Appendix B: SAR System Check Plots

Test Laboratory:Underwriters Laboratories Taiwan Co., Ltd Date: 2022/10/17

System Performance Check-2450MHz

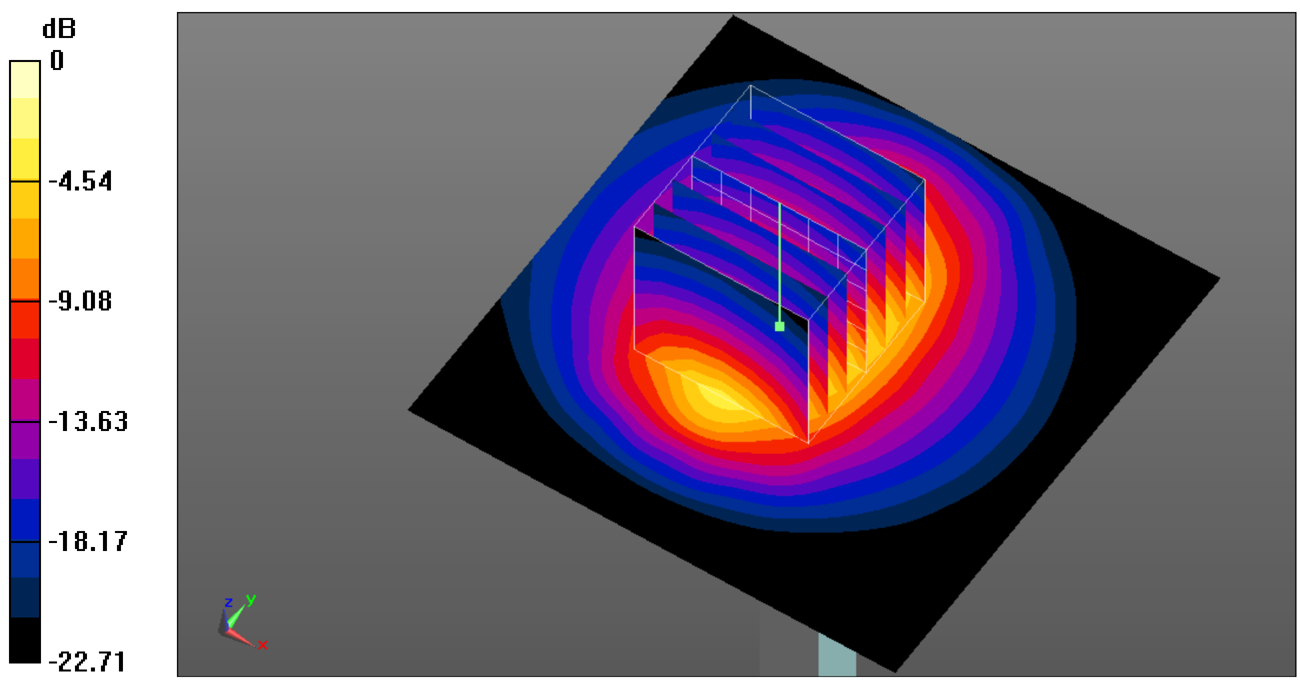
DUT: D2450V2-988

Communication System: UID 0, CW (0); Frequency: 2450 MHz;Duty Cycle: 1:1
Medium: HSL2450 Medium parameters used: f = 2450 MHz; σ = 1.871 S/m; ε_r = 39.502; ρ = 1000 kg/m^3
Ambient Temperature：23.5 ℃; Liquid Temperature：22.5 ℃

DASY5 Configuration:
- Probe: EX3DV4 - SN3820; ConvF(7.24, 7.24, 7.24) @ 2450 MHz; Calibrated: 2022/7/27
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE3 Sn528; Calibrated: 2022/5/19
- Phantom: ELI v5.0_1213; Type: QDOVA001BB; Serial: 1213
- Measurement SW: DASY52, Version 52.10 (4);SEMCAD X Version 14.6.14 (7483)

System Check/2450MHz/Area Scan (71x71x1): Interpolated grid: dx=1.200 mm, dy=1.200 mm
Maximum value of SAR (interpolated) = 22.8 W/kg

System Check/2450MHz/Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 110.7 V/m; Power Drift = 0.13 dB
Peak SAR (extrapolated) = 27.8 W/kg
SAR(1 g) = 13.3 W/kg; SAR(10 g) = 6.2 W/kg
Smallest distance from peaks to all points 3 dB below = 9 mm
Ratio of SAR at M2 to SAR at M1 = 48%
Maximum value of SAR (measured) = 22.2 W/kg



0 dB = 22.2 W/kg = 13.46 dBW/kg

Appendix C: Highest SAR Test Plots

Test Laboratory:Underwriters Laboratories Taiwan Co., Ltd Date: 2022/10/17

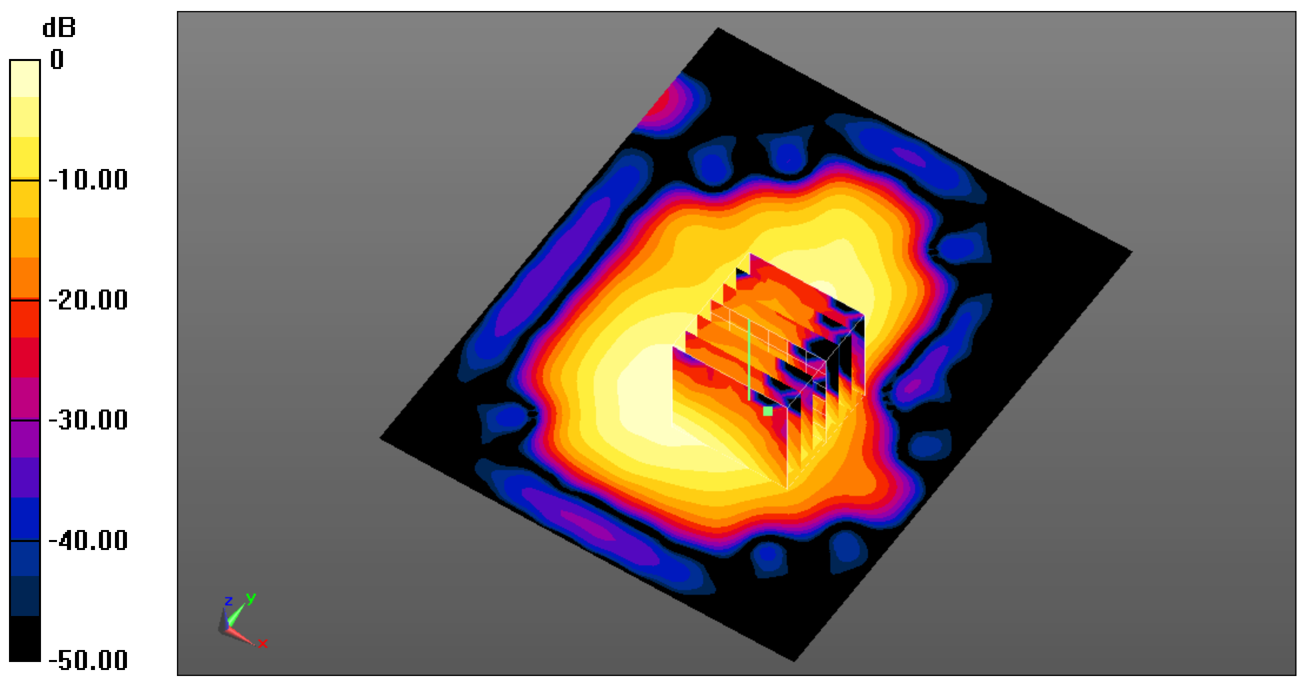
Bluetooth_Rear_ch78

Communication System: UID 0, Bluetooth (0); Frequency: 2480 MHz;Duty Cycle: 1:1
Medium: HSL2450 Medium parameters used: f = 2480 MHz; σ = 1.904 S/m; ε_r = 39.348; ρ = 1000 kg/m^3
Ambient Temperature：23.5 ℃; Liquid Temperature：22.5 ℃

DASY5 Configuration:
- Probe: EX3DV4 - SN3820; ConvF(7.24, 7.24, 7.24) @ 2480 MHz; Calibrated: 2022/7/27
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE3 Sn528; Calibrated: 2022/5/19
- Phantom: ELI v5.0_1213; Type: QDOVA001BB; Serial: 1213
- Measurement SW: DASY52, Version 52.10 (4);SEMCAD X Version 14.6.14 (7483)

Bluetooth_ch78/Area Scan (91x111x1): Interpolated grid: dx=1.200 mm, dy=1.200 mm
Maximum value of SAR (interpolated) = 0.150 W/kg

Bluetooth_ch78/Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 4.986 V/m; Power Drift = -0.17 dB
Peak SAR (extrapolated) = 0.183 W/kg
SAR(1 g) = 0.092 W/kg; SAR(10 g) = 0.042 W/kg
Smallest distance from peaks to all points 3 dB below = 10.6 mm
Ratio of SAR at M2 to SAR at M1 = 51.8%
Maximum value of SAR (measured) = 0.144 W/kg



0 dB = 0.144 W/kg = -8.42 dBW/kg

Appendix D: SAR Probe and Dipole Calibration Certificates

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CALIBRATION
CNAS L0570

Add: No.51 Xueyuan Road, Haidian District, Beijing, 100191, China
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E-mail: cttl@chinattl.com http://www.chinattl.cn

Client UL **Certificate No: Z20-60445**

CALIBRATION CERTIFICATE

Object: D2450V2 - SN: 988

Calibration Procedure(s): FF-Z11-003-01
Calibration Procedures for dipole validation kits

Calibration date: November 10, 2020

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)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	106276	12-May-20 (CTTL, No.J20X02965)	May-21
Power sensor NRP6A	101369	12-May-20 (CTTL, No.J20X02965)	May-21
ReferenceProbe EX3DV4	SN 3617	30-Jan-20(SPEAG,No.EX3-3617_Jan20)	Jan-21
DAE4	SN 771	10-Feb-20(CTTL-SPEAG,No.Z20-60017)	Feb-21
Secondary Standards	**ID #**	**Cal Date(Calibrated by, Certificate No.)**	**Scheduled Calibration**
Signal Generator E4438C	MY49071430	25-Feb-20 (CTTL, No.J20X00516)	Feb-21
NetworkAnalyzer E5071C	MY46110673	10-Feb-20 (CTTL, No.J20X00515)	Feb-21

	Name	Function	Signature
Calibrated by:	Zhao Jing	SAR Test Engineer	
Reviewed by:	Lin Hao	SAR Test Engineer	
Approved by:	Qi Dianyuan	SAR Project Leader	

Issued: November 19, 2020

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E-mail: cttl@chinattl.com http://www.chinattl.cn

Glossary:

TSL	tissue simulating liquid
ConvF	sensitivity in TSL / NORMx,y,z
N/A	not applicable or not measured

Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, “IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques”, June 2013

b) IEC 62209-1, “Measurement procedure for assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices- Part 1: Device used next to the ear (Frequency range of 300MHz to 6GHz)”, July 2016

c) IEC 62209-2, “Procedure to measure the Specific Absorption Rate (SAR) For wireless communication devices used in close proximity to the human body (frequency range of 30MHz to 6GHz)”, March 2010

d) KDB865664, SAR Measurement Requirements for 100 MHz to 6 GHz

Additional Documentation:

e) DASY4/5 System Handbook

Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

The reported uncertainty of measurement is stated as the standard uncertainty of Measurement multiplied by the coverage factor k=2, which for a normal distribution Corresponds to a coverage probability of approximately 95%.

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Measurement Conditions

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

DASY Version	DASY52	V52.10.4
Extrapolation	Advanced Extrapolation	
Phantom	Triple Flat Phantom 5.1C	
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	39.2 ± 6 %	1.78 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm^3 (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	13.0 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	**52.2 W/kg ± 18.8 % (*k*=2)**
SAR averaged over 10 cm^3 (10 g) of Head TSL	Condition	
SAR measured	250 mW input power	5.96 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	**23.9 W/kg ± 18.7 % (*k*=2)**

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Appendix (Additional assessments outside the scope of CNAS L0570)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	54.4Ω+ 3.51jΩ
Return Loss	- 25.4dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.022 ns

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

Additional EUT Data

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E-mail: cttl@chinattl.com http://www.chinattl.cn

DASY5 Validation Report for Head TSL Date: 11.10.2020

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 988

Communication System: UID 0, CW; Frequency: 2450 MHz; Duty Cycle: 1:1

Medium parameters used: f = 2450 MHz; σ = 1.784 S/m; ε_r = 39.22; ρ = 1000 kg/m^3

Phantom section: Center Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3617; ConvF(7.65, 7.65, 7.65) @ 2450 MHz; Calibrated: 2020-01-30
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn771; Calibrated: 2020-02-10
- Phantom: MFP_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (4); SEMCAD X Version 14.6.14 (7483)

Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 106.2 V/m; Power Drift = -0.05 dB

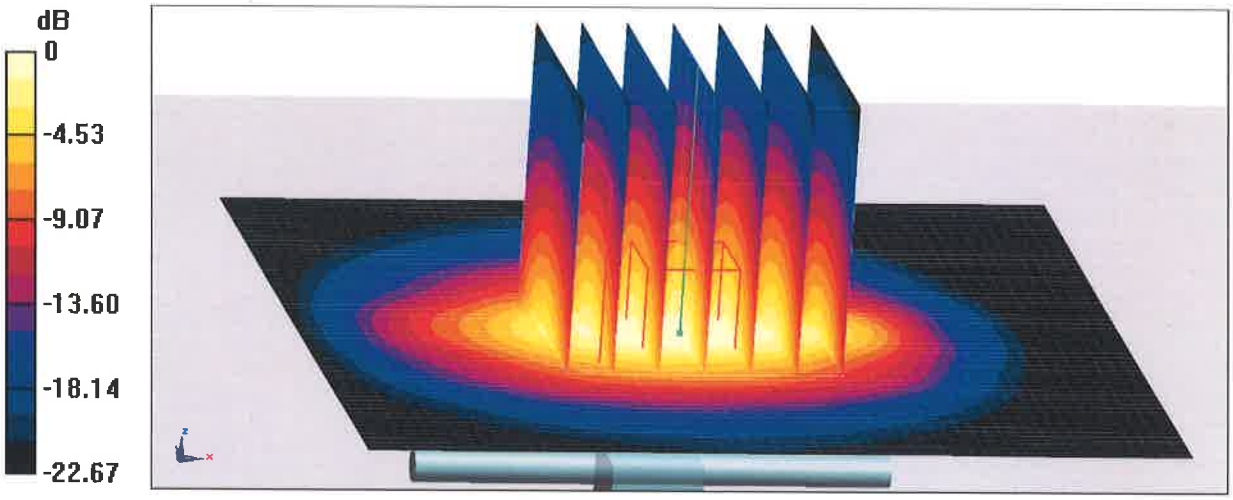
Peak SAR (extrapolated) = 27.6 W/kg

SAR(1 g) = 13 W/kg; SAR(10 g) = 5.96 W/kg

Smallest distance from peaks to all points 3 dB below = 9 mm

Ratio of SAR at M2 to SAR at M1 = 47.1%

Maximum value of SAR (measured) = 22.2 W/kg



0 dB = 22.2 W/kg = 13.46 dBW/kg

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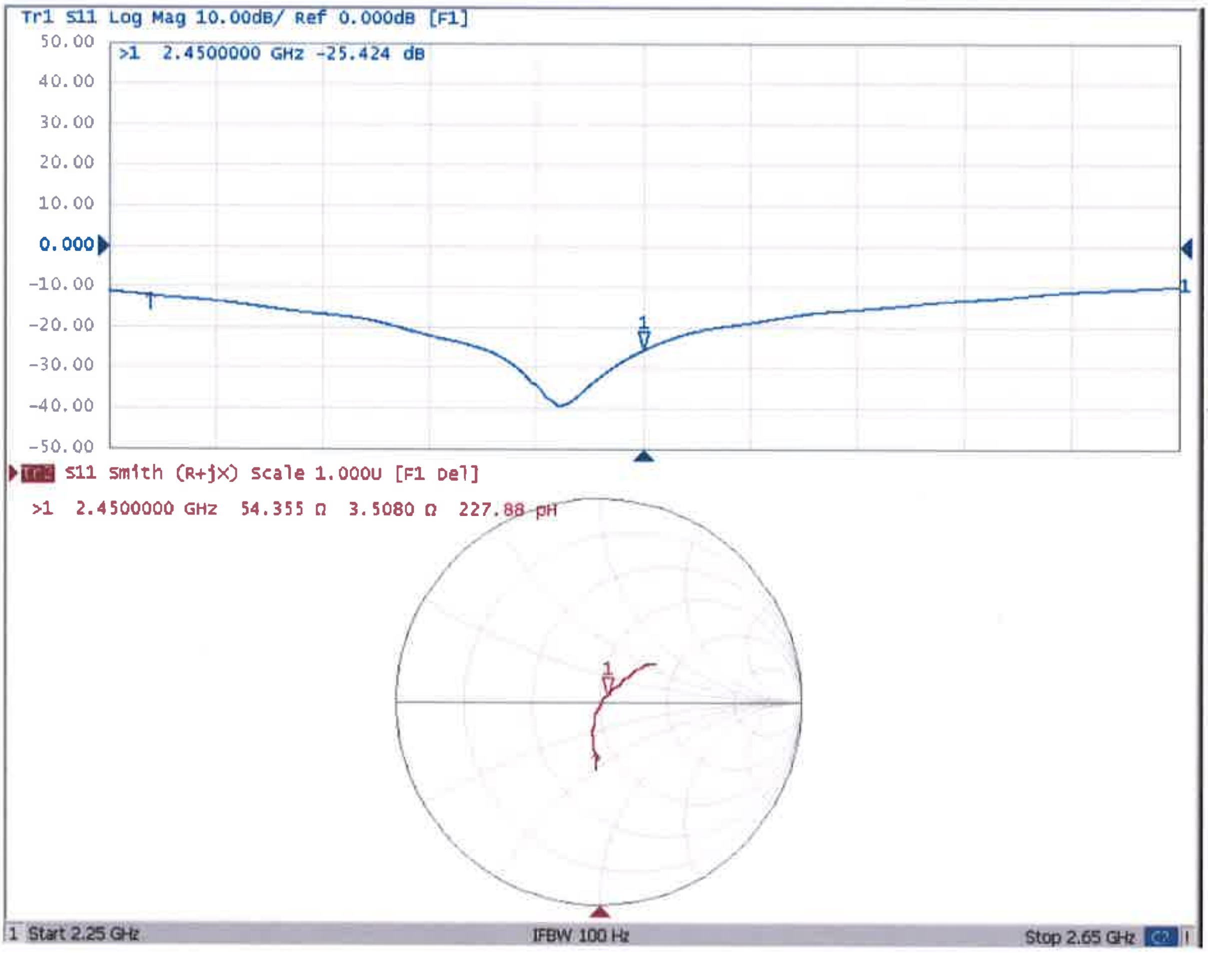
Impedance Measurement Plot for Head TSL



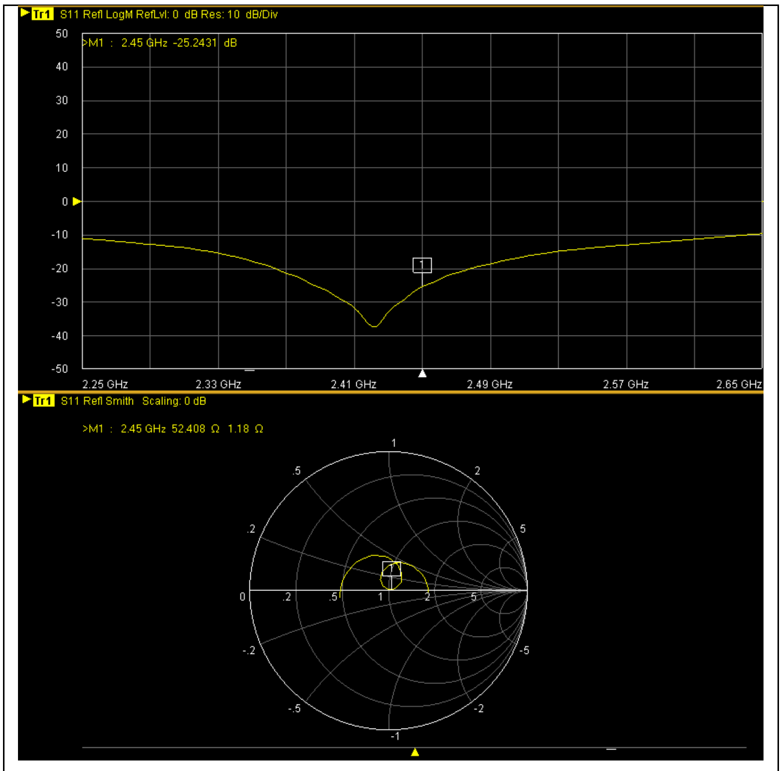
Dipole: 2450MHz, S/N: 988, Dipole calibration

According to KDB 865664 & IEEE Std 1528 - 2013:

3.2.2. Dipole calibration

It is necessary to re-calibrate reference dipoles at regular intervals to confirm the electrical specifications and SAR targets. A dipole must be calibrated using a fully validated SAR system according to the tissue dielectric parameters and SAR probe calibration frequency required for device testing. It is generally unacceptable to calibrate a dipole using the SAR system that has been validated by the same dipole; therefore, dipoles should be returned to the SAR system manufacturer or its designated calibration facilities for re-calibration. However, instead of the typical annual calibration recommended by measurement standards, longer calibration intervals of up to three years may be considered when it is demonstrated that the SAR target, impedance and return loss of a dipole have remain stable according to the following requirements.

1) The test laboratory must ensure that the required supporting information and documentation are included in the SAR report to qualify for the three-year extended calibration interval; otherwise, the IEEE Std 1528-2013 recommended annual calibration applies.
2) Immediate re-calibration is required for the following conditions.
   a) After a dipole is damaged and properly repaired to meet required specifications.
   b) When the measured SAR deviates from the calibrated SAR value by more than 10% due to changes in physical, mechanical, electrical or other relevant dipole conditions; i.e., the error is not introduced by incorrect measurement procedures or other issues relating to the SAR measurement system.
   c) When the most recent return-loss result, measured at least annually, deviates by more than 20% from the previous measurement (i.e. value in dB × 0.2) or not meeting the required 20 dB minimum return-loss requirement.[24]
   d) When the most recent measurement of the real or imaginary parts of the impedance, measured at least annually, deviates by more than 5 Ω from the previous measurement.



Calibration Date	Impedance R (ohm)	Delta (ohm)	Impedance jX (ohm)	Delta (ohm)	Return-loss (dB)	Delta (%)
2020/11/10	54.4	N/A	3.51	N/A	-25.4	N/A
2022/10/11	52.408	-1.99	1.18	-2.33	-25.2431	-0.62

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IMPORTANT NOTICE

USAGE OF THE DAE3

The DAE unit is a delicate, high precision instrument and requires careful treatment by the user. There are no serviceable parts inside the DAE. Special attention shall be given to the following points:

Battery Exchange: The battery cover of the DAE3 unit is connected to a fragile 3-pin battery connector. Customer is responsible to apply outmost caution not to bend or damage the connector when changing batteries.

Shipping of the DAE: Before shipping the DAE to SPEAG for calibration, remove the batteries and pack the DAE in an antistatic bag. This antistatic bag shall then be packed into a larger box or container which protects the DAE from impacts during transportation. The package shall be marked to indicate that a fragile instrument is inside.

E-Stop Failures: Touch detection may be malfunctioning due to broken magnets in the E-stop. Rough handling of the E-stop may lead to damage of these magnets. Touch and collision errors are often caused by dust and dirt accumulated in the E-stop. To prevent E-stop failure, the customer shall always mount the probe to the DAE carefully and keep the DAE unit in a non-dusty environment if not used for measurements.

Repair: Minor repairs are performed at no extra cost during the annual calibration. However, SPEAG reserves the right to charge for any repair especially if rough unprofessional handling caused the defect.

DASY Configuration Files: Since the exa ct values of the DAE input resistances, as measured during the calibration procedure of a DAE unit, are not used by the DASY software, a nominal value of 200 MOhm is given in the corresponding configuration file.

Important Note:
Warranty and calibration is void if the DAE unit is disassembled partly or fully by the Customer.

Important Note:
Never attempt to grease or oil the E-stop assembly. Cleaning and readjusting of the E-stop assembly is allowed by certified SPEAG personnel only and is part of the annual calibration procedure.

Important Note:
To prevent damage of the DAE probe connector pins, use great care when installing the probe to the DAE. Carefully connect the probe with the connector notch oriented in the mating position. Avoid any rotational movement of the probe body versus the DAE while turning the locking nut of the connector. The same care shall be used when disconnecting the probe from the DAE.

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

S **Schweizerischer Kalibrierdienst**
C **Service suisse d'étalonnage**
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Swiss Calibration Service

Accredited by the Swiss Accreditation Service (SAS)
The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Client **Auden**

Certificate No: DAE3-528_May22

CALIBRATION CERTIFICATE

Object	DAE3 - SD 000 D03 AA - SN: 528
Calibration procedure(s)	QA CAL-06.v30 Calibration procedure for the data acquisition electronics (DAE)
Calibration date:	May 19, 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
Keithley Multimeter Type 2001	SN: 0810278	31-Aug-21 (No:31368)	Aug-22
Secondary Standards	**ID #**	**Check Date (in house)**	**Scheduled Check**
Auto DAE Calibration Unit	SE UWS 053 AA 1001	24-Jan-22 (in house check)	In house check: Jan-23
Calibrator Box V2.1	SE UMS 006 AA 1002	24-Jan-22 (in house check)	In house check: Jan-23

	Name	Function	Signature
Calibrated by:	Adrian Gehring	Laboratory Technician	AG
Approved by:	Sven Kühn	Technical Manager	i.V. [signature]

Issued: May 19, 2022

Glossary

DAE	data acquisition electronics
Connector angle	information used in DASY system to align probe sensor X to the robot coordinate system.

Methods Applied and Interpretation of Parameters

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle*: The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
  - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
  - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
  - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
  - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
  - *Input Offset Measurement*: Output voltage and statistical results over a large number of zero voltage measurements.
  - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
  - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
  - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
  - *Power consumption:* Typical value for information. Supply currents in various operating modes.

DC Voltage Measurement

A/D - Converter Resolution nominal

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

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

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

Calibration Factors	**X**	**Y**	**Z**
High Range	404.678 ± 0.02% (k=2)	404.776 ± 0.02% (k=2)	404.698 ± 0.02% (k=2)
Low Range	3.97108 ± 1.50% (k=2)	3.96048 ± 1.50% (k=2)	3.96714 ± 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	51.0 ° ± 1 °

Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	200035.54	-2.70	-0.00
Channel X	+ Input	20008.36	2.37	0.01
Channel X	- Input	-19999.24	6.68	-0.03
Channel Y	+ Input	200035.77	0.58	0.00
Channel Y	+ Input	20006.00	0.05	0.00
Channel Y	- Input	-20003.41	2.64	-0.01
Channel Z	+ Input	200033.50	-1.71	-0.00
Channel Z	+ Input	20006.46	0.65	0.00
Channel Z	- Input	-20003.96	2.18	-0.01

Low Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	2001.61	0.44	0.02
Channel X	+ Input	200.65	-0.42	-0.21
Channel X	- Input	-198.60	0.19	-0.10
Channel Y	+ Input	2001.63	0.59	0.03
Channel Y	+ Input	200.74	-0.29	-0.14
Channel Y	- Input	-199.63	-0.80	0.40
Channel Z	+ Input	2001.04	-0.04	-0.00
Channel Z	+ Input	200.33	-0.69	-0.34
Channel Z	- Input	-199.25	-0.46	0.23

2. Common mode sensitivity

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

	Common mode Input Voltage (mV)	High Range Average Reading (μV)	Low Range Average Reading (μV)
Channel X	200	9.52	8.36
	- 200	-6.15	-8.92
Channel Y	200	14.97	14.83
	- 200	-16.97	-16.80
Channel Z	200	-2.75	-4.14
	- 200	3.72	3.40

3. Channel separation

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

	Input Voltage (mV)	Channel X (μV)	Channel Y (μV)	Channel Z (μV)
Channel X	200	-	2.97	-2.05
Channel Y	200	7.06	-	4.80
Channel Z	200	7.42	5.02	-

4. AD-Converter Values with inputs shorted

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

	High Range (LSB)	Low Range (LSB)
Channel X	15979	16445
Channel Y	15911	17034
Channel Z	16178	16592

5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec
Input 10MΩ

	Average (μV)	min. Offset (μV)	max. Offset (μV)	Std. Deviation (μV)
Channel X	1.28	0.35	2.98	0.45
Channel Y	0.10	-0.98	1.58	0.48
Channel Z	0.23	-1.08	1.37	0.44

6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

7. Input Resistance (Typical values for information)

	Zeroing (kOhm)	Measuring (MOhm)
Channel X	200	200
Channel Y	200	200
Channel Z	200	200

8. Low Battery Alarm Voltage (Typical values for information)

Typical values	**Alarm Level (VDC)**
Supply (+ Vcc)	+7.9
Supply (- Vcc)	-7.6

9. Power Consumption (Typical values for information)

Typical values	**Switched off (mA)**	**Stand by (mA)**	**Transmitting (mA)**
Supply (+ Vcc)	+0.01	+6	+14
Supply (- Vcc)	–0.01	-8	-9

Calibration Laboratory of
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Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland

S Schweizerischer Kalibrierdienst
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Servizio svizzero di taratura
S Swiss Calibration Service

Accredited by the Swiss Accreditation Service (SAS)
The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Client **Auden**

Certificate No **EX-3820_Jul22**

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3820
Calibration procedure(s)	QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date	July 27, 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
OCP DAK-3.5 (weighted)	SN: 1249	20-Oct-21 (OCP-DAK3.5-1249_Oct21)	Oct-22
OCP DAK-12	SN: 1016	20-Oct-21 (OCP-DAK12-1016_Oct21)	Oct-22
Reference 20 dB Attenuator	SN: CC2552 (20x)	04-Apr-22 (No. 217-03527)	Apr-23
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22

Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-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-20)	In house check: Oct-22

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

Issued: August 1, 2022

Glossary

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

Calibration is Performed According to the Following Standards:

a) IEC/IEEE 62209-1528, "Measurement Procedure For The Assessment Of Specific Absorption Rate Of Human Exposure To Radio Frequency Fields From Hand-Held And Body-Worn Wireless Communication Devices – Part 1528: Human Models, Instrumentation And Procedures (Frequency Range of 4 MHz to 10 GHz)", October 2020.
b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z*: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- *DCPx,y,z*: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal. DCP does not depend on frequency nor media.
- *PAR*: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: A, B, C, D* are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters*: Assessed in flat phantom using E-field (or Temperature Transfer Standard for $f \leq 800$ MHz) and inside waveguide using analytical field distributions based on power measurements for $f > 800$ MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to *NORMx,y,z * ConvF* whereby the uncertainty corresponds to that given for *ConvF*. A frequency dependent *ConvF* is used in DASY version 4.4 and higher which allows extending the validity from ±50 MHz to ±100 MHz.
- *Spherical isotropy (3D deviation from isotropy)*: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- *Sensor Offset*: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle*: The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:3820

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm (μV/(V/m)^2) [A]	0.40	0.46	0.49	±10.1%
DCP (mV) [B]	103.4	102.7	100.9	±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	165.0	±3.5%	±4.7%
		Y	0.00	0.00	1.00		152.9		
		Z	0.00	0.00	1.00		162.3		
10352	Pulse Waveform (200Hz, 10%)	X	20.00	91.81	21.54	10.00	60.0	±3.0%	±9.6%
		Y	20.00	89.06	19.90		60.0		
		Z	20.00	92.88	22.35		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	20.00	93.03	20.85	6.99	80.0	±1.4%	±9.6%
		Y	20.00	89.94	19.40		80.0		
		Z	20.00	93.35	21.39		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	20.00	96.42	20.88	3.98	95.0	±1.5%	±9.6%
		Y	20.00	91.26	18.78		95.0		
		Z	20.00	96.14	21.21		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	20.00	100.55	21.18	2.22	120.0	±1.7%	±9.6%
		Y	20.00	94.46	19.04		120.0		
		Z	20.00	100.25	21.58		120.0		
10387	QPSK Waveform, 1 MHz	X	1.77	67.25	15.87	1.00	150.0	±2.9%	±9.6%
		Y	1.89	68.84	16.63		150.0		
		Z	1.76	66.92	15.74		150.0		
10388	QPSK Waveform, 10 MHz	X	2.44	69.88	16.71	0.00	150.0	±1.6%	±9.6%
		Y	2.61	71.17	17.45		150.0		
		Z	2.42	69.63	16.60		150.0		
10396	64-QAM Waveform, 100 kHz	X	4.05	76.16	21.65	3.01	150.0	±1.3%	±9.6%
		Y	3.39	73.99	21.02		150.0		
		Z	4.35	77.40	22.20		150.0		
10399	64-QAM Waveform, 40 MHz	X	3.70	68.23	16.44	0.00	150.0	±2.5%	±9.6%
		Y	3.69	68.29	16.56		150.0		
		Z	3.71	68.18	16.42		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	4.89	65.67	15.68	0.00	150.0	±4.6%	±9.6%
		Y	5.00	66.23	16.02		150.0		
		Z	4.90	65.60	15.65		150.0		

Note: For details on UID parameters see Appendix

The reported uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

[A] The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5 and 6).
[B] Linearization parameter uncertainty for maximum specified field strength.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Parameters of Probe: EX3DV4 - SN:3820

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms V^{-2}$	T2 $ms V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	52.9	400.42	36.54	13.88	0.60	5.09	1.20	0.41	1.01
y	47.9	362.06	36.50	23.72	0.17	5.10	0.74	0.34	1.01
z	54.4	413.73	36.88	18.94	0.69	5.10	1.59	0.36	1.02

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	-82.3°
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:3820

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 ($k = 2$)
750	41.9	0.89	9.44	9.44	9.44	0.55	0.80	±12.0%
835	41.5	0.90	9.20	9.20	9.20	0.46	0.80	±12.0%
900	41.5	0.97	8.96	8.96	8.96	0.52	0.80	±12.0%
1450	40.5	1.20	8.11	8.11	8.11	0.36	0.80	±12.0%
1640	40.2	1.31	8.03	8.03	8.03	0.37	0.86	±12.0%
1750	40.1	1.37	8.00	8.00	8.00	0.23	0.86	±12.0%
1810	40.0	1.40	7.73	7.73	7.73	0.30	0.86	±12.0%
1900	40.0	1.40	7.51	7.51	7.51	0.38	0.86	±12.0%
2000	40.0	1.40	7.45	7.45	7.45	0.38	0.86	±12.0%
2450	39.2	1.80	7.24	7.24	7.24	0.35	0.90	±12.0%
2600	39.0	1.96	7.12	7.12	7.12	0.36	0.90	±12.0%
3300	38.2	2.71	6.85	6.85	6.85	0.30	1.30	±13.1%
3500	37.9	2.91	6.83	6.83	6.83	0.30	1.35	±13.1%
3700	37.7	3.12	6.80	6.80	6.80	0.30	1.35	±13.1%
3900	37.5	3.32	6.29	6.29	6.29	0.40	1.60	±13.1%
4100	37.2	3.53	6.25	6.25	6.25	0.40	1.60	±13.1%
4200	37.1	3.63	6.19	6.19	6.19	0.40	1.70	±13.1%
4400	36.9	3.84	6.13	6.13	6.13	0.40	1.70	±13.1%
4600	36.7	4.04	6.01	6.01	6.01	0.40	1.70	±13.1%
4800	36.4	4.25	5.92	5.92	5.92	0.40	1.80	±13.1%
4950	36.3	4.40	5.68	5.68	5.68	0.40	1.80	±13.1%
5250	35.9	4.71	5.35	5.35	5.35	0.40	1.80	±13.1%
5600	35.5	5.07	4.62	4.62	4.62	0.40	1.80	±13.1%
5750	35.4	5.22	4.70	4.70	4.70	0.40	1.80	±13.1%

[C] Frequency validity above 300 MHz of ±100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ±50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ±10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4–9 MHz, and ConvF assessed at 13 MHz is 9–19 MHz. Above 5 GHz frequency validity can be extended to ±110 MHz.

[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ±5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ±1% for frequencies below 3 GHz and below ±2% for frequencies between 3–6 GHz at any distance larger than half the probe tip diameter from the boundary.

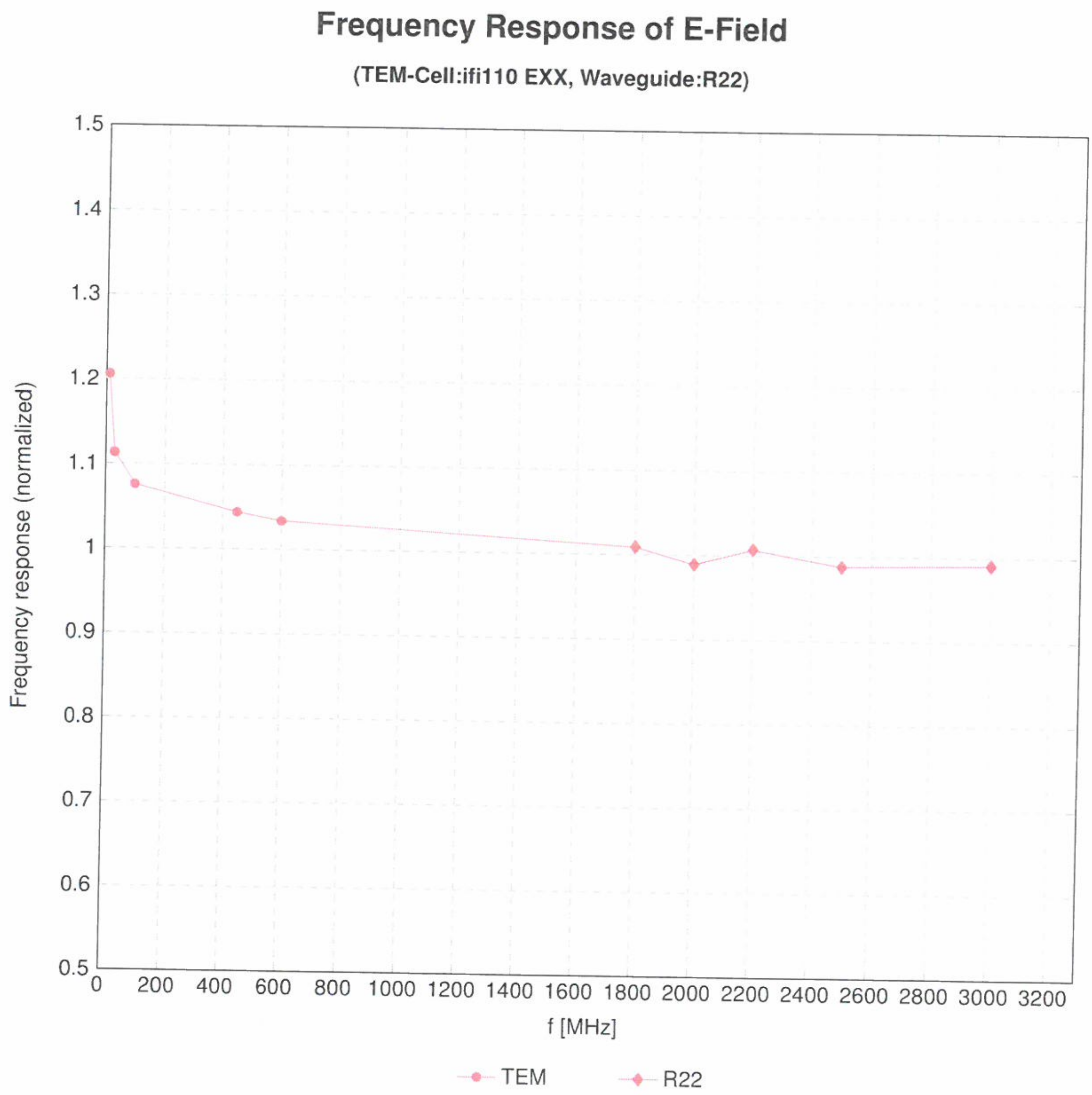
Parameters of Probe: EX3DV4 - SN:3820

Calibration Parameter Determined in Body Tissue Simulating Media

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc ($k = 2$)
750	55.5	0.96	9.41	9.41	9.41	0.42	0.80	±12.0%
835	55.2	0.97	9.26	9.26	9.26	0.45	0.80	±12.0%
900	55.0	1.05	9.07	9.07	9.07	0.47	0.80	±12.0%
1450	54.0	1.30	8.04	8.04	8.04	0.26	0.80	±12.0%
1640	53.7	1.42	7.95	7.95	7.95	0.46	0.86	±12.0%
1750	53.4	1.49	7.76	7.76	7.76	0.33	0.86	±12.0%
1810	53.3	1.52	7.61	7.61	7.61	0.38	0.86	±12.0%
1900	53.3	1.52	7.34	7.34	7.34	0.45	0.86	±12.0%
2000	53.3	1.52	7.30	7.30	7.30	0.34	0.86	±12.0%
2450	52.7	1.95	7.19	7.19	7.19	0.35	0.90	±12.0%
2600	52.5	2.16	7.07	7.07	7.07	0.43	0.90	±12.0%
3300	51.6	3.08	6.23	6.23	6.23	0.40	1.35	±13.1%
3500	51.3	3.31	6.17	6.17	6.17	0.40	1.35	±13.1%
3700	51.0	3.55	6.14	6.14	6.14	0.40	1.35	±13.1%
3900	50.8	3.78	6.11	6.11	6.11	0.40	1.60	±13.1%
4100	50.5	4.01	5.84	5.84	5.84	0.40	1.60	±13.1%
4200	50.4	4.13	5.80	5.80	5.80	0.40	1.60	±13.1%
4400	50.1	4.37	5.56	5.56	5.56	0.40	1.70	±13.1%
4600	49.8	4.60	5.48	5.48	5.48	0.40	1.70	±13.1%
4800	49.6	4.83	5.37	5.37	5.37	0.50	1.90	±13.1%
4950	49.4	5.01	5.10	5.10	5.10	0.50	1.90	±13.1%
5250	48.9	5.36	4.83	4.83	4.83	0.50	1.90	±13.1%
5600	48.5	5.77	4.23	4.23	4.23	0.50	1.90	±13.1%
5750	48.3	5.94	4.28	4.28	4.28	0.50	1.90	±13.1%

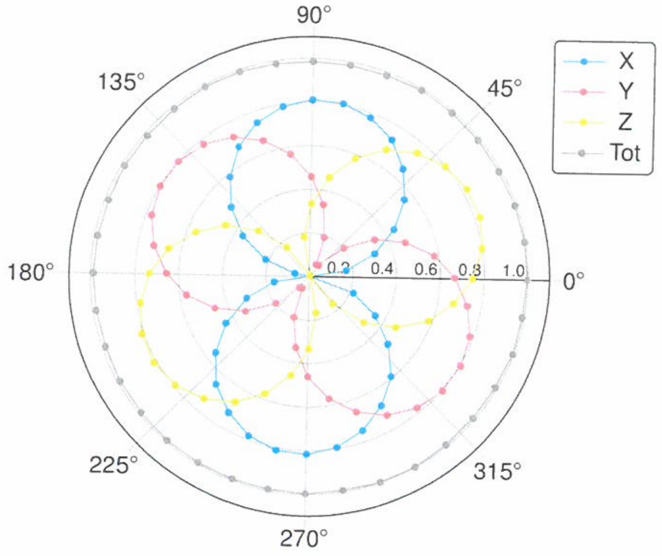
[C] Frequency validity above 300 MHz of ±100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ±50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ±10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4–9 MHz, and ConvF assessed at 13 MHz is 9–19 MHz. Above 5 GHz frequency validity can be extended to ±110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ±5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

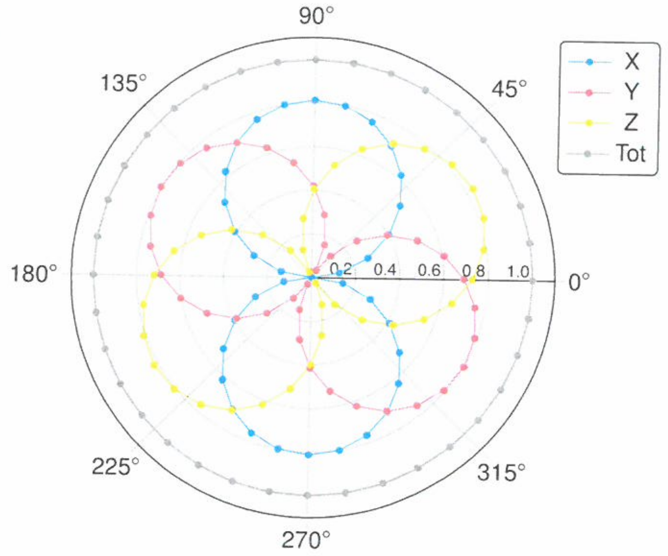
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ±1% for frequencies below 3 GHz and below ±2% for frequencies between 3–6 GHz at any distance larger than half the probe tip diameter from the boundary.

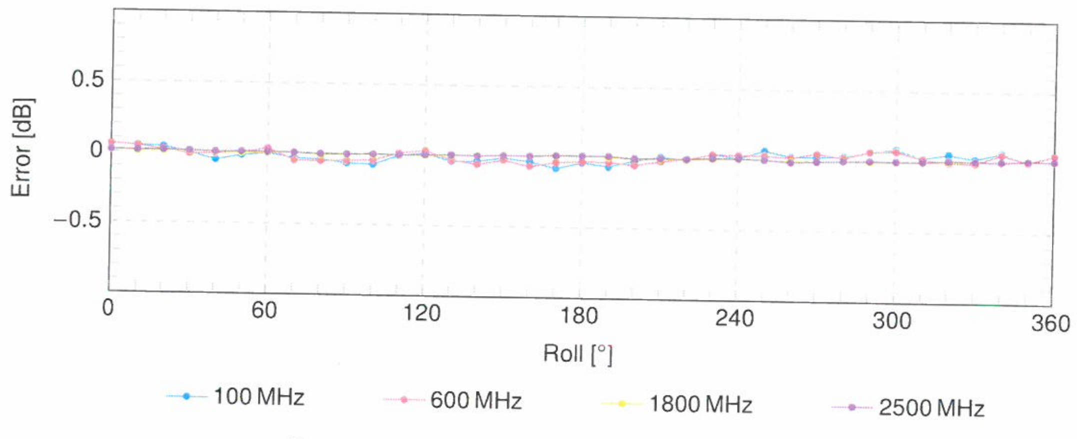


Uncertainty of Frequency Response of E-field: ±6.3% (k=2)

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



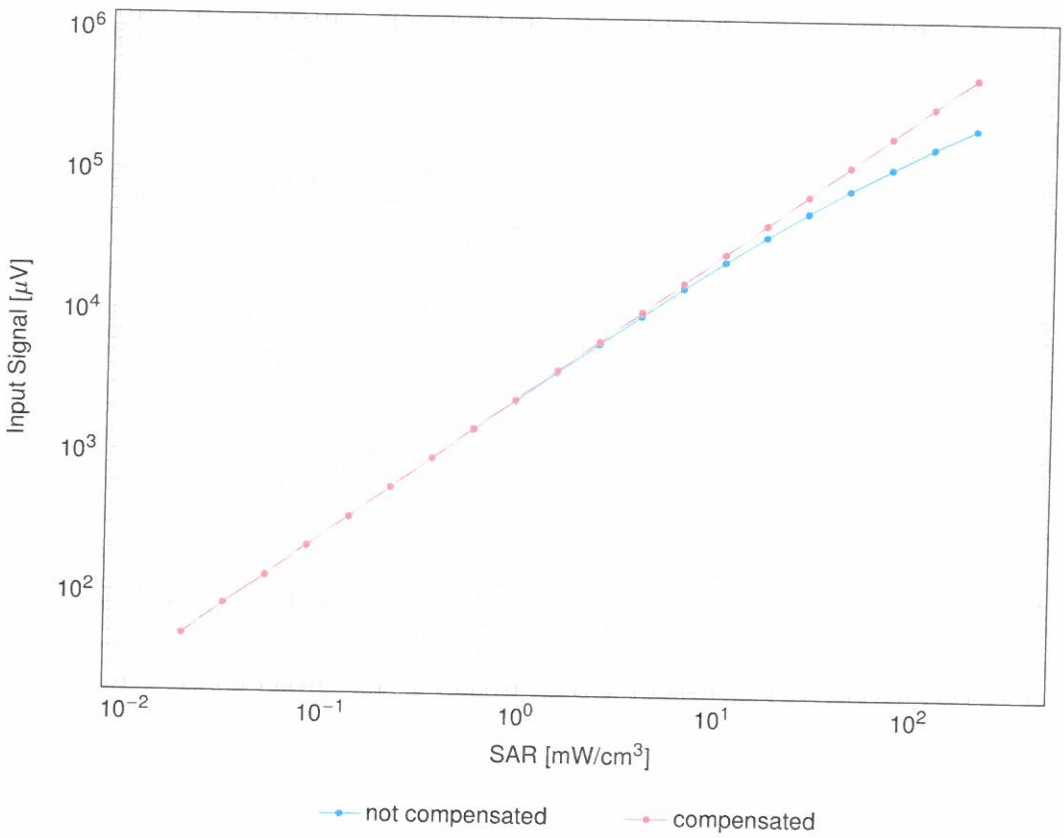


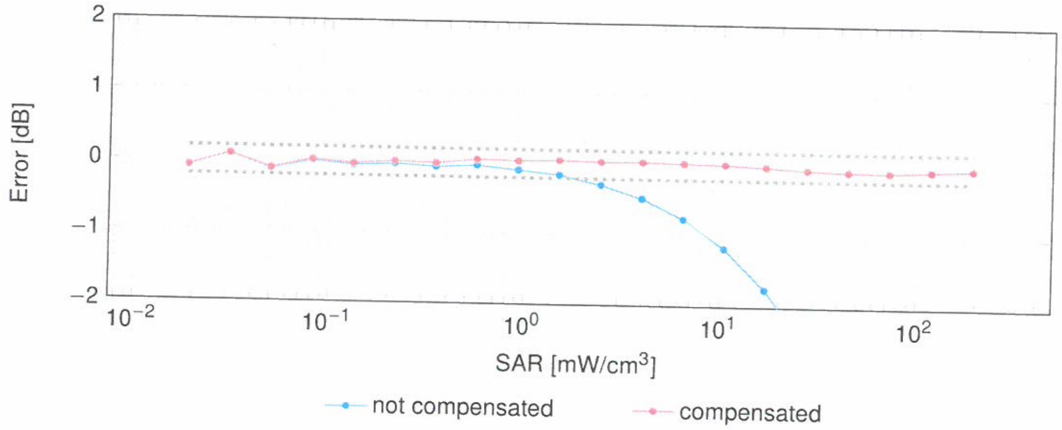


Uncertainty of Axial Isotropy Assessment: ±0.5% (k=2)

Dynamic Range f(SAR_{head})

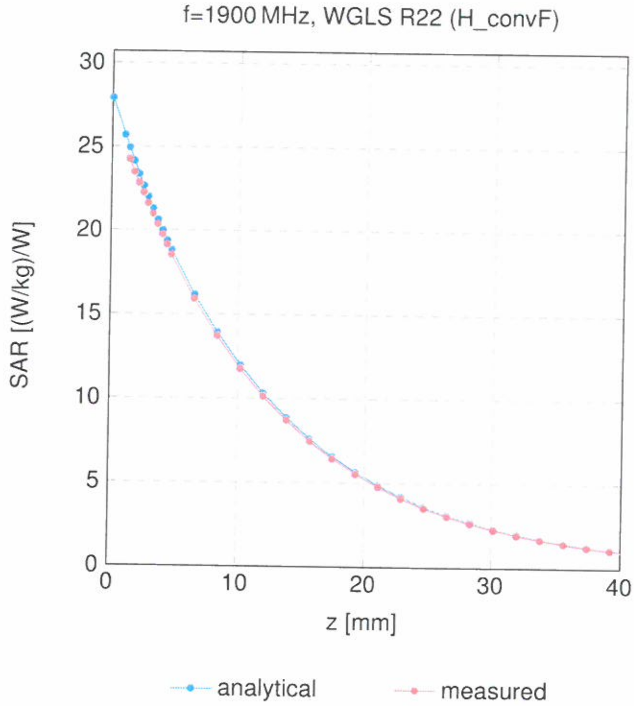
(TEM cell, f_{eval} = 1900 MHz)





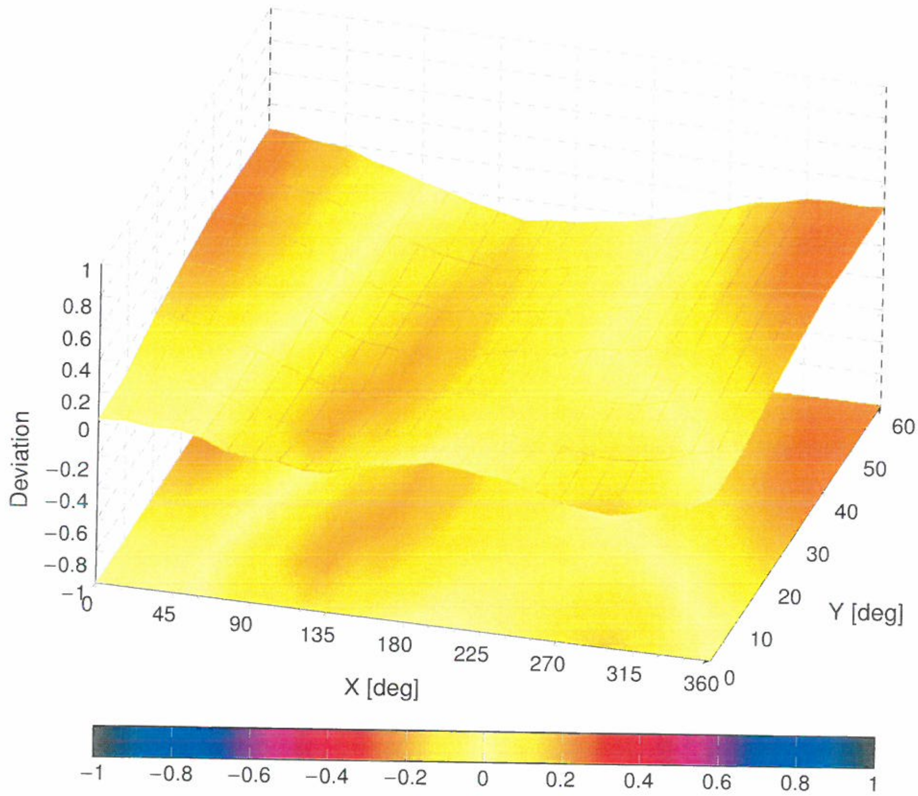
Uncertainty of Linearity Assessment: ±0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid

Error (ϕ,θ), f = 900 MHz



Uncertainty of Spherical Isotropy Assessment: ±2.6% (k=2)