

APPENDIX C CALIBRATION CERTIFICATES



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CALIBRATION LABORATORY

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CALIBRATION
CNAS L0570

Client **BACL**

Certificate No: **Z21-60509**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN : 7329**

Calibration Procedure(s) **FF-Z11-004-02**
Calibration Procedures for Dosimetric E-field Probes

Calibration date: **December 31, 2021**

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(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	101919	15-Jun-21(CTTL, No.J21X04466)	Jun-22
Power sensor NRP-Z91	101547	15-Jun-21(CTTL, No.J21X04466)	Jun-22
Power sensor NRP-Z91	101548	15-Jun-21(CTTL, No.J21X04466)	Jun-22
Reference 10dBAttenuator	18N50W-10dB	10-Feb-20(CTTL, No.J20X00525)	Feb-22
Reference 20dBAttenuator	18N50W-20dB	10-Feb-20(CTTL, No.J20X00526)	Feb-22
Reference Probe EX3DV4	SN 3617	27-Jan-21(SPEAG, No.EX3-3617_Jan21)	Jan-22
DAE4	SN 1555	20-Aug-21(SPEAG, No.DAE4-1555_Aug21/2)	Aug-22
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
SignalGenerator MG3700A	6201052605	16-Jun-21(CTTL, No.J21X04467)	Jun-22
Network Analyzer E5071C	MY46110673	21-Jan-21(CTTL, No.J20X00515)	Jan-22

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

Issued: January 02, 2022

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Glossary:

TSL	tissue simulating liquid
NORM _{x,y,z}	sensitivity in free space
ConvF	sensitivity in TSL / NORM _{x,y,z}
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A,B,C,D	modulation dependent linearization parameters
Polarization Φ	Φ rotation around probe axis
Polarization θ	θ rotation around an axis that is in the plane normal to probe axis (at measurement center), i $\theta=0$ 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:

- 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
- IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- NORM_{x,y,z}:** Assessed for E-field polarization $\theta=0$ ($f \leq 900\text{MHz}$ in TEM-cell; $f > 1800\text{MHz}$: waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not effect the E^2 -field uncertainty inside TSL (see below ConvF).
- NORM(f)_{x,y,z} = NORM_{x,y,z} * frequency_response** (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCP_{x,y,z}:** DCP are numerical linearization parameters assessed based on the data of power sweep (no uncertainty required). DCP does not depend on frequency nor media.
- PAR:** PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics.
- A_{x,y,z}; B_{x,y,z}; C_{x,y,z}; VR_{x,y,z}:** A,B,C 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 $f \leq 800\text{MHz}$) and inside waveguide using analytical field distributions based on power measurements for $f > 800\text{MHz}$. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty valued are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM_{x,y,z} * ConvF whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from $\pm 50\text{MHz}$ to $\pm 100\text{MHz}$.
- Spherical isotropy (3D deviation from isotropy):** in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset:** The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle:** The angle is assessed using the information gained by determining the NORM_x (no uncertainty required).



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DASY/EASY – Parameters of Probe: EX3DV4 – SN:7329

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k=2$)
Norm($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.49	0.41	0.47	$\pm 10.0\%$
DCP(mV) ^B	99.1	102.2	99.6	

Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB $\cdot\mu\text{V}$	C	D dB	VR mV	Unc ^E ($k=2$)
0	CW	X	0.0	0.0	1.0	0.00	160.6	$\pm 2.1\%$
		Y	0.0	0.0	1.0		146.0	
		Z	0.0	0.0	1.0		157.5	

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 E²-field uncertainty inside TSL (see Page 4).

^B Numerical linearization parameter: uncertainty not required.

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



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DASY/EASY – Parameters of Probe: EX3DV4 – SN:7329

Calibration Parameter Determined in Head Tissue Simulating Media

f [MHz] ^C	Relative Permittivity ^F	Conductivity (S/m) ^F	ConvF X	ConvF Y	ConvF Z	Alpha ^G	Depth ^G (mm)	Unct. (k=2)
750	41.9	0.89	10.06	10.06	10.06	0.17	1.16	±12.1%
900	41.5	0.97	9.68	9.68	9.68	0.15	1.43	±12.1%
1450	40.5	1.20	8.64	8.64	8.64	0.15	1.23	±12.1%
1750	40.1	1.37	8.23	8.23	8.23	0.36	0.82	±12.1%
1900	40.0	1.40	8.00	8.00	8.00	0.27	0.98	±12.1%
2100	39.8	1.49	7.90	7.90	7.90	0.23	1.14	±12.1%
2300	39.5	1.67	7.73	7.73	7.73	0.65	0.67	±12.1%
2450	39.2	1.80	7.42	7.42	7.42	0.48	0.84	±12.1%
2600	39.0	1.96	7.15	7.15	7.15	0.40	0.99	±12.1%
5200	36.0	4.66	5.49	5.49	5.49	0.50	1.25	±13.3%
5300	35.9	4.76	5.20	5.20	5.20	0.45	1.40	±13.3%
5600	35.5	5.07	4.77	4.77	4.77	0.60	1.20	±13.3%
5800	35.3	5.27	4.75	4.75	4.75	0.55	1.25	±13.3%

^C Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of 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. Above 5 GHz frequency validity can be extended to ± 110 MHz.

^F At frequency 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.

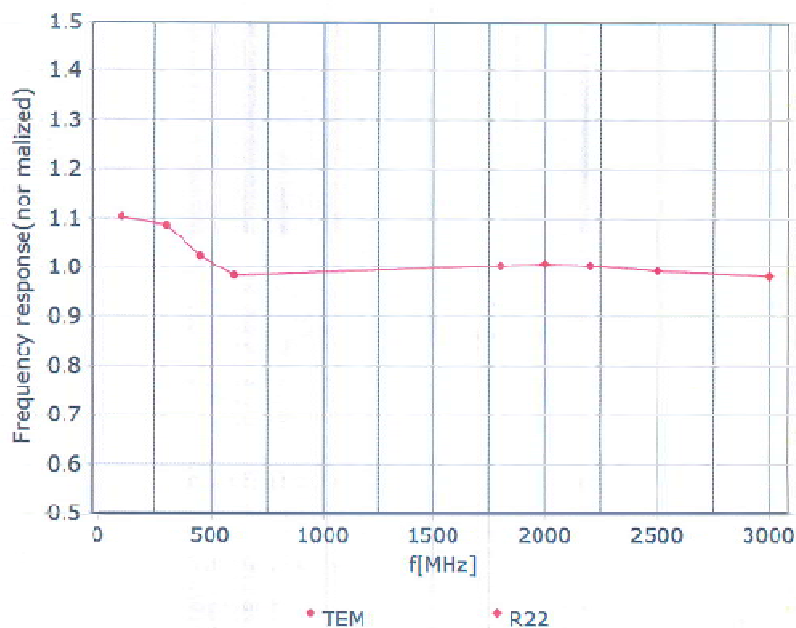
^G Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from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



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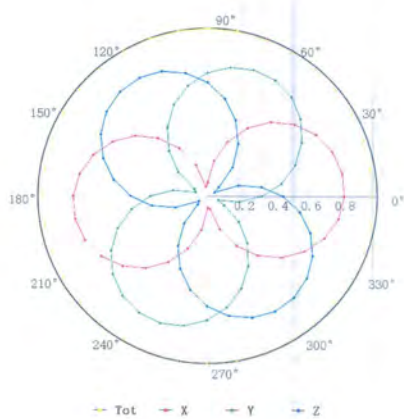
Frequency Response of E-Field (TEM-Cell: ifi110 EXX, Waveguide: R22)



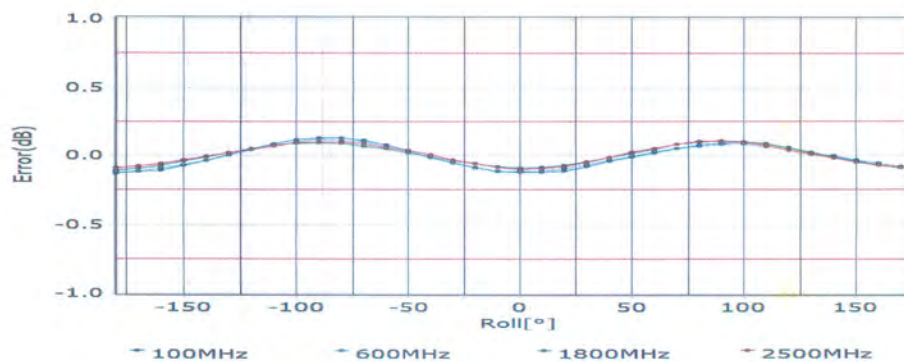
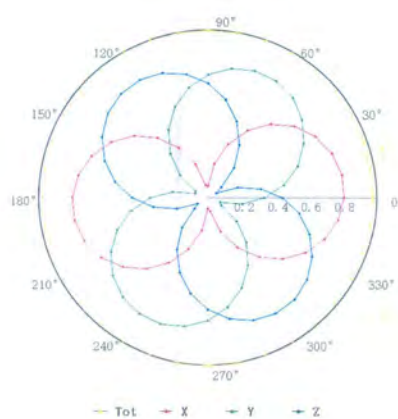
Uncertainty of Frequency Response of E-field: $\pm 7.4\%$ ($k=2$)

Receiving Pattern (Φ), $\theta=0^\circ$

f=600 MHz, TEM

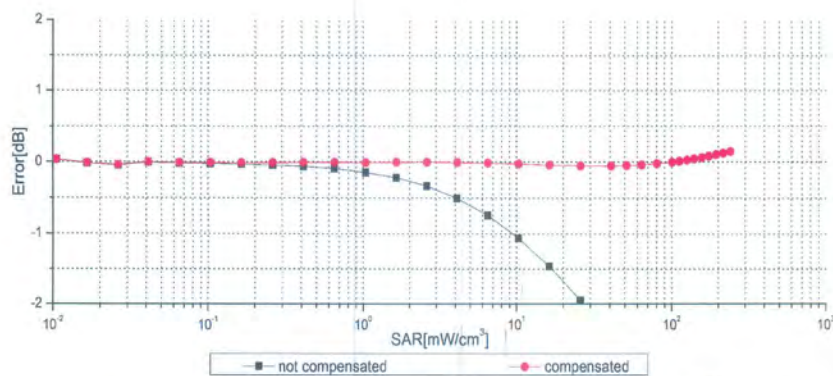
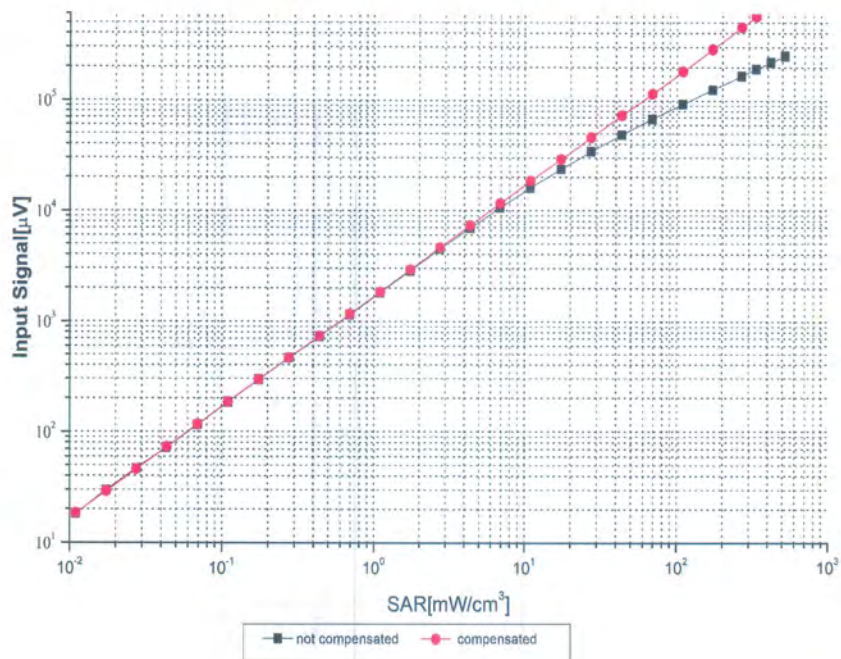


f=1800 MHz, R22



Uncertainty of Axial Isotropy Assessment: $\pm 1.2\%$ ($k=2$)

Dynamic Range f(SAR_{head}) (TEM cell, f = 900 MHz)

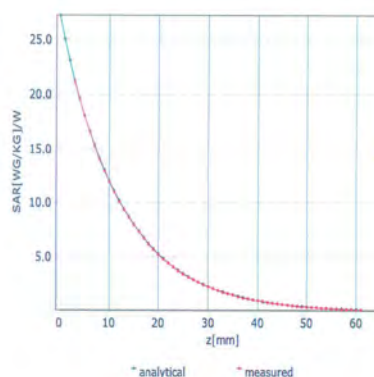
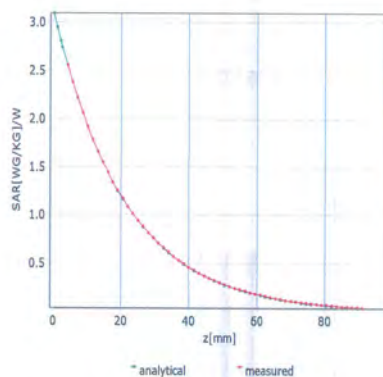


Uncertainty of Linearity Assessment: $\pm 0.9\%$ ($k=2$)

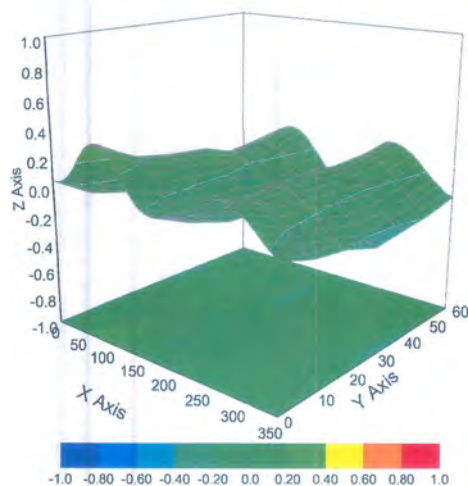
Conversion Factor Assessment

f=750 MHz,WGLS R9(H_convF)

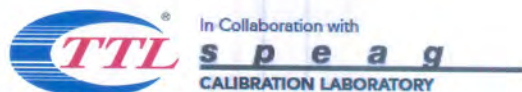
f=1750 MHz,WGLS R22(H_convF)



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: $\pm 3.2\%$ ($k=2$)



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DASY/EASY – Parameters of Probe: EX3DV4 – SN:7329

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	160.7
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disable
Probe Overall Length	337mm
Probe Body Diameter	10mm
Tip Length	9mm
Tip Diameter	2.5mm
Probe Tip to Sensor X Calibration Point	1mm
Probe Tip to Sensor Y Calibration Point	1mm
Probe Tip to Sensor Z Calibration Point	1mm
Recommended Measurement Distance from Surface	1.4mm



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Client **BACL**

Certificate No: **Z22-60480**

CALIBRATION CERTIFICATE

Object **D5GHzV2 - SN: 1246**

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

Calibration date: **November 1, 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 (Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	106276	10-May-22 (CTTL, No.J22X03103)	May-23
Power sensor NRP6A	101369	10-May-22 (CTTL, No.J22X03103)	May-23
Reference Probe EX3DV4	SN 7464	26-Jan-22(SPEAG,No.EX3-7464_Jan22)	Jan-23
DAE4	SN 1556	12-Jan-22(CTTL-SPEAG,No.Z22-60007)	Jan-23
Secondary Standards	ID #	Cal Date (Calibrated by, Certificate No.)	Scheduled Calibration
Signal Generator E4438C	MY49071430	13-Jan-22 (CTTL, No. J22X00409)	Jan-23
Network Analyzer E5071C	MY46110673	14-Jan-22 (CTTL, No.J22X00406)	Jan-23

	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 7, 2022

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Glossary:

TSL	tissue simulating liquid
ConvF	sensitivity in TSL / NORM _{x,y,z}
N/A	not applicable or not measured

Calibration is Performed According to the Following Standards:

- a) IEC/IEEE 62209-1528, "Measurement Procedure for The Assessment of Specific Absorption Rate of Human Exposure to Radio Frequency Fields from Hand-held and Body-mounted Wireless Communication Devices- Part 1528: Human Models, Instrumentation and Procedures (Frequency range of 4 MHz to 10 GHz)", October 2020
- b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Additional Documentation:

- c) 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	52.10.4
Extrapolation	Advanced Extrapolation	
Phantom	Triple Flat Phantom 5.1C	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy = 4 mm, dz = 1.4 mm	Graded Ratio = 1.4 (Z direction)
Frequency	5250 MHz $\pm$ 1 MHz 5600 MHz $\pm$ 1 MHz 5750 MHz $\pm$ 1 MHz	

Head TSL parameters at 5250MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.9	4.71 mho/m
Measured Head TSL parameters	(22.0 $\pm$ 0.2) °C	35.2 $\pm$ 6 %	4.68 mho/m $\pm$ 6 %
Head TSL temperature change during test	<1.0 °C	—	—

SAR result with Head TSL at 5250MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.78 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	77.5 W/kg $\pm$ 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.21 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	22.0 W/kg $\pm$ 24.2 % (k=2)

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Head TSL parameters at 5600MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.5	5.07 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	34.6 ± 6 %	5.05 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	—	—

SAR result with Head TSL at 5600MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.11 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	80.7 W/kg ± 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.30 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	22.8 W/kg ± 24.2 % (k=2)

Head TSL parameters at 5750MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.4	5.22 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	34.4 ± 6 %	5.21 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	—	—

SAR result with Head TSL at 5750MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.89 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	78.4 W/kg ± 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.22 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	22.0 W/kg ± 24.2 % (k=2)



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Appendix (Additional assessments outside the scope of CNAS L0570)

Antenna Parameters with Head TSL at 5250MHz

Impedance, transformed to feed point	49.1 Ω - 3.09j Ω
Return Loss	- 29.8dB

Antenna Parameters with Head TSL at 5600MHz

Impedance, transformed to feed point	52.0 Ω + 4.16j Ω
Return Loss	- 26.9dB

Antenna Parameters with Head TSL at 5750MHz

Impedance, transformed to feed point	53.5 Ω + 2.47j Ω
Return Loss	- 27.6dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.097 ns
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After long term use with 100W radiated power, only a slight warming of the dipole near the feed-point 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 feed-point may be damaged.

Additional EUT Data

Manufactured by	SPEAG
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DASY5 Validation Report for Head TSL

Date: 2022-11-01

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1246

Communication System: CW; Frequency: 5250 MHz, Frequency: 5600 MHz,
Frequency: 5750 MHz

Medium parameters used: $f = 5250 \text{ MHz}$; $\sigma = 4.677 \text{ S/m}$; $\epsilon_r = 35.15$; $\rho = 1000 \text{ kg/m}^3$

Medium parameters used: $f = 5600 \text{ MHz}$; $\sigma = 5.047 \text{ S/m}$; $\epsilon_r = 34.56$; $\rho = 1000 \text{ kg/m}^3$

Medium parameters used: $f = 5750 \text{ MHz}$; $\sigma = 5.211 \text{ S/m}$; $\epsilon_r = 34.35$; $\rho = 1000 \text{ kg/m}^3$

Phantom section: Right Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY5 Configuration:

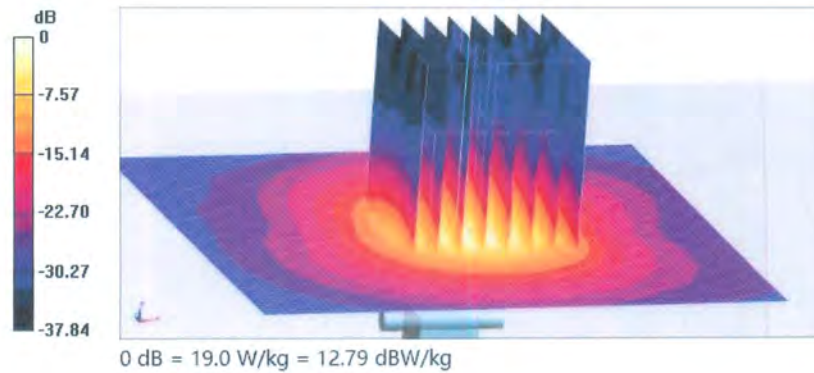
- Probe: EX3DV4 - SN7464; ConvF(5.43, 5.43, 5.43) @ 5250 MHz;
ConvF(4.91, 4.91, 4.91) @ 5600 MHz; ConvF(4.85, 4.85, 4.85) @ 5750
MHz; Calibrated: 2022-01-26
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1556; Calibrated: 2022-01-12
- Phantom: MFP_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx; Serial:
1062
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

Dipole Calibration /Pin=100mW, d=10mm, f=5250 MHz/Zoom Scan,
dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 65.38 V/m; Power Drift = -0.05 dB
Peak SAR (extrapolated) = 31.5 W/kg
SAR(1 g) = 7.78 W/kg; SAR(10 g) = 2.21 W/kg
Smallest distance from peaks to all points 3 dB below = 6.9 mm
Ratio of SAR at M2 to SAR at M1 = 64.9%
Maximum value of SAR (measured) = 17.9 W/kg

Dipole Calibration /Pin=100mW, d=10mm, f=5600 MHz/Zoom Scan,
dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 65.26 V/m; Power Drift = -0.04 dB
Peak SAR (extrapolated) = 35.8 W/kg
SAR(1 g) = 8.11 W/kg; SAR(10 g) = 2.3 W/kg
Smallest distance from peaks to all points 3 dB below = 7.2 mm
Ratio of SAR at M2 to SAR at M1 = 62.3%
Maximum value of SAR (measured) = 19.2 W/kg

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Dipole Calibration /Pin=100mW, d=10mm, f=5750 MHz/Zoom Scan,
dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.56 V/m; Power Drift = -0.07 dB
Peak SAR (extrapolated) = 36.7 W/kg
SAR(1 g) = 7.89 W/kg; SAR(10 g) = 2.22 W/kg
Smallest distance from peaks to all points 3 dB below = 7.2 mm
Ratio of SAR at M2 to SAR at M1 = 60.9%
Maximum value of SAR (measured) = 19.0 W/kg





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Impedance Measurement Plot for Head TSL

