


FCC SAR Test Report

Report No. : SA170621W001
Applicant : Sonim Technologies, Inc.
Address : 1825 S.Grant Street, Suite 200, San Mateo, CA 94402
Product : XPi
FCC ID : WYPEU0312
Brand : Sonim
Model No. : XPi812
Standards : FCC 47 CFR Part 2 (2.1093) / IEEE C95.1:1992 / IEEE 1528:2013
KDB 865664 D01 v01r04 / KDB 865664 D02 v01r02
KDB 447498 D01 v06 / KDB 941225 D05 v02r05
Sample Received Date : Sep. 12, 2017
Date of Testing : Sep. 13, 2017 ~ Sep. 15, 2017

CERTIFICATION: The above equipment have been tested by **BV 7LAYERS COMMUNICATIONS TECHNOLOGY (SHENZHEN) CO. LTD.**, and found compliance with the requirement of the above standards. The test record, data evaluation & Equipment Under Test (EUT) configurations represented herein are true and accurate accounts of the measurements of the sample's SAR characteristics under the conditions specified in this report. It should not be reproduced except in full, without the written approval of our laboratory. The client should not use it to claim product certification, approval, or endorsement by A2LA or any government agencies.

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Table of Contents

Release Control Record	3
1. Summary of Maximum SAR Value	4
2. Description of Equipment Under Test	5
3. SAR Measurement System	6
3.1 Definition of Specific Absorption Rate (SAR)	6
3.2 SPEAG DASY System	6
3.2.1 Robot.....	7
3.2.2 Probes.....	8
3.2.3 Data Acquisition Electronics (DAE)	8
3.2.4 Phantoms	9
3.2.5 Device Holder.....	10
3.2.6 System Validation Dipoles.....	10
3.2.7 Tissue Simulating Liquids.....	11
3.3 SAR System Verification	14
3.4 SAR Measurement Procedure	15
3.4.1 Area & Zoom Scan Procedure	15
3.4.2 Volume Scan Procedure.....	15
3.4.3 Power Drift Monitoring.....	16
3.4.4 Spatial Peak SAR Evaluation	16
3.4.5 SAR Averaged Methods	16
4. SAR Measurement Evaluation	17
4.1 EUT Configuration and Setting.....	17
4.2 EUT Testing Position	18
4.2.1 Body Exposure Conditions	18
4.2.2 SAR Test Exclusion Evaluations	19
4.2.3 Simultaneous Transmission Possibilities.....	19
4.3 Tissue Verification	20
4.4 System Validation.....	20
4.5 System Verification.....	20
4.6 Maximum Output Power.....	21
4.6.1 Maximum Conducted Power	21
4.6.2 Measured Conducted Power Result.....	21
4.7 SAR Testing Results	26
4.7.1 SAR Test Reduction Considerations	26
4.7.2 SAR Results for Body Exposure Condition (Separation Distance is 1.0 cm Gap).....	27
4.7.3 SAR Measurement Variability.....	29
4.7.4 Simultaneous Multi-band Transmission Evaluation	30
5. Calibration of Test Equipment.....	32
6. Measurement Uncertainty.....	33
7. Information on the Testing Laboratories.....	34
Appendix A. SAR Plots of System Verification	
Appendix B. SAR Plots of SAR Measurement	
Appendix C. Calibration Certificate for Probe and Dipole	
Appendix D. Photographs of EUT and Setup	

Release Control Record

Report No.	Reason for Change	Date Issued
SA170621W001	Initial release	Oct. 16, 2017

FCC SAR Test Report

1. Summary of Maximum SAR Value

Equipment Class	Mode	Highest Reported Body SAR _{1g} (1.0 cm Gap) (W/kg)
PCB	LTE 2	0.70
	LTE 4	1.10
	LTE 12	1.04
DTS	BT_LE	N/A
Highest Simultaneous Transmission SAR		Body (W/kg)
PCB + DTS		1.14

Note:

1. The SAR limit (**Head & Body: SAR_{1g} 1.6 W/kg**) for general population / uncontrolled exposure is specified in FCC 47 CFR part 2 (2.1093) and ANSI/IEEE C95.1-1992.

FCC SAR Test Report

2. Description of Equipment Under Test

EUT Type	XPi
FCC ID	WYPEU0312
Brand Name	Sonim
Model Name	XPi812
HW Version	1.0
SW Version	1.20.2.1
Tx Frequency Bands (Unit: MHz)	LTE Band 2 : 1850.7 ~ 1909.3 (1.4M), 1851.5 ~ 1908.5 (3M), 1852.5 ~ 1907.5 (5M), 1855 ~ 1905 (10M), 1857.5 ~ 1902.5 (15M), 1860 ~ 1900 (20M) LTE Band 4 : 1710.7 ~ 1754.3 (1.4M), 1711.5 ~ 1753.5 (3M), 1712.5 ~ 1752.5 (5M), 1715 ~ 1750 (10M), 1717.5 ~ 1747.5 (15M), 1720 ~ 1745 (20M) LTE Band 12 : 699.7 ~ 715.3 (1.4M), 700.5 ~ 714.5 (3M), 701.5 ~ 713.5 (5M), 704 ~ 711 (10M) BT_LE : 2402 ~ 2480
Uplink Modulations	LTE : QPSK, 16QAM BT_LE : GFSK
Maximum Tune-up Conducted Power (Unit: dBm)	LTE Band 2 : 21.0 LTE Band 4 : 21.0 LTE Band 12 : 23.5 BT_LE : 2.5
Antenna Type	BT_LE: PCB Antenna WWAN: Fixed Internal Antenna
EUT Stage	Production Unit

Note:

- The above EUT information is declared by manufacturer and for more detailed features description please refers to the manufacturer's specifications or User's Manual.

List of Accessory:

Battery	Brand Name	VEKEN
	Model Name	SNL11-X350
	Power Rating	3.7Vdc, 1400mAh
	Type	Li-ion

3. SAR Measurement System

3.1 Definition of Specific Absorption Rate (SAR)

SAR is related to the rate at which energy is absorbed per unit mass in an object exposed to a radio field. The SAR distribution in a biological body is complicated and is usually carried out by experimental techniques or numerical modeling. The standard recommends limits for two tiers of groups, occupational/controlled and general population/uncontrolled, based on a person's awareness and ability to exercise control over his or her exposure. In general, occupational/controlled exposure limits are higher than the limits for general population/uncontrolled.

The SAR definition is the time derivative (rate) of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dv) of a given density (ρ). The equation description is as below:

$$SAR = \frac{d}{dt} \left(\frac{dW}{dm} \right) = \frac{d}{dt} \left(\frac{dW}{\rho dv} \right)$$

SAR is expressed in units of Watts per kilogram (W/kg)

SAR measurement can be related to the electrical field in the tissue by

$$SAR = \frac{\sigma |E|^2}{\rho}$$

Where: σ is the conductivity of the tissue, ρ is the mass density of the tissue and E is the RMS electrical field strength.

3.2 SPEAG DASY System

DASY system consists of high precision robot, probe alignment sensor, phantom, robot controller, controlled measurement server and near-field probe. The robot includes six axes that can move to the precision position of the DASY5 software defined. The DASY software can define the area that is detected by the probe. The robot is connected to controlled box. Controlled measurement server is connected to the controlled robot box. The DAE includes amplifier, signal multiplexing, AD converter, offset measurement and surface detection. It is connected to the Electro-optical coupler (ECO). The ECO performs the conversion from the optical into digital electric signal of the DAE and transfers data to the PC.

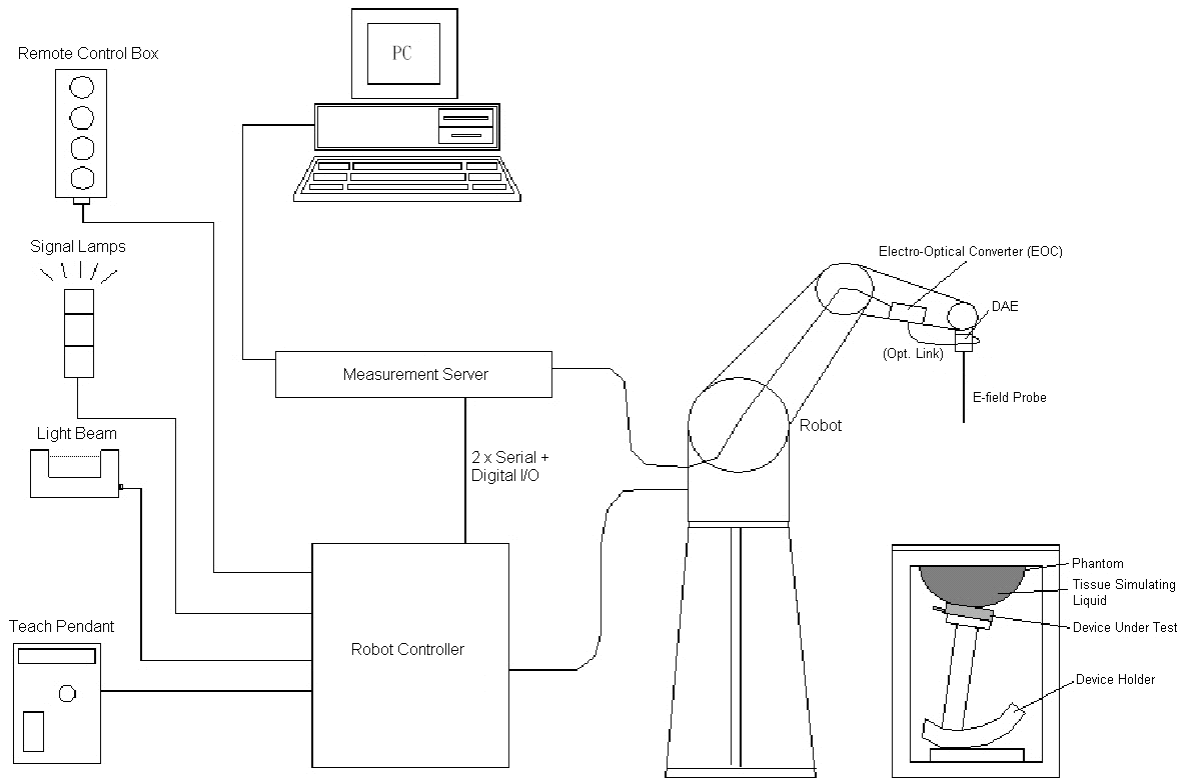


Fig-3.1 DASY System Setup

3.2.1 Robot

The DASY system uses the high precision robots from Stäubli SA (France). For the 6-axis controller system, the robot controller version (DASY5: CS8c) from Stäubli is used. The Stäubli robot series have many features that are important for our application:

- High precision (repeatability ± 0.035 mm)
- High reliability (industrial design)
- Jerk-free straight movements
- Low ELF interference (the closed metallic construction shields against motor control fields)





Fig-3.2 DASY5

FCC SAR Test Report

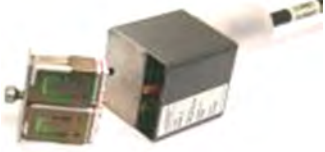
3.2.2 Probes

The SAR measurement is conducted with the dosimetric probe. The probe is specially designed and calibrated for use in liquid with high permittivity. The dosimetric probe has special calibration in liquid at different frequency.

Model	EX3DV4	
Construction	Symmetrical design with triangular core. Built-in shielding against static charges. PEEK enclosure material (resistant to organic solvents, e.g., DGBE).	
Frequency	10 MHz to 6 GHz Linearity: ± 0.2 dB	
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 mW/g Linearity: ± 0.2 dB (noise: typically < 1 μ W/g)	
Dimensions	Overall length: 337 mm (Tip: 20 mm) Tip diameter: 2.5 mm (Body: 12 mm) Typical distance from probe tip to dipole centers: 1 mm	


Model	ES3DV3	
Construction	Symmetrical design with triangular core. Interleaved sensors. Built-in shielding against static charges. PEEK enclosure material (resistant to organic solvents, e.g., DGBE).	
Frequency	10 MHz to 4 GHz Linearity: ± 0.2 dB	
Directivity	± 0.2 dB in HSL (rotation around probe axis) ± 0.3 dB in tissue material (rotation normal to probe axis)	
Dynamic Range	5 μ W/g to 100 mW/g Linearity: ± 0.2 dB	
Dimensions	Overall length: 337 mm (Tip: 20 mm) Tip diameter: 3.9 mm (Body: 12 mm) Distance from probe tip to dipole centers: 2.0 mm	


3.2.3 Data Acquisition Electronics (DAE)

Model	DAE3, DAE4	
Construction	Signal amplifier, multiplexer, A/D converter and control logic. Serial optical link for communication with DASY embedded system (fully remote controlled). Two step probe touch detector for mechanical surface detection and emergency robot stop.	
Measurement Range	-100 to +300 mV (16 bit resolution and two range settings: 4mV, 400mV)	
Input Offset Voltage	$< 5\mu$ V (with auto zero)	
Input Bias Current	< 50 fA	
Dimensions	60 x 60 x 68 mm	

FCC SAR Test Report


3.2.4 Phantoms

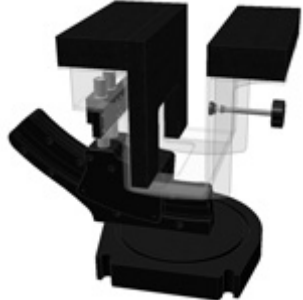
Model	Twin SAM	
Construction	The shell corresponds to the specifications of the Specific Anthropomorphic Mannequin (SAM) phantom defined in IEEE 1528 and IEC 62209-1. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. A cover prevents evaporation of the liquid. Reference markings on the phantom allow the complete setup of all predefined phantom positions and measurement grids by teaching three points with the robot.	
Material	Vinylester, glass fiber reinforced (VE-GF)	
Shell Thickness	2 ± 0.2 mm (6 ± 0.2 mm at ear point)	
Dimensions	Length: 1000 mm Width: 500 mm Height: adjustable feet	
Filling Volume	approx. 25 liters	

Model	ELI	
Construction	Phantom for compliance testing of handheld and body-mounted wireless devices in the frequency range of 30 MHz to 6 GHz. ELI is fully compatible with the IEC 62209-2 standard and all known tissue simulating liquids. ELI has been optimized regarding its performance and can be integrated into our standard phantom tables. A cover prevents evaporation of the liquid. Reference markings on the phantom allow installation of the complete setup, including all predefined phantom positions and measurement grids, by teaching three points. The phantom is compatible with all SPEAG dosimetric probes and dipoles.	
Material	Vinylester, glass fiber reinforced (VE-GF)	
Shell Thickness	2.0 ± 0.2 mm (bottom plate)	
Dimensions	Major axis: 600 mm Minor axis: 400 mm	
Filling Volume	approx. 30 liters	


FCC SAR Test Report

3.2.5 Device Holder

Model	Mounting Device	
Construction	In combination with the Twin SAM Phantom or ELI4, the Mounting Device enables the rotation of the mounted transmitter device in spherical coordinates. Rotation point is the ear opening point. Transmitter devices can be easily and accurately positioned according to IEC, IEEE, FCC or other specifications. The device holder can be locked for positioning at different phantom sections (left head, right head, flat).	
Material	POM	

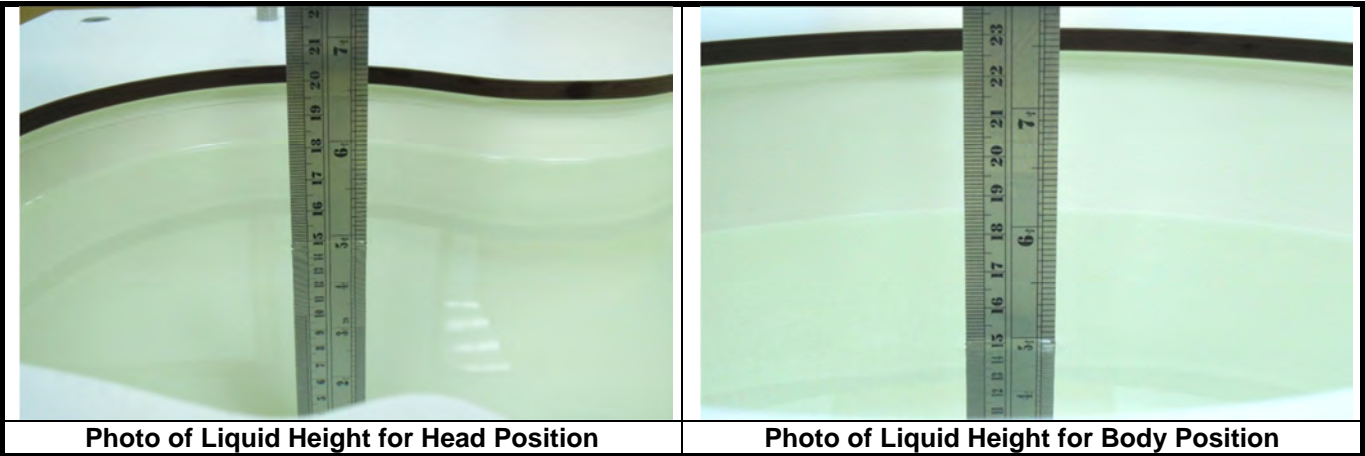
Model	Laptop Extensions Kit	
Construction	Simple but effective and easy-to-use extension for Mounting Device that facilitates the testing of larger devices according to IEC 62209-2 (e.g., laptops, cameras, etc.). It is lightweight and fits easily on the upper part of the Mounting Device in place of the phone positioner.	
Material	POM, Acrylic glass, Foam	

3.2.6 System Validation Dipoles

Model	D-Serial	
Construction	Symmetrical dipole with 1/4 balun. Enables measurement of feed point impedance with NWA. Matched for use near flat phantoms filled with tissue simulating solutions.	
Frequency	750 MHz to 5800 MHz	
Return Loss	> 20 dB	
Power Capability	> 100 W (f < 1GHz), > 40 W (f > 1GHz)	

3.2.7 Tissue Simulating Liquids

For SAR measurement of the field distribution inside the phantom, the phantom must be filled with homogeneous tissue simulating liquid to a depth of at least 15 cm. For head SAR testing, the liquid height from the ear reference point (ERP) of the phantom to the liquid top surface is larger than 15 cm. For body SAR testing, the liquid height from the center of the flat phantom to the liquid top surface is larger than 15 cm. The nominal dielectric values of the tissue simulating liquids in the phantom and the tolerance of 5% are listed in Table-3.1.



The dielectric properties of the head tissue simulating liquids are defined in IEEE 1528, and KDB 865664 D01 Appendix A. For the body tissue simulating liquids, the dielectric properties are defined in KDB 865664 D01 Appendix A. The dielectric properties of the tissue simulating liquids were verified prior to the SAR evaluation using a dielectric assessment kit and a network analyzer.

FCC SAR Test Report

Table-3.1 Targets of Tissue Simulating Liquid

Frequency (MHz)	Target Permittivity	Range of $\pm 5\%$	Target Conductivity	Range of $\pm 5\%$
For Head				
750	41.9	39.8 ~ 44.0	0.89	0.85 ~ 0.93
835	41.5	39.4 ~ 43.6	0.90	0.86 ~ 0.95
900	41.5	39.4 ~ 43.6	0.97	0.92 ~ 1.02
1450	40.5	38.5 ~ 42.5	1.20	1.14 ~ 1.26
1640	40.3	38.3 ~ 42.3	1.29	1.23 ~ 1.35
1750	40.1	38.1 ~ 42.1	1.37	1.30 ~ 1.44
1800	40.0	38.0 ~ 42.0	1.40	1.33 ~ 1.47
1900	40.0	38.0 ~ 42.0	1.40	1.33 ~ 1.47
2000	40.0	38.0 ~ 42.0	1.40	1.33 ~ 1.47
2300	39.5	37.5 ~ 41.5	1.67	1.59 ~ 1.75
2450	39.2	37.2 ~ 41.2	1.80	1.71 ~ 1.89
2600	39.0	37.1 ~ 41.0	1.96	1.86 ~ 2.06
3500	37.9	36.0 ~ 39.8	2.91	2.76 ~ 3.06
5200	36.0	34.2 ~ 37.8	4.66	4.43 ~ 4.89
5300	35.9	34.1 ~ 37.7	4.76	4.52 ~ 5.00
5500	35.6	33.8 ~ 37.4	4.96	4.71 ~ 5.21
5600	35.5	33.7 ~ 37.3	5.07	4.82 ~ 5.32
5800	35.3	33.5 ~ 37.1	5.27	5.01 ~ 5.53
For Body				
750	55.5	52.7 ~ 58.3	0.96	0.91 ~ 1.01
835	55.2	52.4 ~ 58.0	0.97	0.92 ~ 1.02
900	55.0	52.3 ~ 57.8	1.05	1.00 ~ 1.10
1450	54.0	51.3 ~ 56.7	1.30	1.24 ~ 1.37
1640	53.8	51.1 ~ 56.5	1.40	1.33 ~ 1.47
1750	53.4	50.7 ~ 56.1	1.49	1.42 ~ 1.56
1800	53.3	50.6 ~ 56.0	1.52	1.44 ~ 1.60
1900	53.3	50.6 ~ 56.0	1.52	1.44 ~ 1.60
2000	53.3	50.6 ~ 56.0	1.52	1.44 ~ 1.60
2300	52.9	50.3 ~ 55.5	1.81	1.72 ~ 1.90
2450	52.7	50.1 ~ 55.3	1.95	1.85 ~ 2.05
2600	52.5	49.9 ~ 55.1	2.16	2.05 ~ 2.27
3500	51.3	48.7 ~ 53.9	3.31	3.14 ~ 3.48
5200	49.0	46.6 ~ 51.5	5.30	5.04 ~ 5.57
5300	48.9	46.5 ~ 51.3	5.42	5.15 ~ 5.69
5500	48.6	46.2 ~ 51.0	5.65	5.37 ~ 5.93
5600	48.5	46.1 ~ 50.9	5.77	5.48 ~ 6.06
5800	48.2	45.8 ~ 50.6	6.00	5.70 ~ 6.30

FCC SAR Test Report

The following table gives the recipes for tissue simulating liquids.

Table-3.2 Recipes of Tissue Simulating Liquid

Tissue Type	Bactericide	DGBE	HEC	NaCl	Sucrose	Triton X-100	Water	Diethylene Glycol Mono-hexylether
H750	0.2	-	0.2	1.5	56.0	-	42.1	-
H835	0.2	-	0.2	1.5	57.0	-	41.1	-
H900	0.2	-	0.2	1.4	58.0	-	40.2	-
H1450	-	43.3	-	0.6	-	-	56.1	-
H1640	-	45.8	-	0.5	-	-	53.7	-
H1750	-	47.0	-	0.4	-	-	52.6	-
H1800	-	44.5	-	0.3	-	-	55.2	-
H1900	-	44.5	-	0.2	-	-	55.3	-
H2000	-	44.5	-	0.1	-	-	55.4	-
H2300	-	44.9	-	0.1	-	-	55.0	-
H2450	-	45.0	-	0.1	-	-	54.9	-
H2600	-	45.1	-	0.1	-	-	54.8	-
H3500	-	8.0	-	0.2	-	20.0	71.8	-
H5G	-	-	-	-	-	17.2	65.5	17.3
B750	0.2	-	0.2	0.8	48.8	-	50.0	-
B835	0.2	-	0.2	0.9	48.5	-	50.2	-
B900	0.2	-	0.2	0.9	48.2	-	50.5	-
B1450	-	34.0	-	0.3	-	-	65.7	-
B1640	-	32.5	-	0.3	-	-	67.2	-
B1750	-	31.0	-	0.2	-	-	68.8	-
B1800	-	29.5	-	0.4	-	-	70.1	-
B1900	-	29.5	-	0.3	-	-	70.2	-
B2000	-	30.0	-	0.2	-	-	69.8	-
B2300	-	31.0	-	0.1	-	-	68.9	-
B2450	-	31.4	-	0.1	-	-	68.5	-
B2600	-	31.8	-	0.1	-	-	68.1	-
B3500	-	28.8	-	0.1	-	-	71.1	-
B5G	-	-	-	-	-	10.7	78.6	10.7

3.3 SAR System Verification

The system check verifies that the system operates within its specifications. It is performed daily or before every SAR measurement. The system check uses normal SAR measurements in the flat section of the phantom with a matched dipole at a specified distance. The system verification setup is shown as below.

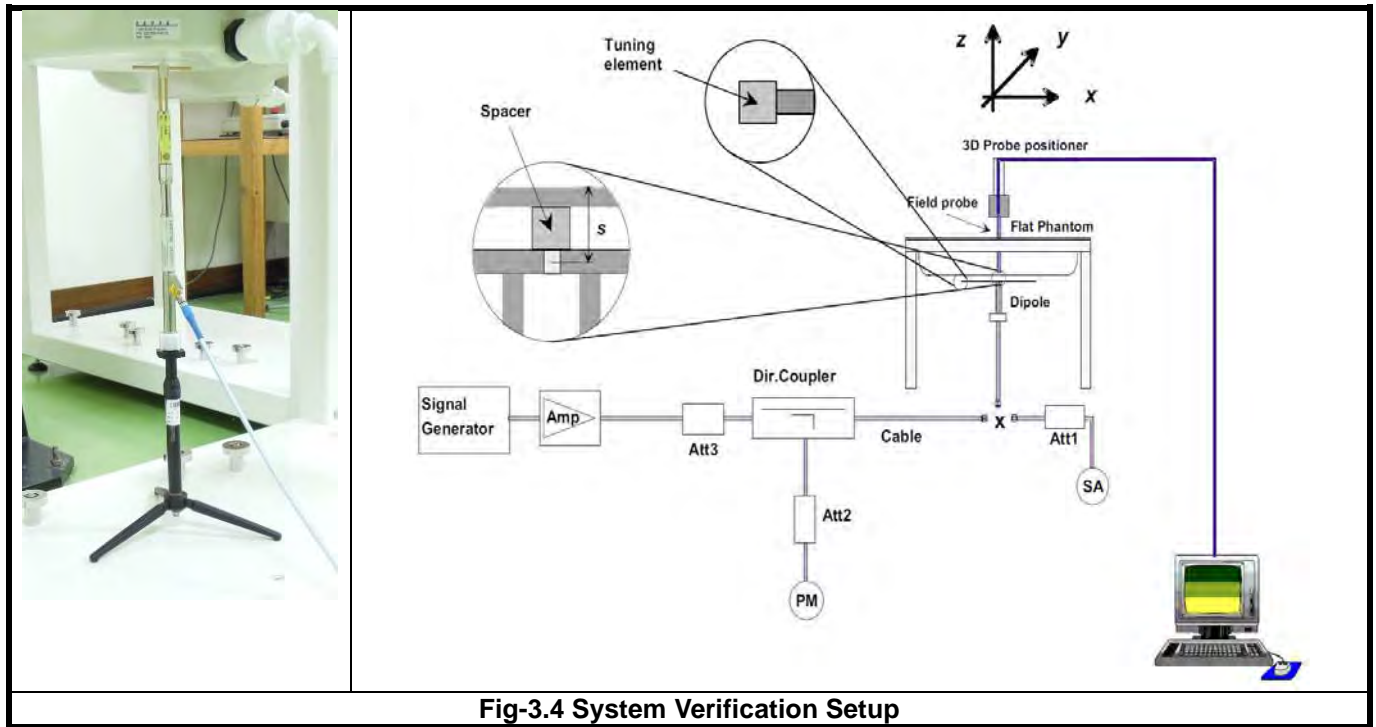


Fig-3.4 System Verification Setup

The validation dipole is placed beneath the flat phantom with the specific spacer in place. The distance spacer is touch the phantom surface with a light pressure at the reference marking and be oriented parallel to the long side of the phantom. The spectrum analyzer measures the forward power at the location of the system check dipole connector. The signal generator is adjusted for the desired forward power (250 mW is used for 700 MHz to 3 GHz, 100 mW is used for 3.5 GHz to 6 GHz) at the dipole connector and the power meter is read at that level. After connecting the cable to the dipole, the signal generator is readjusted for the same reading at power meter.

After system check testing, the SAR result will be normalized to 1W forward input power and compared with the reference SAR value derived from validation dipole certificate report. The deviation of system check should be within 10 %.

3.4 SAR Measurement Procedure

According to the SAR test standard, the recommended procedure for assessing the peak spatial-average SAR value consists of the following steps:

- Power reference measurement
- Area scan
- Zoom scan
- Power drift measurement

The SAR measurement procedures for each of test conditions are as follows:

- Make EUT to transmit maximum output power
- Measure conducted output power through RF cable
- Place the EUT in the specific position of phantom
- Perform SAR testing steps on the DASY system
- Record the SAR value

3.4.1 Area & Zoom Scan Procedure

First Area Scan is used to locate the approximate location(s) of the local peak SAR value(s). The measurement grid within an Area Scan is defined by the grid extent, grid step size and grid offset. Next, in order to determine the EM field distribution in a three-dimensional spatial extension, Zoom Scan is required. The Zoom Scan is performed around the highest E-field value to determine the averaged SAR-distribution over 10 g. According to KDB 865664 D01, the resolution for Area and Zoom scan is specified in the table below.

Items	<= 2 GHz	2-3 GHz	3-4 GHz	4-5 GHz	5-6 GHz
Area Scan ($\Delta x, \Delta y$)	<= 15 mm	<= 12 mm	<= 12 mm	<= 10 mm	<= 10 mm
Zoom Scan ($\Delta x, \Delta y$)	<= 8 mm	<= 5 mm	<= 5 mm	<= 4 mm	<= 4 mm
Zoom Scan (Δz)	<= 5 mm	<= 5 mm	<= 4 mm	<= 3 mm	<= 2 mm
Zoom Scan Volume	>= 30 mm	>= 30 mm	>= 28 mm	>= 25 mm	>= 22 mm

Note:

When zoom scan is required and report SAR is <= 1.4 W/kg, the zoom scan resolution of $\Delta x / \Delta y$ (2-3GHz: <= 8 mm, 3-4GHz: <= 7 mm, 4-6GHz: <= 5 mm) may be applied.

3.4.2 Volume Scan Procedure

The volume scan is used for assess overlapping SAR distributions for antennas transmitting in different frequency bands. It is equivalent to an oversized zoom scan used in standalone measurements. The measurement volume will be used to enclose all the simultaneous transmitting antennas. For antennas transmitting simultaneously in different frequency bands, the volume scan is measured separately in each frequency band. In order to sum correctly to compute the 1g aggregate SAR, the EUT remain in the same test position for all measurements and all volume scan use the same spatial resolution and grid spacing. When all volume scan were completed, the software, SEMCAD postprocessor can combine and subsequently superpose these measurement data to calculating the multiband SAR.

3.4.3 Power Drift Monitoring

All SAR testing is under the EUT install full charged battery and transmit maximum output power. In DASY measurement software, the power reference measurement and power drift measurement procedures are used for monitoring the power drift of EUT during SAR test. Both these procedures measure the field at a specified reference position before and after the SAR testing. The software will calculate the field difference in dB. If the power drift more than 5%, the SAR will be retested.

3.4.4 Spatial Peak SAR Evaluation

The procedure for spatial peak SAR evaluation has been implemented according to the test standard. It can be conducted for 1g and 10g, as well as for user-specific masses. The DASY software includes all numerical procedures necessary to evaluate the spatial peak SAR value.

The base for the evaluation is a "cube" measurement. The measured volume must include the 1g and 10g 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.

The entire evaluation of the spatial peak values is performed within the post-processing engine (SEMCAD). The system always gives the maximum values for the 1g and 10g cubes. The algorithm to find the cube with highest averaged SAR is divided into the following stages:

- (a) Extraction of the measured data (grid and values) from the Zoom Scan
- (b) Calculation of the SAR value at every measurement point based on all stored data (A/D values and measurement parameters)
- (c) Generation of a high-resolution mesh within the measured volume
- (d) Interpolation of all measured values from the measurement grid to the high-resolution grid
- (e) Extrapolation of the entire 3-D field distribution to the phantom surface over the distance from sensor to surface
- (f) Calculation of the averaged SAR within masses of 1g and 10g

3.4.5 SAR Averaged Methods

In DASY, the interpolation and extrapolation are both based on the modified Quadratic Shepard's method. 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.

Extrapolation routines are used to obtain SAR values between the lowest measurement points and the inner phantom surface. The extrapolation distance is determined by the surface detection distance and the probe sensor offset. 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.

4. SAR Measurement Evaluation

4.1 EUT Configuration and Setting

<Connections between EUT and System Simulator>

For WWAN SAR testing, the EUT was linked and controlled by base station emulator (Anritsu MT8820C is used for LTE). Communication between the EUT and the emulator was established by air link. The distance between the EUT and the communicating antenna of the emulator is larger than 50 cm and the output power radiated from the emulator antenna is at least 30 dB smaller than the output power of EUT. The EUT was set from the emulator to radiate maximum output power during SAR testing.

<Considerations Related to LTE for Setup and Testing>

This device contains LTE transmitter which follows 3GPP standards, is category 3, supports both QPSK and 16QAM modulations, and supported LTE band and channel bandwidth is listed in below. The output power was tested per 3GPP TS 36.521-1 maximum transmit procedures for both QPSK and 16QAM modulation. The results please refer to section 4.6 of this report.

EUT Supported LTE Band and Channel Bandwidth						
LTE Band	BW 1.4 MHz	BW 3 MHz	BW 5 MHz	BW 10 MHz	BW 15 MHz	BW 20 MHz
2	V	V	V	V	V	V
4	V	V	V	V	V	V
12	V	V	V	V		

The LTE maximum power reduction (MPR) in accordance with 3GPP TS 36.101 is active all times during LTE operation. The allowed MPR for the maximum output power is specified in below.

Modulation	Channel Bandwidth / RB Configurations						LTE MPR Setting (dB)
	BW 1.4 MHz	BW 3 MHz	BW 5 MHz	BW 10 MHz	BW 15 MHz	BW 20 MHz	
QPSK	> 5	> 4	> 8	> 12	> 16	> 18	1
16QAM	<= 5	<= 4	<= 8	<= 12	<= 16	<= 18	1
16QAM	> 5	> 4	> 8	> 12	> 16	> 18	2

Note: MPR is according to the standard and implemented in the circuit (mandatory).

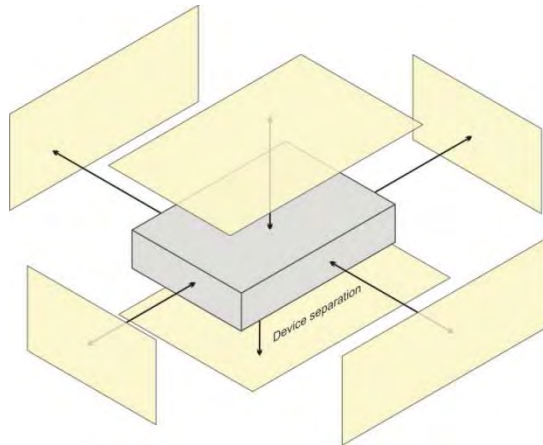
In addition, the device is compliant with additional maximum power reduction (A-MPR) requirements defined in 3GPP TS 36.101 section 6.2.4 that was disabled for all FCC compliance testing.

During LTE SAR testing, the related parameters of operating band, channel bandwidth, uplink channel number, modulation type, and RB was set in base station simulator. When the EUT has registered and communicated to base station simulator, the simulator set to make EUT transmitting the maximum radiated power.

4.2 EUT Testing Position

4.2.1 Body Exposure Conditions

A test separation distance of 10 mm is required between the phantom and all surfaces and edges with a transmitting antenna located within 25 mm from that surface or edge..



Based on the antenna location shown on appendix D of this report, the SAR testing required is listed as below.

Antenna	Front Face	Rear Face	Left Side	Right Side	Top Side	Bottom Side
WWAN Ant-0	V	V	V	V	V	V

FCC SAR Test Report

4.2.2 SAR Test Exclusion Evaluations

According to KDB 447498 D01, the SAR test exclusion condition is based on source-based time-averaged maximum conducted output power, adjusted for tune-up tolerance, and the minimum test separation distance required for the exposure conditions. The SAR exclusion threshold is determined by the following formula.

$$\frac{\text{Max. Tune up Power}_{(\text{mW})}}{\text{Min. Test Separation Distance}_{(\text{mm})}} \times \sqrt{f_{(\text{GHz})}} \leq 3.0 \text{ for SAR-1g, } \leq 7.5 \text{ for SAR-10g}$$

When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.

Mode	Max. Tune-up Power (dBm)	Max. Tune-up Power (mW)	Body		
			Ant. to Surface (mm)	Calculated Result	Require SAR Testing?
BT_LE	2.5	1.78	5	10	No

Note:

- When separation distance <= 50 mm and the calculated result shown in above table is <= 3.0 for SAR-1g exposure condition, or <= 7.5 for SAR-10g exposure condition, the SAR testing exclusion is applied.

4.2.3 Simultaneous Transmission Possibilities

The simultaneous transmission possibilities for this device are listed as below.

Simultaneous TX Combination	Capable Transmit Configurations	Body Exposure Condition
1	LTE 2 (Data) + BT_LE (Data)	Yes
2	LTE 4 (Data) + BT_LE (Data)	Yes
3	LTE 12 (Data) + BT_LE (Data)	Yes

Note :

- This device does not support voice transmission capability.

FCC SAR Test Report

4.3 Tissue Verification

The measuring results for tissue simulating liquid are shown as below.

Test Date	Tissue Type	Frequency (MHz)	Liquid Temp. (°C)	Measured Conductivity (σ)	Measured Permittivity (ϵ_r)	Target Conductivity (σ)	Target Permittivity (ϵ_r)	Conductivity Deviation (%)	Permittivity Deviation (%)
Sep. 13, 2017	B750	750	22.2	0.963	53.779	0.96	55.50	0.31	-3.10
Sep. 15, 2017	B1750	1750	22.3	1.437	53.650	1.49	53.40	-3.56	0.47
Sep. 15, 2017	B1900	1900	22.3	1.585	53.657	1.52	53.30	4.28	0.67

Note:

The dielectric properties of the tissue simulating liquid must be measured within 24 hours before the SAR testing and within $\pm 5\%$ of the target values. Liquid temperature during the SAR testing must be within $\pm 2^\circ\text{C}$.

4.4 System Validation

The SAR measurement system was validated according to procedures in KDB 865664 D01. The validation status in tabulated summary is as below.

Test Date	Probe S/N	Calibration Point		Measured Conductivity (σ)	Measured Permittivity (ϵ_r)	Validation for CW			Validation for Modulation		
						Sensitivity Range	Probe Linearity	Probe Isotropy	Modulation Type	Duty Factor	PAR
Sep. 13, 2017	3661	Body	750	0.963	53.779	Pass	Pass	Pass	N/A	N/A	N/A
Sep. 15, 2017	3661	Body	1750	1.437	53.650	Pass	Pass	Pass	N/A	N/A	N/A
Sep. 15, 2017	3661	Body	1900	1.585	53.657	Pass	Pass	Pass	N/A	N/A	N/A

4.5 System Verification

The measuring result for system verification is tabulated as below.

Test Date	Mode	Frequency (MHz)	1W Target SAR-1g (W/kg)	Measured SAR-1g (W/kg)	Normalized to 1W SAR-1g (W/kg)	Deviation (%)	Dipole S/N	Probe S/N	DAE S/N
Sep. 13, 2017	Body	750	8.67	2.12	8.48	-2.19	1078	3661	914
Sep. 15, 2017	Body	1750	36.90	8.83	35.32	-4.28	1023	3661	914
Sep. 15, 2017	Body	1900	40.60	9.80	39.20	-3.45	5d018	3661	914

Note:

Comparing to the reference SAR value provided by SPEAG, the validation data should be within its specification of 10 %. The result indicates the system check can meet the variation criterion and the plots can be referred to Appendix A of this report.

FCC SAR Test Report

4.6 Maximum Output Power

4.6.1 Maximum Conducted Power

The maximum conducted average power (Unit: dBm) including tune-up tolerance is shown as below.

Mode	LTE 2	LTE 4	LTE 12
QPSK / 16QAM	21.0	21.0	23.5

Mode	2.4G Bluetooth
LE	2.5

4.6.2 Measured Conducted Power Result

The measuring conducted average power (Unit: dBm) is shown as below.

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 18607	Mid CH 18900	High CH 19193		Low CH 18607	Mid CH 18900	High CH 19193	
			1850.7 MHz	1880.0 MHz	1909.3 MHz		1850.7 MHz	1880.0 MHz	1909.3 MHz	
2 / 1.4M	1	0	20.45	20.51	20.49	0	18.34	19.08	18.38	1
	1	2	20.05	19.97	20.09	0	18.31	19.01	18.35	1
	1	5	19.56	19.91	19.60	0	18.27	18.98	18.31	1
	3	0	20.44	20.50	20.48	0	18.32	19.06	18.36	1
	3	1	20.04	19.96	20.08	0	18.29	18.99	18.33	1
	3	3	19.55	19.90	19.59	0	18.25	18.96	18.29	1
	6	0	18.88	19.08	18.92	1	17.76	18.13	17.80	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 18615	Mid CH 18900	High CH 19185		Low CH 18615	Mid CH 18900	High CH 19185	
			1851.5 MHz	1880.0 MHz	1908.5 MHz		1851.5 MHz	1880.0 MHz	1908.5 MHz	
2 / 3M	1	0	20.48	20.54	20.52	0	18.37	19.11	18.41	1
	1	7	20.08	20.00	20.12	0	18.34	19.04	18.38	1
	1	14	19.59	19.94	19.63	0	18.30	19.01	18.34	1
	8	0	18.96	19.24	19.00	1	17.97	18.35	18.01	2
	8	3	18.94	19.18	18.98	1	17.94	18.30	17.98	2
	8	7	18.90	19.15	18.94	1	17.90	18.26	17.94	2
	15	0	18.91	19.11	18.95	1	17.79	18.16	17.83	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 18625	Mid CH 18900	High CH 19175		Low CH 18625	Mid CH 18900	High CH 19175	
			1852.5 MHz	1880.0 MHz	1907.5 MHz		1852.5 MHz	1880.0 MHz	1907.5 MHz	
2 / 5M	1	0	20.51	20.57	20.55	0	18.40	19.14	18.44	1
	1	12	20.11	20.03	20.15	0	18.37	19.07	18.41	1
	1	24	19.62	19.97	19.66	0	18.33	19.04	18.37	1
	12	0	18.99	19.27	19.03	1	18.00	18.38	18.04	2
	12	6	18.97	19.21	19.01	1	17.97	18.33	18.01	2
	12	13	18.93	19.18	18.97	1	17.93	18.29	17.97	2
	25	0	18.94	19.14	18.98	1	17.82	18.19	17.86	2

FCC SAR Test Report

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 18650	Mid CH 18900	High CH 19150		Low CH 18650	Mid CH 18900	High CH 19150	
			1855.0 MHz	1880.0 MHz	1905.0 MHz		1855.0 MHz	1880.0 MHz	1905.0 MHz	
2 / 10M	1	0	20.53	20.59	20.57	0	18.42	19.16	18.46	1
	1	24	20.13	20.05	20.17	0	18.39	19.09	18.43	1
	1	49	19.64	19.99	19.68	0	18.35	19.06	18.39	1
	25	0	19.01	19.29	19.05	1	18.02	18.40	18.06	2
	25	12	18.99	19.23	19.03	1	17.99	18.35	18.03	2
	25	25	18.95	19.20	18.99	1	17.95	18.31	17.99	2
	50	0	18.96	19.16	19.00	1	17.84	18.21	17.88	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 18675	Mid CH 18900	High CH 19125		Low CH 18675	Mid CH 18900	High CH 19125	
			1857.5 MHz	1880.0 MHz	1902.5 MHz		1857.5 MHz	1880.0 MHz	1902.5 MHz	
2 / 15M	1	0	20.56	20.62	20.60	0	18.45	19.19	18.49	1
	1	37	20.16	20.08	20.20	0	18.42	19.12	18.46	1
	1	74	19.67	20.02	19.71	0	18.38	19.09	18.42	1
	36	0	19.04	19.32	19.08	1	18.05	18.43	18.09	2
	36	19	19.02	19.26	19.06	1	18.02	18.38	18.06	2
	36	39	18.98	19.23	19.02	1	17.98	18.34	18.02	2
	75	0	18.99	19.19	19.03	1	17.87	18.24	17.91	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 18700	Mid CH 18900	High CH 19100		Low CH 18700	Mid CH 18900	High CH 19100	
			1860.0 MHz	1880.0 MHz	1900.0 MHz		1860.0 MHz	1880.0 MHz	1900.0 MHz	
2 / 20M	1	0	20.61	20.67	20.65	0	18.50	19.24	18.54	1
	1	50	20.21	20.13	20.25	0	18.47	19.17	18.51	1
	1	99	19.72	20.07	19.76	0	18.43	19.14	18.47	1
	50	0	19.09	19.37	19.13	1	18.10	18.48	18.14	2
	50	25	19.07	19.31	19.11	1	18.07	18.43	18.11	2
	50	50	19.03	19.28	19.07	1	18.03	18.39	18.07	2
	100	0	19.04	19.24	19.08	1	17.92	18.29	17.96	2

FCC SAR Test Report

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 19957	Mid CH 20175	High CH 20393		Low CH 19957	Mid CH 20175	High CH 20393	
			1710.7 MHz	1732.5 MHz	1754.3 MHz		1710.7 MHz	1732.5 MHz	1754.3 MHz	
4 / 1.4M	1	0	20.64	20.81	20.71	0	19.27	19.44	19.34	1
	1	2	19.98	20.15	20.05	0	19.24	19.41	19.31	1
	1	5	19.81	19.98	19.88	0	19.19	19.36	19.26	1
	3	0	20.62	20.79	20.69	0	19.26	19.43	19.33	1
	3	1	19.96	20.13	20.03	0	19.23	19.40	19.30	1
	3	3	19.79	19.96	19.86	0	19.18	19.35	19.25	1
	6	0	19.17	19.34	19.24	1	18.21	18.38	18.28	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 19965	Mid CH 20175	High CH 20385		Low CH 19965	Mid CH 20175	High CH 20385	
			1711.5 MHz	1732.5 MHz	1753.5 MHz		1711.5 MHz	1732.5 MHz	1753.5 MHz	
4 / 3M	1	0	20.65	20.82	20.72	0	19.28	19.45	19.35	1
	1	7	19.99	20.16	20.06	0	19.25	19.42	19.32	1
	1	14	19.82	19.99	19.89	0	19.20	19.37	19.27	1
	8	0	19.38	19.55	19.45	1	18.46	18.63	18.53	2
	8	3	19.34	19.51	19.41	1	18.42	18.59	18.49	2
	8	7	19.31	19.48	19.38	1	18.38	18.55	18.45	2
	15	0	19.18	19.35	19.25	1	18.22	18.39	18.29	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 19975	Mid CH 20175	High CH 20375		Low CH 19975	Mid CH 20175	High CH 20375	
			1712.5 MHz	1732.5 MHz	1752.5 MHz		1712.5 MHz	1732.5 MHz	1752.5 MHz	
4 / 5M	1	0	20.68	20.85	20.75	0	19.31	19.48	19.38	1
	1	12	20.02	20.19	20.09	0	19.28	19.45	19.35	1
	1	24	19.85	20.02	19.92	0	19.23	19.40	19.30	1
	12	0	19.41	19.58	19.48	1	18.49	18.66	18.56	2
	12	6	19.37	19.54	19.44	1	18.45	18.62	18.52	2
	12	13	19.34	19.51	19.41	1	18.41	18.58	18.48	2
	25	0	19.21	19.38	19.28	1	18.25	18.42	18.32	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 20000	Mid CH 20175	High CH 20350		Low CH 20000	Mid CH 20175	High CH 20350	
			1715.0 MHz	1732.5 MHz	1750.0 MHz		1715.0 MHz	1732.5 MHz	1750.0 MHz	
4 / 10M	1	0	20.72	20.89	20.79	0	19.35	19.52	19.42	1
	1	24	20.06	20.23	20.13	0	19.32	19.49	19.39	1
	1	49	19.89	20.06	19.96	0	19.27	19.44	19.34	1
	25	0	19.45	19.62	19.52	1	18.53	18.70	18.60	2
	25	12	19.41	19.58	19.48	1	18.49	18.66	18.56	2
	25	25	19.38	19.55	19.45	1	18.45	18.62	18.52	2
	50	0	19.25	19.42	19.32	1	18.29	18.46	18.36	2

FCC SAR Test Report

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 20025	Mid CH 20175	High CH 20325		Low CH 20025	Mid CH 20175	High CH 20325	
			1717.5 MHz	1732.5 MHz	1747.5 MHz		1717.5 MHz	1732.5 MHz	1747.5 MHz	
4 / 15M	1	0	20.78	20.95	20.85	0	19.41	19.58	19.48	1
	1	37	20.12	20.29	20.19	0	19.38	19.55	19.45	1
	1	74	19.95	20.12	20.02	0	19.33	19.50	19.40	1
	36	0	19.51	19.68	19.58	1	18.59	18.76	18.66	2
	36	19	19.47	19.64	19.54	1	18.55	18.72	18.62	2
	36	39	19.44	19.61	19.51	1	18.51	18.68	18.58	2
	75	0	19.31	19.48	19.38	1	18.35	18.52	18.42	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 20050	Mid CH 20175	High CH 20300		Low CH 20050	Mid CH 20175	High CH 20300	
			1720.0 MHz	1732.5 MHz	1745.0 MHz		1720.0 MHz	1732.5 MHz	1745.0 MHz	
4 / 20M	1	0	20.81	20.98	20.88	0	19.44	19.61	19.51	1
	1	50	20.15	20.32	20.22	0	19.41	19.58	19.48	1
	1	99	19.98	20.15	20.05	0	19.36	19.53	19.43	1
	50	0	19.54	19.71	19.61	1	18.62	18.79	18.69	2
	50	25	19.50	19.67	19.57	1	18.58	18.75	18.65	2
	50	50	19.47	19.64	19.54	1	18.54	18.71	18.61	2
	100	0	19.34	19.51	19.41	1	18.38	18.55	18.45	2

FCC SAR Test Report

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 23017	Mid CH 23095	High CH 23173		Low CH 23017	Mid CH 23095	High CH 23173	
			699.7 MHz	707.5 MHz	715.3 MHz		699.7 MHz	707.5 MHz	715.3 MHz	
12 / 1.4M	1	0	22.83	22.64	22.69	0	21.09	20.96	21.01	1
	1	2	22.80	22.60	22.65	0	21.06	20.93	20.98	1
	1	5	22.73	22.53	22.58	0	21.01	20.89	20.94	1
	3	0	22.81	22.62	22.67	0	21.08	20.95	21.00	1
	3	1	22.78	22.58	22.63	0	21.05	20.92	20.97	1
	3	3	22.71	22.51	22.56	0	21.00	20.88	20.93	1
	6	0	21.56	21.43	21.48	1	20.68	20.43	20.48	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 23025	Mid CH 23095	High CH 23165		Low CH 23025	Mid CH 23095	High CH 23165	
			700.5 MHz	707.5 MHz	714.5 MHz		700.5 MHz	707.5 MHz	714.5 MHz	
12 / 3M	1	0	22.87	22.68	22.73	0	21.13	21.00	21.05	1
	1	7	22.84	22.64	22.69	0	21.10	20.97	21.02	1
	1	14	22.77	22.57	22.62	0	21.05	20.93	20.98	1
	8	0	21.66	21.47	21.52	1	20.74	20.60	20.65	2
	8	3	21.62	21.45	21.50	1	20.70	20.57	20.62	2
	8	7	21.58	21.39	21.44	1	20.66	20.53	20.58	2
	15	0	21.60	21.47	21.52	1	20.72	20.47	20.52	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 23035	Mid CH 23095	High CH 23155		Low CH 23035	Mid CH 23095	High CH 23155	
			701.5 MHz	707.5 MHz	713.5 MHz		701.5 MHz	707.5 MHz	713.5 MHz	
12 / 5M	1	0	22.93	22.74	22.79	0	21.19	21.06	21.11	1
	1	12	22.90	22.70	22.75	0	21.16	21.03	21.08	1
	1	24	22.83	22.63	22.68	0	21.11	20.99	21.04	1
	12	0	21.72	21.53	21.58	1	20.80	20.66	20.71	2
	12	6	21.68	21.51	21.56	1	20.76	20.63	20.68	2
	12	13	21.64	21.45	21.50	1	20.72	20.59	20.64	2
	25	0	21.66	21.53	21.58	1	20.78	20.53	20.58	2

LTE Band / BW	RB Size	RB Offset	QPSK			3GPP MPR (dB)	16QAM			3GPP MPR (dB)
			Low CH 23060	Mid CH 23095	High CH 23130		Low CH 23060	Mid CH 23095	High CH 23130	
			704.0 MHz	707.5 MHz	711.0 MHz		704.0 MHz	707.5 MHz	711.0 MHz	
12 / 10M	1	0	22.96	22.77	22.82	0	21.22	21.09	21.14	1
	1	24	22.93	22.73	22.78	0	21.19	21.06	21.11	1
	1	49	22.86	22.66	22.71	0	21.14	21.02	21.07	1
	25	0	21.75	21.56	21.61	1	20.83	20.69	20.74	2
	25	12	21.71	21.54	21.59	1	20.79	20.66	20.71	2
	25	25	21.67	21.48	21.53	1	20.75	20.62	20.67	2
	50	0	21.69	21.56	21.61	1	20.81	20.56	20.61	2

FCC SAR Test Report

<Bluetooth>

Mode	Bluetooth LE		
Channel / Frequency (MHz)	0 (2402)	21 (2442)	39 (2480)
Average Power	1.92	2.12	2.29

4.7 SAR Testing Results

4.7.1 SAR Test Reduction Considerations

<KDB 447498 D01, General RF Exposure Guidance>

Testing of other required channels within the operating mode of a frequency band is not required when the reported SAR for the mid-band or highest output power channel is:

- (1) ≤ 0.8 W/kg or 2.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≤ 100 MHz
- (2) ≤ 0.6 W/kg or 1.5 W/kg, for 1-g or 10-g respectively, when the transmission band is between 100 MHz and 200 MHz
- (3) ≤ 0.4 W/kg or 1.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≥ 200 MHz

<KDB 941225 D05, SAR Evaluation Considerations for LTE Devices>

- (1) QPSK with 1 RB and 50% RB allocation

Start with the largest channel bandwidth and measure SAR, using the RB offset and required test channel combination with the highest maximum output power among RB offsets at the upper edge, middle and lower edge of each required test channel. When the reported SAR is ≤ 0.8 W/kg, testing of the remaining RB offset configurations and required test channels is not required; otherwise, SAR is required for the remaining required test channels and only for the RB offset configuration with the highest output power for that channel. When the reported SAR of a required test channel is > 1.45 W/kg, SAR is required for all three RB offset configurations for that required test channel.

- (2) QPSK with 100% RB allocation

SAR is not required when the highest maximum output power for 100% RB allocation is less than the highest maximum output power in 50% and 1 RB allocations and the highest reported SAR for 1 RB and 50% RB allocation are ≤ 0.8 W/kg. Otherwise, SAR is measured for the highest output power channel; and if the reported SAR is > 1.45 W/kg, the remaining required test channels must also be tested.

- (3) Higher order modulations

SAR is required only when the highest maximum output power for the configuration in the higher order modulation is $> 1/2$ dB higher than the same configuration in QPSK or when the reported SAR for the QPSK configuration is > 1.45 W/kg.

- (4) Other channel bandwidth

SAR is required when the highest maximum output power of the smaller channel bandwidth is $> 1/2$ dB higher than the equivalent channel configurations in the largest channel bandwidth configuration or the reported SAR of a configuration for the largest channel bandwidth is > 1.45 W/kg.

FCC SAR Test Report

4.7.2 SAR Results for Body Exposure Condition (Separation Distance is 1.0 cm Gap)

Plot No.	Band	Mode	Test Position	Ch.	GPS	RB#	RB Offset	Max. Tune-up Power (dBm)	Measured Conducted Power (dBm)	Power Drift (dB)	Measured SAR-1g (W/kg)	Scaling Factor	Scaled SAR-1g (W/kg)
1	LTE 2	QPSK20M	Front Face	18900	-	1	0	21.0	20.67	-0.01	0.649	1.08	0.70
	LTE 2	QPSK20M	Rear Face	18900	-	1	0	21.0	20.67	0.03	0.567	1.08	0.61
	LTE 2	QPSK20M	Left Side	18900	-	1	0	21.0	20.67	0.00	0.385	1.08	0.42
	LTE 2	QPSK20M	Right Side	18900	-	1	0	21.0	20.67	0.00	0.063	1.08	0.07
	LTE 2	QPSK20M	Top Side	18900	-	1	0	21.0	20.67	0.00	0.554	1.08	0.60
	LTE 2	QPSK20M	Bottom Side	18900	-	1	0	21.0	20.67	0.01	0.026	1.08	0.03
	LTE 2	QPSK20M	Front Face	18900	-	50	0	20.0	19.37	0.05	0.444	1.16	0.51
	LTE 2	QPSK20M	Rear Face	18900	-	50	0	20.0	19.37	0.04	0.439	1.16	0.51
	LTE 2	QPSK20M	Left Side	18900	-	50	0	20.0	19.37	0.00	0.298	1.16	0.34
	LTE 2	QPSK20M	Right Side	18900	-	50	0	20.0	19.37	0.01	0.049	1.16	0.06
	LTE 2	QPSK20M	Top Side	18900	-	50	0	20.0	19.37	0.08	0.429	1.16	0.50
	LTE 2	QPSK20M	Bottom Side	18900	-	50	0	20.0	19.37	-0.03	0.021	1.16	0.02
	LTE 2	QPSK20M	Front Face	18900	V	1	0	21.0	20.67	-0.06	0.574	1.08	0.62
	LTE 4	QPSK20M	Front Face	20175	-	1	0	21.0	20.98	-0.02	0.893	1.00	0.90
	LTE 4	QPSK20M	Rear Face	20175	-	1	0	21.0	20.98	-0.04	0.895	1.00	0.90
	LTE 4	QPSK20M	Left Side	20175	-	1	0	21.0	20.98	-0.06	0.599	1.00	0.60
	LTE 4	QPSK20M	Right Side	20175	-	1	0	21.0	20.98	0.01	0.123	1.00	0.12
2	LTE 4	QPSK20M	Top Side	20175	-	1	0	21.0	20.98	-0.08	1.09	1.00	1.10
	LTE 4	QPSK20M	Bottom Side	20175	-	1	0	21.0	20.98	0.12	0.051	1.00	0.05
	LTE 4	QPSK20M	Front Face	20175	-	50	0	20.0	19.71	-0.02	0.716	1.07	0.77
	LTE 4	QPSK20M	Rear Face	20175	-	50	0	20.0	19.71	0.12	0.675	1.07	0.72
	LTE 4	QPSK20M	Left Side	20175	-	50	0	20.0	19.71	0.01	0.481	1.07	0.51
	LTE 4	QPSK20M	Right Side	20175	-	50	0	20.0	19.71	0.01	0.098	1.07	0.10
	LTE 4	QPSK20M	Top Side	20175	-	50	0	20.0	19.71	0.06	0.874	1.07	0.93
	LTE 4	QPSK20M	Bottom Side	20175	-	50	0	20.0	19.71	0.01	0.041	1.07	0.04
	LTE 4	QPSK20M	Front Face	20050	-	1	0	21.0	20.81	0.00	0.837	1.04	0.87
	LTE 4	QPSK20M	Front Face	20300	-	1	0	21.0	20.88	-0.03	0.959	1.03	0.99
	LTE 4	QPSK20M	Rear Face	20050	-	1	0	21.0	20.81	0.02	0.784	1.04	0.82
	LTE 4	QPSK20M	Rear Face	20300	-	1	0	21.0	20.88	0.03	0.899	1.03	0.92
	LTE 4	QPSK20M	Top Side	20050	-	1	0	21.0	20.81	-0.04	0.932	1.04	0.97
	LTE 4	QPSK20M	Top Side	20300	-	1	0	21.0	20.88	-0.17	0.899	1.03	0.92
	LTE 4	QPSK20M	Top Side	20050	-	50	0	20.0	19.54	-0.01	0.569	1.11	0.63
	LTE 4	QPSK20M	Top Side	20300	-	50	0	20.0	19.61	0.03	0.6	1.09	0.66
	LTE 4	QPSK20M	Top Side	20175	-	100	0	20.0	19.51	0.06	0.661	1.12	0.74
	LTE 4	QPSK20M	Top Side	20175	V	1	0	21.0	20.98	0.00	0.671	1.00	0.67
	LTE 4	QPSK20M	Top Side	20175	-	1	0	21.0	20.98	-0.08	1.03	1.00	1.03

FCC SAR Test Report

Plot No.	Band	Mode	Test Position	Ch.	GPS	RB#	RB Offset	Max. Tune-up Power (dBm)	Measured Conducted Power (dBm)	Power Drift (dB)	Measured SAR-1g (W/kg)	Scaling Factor	Scaled SAR-1g (W/kg)
	LTE 12	QPSK10M	Front Face	23060	-	1	0	23.5	22.96	-0.03	0.886	1.13	1.00
	LTE 12	QPSK10M	Rear Face	23060	-	1	0	23.5	22.96	-0.17	0.8	1.13	0.91
	LTE 12	QPSK10M	Left Side	23060	-	1	0	23.5	22.96	-0.09	0.328	1.13	0.37
	LTE 12	QPSK10M	Right Side	23060	-	1	0	23.5	22.96	0.02	0.377	1.13	0.43
	LTE 12	QPSK10M	Top Side	23060	-	1	0	23.5	22.96	-0.09	0.197	1.13	0.22
	LTE 12	QPSK10M	Bottom Side	23060	-	1	0	23.5	22.96	-0.02	0.033	1.13	0.04
	LTE 12	QPSK10M	Front Face	23060	-	25	0	22.5	21.75	-0.01	0.723	1.19	0.86
	LTE 12	QPSK10M	Rear Face	23060	-	25	0	22.5	21.75	0.04	0.658	1.19	0.78
	LTE 12	QPSK10M	Left Side	23060	-	25	0	22.5	21.75	0.01	0.268	1.19	0.32
	LTE 12	QPSK10M	Right Side	23060	-	25	0	22.5	21.75	-0.03	0.307	1.19	0.36
	LTE 12	QPSK10M	Top Side	23060	-	25	0	22.5	21.75	0.05	0.161	1.19	0.19
	LTE 12	QPSK10M	Bottom Side	23060	-	25	0	22.5	21.75	0.04	0.027	1.19	0.03
	LTE 12	QPSK10M	Front Face	23095	-	1	0	23.5	22.77	0.03	0.866	1.18	1.02
3	LTE 12	QPSK10M	Front Face	23130	-	1	0	23.5	22.82	0.04	0.888	1.17	1.04
	LTE 12	QPSK10M	Rear Face	23095	-	1	0	23.5	22.77	0.01	0.786	1.18	0.93
	LTE 12	QPSK10M	Rear Face	23130	-	1	0	23.5	22.82	0.08	0.834	1.17	0.98
	LTE 12	QPSK10M	Front Face	23095	-	25	0	22.5	21.56	0.05	0.638	1.24	0.79
	LTE 12	QPSK10M	Front Face	23130	-	25	0	22.5	21.61	-0.04	0.612	1.23	0.75
	LTE 12	QPSK10M	Front Face	23060	-	50	0	22.5	21.69	-0.05	0.537	1.21	0.65
	LTE 12	QPSK10M	Front Face	23130	V	1	0	23.5	22.82	0.06	0.642	1.17	0.75
	LTE 12	QPSK10M	Front Face	23130	-	1	0	23.5	22.82	0.01	0.881	1.17	1.03

FCC SAR Test Report

4.7.3 SAR Measurement Variability

According to KDB 865664 D01, SAR measurement variability was assessed for each frequency band, which is determined by the SAR probe calibration point and tissue-equivalent medium used for the device measurements. When both head and body tissue-equivalent media are required for SAR measurements in a frequency band, the variability measurement procedures should be applied to the tissue medium with the highest measured SAR, using the highest measured SAR configuration for that tissue-equivalent medium. Alternatively, if the highest measured SAR for both head and body tissue-equivalent media are ≤ 1.45 W/kg and the ratio of these highest SAR values, i.e., largest divided by smallest value, is ≤ 1.10 , the highest SAR configuration for either head or body tissue-equivalent medium may be used to perform the repeated measurement. These additional measurements are repeated after the completion of all measurements requiring the same head or body tissue-equivalent medium in a frequency band. The test device should be returned to ambient conditions (normal room temperature) with the battery fully charged before it is re-mounted on the device holder for the repeated measurement(s) to minimize any unexpected variations in the repeated results.

SAR repeated measurement procedure:

1. When the highest measured SAR is < 0.80 W/kg, repeated measurement is not required.
2. When the highest measured SAR is ≥ 0.80 W/kg, repeat that measurement once.
3. If the ratio of largest to smallest SAR for the original and first repeated measurements is > 1.20 , or when the original or repeated measurement is ≥ 1.45 W/kg, perform a second repeated measurement.
4. If the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20 , and the original, first or second repeated measurement is ≥ 1.5 W/kg, perform a third repeated measurement.

Band	Mode	Test Position	Ch.	Original Measured SAR-1g (W/kg)	1st Repeated SAR-1g (W/kg)	L/S Ratio	2nd Repeated SAR-1g (W/kg)	L/S Ratio	3rd Repeated SAR-1g (W/kg)	L/S Ratio
LTE 4	QPSK20M	Top Side	20175	1.09	1.03	1.06	N/A	N/A	N/A	N/A
LTE 12	QPSK10M	Front Face	23130	0.888	0.881	1.01	N/A	N/A	N/A	N/A

FCC SAR Test Report

4.7.4 Simultaneous Multi-band Transmission Evaluation

<Estimated SAR Calculation>

According to KDB 447498 D01, when standalone SAR test exclusion applies to an antenna that transmits simultaneously with other antennas, the standalone SAR was estimated according to following formula to result in substantially conservative SAR values of ≤ 0.4 W/kg to determine simultaneous transmission SAR test exclusion.

$$\text{Estimated SAR} = \frac{\text{Max. Tune up Power}_{(\text{mW})}}{\text{Min. Test Separation Distance}_{(\text{mm})}} \times \frac{\sqrt{f_{(\text{GHz})}}}{7.5}$$

If the minimum test separation distance is < 5 mm, a distance of 5 mm is used for estimated SAR calculation. When the test separation distance is > 50 mm, the 0.4 W/kg is used for SAR-1g.

Mode / Band	Frequency (GHz)	Max. Tune-up Power (dBm)	Test Position	Separation Distance (mm)	Estimated SAR (W/kg)
BT_LE (DTS)	2.48	2.5	Body	10	0.04

Note:

1. The separation distance is determined from the outer housing of the EUT to the user.
2. When standalone SAR testing is not required, an estimated SAR can be applied to determine simultaneous transmission SAR test exclusion.

FCC SAR Test Report

<SAR Summation Analysis>

Simultaneous transmission SAR test exclusion is determined for each operating configuration and exposure condition according to the reported standalone SAR of each applicable simultaneous transmitting antenna. When the sum of SAR_{1g} of all simultaneously transmitting antennas in an operating mode and exposure condition combination is within the SAR limit (SAR_{1g} 1.6 W/kg), the simultaneous transmission SAR is not required. When the sum of SAR_{1g} is greater than the SAR limit (SAR_{1g} 1.6 W/kg), SAR test exclusion is determined by the SPLSR.

No.	Conditions (SAR1 + SAR2)	Exposure Condition	Test Position	Max. SAR1	Max. SAR2	SAR Summation	SPLSR Analysis
1	LTE B2 + BT_LE (DTS)	Body	Front Face	0.70	0.04	0.74	Σ SAR < 1.6, Not required
			Rear Face	0.61	0.04	0.65	Σ SAR < 1.6, Not required
			Left Side	0.42	0.04	0.46	Σ SAR < 1.6, Not required
			Right Side	0.07	0.04	0.11	Σ SAR < 1.6, Not required
			Top Side	0.60	0.04	0.64	Σ SAR < 1.6, Not required
			Bottom Side	0.03	0.04	0.07	Σ SAR < 1.6, Not required

No.	Conditions (SAR1 + SAR2)	Exposure Condition	Test Position	Max. SAR1	Max. SAR2	SAR Summation	SPLSR Analysis
2	LTE B4 + BT (DTS)	Body	Front Face	0.99	0.04	1.03	Σ SAR < 1.6, Not required
			Rear Face	0.92	0.04	0.96	Σ SAR < 1.6, Not required
			Left Side	0.60	0.04	0.64	Σ SAR < 1.6, Not required
			Right Side	0.12	0.04	0.16	Σ SAR < 1.6, Not required
			Top Side	1.10	0.04	1.14	Σ SAR < 1.6, Not required
			Bottom Side	0.05	0.04	0.09	Σ SAR < 1.6, Not required

No.	Conditions (SAR1 + SAR2)	Exposure Condition	Test Position	Max. SAR1	Max. SAR2	SAR Summation	SPLSR Analysis
3	LTE B12 + BT (DTS)	Body	Front Face	1.04	0.04	1.08	Σ SAR < 1.6, Not required
			Rear Face	0.98	0.04	1.02	Σ SAR < 1.6, Not required
			Left Side	0.37	0.04	0.41	Σ SAR < 1.6, Not required
			Right Side	0.43	0.04	0.47	Σ SAR < 1.6, Not required
			Top Side	0.22	0.04	0.26	Σ SAR < 1.6, Not required
			Bottom Side	0.04	0.04	0.08	Σ SAR < 1.6, Not required

Test Engineer : Xianxiong Qin

FCC SAR Test Report

5. Calibration of Test Equipment

Equipment	Manufacturer	Model	SN	Cal. Date	Cal. Interval
System Validation Dipole	SPEAG	D750V3	1078	Jun. 20, 2017	1 Year
System Validation Dipole	SPEAG	D1750V2	1023	Jun. 27, 2017	1 Year
System Validation Dipole	SPEAG	D1900V2	5d018	Jun. 28, 2017	1 Year
Dosimetric E-Field Probe	SPEAG	EX3DV4	3661	May. 05, 2017	1 Year
Data Acquisition Electronics	SPEAG	DAE4	914	Jan. 06, 2017	1 Year
Radio Communication Analyzer	ANRITSU	MT8820C	6201300717	Jul. 24, 2017	1 Year
Wireless Communication Test Set	Agilent	E5515C	MY50260600	Jun. 28, 2017	1 Year
ENA Series Network Analyzer	Agilent	E5071C	MY46214638	Jul. 24, 2017	1 Year
MXG Analog Signal Generator	KEYSIGHT	N5183A	MY50143024	Mar. 01, 2017	1 Year
Power Meter	Agilent	N1914A	MY52180044	Aug. 12, 2016	2 Years
Power Sensor	Agilent	E9304A H18	MY52050011	Dec. 27, 2016	1 Year
Power Meter	Agilent	ML2495A	1506002	Mar. 01, 2017	1 Year
Power Sensor	Agilent	MA2411B	1339353	Mar. 01, 2017	1 Year
Temp. & Humi. Recorder	CLOCK	HTC-1	157248	Jul. 26, 2017	1 Year
Electronic Thermometer	YONGFA	YF-160A	120100323	Sep. 22, 2017	1 Year
Coupler	Woken	0110A056020-10	COM27RW1A3	Sep. 20, 2017	1 Year

FCC SAR Test Report

6. Measurement Uncertainty

Source of Uncertainty	Tolerance (± %)	Probability Distribution	Divisor	Ci (1g)	Ci (10g)	Standard Uncertainty (± %, 1g)	Standard Uncertainty (± %, 10g)	Vi
Measurement System								
Probe Calibration	6.0	Normal	1	1	1	6.0	6.0	∞
Axial Isotropy	4.7	Rectangular	√3	0.707	0.707	1.9	1.9	∞
Hemispherical Isotropy	9.6	Rectangular	√3	0.707	0.707	3.9	3.9	∞
Boundary Effect	1.0	Rectangular	√3	1	1	0.6	0.6	∞
Linearity	4.7	Rectangular	√3	1	1	2.7	2.7	∞
System Detection Limits	0.25	Rectangular	√3	1	1	0.14	0.14	∞
Readout Electronics	0.3	Normal	1	1	1	0.3	0.3	∞
Response Time	0.0	Rectangular	√3	1	1	0.0	0.0	∞
Integration Time	1.7	Rectangular	√3	1	1	1.0	1.0	∞
RF Ambient Conditions - Noise	3.0	Rectangular	√3	1	1	1.7	1.7	∞
RF Ambient Conditions - Reflections	3.0	Rectangular	√3	1	1	1.7	1.7	∞
Probe Positioner Mechanical Tolerance	0.4	Rectangular	√3	1	1	0.2	0.2	∞
Probe Positioning with Respect to Phantom Shell	2.9	Rectangular	√3	1	1	1.7	1.7	∞
Extrapolation, interpolation, and integration algorithms for max. SAR evaluation	2.0	Rectangular	√3	1	1	1.2	1.2	∞
Test Sample Related								
Test Sample Positioning	1.5 / 0.7	Normal	1	1	1	1.5	0.7	32
Device Holder Uncertainty	4.2 / 1.8	Normal	1	1	1	4.2	1.8	32
Output Power Variation - SAR Drift Measurement	5.0	Rectangular	√3	1	1	2.9	2.9	∞
Phantom and Tissue Parameters								
Phantom Uncertainty (Shape and Thickness Tolerances)	7.2	Rectangular	√3	1	1	4.2	4.2	∞
Liquid Conductivity - Deviation from Target Values	5.0	Rectangular	√3	0.64	0.43	1.8	1.2	∞
Liquid Conductivity - Measurement Uncertainty	1.0	Normal	1	0.64	0.43	0.6	0.4	25
Liquid Permittivity - Deviation from Target Values	5.0	Rectangular	√3	0.60	0.49	1.7	1.4	∞
Liquid Permittivity - Measurement Uncertainty	0.5	Normal	1	0.60	0.49	0.3	0.2	25
Combined Standard Uncertainty						± 11.2 %	± 10.4 %	
Expanded Uncertainty (K=2)						± 22.4 %	± 20.8 %	

Uncertainty budget for frequency range 300 MHz to 3 GHz

7. Information on the Testing Laboratories

We, BV 7LAYERS COMMUNICATIONS TECHNOLOGY (SHENZHEN) CO. LTD., were founded in 2015 to provide our best service in EMC, Radio, Telecom and Safety consultation. Our laboratories are accredited and approved according to ISO/IEC 17025.

If you have any comments, please feel free to contact us at the following:

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Web Site: www.bureauveritas.com

The road map of all our labs can be found in our web site also.

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Appendix A. SAR Plots of System Verification

The plots for system verification with largest deviation for each SAR system combination are shown as follows.

System Check_B750_170913**DUT: Dipole:750 MHz;Type:D750V3;SN:1078**

Communication System: CW; Frequency: 750 MHz;Duty Cycle: 1:1

Medium: B750_0913 Medium parameters used: $f = 750$ MHz; $\sigma = 0.963$ S/m; $\epsilon_r = 53.779$; $\rho = 1000$ kg/m³

Ambient Temperature : 23.2 °C; Liquid Temperature : 22.2 °C

DASY5 Configuration:

- Probe: EX3DV4 - SN3661; ConvF(9.85, 9.85, 9.85); Calibrated: 2017/05/05;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn914; Calibrated: 2017/01/06
- Phantom: Left Phantom with CRP v5.0; Type: QD000P40CD; Serial: TP:1722
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

Pin=250mW/Area Scan (71x111x1): Interpolated grid: dx=1.500 mm, dy=1.500 mm

Maximum value of SAR (interpolated) = 2.46 W/kg

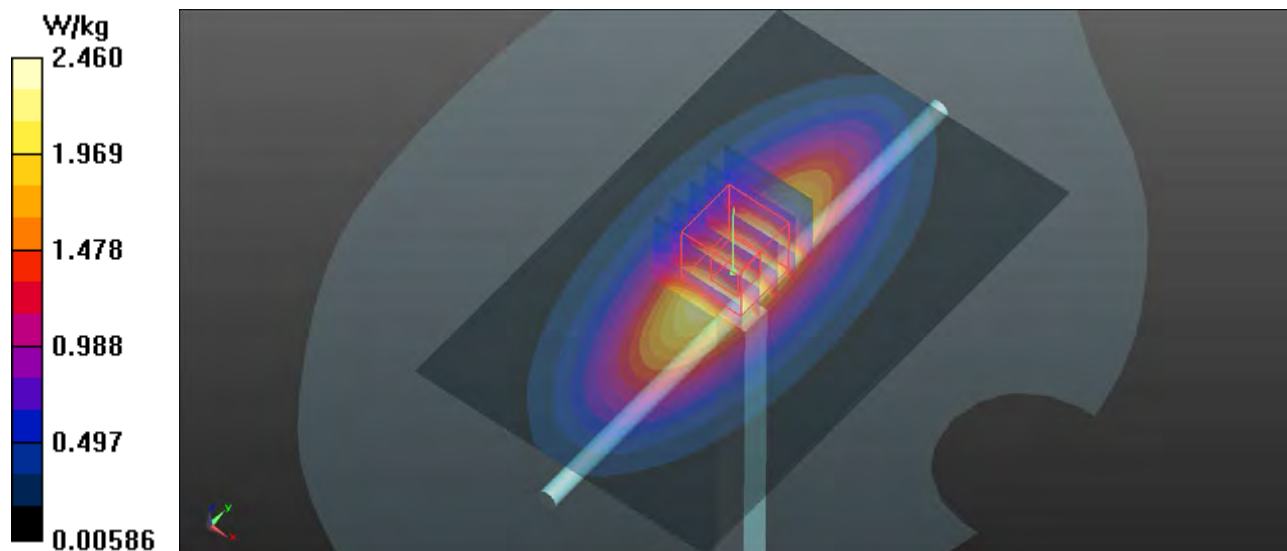
Pin=250mW/Zoom Scan (5x5x7)/Cube 0: Measurement grid: dx=8mm, dy=8mm, dz=5mm

Reference Value = 49.83 V/m; Power Drift = 0.13 dB

Peak SAR (extrapolated) = 2.82 W/kg

SAR(1 g) = 2.12 W/kg; SAR(10 g) = 1.44 W/kg

Maximum value of SAR (measured) = 2.43 W/kg



System Check_B1750_170915**DUT: Dipole 1750 MHz;Type:D1750V2; SN:1023**

Communication System: CW; Frequency: 1750 MHz;Duty Cycle: 1:1

Medium: B1750_0915 Medium parameters used: $f = 1750$ MHz; $\sigma = 1.437$ S/m; $\epsilon_r = 53.65$; $\rho = 1000$ kg/m³

Ambient Temperature : 23.1 °C; Liquid Temperature : 22.3 °C

DASY5 Configuration:

- Probe: EX3DV4 - SN3661; ConvF(8.26, 8.26, 8.26); Calibrated: 2017/05/05;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn914; Calibrated: 2017/01/06
- Phantom: Front Phantom with CRP v5.0; Type: QD000P40CD; Serial: TP:1695
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

Pin=250mW/Area Scan (61x61x1): Interpolated grid: dx=1.500 mm, dy=1.500 mm

Maximum value of SAR (interpolated) = 10.3 W/kg

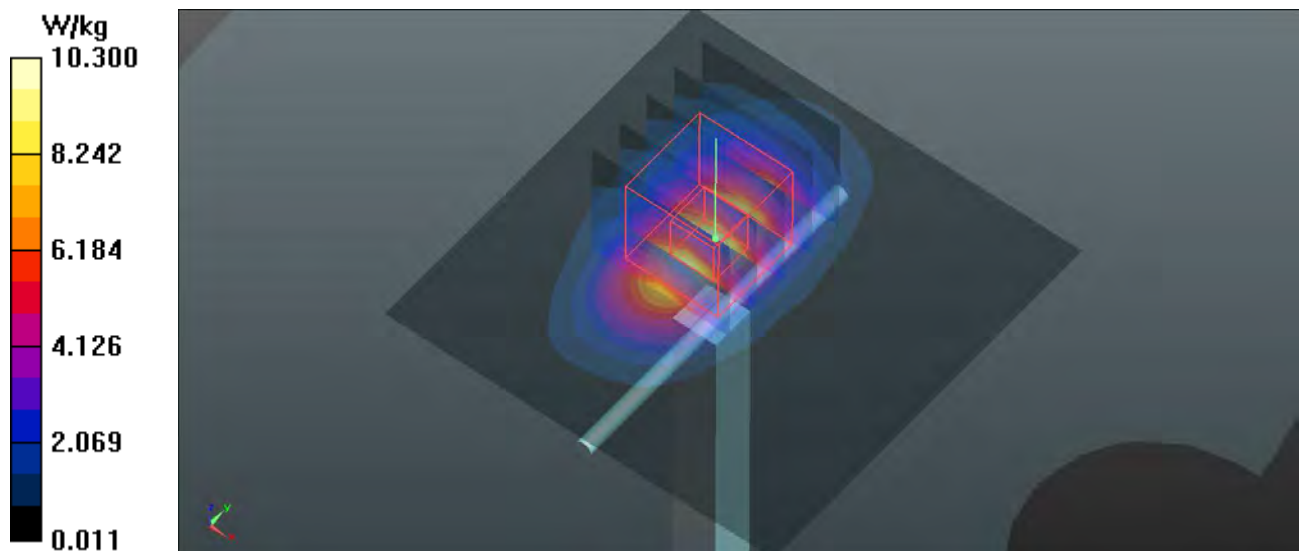
Pin=250mW/Zoom Scan (5x5x7)/Cube 0: Measurement grid: dx=8mm, dy=8mm, dz=5mm

Reference Value = 79.57 V/m; Power Drift = 0.08 dB

Peak SAR (extrapolated) = 12.8 W/kg

SAR(1 g) = 8.83 W/kg; SAR(10 g) = 4.82 W/kg

Maximum value of SAR (measured) = 10.4 W/kg



System Check_B1900_170915**DUT: Dipole:1900MHz;Type:D1900V2; SN:5d018**

Communication System: CW; Frequency: 1900 MHz;Duty Cycle: 1:1

Medium: B1900_0915 Medium parameters used: $f = 1900$ MHz; $\sigma = 1.585$ S/m; $\epsilon_r = 53.657$; $\rho = 1000$ kg/m³

Ambient Temperature : 23.1 °C; Liquid Temperature : 22.3 °C

DASY5 Configuration:

- Probe: EX3DV4 - SN3661; ConvF(7.88, 7.88, 7.88); Calibrated: 2017/05/05;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn914; Calibrated: 2017/01/06
- Phantom: Front Phantom with CRP v5.0; Type: QD000P40CD; Serial: TP:1695
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

Pin=250mW/Area Scan (61x61x1): Interpolated grid: dx=1.500 mm, dy=1.500 mm

Maximum value of SAR (interpolated) = 13.5 W/kg

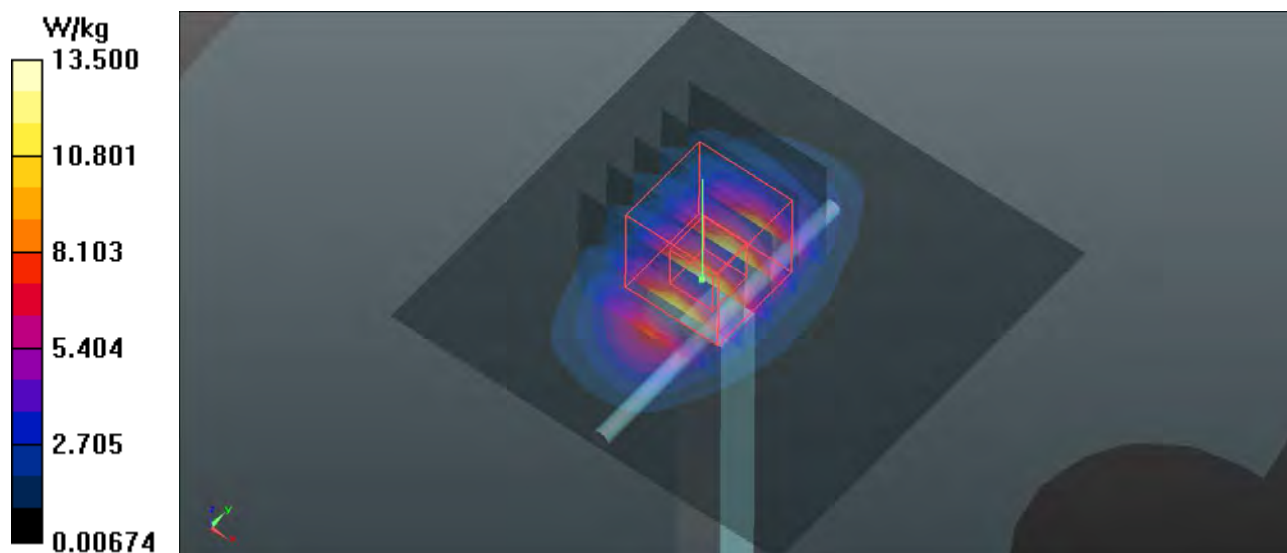
Pin=250mW/Zoom Scan (5x5x7)/Cube 0: Measurement grid: dx=8mm, dy=8mm, dz=5mm

Reference Value = 94.61 V/m; Power Drift = 0.06 dB

Peak SAR (extrapolated) = 17.1 W/kg

SAR(1 g) = 9.8 W/kg; SAR(10 g) = 5.15 W/kg

Maximum value of SAR (measured) = 13.8 W/kg



Appendix B. SAR Plots of SAR Measurement

The SAR plots for highest measured SAR in each exposure configuration, wireless mode and frequency band combination, and measured SAR > 1.5 W/kg are shown as follows.

P01 LTE 2_QPSK20M_Front Face_1cm_Ch18900_1RB_OS0**DUT: 170620W003**

Communication System: LTE; Frequency: 1880 MHz; Duty Cycle: 1:1

Medium: B1900_0915 Medium parameters used: $f = 1880$ MHz; $\sigma = 1.563$ S/m; $\epsilon_r = 53.733$; $\rho = 1000$ kg/m³

Ambient Temperature : 23.1 °C; Liquid Temperature : 22.3 °C

DASY5 Configuration:

- Probe: EX3DV4 - SN3661; ConvF(7.88, 7.88, 7.88); Calibrated: 2017/05/05;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn914; Calibrated: 2017/01/06
- Phantom: Front Phantom with CRP v5.0; Type: QD000P40CD; Serial: TP:1695
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

- **Area Scan (61x91x1):** Interpolated grid: $dx=1.500$ mm, $dy=1.500$ mm

Maximum value of SAR (interpolated) = 0.941 W/kg

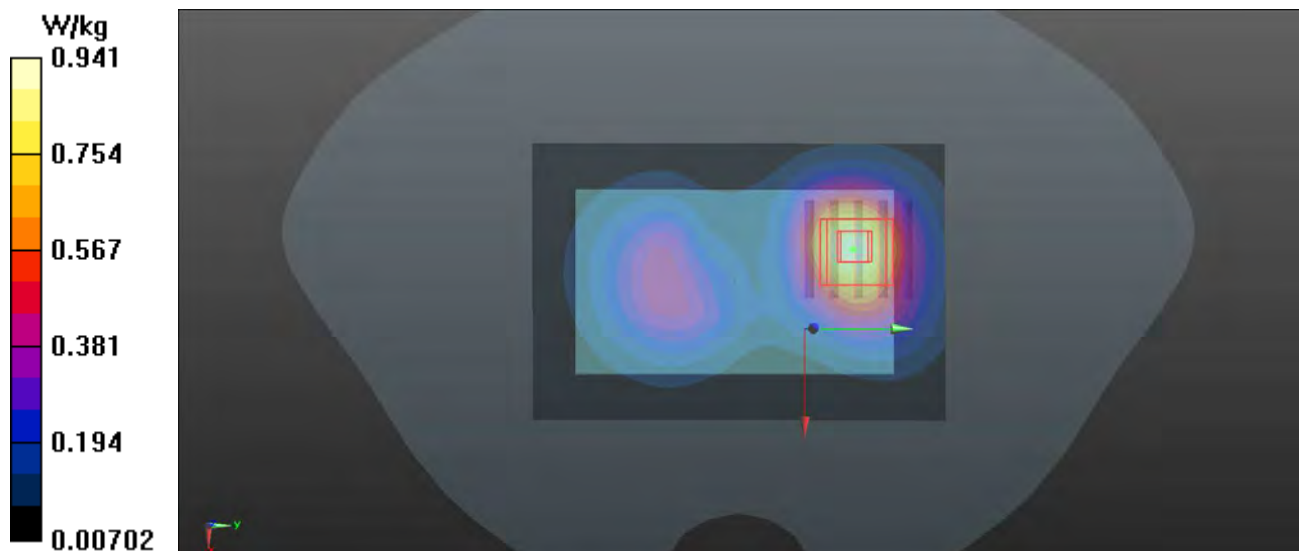
- **Zoom Scan (5x5x7)/Cube 0:** Measurement grid: $dx=8$ mm, $dy=8$ mm, $dz=5$ mm

Reference Value = 15.96 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 1.02 W/kg

SAR(1 g) = 0.649 W/kg; SAR(10 g) = 0.416 W/kg

Maximum value of SAR (measured) = 0.884 W/kg



P02 LTE 4_QPSK20M_Top Side_1cm_Ch20175_1RB_OS0**DUT: 170620W003**

Communication System: LTE; Frequency: 1732.5 MHz; Duty Cycle: 1:1

Medium: B1750_0915 Medium parameters used: $f = 1732.5$ MHz; $\sigma = 1.423$ S/m; $\epsilon_r = 53.682$; $\rho = 1000$ kg/m³

Ambient Temperature : 23.1 °C; Liquid Temperature : 22.3 °C

DASY5 Configuration:

- Probe: EX3DV4 - SN3661; ConvF(8.26, 8.26, 8.26); Calibrated: 2017/05/05;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn914; Calibrated: 2017/01/06
- Phantom: Front Phantom with CRP v5.0; Type: QD000P40CD; Serial: TP:1695
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

- Area Scan (41x71x1): Interpolated grid: $dx=1.500$ mm, $dy=1.500$ mm

Maximum value of SAR (interpolated) = 1.52 W/kg

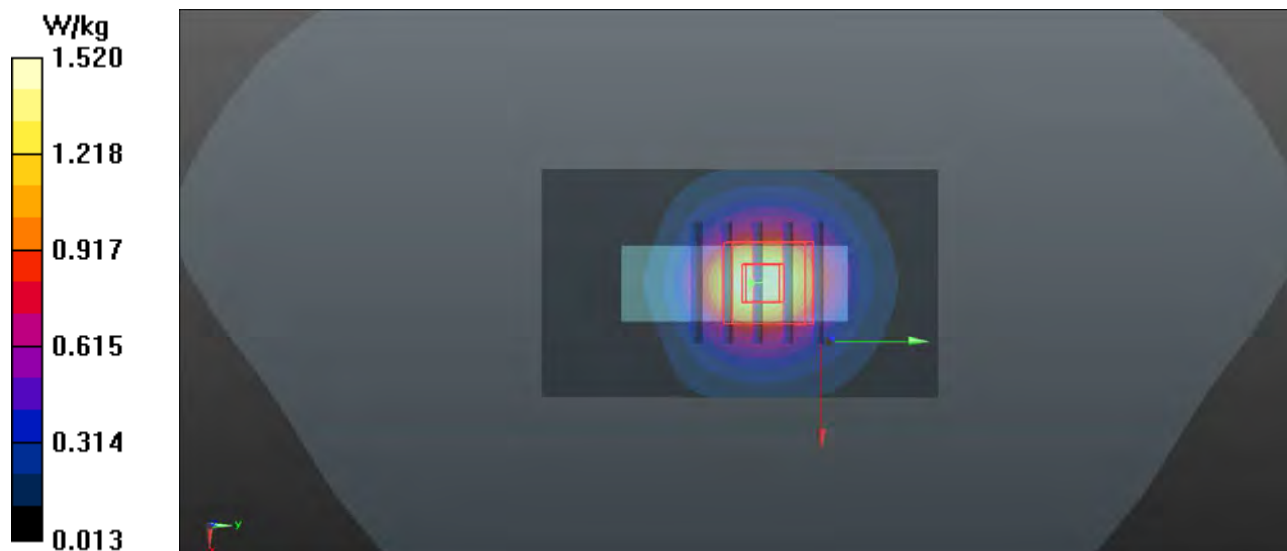
- Zoom Scan (5x5x7)/Cube 0: Measurement grid: $dx=8$ mm, $dy=8$ mm, $dz=5$ mm

Reference Value = 27.86 V/m; Power Drift = -0.08 dB

Peak SAR (extrapolated) = 1.84 W/kg

SAR(1 g) = 1.09 W/kg; SAR(10 g) = 0.609 W/kg

Maximum value of SAR (measured) = 1.55 W/kg



P03 LTE 12_QPSK10M_Front Face_1cm_Ch23130_1RB_OS0**DUT: 170620W003**

Communication System: LTE; Frequency: 711 MHz; Duty Cycle: 1:1

Medium: B750_0913 Medium parameters used: $f = 711$ MHz; $\sigma = 0.922$ S/m; $\epsilon_r = 54.233$; $\rho = 1000$ kg/m³

Ambient Temperature : 23.2 °C ; Liquid Temperature : 22.2 °C

DASY5 Configuration:

- Probe: EX3DV4 - SN3661; ConvF(9.85, 9.85, 9.85); Calibrated: 2017/05/05;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn914; Calibrated: 2017/01/06
- Phantom: Left Phantom with CRP v5.0; Type: QD000P40CD; Serial: TP:1722
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

- Area Scan (61x91x1): Interpolated grid: dx=1.500 mm, dy=1.500 mm

Maximum value of SAR (interpolated) = 1.10 W/kg

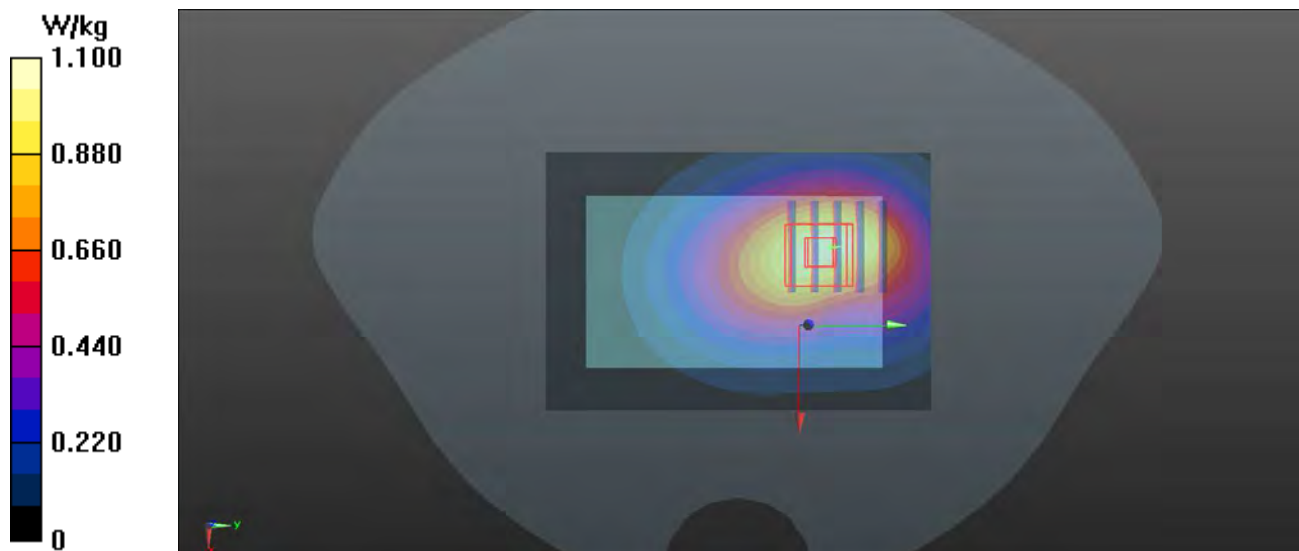
- Zoom Scan (5x5x7)/Cube 0: Measurement grid: dx=8mm, dy=8mm, dz=5mm

Reference Value = 29.56 V/m; Power Drift = 0.04 dB

Peak SAR (extrapolated) = 1.20 W/kg

SAR(1 g) = 0.888 W/kg; SAR(10 g) = 0.652 W/kg

Maximum value of SAR (measured) = 1.09 W/kg



Appendix C. Calibration Certificate for Probe and Dipole

The SPEAG calibration certificates are shown as follows.



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: **D750V3-1078_Jun17**

CALIBRATION CERTIFICATE

Object **D750V3 - SN:1078**

Calibration procedure(s) **QA CAL-05.v9**
Calibration procedure for dipole validation kits above 700 MHz

Calibration date: **June 20, 2017**

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-17 (No. 217-02521/02522)	Apr-18
Power sensor NRP-Z91	SN: 103244	04-Apr-17 (No. 217-02521)	Apr-18
Power sensor NRP-Z91	SN: 103245	04-Apr-17 (No. 217-02522)	Apr-18
Reference 20 dB Attenuator	SN: 5058 (20k)	07-Apr-17 (No. 217-02528)	Apr-18
Type-N mismatch combination	SN: 5047.2 / 06327	07-Apr-17 (No. 217-02529)	Apr-18
Reference Probe EX3DV4	SN: 7349	31-May-17 (No. EX3-7349_May17)	May-18
DAE4	SN: 601	28-Mar-17 (No. DAE4-601_Mar17)	Mar-18
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Power meter EPM-442A	SN: GB37480704	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
Power sensor HP 8481A	SN: US37292783	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
Power sensor HP 8481A	SN: MY41092317	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
RF generator R&S SMT-06	SN: 100972	15-Jun-15 (in house check Oct-16)	In house check: Oct-18
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-16)	In house check: Oct-17

Calibrated by: **Leif Klysner** Name: **Leif Klysner** Function: **Laboratory Technician**

Approved by: **Katja Pokovic** Technical Manager

Signature

Issued: June 27, 2017

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



Accredited by the Swiss Accreditation Service (SAS)

The Swiss Accreditation Service is one of the signatories to the EA
Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Glossary:

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

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"

Additional Documentation:

- 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%.

Measurement Conditions

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

DASY Version	DASY5	V52.10.0
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	15 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	750 MHz \pm 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	41.9	0.89 mho/m
Measured Head TSL parameters	(22.0 \pm 0.2) °C	41.2 \pm 6 %	0.91 mho/m \pm 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	2.14 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	8.39 W/kg \pm 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	1.39 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	5.47 W/kg \pm 16.5 % (k=2)

Body TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	55.5	0.96 mho/m
Measured Body TSL parameters	(22.0 \pm 0.2) °C	54.8 \pm 6 %	0.97 mho/m \pm 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	2.19 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	8.67 W/kg \pm 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	250 mW input power	1.44 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	5.71 W/kg \pm 16.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	$55.5 \Omega + 0.0 j\Omega$
Return Loss	- 25.6 dB

Antenna Parameters with Body TSL

Impedance, transformed to feed point	$51.0 \Omega - 2.5 j\Omega$
Return Loss	- 31.5 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.034 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

Manufactured by	SPEAG
Manufactured on	November 15, 2012

DASY5 Validation Report for Head TSL

Date: 20.06.2017

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 750 MHz; Type: D750V3; Serial: D750V3 - SN:1078

Communication System: UID 0 - CW; Frequency: 750 MHz

Medium parameters used: $f = 750 \text{ MHz}$; $\sigma = 0.91 \text{ S/m}$; $\epsilon_r = 41.2$; $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(10.49, 10.49, 10.49); Calibrated: 31.05.2017;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 28.03.2017
- Phantom: Flat Phantom 4.9 (front); Type: QD 00L P49 AA; Serial: 1001
- DASY52 52.10.0(1446); SEMCAD X 14.6.10(7417)

Dipole Calibration for Head Tissue/Pin=250 mW, d=15mm/Zoom Scan (7x7x7)/Cube 0:

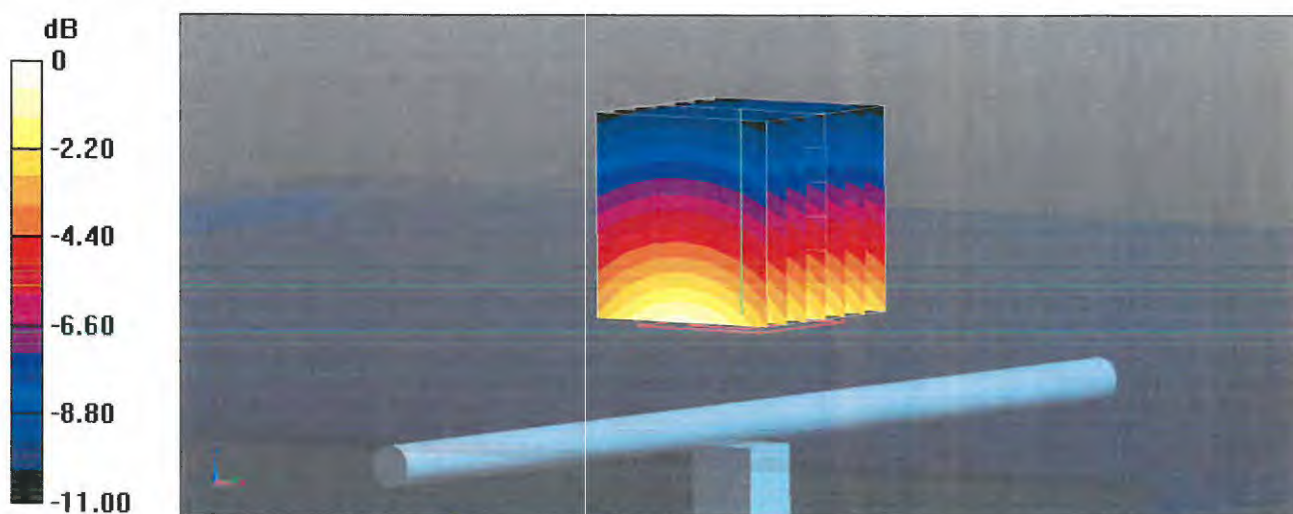
Measurement grid: $dx=5\text{mm}$, $dy=5\text{mm}$, $dz=5\text{mm}$

Reference Value = 59.13 V/m; Power Drift = -0.00 dB

Peak SAR (extrapolated) = 3.27 W/kg

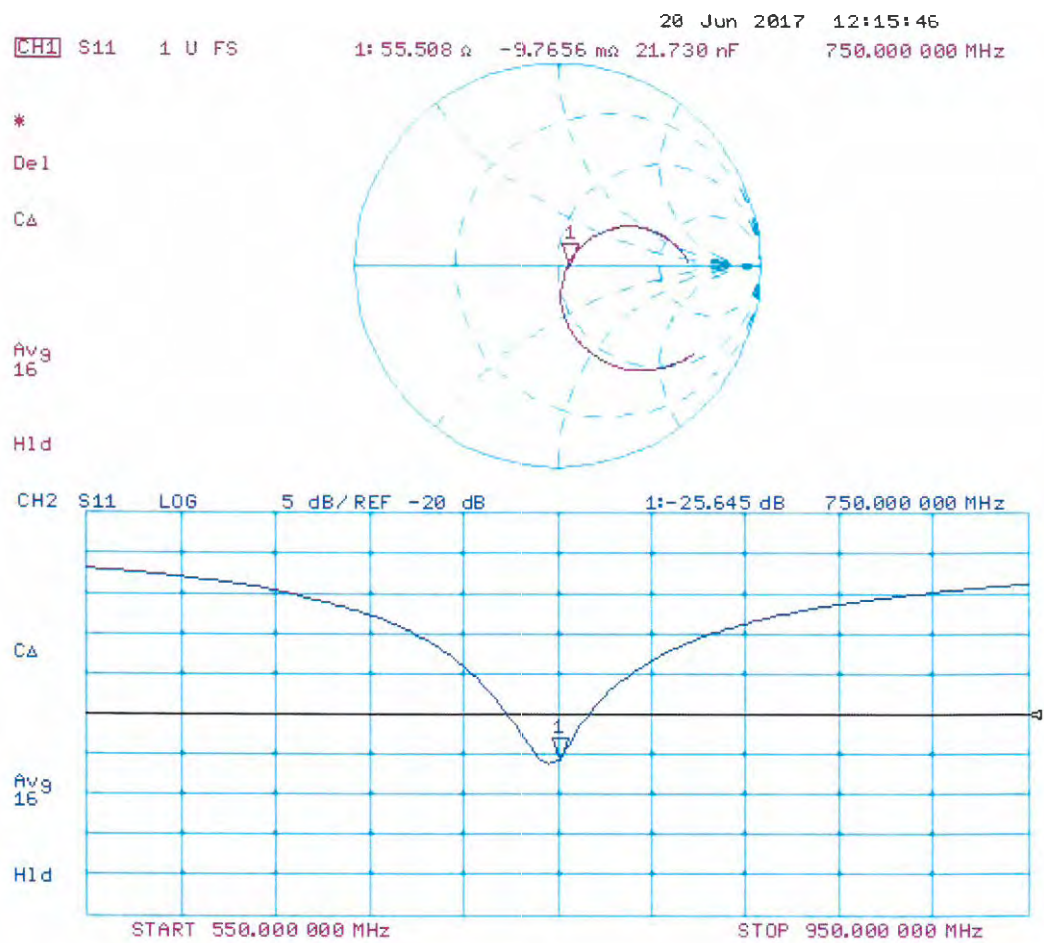
SAR(1 g) = 2.14 W/kg; SAR(10 g) = 1.39 W/kg

Maximum value of SAR (measured) = 2.89 W/kg



0 dB = 2.89 W/kg = 4.61 dBW/kg

Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 20.06.2017

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 750 MHz; Type: D750V3; Serial: D750V3 - SN:1078

Communication System: UID 0 - CW; Frequency: 750 MHz

Medium parameters used: $f = 750$ MHz; $\sigma = 0.97$ S/m; $\epsilon_r = 54.8$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(10.35, 10.35, 10.35); Calibrated: 31.05.2017;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 28.03.2017
- Phantom: Flat Phantom 4.9 (Back); Type: QD 00R P49 AA; Serial: 1005
- DASY52 52.10.0(1446); SEMCAD X 14.6.10(7417)

Dipole Calibration for Body Tissue/Pin=250 mW, d=15mm/Zoom Scan (7x7x7)/Cube 0:

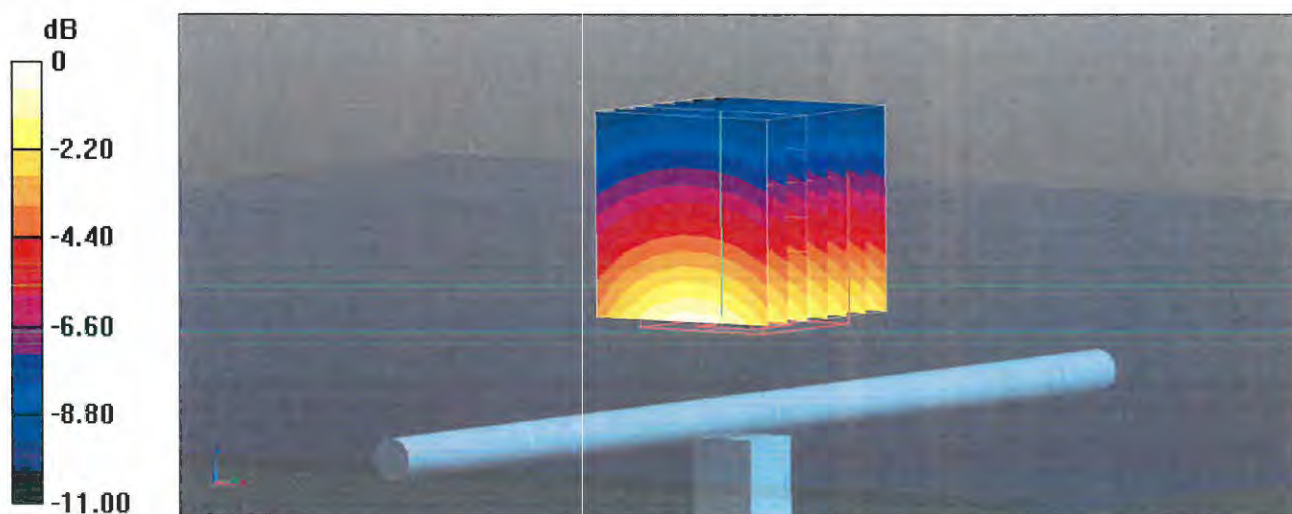
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 57.36 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 3.29 W/kg

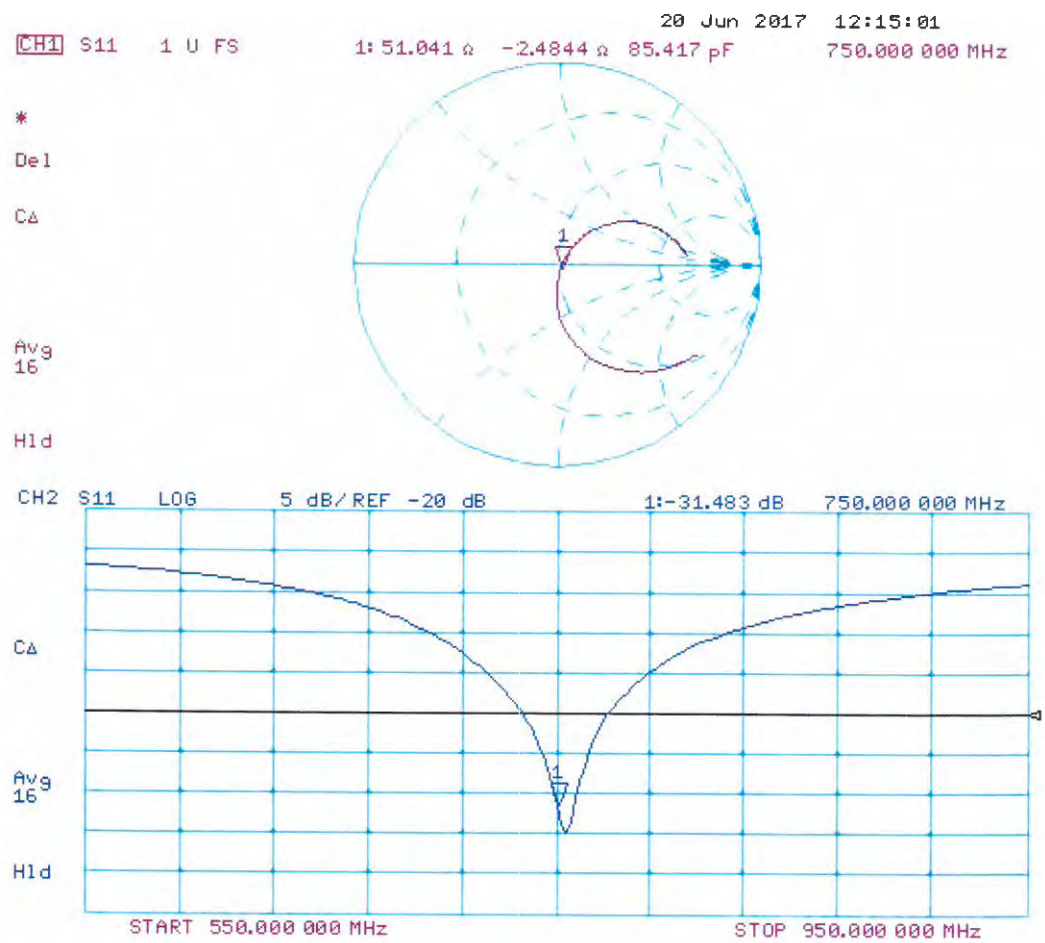
SAR(1 g) = 2.19 W/kg; SAR(10 g) = 1.44 W/kg

Maximum value of SAR (measured) = 2.88 W/kg



0 dB = 2.88 W/kg = 4.59 dBW/kg

Impedance Measurement Plot for Body TSL





Accredited by the Swiss Accreditation Service (SAS)
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 Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **Auden**

Certificate No: **D1750V2-1023_Jun17**

CALIBRATION CERTIFICATE

Object **D1750V2 - SN:1023**

Calibration procedure(s) **QA CAL-05.v9**
Calibration procedure for dipole validation kits above 700 MHz

Calibration date: **June 27, 2017**

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 $(22 \pm 3)^\circ\text{C}$ 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-17 (No. 217-02521/02522)	Apr-18
Power sensor NRP-Z91	SN: 103244	04-Apr-17 (No. 217-02521)	Apr-18
Power sensor NRP-Z91	SN: 103245	04-Apr-17 (No. 217-02522)	Apr-18
Reference 20 dB Attenuator	SN: 5058 (20k)	07-Apr-17 (No. 217-02528)	Apr-18
Type-N mismatch combination	SN: 5047.2 / 06327	07-Apr-17 (No. 217-02529)	Apr-18
Reference Probe EX3DV4	SN: 7349	31-May-17 (No. EX3-7349_May17)	May-18
DAE4	SN: 601	28-Mar-17 (No. DAE4-601_Mar17)	Mar-18
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Power meter EPM-442A	SN: GB37480704	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
Power sensor HP 8481A	SN: US37292783	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
Power sensor HP 8481A	SN: MY41092317	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
RF generator R&S SMT-06	SN: 100972	15-Jun-15 (in house check Oct-16)	In house check: Oct-18
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-16)	In house check: Oct-17

Calibrated by: **Johannes Kurikka** Function: **Laboratory Technician**

Approved by: **Katja Pokovic** Technical Manager

Signature

Issued: June 27, 2017

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



Accredited by the Swiss Accreditation Service (SAS)

The Swiss Accreditation Service is one of the signatories to the EA
Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Glossary:

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

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"

Additional Documentation:

- 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%.

Measurement Conditions

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

DASY Version	DASY5	V52.10.0
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	1750 MHz \pm 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	40.1	1.37 mho/m
Measured Head TSL parameters	(22.0 \pm 0.2) °C	39.2 \pm 6 %	1.36 mho/m \pm 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	9.23 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	36.9 W/kg \pm 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	4.87 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	19.5 W/kg \pm 16.5 % (k=2)

Body TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	53.4	1.49 mho/m
Measured Body TSL parameters	(22.0 \pm 0.2) °C	53.2 \pm 6 %	1.47 mho/m \pm 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	9.15 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	36.9 W/kg \pm 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	250 mW input power	4.91 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	19.7 W/kg \pm 16.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	$50.2 \Omega + 0.5 j\Omega$
Return Loss	- 45.3 dB

Antenna Parameters with Body TSL

Impedance, transformed to feed point	$47.9 \Omega - 0.7 j\Omega$
Return Loss	- 32.9 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.218 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

Manufactured by	SPEAG
Manufactured on	August 20, 2009

DASY5 Validation Report for Head TSL

Date: 27.06.2017

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 1750 MHz; Type: D1750V2; Serial: D1750V2 - SN:1023

Communication System: UID 0 - CW; Frequency: 1750 MHz

Medium parameters used: $f = 1750$ MHz; $\sigma = 1.36$ S/m; $\epsilon_r = 39.2$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(8.73, 8.73, 8.73); Calibrated: 31.05.2017;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 28.03.2017
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.0(1446); SEMCAD X 14.6.10(7417)

Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

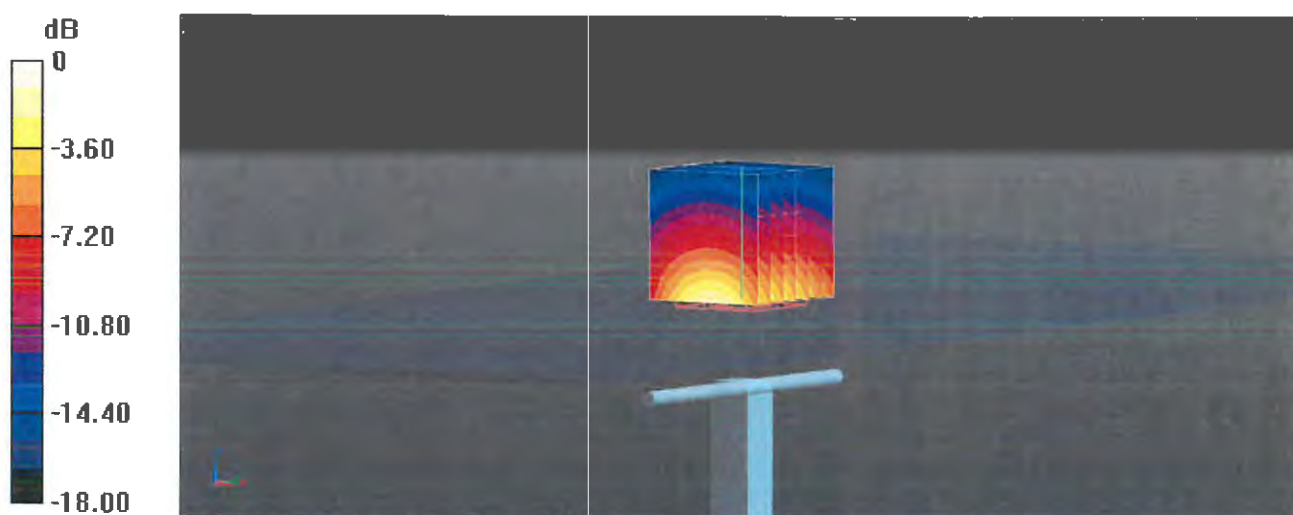
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 105.0 V/m; Power Drift = -0.02 dB

Peak SAR (extrapolated) = 17.2 W/kg

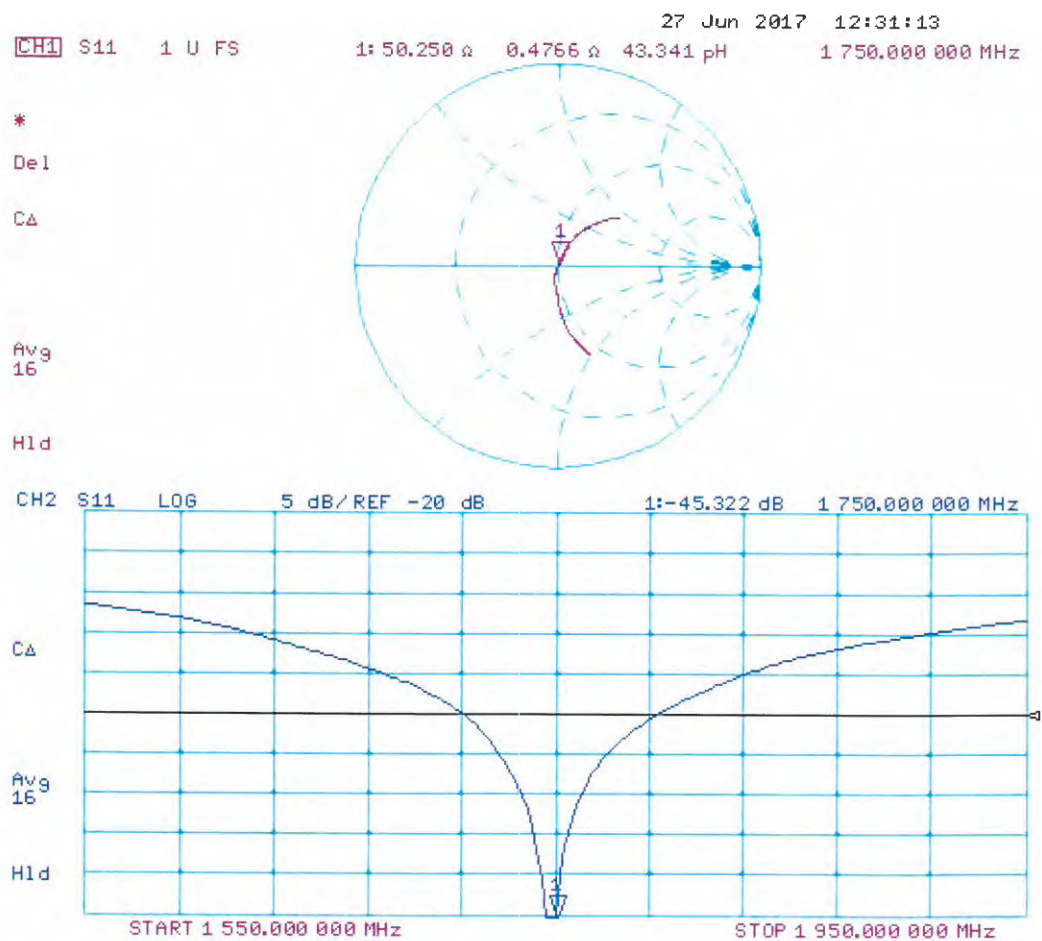
SAR(1 g) = 9.23 W/kg; SAR(10 g) = 4.87 W/kg

Maximum value of SAR (measured) = 14.0 W/kg



0 dB = 14.0 W/kg = 11.46 dBW/kg

Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 27.06.2017

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 1750 MHz; Type: D1750V2; Serial: D1750V2 - SN:1023

Communication System: UID 0 - CW; Frequency: 1750 MHz

Medium parameters used: $f = 1750$ MHz; $\sigma = 1.47$ S/m; $\epsilon_r = 53.2$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(8.46, 8.46, 8.46); Calibrated: 31.05.2017;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 28.03.2017
- Phantom: Flat Phantom 5.0 (back); Type: QD 000 P50 AA; Serial: 1002
- DASY52 52.10.0(1446); SEMCAD X 14.6.10(7417)

Dipole Calibration for Body Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

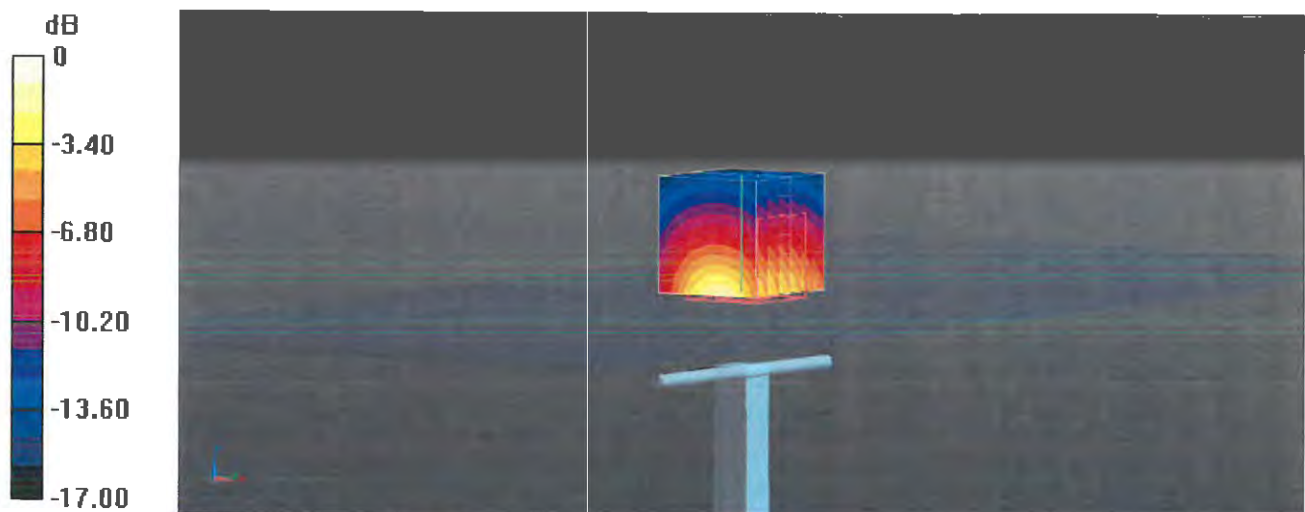
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 99.38 V/m; Power Drift = -0.06 dB

Peak SAR (extrapolated) = 15.9 W/kg

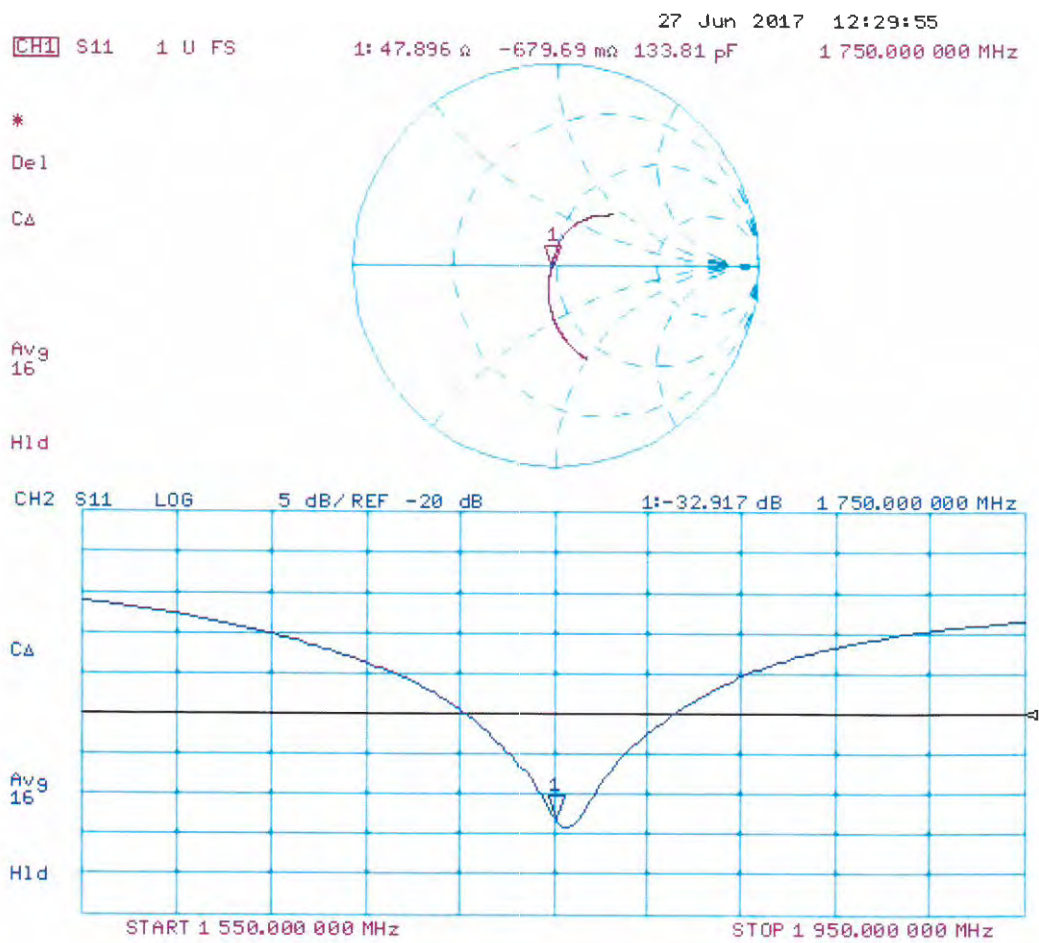
SAR(1 g) = 9.15 W/kg; SAR(10 g) = 4.91 W/kg

Maximum value of SAR (measured) = 13.0 W/kg



0 dB = 13.0 W/kg = 11.14 dBW/kg

Impedance Measurement Plot for Body TSL





Accredited by the Swiss Accreditation Service (SAS)

Accreditation No.: **SCS 0108**

The Swiss Accreditation Service is one of the signatories to the EA
Multilateral Agreement for the recognition of calibration certificates

Client **Auden**

Certificate No: **D1900V2-5d018_Jun17**

CALIBRATION CERTIFICATE

Object **D1900V2 - SN:5d018**

Calibration procedure(s) **QA CAL-05.v9**
Calibration procedure for dipole validation kits above 700 MHz

Calibration date: **June 28, 2017**

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-17 (No. 217-02521/02522)	Apr-18
Power sensor NRP-Z91	SN: 103244	04-Apr-17 (No. 217-02521)	Apr-18
Power sensor NRP-Z91	SN: 103245	04-Apr-17 (No. 217-02522)	Apr-18
Reference 20 dB Attenuator	SN: 5058 (20k)	07-Apr-17 (No. 217-02528)	Apr-18
Type-N mismatch combination	SN: 5047.2 / 06327	07-Apr-17 (No. 217-02529)	Apr-18
Reference Probe EX3DV4	SN: 7349	31-May-17 (No. EX3-7349_May17)	May-18
DAE4	SN: 601	28-Mar-17 (No. DAE4-601_Mar17)	Mar-18

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Power meter EPM-442A	SN: GB37480704	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
Power sensor HP 8481A	SN: US37292783	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
Power sensor HP 8481A	SN: MY41092317	07-Oct-15 (in house check Oct-16)	In house check: Oct-18
RF generator R&S SMT-06	SN: 100972	15-Jun-15 (in house check Oct-16)	In house check: Oct-18
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-16)	In house check: Oct-17

	Name	Function	Signature
Calibrated by:	Johannes Kurikka	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: June 29, 2017

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Accreditation No.: **SCS 0108**

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Multilateral Agreement for the recognition of calibration certificates

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:

- 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"

Additional Documentation:

- 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%.

Measurement Conditions

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

DASY Version	DASY5	V52.10.0
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	1900 MHz \pm 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	40.0	1.40 mho/m
Measured Head TSL parameters	(22.0 \pm 0.2) °C	40.8 \pm 6 %	1.37 mho/m \pm 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	9.85 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	40.1 W/kg \pm 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	5.18 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	20.9 W/kg \pm 16.5 % (k=2)

Body TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	53.3	1.52 mho/m
Measured Body TSL parameters	(22.0 \pm 0.2) °C	54.0 \pm 6 %	1.49 mho/m \pm 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	9.99 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	40.6 W/kg \pm 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	250 mW input power	5.32 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	21.5 W/kg \pm 16.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	$51.2 \Omega + 1.7 j\Omega$
Return Loss	- 33.5 dB

Antenna Parameters with Body TSL

Impedance, transformed to feed point	$47.7 \Omega + 3.6 j\Omega$
Return Loss	- 27.1 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.194 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

Manufactured by	SPEAG
Manufactured on	June 04, 2002

DASY5 Validation Report for Head TSL

Date: 28.06.2017

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN:5d018

Communication System: UID 0 - CW; Frequency: 1900 MHz

Medium parameters used: $f = 1900$ MHz; $\sigma = 1.37$ S/m; $\epsilon_r = 40.8$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(8.43, 8.43, 8.43); Calibrated: 31.05.2017;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 28.03.2017
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.0(1446); SEMCAD X 14.6.10(7417)

Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

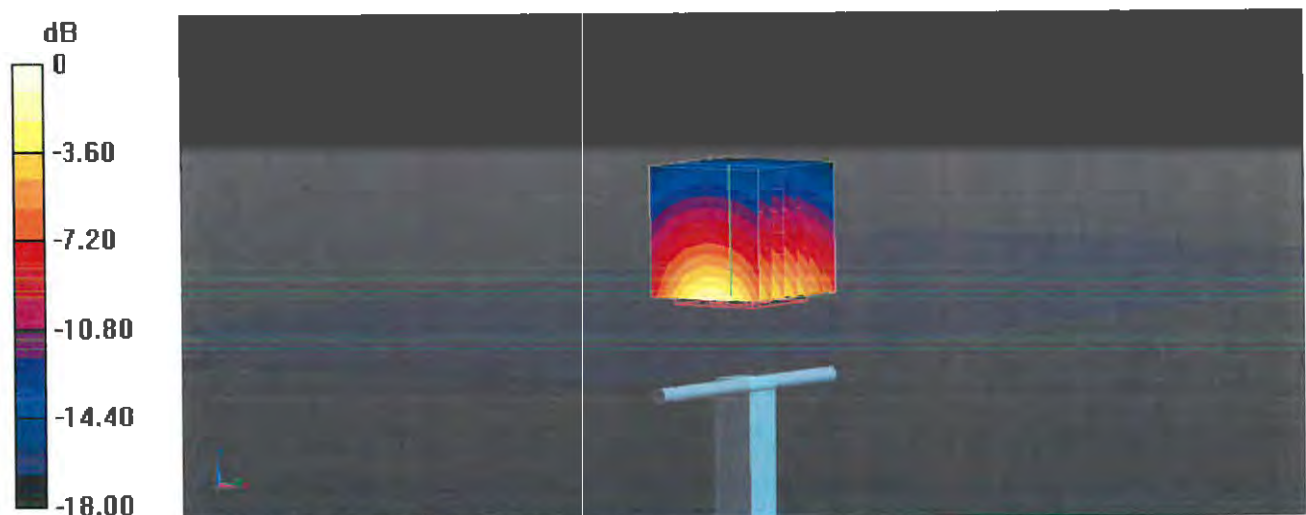
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 106.0 V/m; Power Drift = -0.03 dB

Peak SAR (extrapolated) = 18.2 W/kg

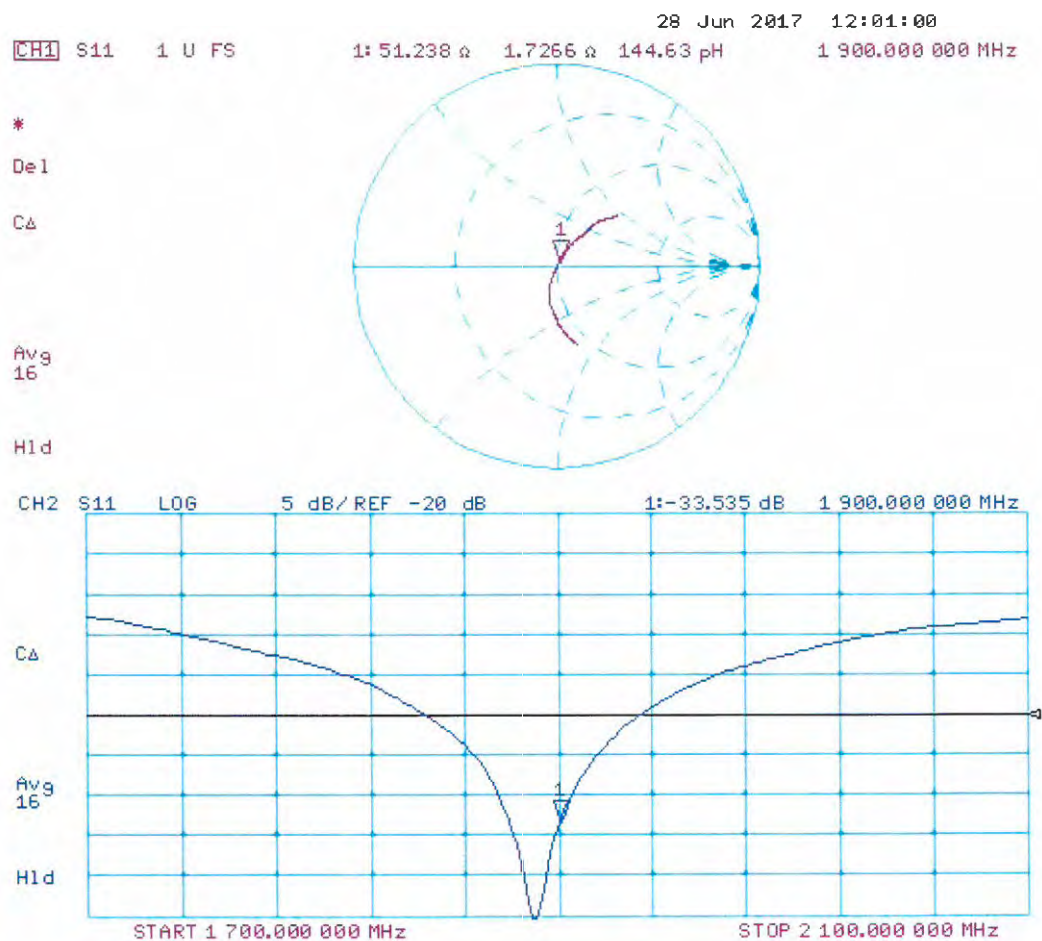
SAR(1 g) = 9.85 W/kg; SAR(10 g) = 5.18 W/kg

Maximum value of SAR (measured) = 15.0 W/kg



0 dB = 15.0 W/kg = 11.76 dBW/kg

Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 28.06.2017

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN:5d018

Communication System: UID 0 - CW; Frequency: 1900 MHz

Medium parameters used: $f = 1900$ MHz; $\sigma = 1.49$ S/m; $\epsilon_r = 54$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(8.2, 8.2, 8.2); Calibrated: 31.05.2017;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 28.03.2017
- Phantom: Flat Phantom 5.0 (back); Type: QD 000 P50 AA; Serial: 1002
- DASY52 52.10.0(1446); SEMCAD X 14.6.10(7417)

Dipole Calibration for Body Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

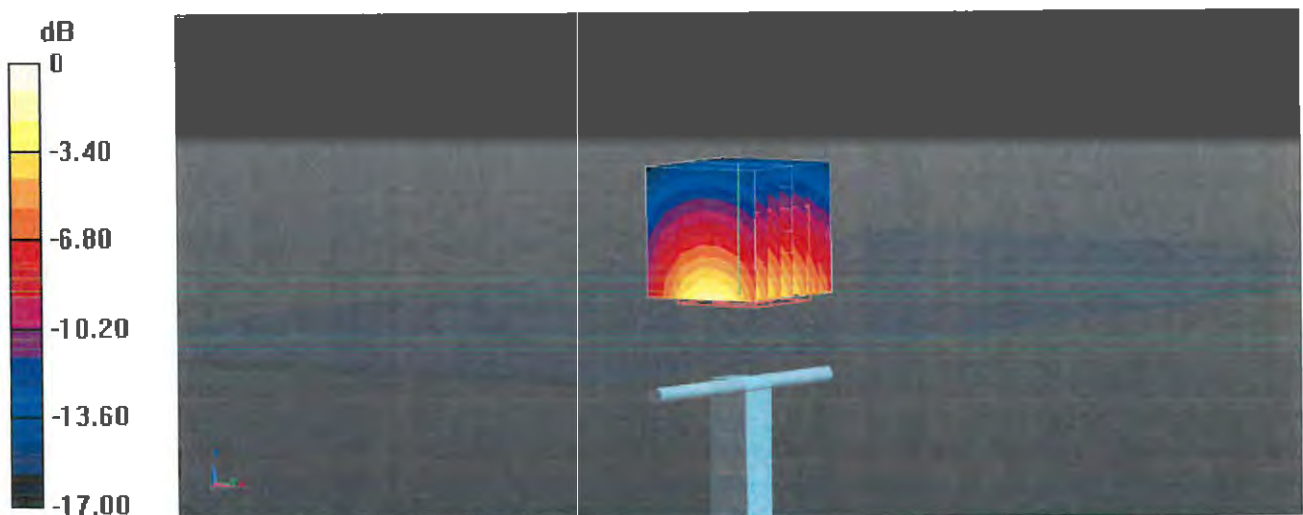
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 103.1 V/m; Power Drift = -0.04 dB

Peak SAR (extrapolated) = 17.5 W/kg

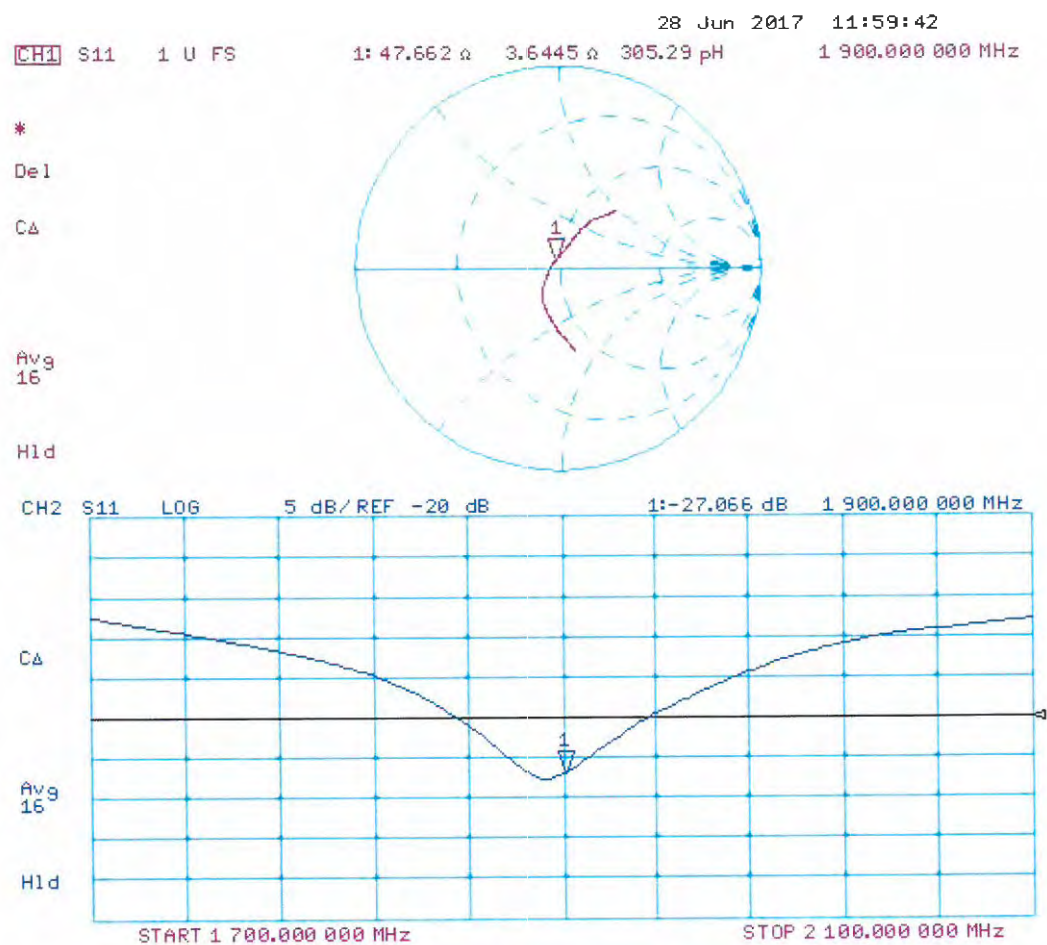
SAR(1 g) = 9.99 W/kg; SAR(10 g) = 5.32 W/kg

Maximum value of SAR (measured) = 14.5 W/kg



0 dB = 14.5 W/kg = 11.61 dBW/kg

Impedance Measurement Plot for Body TSL





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Client

Auden

Certificate No: Z17-97051

CALIBRATION CERTIFICATE

Object EX3DV4 - SN:3661

Calibration Procedure(s) FF-Z11-004-01
Calibration Procedures for Dosimetric E-field Probes

Calibration date: May 05, 2017

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	27-Jun-16 (CTTL, No.J16X04777)	Jun-17
Power sensor NRP-Z91	101547	27-Jun-16 (CTTL, No.J16X04777)	Jun-17
Power sensor NRP-Z91	101548	27-Jun-16 (CTTL, No.J16X04777)	Jun-17
Reference10dBAttenuator	18N50W-10dB	13-Mar-16(CTTL,No.J16X01547)	Mar-18
Reference20dBAttenuator	18N50W-20dB	13-Mar-16(CTTL, No.J16X01548)	Mar-18
Reference Probe EX3DV4	SN 7433	26-Sep-16(SPEAG,No.EX3-7433_Sep16)	Sep-17
DAE4	SN 549	13-Dec-16(SPEAG, No.DAE4-549_Dec16)	Dec -17
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
SignalGeneratorMG3700A	6201052605	27-Jun-16 (CTTL, No.J16X04776)	Jun-17
Network Analyzer E5071C	MY46110673	13-Jan-17 (CTTL, No.J17X00285)	Jan -18

	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: May 06, 2017

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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, "Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300MHz to 3GHz)", February 2005
- 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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Probe EX3DV4

SN: 3661

Calibrated: May 05, 2017

Calibrated for DASY/EASY Systems

(Note: non-compatible with DASY2 system!)



DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3661

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm($\mu\text{V}/(\text{V/m})^2$) ^A	0.48	0.52	0.48	±10.0%
DCP(mV) ^B	101.6	100.2	102.2	

Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Unc ^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	201.4	±2.0%
		Y	0.0	0.0	1.0		213.0	
		Z	0.0	0.0	1.0		202.8	

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 5 and Page 6).

^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.



DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3661

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	9.89	9.89	9.89	0.30	0.85	± 12.1%
835	41.5	0.90	9.57	9.57	9.57	0.13	1.40	± 12.1%
900	41.5	0.97	9.73	9.73	9.73	0.13	1.36	± 12.1%
1750	40.1	1.37	8.47	8.47	8.47	0.17	1.36	± 12.1%
1900	40.0	1.40	8.10	8.10	8.10	0.21	1.10	± 12.1%
2000	40.0	1.40	8.09	8.09	8.09	0.20	1.11	± 12.1%
2300	39.5	1.67	7.93	7.93	7.93	0.39	0.83	± 12.1%
2450	39.2	1.80	7.64	7.64	7.64	0.43	0.82	± 12.1%
2600	39.0	1.96	7.35	7.35	7.35	0.55	0.71	± 12.1%
3500	37.9	2.91	7.23	7.23	7.23	0.53	0.84	± 13.3%
5250	35.9	4.71	5.36	5.36	5.36	0.40	1.30	± 13.3%
5600	35.5	5.07	4.88	4.88	4.88	0.40	1.50	± 13.3%
5750	35.4	5.22	4.87	4.87	4.87	0.40	1.50	± 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.

DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3661

Calibration Parameter Determined in Body 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	55.5	0.96	9.85	9.85	9.85	0.30	0.90	± 12.1%
835	55.2	0.97	9.60	9.60	9.60	0.16	1.43	± 12.1%
900	55.0	1.05	9.69	9.69	9.69	0.20	1.19	± 12.1%
1750	53.4	1.49	8.26	8.26	8.26	0.22	1.11	± 12.1%
1900	53.3	1.52	7.88	7.88	7.88	0.15	1.55	± 12.1%
2000	53.3	1.52	7.92	7.92	7.92	0.21	1.24	± 12.1%
2300	52.9	1.81	7.81	7.81	7.81	0.37	1.05	± 12.1%
2450	52.7	1.95	7.54	7.54	7.54	0.29	1.46	± 12.1%
2600	52.5	2.16	7.45	7.45	7.45	0.32	1.19	± 12.1%
3500	51.3	3.31	6.67	6.67	6.67	0.59	0.94	± 13.3%
5250	48.9	5.36	4.94	4.94	4.94	0.50	1.45	± 13.3%
5600	48.5	5.77	4.32	4.32	4.32	0.55	1.35	± 13.3%
5750	48.3	5.94	4.52	4.52	4.52	0.55	1.75	± 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.

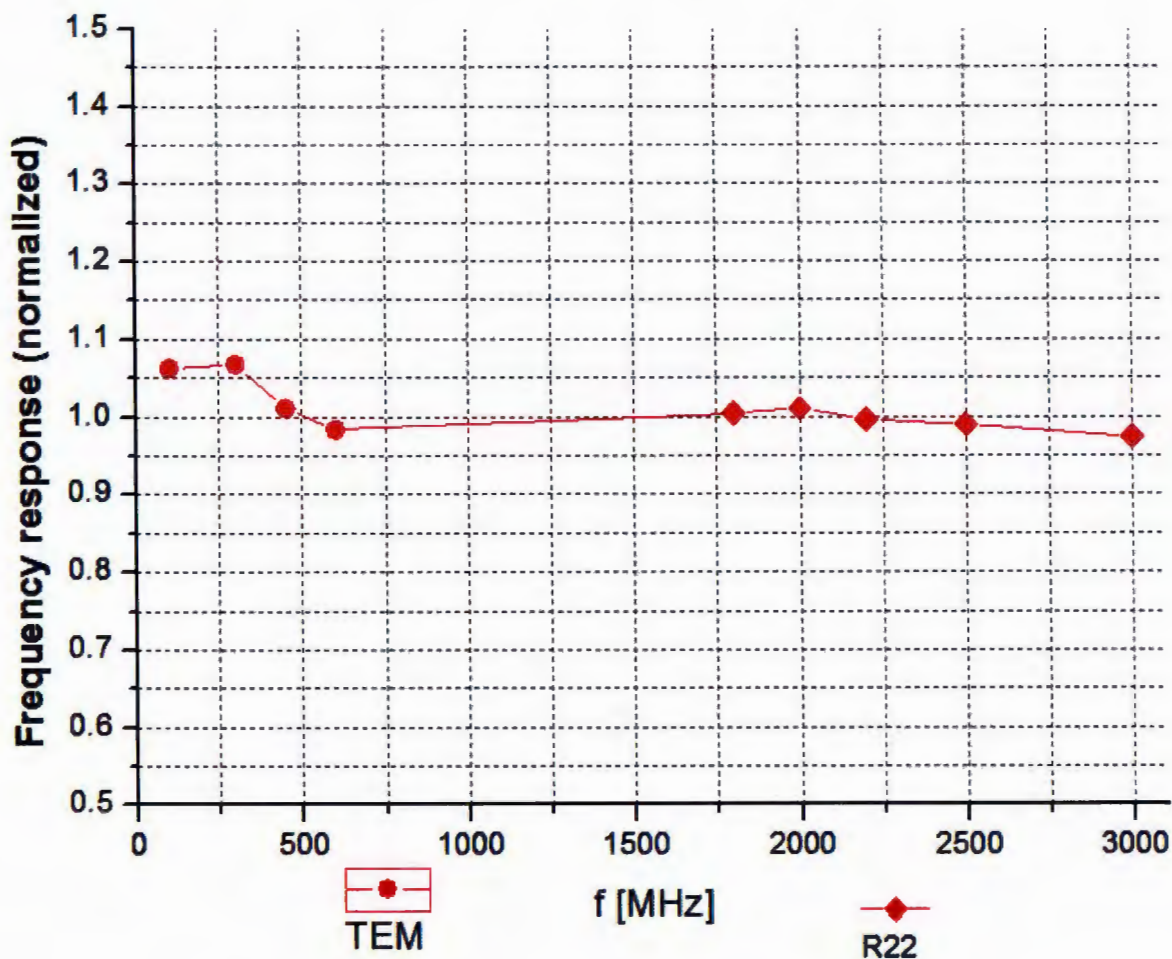
^F At frequency below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ±5%. The uncertainty is the RSS of the ConvF uncertainty 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: $\pm 7.4\%$ ($k=2$)

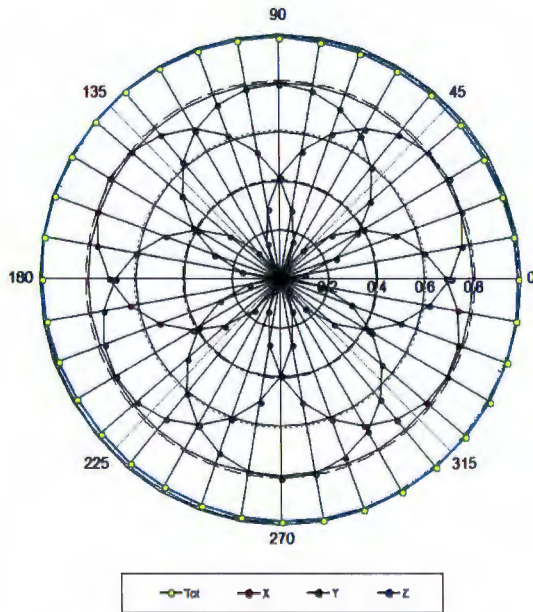


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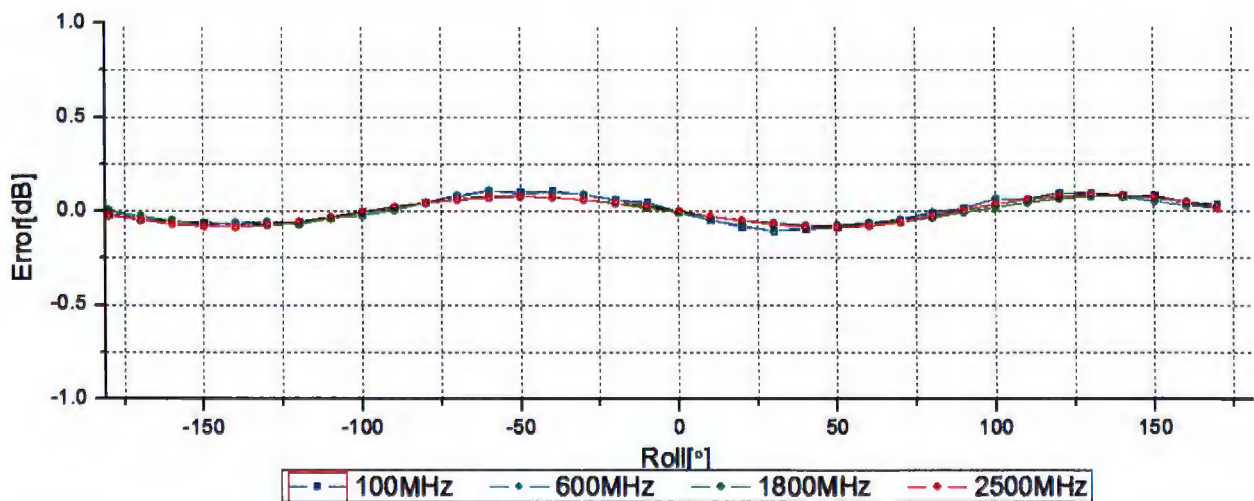
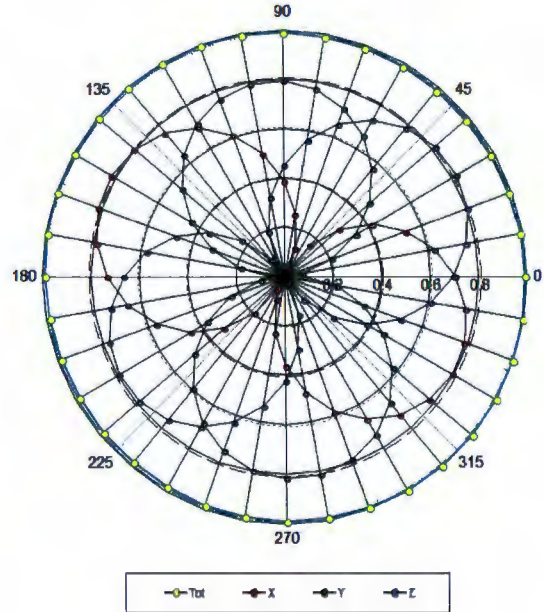
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Receiving Pattern (Φ), $\theta=0^\circ$

f=600 MHz, TEM



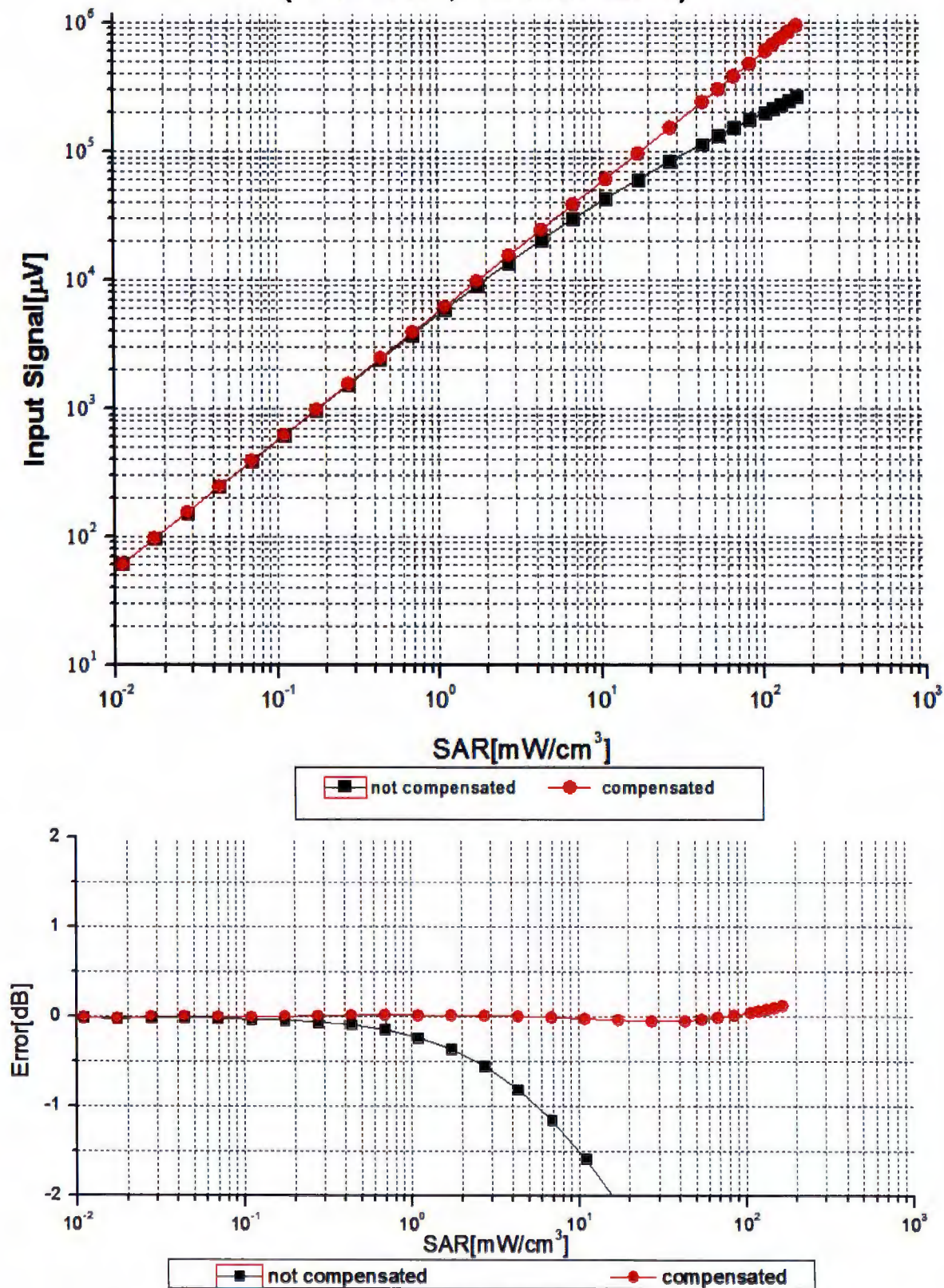
f=1800 MHz, R22



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



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



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



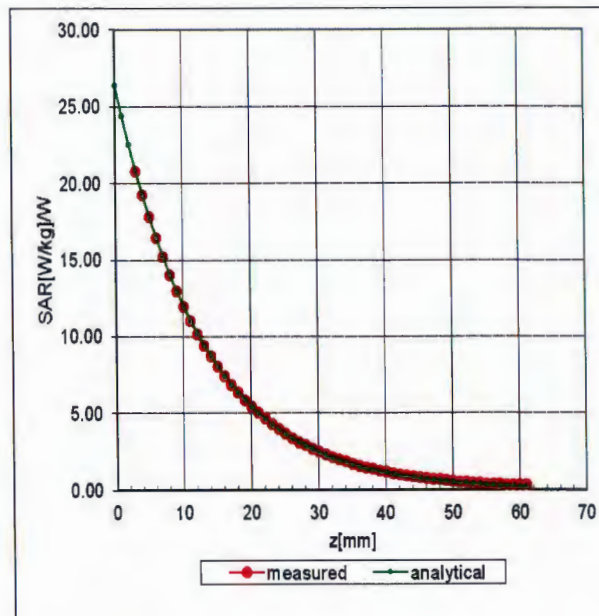
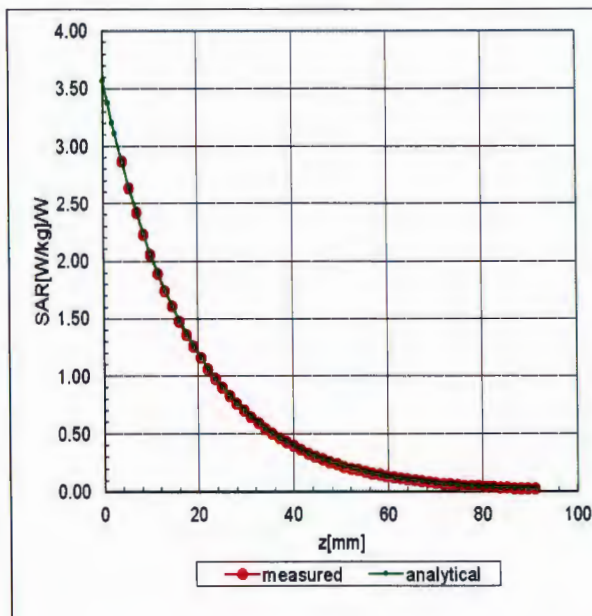
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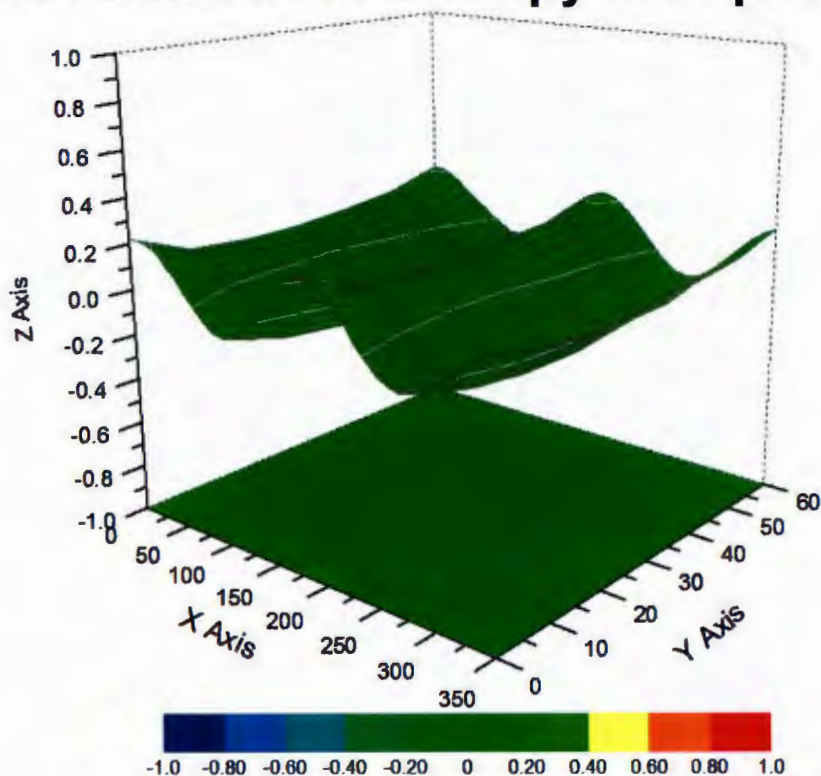
Conversion Factor Assessment

f=900 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: 3661

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	129.5
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

g14

IMPORTANT NOTICE

USAGE OF THE DAE 4

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 DAE4 unit is closed using a screw, over tightening the screw may cause the threads inside the DAE to wear out.

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 exact 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.



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: **DAE4-914_Jan17**

CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BK - SN: 914**

Calibration procedure(s) **QA CAL-06.v29**
Calibration procedure for the data acquisition electronics (DAE)

Calibration date: **January 06, 2017**

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 $(22 \pm 3)^{\circ}\text{C}$ 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	09-Sep-16 (No:19065)	Sep-17
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	05-Jan-16 (in house check)	In house check: Jan-17
Calibrator Box V2.1	SE UMS 006 AA 1002	05-Jan-16 (in house check)	In house check: Jan-17

Calibrated by:	Name	Function	Signature
	Adrian Gehring	Technician	

Approved by:	Fin Bomholt	Deputy Technical Manager
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Issued: January 6, 2017

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



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Accreditation No.: **SCS 0108**

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 = 6.1 μ V , full range = -100...+300 mV

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

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

Calibration Factors	X	Y	Z
High Range	405.068 \pm 0.02% (k=2)	404.262 \pm 0.02% (k=2)	403.838 \pm 0.02% (k=2)
Low Range	3.99100 \pm 1.50% (k=2)	3.98852 \pm 1.50% (k=2)	3.98993 \pm 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	63.0 ° \pm 1 °
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Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	200030.35	-2.48	-0.00
Channel X	+ Input	20004.16	-0.79	-0.00
Channel X	- Input	-20002.66	2.18	-0.01
Channel Y	+ Input	200031.50	-1.21	-0.00
Channel Y	+ Input	20001.20	-3.60	-0.02
Channel Y	- Input	-20005.09	-0.13	0.00
Channel Z	+ Input	200030.04	-2.90	-0.00
Channel Z	+ Input	20001.59	-3.09	-0.02
Channel Z	- Input	-20005.25	-0.22	0.00

Low Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	2001.33	0.09	0.00
Channel X	+ Input	201.16	-0.23	-0.11
Channel X	- Input	-198.51	0.20	-0.10
Channel Y	+ Input	2001.28	0.13	0.01
Channel Y	+ Input	200.65	-0.57	-0.28
Channel Y	- Input	-198.57	0.21	-0.10
Channel Z	+ Input	2001.06	-0.12	-0.01
Channel Z	+ Input	200.14	-1.11	-0.55
Channel Z	- Input	-200.23	-1.40	0.70

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	-12.74	-14.35
	- 200	15.28	13.78
Channel Y	200	-5.02	-5.61
	- 200	4.04	3.96
Channel Z	200	5.14	5.29
	- 200	-8.12	-7.94

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	-	2.77	-4.96
Channel Y	200	7.37	-	3.14
Channel Z	200	9.77	5.64	-

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	16120	13405
Channel Y	16156	16416
Channel Z	16016	14609

5. Input Offset Measurement

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

Input 10M Ω

	Average (μ V)	min. Offset (μ V)	max. Offset (μ V)	Std. Deviation (μ V)
Channel X	0.49	-1.54	2.62	0.45
Channel Y	0.81	-0.16	2.34	0.55
Channel Z	-0.14	-2.56	1.83	0.56

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

Appendix D. Photographs of EUT and Setup