

# SAR TEST REPORT



The following samples were submitted and identified on behalf of the client as:

<b>Product Name</b>	Single Stream 802.11 a/b/g/n/ac + BT4.1 M.2 Type Card
<b>Brand Name</b>	Qualcomm Atheros
<b>Model No.</b>	QCNFA435
<b>Prepared for</b>	Qualcomm Atheros, Inc. 1700 Technology Drive, San Jose, CA 95110
<b>Standards</b>	IEEE/ANSI C95.1-1992, IEEE 1528-2013, KDB248227D01v02r02, KDB865664D01v01r04, KDB865664D02v01r02, KDB447498D01v06, KDB616217D04v01r02
<b>FCC ID</b>	PPD-QCNFA435
<b>Date of Receipt</b>	Jul. 13, 2016
<b>Date of Test(s)</b>	Aug. 01, 2016 ~ Aug. 03, 2016
<b>Date of Issue</b>	Sep. 13, 2016

In the configuration tested, the EUT complied with the standards specified above.

**Remarks:**

This report details the results of the testing carried out on one sample, the results contained in this test report do not relate to other samples of the same product. The manufacturer should ensure that all products in series production are in conformity with the product sample detailed in this report.

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**Signed on behalf of SGS****Engineer****Afu Chen****Date: Sep. 13, 2016****Supervisor****John Yeh****Date: Sep. 13, 2016**

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## Revision History

Report Number	Revision	Description	Issue Date
E5/2016/70014	Rev.00	Initial creation of document	Aug. 12, 2016
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E5/2016/70014	Rev.02	2 <sup>nd</sup> modification	Aug. 17, 2016
E5/2016/70014	Rev.03	3 <sup>rd</sup> modification	Sep. 08, 2016
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## 1. General Information

### 1.1 Testing Laboratory

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No.134, Wu Kung Road, New Taipei Industrial Park, Wuku District, New Taipei City, Taiwan	
Tel	+886-2-2299-3279
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Internet	<a href="http://www.tw.sgs.com/">http://www.tw.sgs.com/</a>

### 1.2 Details of Applicant

Company Name	Acer Incorporated
Company Address	8F., No. 88, Sec. 1, Xintai 5th Rd., Xizhi, New Taipei City 22181, Taiwan (R.O.C)

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### 1.3 Description of EUT

Product Name of Host	Notebook Computer	
Brand Name		
Model No. of Host	N16P9	
Model No. of BT/WLAN Module	QCNFA435	
FCC ID	PPD-QCNFA435	
Antenna Designation (Maximum Gain)	Main_2.45GHz: -2.71, 5GHz: -0.99	
Mode of Operation	<input checked="" type="checkbox"/> WLAN802.11 a/b/g/n(20M/40M)/ac(20M/40M/80M) <input checked="" type="checkbox"/> Bluetooth	
Duty Cycle	WLAN802.11 a/b/g/n(20M/40M)/ac(20M/40M/80M)	1
	Bluetooth	1
TX Frequency Range (MHz)	WLAN802.11 b/g/n(20M)	2412 — 2462
	WLAN802.11 n(40M)	2422 — 2452
	WLAN802.11 a/n(20M)/ac(20M) 5.2G	5180 — 5240
	WLAN802.11 n(40M)/ac(40M) 5.2G	5190 — 5230
	WLAN802.11 ac(80M) 5.2G	5210
	WLAN802.11 a/n(20M)/ac(20M) 5.3G	5260 — 5320
	WLAN802.11 n(40M)/ac(40M) 5.3G	5270 — 5310
	WLAN802.11 ac(80M) 5.3G	5290
	WLAN802.11 a/n/ac(20M) 5.6G	5500 — 5720
	WLAN802.11 n/ac(40M) 5.6G	5510 — 5710
	WLAN802.11 ac(80M) 5.6G	5530 — 5690
	WLAN802.11 a/n(20M)/ac(20M) 5.8G	5745 — 5825
	WLAN802.11 n(40M)/ac(40M) 5.8G	5710 — 5795
	WLAN802.11 ac(80M) 5.8G	5775
	Bluetooth	2402 — 2480

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Channel Number (ARFCN)	WLAN802.11 b/g/n(20M)	1	—	11
	WLAN802.11 n(40M)	3	—	9
	WLAN802.11 a/n(20M)/ac(20M) 5.2G	36	—	48
	WLAN802.11 n(40M)/ac(40M) 5.2G	38	—	46
	WLAN802.11 ac(80M) 5.2G			42
	WLAN802.11 a/n(20M)/ac(20M) 5.3G	52	—	64
	WLAN802.11 n(40M)/ac(40M) 5.3G	54	—	62
	WLAN802.11 ac(80M) 5.3G			58
	WLAN802.11 a/n/ac(20M) 5.6G	100	—	144
	WLAN802.11 n/ac(40M) 5.6G	102	—	142
	WLAN802.11 ac(80M) 5.6G	106	—	138
	WLAN802.11 a/n(20M)/ac(20M) 5.8G	149	—	165
	WLAN802.11 n(40M)/ac(40M) 5.8G	142	—	159
	WLAN802.11 ac(80M) 5.8G			155
	Bluetooth	0	—	78

Max. SAR (1 g) (Unit: W/Kg)					
Antenna	Band	Measured	Reported	Channel	Position
Main	WLAN802.11b	0.442	0.443	6	Top side
	WLAN802.11 a 5.2G	0.478	0.481	48	Top side
	WLAN802.11 a 5.3G	0.523	0.524	56	Top side
	WLAN802.11 a 5.6G	0.277	0.278	120	Back side
	WLAN802.11 a 5.8G	0.284	0.287	165	Back side

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**WLAN802.11 a/b/g/n(20M/40M)/ac(20M/40M/80M) conducted power table:****Main (CH0)**

802.11 b		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)	
CH	Frequency (MHz)		Data Rate (Mbps)	
			1	
1	2412	20.5	20.34	
6	2437	20.5	20.49	
11	2462	20.5	20.48	

802.11 g		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)	
CH	Frequency (MHz)		Data Rate (Mbps)	
			6	
1	2412	17.5	17.21	
6	2437	19.5	19.33	
11	2462	18	17.85	

802.11 n(20M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)	
CH	Frequency (MHz)		Data Rate (Mbps)	
			6.5	
1	2412	17.5	17.31	
6	2437	19.5	19.24	
11	2462	17	16.82	

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**Main (CH0)**

802.11 n(40M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)
CH	Frequency (MHz)		Data Rate (Mbps)
			13.5
3	2422	16.5	16.31
6	2437	18.5	18.44
9	2452	15	14.98

802.11 ac(20M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)
CH	Frequency (MHz)		Data Rate (Mbps)
			13
1	2412	17.5	17.12
6	2437	19.5	19.44
11	2462	17	16.54

802.11 ac(40M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)
CH	Frequency (MHz)		Data Rate (Mbps)
			27
3	2422	16.5	16.21
6	2437	18.5	18.13
9	2452	15	14.88

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**Main (CH0)**

802.11 a		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)	
5.2/5.3/5.6/5.8G			Data Rate (Mbps)	
CH	Frequency (MHz)		6	
36	5180	15.5	15.48	
40	5200	17	16.80	
44	5220	17	16.71	
48	5240	17	16.97	
52	5260	17	16.91	
56	5280	17	16.99	
60	5300	17	16.98	
64	5320	16	15.88	
100	5500	15	14.64	
104	5520	17	16.97	
120	5600	17	16.99	
136	5680	17	16.96	
140	5700	14.5	14.21	
149	5745	17	16.82	
157	5785	17	16.92	
165	5825	17	16.95	

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**Main (CH0)**

802.11 n(20M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)	
5.2/5.3/5.6/5.8G			Data Rate (Mbps)	
CH	Frequency (MHz)		6.5	
36	5180	15.5	15.33	
40	5200	17	16.92	
44	5220	17	16.91	
48	5240	17	16.83	
52	5260	17	16.66	
56	5280	16	15.67	
60	5300	17	16.72	
64	5320	15	14.72	
100	5500	15	14.64	
120	5600	17	16.88	
140	5700	15	14.73	
149	5745	17	16.67	
157	5785	17	16.61	
165	5825	17	16.73	

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**Main (CH0)**

802.11 n(40M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)	
5.2/5.3/5.6/5.8G			Data Rate (Mbps)	
CH	Frequency (MHz)		13.5	
38	5190	12	11.85	
46	5230	16	15.82	
54	5270	16	15.81	
62	5310	13	12.78	
102	5510	13	12.91	
110	5550	16	15.66	
118	5590	16	15.63	
134	5670	15.5	15.24	
151	5755	15	14.93	
159	5795	16	15.79	

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**Main (CH0)**

802.11 ac(20M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)	
5.2/5.3/5.6/5.8G			Data Rate (Mbps)	
CH	Frequency (MHz)		6.5	
36	5180	15.5	15.34	
40	5200	17	16.65	
44	5220	17	16.54	
48	5240	17	16.92	
52	5260	17	16.78	
56	5280	16	15.82	
60	5300	17	16.99	
64	5320	15	14.82	
100	5500	15	14.81	
104	5520	17	16.92	
120	5600	17	16.94	
136	5680	17	16.86	
140	5700	15	14.67	
144	5720	17	16.93	
149	5745	17	16.42	
157	5785	17	16.81	
165	5825	17	16.62	

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**Main (CH0)**

802.11 ac(40M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)
CH	Frequency (MHz)		Data Rate (Mbps)
			13.5
38	5190	12	11.99
46	5230	16	15.43
54	5270	16	15.68
62	5310	13	12.92
102	5510	13	12.91
118	5590	16	15.82
134	5670	15.5	15.24
142	5710	16	15.83
151	5755	15	14.93
159	5795	16	15.99

802.11 ac(80M)		Max. Rated Avg. Power + Max. Tolerance (dBm)	Average conducted output power (dBm)
CH	Frequency (MHz)		Data Rate (Mbps)
			29.3
42	5210	14	13.92
58	5290	12	11.78
106	5530	12	11.72
122	5610	16	15.67
138	5690	16	15.83
155	5775	14.5	14.44

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**Bluetooth conducted power table:**

Frequency (MHz)	Data Rate	Max. power(dBm)	Avg.	
			dBm	mW
2402	1	6	3.98	2.500
2441	1	6	4.34	2.716
2480	1	6	4.35	2.723
2402	2	6	0.88	1.225
2441	2	6	1.35	1.365
2480	2	6	1.35	1.365
2402	3	6	0.92	1.236
2441	3	6	1.34	1.361
2480	3	6	1.34	1.361

Frequency (MHz)	Max. power(dBm)	Avg.	
		BT4.0	
		dBm	mW
2402	6	1.88	1.540
2442	6	2.04	1.598
2480	6	1.90	1.550

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## 1.4 Test Environment

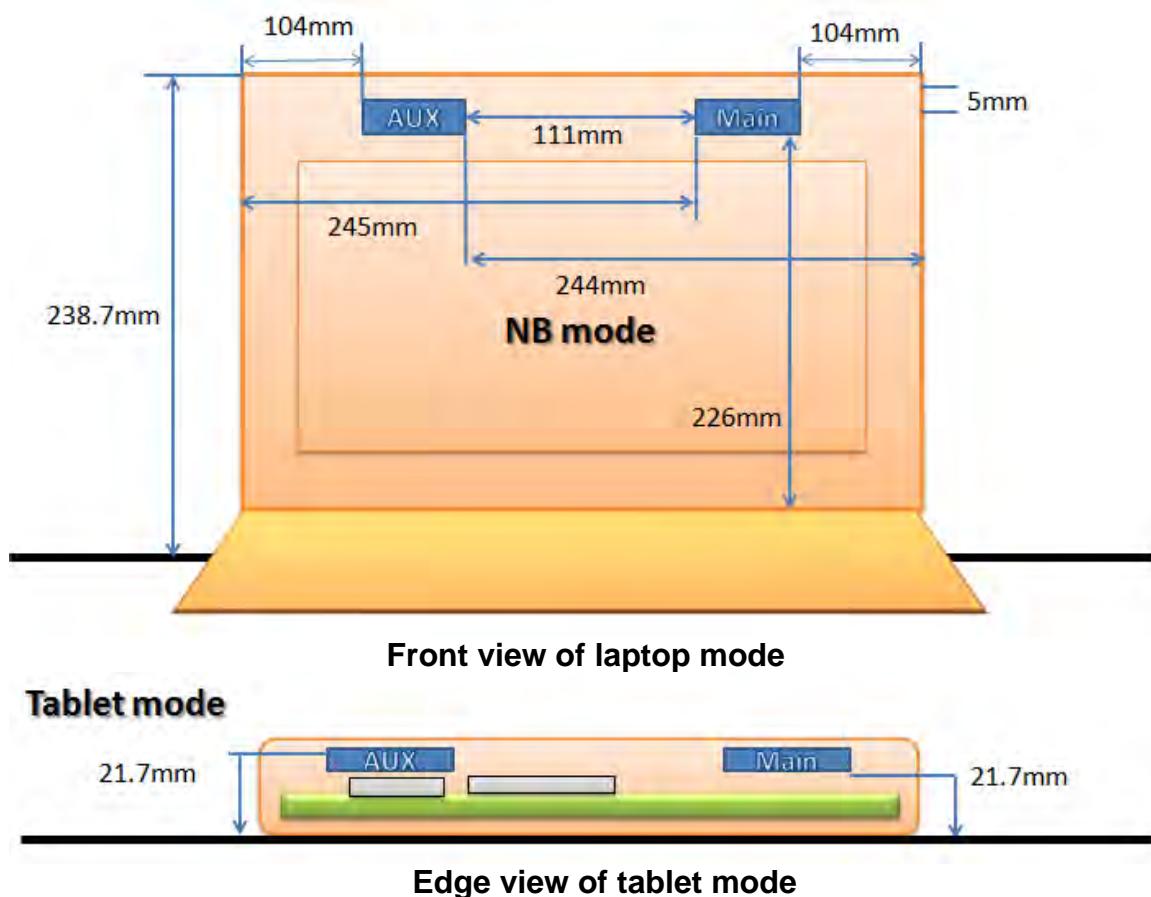
Ambient Temperature:  $22 \pm 2^\circ \text{C}$   
Tissue Simulating Liquid:  $22 \pm 2^\circ \text{C}$

## 1.5 Operation Description

Use chipset specific software to control the EUT, and makes it transmit in maximum power. Measurements are performed respectively on the lowest, middle and highest channels of the operating band(s). The EUT is set to maximum power level during all tests, and at the beginning of each test the battery is fully charged.

EUT was tested in the following configurations:

**WLAN Main: back/top sides with test distance 0mm. (tablet mode)**  
**(SAR measurement is not required for laptop mode since the distance between the antenna and the bottom of keyboard is > 20cm)**



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Note:

802.11b DSSS SAR Test Requirements:

1. SAR is measured for 2.4 GHz 802.11b DSSS mode using the highest measured maximum output power channel, when the reported SAR of the highest measured maximum output power channel for the exposure configuration is  $\leq$  0.8 W/kg, no further SAR testing is required for 802.11b DSSS in that exposure configuration.
2. When the reported SAR is  $>$  0.8 W/kg, SAR is required for that exposure configuration using the next highest measured output power channel. When any reported SAR is  $>$  1.2 W/kg, SAR is required for the third channel; i.e., all channels require testing.

802.11g/n OFDM SAR Test Exclusion Requirements:

3. SAR is not required for 802.11g/n since the highest reported SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and the adjusted SAR is  $\leq$  1.2 W/kg.

Initial Test Configuration:

4. An initial test configuration is determined for OFDM transmission modes according to the channel bandwidth, modulation and data rate combination(s) with the highest maximum output power specified for production units in each standalone and aggregated frequency band.
5. SAR is measured using the highest measured maximum output power channel. When the reported SAR of the initial test configuration is  $>$  0.8 W/kg, SAR measurement is required for the subsequent next highest measured output power channel(s) in the initial test configuration until the reported SAR is  $\leq$  1.2 W/kg or all required channels are tested.
6. For WLAN Main antenna, 5.2a/5.3a/5.6a/5.8a is chosen to be the initial test configurations.
7. Since the highest reported SAR for the initial test configuration is adjusted by the ratio of the subsequent test configuration to initial test configuration specified maximum output power and the adjusted SAR is  $<$  1.2 W/kg, SAR is not required for subsequent test configuration.
8. BT and WLAN Main use the same antenna path and Bluetooth can't transmit simultaneously with WLAN Main.
9. The device supports 1Tx only for Main antenna.

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10. According to KDB447498 D01, testing of other required channels is not required when the reported 1-g SAR for the highest output channel is  $\leq 0.8$  W/kg, when the transmission band is  $\leq 100$  MHz.
11. According to KDB865664 D01, SAR measurement variability must be assessed for each frequency band. When the original highest measured SAR is  $\geq 0.8$  W/kg, repeated that measurement once. Perform a second repeated measurement only 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  $\geq 1.45$  W/kg (~10% from the 1-g SAR limit)
12. Based on KDB447498D01,

- (1) SAR test exclusion thresholds for 100 MHz to 6 GHz at test separation distances  $\leq 50$  mm are determined by:

$$\frac{\text{Max. tune up power(mW)}}{\text{Min. test separation distance(mm)}} \times \sqrt{f(\text{GHz})} \leq 3$$

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

- (2) For test separation distances  $> 50$  mm, and the frequency at 100 MHz to 1500MHz, the SAR test exclusion threshold is determined according to the following, and as illustrated in Appendix B of KDB447498 D01.  
 $[(\text{Threshold at } 50\text{mm in step1}) + (\text{test separation distance}-50\text{mm}) \times (\frac{f(\text{MHz})}{150})](\text{mW})$ ,
- (3) For test separation distances  $> 50$  mm, and the frequency at  $>1500$ MHz to 6GHz, the SAR test exclusion threshold is determined according to the following, and as illustrated in Appendix B of KDB447498 D01.  
 $[(\text{Threshold at } 50\text{mm in step1}) + (\text{test separation distance}-50\text{mm}) \times 10](\text{mW})$ ,

#### SAR test exclusion evaluation for tablet mode

Mode	Max. tune-up power(dBm)	Max. tune-up power(mW)	Top side			Right side			Left side		
			antenna to user separation distance (mm)	Calculation value	Require SAR testing?	antenna to user separation distance (mm)	Calculation value	Require SAR testing?	antenna to user separation distance (mm)	>20cm	Require SAR testing?
WLAN Main 2.45GHz	20.5	112.202	5	35.339	YES	104	543.534	NO	245	YES	NO
WLAN Main 5GHz	17	50.119	5	24.192	YES	104	542.419	NO	245	YES	NO
BT	6	3.981	5	1.254	NO	104	540.125	NO	245	YES	NO

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Mode	Max. tune-up power(dBm)	Max. tune-up power(mW)	Bottom side			Back side		
			antenna to user separation distance (mm)	>20cm	Require SAR testing?	antenna to user separation distance (mm)	Calculation value	Require SAR testing?
WLAN Main 2.45GHz	20.5	112.202	226	YES	NO	21.7	8.113	YES
WLAN Main 5GHz	17	50.119	226	YES	NO	21.7	5.574	YES
BT	6	3.981	226	YES	NO	21.7	0.289	NO

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## 1.6 The SAR Measurement System

A block diagram of the SAR measurement System is given in Fig. a. This SAR Measurement System uses a Computer-controlled 3-D stepper motor system (SPEAG DASY 5 professional system). The model EX3DV4 field probe is used to determine the internal electric fields. The SAR can be obtained from the equation  $SAR = \sigma (|E_i|^2) / \rho$  where  $\sigma$  and  $\rho$  are the conductivity and mass density of the tissue-simulant.

The DASY 5 system for performing compliance tests consists of the following items:

1. A standard high precision 6-axis robot (Staubli RX family) with controller, teach pendant and software. An arm extension is for accommodating the data acquisition electronics (DAE).
2. A dosimetric probe, i.e., an isotropic E-field probe optimized and calibrated for usage intissue simulating liquid. The probe is equipped with an optical surface detector system.
3. A data acquisition electronics (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.

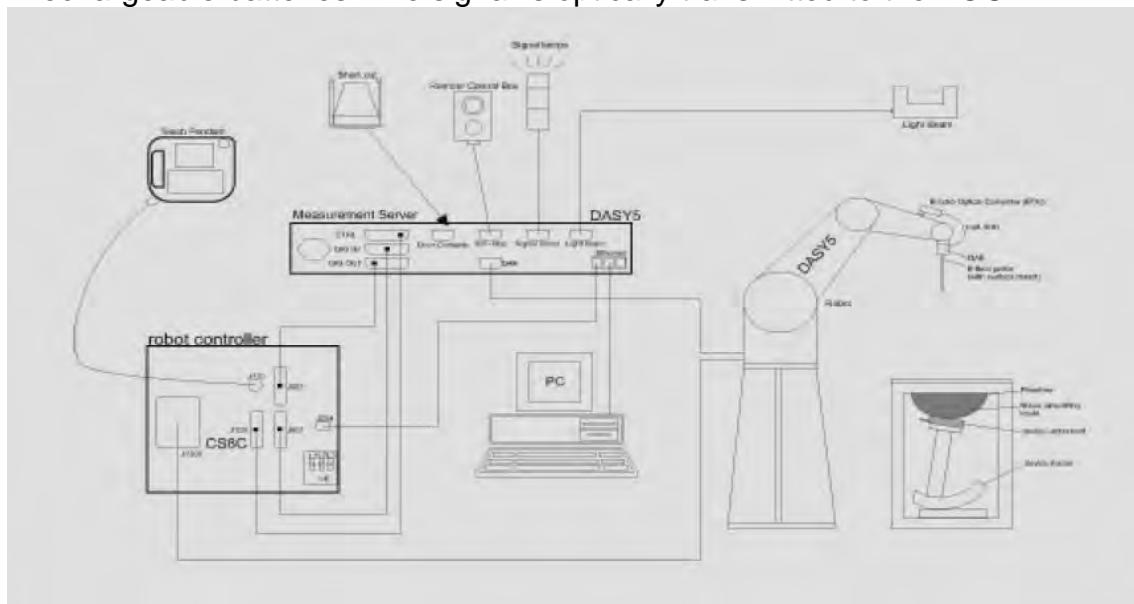


Fig. a The block diagram of SAR system

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4. The Electro-optical converter (EOC) performs the conversion between optical and electrical of the signals for the digital communication to the DAE and for the analog signal from the optical surface detection. The EOC is connected to the measurement server.
5. The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
6. A probe alignment unit which improves the (absolute) accuracy of the probe positioning.
7. A computer operating Windows 7.
8. DASY 5 software.
9. Remote control with teach pendant and additional circuitry for robot safety such as warning lamps, etc.
10. The SAM twin phantom enabling testing left-hand and right-hand usage.
11. The device holder for handheld mobile phones.
12. Tissue simulating liquid mixed according to the given recipes.
13. Validation dipole kits allowing to validate the proper functioning of the system.

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## 1.7 System Components

### EX3DV4 E-Field Probe

Construction	Symmetrical design with triangular core Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)	
Calibration	Basic Broad Band Calibration in air Conversion Factors (CF) for HSL 2450/5200/5300/5600/5800 MHz Additional CF for other liquids and frequencies upon request	
Frequency	10 MHz to > 6 GHz	
Directivity	± 0.3 dB in HSL (rotation around probe axis) ± 0.5 dB in tissue material (rotation normal to probe axis)	
Dynamic Range	10 µW/g to > 100 mW/g Linearity: ± 0.2 dB (noise: typically < 1 µW/g)	
Dimensions	Tip diameter: 2.5 mm	
Application	High precision dosimetric measurements in any exposure scenario (e.g., very strong gradient fields). Only probe which enables compliance testing for frequencies up to 6 GHz with precision of better 30%.	

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**SAM PHANTOM V4.0C**

Construction	The shell corresponds to the specifications of the Specific Anthropomorphic Mannequin (SAM) phantom defined in IEEE 1528 and IEC 62209. 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 manually teaching three points with the robot.
Shell Thickness	2 ± 0.2 mm
Filling Volume	Approx. 25 liters
Dimensions	Height: 850 mm; Length: 1000 mm; Width: 500 mm

**DEVICE HOLDER**

Construction	The device holder (Supporter) for Notebook is made by POM (polyoxymethylene resin), which is non-metal and non-conductive. The height can be adjusted to fit varies kind of notebooks.	
Device Holder		

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## 1.8 SAR System Verification

The microwave circuit arrangement for system verification is sketched in Fig. b. The daily system accuracy verification occurs within the flat section of the SAM phantom. A SAR measurement was performed to see if the measured SAR was within  $\pm 10\%$  from the target SAR values. These tests were done at 2450/5200/5300/5600/5800 MHz. The tests were conducted on the same days as the measurement of the DUT. The obtained results from the system accuracy verification are displayed in the table 1 (SAR values are normalized to 1W forward power delivered to the dipole). During the tests, the ambient temperature of the laboratory was 21.7°C, the relative humidity was 62% and the liquid depth above the ear reference points was  $\geq 15 \text{ cm} \pm 5 \text{ mm}$  (frequency  $\leq 3 \text{ GHz}$ ) or  $\geq 10 \text{ cm} \pm 5 \text{ mm}$  (frequency  $> 3 \text{ GHz}$ ) in all the cases. It is seen that the system is operating within its specification, as the results are within acceptable tolerance of the reference values.

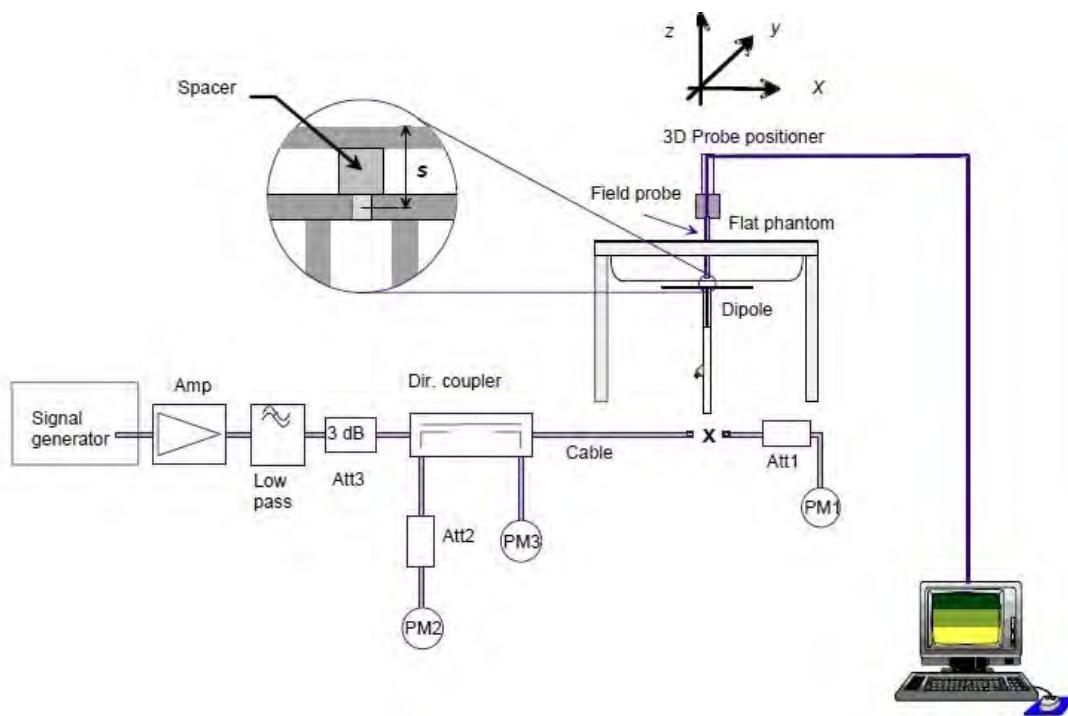


Fig. b The block diagram of system verification

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Validation Kit	S/N	Frequency (MHz)		1W Target SAR-1g (mW/g)	Measured SAR-1g (mW/g)	Measured SAR-1g normalized to 1W (mW/g)	Deviation (%)	Measured Date
D2450V2	727	2450	Body	49.6	12.5	50	0.81%	Aug. 01, 2016
D5GHzV2	1023	5200	Body	71.9	7.1	71	-1.25%	Aug. 01, 2016
		5300	Body	75.1	7.34	73.4	-2.26%	Aug. 01, 2016
		5600	Body	78.3	7.87	78.7	0.51%	Aug. 03, 2016
		5800	Body	75.3	7.55	75.5	0.27%	Aug. 03, 2016

Table 1. Results of system validation

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## 1.9 Tissue Simulant Fluid for the Frequency Band

The dielectric properties for this body-simulant fluid were measured by using the Agilent Model 85070E Dielectric Probe (rates frequency band 200 MHz to 20 GHz) in conjunction with Network Analyzer (30 KHz-6000 MHz).

All dielectric parameters of tissue simulates were measured within 24 hours of SAR measurements. The depth of the tissue simulant in the flat section of the phantom was  $\geq 15 \text{ cm} \pm 5 \text{ mm}$  (Frequency  $\leq 3\text{G}$ ) or  $\geq 10 \text{ cm} \pm 5 \text{ mm}$  (Frequency  $> 3\text{G}$ ) during all tests. (Fig. 2)

Tissue Type	Measurement Date	Measured Frequency (MHz)	Target Dielectric Constant, $\epsilon_r$	Target Conductivity, $\sigma$ (S/m)	Measured Dielectric Constant, $\epsilon_r$	Measured Conductivity, $\sigma$ (S/m)	% dev $\epsilon_r$	% dev $\sigma$
Body	Aug.1, 2016	2437	52.717	1.938	51.153	2.016	2.97%	-4.05%
		2450	52.700	1.950	51.08	2.033	3.07%	-4.26%
		5200	49.014	5.299	49.007	5.178	0.01%	2.29%
		5240	48.960	5.346	48.877	5.245	0.17%	1.89%
		5280	48.906	5.393	48.758	5.302	0.30%	1.68%
		5300	48.879	5.416	48.692	5.324	0.38%	1.70%
	Aug.3, 2016	5600	48.471	5.766	47.77	5.829	1.45%	-1.09%
		5800	48.200	6.000	47.148	6.137	2.18%	-2.28%
		5825	48.166	6.029	47.057	6.183	2.30%	-2.55%

Table 2. Dielectric Parameters of Tissue Simulant Fluid

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## The composition of the tissue simulating liquid:

Frequency (MHz)	Mode	Ingredient						Total amount
		DGMBE	Water	Salt	Preventol D-7	Cellulose	Sugar	
2450M	Body	301.7ml	698.3ml	—	—	—	—	1.0L(Kg)

## Body Simulating Liquids for 5 GHz, Manufactured by SPEAG:

Ingredients	Water	Esters, Emulsifiers, Inhibitors	Sodium and Salt
(% by weight)	60-80	20-40	0-1.5

Table 3. Recipes for Tissue Simulating Liquid

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## 1.10 Evaluation Procedures

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 1 g and 10 g cubes. The algorithm to find the cube with highest averaged SAR is divided into the following stages:

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

The probe is calibrated at the center of the dipole sensors that is located 1 to 2.7mm away from the probe tip. During measurements, the probe stops shortly above the phantom surface, depending on the probe and the surface detecting system. Both distances are included as parameters in the probe configuration file. The software always knows exactly how far away the measured point is from the surface. As the probe cannot directly measure at the surface, the values between the deepest measured point and the surface must be extrapolated. The angle between the probe axis and the surface normal line is less than 30 degree.

In the Area Scan, the gradient of the interpolation function is evaluated to find all the extreme of the SAR distribution. The uncertainty on the locations of the extreme is less than 1/20 of the grid size. Only local maximum within -2 dB of the global maximum are searched and passed for the Cube Scan measurement. In the Cube Scan, the interpolation function is used to extrapolate the Peak SAR from the lowest measurement points to the inner phantom surface (the extrapolation distance). The uncertainty increases with the extrapolation distance. To keep the uncertainty within 1% for the 1 g and 10 g cubes, the extrapolation distance should not be larger than 5mm.

The maximum search is automatically performed after each area scan measurement. It is based on splines in two or three dimensions. The procedure can find the maximum for most SAR distributions even with relatively large grid spacing. After the area scanning measurement, the probe is automatically moved to a position at the interpolated maximum. The following scan can directly use this position for reference, e.g., for a finer resolution grid or the cube evaluations. The 1g and 10g peak evaluations are only available for the predefined cube 7x7x7 scans. The routines are verified and optimized for the grid dimensions used in these cube measurements.

The measured volume of 30x30x30mm contains about 30g of tissue.

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The first procedure is an extrapolation (incl. Boundary correction) to get the points between the lowest measured plane and the surface. The next step uses 3D interpolation to get all points within the measured volume. In the last step, a 1g cube is placed numerically into the volume and its averaged SAR is calculated. This cube is moved around until the highest averaged SAR is found. If the highest SAR is found at the edge of the measured volume, the system will issue a warning: higher SAR values might be found outside of the measured volume. In that case the cube measurement can be repeated, using the new interpolated maximum as the center.

## 1.11 Probe Calibration Procedures

For the calibration of E-field probes in lossy liquids, an electric field with an accurately known field strength must be produced within the measured liquid. For standardization purposes it would be desirable if all measurements which are necessary to assess the correct field strength would be traceable to standardized measurement procedures. In the following two different calibration techniques are summarized:

### 1.11.1 Transfer Calibration with Temperature Probes

In lossy liquids the specific absorption rate (SAR) is related both to the electric field ( $E$ ) and the temperature gradient ( $\delta T / \delta t$ ) in the liquid.

$$SAR = \frac{\sigma}{\rho} |E|^2 = c \frac{\delta T}{\delta t}$$

whereby  $\sigma$  is the conductivity,  $\rho$  the density and  $c$  the heat capacity of the liquid.

Hence, the electric field in lossy liquid can be measured indirectly by measuring the temperature gradient in the liquid. Non-disturbing temperature probes (optical probes or thermistor probes with resistive lines) with high spatial resolution (<1-2 mm) and fast reaction time (<1 s) are available and can be easily calibrated with high precision [1]. The setup and the exciting source have no influence on the calibration; only the relative positioning uncertainties of the standard temperature probe and the E-field probe to be calibrated must be considered. However, several problems limit the available accuracy of probe calibrations with temperature probes:

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- The temperature gradient is not directly measurable but must be evaluated from temperature measurements at different time steps. Special precaution is necessary to avoid measurement errors caused by temperature gradients due to energy equalizing effects or convection currents in the liquid. Such effects cannot be completely avoided, as the measured field itself destroys the thermal equilibrium in the liquid. With a careful setup these errors can be kept small.
- The measured volume around the temperature probe is not well defined. It is difficult to calculate the energy transfer from a surrounding gradient temperature field into the probe. These effects must be considered, since temperature probes are calibrated in liquid with homogeneous temperatures. There is no traceable standard for temperature rise measurements.
- The calibration depends on the assessment of the specific density, the heat capacity and the conductivity of the medium. While the specific density and heat capacity can be measured accurately with standardized procedures (~ 2% for  $c$ ; much better for  $\rho$ ), there is no standard for the measurement of the conductivity. Depending on the method and liquid, the error can well exceed  $\pm 5\%$ .
- Temperature rise measurements are not very sensitive and therefore are often performed at a higher power level than the E-field measurements. The nonlinearities in the system (e.g., power measurements, different components, etc.) must be considered.

Considering these problems, the possible accuracy of the calibration of E-field probes with temperature gradient measurements in a carefully designed setup is about  $\pm 10\%$  (RSS) [2]. Recently, a setup which is a combination of the waveguide techniques and the thermal measurements was presented in [3]. The estimated uncertainty of the setup is  $\pm 5\%$  (RSS) when the same liquid is used for the calibration and for actual measurements and  $\pm 7\text{--}9\%$  (RSS) when not, which is in good agreement with the estimates given in [2].

### 1.11.2 Calibration with Analytical Fields

In this method a technical setup is used in which the field can be calculated analytically from measurements of other physical magnitudes (e.g., input power). This corresponds to the standard field method for probe calibration in air; however, there is no standard defined for fields in lossy liquids.

When using calculated fields in lossy liquids for probe calibration, several points must be considered in the assessment of the uncertainty:

- The setup must enable accurate determination of the incident power.
- The accuracy of the calculated field strength will depend on the assessment of the dielectric parameters of the liquid.

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- Due to the small wavelength in liquids with high permittivity, even small setups might be above the resonant cutoff frequencies. The field distribution in the setup must be carefully checked for conformity with the theoretical field distribution.

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## 1.12 Test Standards and Limits

According to FCC 47CFR §2.1093(d) The limits to be used for evaluation are based generally on criteria published by the American National Standards Institute (ANSI) for localized specific absorption rate (“SAR”) in Section 4.2 of “IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz,” ANSI/IEEE C95.1, By the Institute of Electrical and Electronics Engineers, Inc., New York, New York 10017. These criteria for SAR evaluation are similar to those recommended by the National Council on Radiation Protection and Measurements (NCRP) in “Biological Effects and Exposure Criteria for Radio frequency Electromagnetic Fields,” NCRP Report No. 86, Section 17.4.5. Copyright NCRP, 1986, Bethesda, Maryland 20814. SAR is a measure of the rate of energy absorption due to exposure to an RF transmitting source. SAR values have been related to threshold levels for potential biological hazards. The criteria to be used are specified in paragraphs (d)(1) and (d)(2) of this section and shall apply for portable devices transmitting in the frequency range from 100 kHz to 6 GHz. Portable devices that transmit at frequencies above 6 GHz are to be evaluated in terms of the MPE limits specified in § 1.1310 of this chapter. Measurements and calculations to demonstrate compliance with MPE field strength or power density limits for devices operating above 6 GHz should be made at a minimum distance of 5 cm from the radiating source.

- (1) Limits for Occupational/Controlled exposure: 0.4 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 8 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 20 W/kg, as averaged over an 10 grams of tissue (defined as a tissue volume in the shape of a cube).
- (2) Occupational/Controlled limits apply when persons are exposed as a consequence of their employment provided these persons are fully aware of and exercise control over their exposure. Awareness of exposure can be accomplished by use of warning labels or by specific training or education through appropriate means, such as an RF safety program in a work environment.
- (3) Limits for General Population/Uncontrolled exposure: 0.08 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 1.6 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 4 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). General Population/Uncontrolled limits apply when the general public may be exposed, or when persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or do not

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exercise control over their exposure. Warning labels placed on consumer devices such as cellular telephones will not be sufficient reason to allow these devices to be evaluated subject to limits for occupational/controlled exposure in paragraph (d)(1) of this section. (Table 4.)

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

Table 4. RF exposure limits

Notes:

1. Uncontrolled environments are defined as locations where there is potential exposure of individuals who have no knowledge or control of their potential exposure.
2. Controlled environments are defined as locations where there is potential exposure of individuals who have knowledge of their potential exposure and can exercise control over their exposure.

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## 2. Summary of Results

### WLAN Main Antenna

Antenna	Mode	Position	Distance (mm)	CH	Freq. (MHz)	Max. Rated Avg. Power + Max. Tolerance (dBm)	Measured Avg. Power (dBm)	Scaling	Averaged SAR over 1g (W/kg)		Plot page
									Measured	Reported	
Main	WLAN802.11 b	Back side	0	6	2437	20.5	20.49	0.23%	0.170	0.170	-
		Top side	0	6	2437	20.5	20.49	0.23%	0.442	0.443	35
	WLAN802.11 a 5.2G	Back side	0	48	5240	17	16.97	0.69%	0.235	0.237	-
		Top side	0	48	5240	17	16.97	0.69%	0.478	0.481	36
	WLAN802.11 a 5.3G	Back side	0	56	5280	17	16.99	0.23%	0.242	0.243	-
		Top side	0	56	5280	17	16.99	0.23%	0.523	0.524	37
	WLAN802.11 a 5.6G	Back side	0	120	5600	17	16.99	0.23%	0.277	0.278	38
		Top side	0	120	5600	17	16.99	0.23%	0.247	0.248	-
	WLAN802.11 a 5.8G	Back side	0	165	5825	17	16.95	1.16%	0.284	0.287	39
		Top side	0	165	5825	17	16.95	1.16%	0.198	0.200	-

Note:

$$\text{Scaling} = \frac{\text{Reported SAR}}{\text{Measured SAR}} = \frac{P_2(\text{mW})}{P_1(\text{mW})} = 10^{\left(\frac{P_2 - P_1}{10}\right) \text{ (dBm)}}$$

Reported SAR = measured SAR \* (scaling)

Where P2 is maximum specified power, P1 is measured conducted power

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### 3. Instruments List

Manufacturer	Device	Type	Serial number	Date of last calibration	Date of next calibration
Schmid & Partner Engineering AG	Dosimetric E-Field Probe	EX3DV4	3770	Apr.27,2016	Apr.26,2017
Schmid & Partner Engineering AG	System Validation Dipole	D2450V2	727	Apr.19,2016	Apr.18,2017
		D5GHzV2	1023	Jan.26,2016	Jan.25,2017
Schmid & Partner Engineering AG	Data acquisition Electronics	DAE4	856	Apr.21,2016	Apr.20,2017
Schmid & Partner Engineering AG	Software	DASY 52 V52.8.8	N/A	Calibration not required	Calibration not required
Schmid & Partner Engineering AG	Phantom	SAM	N/A	Calibration not required	Calibration not required
Agilent	Network Analyzer	E5071C	MY46107530	Jan.07,2016	Jan.06,2017
Agilent	Dielectric Probe Kit	85070E	MY44300677	Calibration not required	Calibration not required
Agilent	Dual-directional coupler	772D	MY52180142	Apr.13,2016	Apr.12,2017
		778D	MY52180302	Apr.13,2016	Apr.12,2017
Agilent	RF Signal Generator	N5181A	MY50145142	Feb.19,2016	Feb.18,2017
Agilent	Power Meter	E4417A	MY51410006	Jan.07,2016	Jan.06,2017
Agilent	Power Sensor	E9301H	MY51470001	Jan.07,2016	Jan.06,2017
			MY51470002	Jan.07,2016	Jan.06,2017
TECPTEL	Digital thermometer	DTM-303A	TP130073	Feb.26,2016	Feb.25,2017

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## 4. Measurements

Date: 2016/8/1

### WLAN 802.11b\_Body\_Top side\_CH 6\_Main

Communication System: WLAN 2.45G; Frequency: 2437 MHz

Medium parameters used:  $f = 2437 \text{ MHz}$ ;  $\sigma = 2.016 \text{ S/m}$ ;  $\epsilon_r = 51.153$ ;  $\rho = 1000 \text{ kg/m}^3$ 

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(7.37, 7.37, 7.37); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Body/Area Scan (61x141x1):** Interpolated grid:  $dx=12 \text{ mm}$ ,  $dy=12 \text{ mm}$ 

Maximum value of SAR (interpolated) = 0.684 W/kg

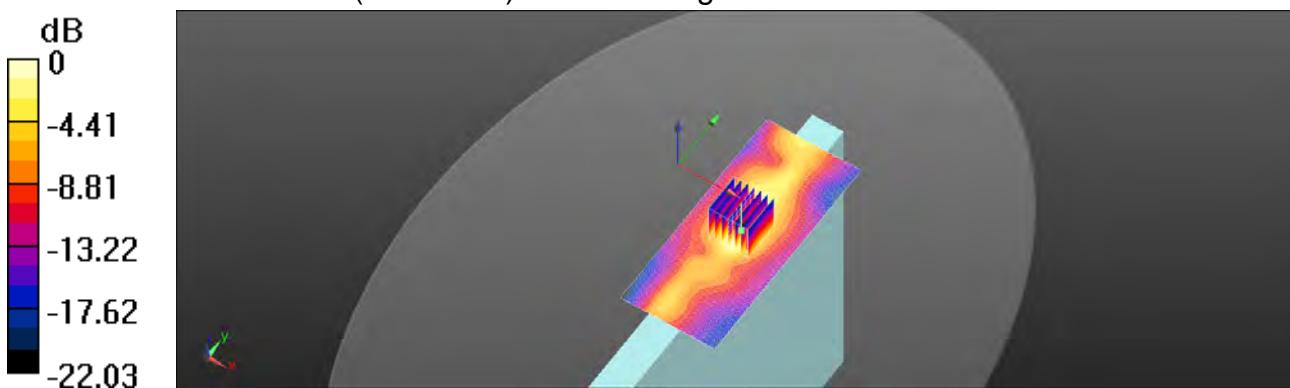
**Configuration/Body/Zoom Scan (7x7x7)/Cube 0:** Measurement grid:  $dx=5\text{mm}$ ,  $dy=5\text{mm}$ ,  $dz=5\text{mm}$ 

Reference Value = 4.887 V/m; Power Drift = 0.07 dB

Peak SAR (extrapolated) = 0.920 W/kg

**SAR(1 g) = 0.442 W/kg; SAR(10 g) = 0.213 W/kg**

Maximum value of SAR (measured) = 0.662 W/kg



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Date: 2016/8/1

**WLAN 802.11a 5.2G\_Body\_Top side\_CH 48\_Main**

Communication System: WLAN 5G; Frequency: 5240 MHz

Medium parameters used:  $f = 5240$  MHz;  $\sigma = 5.245$  S/m;  $\epsilon_r = 48.877$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(4.34, 4.34, 4.34); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Body/Area Scan (71x151x1):** Interpolated grid: dx=10 mm, dy=10 mm

Maximum value of SAR (interpolated) = 0.895 W/kg

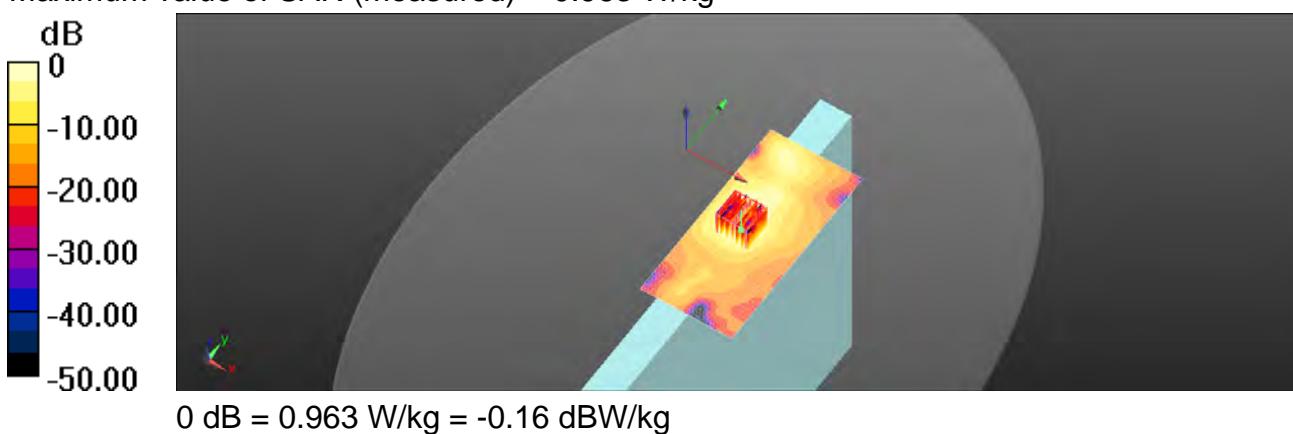
**Configuration/Body/Zoom Scan (7x7x12)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=2mm

Reference Value = 1.232 V/m; Power Drift = -0.08 dB

Peak SAR (extrapolated) = 2.01 W/kg

**SAR(1 g) = 0.478 W/kg; SAR(10 g) = 0.149 W/kg**

Maximum value of SAR (measured) = 0.963 W/kg



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Date: 2016/8/1

**WLAN 802.11a 5.3G\_Body\_Top side\_CH 56\_Main**

Communication System: WLAN 5G; Frequency: 5280 MHz

Medium parameters used:  $f = 5280$  MHz;  $\sigma = 5.302$  S/m;  $\epsilon_r = 48.758$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(4.34, 4.34, 4.34); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Body/Area Scan (71x161x1):** Interpolated grid: dx=10 mm, dy=10 mm

Maximum value of SAR (interpolated) = 0.903 W/kg

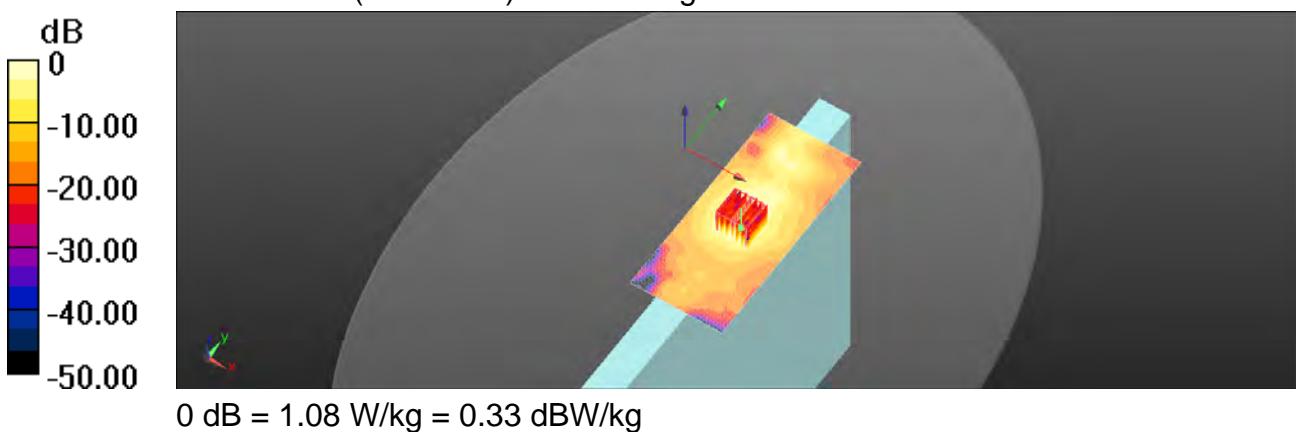
**Configuration/Body/Zoom Scan (7x7x12)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=2mm

Reference Value = 1.343 V/m; Power Drift = 0.16 dB

Peak SAR (extrapolated) = 2.18 W/kg

**SAR(1 g) = 0.523 W/kg; SAR(10 g) = 0.165 W/kg**

Maximum value of SAR (measured) = 1.08 W/kg



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Date: 2016/8/3

**WLAN 802.11a 5.6G\_Body\_Back side\_CH 120\_Main**

Communication System: WLAN 5G; Frequency: 5600 MHz

Medium parameters used:  $f = 5600$  MHz;  $\sigma = 5.829$  S/m;  $\epsilon_r = 47.77$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(3.7, 3.7, 3.7); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Body/Area Scan (71x151x1):** Interpolated grid: dx=10 mm, dy=10 mm

Maximum value of SAR (interpolated) = 0.503 W/kg

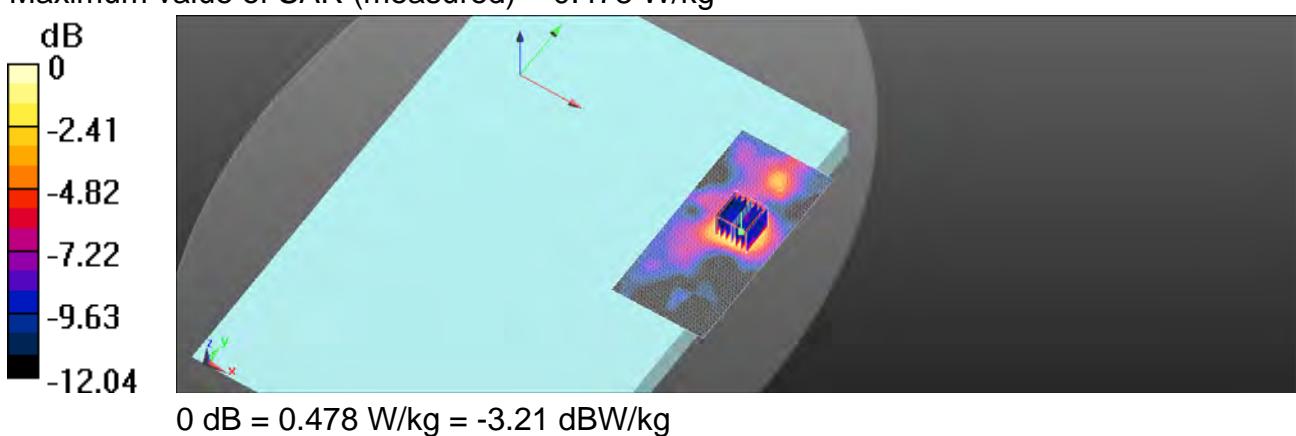
**Configuration/Body/Zoom Scan (7x7x12)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=2mm

Reference Value = 2.547 V/m; Power Drift = 0.14 dB

Peak SAR (extrapolated) = 0.920 W/kg

**SAR(1 g) = 0.277 W/kg; SAR(10 g) = 0.134 W/kg**

Maximum value of SAR (measured) = 0.478 W/kg



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Date: 2016/8/3

**WLAN 802.11a 5.8G\_Body\_Back side\_CH 165\_Main**

Communication System: WLAN 5G; Frequency: 5825 MHz

Medium parameters used:  $f = 5825$  MHz;  $\sigma = 6.183$  S/m;  $\epsilon_r = 47.057$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(4.07, 4.07, 4.07); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Body/Area Scan (71x151x1):** Interpolated grid: dx=10 mm, dy=10 mm

Maximum value of SAR (interpolated) = 0.499 W/kg

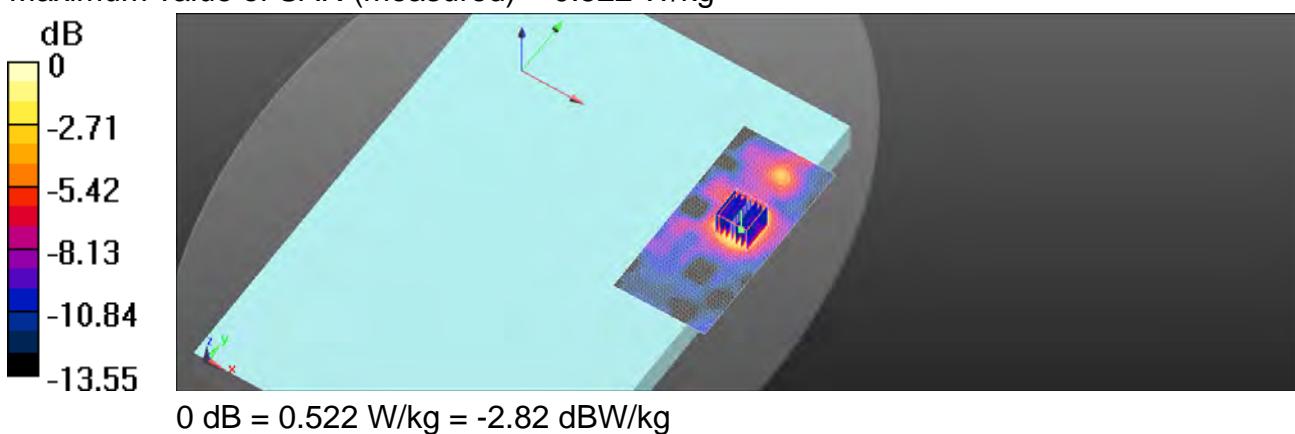
**Configuration/Body/Zoom Scan (7x7x12)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=2mm

Reference Value = 1.234 V/m; Power Drift = 0.17 dB

Peak SAR (extrapolated) = 1.02 W/kg

**SAR(1 g) = 0.284 W/kg; SAR(10 g) = 0.130 W/kg**

Maximum value of SAR (measured) = 0.522 W/kg



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## 5. SAR System Performance Verification

Date: 2016/8/1

### Dipole 2450 MHz\_SN:727\_Body

Communication System: CW; Frequency: 2450 MHz

Medium parameters used:  $f = 2450$  MHz;  $\sigma = 2.033$  S/m;  $\epsilon_r = 51.08$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(7.37, 7.37, 7.37); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Pin=250mW/Area Scan (51x51x1):** Interpolated grid: dx=12 mm, dy=12 mm

Maximum value of SAR (interpolated) = 20.4 W/kg

**Configuration/Pin=250mW/Zoom Scan (7x7x7)/Cube 0:** Measurement grid:

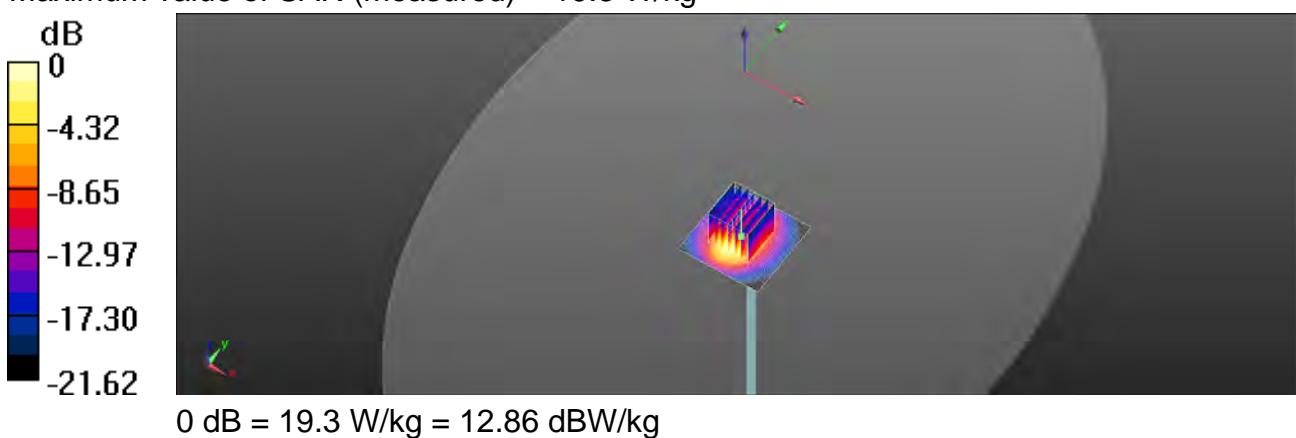
dx=5mm, dy=5mm, dz=5mm

Reference Value = 95.62 V/m; Power Drift = 0.06 dB

Peak SAR (extrapolated) = 26.1 W/kg

**SAR(1 g) = 12.5 W/kg; SAR(10 g) = 5.76 W/kg**

Maximum value of SAR (measured) = 19.3 W/kg



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Date: 2016/8/1

**Dipole 5200 MHz\_SN:1023\_Body**

Communication System: CW; Frequency: 5200 MHz

Medium parameters used:  $f = 5200$  MHz;  $\sigma = 5.178$  S/m;  $\epsilon_r = 49.007$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(4.34, 4.34, 4.34); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Pin=100mW/Area Scan (51x51x1):** Interpolated grid: dx=10 mm, dy=10 mm

Maximum value of SAR (interpolated) = 15.1 W/kg

**Configuration/Pin=100mW/Zoom Scan (7x7x12)/Cube 0:** Measurement grid:

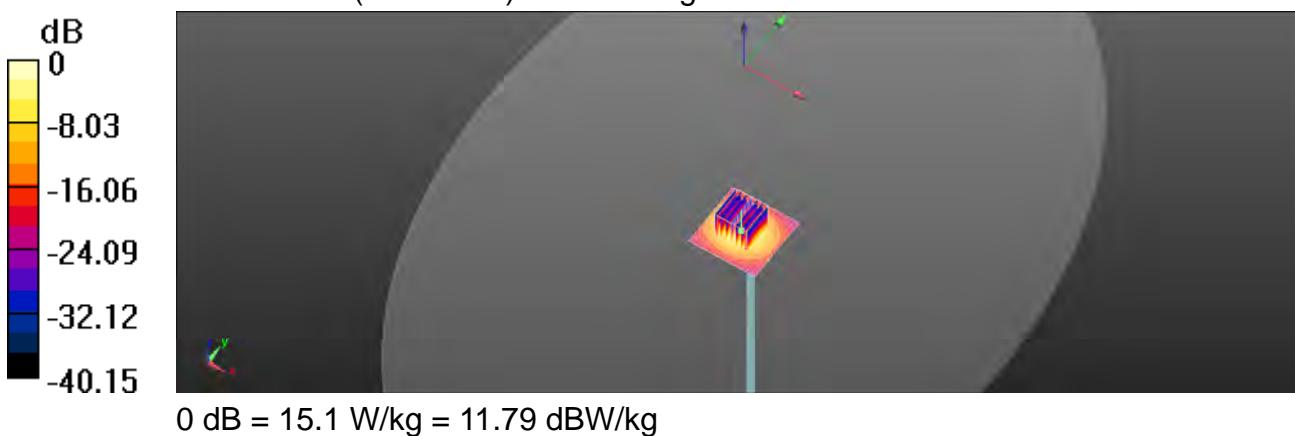
dx=4mm, dy=4mm, dz=2mm

Reference Value = 57.95 V/m; Power Drift = 0.09 dB

Peak SAR (extrapolated) = 30.5 W/kg

**SAR(1 g) = 7.1 W/kg; SAR(10 g) = 1.96 W/kg**

Maximum value of SAR (measured) = 15.1 W/kg



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Date: 2016/8/1

**Dipole 5300 MHz\_SN:1023\_Body**

Communication System: CW; Frequency: 5300 MHz

Medium parameters used:  $f = 5300$  MHz;  $\sigma = 5.324$  S/m;  $\epsilon_r = 48.692$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(4.34, 4.34, 4.34); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Pin=100mW/Area Scan (51x51x1):** Interpolated grid: dx=10 mm, dy=10 mm

Maximum value of SAR (interpolated) = 15.6 W/kg

**Configuration/Pin=100mW/Zoom Scan (7x7x12)/Cube 0:** Measurement grid:

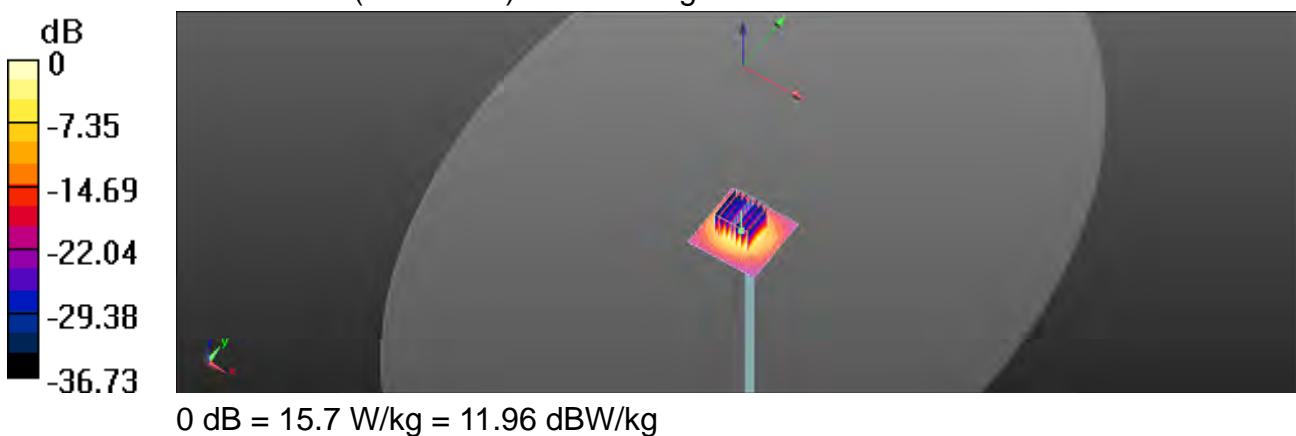
dx=4mm, dy=4mm, dz=2mm

Reference Value = 58.54 V/m; Power Drift = 0.10 dB

Peak SAR (extrapolated) = 32.0 W/kg

**SAR(1 g) = 7.34 W/kg; SAR(10 g) = 2.02 W/kg**

Maximum value of SAR (measured) = 15.7 W/kg



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Date: 2016/8/3

**Dipole 5600 MHz\_SN:1023\_Body**

Communication System: CW; Frequency: 5600 MHz

Medium parameters used:  $f = 5600$  MHz;  $\sigma = 5.829$  S/m;  $\epsilon_r = 47.77$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(3.7, 3.7, 3.7); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Pin=100mW/Area Scan (51x51x1):** Interpolated grid: dx=10 mm, dy=10 mm

Maximum value of SAR (interpolated) = 17.6 W/kg

**Configuration/Pin=100mW/Zoom Scan (7x7x12)/Cube 0:** Measurement grid:

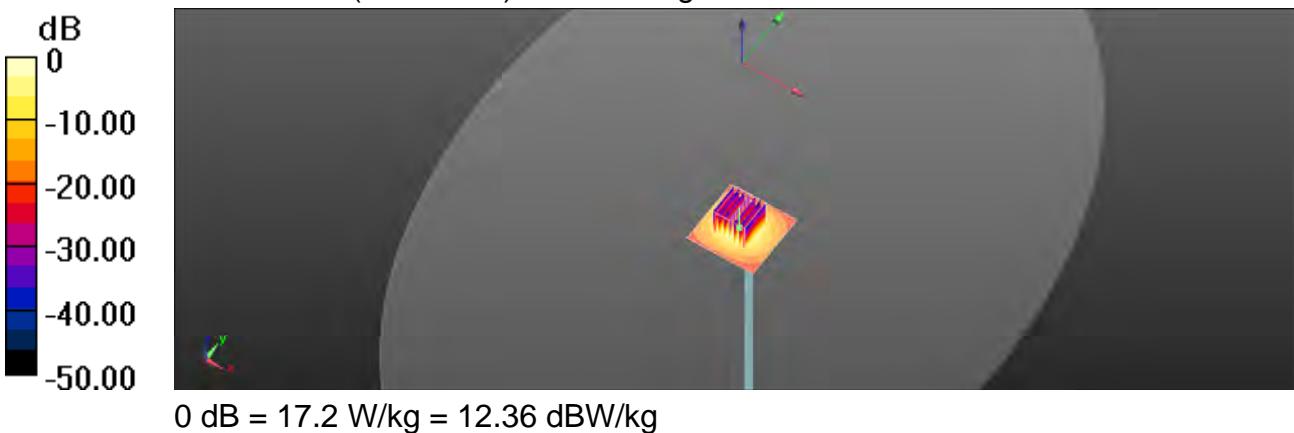
dx=4mm, dy=4mm, dz=2mm

Reference Value = 60.08 V/m; Power Drift = 0.04 dB

Peak SAR (extrapolated) = 35.2 W/kg

**SAR(1 g) = 7.87 W/kg; SAR(10 g) = 2.14 W/kg**

Maximum value of SAR (measured) = 17.2 W/kg



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Date: 2016/8/3

**Dipole 5800 MHz\_SN:1023\_Body**

Communication System: CW; Frequency: 5800 MHz

Medium parameters used:  $f = 5800$  MHz;  $\sigma = 6.137$  S/m;  $\epsilon_r = 47.148$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3770; ConvF(4.07, 4.07, 4.07); Calibrated: 2016/4/27;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn856; Calibrated: 2016/4/21
- Phantom: Body
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

**Configuration/Pin=100mW/Area Scan (51x51x1):** Interpolated grid: dx=10 mm, dy=10 mm

Maximum value of SAR (interpolated) = 16.6 W/kg

**Configuration/Pin=100mW/Zoom Scan (7x7x12)/Cube 0:** Measurement grid:

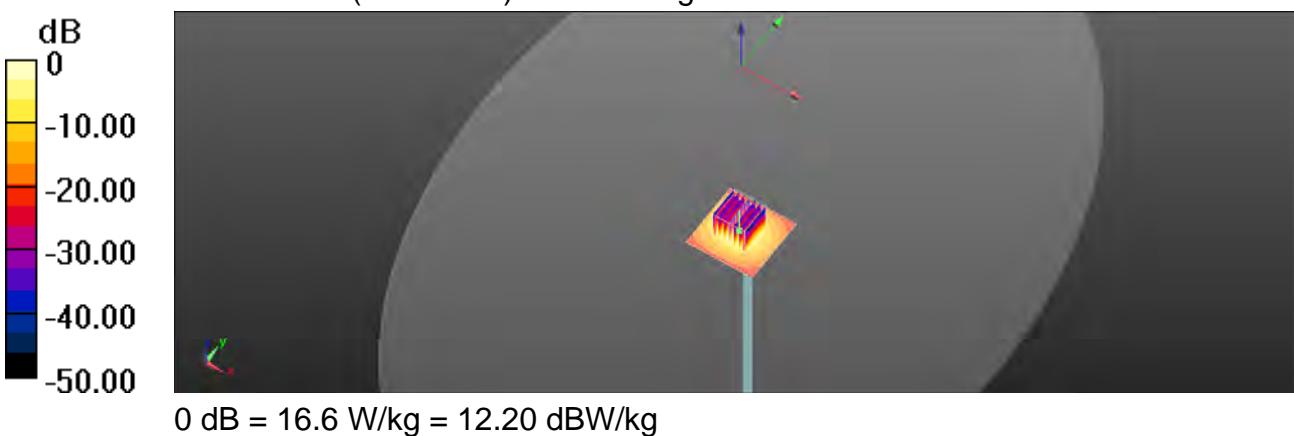
dx=4mm, dy=4mm, dz=2mm

Reference Value = 55.88 V/m; Power Drift = 0.12 dB

Peak SAR (extrapolated) = 35.5 W/kg

**SAR(1 g) = 7.55 W/kg; SAR(10 g) = 2.06 W/kg**

Maximum value of SAR (measured) = 16.6 W/kg



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## 6. DAE & Probe Calibration Certificate

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



S Schweizerischer Kaliibrierdienst  
C Service suisse d'étalonnage  
S Servizio svizzero di taratura  
S Swiss Calibration Service

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

Accreditation No.: **SCS 0108**Client **SGS-TW (Auden)**Certificate No: **DAE4-856\_Apr16**

### CALIBRATION CERTIFICATE

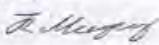
Object **DAE4 - SD 000 D04 BM - SN: 856**Calibration procedure(s) **QA CAL-06.v29**  
Calibration procedure for the data acquisition electronics (DAE)Calibration date: **April 21, 2016**

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&amp;TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Keithley Multimeter Type 2001	SN: 0810278	09-Sep-15 (No:17153)	Sep-16
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit Calibrator Box V2.1	SE UWS 053 AA 1001 SE UMS 006 AA 1002	05-Jan-16 (in house check) 05-Jan-16 (in house check)	In house check: Jan-17 In house check: Jan-17

Calibrated by:	Name R.Mayoraz	Function Technician	Signature 
Approved by:	Fin Bomholz	Deputy Technical Manager	

Issued: April 21, 2016

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

Certificate No: **DAE4-856\_Apr16**

Page 1 of 5

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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 $\mu$ V, full range = -100...+300 mV

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

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

Calibration Factors	X	Y	Z
High Range	403.450 ± 0.02% (k=2)	404.571 ± 0.02% (k=2)	403.888 ± 0.02% (k=2)
Low Range	3.97641 ± 1.50% (k=2)	3.97912 ± 1.50% (k=2)	3.97796 ± 1.50% (k=2)

**Connector Angle**

Connector Angle to be used in DASY system	52.0 ° ± 1 °
---	--------------

**Appendix (Additional assessments outside the scope of SCS0108)****1. DC Voltage Linearity**

High Range	Reading (µV)	Difference (µV)	Error (%)
Channel X + Input	199996.11	0.91	0.00
Channel X + Input	19999.18	-2.34	-0.01
Channel X - Input	-19999.41	1.06	-0.01
Channel Y + Input	199997.66	2.51	0.00
Channel Y + Input	19998.64	-2.84	-0.01
Channel Y - Input	-20002.21	-1.65	0.01
Channel Z + Input	199995.99	0.62	0.00
Channel Z + Input	19999.35	-2.13	-0.01
Channel Z - Input	-20002.57	-1.88	0.01

Low Range	Reading (µV)	Difference (µV)	Error (%)
Channel X + Input	2001.58	0.10	0.01
Channel X + Input	202.26	0.40	0.20
Channel X - Input	-197.29	0.76	-0.38
Channel Y + Input	2001.59	0.10	0.00
Channel Y + Input	200.88	-1.06	-0.52
Channel Y - Input	-199.46	-1.39	0.70
Channel Z + Input	2001.75	0.28	0.01
Channel Z + Input	201.40	-0.39	-0.19
Channel Z - Input	-198.94	-0.69	0.35

**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	-14.19	-16.06
	-200	18.03	16.49
Channel Y	200	-2.43	-2.73
	-200	0.85	0.06
Channel Z	200	10.84	10.78
	-200	-12.44	-12.80

**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	-	1.98	-2.81
Channel Y	200	7.60	-	4.11
Channel Z	200	9.54	4.60	-

**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	16223	16358
Channel Y	15947	17393
Channel Z	15877	17066

**5. Input Offset Measurement**

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

Input 10MΩ

	Average (µV)	min. Offset (µV)	max. Offset (µV)	Std. Deviation (µV)
Channel X	0.86	0.04	1.50	0.29
Channel Y	-0.51	-2.36	0.33	0.41
Channel Z	-0.75	-2.04	0.01	0.30

**6. Input Offset Current**

Nominal Input circuitry offset current on all channels: &lt;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

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



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Client SGS-TW (Auden)

Certificate No: EX3-3770\_Apr16

**CALIBRATION CERTIFICATE**

Object EX3DV4 - SN:3770

Calibration procedure(s): QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v4, QA CAL-23.v5,  
QA CAL-25.v6  
Calibration procedure for dosimetric E-field probes

Calibration date: April 27, 2016

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 ± 5°C and humidity < 70%).

Calibration Equipment used (M&amp;TE critical for calibration)

Primary Standards	ID	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP	SN: 104778	06-Apr-16 (No. 217-02288/02289)	Apr-17
Power sensor NRP-Z91	SN: 103244	06-Apr-16 (No. 217-02288)	Apr-17
Power sensor NRP-Z91	SN: 103245	06-Apr-16 (No. 217-02289)	Apr-17
Reference 20 dB Attenuator	SN: S5277 (20x)	05-Apr-16 (No. 217-02293)	Apr-17
Reference Probe ES3DV2	SN: 3013	31-Dec-15 (No. ES3-3013_Dec15)	Dec-16
DAE4	SN: 660	23-Dec-15 (No. DAE4-660 Dec15)	Dec-16
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41299874	06-Apr-16 (No. 217-02285/02284)	In house check: Jun-16
Power sensor E4412A	SN: MY41498087	06-Apr-16 (No. 217-02285)	In house check: Jun-16
Power sensor E4412A	SN: 000110210	06-Apr-16 (No. 217-02284)	In house check: Jun-16
RF generator HP B648C	SN: US3642U01700	04-Aug-99 (in house check Apr-13)	In house check: Jun-16
Network Analyzer HP 8753E	SN: US37390565	18-Oct-01 (in house check Oct-15)	In house check: Oct-16

Calibrated by:	Name: Claudio Lüscher	Function: Laboratory Technician	Signature:
Approved by:	Name: Katja Pokovic	Function: Technical Manager	Signature:

Issued: April 27, 2016

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

Certificate No: EX3-3770\_Apr16

Page 1 of 11

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Accreditation No.: **SCS 0108****Glossary:**

TSL	tissue simulating liquid
NORM <sub>x,y,z</sub>	sensitivity in free space
ConvF	sensitivity in TSL / NORM <sub>x,y,z</sub>
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C, D	modulation dependent linearization parameters
Polarization $\varphi$	$\varphi$ rotation around probe axis
Polarization $\beta$	$\beta$ rotation around an axis that is in the plane normal to probe axis (at measurement center). i.e., $\beta = 0$ 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 300 MHz to 3 GHz)", 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 B65664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

**Methods Applied and Interpretation of Parameters:**

- $NORM_{x,y,z}$ : Assessed for E-field polarization  $\beta = 0$  ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide).  $NORM_{x,y,z}$  are only intermediate values, i.e., the uncertainties of  $NORM_{x,y,z}$  does not affect the E<sup>2</sup>-field uncertainty inside TSL (see below ConvF).
- $NORM_{(x,y,z)} = NORM_{x,y,z} * frequency\_response$  (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.
- $DCPx,y,z$ : DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (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
- $A_{x,y,z}$ ;  $B_{x,y,z}$ ;  $C_{x,y,z}$ ;  $D_{x,y,z}$ ;  $VR_{x,y,z}$ ;  $A$ ,  $B$ ,  $C$ ,  $D$  are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters:** Assessed in flat phantom using E-field (or Temperature Transfer Standard for  $f \leq 800$  MHz) and inside waveguide using analytical field distributions based on power measurements for  $f > 800$  MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to  $NORM_{x,y,z} * ConvF$  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  $\pm 50$  MHz to  $\pm 100$  MHz.
- Spherical Isotropy (3D deviation from isotropy):** in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset:** The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle:** The angle is assessed using the information gained by determining the  $NORM_{x}$  (no uncertainty required).

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EX3DV4 - SN:3770

April 27, 2016

# Probe EX3DV4

## SN:3770

Manufactured: July 6, 2010  
Calibrated: April 27, 2016

Calibrated for DASY/EASY Systems  
(Note: non-compatible with DASY2 system!)

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**DASY/EASY - Parameters of Probe: EX3DV4 - SN:3770****Basic Calibration Parameters**

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup>	0.31	0.61	0.40	$\pm 10.1\%$
DCP (mV) <sup>B</sup>	100.4	97.4	102.0	

**Modulation Calibration Parameters**

UID	Communication System Name	A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Unc <sup>C</sup> (k=2)
0	CW	X 0.0	0.0	1.0	0.00	145.0	$\pm 2.2\%$
		Y 0.0	0.0	1.0		148.7	
		Z 0.0	0.0	1.0		135.3	

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%.

<sup>A</sup> The uncertainties of Norm X,Y,Z do not affect the E<sup>2</sup>-field uncertainty inside TSL (see Pages 5 and 6).

<sup>B</sup> Numerical linearization parameter; uncertainty not required.

<sup>C</sup> 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:3770****Calibration Parameter Determined in Head Tissue Simulating Media**

f (MHz) <sup>c</sup>	Relative Permittivity <sup>f</sup>	Conductivity (S/m) <sup>f</sup>	ConvF X	ConvF Y	ConvF Z	Alpha <sup>g</sup>	Depth <sup>h</sup> (mm)	Unc (k=2)
450	43.5	0.87	11.36	11.36	11.36	0.18	1.20	± 13.3 %
750	41.9	0.89	9.83	9.83	9.83	0.41	0.88	± 12.0 %
835	41.5	0.90	9.47	9.47	9.47	0.14	1.48	± 12.0 %
900	41.5	0.97	9.17	9.17	9.17	0.15	1.78	± 12.0 %
1750	40.1	1.37	8.19	8.19	8.19	0.12	1.68	± 12.0 %
1900	40.0	1.40	7.88	7.88	7.88	0.12	1.77	± 12.0 %
2000	40.0	1.40	7.91	7.91	7.91	0.14	1.61	± 12.0 %
2300	39.5	1.87	7.47	7.47	7.47	0.13	2.08	± 12.0 %
2450	39.2	1.80	7.12	7.12	7.12	0.14	2.00	± 12.0 %
2600	39.0	1.96	6.95	6.95	6.95	0.21	1.26	± 12.0 %
5250	35.9	4.71	5.03	5.03	5.03	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.42	4.42	4.42	0.50	1.80	± 13.1 %
5750	35.4	5.22	4.83	4.83	4.83	0.50	1.80	± 13.1 %

<sup>c</sup> Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

<sup>f</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) 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 ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

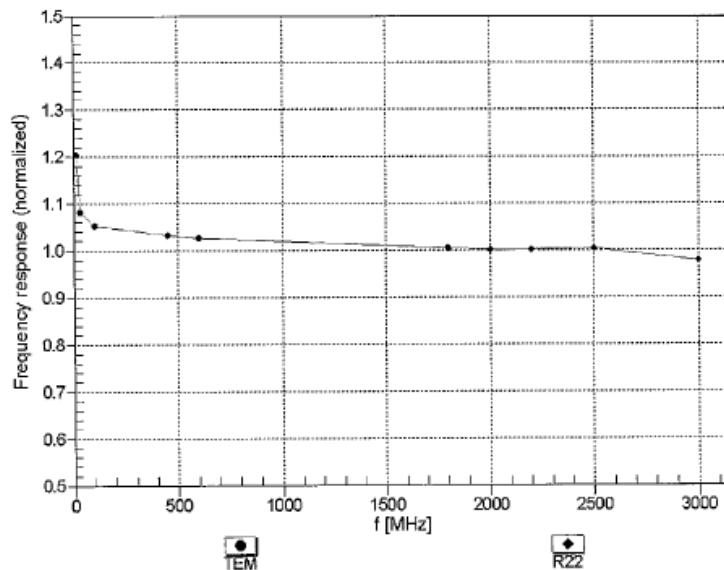
**DASY/EASY - Parameters of Probe: EX3DV4 - SN:3770****Calibration Parameter Determined in Body Tissue Simulating Media**

f (MHz) <sup>c</sup>	Relative Permittivity <sup>f</sup>	Conductivity (S/m) <sup>g</sup>	ConvF X	ConvF Y	ConvF Z	Alpha <sup>h</sup>	Depth <sup>i</sup> (mm)	Unc (k=2)
450	56.7	0.94	10.49	10.49	10.49	0.09	1.20	± 13.3 %
750	55.5	0.96	9.43	9.43	9.43	0.19	1.26	± 12.0 %
835	55.2	0.97	9.30	9.30	9.30	0.17	1.43	± 12.0 %
900	55.0	1.05	9.15	9.15	9.15	0.28	1.06	± 12.0 %
1750	53.4	1.49	7.88	7.88	7.88	0.10	2.60	± 12.0 %
1900	53.3	1.52	7.71	7.71	7.71	0.11	2.44	± 12.0 %
2000	53.3	1.52	7.82	7.82	7.82	0.18	1.42	± 12.0 %
2300	52.9	1.81	7.53	7.53	7.53	0.54	0.69	± 12.0 %
2450	52.7	1.95	7.37	7.37	7.37	0.80	0.56	± 12.0 %
2600	52.5	2.16	7.12	7.12	7.12	0.80	0.56	± 12.0 %
5250	48.9	5.36	4.34	4.34	4.34	0.50	1.90	± 13.1 %
5600	48.5	5.77	3.70	3.70	3.70	0.60	1.90	± 13.1 %
5750	48.3	5.94	4.07	4.07	4.07	0.60	1.90	± 13.1 %

<sup>c</sup> Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

<sup>f</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) 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 ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

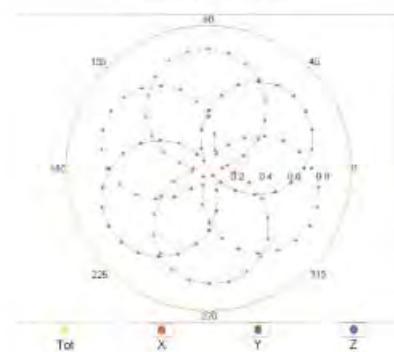
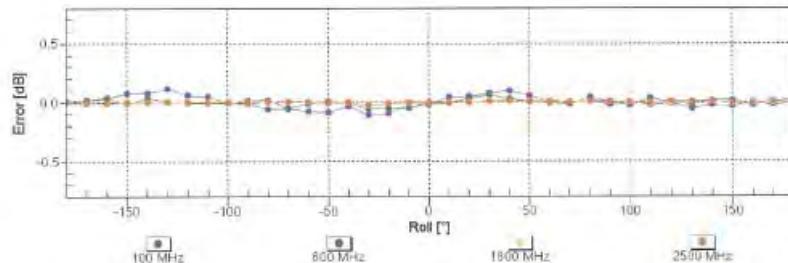
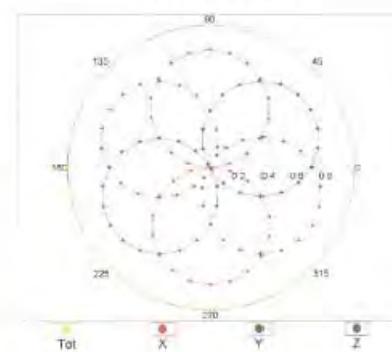
**Frequency Response of E-Field**  
(TEM-Cell:ifi110 EXX, Waveguide: R22)Uncertainty of Frequency Response of E-field:  $\pm 6.3\% (k=2)$ 

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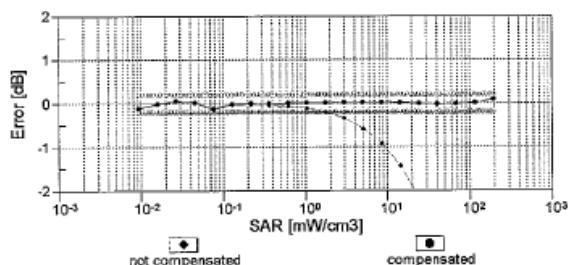
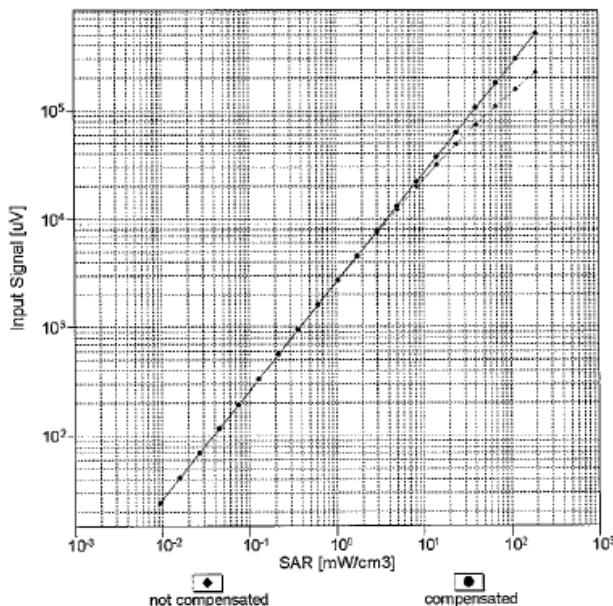
**Receiving Pattern ( $\phi$ ),  $\theta = 0^\circ$**  $f=600 \text{ MHz, TEM}$  $f=1800 \text{ MHz, R22}$ **Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  ( $k=2$ )**

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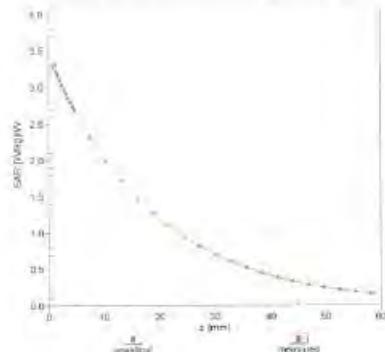
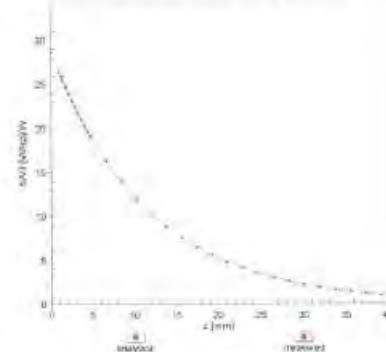
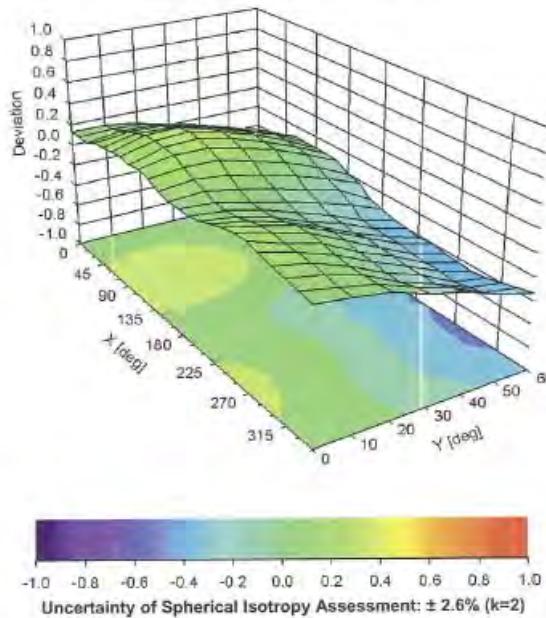
**Dynamic Range f(SAR<sub>head</sub>)**  
(TEM cell, f<sub>eval</sub> = 1900 MHz)**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

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**Conversion Factor Assessment** $f = 835 \text{ MHz}, \text{WGLS R9 (H\_convF)}$  $f = 1900 \text{ MHz}, \text{WGLS R22 (H\_convF)}$ **Deviation from Isotropy in Liquid  
Error ( $\phi, \theta$ ),  $f = 900 \text{ MHz}$** Uncertainty of Spherical Isotropy Assessment:  $\pm 2.6\% (k=2)$ 

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**DASY/EASY - Parameters of Probe: EX3DV4 - SN:3770****Other Probe Parameters**

Sensor Arrangement	Triangular
Connector Angle (°)	-29.9
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	9 mm
Tip Diameter	2.5 mm
Probe Tip to Sensor X Calibration Point	1 mm
Probe Tip to Sensor Y Calibration Point	1 mm
Probe Tip to Sensor Z Calibration Point	1 mm
Recommended Measurement Distance from Surface	1.4 mm

## 7. Uncertainty Budget

Measurement Uncertainty evaluation template for DUT SAR test (3-6G)

A	c	D	e	f	g	$h=c * f / e$	$i=c * g / e$	k
Source of Uncertainty	Tolerance/ Uncertainty	Probability	Div	Div Value	ci (1g)	ci (10g)	Standard uncertainty	Standard uncertainty vi, or Veff
<b>Measurement system</b>								
Probe calibration	6.55%	N	1	1	1	1	6.55%	6.55% $\infty$
<i>Isotropy, Axial</i>	3.50%	R	$\sqrt{3}$	1.732	1	1	2.02%	2.02% $\infty$
<i>Isotropy, Hemispherical</i>	9.60%	R	$\sqrt{3}$	1.732	1	1	5.54%	5.54% $\infty$
Modulation Response	2.40%	R	$\sqrt{3}$	1.732	1	1	1.40%	1.40% $\infty$
Boundary Effect	1.00%	R	$\sqrt{3}$	1.732	1	1	0.58%	0.58% $\infty$
Linearity	4.70%	R	$\sqrt{3}$	1.732	1	1	2.71%	2.71% $\infty$
Detection Limits	1.00%	R	$\sqrt{3}$	1.732	1	1	0.58%	0.58% $\infty$
Readout Electronics	0.30%	N	1	1	1	1	0.30%	0.30% $\infty$
Response time	0.80%	R	$\sqrt{3}$	1.732	1	1	0.46%	0.46% $\infty$
Integration Time	2.60%	R	$\sqrt{3}$	1.732	1	1	1.50%	1.50% $\infty$
<i>Measurement drift (class A evaluation)</i>	1.75%	R	$\sqrt{3}$	1.732	1	1	1.01%	1.01% $\infty$
RF ambient condition - noise	3.00%	R	$\sqrt{3}$	1.732	1	1	1.73%	1.73% $\infty$
RF ambient conditions - reflections	3.00%	R	$\sqrt{3}$	1.732	1	1	1.73%	1.73% $\infty$
Probe positioner Mechanical restrictions	0.40%	R	$\sqrt{3}$	1.732	1	1	0.23%	0.23% $\infty$
Probe Positioning with respect to phantom	2.90%	R	$\sqrt{3}$	1.732	1	1	1.67%	1.67% $\infty$
Post-processing	1.00%	R	$\sqrt{3}$	1.732	1	1	0.58%	0.58% $\infty$
Max SAR Eval	1.00%	R	$\sqrt{3}$	1.732	1	1	0.58%	0.58% $\infty$
<b>Test Sample related</b>								
Test sample positioning	2.90%	N	1	1	1	1	2.90%	2.90% M-1
Device Holder Uncertainty	3.60%	N	1	1	1	1	3.60%	3.60% M-1
Drift of output power	5.00%	R	$\sqrt{3}$	1.732	1	1	2.89%	2.89% $\infty$
<b>Phantom and Setup</b>								
Phantom Uncertainty	4.00%	R	$\sqrt{3}$	1.732	1	1	2.31%	2.31% $\infty$
Liquid permittivity (mea.)	2.30%	N	1	1	0.64	0.43	1.47%	0.99% M
Liquid Conductivity (mea.)	2.55%	N	1	1	0.6	0.49	1.53%	1.25% M
Combined standard uncertainty		RSS					11.91%	11.81%
Explant uncertainty (95% confidence)							23.81%	23.63%

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## Measurement Uncertainty evaluation template for DUT SAR test (0.3-3G)

A	c	D	e	f	g	$h=c * f / e$	$i=c * g / e$	k
Source of Uncertainty	Tolerance/ Uncertainty	Probability	Div	Div Value	$ci (1g)$	$ci (10g)$	Standard uncertainty	Standard uncertainty $vi, \text{ or } V_{eff}$
<b>Measurement system</b>								
Probe calibration	6.00%	N	1	1	1	1	6.00%	6.00% $\infty$
<i>Isotropy, Axial</i>	3.50%	R	$\sqrt{3}$	1.732	1	1	2.02%	2.02% $\infty$
<i>Isotropy, Hemispherical</i>	9.60%	R	$\sqrt{3}$	1.732	1	1	5.54%	5.54% $\infty$
Modulation Response	2.40%	R	$\sqrt{3}$	1.732	1	1	1.40%	1.40% $\infty$
Boundary Effect	1.00%	R	$\sqrt{3}$	1.732	1	1	0.58%	0.58% $\infty$
Linearity	4.70%	R	$\sqrt{3}$	1.732	1	1	2.71%	2.71% $\infty$
Detection Limits	1.00%	R	$\sqrt{3}$	1.732	1	1	0.58%	0.58% $\infty$
Readout Electronics	0.30%	N	1	1	1	1	0.30%	0.30% $\infty$
Response time	0.80%	R	$\sqrt{3}$	1.732	1	1	0.46%	0.46% $\infty$
Integration Time	2.60%	R	$\sqrt{3}$	1.732	1	1	1.50%	1.50% $\infty$
<i>Measurement drift (class A evaluation)</i>	1.75%	R	$\sqrt{3}$	1.732	1	1	1.01%	1.01% $\infty$
RF ambient condition - noise	3.00%	R	$\sqrt{3}$	1.732	1	1	1.73%	1.73% $\infty$
RF ambient conditions - reflections	3.00%	R	$\sqrt{3}$	1.732	1	1	1.73%	1.73% $\infty$
Probe positioner Mechanical restrictions	0.40%	R	$\sqrt{3}$	1.732	1	1	0.23%	0.23% $\infty$
Probe Positioning with respect to phantom	2.90%	R	$\sqrt{3}$	1.732	1	1	1.67%	1.67% $\infty$
Post-processing	1.00%	R	$\sqrt{3}$	1.732	1	1	0.58%	0.58% $\infty$
Max SAR Eval	1.00%	R	$\sqrt{3}$	1.732	1	1	0.58%	0.58% $\infty$
<b>Test Sample related</b>								
Test sample positioning	2.90%	N	1	1	1	1	2.90%	2.90% M-1
Device Holder Uncertainty	3.60%	N	1	1	1	1	3.60%	3.60% M-1
Drift of output power	5.00%	R	$\sqrt{3}$	1.732	1	1	2.89%	2.89% $\infty$
<b>Phantom and Setup</b>								
Phantom Uncertainty	4.00%	R	$\sqrt{3}$	1.732	1	1	2.31%	2.31% $\infty$
Liquid permittivity (mea.)	3.07%	N	1	1	0.64	0.43	1.96%	1.32% M
Liquid Conductivity (mea.)	4.26%	N	1	1	0.6	0.49	2.56%	2.09% M
Combined standard uncertainty		RSS					11.86%	11.67%
Expan uncertainty (95% confidence)							23.73%	23.34%

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## 8. Phantom Description

Schmid &amp; Partner Engineering AG

**s p e a g**Zeughausstrasse 43, 8004 Zurich, Switzerland  
Phone +41 1 245 9700, Fax +41 1 245 9779  
Info@speag.com, http://www.speag.com**Certificate of Conformity / First Article Inspection**

Item	SAM Twin Phantom V4.0
Type No	QD 000 P40 C
Series No	TP-1150 and higher
Manufacturer	SPEAG Zeughausstrasse 43 CH-8004 Zurich Switzerland

**Tests**

The series production process used allows the limitation to test of first articles.  
Complete tests were made on the pre-series Type No. QD 000 P40 AA, Serial No. TP-1001 and on the series first article Type No. QD 000 P40 BA, Serial No. TP-1006. Certain parameters have been retested using further series items (called samples) or are tested at each item.

Test	Requirement	Details	Units tested
Dimensions	Compliant with the geometry according to the CAD model.	IT'IS CAD File (*)	First article, Samples
Material thickness of shell	Compliant with the requirements according to the standards	2mm +/- 0.2mm in flat and specific areas of head section	First article, Samples, TP-1214 fl.
Material thickness at ERP	Compliant with the requirements according to the standards	6mm +/- 0.2mm at ERP	First article, All items
Material parameters	Dielectric parameters for required frequencies	300 MHz – 6 GHz: Relative permittivity < 5, Loss tangent < 0.05	Material samples
Material resistivity	The material has been tested to be compatible with the liquids defined in the standards (if handled and cleaned according to the instructions). Observe technical Note for material compatibility.	DEGMBe based simulating liquids	Pre-series, First article, Material samples
Sagging	Compliant with the requirements according to the standards. Sagging of the flat section when filled with tissue simulating liquid	< 1% typical < 0.8% if filled with 155mm of HSL900 and without DUT below	Prototypes, Sample testing

**Standards**

- [1] CENELEC EN 50361
- [2] IEEE Std 1528-2003
- [3] IEC 62209 Part I
- [4] FCC OET Bulletin 65, Supplement C, Edition 01-01

(\*) The IT'IS CAD file is derived from [2] and is also within the tolerance requirements of the shapes of the other documents.

**Conformity**

Based on the sample tests above, we certify that this item is in compliance with the uncertainty requirements of SAR measurements specified in standards [1] to [4].

Date

07.07.2006

**s p e a g**

Signature / Stamp

Schmid & Partner Engineering AG  
Zeughausstrasse 43, 8004 Zurich, Switzerland  
Phone +41 1 245 9700, Fax +41 1 245 9779  
Info@speag.com, http://www.speag.com

Doc No. E5/1 - QD 000 P40 C - F

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## 9. System Validation from Original Equipment Supplier

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



S Schweizerischer Kalibrierdienst  
C Service suisse d'étalonnage  
S Servizio svizzero di taratura  
S Swiss Calibration Service

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

Accreditation No.: SCS 0108

Client SGS-TW (Auden)

Certificate No: D2450V2-727\_Apr16

### CALIBRATION CERTIFICATE

Object D2450V2 - SN:727

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

Calibration date: April 19, 2016

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.

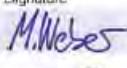
All calibrations have been conducted in the closed laboratory facility, environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&amp;TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP	SN: 104778	06-Apr-16 (No. 217-02288/02289)	Apr-17
Power sensor NRP-Z91	SN: 103244	06-Apr-16 (No. 217-02288)	Apr-17
Power sensor NRP-Z91	SN: 103245	06-Apr-16 (No. 217-02289)	Apr-17
Reference 20 dB Attenuator	SN: 5058 (20k)	05-Apr-16 (No. 217-02292)	Apr-17
Type-N mismatch combination	SN: 5047.2 / 06327	05-Apr-16 (No. 217-02295)	Apr-17
Reference Probe EX3DV4	SN: 7349	31-Dec-15 (No. EX3-7349 Dec15)	Dec-16
DAE4	SN: 501	30-Dec-15 (No. DAE4-501_Dec15)	Dec-16

Secondary Standards	ID #	Check Date (In house)	Scheduled Check
Power meter EPM-442A	SN: GB37480704	07-Oct-15 (No. 217-02222)	In house check: Oct-16
Power sensor HP 8481A	SN: US37292783	07-Oct-15 (No. 217-02222)	In house check: Oct-16
Power sensor HP 8481A	SN: MY41092317	07-Oct-15 (No. 217-02223)	In house check: Oct-16
RF generator R&S SMT-06	SN: 100972	15-Jun-15 (in house check Jun-15)	In house check: Oct-16
Network Analyzer HP 8753E	SN: US37380585	18-Oct-15 (in house check Oct-15)	In house check: Oct-16

Calibrated by:	Name	Function	Signature
	Michael Weber	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: April 20, 2016

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

Certificate No: D2450V2-727\_Apr16

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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

**Glossary:**

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

**Calibration is Performed According to the Following Standards:**

- a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- b) IEC 62209-1, "Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)", February 2005
- c) 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
- d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

**Additional Documentation:**

- e) DASY4/5 System Handbook

**Methods Applied and Interpretation of Parameters:**

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

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

**Measurement Conditions**

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

DASY Version	DASY5	V52.8.8
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	2450 MHz ± 1 MHz	

**Head TSL parameters**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	39.2	1.80 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	40.0 ± 6 %	1.83 mho/m ± 6 %
Head TSL temperature change during test	< 0.5 °C	---	---

**SAR result with Head TSL**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	12.8 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	51.0 W/kg ± 17.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	condition	
SAR measured	250 mW input power	5.93 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	23.7 W/kg ± 16.5 % (k=2)

**Body TSL parameters**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	52.7	1.95 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	52.7 ± 6 %	1.98 mho/m ± 6 %
Body TSL temperature change during test	< 0.5 °C	---	---

**SAR result with Body TSL**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	12.5 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	49.6 W/kg ± 17.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	condition	
SAR measured	250 mW input power	5.86 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	23.3 W/kg ± 16.5 % (k=2)

**Appendix (Additional assessments outside the scope of SCS 0108)****Antenna Parameters with Head TSL**

Impedance, transformed to feed point	55.3 $\Omega$ + 2.0 $j\Omega$
Return Loss	- 25.4 dB

**Antenna Parameters with Body TSL**

Impedance, transformed to feed point	52.1 $\Omega$ + 4.8 $j\Omega$
Return Loss	- 25.9 dB

**General Antenna Parameters and Design**

Electrical Delay (one direction)	1.148 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	January 09, 2003

**DASY5 Validation Report for Head TSL**

Date: 19.04.2016

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 727**

Communication System: UID 0 - CW; Frequency: 2450 MHz

Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.83$  S/m;  $\epsilon_r = 40$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.76, 7.76, 7.76); Calibrated: 31.12.2015;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.12.2015
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.8(1258); SEMCAD X 14.6.10(7372)

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

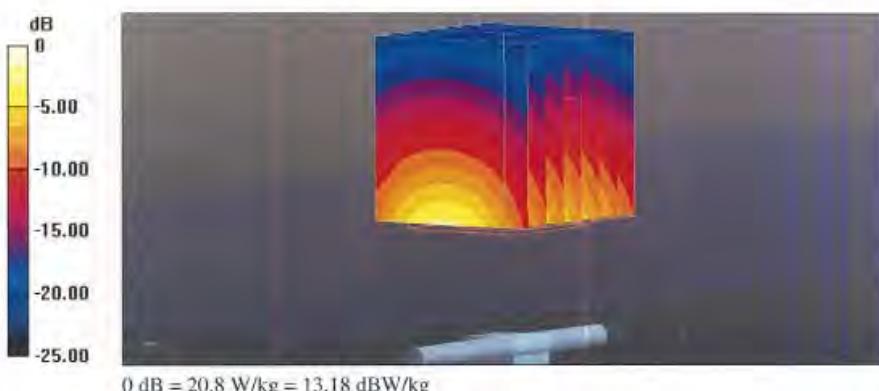
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 112.1 V/m; Power Drift = 0.05 dB

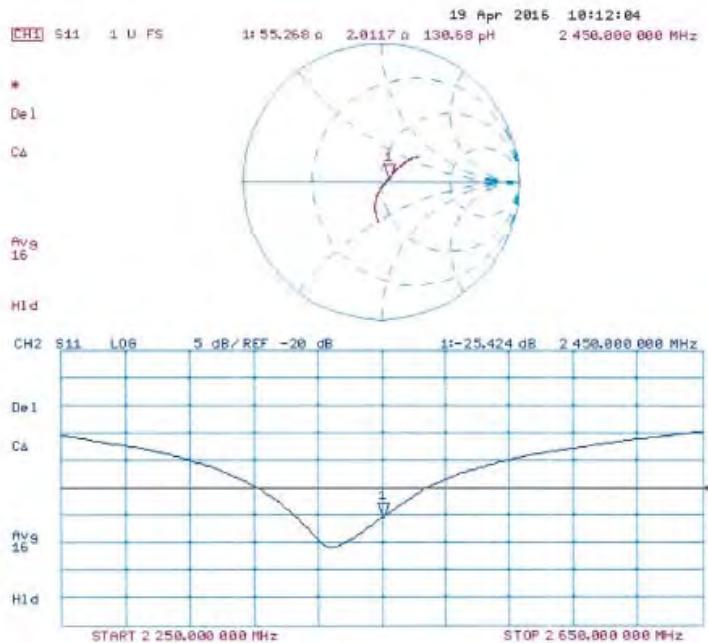
Peak SAR (extrapolated) = 25.7 W/kg

SAR(1 g) = 12.8 W/kg; SAR(10 g) = 5.93 W/kg

Maximum value of SAR (measured) = 20.8 W/kg



## Impedance Measurement Plot for Head TSL



**DASY5 Validation Report for Body TSL**

Date: 19.04.2016

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 727**

Communication System: UID 0 - CW; Frequency: 2450 MHz  
Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.98$  S/m;  $\epsilon_r = 52.7$ ;  $\rho = 1000$  kg/m<sup>3</sup>  
Phantom section: Flat Section  
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

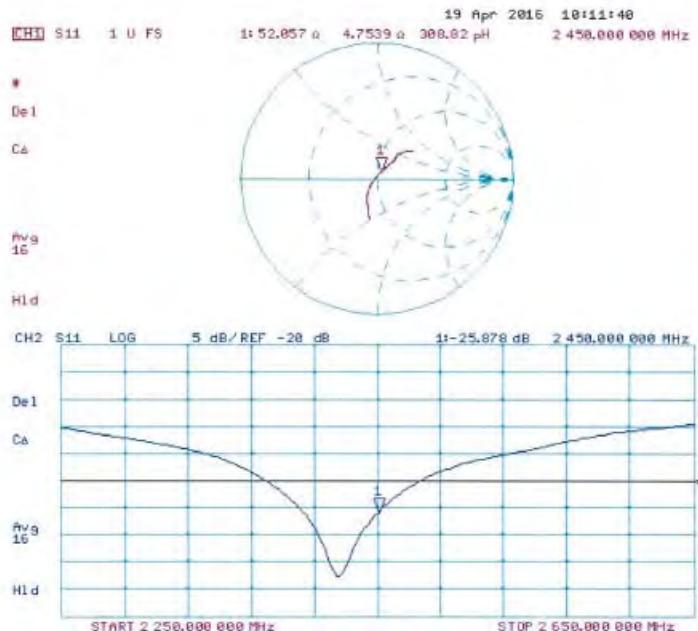
- Probe: EX3DV4 - SN7349; ConvF(7.79, 7.79, 7.79); Calibrated: 31.12.2015;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.12.2015
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.8(1258); SEMCAD X 14.6.10(7372)

**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 = 105.0 V/m; Power Drift = 0.04 dB  
Peak SAR (extrapolated) = 24.9 W/kg  
SAR(1 g) = 12.5 W/kg; SAR(10 g) = 5.86 W/kg  
Maximum value of SAR (measured) = 20.2 W/kg



## Impedance Measurement Plot for Body TSL



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



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Accreditation No.: SCS 0108

Client SGS-TW (Auden)

Certificate No: D5GHzV2-1023\_Jan16

**CALIBRATION CERTIFICATE**

Object D5GHzV2 -SN: 1023

Calibration procedure(s) QA CAL-22.v2  
Calibration procedure for dipole validation kits between 3-6 GHz

Calibration date January 26, 2016

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&amp;TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Power meter EPM-442A	GB37480704	07-Oct-15 (No. 217-02222)	Oct-16
Power sensor HP 8481A	US37292785	07-Oct-15 (No. 217-02222)	Oct-16
Power sensor HP 8481A	MY41092317	07-Oct-15 (No. 217-02223)	Oct-16
Reference 20 dB Attenuator	SN: 5059 (20K)	01-Apr-16 (No. 217-02131)	Mar-16
Type-N mismatch combination	SN: 5047.2 / 05227	01-Apr-16 (No. 217-02134)	Mar-16
Reference Probe EX3DV4	SN: 3503	31-Dec-15 (No. EX3-3633_Dec15)	Dec-16
DAE4	SN: 001	30-Dec-15 (No. DAE4-601_Dec15)	Dec-16
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
RF generator R&S SMT-06	100872	15-Jun-15 (in house check Jun-15)	In house check: Jun-16
Network Analyzer HP 8753E	US37390685-54206	18-Oct-01 (in house check Oct-15)	In house check: Oct-16

Calibrated by: Name: Michael Weber Function: Laboratory Technician  
Approved by: Name: Katica Pokovic Function: Technical Manager

Issued: January 28, 2016

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

Certificate No: D5GHzV2-1023\_Jan16

Page 1 of 15

Unless otherwise stated the results shown in this test report refer only to the sample(s) tested and such sample(s) are retained for 90 days only.

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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:**

- a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices; Measurement Techniques", June 2013
- b) IEC 62209-2, "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
- c) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

**Additional Documentation:**

- d) 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	V52.8.8
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom V5.0	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	$dx, dy = 4.0 \text{ mm}, dz = 1.4 \text{ mm}$	Graded Ratio = 1.4 (Z direction)
Frequency	5200 MHz $\pm 1 \text{ MHz}$ 5300 MHz $\pm 1 \text{ MHz}$ 5600 MHz $\pm 1 \text{ MHz}$ 5800 MHz $\pm 1 \text{ MHz}$	

**Head TSL parameters at 5200 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	36.0	4.66 mho/m
Measured Head TSL parameters	(22.0 $\pm 0.2$ ) °C	36.2 $\pm 6$ %	4.51 mho/m $\pm 6$ %
Head TSL temperature change during test	< 0.5 °C	---	---

**SAR result with Head TSL at 5200 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.74 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	77.0 W/kg $\pm 19.9$ % (k=2)

SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.23 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	22.1 W/kg $\pm 19.5$ % (k=2)

**Head TSL parameters at 5300 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.9	4.76 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	35.1 ± 6 %	4.60 mho/m ± 6 %
Head TSL temperature change during test	< 0.5 °C	---	---

**SAR result with Head TSL at 5300 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.08 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	79.9 W / kg ± 19.9 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.33 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	23.1 W/kg ± 19.5 % (k=2)

**Head TSL parameters at 5600 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	36.5	5.07 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	34.7 ± 6 %	4.90 mho/m ± 6 %
Head TSL temperature change during test	< 0.5 °C	---	---

**SAR result with Head TSL at 5600 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.31 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	82.6 W/kg ± 19.9 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.38 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	23.6 W/kg ± 19.5 % (k=2)

**Head TSL parameters at 5800 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.3	5.27 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	34.4 ± 6 %	5.10 mho/m ± 6 %
Head TSL temperature change during test	< 0.5 °C	---	---

**SAR result with Head TSL at 5800 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.78 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	77.3 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.22 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	22.0 W/kg ± 19.5 % (k=2)

**Body TSL parameters at 5200 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
<b>Nominal Body TSL parameters</b>	22.0 °C	49.0	5.30 mho/m
<b>Measured Body TSL parameters</b>	(22.0 ± 0.2) °C	47.1 ± 6 %	5.37 mho/m ± 6 %
<b>Body TSL temperature change during test</b>	< 0.5 °C	---	---

**SAR result with Body TSL at 5200 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.25 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	71.9 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.05 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	20.3 W/kg ± 19.5 % (k=2)

**Body TSL parameters at 5300 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
<b>Nominal Body TSL parameters</b>	22.0 °C	48.9	5.42 mho/m
<b>Measured Body TSL parameters</b>	(22.0 ± 0.2) °C	46.9 ± 6 %	5.50 mho/m ± 6 %
<b>Body TSL temperature change during test</b>	< 0.5 °C	---	---

**SAR result with Body TSL at 5300 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.57 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	75.1 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.14 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	21.2 W/kg ± 19.5 % (k=2)

Unless otherwise stated the results shown in this test report refer only to the sample(s) tested and such sample(s) are retained for 90 days only.

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**Body TSL parameters at 5600 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
<b>Nominal Body TSL parameters</b>	22.0 °C	48.5	5.77 mho/m
<b>Measured Body TSL parameters</b>	(22.0 ± 0.2) °C	46.4 ± 6 %	5.91 mho/m ± 6 %
<b>Body TSL temperature change during test</b>	< 0.5 °C	---	---

**SAR result with Body TSL at 5600 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.89 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	78.3 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.23 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	22.1 W/kg ± 19.5 % (k=2)

**Body TSL parameters at 5800 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
<b>Nominal Body TSL parameters</b>	22.0 °C	48.2	6.00 mho/m
<b>Measured Body TSL parameters</b>	(22.0 ± 0.2) °C	46.0 ± 6 %	6.19 mho/m ± 6 %
<b>Body TSL temperature change during test</b>	< 0.5 °C	---	---

**SAR result with Body TSL at 5800 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.59 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	75.3 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.13 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	21.1 W/kg ± 19.5 % (k=2)

**Appendix (Additional assessments outside the scope of SCS 0108)****Antenna Parameters with Head TSL at 5200 MHz**

Impedance, transformed to feed point	49.1 $\Omega$ - 8.4 $j\Omega$
Return Loss	- 21.4 dB

**Antenna Parameters with Head TSL at 5300 MHz**

Impedance, transformed to feed point	49.6 $\Omega$ - 4.2 $j\Omega$
Return Loss	- 27.4 dB

**Antenna Parameters with Head TSL at 5600 MHz**

Impedance, transformed to feed point	54.9 $\Omega$ - 1.4 $j\Omega$
Return Loss	- 26.3 dB

**Antenna Parameters with Head TSL at 5800 MHz**

Impedance, transformed to feed point	55.9 $\Omega$ + 2.2 $j\Omega$
Return Loss	- 24.5 dB

**Antenna Parameters with Body TSL at 5200 MHz**

Impedance, transformed to feed point	49.4 $\Omega$ - 6.8 $j\Omega$
Return Loss	- 23.3 dB

**Antenna Parameters with Body TSL at 5300 MHz**

Impedance, transformed to feed point	50.9 $\Omega$ - 2.4 $j\Omega$
Return Loss	- 31.8 dB

**Antenna Parameters with Body TSL at 5600 MHz**

Impedance, transformed to feed point	56.0 $\Omega$ - 0.1 $j\Omega$
Return Loss	- 25.0 dB

**Antenna Parameters with Body TSL at 5800 MHz**

Impedance, transformed to feed point	56.4 Ω + 2.4 jΩ
Return Loss	- 23.8 dB

**General Antenna Parameters and Design**

Electrical Delay (one direction)	1.199 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	February 05, 2004

## DASY5 Validation Report for Head TSL

Date: 26.01.2016

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1023**

Communication System: UID 0 - CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz

Medium parameters used:  $f = 5200 \text{ MHz}$ ;  $\sigma = 4.51 \text{ S/m}$ ;  $\epsilon_r = 35.2$ ;  $\rho = 1000 \text{ kg/m}^3$ , Medium parameters used:  $f = 5300 \text{ MHz}$ ;  $\sigma = 4.6 \text{ S/m}$ ;  $\epsilon_r = 35.1$ ;  $\rho = 1000 \text{ kg/m}^3$ , Medium parameters used:  $f = 5600 \text{ MHz}$ ;  $\sigma = 4.9 \text{ S/m}$ ;  $\epsilon_r = 34.7$ ;  $\rho = 1000 \text{ kg/m}^3$ , Medium parameters used:  $f = 5800 \text{ MHz}$ ;  $\sigma = 5.1 \text{ S/m}$ ;  $\epsilon_r = 34.4$ ;  $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.59, 5.59, 5.59); Calibrated: 31.12.2015, ConvF(5.25, 5.25, 5.25); Calibrated: 31.12.2015, ConvF(4.99, 4.99, 4.99); Calibrated: 31.12.2015, ConvF(4.95, 4.95, 4.95); Calibrated: 31.12.2015;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.12.2015
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.8(1258); SEMCAD X 14.6.10(7372)

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 72.68 V/m; Power Drift = 0.07 dB

Peak SAR (extrapolated) = 28.1 W/kg

SAR(1 g) = 7.74 W/kg; SAR(10 g) = 2.23 W/kg

Maximum value of SAR (measured) = 17.8 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 73.14 V/m; Power Drift = 0.04 dB

Peak SAR (extrapolated) = 30.0 W/kg

SAR(1 g) = 8.03 W/kg; SAR(10 g) = 2.33 W/kg

Maximum value of SAR (measured) = 18.7 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 73.32 V/m; Power Drift = 0.08 dB

Peak SAR (extrapolated) = 32.6 W/kg

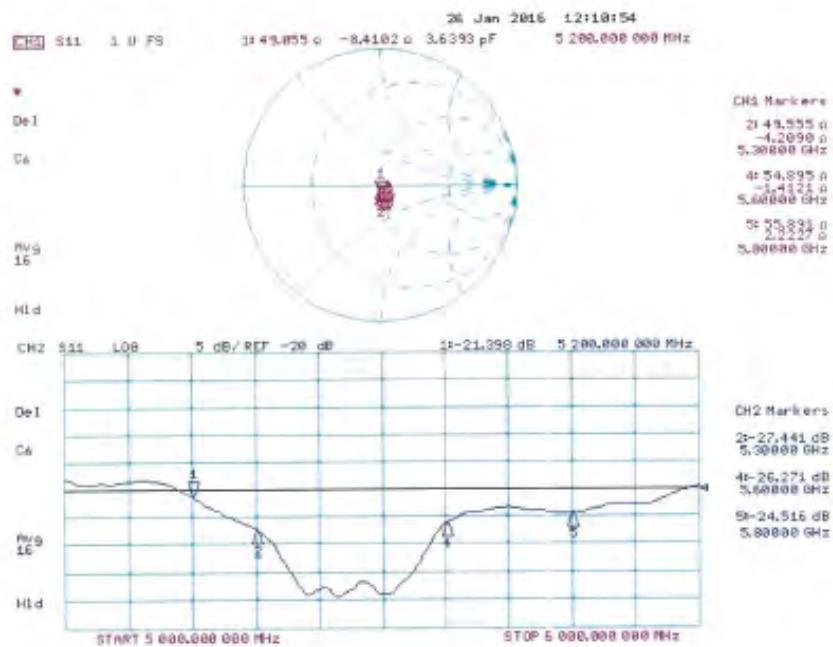
SAR(1 g) = 8.31 W/kg; SAR(10 g) = 2.38 W/kg

Maximum value of SAR (measured) = 19.8 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 70.15 V/m; Power Drift = 0.04 dB  
Peak SAR (extrapolated) = 32.0 W/kg  
SAR(1 g) = 7.78 W/kg; SAR(10 g) = 2.22 W/kg  
Maximum value of SAR (measured) = 18.8 W/kg



## Impedance Measurement Plot for Head TSL



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## DASY5 Validation Report for Body TSL

Date: 25.01.2016

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1023**

Communication System: UID 0 - CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz

Medium parameters used:  $f = 5200 \text{ MHz}$ ;  $\sigma = 5.37 \text{ S/m}$ ;  $\epsilon_r = 47.1$ ;  $\rho = 1000 \text{ kg/m}^3$ , Medium parameters used:  $f = 5300 \text{ MHz}$ ;  $\sigma = 5.5 \text{ S/m}$ ;  $\epsilon_r = 46.9$ ;  $\rho = 1000 \text{ kg/m}^3$ , Medium parameters used:  $f = 5600 \text{ MHz}$ ;  $\sigma = 5.91 \text{ S/m}$ ;  $\epsilon_r = 46.4$ ;  $\rho = 1000 \text{ kg/m}^3$ , Medium parameters used:  $f = 5800 \text{ MHz}$ ;  $\sigma = 6.19 \text{ S/m}$ ;  $\epsilon_r = 46$ ;  $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(4.99, 4.99, 4.99); Calibrated: 31.12.2015, ConvF(4.75, 4.75, 4.75); Calibrated: 31.12.2015, ConvF(4.35, 4.35, 4.35); Calibrated: 31.12.2015, ConvF(4.27, 4.27, 4.27); Calibrated: 31.12.2015;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.12.2015
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.8(1258); SEMCAD X 14.6.10(7372)

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid:  $dx=4\text{mm}$ ,  $dy=4\text{mm}$ ,  $dz=1.4\text{mm}$

Reference Value = 66.72 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 27.1 W/kg

SAR(1 g) = 7.25 W/kg; SAR(10 g) = 2.05 W/kg

Maximum value of SAR (measured) = 16.8 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid:  $dx=4\text{mm}$ ,  $dy=4\text{mm}$ ,  $dz=1.4\text{mm}$

Reference Value = 67.43 V/m; Power Drift = 0.02 dB

Peak SAR (extrapolated) = 29.1 W/kg

SAR(1 g) = 7.57 W/kg; SAR(10 g) = 2.14 W/kg

Maximum value of SAR (measured) = 17.7 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid:  $dx=4\text{mm}$ ,  $dy=4\text{mm}$ ,  $dz=1.4\text{mm}$

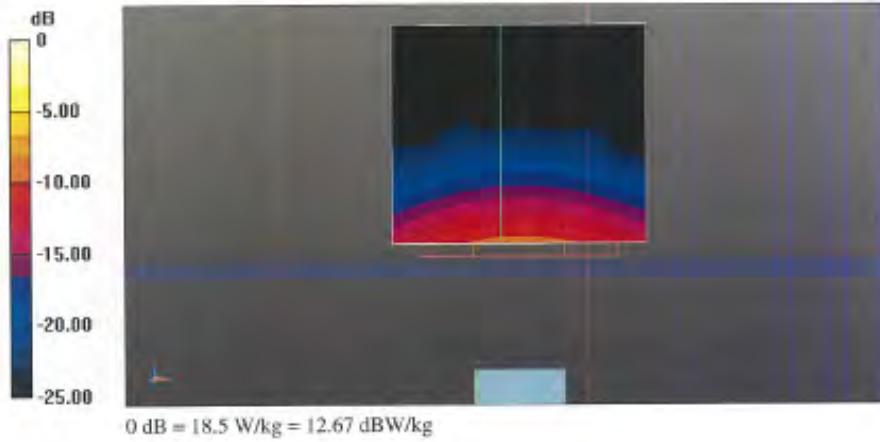
Reference Value = 67.67 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 32.6 W/kg

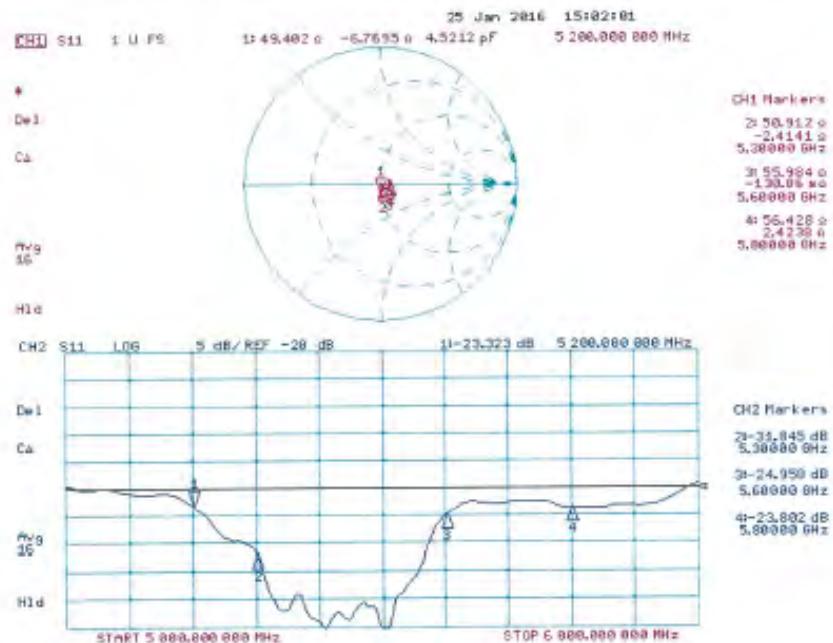
SAR(1 g) = 7.89 W/kg; SAR(10 g) = 2.23 W/kg

Maximum value of SAR (measured) = 19.1 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 65.76 V/m; Power Drift = -0.02 dB  
Peak SAR (extrapolated) = 33.0 W/kg  
SAR(1 g) = 7.59 W/kg; SAR(10 g) = 2.13 W/kg  
Maximum value of SAR (measured) = 18.5 W/kg



### Impedance Measurement Plot for Body TSL



Certificate No: D5GHzV2-1023\_Jan16

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## **- End of 1<sup>st</sup> part of report -**

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