



In Collaboration with

**s p e a g**  
**CALIBRATION LABORATORY**

Add: No.51 Xueyuan Road, Haidian District, Beijing, 100191, China

Tel: +86-10-62304633-2079

Fax: +86-10-62304633-2504

E-mail: cttl@chinattl.com

Http://www.chinattl.cn

### Glossary:

|       |                                            |
|-------|--------------------------------------------|
| TSL   | tissue simulating liquid                   |
| ConvF | sensitivity in TSL / NORM <sub>x,y,z</sub> |
| N/A   | not applicable or not measured             |

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

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Procedure to measure the Specific Absorption Rate (SAR) For hand-held devices used in close proximity to the ear (frequency range of 300MHz to 3GHz)", February 2005
- IEC 62209-2, "Procedure to measure the Specific Absorption Rate (SAR) For wireless communication devices used in close proximity to the human body (frequency range of 30MHz to 6GHz)", March 2010
- KDB865664, SAR Measurement Requirements for 100 MHz to 6 GHz

### Additional Documentation:

- DASY4/5 System Handbook

### Methods Applied and Interpretation of Parameters:

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

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



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## Measurement Conditions

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

|                              |                          |             |
|------------------------------|--------------------------|-------------|
| DASY Version                 | DASY52                   | 52.8.8.1258 |
| Extrapolation                | Advanced Extrapolation   |             |
| Phantom                      | Triple Flat Phantom 5.1C |             |
| Distance Dipole Center - TSL | 10 mm                    | with Spacer |
| Zoom Scan Resolution         | dx, dy, dz = 5 mm        |             |
| Frequency                    | 2600 MHz $\pm$ 1 MHz     |             |

## Head TSL parameters

The following parameters and calculations were applied.

|                                         | Temperature         | Permittivity   | Conductivity         |
|-----------------------------------------|---------------------|----------------|----------------------|
| Nominal Head TSL parameters             | 22.0 °C             | 39.0           | 1.96 mho/m           |
| Measured Head TSL parameters            | (22.0 $\pm$ 0.2) °C | 39.4 $\pm$ 6 % | 1.97 mho/m $\pm$ 6 % |
| Head TSL temperature change during test | <1.0 °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 | 14.2 mW / g                    |
| SAR for nominal Head TSL parameters                     | normalized to 1W   | 56.8 mW / g $\pm$ 20.8 % (k=2) |
| SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL | Condition          |                                |
| SAR measured                                            | 250 mW input power | 6.40 mW / g                    |
| SAR for nominal Head TSL parameters                     | normalized to 1W   | 25.6 mW / g $\pm$ 20.4 % (k=2) |

## Body TSL parameters

The following parameters and calculations were applied.

|                                         | Temperature         | Permittivity   | Conductivity         |
|-----------------------------------------|---------------------|----------------|----------------------|
| Nominal Body TSL parameters             | 22.0 °C             | 52.5           | 2.16 mho/m           |
| Measured Body TSL parameters            | (22.0 $\pm$ 0.2) °C | 52.2 $\pm$ 6 % | 2.18 mho/m $\pm$ 6 % |
| Body TSL temperature change during test | <1.0 °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 | 13.9 mW / g                    |
| SAR for nominal Body TSL parameters                     | normalized to 1W   | 55.2 mW / g $\pm$ 20.8 % (k=2) |
| SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL | Condition          |                                |
| SAR measured                                            | 250 mW input power | 6.28 mW / g                    |
| SAR for nominal Body TSL parameters                     | normalized to 1W   | 25.0 mW / g $\pm$ 20.4 % (k=2) |



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## Appendix

### Antenna Parameters with Head TSL

|                                      |               |
|--------------------------------------|---------------|
| Impedance, transformed to feed point | 48.3Ω- 1.82jΩ |
| Return Loss                          | - 31.8dB      |

### Antenna Parameters with Body TSL

|                                      |               |
|--------------------------------------|---------------|
| Impedance, transformed to feed point | 45.8Ω- 1.91jΩ |
| Return Loss                          | - 26.4dB      |

### General Antenna Parameters and Design

|                                  |          |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.046 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 |
|-----------------|-------|



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## DASY5 Validation Report for Head TSL

Date: 08.30.2016

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 2600 MHz; Type: D2600V2; Serial: D2600V2 - SN: 1008**

Communication System: UID 0, CW; Frequency: 2600 MHz; Duty Cycle: 1:1

Medium parameters used:  $f = 2600$  MHz;  $\sigma = 1.974$  S/m;  $\epsilon_r = 39.43$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Right Section

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

DASY5 Configuration:

- Probe: EX3DV4 - SN3801; ConvF(6.64, 6.64, 6.64); Calibrated: 6/29/2016;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn777; Calibrated: 8/22/2016
- Phantom: Triple Flat Phantom 5.1C; Type: QD 000 P51 CA; Serial: 1161/1
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7372)

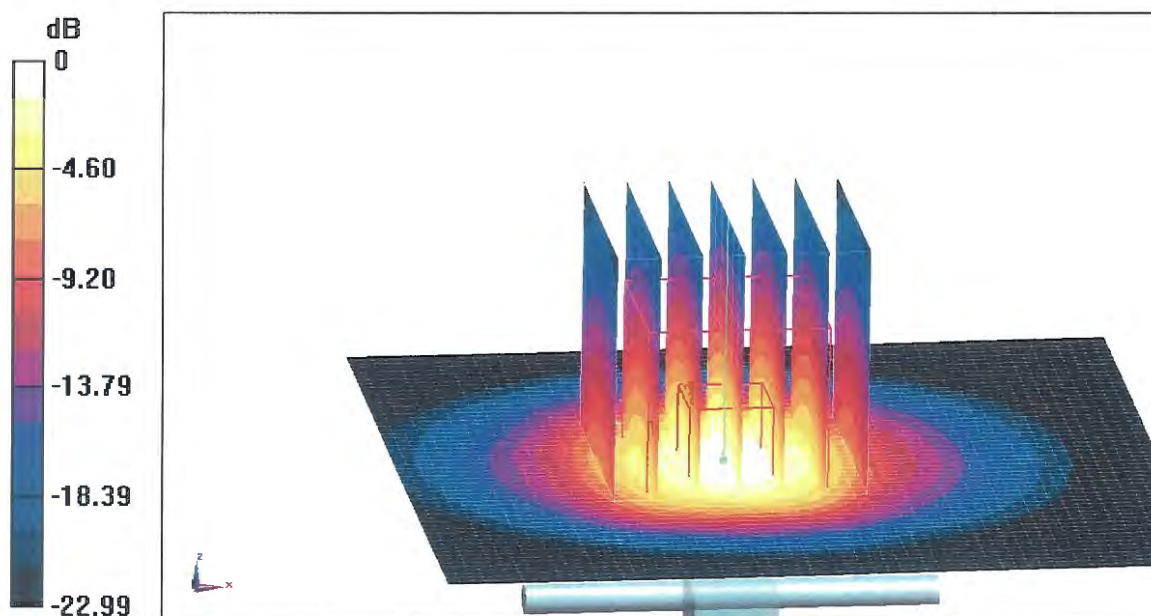
**Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 107.4 V/m; Power Drift = 0.02 dB

Peak SAR (extrapolated) = 30.0 W/kg

**SAR(1 g) = 14.2 W/kg; SAR(10 g) = 6.4 W/kg**

Maximum value of SAR (measured) = 22.1 W/kg



0 dB = 22.1 W/kg = 13.44 dBW/kg



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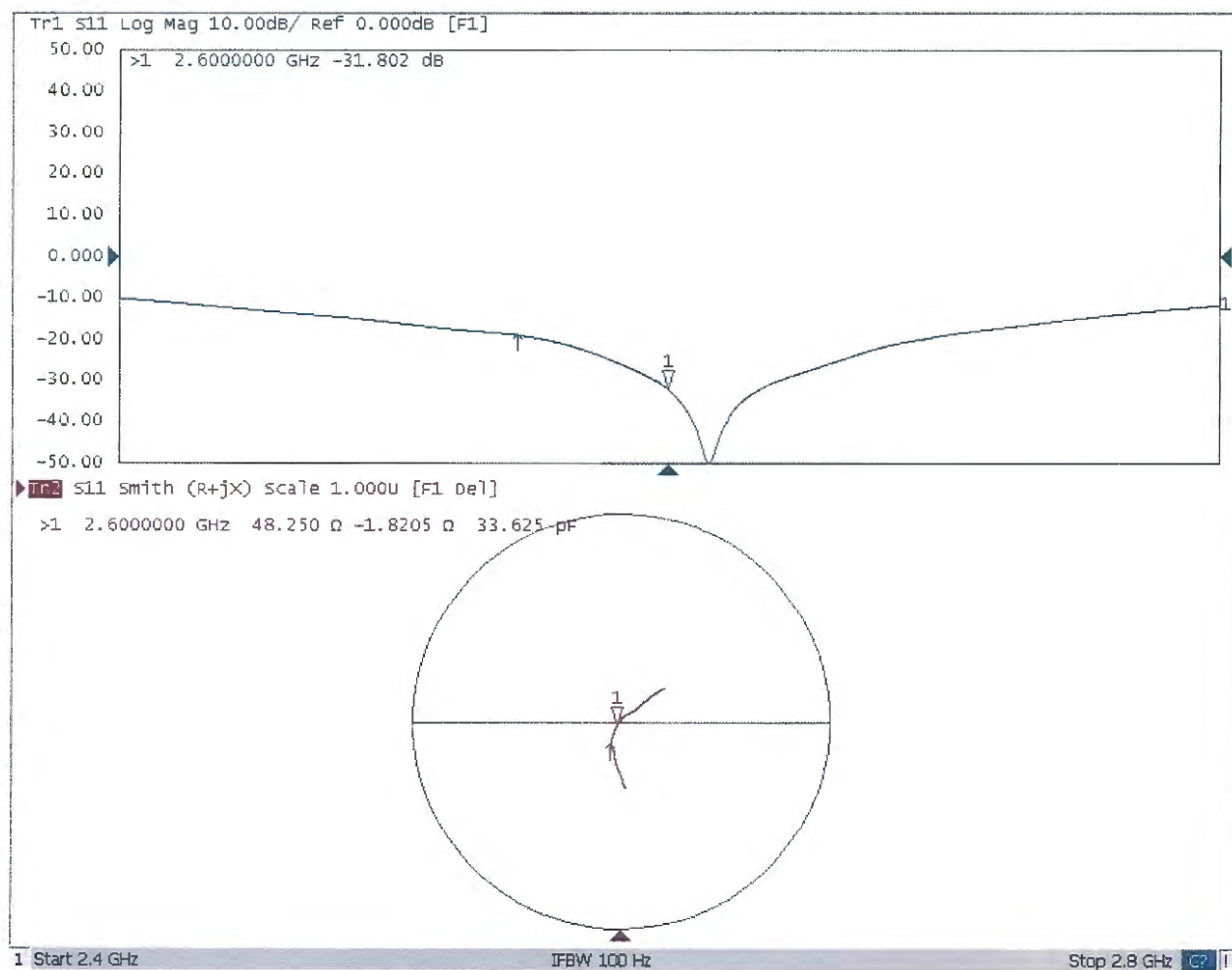
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## Impedance Measurement Plot for Head TSL





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## DASY5 Validation Report for Body TSL

Date: 08.30.2016

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 2600 MHz; Type: D2600V2; Serial: D2600V2 - SN: 1008**

Communication System: UID 0, CW; Frequency: 2600 MHz; Duty Cycle: 1:1

Medium parameters used:  $f = 2600$  MHz;  $\sigma = 2.184$  S/m;  $\epsilon_r = 52.15$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Left Section

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

DASY5 Configuration:

- Probe: EX3DV4 - SN3801; ConvF(6.7, 6.7,6.7); Calibrated: 6/29/2016;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn777; Calibrated: 8/22/2016
- Phantom: Triple Flat Phantom 5.1C; Type: QD 000 P51 CA; Serial: 1161/1
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7372)

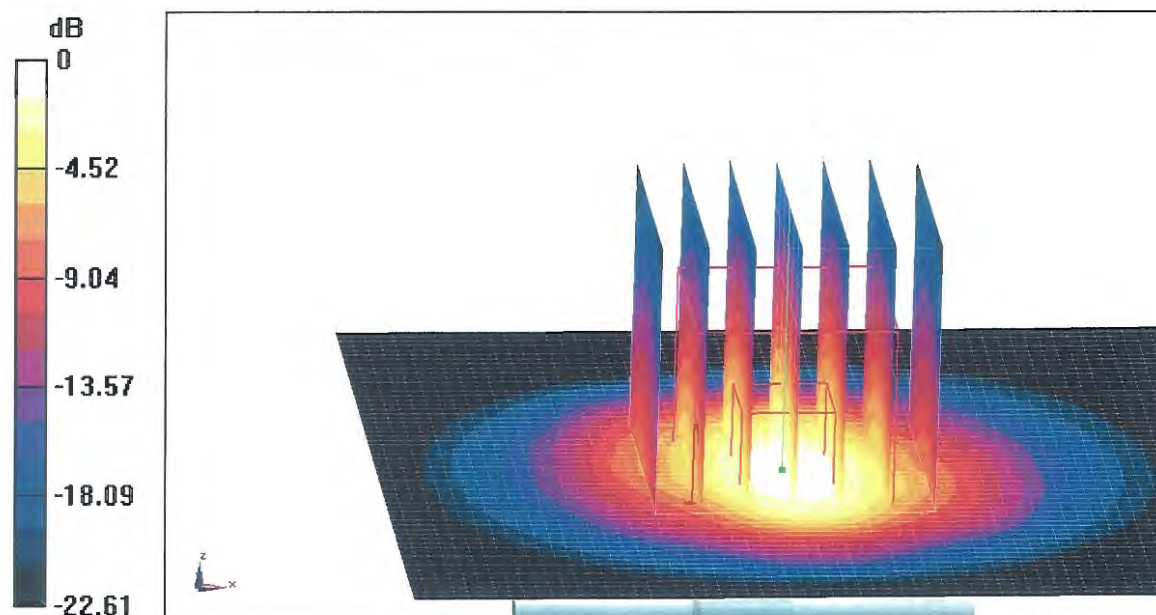
**Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 94.70 V/m; Power Drift = -0.00 dB

Peak SAR (extrapolated) = 28.8 W/kg

**SAR(1 g) = 13.9 W/kg; SAR(10 g) = 6.28 W/kg**

Maximum value of SAR (measured) = 21.3 W/kg



0 dB = 21.3 W/kg = 13.28 dBW/kg



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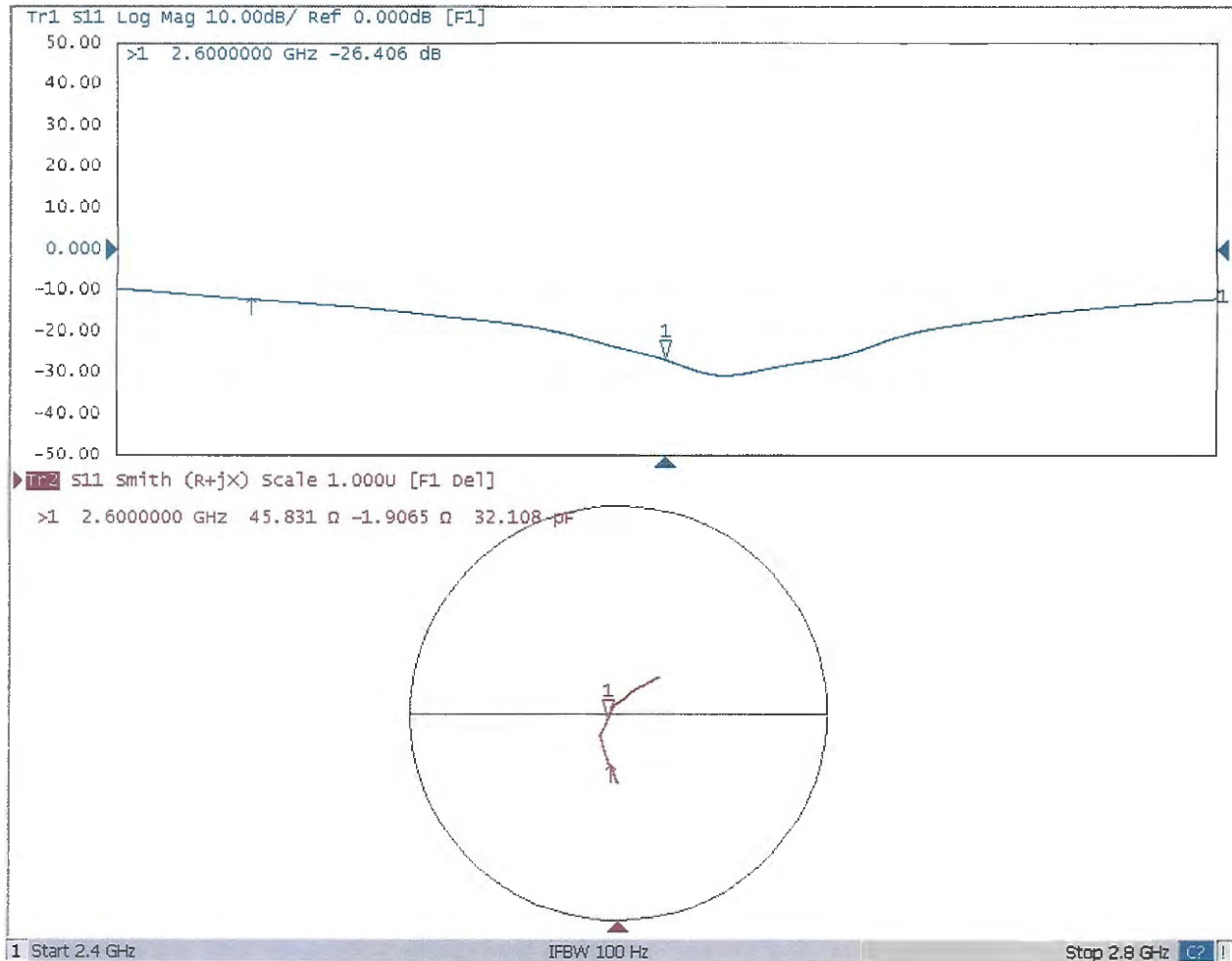
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## Impedance Measurement Plot for Body TSL





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 **Sporton-SZ (Auden)**

Certificate No: **D5GHzV2-1167\_Jul16**

## CALIBRATION CERTIFICATE

Object **D5GHzV2 - SN:1167**

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

Calibration date: **July 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 ( $22 \pm 3$ )°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards           | ID #               | Cal Date (Certificate No.)      | Scheduled Calibration |
|-----------------------------|--------------------|---------------------------------|-----------------------|
| Power meter NRP             | SN: 104778         | 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: 3503           | 30-Jun-16 (No. EX3-3503_Jun16)  | Jun-17                |
| DAE4                        | SN: 601            | 30-Dec-15 (No. DAE4-601_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: US37390585 | 18-Oct-01 (in house check Oct-15) | In house check: Oct-16 |

Calibrated by: **Name** Claudio Leubler **Function** Laboratory Technician

Approved by: **Name** Katja Pokovic **Function** Technical Manager

Signature

Issued: July 27, 2016

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



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

### Glossary:

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

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

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

### Additional Documentation:

- DASY4/5 System Handbook

### Methods Applied and Interpretation of Parameters:

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

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

## Measurement Conditions

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

|                              |                                                                      |                                  |
|------------------------------|----------------------------------------------------------------------|----------------------------------|
| DASY Version                 | DASY5                                                                | V52.8.8                          |
| Extrapolation                | Advanced Extrapolation                                               |                                  |
| Phantom                      | Modular Flat Phantom V5.0                                            |                                  |
| Distance Dipole Center - TSL | 10 mm                                                                | with Spacer                      |
| Zoom Scan Resolution         | dx, dy = 4.0 mm, dz = 1.4 mm                                         | Graded Ratio = 1.4 (Z direction) |
| Frequency                    | 5250 MHz $\pm$ 1 MHz<br>5600 MHz $\pm$ 1 MHz<br>5750 MHz $\pm$ 1 MHz |                                  |

## Head TSL parameters at 5250 MHz

The following parameters and calculations were applied.

|                                         | Temperature         | Permittivity   | Conductivity         |
|-----------------------------------------|---------------------|----------------|----------------------|
| Nominal Head TSL parameters             | 22.0 °C             | 35.9           | 4.71 mho/m           |
| Measured Head TSL parameters            | (22.0 $\pm$ 0.2) °C | 34.4 $\pm$ 6 % | 4.52 mho/m $\pm$ 6 % |
| Head TSL temperature change during test | < 0.5 °C            | ----           | ----                 |

## SAR result with Head TSL at 5250 MHz

|                                                       |                    |                                                |
|-------------------------------------------------------|--------------------|------------------------------------------------|
| SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL | Condition          |                                                |
| SAR measured                                          | 100 mW input power | 7.79 W/kg                                      |
| SAR for nominal Head TSL parameters                   | normalized to 1W   | <b>77.1 W/kg <math>\pm</math> 19.9 % (k=2)</b> |

|                                                         |                    |                                                |
|---------------------------------------------------------|--------------------|------------------------------------------------|
| SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL | condition          |                                                |
| SAR measured                                            | 100 mW input power | 2.24 W/kg                                      |
| SAR for nominal Head TSL parameters                     | normalized to 1W   | <b>22.1 W/kg <math>\pm</math> 19.5 % (k=2)</b> |

### Head TSL parameters at 5600 MHz

The following parameters and calculations were applied.

|                                         | Temperature     | Permittivity | Conductivity     |
|-----------------------------------------|-----------------|--------------|------------------|
| Nominal Head TSL parameters             | 22.0 °C         | 35.5         | 5.07 mho/m       |
| Measured Head TSL parameters            | (22.0 ± 0.2) °C | 33.9 ± 6 %   | 4.86 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C        | ----         | ----             |

### SAR result with Head TSL at 5600 MHz

|                                                             |                    |                                   |
|-------------------------------------------------------------|--------------------|-----------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Head TSL</b> | Condition          |                                   |
| SAR measured                                                | 100 mW input power | 8.19 W/kg                         |
| SAR for nominal Head TSL parameters                         | normalized to 1W   | <b>81.0 W / kg ± 19.9 % (k=2)</b> |

|                                                               |                    |                                 |
|---------------------------------------------------------------|--------------------|---------------------------------|
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Head TSL</b> | condition          |                                 |
| SAR measured                                                  | 100 mW input power | 2.34 W/kg                       |
| SAR for nominal Head TSL parameters                           | normalized to 1W   | <b>23.1 W/kg ± 19.5 % (k=2)</b> |

### Head TSL parameters at 5750 MHz

The following parameters and calculations were applied.

|                                         | Temperature     | Permittivity | Conductivity     |
|-----------------------------------------|-----------------|--------------|------------------|
| Nominal Head TSL parameters             | 22.0 °C         | 35.4         | 5.22 mho/m       |
| Measured Head TSL parameters            | (22.0 ± 0.2) °C | 33.7 ± 6 %   | 5.02 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C        | ----         | ----             |

### SAR result with Head TSL at 5750 MHz

|                                                             |                    |                                 |
|-------------------------------------------------------------|--------------------|---------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Head TSL</b> | Condition          |                                 |
| SAR measured                                                | 100 mW input power | 7.93 W/kg                       |
| SAR for nominal Head TSL parameters                         | normalized to 1W   | <b>78.4 W/kg ± 19.9 % (k=2)</b> |

|                                                               |                    |                                 |
|---------------------------------------------------------------|--------------------|---------------------------------|
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Head TSL</b> | condition          |                                 |
| SAR measured                                                  | 100 mW input power | 2.25 W/kg                       |
| SAR for nominal Head TSL parameters                           | normalized to 1W   | <b>22.2 W/kg ± 19.5 % (k=2)</b> |

### Body TSL parameters at 5250 MHz

The following parameters and calculations were applied.

|                                         | Temperature     | Permittivity | Conductivity     |
|-----------------------------------------|-----------------|--------------|------------------|
| Nominal Body TSL parameters             | 22.0 °C         | 48.9         | 5.36 mho/m       |
| Measured Body TSL parameters            | (22.0 ± 0.2) °C | 47.1 ± 6 %   | 5.42 mho/m ± 6 % |
| Body TSL temperature change during test | < 0.5 °C        | ----         | ----             |

### SAR result with Body TSL at 5250 MHz

|                                                             |                    |                                 |
|-------------------------------------------------------------|--------------------|---------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Body TSL</b> | Condition          |                                 |
| SAR measured                                                | 100 mW input power | 7.64 W/kg                       |
| SAR for nominal Body TSL parameters                         | normalized to 1W   | <b>75.8 W/kg ± 19.9 % (k=2)</b> |

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

### Body TSL parameters at 5600 MHz

The following parameters and calculations were applied.

|                                         | Temperature     | Permittivity | Conductivity     |
|-----------------------------------------|-----------------|--------------|------------------|
| Nominal Body TSL parameters             | 22.0 °C         | 48.5         | 5.77 mho/m       |
| Measured Body TSL parameters            | (22.0 ± 0.2) °C | 46.5 ± 6 %   | 5.88 mho/m ± 6 % |
| Body TSL temperature change during test | < 0.5 °C        | ----         | ----             |

### SAR result with Body TSL at 5600 MHz

|                                                             |                    |                                 |
|-------------------------------------------------------------|--------------------|---------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Body TSL</b> | Condition          |                                 |
| SAR measured                                                | 100 mW input power | 7.90 W/kg                       |
| SAR for nominal Body TSL parameters                         | normalized to 1W   | <b>78.4 W/kg ± 19.9 % (k=2)</b> |

|                                                               |                    |                                 |
|---------------------------------------------------------------|--------------------|---------------------------------|
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Body TSL</b> | condition          |                                 |
| SAR measured                                                  | 100 mW input power | 2.21 W/kg                       |
| SAR for nominal Body TSL parameters                           | normalized to 1W   | <b>21.9 W/kg ± 19.5 % (k=2)</b> |

### Body TSL parameters at 5750 MHz

The following parameters and calculations were applied.

|                                         | Temperature     | Permittivity | Conductivity     |
|-----------------------------------------|-----------------|--------------|------------------|
| Nominal Body TSL parameters             | 22.0 °C         | 48.3         | 5.94 mho/m       |
| Measured Body TSL parameters            | (22.0 ± 0.2) °C | 46.2 ± 6 %   | 6.11 mho/m ± 6 % |
| Body TSL temperature change during test | < 0.5 °C        | ----         | ----             |

### SAR result with Body TSL at 5750 MHz

|                                                       |                    |                                 |
|-------------------------------------------------------|--------------------|---------------------------------|
| SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL | Condition          |                                 |
| SAR measured                                          | 100 mW input power | 7.65 W/kg                       |
| SAR for nominal Body TSL parameters                   | normalized to 1W   | <b>75.9 W/kg ± 19.9 % (k=2)</b> |

|                                                         |                    |                                 |
|---------------------------------------------------------|--------------------|---------------------------------|
| 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   | <b>21.1 W/kg ± 19.5 % (k=2)</b> |

## Appendix (Additional assessments outside the scope of SCS 0108)

### Antenna Parameters with Head TSL at 5250 MHz

|                                      |                                 |
|--------------------------------------|---------------------------------|
| Impedance, transformed to feed point | 46.9 $\Omega$ - 13.4 j $\Omega$ |
| Return Loss                          | - 17.0 dB                       |

### Antenna Parameters with Head TSL at 5600 MHz

|                                      |                                |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 53.9 $\Omega$ - 9.8 j $\Omega$ |
| Return Loss                          | - 19.9 dB                      |

### Antenna Parameters with Head TSL at 5750 MHz

|                                      |                                 |
|--------------------------------------|---------------------------------|
| Impedance, transformed to feed point | 53.9 $\Omega$ - 11.8 j $\Omega$ |
| Return Loss                          | - 18.5 dB                       |

### Antenna Parameters with Body TSL at 5250 MHz

|                                      |                                 |
|--------------------------------------|---------------------------------|
| Impedance, transformed to feed point | 45.5 $\Omega$ - 11.0 j $\Omega$ |
| Return Loss                          | - 18.2 dB                       |

### Antenna Parameters with Body TSL at 5600 MHz

|                                      |                                |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 53.9 $\Omega$ - 8.9 j $\Omega$ |
| Return Loss                          | - 20.6 dB                      |

### Antenna Parameters with Body TSL at 5750 MHz

|                                      |                                 |
|--------------------------------------|---------------------------------|
| Impedance, transformed to feed point | 52.7 $\Omega$ - 11.8 j $\Omega$ |
| Return Loss                          | - 18.7 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 | October 30, 2013 |

## DASY5 Validation Report for Head TSL

Date: 27.07.2016

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN:1167**

Communication System: UID 0 - CW; Frequency: 5250 MHz, Frequency: 5600 MHz, Frequency: 5750 MHz

Medium parameters used:  $f = 5250 \text{ MHz}$ ;  $\sigma = 4.52 \text{ S/m}$ ;  $\epsilon_r = 34.4$ ;  $\rho = 1000 \text{ kg/m}^3$

Medium parameters used:  $f = 5600 \text{ MHz}$ ;  $\sigma = 4.86 \text{ S/m}$ ;  $\epsilon_r = 33.9$ ;  $\rho = 1000 \text{ kg/m}^3$

Medium parameters used:  $f = 5750 \text{ MHz}$ ;  $\sigma = 5.02 \text{ S/m}$ ;  $\epsilon_r = 33.7$ ;  $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.42, 5.42, 5.42); Calibrated: 30.06.2016, ConvF(4.89, 4.89, 4.89); Calibrated: 30.06.2016, ConvF(4.85, 4.85, 4.85); Calibrated: 30.06.2016;
- 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=5250 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 = 73.17 V/m; Power Drift = -0.04 dB

Peak SAR (extrapolated) = 28.5 W/kg

**SAR(1 g) = 7.79 W/kg; SAR(10 g) = 2.24 W/kg**

Maximum value of SAR (measured) = 18.0 W/kg

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

Reference Value = 73.11 V/m; Power Drift = 0.02 dB

Peak SAR (extrapolated) = 32.1 W/kg

**SAR(1 g) = 8.19 W/kg; SAR(10 g) = 2.34 W/kg**

Maximum value of SAR (measured) = 19.5 W/kg

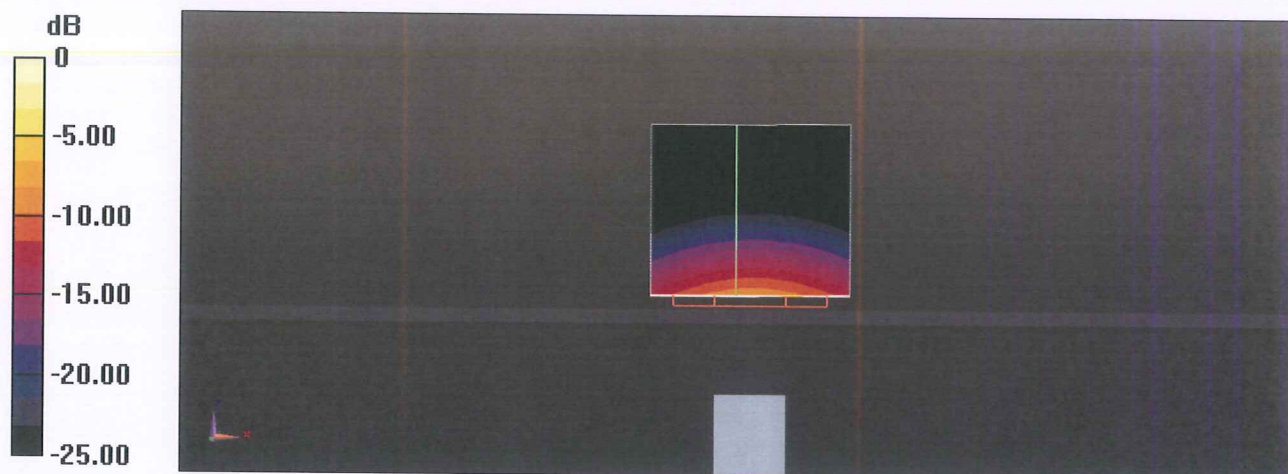
**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5750 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid:  $dx=4\text{mm}$ ,  $dy=4\text{mm}$ ,  $dz=1.4\text{mm}$

Reference Value = 71.18 V/m; Power Drift = 0.02 dB

Peak SAR (extrapolated) = 32.5 W/kg

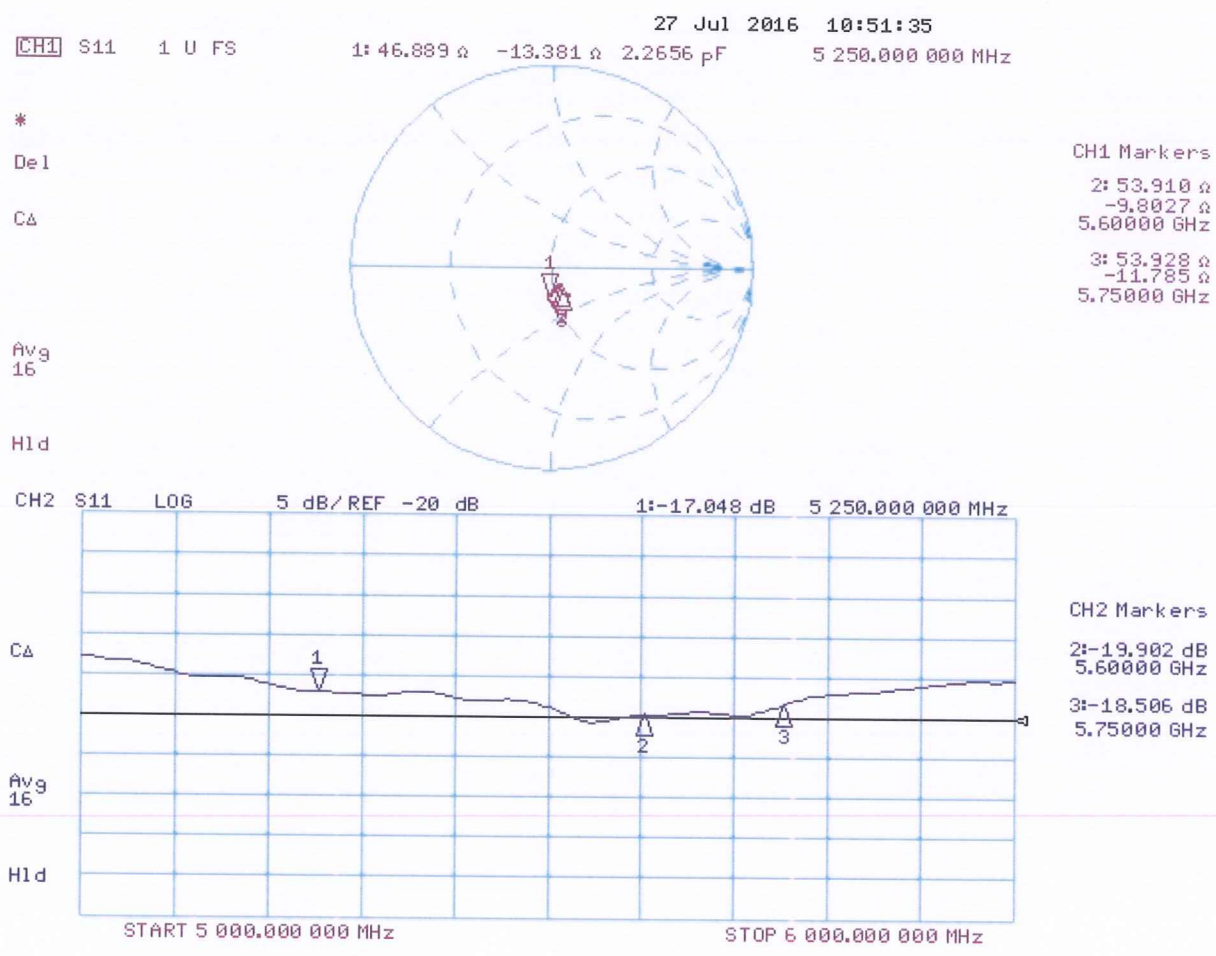
**SAR(1 g) = 7.93 W/kg; SAR(10 g) = 2.25 W/kg**

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



0 dB = 19.3 W/kg = 12.86 dBW/kg

Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Date: 26.07.2016

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN:1167**

Communication System: UID 0 - CW; Frequency: 5250 MHz, Frequency: 5600 MHz, Frequency: 5750 MHz

Medium parameters used:  $f = 5250 \text{ MHz}$ ;  $\sigma = 5.42 \text{ S/m}$ ;  $\epsilon_r = 47.1$ ;  $\rho = 1000 \text{ kg/m}^3$

Medium parameters used:  $f = 5600 \text{ MHz}$ ;  $\sigma = 5.88 \text{ S/m}$ ;  $\epsilon_r = 46.5$ ;  $\rho = 1000 \text{ kg/m}^3$

Medium parameters used:  $f = 5750 \text{ MHz}$ ;  $\sigma = 6.11 \text{ S/m}$ ;  $\epsilon_r = 46.2$ ;  $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(4.85, 4.85, 4.85); Calibrated: 30.06.2016, ConvF(4.35, 4.35, 4.35); Calibrated: 30.06.2016, ConvF(4.3, 4.3, 4.3); Calibrated: 30.06.2016;
- 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=5250MHz/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 = 68.19 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 29.0 W/kg

**SAR(1 g) = 7.64 W/kg; SAR(10 g) = 2.13 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 = 68.01 V/m; Power Drift = 0.01 dB

Peak SAR (extrapolated) = 32.7 W/kg

**SAR(1 g) = 7.9 W/kg; SAR(10 g) = 2.21 W/kg**

Maximum value of SAR (measured) = 18.9 W/kg

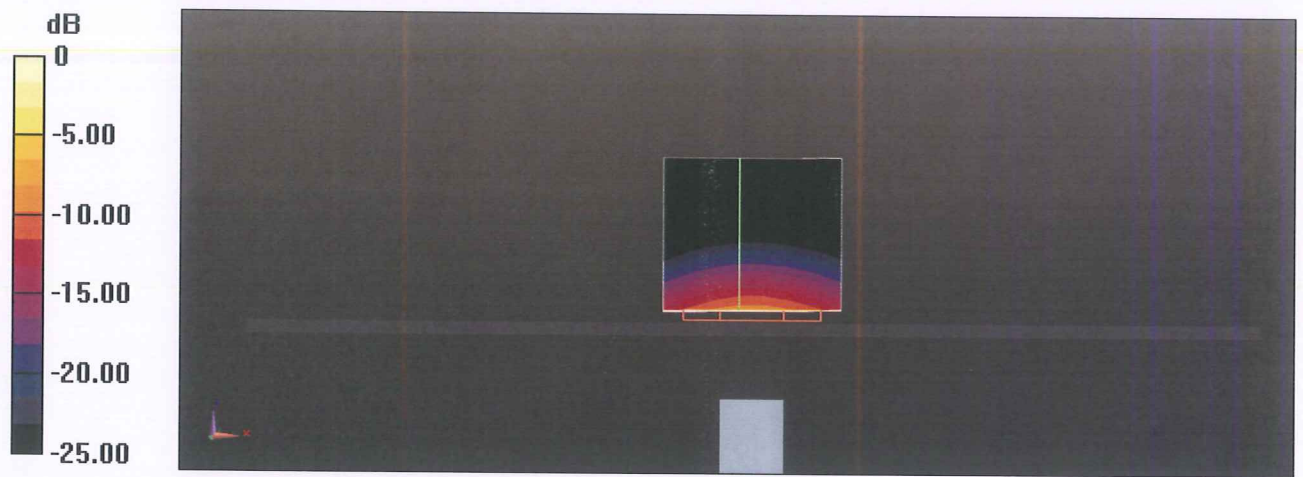
**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5750 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid:  $dx=4\text{mm}$ ,  $dy=4\text{mm}$ ,  $dz=1.4\text{mm}$

Reference Value = 66.17 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 33.2 W/kg

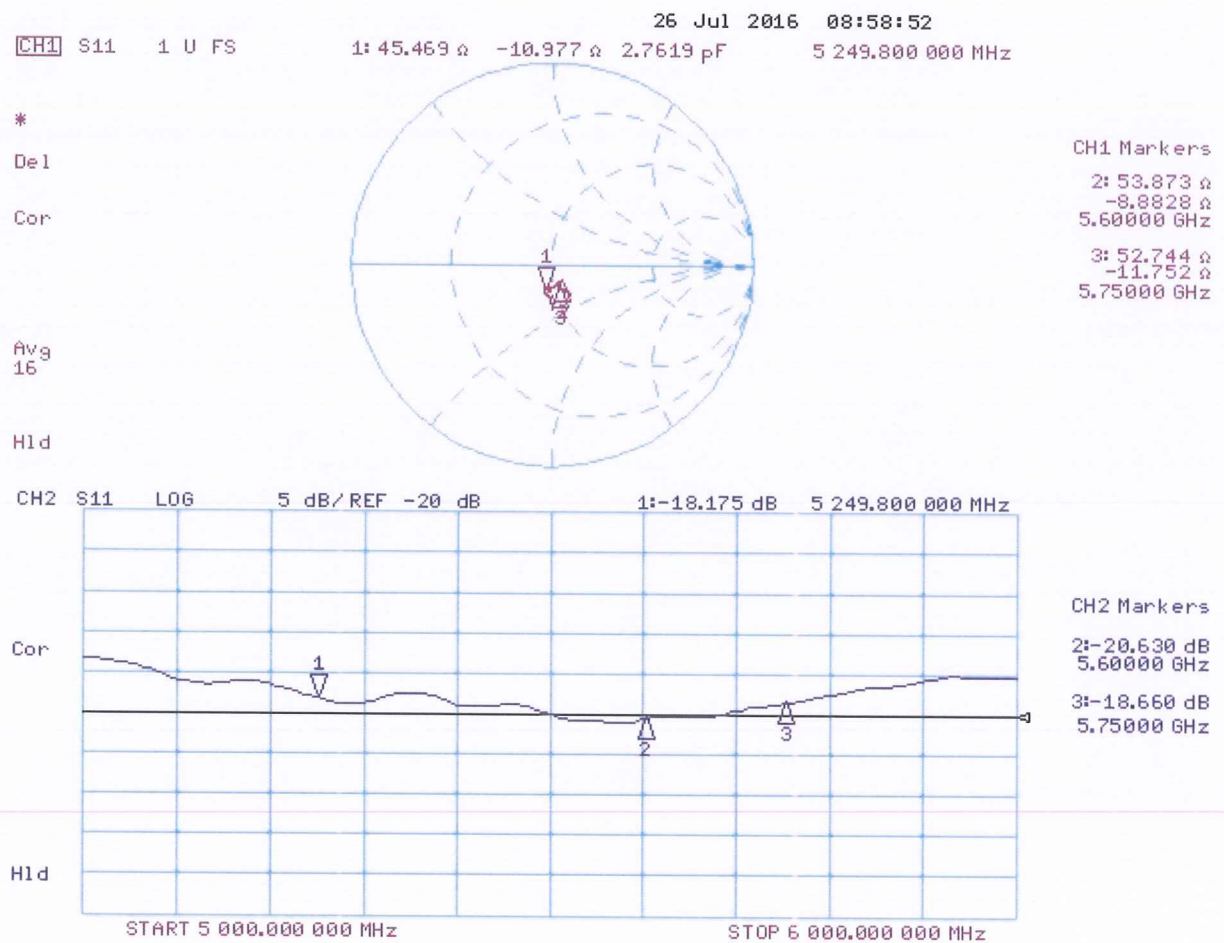
**SAR(1 g) = 7.65 W/kg; SAR(10 g) = 2.13 W/kg**

Maximum value of SAR (measured) = 18.6 W/kg



0 dB = 18.6 W/kg = 12.70 dBW/kg

# Impedance Measurement Plot for Body TSL



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## IMPORTANT NOTICE

### USAGE OF THE DAE 4

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

**Battery Exchange:** The battery cover of the DAE4 unit is closed using a screw, over tightening the screw may cause the threads inside the DAE to wear out.

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

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

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

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

**Important Note:**

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

**Important Note:**

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

**Important Note:**

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



Accredited by the Swiss Accreditation Service (SAS)

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

Accreditation No.: **SCS 0108**

Client **Auden**

Certificate No: **DAE4-915\_Jun16**

## CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BK - SN: 915**

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

Calibration date: **June 22, 2016**

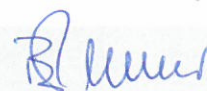
This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).  
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature  $(22 \pm 3)^{\circ}\text{C}$  and humidity  $< 70\%$ .

Calibration Equipment used (M&TE critical for calibration)

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

Calibrated by: **Dominique Steffen**      Name: **Dominique Steffen**      Function: **Technician**      Signature: 

Approved by: **Fin Bomholt**      Name: **Fin Bomholt**      Function: **Deputy Technical Manager**      Signature: 

Issued: June 22, 2016

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



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Multilateral Agreement for the recognition of calibration certificates

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          | 404.308 $\pm$ 0.02% (k=2) | 404.426 $\pm$ 0.02% (k=2) | 404.774 $\pm$ 0.02% (k=2) |
| Low Range           | 3.97934 $\pm$ 1.50% (k=2) | 3.99489 $\pm$ 1.50% (k=2) | 3.98860 $\pm$ 1.50% (k=2) |

## Connector Angle

|                                           |                   |
|-------------------------------------------|-------------------|
| Connector Angle to be used in DASY system | 115.0 ° $\pm$ 1 ° |
|-------------------------------------------|-------------------|

## Appendix (Additional assessments outside the scope of SCS0108)

### 1. DC Voltage Linearity

| High Range        | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 199997.28                 | 2.63                         | 0.00      |
| Channel X + Input | 20001.62                  | 0.61                         | 0.00      |
| Channel X - Input | -19999.90                 | 1.13                         | -0.01     |
| Channel Y + Input | 199996.67                 | 2.01                         | 0.00      |
| Channel Y + Input | 20001.55                  | 0.46                         | 0.00      |
| Channel Y - Input | -20000.02                 | 0.95                         | -0.00     |
| Channel Z + Input | 199994.48                 | -0.20                        | -0.00     |
| Channel Z + Input | 19999.69                  | -1.34                        | -0.01     |
| Channel Z - Input | -20000.19                 | 0.92                         | -0.00     |

| Low Range         | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 2000.55                   | -0.24                        | -0.01     |
| Channel X + Input | 201.51                    | 0.15                         | 0.08      |
| Channel X - Input | -198.17                   | 0.42                         | -0.21     |
| Channel Y + Input | 2000.45                   | -0.42                        | -0.02     |
| Channel Y + Input | 200.34                    | -1.08                        | -0.54     |
| Channel Y - Input | -199.05                   | -0.45                        | 0.23      |
| Channel Z + Input | 2001.12                   | 0.26                         | 0.01      |
| Channel Z + Input | 200.77                    | -0.56                        | -0.28     |
| Channel Z - Input | -199.58                   | -0.93                        | 0.47      |

### 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 ( $\mu\text{V}$ ) | Low Range Average Reading ( $\mu\text{V}$ ) |
|-----------|--------------------------------|----------------------------------------------|---------------------------------------------|
| Channel X | 200                            | -15.47                                       | -17.16                                      |
|           | - 200                          | 17.86                                        | 16.67                                       |
| Channel Y | 200                            | -5.83                                        | -5.83                                       |
|           | - 200                          | 5.10                                         | 4.55                                        |
| Channel Z | 200                            | -1.03                                        | -1.11                                       |
|           | - 200                          | -0.60                                        | -0.75                                       |

### 3. Channel separation

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

|           | Input Voltage (mV) | Channel X ( $\mu\text{V}$ ) | Channel Y ( $\mu\text{V}$ ) | Channel Z ( $\mu\text{V}$ ) |
|-----------|--------------------|-----------------------------|-----------------------------|-----------------------------|
| Channel X | 200                | -                           | 3.80                        | -3.70                       |
| Channel Y | 200                | 7.72                        | -                           | 4.67                        |
| Channel Z | 200                | 9.17                        | 6.43                        | -                           |

#### 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 | 16113            | 17618           |
| Channel Y | 15977            | 16908           |
| Channel Z | 15892            | 16752           |

#### 5. Input Offset Measurement

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

Input 10M $\Omega$

|           | Average ( $\mu$ V) | min. Offset ( $\mu$ V) | max. Offset ( $\mu$ V) | Std. Deviation ( $\mu$ V) |
|-----------|--------------------|------------------------|------------------------|---------------------------|
| Channel X | 0.26               | -0.94                  | 1.39                   | 0.42                      |
| Channel Y | -1.21              | -1.80                  | -0.32                  | 0.32                      |
| Channel Z | -1.23              | -2.12                  | 0.21                   | 0.36                      |

#### 6. Input Offset Current

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

#### 7. Input Resistance (Typical values for information)

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

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

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

#### 9. Power Consumption (Typical values for information)

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