39,0	1,96	18,5	17,2	6,2	5,9	5,0
3 000	38,5	2,40	16,1	13,9	5,4	4,8	5,0
4 000	37,4	3,43	12,3	9,6	4,1	3,3	3,3
5 000	36,2	4,45	10,0	7,3	3,3	2,5	2,5
5 200	36,0	4,66	9,6	7,0	3,2	2,4	2,4
5 400	35,8	4,86	9,3	6,7	3,1	2,3	2,3
5 600	35,5	5,07	9,0	6,4	3,0	2,2	2,2
5 800	35,3	5,27	8,7	6,1	2,9	2,1	2,1
6 000	35,1	5,48	8,4	5,9	2,8	2,0	2,0

Further probe parameters can be seen in Annex M of IEC 62209-2.

8.1.7 Comparison of DASY 52 NEO and cDASY6/DASY8

CTC advanced actually uses both systems side by side and the main differences of the DASY52 NEO and cDASY6/DASY8 system are system operation, reporting tools and measurement speed. DASY 52 still uses the DASY measurement software which has further in-depth options to adapt measurements to sophisticated test setups. For the reporting of the measurement results the companion software SEMCAD X is used. cDASY6/DASY8 is a different measurement system that is especially aimed to speed up standardized compliant measurements with high repeatability and less freedom of usability. It makes it possible to handle and rate compliance tests for a standardized product like a mobile phone in one place and it provides its own backend for reporting. The higher measurement speed is bought for the cost of less flexibility in the measurement setup and adding further sophisticated maintenance as it is necessary to perform regular mother scans.

Feature comparison:		
	DASY 52 (NEO)	cDASY6/DASY8
Warning feature for Zoom Scan according IEC 62209-2 AMD1 (graded Grid conditions)*	yes**	yes
Graded Grids for Area and Zoom Scan supported	yes**	yes
Measurement software	DASY 52 NEO	cDASY6/DASY8
Reporting tool	SEMCAD X post processor	cDASY6/DASY8 integrated post processor
Collusion detection to set probe to surface distance	yes	yes
Mother scans	no	yes

*) A warning appears if the stricter zoom scan criteria as defined in IEC 62209-2 AMD1 are violated using the actual zoom scan settings. In these cases a re-measurement with graded grid is performed and the result plot is updated with the information about the graded grid. This approach guarantees that the difference between the positions with maximum SAR to any adjacent point both horizontally and vertically is below the defined thresholds and that the SAR evaluation is correct.
(respecting both the 3 dB and the 30% criteria from section 6.3.1 d) of IEC 62209-2 AMD1.)

**) features were added with version: DASY52 - 52.10.2(1504) to satisfy IEC 62209-2 AMD1.

8.1.8 Spatial Peak SAR Evaluation

Both DASY5 V5.2 and cDASY6/DASY8 Module SAR software include all numerical procedures necessary to evaluate the spatial peak SAR values. Based on the IEEE 1528 standard, a new algorithm has been implemented. The spatial-peak SAR can be computed over any required mass.

The base for the evaluation is a "cube" measurement in a volume of 30mm³ below 3GHz or 22mm³ above 3GHz. The measured volume must include the 1 g and 10 g cubes with the highest averaged SAR values. For that purpose, the center of the measured volume is aligned to the interpolated peak SAR value of a previously performed area scan. If the 10g cube or both cubes are not entirely inside the measured volumes, the system issues a warning regarding the evaluated spatial peak values within the post-processing engine. This means that if the measured volume is shifted, higher values might be possible. To get the correct values a finer measurement grid for the area scan is used. In complicated field distributions, a large grid spacing for the area scan might miss some details and give an incorrectly interpolated peak location. Both DASY5 V5.2 and cDASY6/DASY8 Module SAR allow to automatically extend the grid to make sure that both cubes are inside the measured volume.

The entire evaluation of the spatial peak values is performed within the application in case of cDASY6/DASY8 Module SAR software or within Post-processing engine (SEMCAD X) for DASY5 V5.2. The system always gives the maximum values for the 1 g and 10 g cubes. The cDASY6/DASY8 software allow to automatically extend the grid to make sure that both cubes are inside the measured volume. The algorithm to find the cube with highest averaged SAR is divided into the following stages:

1. extraction of the measured data (grid and values) from the Zoom Scan
2. calculation of the SAR value at every measurement point based on all stored data (A/D values and measurement parameters)
3. generation of a high-resolution mesh within the measured volume
4. interpolation of all measured values from the measurement grid to the high-resolution grid
5. extrapolation of the entire 3-D field distribution to the phantom surface over the distance from sensor to surface
6. calculation of the averaged SAR within masses of 1 g and 10 g The significant parts are outlined in more detail within the following sections.

Interpolation, Extrapolation and Detection of Maxima

The probe is calibrated at the center of the dipole sensors which is located 1 to 2.7mm away from the probe tip. During measurements, the probe stops shortly above the phantom surface, depending on the probe and the surface detecting system. Both distances are included as parameters in the probe configuration file. The software always knows exactly how far away the measured point is from the surface. As the probe cannot directly measure at the surface, the values between the deepest measured point and the surface must be extrapolated.

The choice of the coordinate system defining the location of the measurement points has no influence on the uncertainty of the interpolation, Maxima Search and extrapolation routines. The interpolation, extrapolation and maximum search routines 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.].

Thereby, the interpolation scheme combines a least-square fitted function method and a weighted average method which are the two basic types of computational interpolation and approximation. The cDASY6/DASY8 routines construct a once-continuously differentiable function that interpolates the measurement values as follows:

- For each measurement point a trivariate (3-D) / bivariate (2-D) quadratic is computed. It interpolates the measurement values at the data point and forms a least-square fit to neighbouring measurement values.
- the spatial location of the quadratic with respect to the measurement values is attenuated by an inverse distance weighting. This is performed since the calculated quadratic will fit measurement values at nearby points more accurate than at points located further away.
- After the quadratics are calculated at all measurement points, the interpolating function is calculated as a weighted average of the quadratics.

There are two control parameters that govern the behavior of the interpolation method.

One specifies the number of measurement points to be used in computing the least-square fits for the local quadratics. These measurement points are the ones nearest the input point for which the quadratic is being computed.

The second parameter specifies the number of measurement points that will be used in calculating the weights for the quadratics to produce the final function. The input data points used there are the ones nearest the point at which the interpolation is desired. Appropriate defaults are chosen for each of the control parameters.

The trivariate quadratics that have been previously computed for the 3-D interpolation and whose input data are at the closest distance from the phantom surface, are used in order to extrapolate the fields to the surface of the phantom.

In order to determine all the field maxima in 2-D (Area Scan) and 3-D (Zoom Scan), the measurement grid is refined by a default factor of 10 (area) and 5 (zoom), respectively, and the interpolation function is used to evaluate all field values between corresponding measurement points. Subsequently, a linear search is applied to find all the candidate maxima. In a last step, non physical maxima are removed and only those maxima which are within 2 dB of the global maximum value are retained.

Important: To be processable by the interpolation/extrapolation scheme, the Area Scan requires at least 6 measurement points. The Zoom Scan requires at least 10 measurement points to allow the application of these algorithms.

In the Area Scan, the gradient of the interpolation function is evaluated to find all the extrema of the SAR distribution. The uncertainty on the locations of the extrema is less than 1/20 of the grid size. Only local maxima within 2 dB of the global maximum are searched and passed for the Zoom Scan measurement.

In the Zoom Scan, the interpolation function is used to extrapolate the Peak SAR from the lowest measurement points to the inner phantom surface (the extrapolation distance). The uncertainty increases with the extrapolation distance. To keep the uncertainty within 1% for the 1 g and 10 g cubes, the extrapolation distance should not be larger than 5 mm.

Averaging and Determination of spatial Peak SAR

Within DASY5 V5.2 software, the interpolated data is used to average the SAR over the 1g and 10g cubes by spatially discretizing the entire measured volume. The resolution of this spatial grid is around 1mm and chosen such that the cube side length is a multiple of the resolution. The resulting volumes are defined as cubical volumes containing the appropriate tissue parameters that are centered at the location. The location is defined as the center of the incremental volume.

The spatial-peak SAR must be evaluated in cubical volumes containing a mass that is within 5% of the required mass. The cubical volume centered at each location, as defined above, should be expanded in all directions until the desired value for the mass is reached, with no surface boundaries of the averaging volume extending beyond the outermost surface of the considered region. In addition, the cubical volume should not consist of more than 10% of non-liquid volume. If these conditions are not satisfied, then the center of the averaging volume is moved to the next location.

Reference is kept of all locations used and those not used for averaging the SAR. All average SAR values are finally assigned to the centered location in each valid averaging volume. All locations included in an averaging volume are marked as used to indicate that they have been used at least once. If a location has been marked as used, but has never been the center of a cube, the highest averaged SAR value of all other cubical volumes which have used this location for averaging is assigned to this location. For the case of an unused location, a new averaging volume must be constructed which will have the unused location centered at one surface of the cube. The remaining five surfaces are expanded evenly in all directions until the required mass is enclosed, regardless of the amount of included air. Of the six possible cubes with one surface centered on the unused location, the smallest cube is used, which still contains the required mass.

If the final cube containing the highest averaged SAR touches the surface of the measured volume, an appropriate warning is issued within the Post-processing engine.

Within cDASY6/DASY8 Module SAR software, the measured grid is interpolated to a high resolution grid, where the resolution is around 1mm and chosen such that the cube volume is a multiple of the resolution. Points which are outside of the measured grid are masked out and set to zero. Then, the antiderivative of the interpolated grid is computed by using a Gaussian quadrature consecutively for all spatial dimensions.

The antiderivative is used to compute all cube averages of the volume with the same resolution as the interpolated grid. The maximum of these SAR averages is reported. If the cube containing the maximum averaged SAR touches the surface of the measured volume, an appropriate warning is issued within the Post-processing engine.

8.1.9 Data Storage and Evaluation

Data Storage

The DASY software stores the acquired data from the data acquisition electronics as raw data (in microvolt readings from the probe sensors), together with all necessary software parameters for the data evaluation (probe calibration data, liquid parameters and device frequency and modulation data) in measurement files with the extension ".DA4", ".DA5x". The software evaluates the desired unit and format for output each time the data is visualized or exported. This allows verification of the complete software setup even after the measurement and allows correction of incorrect parameter settings. For example, if a measurement has been performed with a wrong crest factor parameter in the device setup, the parameter can be corrected afterwards and the data can be re-evaluated.

The measured data can be visualized or exported in different units or formats, depending on the selected probe type ([V/m], [A/m], [°C], [W/kg], [mW/cm²], [dBrel], etc.). Some of these units are not available in certain situations or show meaningless results, e.g., a SAR output in a lossless media will always be zero. Raw data can also be exported to perform the evaluation with other software packages.

Data Evaluation by SEMCAD

The SEMCAD software automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. The parameters used in the evaluation are stored in the configuration modules of the software:

Probe parameters:	- Sensitivity	$\text{Norm}_i, a_{i0}, a_{i1}, a_{i2}$
	- Conversion factor	ConvF_i
	- Diode compression point	Dcpi
Device parameters:	- Frequency	f
	- Crest factor	cf
Media parameters:	- Conductivity	σ
	- Density	ρ

These parameters must be set correctly in the software. They can be found in the component documents or they can be imported into the software from the configuration files issued for the DASY components. In the direct measuring mode of the multimeter option, the parameters of the actual system setup are used. In the scan visualization and export modes, the parameters stored in the corresponding document files are used.

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 as:

$$V_i = U_i + U_i^2 \cdot cf/dcp_i$$

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: $E_i = (V_i / Norm_i \cdot ConvF)^{1/2}$

H-field probes: $H_i = (V_i)^{1/2} \cdot (a_{i0} + a_{i1}f + a_{i2}f^2)/f$

with V_i = compensated signal of channel i (i = x, y, z)
 $Norm_i$ = sensor sensitivity of channel i (i = x, y, z)
[mV/(V/m)²] for E-field Probes
 $ConvF$ = sensitivity enhancement in solution
 a_{ij} = sensor sensitivity factors for H-field probes
 f = carrier frequency [GHz]
 E_i = electric field strength of channel i in V/m
 H_i = magnetic field strength of channel i in A/m

The RSS value of the field components gives the total field strength (Hermitian magnitude):

$$E_{tot} = (E_x^2 + E_y^2 + E_z^2)^{1/2}$$

The primary field data are used to calculate the derived field units.

$$SAR = (E_{tot}^2 \cdot \sigma) / (\rho \cdot 1000)$$

with SAR = local specific absorption rate in W/kg
 E_{tot} = total field strength in V/m
 σ = conductivity in [mho/m] or [Siemens/m]
 ρ = equivalent tissue density in g/cm³

Note that the density is normally set to 1 (or 1.06), to account for actual brain density rather than the density of the simulation liquid. The power flow density is calculated assuming the excitation field to be a free space field.

$$P_{pwe} = E_{tot}^2 / 3770 \quad \text{or} \quad P_{pwe} = H_{tot}^2 \cdot 37.7$$

with P_{pwe} = equivalent power density of a plane wave in mW/cm²
 E_{tot} = total electric field strength in V/m
 H_{tot} = total magnetic field strength in A/m

Data Evaluation in cDASY6/DASY8

cDASY6/DASY8 features basic evaluation capabilities comparable to the above described SEMCAD evaluation. The main difference is that cDASY6/DASY8 is a stand-alone all-in-one solution whilst SEMCAD is only used to add these features to the DASY5.2 (NEO) platform. The final results are fully comparable no matter if they were generated by DASY5.2(NEO) + SEMCAD or in cDASY6/DASY8 directly.

8.1.10 Measurement uncertainty evaluation for SAR test

DASY6/8 Uncertainty Budget									
According to IEC/IEEE 62209-1528,Specific Phantoms (Frequency band: 300 MHz - 3 GHz range)									
Symbol	Error Description	Uncertainty Value		Probability Distribution	Divisor	c _i (1g)	c _i (10g)	Standard Uncertainty	
								± %, (1g)	± %, (10g)
Measurement System Errors									
CF	Probe Calibration Repeat.	± 12.0 %		Normal	2	1	1	± 6.0 %	± 6.0 %
CFdrift	Probe Calibration Drift	± 1.7 %		Rectangular	√ 3	1	1	± 1.0 %	± 1.0 %
LIN	Probe linearity	± 4.7 %		Rectangular	√ 3	1	1	± 2.7 %	± 2.7 %
BBS	Broadband Signal	± 3.0 %		Rectangular	√ 3	1	1	± 1.7 %	± 1.7 %
ISO	Probe Isotropy (axial)	± 9.6 %		Rectangular	√ 3	1	1	± 5.5 %	± 5.5 %
DAE	Data Acquisition	± 0.3 %		Normal	1	1	1	± 0.3 %	± 0.3 %
AMB	RF Ambient	± 1.8 %		Normal	1	1	1	± 1.8 %	± 1.8 %
Δ _{sys}	Probe Positioning	± 0.006 mm		Normal	1	0.14	0.14	± 0.1 %	± 0.1 %
DAT	Data Processing	± 8.7 %		Normal	1	1	1	± 8.7 %	± 8.7 %
Phantom and Device Errors									
LIQ(σ)	Conductivity (meas.) ^{DAK}	± 2.5 %		Normal	1	0.78	0.71	± 2.0 %	± 1.8 %
LIQ(Tσ)	Conductivity (temp.) ^{BB}	± 3.3 %		Rectangular	√ 3	0.78	0.71	± 1.5 %	± 1.4 %
EPS	Phantom Permittivity	± 14.0 %		Rectangular	√ 3	0	0	± 0.0 %	± 0.0 %
DIS	Distance DUT - TSL	± 2.0 %		Normal	1	2	2	± 4.0 %	± 4.0 %
D _{xyz}	Device Positioning	± 1.0 %		Normal	1	1	1	± 1.0 %	± 1.0 %
H	Device Holder	± 3.6 %		Normal	1	1	1	± 3.6 %	± 3.6 %
MOD	DUT Modulation ^m	± 2.4 %		Rectangular	√ 3	1	1	± 1.4 %	± 1.4 %
TAS	Time-average SAR	± 1.7 %		Rectangular	√ 3	1	1	± 1.0 %	± 1.0 %
RF _{drift}	DUT drift	± 2.5 %		Normal	1	1	1	± 2.5 %	± 2.5 %
VAL	Val Antenna Unc. ^{val}	± 0.0 %		Normal	1	1	1	± 0.0 %	± 0.0 %
RF _{in}	Unc. Input Power ^{val}	± 0.0 %		Normal	1	1	1	± 0.0 %	± 0.0 %
Correction to the SAR results									
C(ε, σ)	Deviation to Target	± 1.9 %		Normal	1	1	0.84	± 1.9 %	± 1.6 %
C(R)	SAR scaling ^p	± 0.0 %		Rectangular	√ 3	1	1	± 0.0 %	± 0.0 %
u(ΔSAR)	Combined Uncertainty							± 14.3 %	± 14.3 %
U	Expanded Uncertainty							± 28.7 %	± 28.5 %

Table 2: Measurement uncertainties

Worst-Case uncertainty budget for DASY6/8 assessed according to IEC/IEEE 62209-1528 [4]. The budget is valid for the frequency range 300MHz - 3GHz and represents a worst-case analysis. For specific tests and configurations, the uncertainty could be considerable smaller. All listed error components have *veff* equal to ∞ .

Footnote details:

^m SMC calibration is a new method for determining the total deviation from linearity. The uncertainty is $\leq 2.4\%$ for psSAR ≤ 2 W/kg, $\leq 4.8\%$ for psSAR1g/10g ≤ 4 W/kg and $\leq 9.6\%$ for psSAR1g/10g ≤ 10 W/kg (see modulation calibration parameter uncertainty in the probe calibration certificate);

^{BB} if SPEAG's broad-band liquids (BBL) are used that have low temperature coefficients;

^{DAK} if SPEAG's high precision dielectric probe kit (DAK) is applied;

^p if power scaling is used, error item "SAR Scaling" must be adjusted accordingly;

^{val} only applies in case of validation measurements.

DASY6/8 Uncertainty Budget According to IEC/IEEE 62209-1528 (Frequency band: 300 MHz - 3 GHz range)									
Symbol	Error Description	Uncertainty Value		Probability Distribution	Divisor	c _i (1g)	c _i (10g)	Standard Uncertainty	
								± %, (1g)	± %, (10g)
Measurement System Errors									
CF	Probe Calibration Repeat.	± 12.0	%	Normal	2	1	1	± 6.0	% ± 6.0
CFdrift	Probe Calibration Drift	± 1.7	%	Rectangular	√ 3	1	1	± 1.0	% ± 1.0
LIN	Probe linearity	± 4.7	%	Rectangular	√ 3	1	1	± 2.7	% ± 2.7
BBS	Broadband Signal	± 3.0	%	Rectangular	√ 3	1	1	± 1.7	% ± 1.7
ISO	Probe Isotropy (axial)	± 7.6	%	Rectangular	√ 3	1	1	± 4.4	% ± 4.4
DAE	Data Acquisition	± 0.3	%	Normal	1	1	1	± 0.3	% ± 0.3
AMB	RF Ambient	± 1.8	%	Normal	1	1	1	± 1.8	% ± 1.8
Δ _{sys}	Probe Positioning	± 0.006	mm	Normal	1	0.14	0.14	± 0.1	% ± 0.1
DAT	Data Processing	± 1.2	%	Normal	1	1	1	± 1.2	% ± 1.2
Phantom and Device Errors									
LIQ(σ)	Conductivity (meas.) ^{DAK}	± 2.5	%	Normal	1	0.78	0.71	± 2.0	% ± 1.8
LIQ(Tσ)	Conductivity (temp.) ^{BB}	± 3.3	%	Rectangular	√ 3	0.78	0.71	± 1.5	% ± 1.4
EPS	Phantom Permittivity	± 14.0	%	Rectangular	√ 3	0	0	± 0.0	% ± 0.0
DIS	Distance DUT - TSL	± 2.0	%	Normal	1	2	2	± 4.0	% ± 4.0
D _{xyz}	Device Positioning	± 1.0	%	Normal	1	1	1	± 1.0	% ± 1.0
H	Device Holder	± 3.6	%	Normal	1	1	1	± 3.6	% ± 3.6
MOD	DUT Modulation ^m	± 2.4	%	Rectangular	√ 3	1	1	± 1.4	% ± 1.4
TAS	Time-average SAR	± 1.7	%	Rectangular	√ 3	1	1	± 1.0	% ± 1.0
RF _{drift}	DUT drift	± 2.5	%	Normal	1	1	1	± 2.5	% ± 2.5
VAL	Val Antenna Unc. ^{val}	± 0.0	%	Normal	1	1	1	± 0.0	% ± 0.0
RF _{in}	Unc. Input Power ^{val}	± 0.0	%	Normal	1	1	1	± 0.0	% ± 0.0
Correction to the SAR results									
C(ε, σ)	Deviation to Target	± 1.9	%	Normal	1	1	0.84	± 1.9	% ± 1.6
C(R)	SAR scaling ^p	± 0.0	%	Rectangular	√ 3	1	1	± 0.0	% ± 0.0
u(ΔSAR)	Combined Uncertainty							± 11.0	% ± 10.9
U	Expanded Uncertainty							± 21.9	% ± 21.7

Table 3: Measurement uncertainties

Worst-Case uncertainty budget for DASY6/8 assessed according to IEC/IEEE 62209-1528 [4]. The budget is valid for the frequency range 300MHz - 3 GHz and represents a worst-case analysis. For specific tests and configurations, the uncertainty could be considerable smaller. All listed error components have *veff* equal to ∞ .

Footnote details:

^m SMC calibration is a new method for determining the total deviation from linearity. The uncertainty is $\leq 2.4\%$ for psSAR ≤ 2 W/kg, $\leq 4.8\%$ for psSAR1g/10g ≤ 4 W/kg and $\leq 9.6\%$ for psSAR1g/10g ≤ 10 W/kg (see modulation calibration parameter uncertainty in the probe calibration certificate);

^{BB} if SPEAG's broad-band liquids (BBL) are used that have low temperature coefficients;

^{DAK} if SPEAG's high precision dielectric probe kit (DAK) is applied;

^p if power scaling is used, error item "SAR Scaling" must be adjusted accordingly;

^{val} only applies in case of validation measurements.

8.1.11 Measurement uncertainty evaluation for System Check

Repeatability Budget for System Check (Frequency band: 300MHz - 6GHz range) with DASY6/8 System									
Symbol	Error Description	Uncertainty Value		Probability Distribution	Divisor	C _i	C _i	Standard Uncertainty	
						(1g)	(10g)	± %, (1g)	± %, (10g)
Measurement System Errors									
CF	Probe Calibration Repeat.	± 3.6 %		Normal	2	2	1	± 5.1 %	± 2.5 %
CFdrift	Probe Calibration Drift	± 1.7 %		Rectangular	√ 3	1	1	± 1.0 %	± 1.0 %
LIN	Probe linearity	± 4.7 %		Rectangular	√ 3	0	0	± 0.0 %	± 0.0 %
BBS	Broadband Signal	± 0.0 %		Rectangular	√ 3	0	0	± 0.0 %	± 0.0 %
ISO	Probe Isotropy (axial)	± 4.7 %		Rectangular	√ 3	0	0	± 0.0 %	± 0.0 %
DAE	Data Acquisition	± 0.3 %		Normal	1	0	0	± 0.0 %	± 0.0 %
AMB	RF Ambient	± 0.6 %		Normal	1	0	0	± 0.0 %	± 0.0 %
Δ _{sys}	Probe Positioning	± 0.2 %		Normal	1	0.33	0.33	± 0.1 %	± 0.1 %
DAT	Data Processing	± 0.0 %		Normal	1	1	1	± 0.0 %	± 0.0 %
Phantom and Device Errors									
LIQ(σ)	Conductivity (meas.) ^{DAK}	± 2.5 %		Normal	1	0.78	0.71	± 2.0 %	± 1.8 %
LIQ(Tσ)	Conductivity (temp.) ^{BB}	± 3.4 %		Rectangular	√ 3	0.78	0.71	± 1.5 %	± 1.4 %
EPS	Phantom Permittivity	± 14.0 %		Rectangular	√ 3	0	0	± 0.0 %	± 0.0 %
DIS	Distance Phantom - DUT	± 1.0 %		Normal	1	2	2	± 2.0 %	± 2.0 %
MOD	DUT Modulation ^m	± 0.0 %		Rectangular	√ 3	1	1	± 0.0 %	± 0.0 %
TAS	Time-average SAR	± 0.0 %		Rectangular	√ 3	1	1	± 0.0 %	± 0.0 %
VAL	Validation antenna	± 0.0 %		Normal	1	1	1	± 0.0 %	± 0.0 %
P _{in}	Accepted power	± 1.2 %		Normal	1	1	1	± 1.2 %	± 1.2 %
Correction to the SAR results									
C(ε, σ)	Deviation to Target	± 1.9 %		Normal	1	1	0.84	± 1.9 %	± 1.6 %
u(ΔSAR)	Combined Uncertainty							± 6.5 %	± 4.5 %
U	Expanded Uncertainty							± 13.0 %	± 9.1 %

Table 4: Repeatability of the system check (300MHz - 6 GHz).

All listed error components have v_{eff} equal to ∞ .

Footnote details:

^{BB} if SPEAG's broad-band liquids (BBL) are used that have low temperature coefficients;

^{DAK} if SPEAG's high precision dielectric probe kit (DAK) is applied.

Note: Worst case probe calibration uncertainty has been applied for all probes used during the measurements.

8.1.12 Tissue simulating liquids: dielectric properties

The following materials are used for producing the tissue-equivalent materials.

HBBL600-10000MHz Simulating Head Liquid, Manufactured by SPEAG:

Ingredients	(% by weight)
Water	50-65%
Mineral oil	10-30%
Emulsifiers	8-25%
Sodium salt	0-1.5%

Table 5: Head tissue dielectric properties

8.1.13 Tissue simulating liquids: parameters

Liquid HSL	Freq. (MHz)	Target head tissue		Measurement head tissue					Measurement date
		Permittivity	Conductivity [S/m]	Permittivity	Dev. %	Conductivity		Dev. %	
						ε"	[S/m]		
2450	2402	39.28	1.76	36.5	-7.0	12.75	1.70	-3.0	2024-12-13
	2440	39.22	1.79	36.5	-7.0	12.73	1.73	-3.5	
	2450	39.20	1.80	36.5	-7.0	12.72	1.73	-3.7	
	2480	39.19	1.83	36.4	-7.1	12.70	1.75	-4.4	

Table 6: Parameter of the head tissue simulating liquid (HSL)

Note: The dielectric properties have been measured using the contact probe method at 22°C.

*) as the liquid parameters deviation is $\geq \pm 5\%$ an extrapolation according IEC / IEEE 62209-1528 chapter 7.8.2 approach 3 is necessary. The DASY software is capable to perform the necessary corrections directly from the tissue and measurement data. The uncertainties in this document have been adjusted accordingly.

For detailed information see chapter 8.2.7 SAR correction for deviations of complex permittivity from targets on page 43.

8.2 Detailed test results for 2450 MHz BT LE

8.2.1 System check

The system check is performed for verifying the accuracy of the complete measurement system and performance of the software. The following table shows system check results for all frequency bands and tissue liquids used during the tests (plot(s) see annex A).

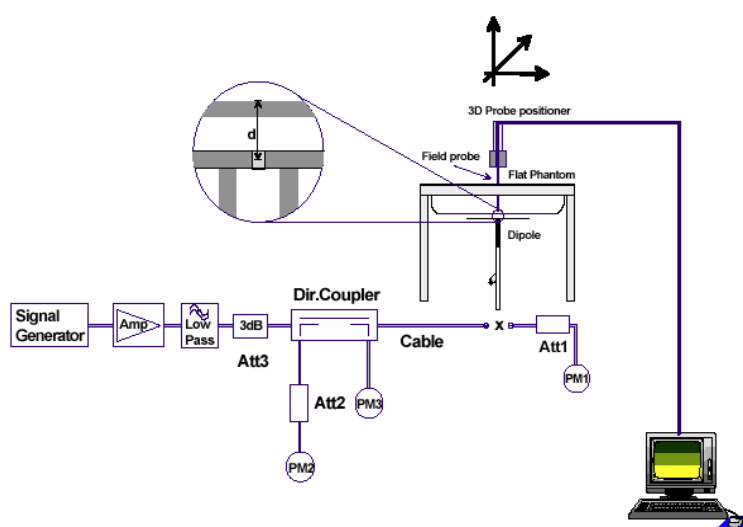
System performance check (1000 mW)									
System validation Kit	Probe	Frequency	Target SAR _{1g}	Target SAR _{10g}	Measured SAR _{1g}	SAR _{1g}	Measured SAR _{10g}	SAR _{10g}	Measured date
		MHz	W/kg (+/- 10%)		W/kg	dev.	W/kg	dev.	
D2450V2 S/N: 710	EX3DV4 S/N: 7566	2450	51.80	24.10	53.00	2.3%	24.80	2.9%	2024-12-13

Table 7: Results system check

8.2.2 System check procedure

The system check is performed by using a validation dipole which is positioned parallel to the planar part of the SAM phantom at the reference point. The distance of the dipole to the SAM phantom is determined by a plexiglass spacer. The dipole is connected to the signal source consisting of signal generator and amplifier via a directional coupler, N-connector cable and adaption to SMA. It is fed with a power of 100 mW or 50 mW if used Powersource1. To adjust this power a power meter is used. The power sensor is connected to the cable before the system check to measure the power at this point and do adjustments at the signal generator. At the outputs of the directional coupler both return loss as well as forward power are controlled during the validation to make sure that emitted power at the dipole is kept constant. This can also be checked by the power drift measurement after the test (result on plot).

System check results have to be equal or near the values determined during dipole calibration (target SAR in table above) with the relevant liquids and test system.



8.2.3 System validation

The system validation is performed in a similar way as a system check. It needs to be performed once a SAR measurement system has been established and allows an evaluation of the system accuracy with all components used together with the specified system. It has to be repeated at least once a year or when new system components are used (DAE, probe, phantom, dipole, liquid type).

In addition to the procedure used during system check a system validation also includes checks of probe isotropy, probe modulation factor and RF signal.

The following table lists the system validations relevant for this test report:

Frequency (MHz)	DASY SW	Dipole Type / SN	Probe Type / SN	Calibrated signal type(s)	DAE unit Type / SN	HSL validation
2450	DASY8 SAR V16.4.0.5005	D2450V2 / 710	EX3DV4 / 7566	CW	DAE4 / 1387	2024-08-27

8.2.4 General description of test procedures

- The DUT is tested using a test software to control test channels and maximum output power of the DUT.
- For the extrapolation of the reported SAR (extrapolated), the following formula was used:

$$SAR_{\text{reported}} = \frac{\text{decl.max.}}{\text{meas.max.}} \cdot SAR_{\text{meas.}}$$

8.2.5 Conducted Results

Conducted output power BT LE 2450 MHz (dBm)							
mod.	test cond.	Peak. power			Avg. power		
		CH 0	CH 19	CH 39	CH 0	CH 19	CH 39
		2402 MHz	2440 MHz	2480 MHz	2402 MHz	2440 MHz	2480 MHz
GFSK	1 Msps	7.8	6.2	8.6	7.1	5.5	7.9
GFSK	2 Msps	11.1	7.8	6.2	10.3	7.0	5.5

8.2.6 SAR Results

measured / extrapolated SAR numbers - Bluetooth LE 2450 MHz												
Ch.	Freq. (MHz)	test cond.	Position	cond. P _{max} (dBm)		SAR _{1g} (W/kg)		SAR _{10g} (W/kg)		P _{drift} (dB)	liquid (°C)	dist. (mm)
				decl.*	meas.	meas.	extrap.	meas.	extrap.			
0	2402	2 Msps	front	11.0	10.3	0.044	0.052	0.020	0.023	-0.01	20.9	0
0	2402	2 Msps	back	11.0	10.3	0.028	0.033	0.015	0.018	-0.16	20.9	0
0	2402	2 Msps	left	11.0	10.3	0.011	0.013	0.003	0.004	0.18	20.9	0
0	2402	2 Msps	right	11.0	10.3	0.027	0.032	0.013	0.015	-0.12	20.9	0
0	2402	2 Msps	top	11.0	10.3	0.027	0.032	0.013	0.015	-0.03	20.9	0
0	2402	2 Msps	bottom	11.0	10.3	0.013	0.015	0.002	0.002	-0.11	20.9	0
19	2440	2 Msps	front	9.0	7.0	0.027	0.043	0.011	0.017	-0.13	20.9	0
39	2480	1 Msps	front	9.0	7.9	0.026	0.033	0.012	0.015	-0.17	20.9	0

Table 8: Test results SAR BT LE 2450 MHz

* - maximum possible output power declared by manufacturer.

8.2.7 SAR correction for deviations of complex permittivity from targets

The max reported SAR values are once more corrected wherever the deviation of the liquid parameters is larger than $\pm 5\%$.

According IEC / IEEE 62209-1528 chapter 7.8.2 SAR correction formula

there is a linear relationship between the percentage change in SAR (denoted ΔSAR) and the percentage change in the permittivity and conductivity from the target values (denoted $\Delta\epsilon_r$ and $\Delta\sigma$, respectively). The relationship is given by:

$$\Delta\text{SAR} = c_\epsilon \Delta\epsilon_r + c_\sigma \Delta\sigma$$

where

$c_\epsilon = \partial (\Delta\text{SAR}) / \partial (\Delta\epsilon_r)$ is the coefficient representing the sensitivity of SAR to permittivity where SAR is normalized to output power;

$c_\sigma = \partial (\Delta\text{SAR}) / \partial (\Delta\sigma)$ is the coefficient representing the sensitivity of SAR to conductivity, where SAR is normalized to output power.

The values of c_ϵ and c_σ have a simple relationship with frequency that can be described using polynomial equations. For dipole antennas at frequencies from 4 MHz to 6 GHz, the **1 g averaged SAR** c_ϵ and c_σ are given by

$$c_\epsilon = -7.854 \times 10^{-4} \times f^3 + 9.402 \times 10^{-3} \times f^2 - 2.742 \times 10^{-2} \times f - 0.2026$$

$$c_\sigma = 9.804 \times 10^{-3} \times f^3 - 8.661 \times 10^{-2} \times f^2 + 2.981 \times 10^{-2} \times f + 0.7829$$

where f is the frequency in GHz. Above 6 GHz, the sensitivity is non-varying with frequency due to the small penetration depth; the values of $c_\epsilon = -0,198$ and $c_\sigma = 0$ shall be used.

For frequencies from 4 MHz to 6 GHz, the **10 g averaged SAR** c_ϵ and c_σ are given by:

$$c_\epsilon = 3.456 \times 10^{-3} \times f^3 - 3.531 \times 10^{-2} \times f^2 + 7.675 \times 10^{-2} \times f - 0.1860$$

$$c_\sigma = 4.479 \times 10^{-3} \times f^3 - 1.586 \times 10^{-2} \times f^2 - 0.1972 \times f + 0.7717$$

where f is the frequency in GHz. Above 6 GHz, the sensitivity is non-varying with frequency due to the small penetration depth; the values of $c_\epsilon = -0,250$ and $c_\sigma = 0$ shall be used.

NOTE:

The Tables in the uncertainties of this report are updated accordingly with the values from table 6 – Root-mean-squared error SAR correction formula as a function of the maximum change in permittivity or conductivity:

Max. change in ϵ_r or σ	RMS uncertainty for SAR _{1g} %	RMS uncertainty for SAR _{10g} %
$\pm 5\%$	1,2	0,97
$\pm 10\%$	1,9	1,6

NOTE:

The DASY software is capable of directly correcting the measured values according to the above-described procedure, fully compliant to IEC / IEEE 62209-1528, so that no further evaluation is necessary.

9 Multiple Transmitter Information

SAR _{max} /W/kg _(1g)		ΣSAR _(1g)
457 kHz Avalanche Bacon	2450 MHz BT LE	<1.6W/kg
0.00275	0.05200	0.055

Table 9: SAR_{max} 457kHz Avalanche Bacon and Bluetooth 2450MHz, ΣSAR evaluation

Conclusion:

ΣSAR < 1.6 W/kg, therefore simultaneous transmissions SAR measurement with the enlarged zoom scan measurement and volume scan post-processing procedures is **not** required.

10 Test equipment and ancillaries used for tests

To simplify the identification of the test equipment and/or ancillaries which were used, the reporting of the relevant test cases only refer to the test item number as specified in the table below.

Equipment	Type	Manufacturer	Serial No.	Last Calibration	Frequency (months)
E / H Field Probe	MAGPy-8H3D+E3D V2	Schmid & Partner Engineering AG	3079	Oct 24, 2023	12
Data Acquisition System	MAGPy-DAS V2	Schmid & Partner Engineering AG	1023	Oct 24, 2023	12
DASY8 Module WPT (2.6) software	SW – Version 2.6.0.5002	Schmid & Partner Engineering AG	---	N/A	--
Notebook Jupyter v2.6.07	SW – Version 2.0.61, backend: 2.2.22	Schmid & Partner Engineering AG	---	N/A	--
Sim4Life V Simulation Software (+Plug In)	SW – Version 8.0.1.15446	Schmid & Partner Engineering AG / ZMT Zurich MedTech AG	---	N/A	--
Dosimetric E-Field Probe	EX3DV4	Schmid & Partner Engineering AG	7566	August 12, 2024	12
2450 MHz System Validation Dipole	D2450V2	Schmid & Partner Engineering AG	710	May 11, 2022	36
Data acquisition electronics	DAE4	Schmid & Partner Engineering AG	1387	August 8, 2024	12
Software	V16.4.0.5005	Schmid & Partner Engineering AG	---	N/A	--
SAM Twin Phantom V8.0	QD 000 P41 A	Schmid & Partner Engineering AG	2061	N/A	--
Network Analyser 300 kHz to 6 GHz	8753ES	Agilent Technologies)*	US39174436	December 14, 2023	24
Dielectric Probe Kit	85033D	Hewlett Packard	3423A06060	January 04, 2021	36
Dielectric Assessment Kit (DAK)	DAK 200MHz – 20GHz Package	Schmid & Partner Engineering AG	1127	N/A	--
Signal Generator	SML03	Rohde & Schwarz	102519	December 05, 2023	24
RF Power Amplifier	BLMA 0760-6 (6 Watt)	BONN Elektronik	1510273	N/A	--
Power Meter	NRP	Rohde & Schwarz	101367	December 05, 2023	12
Power Meter Sensor	NRP Z22	Rohde & Schwarz	100227	December 05, 2023	12
Power Meter Sensor	NRP Z22	Rohde & Schwarz	100234	December 05, 2023	12
Directional Coupler	778D	Hewlett Packard	19171	December 05, 2023	12

)* : Network analyzer probe calibration against air, distilled water and a shorting block performed before measuring liquid parameters.

11 Observations

No observations exceeding those reported with the single test cases have been made.

Annex A: Photo documentation

Photo documentation is described in the additional document: **1-8581-24-01-17_TR2-A101-R01**

Annex B: Detailed test results from system WPT

Detailed test results from WPT System are in the additional document: **1-8581-24-01-17_TR2-A201-R01**

Annex C: Calibration parameters

Calibration parameters are described in the additional document: **1-8581-24-01-17_TR2-A301-R01**

Annex D: Detailed test results for SAR (2450 MHz BT LE)

Date/Time: 2024-12-13, 11:58 2024-12-13, 12:06

SystemPerformanceCheck-D2450**DUT: Dipole; Type: D2450V2; Serial: 710**

Communication System: CW; Communication System Frequency: 2450.0 MHz

Medium parameters used: $f = 2450.0$ MHz, $\sigma = 1.73$ S/m; $\epsilon_r = 36.5$; $\rho = 1000$ kg/m³

Phantom Section: Flat

Measurement Standard: DASY 6

DASY Configuration:

- Probe: EX3DV4 - SN7566; ConvF(7.67, 7.5, 6.89); Calibrated: 2024-08-12
- Sensor-Surface: 1.4 mm
- DAE: DAE4 Sn1387; Calibrated: 2024-08-08
- Phantom: Twin-SAM V8.0 (30deg probe tilt); Serial: 2061;
- Software: cDASY6 (16.4.0.5005)

HBBL-600-10000/2450.0MHz/Area Scan (10.0 x 10.0 x 1.0) :

Grid Extents [mm]: 40.0 x 80.0

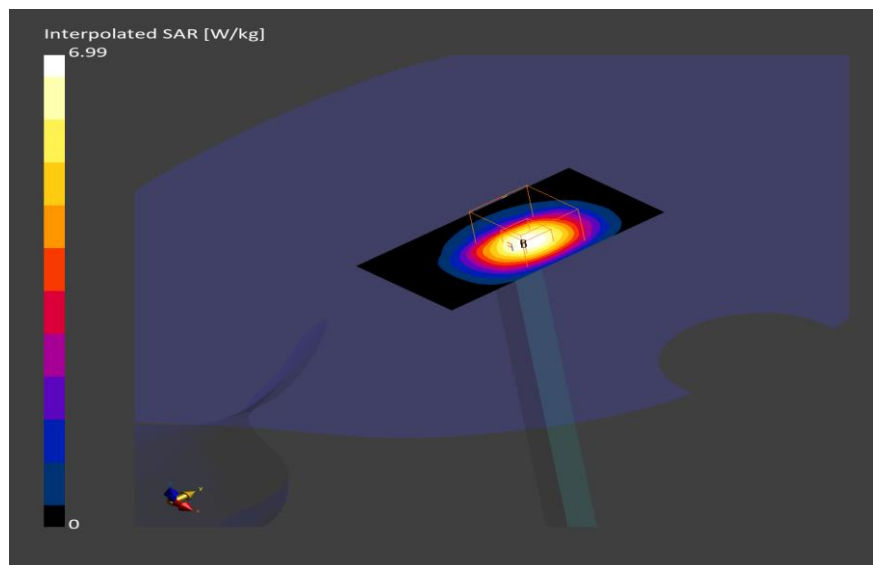
Maximum value of SAR (interpolated) - SAR(1 g) = 5.49 W/kg; SAR(10 g) = 2.64 W/kg

HBBL-600-10000/2450.0MHz/Zoom Scan (5.0 x 5.0 x 1.5) :

Grid Extents [mm]: 30.0 x 30.0 x 30.0

SPC Power = 20.0 dBm

Power Drift = -0.03 dB

SAR(1 g) = 5.30 W/kg; SAR(10 g) = 2.48 W/kg**Additional information:**

ambient temperature: 22.9°C; liquid temperature: 20.9°C;

SAR plots for **the highest measured SAR** in each exposure configuration, wireless mode and frequency band combination according to FCC KDB 865664 D02

Date/Time: 2024-12-13, 14:49 2024-12-13, 14:57

BT LE

DUT: nivia 3D finder; Type: Avalanche Beacon; Serial: 4

Communication System: Bluetooth Low Energy; Communication System Band: ISM 2.4 GHz Band;

Communication System Frequency: 2402.0 MHz

Medium parameters used: $f = 2402.0$ MHz, $\sigma = 1.70$ S/m; $\epsilon_r = 36.5$; $\rho = 1000$ kg/m³

Phantom Section: Flat

Measurement Standard: DASY 6

DASY Configuration:

- Probe: EX3DV4 - SN7566; ConvF(7.67, 7.5, 6.89); Calibrated: 2024-08-12
- Sensor-Surface: 1.4mm
- DAE: DAE4 Sn1387; Calibrated: 2024-08-08
- Phantom: Twin-SAM V8.0 (30deg probe tilt); Serial: 2061;
- Software: cDASY6 (16.4.0.5005)

HBBL-600-10000/FRONT, 0 mm - Channel 0/Area Scan (10.0 x 10.0 x 1.0) :

Grid Extents [mm]: 100.0 x 160.0

Maximum value of SAR (interpolated) - SAR(1 g) = 0.039 W/kg; SAR(10 g) = 0.020 W/kg

HBBL-600-10000/FRONT, 0 mm - Channel 0/Zoom Scan (5.0 x 5.0 x 1.5) :

Grid Extents [mm]: 30.0 x 30.0 x 30.0

Graded Grid: Ratio 1.5 - Distance Sensor to Surface 1.4 mm

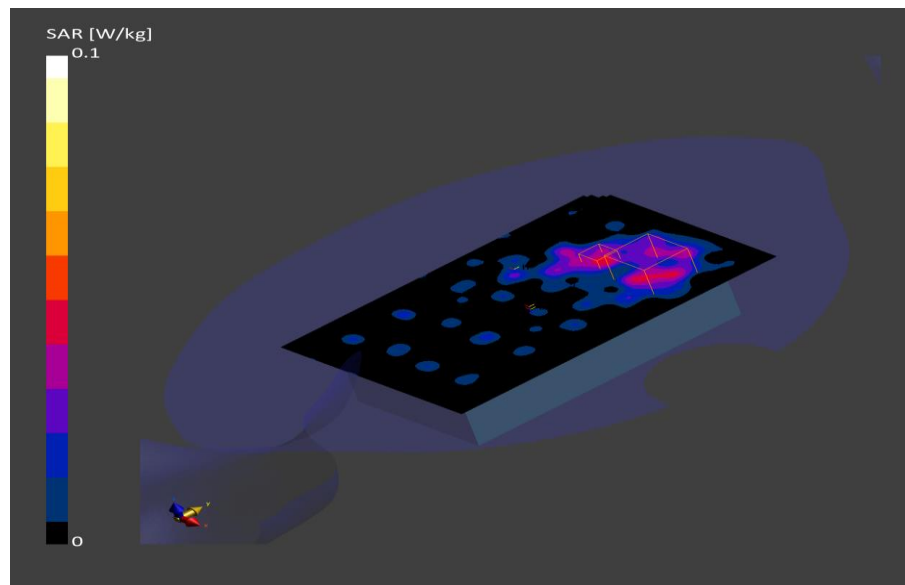
Power Drift = -0.01 dB

SAR(1 g) = 0.044 W/kg; SAR(10 g) = 0.020 W/kg

Additional Info for IEC 62209-2 AMD1:

TDist 3dB Peak [mm]: 7.3

M2/M1 [%]: 80.7



Additional information:

position or distance of DUT to SAM: 0 mm

ambient temperature: 22.6°C; liquid temperature: 20.9°C;

Annex E: Document History

Version	Applied Changes	Date of Release
R01	Initial Release	2025-02-05

Annex F: Further Information**Glossary**

DUT	-	Device under Test
EUT	-	Equipment under Test
FCC	-	Federal Communication Commission
FCC ID	-	Company Identifier at FCC
HW	-	Hardware
ISED	-	Innovation, Science and Economic Development Canada
N/A	-	not applicable
S/N	-	Serial Number
SW	-	Software