Calibration Laboratory of Schmid \& Partner<br>Engineering AG<br>Zeughausstrasse 43, 8004 Zurich, Switzerland



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

Accredited by the Swiss Accreditation Service (SAS)
Accreditation No.: SCS 0108
The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates
Client TüV Süd Zacta (Vitec) Certificate No: D2450V2-925_Dec15

## CALIBRATION CERTIFICATE

| Object | D2450V2-SN: 925 |  |  |
| :---: | :---: | :---: | :---: |
| Calibration procedure(s) | QA CAL-05.v9 <br> Calibration procedure for dipole validation kits above 700 MHz |  |  |
| Calibration date: | December 10, 2015 |  |  |
| 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 ( $22 \pm 3)^{\circ} \mathrm{C}$ and humidity $<70 \%$. |  |  |  |
| Calibration Equipment used (M\&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 | US37292783 | 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: 5058 (20k) | 01-Apr-15 (No. 217-02131) | Mar-16 |
| Type-N mismatch combination | SN: 5047.2 / 06327 | 01-Apr-15 (No. 217-02134) | Mar-16 |
| Reference Probe EX3DV4 | SN: 7349 | 30-Dec-14 (No. EX3-7349_Dec14) | Dec-15 |
| DAE4 | SN: 601 | 17-Aug-15 (No. DAE4-601_Aug15) | Aug-16 |
| Secondary Standards | ID \# | Check Date (in house) | Scheduled Check |
| RF generator R\&S SMT-06 | 100972 | 15-Jun-15 (in house check Jun-15) | In house check: Jun-18 |
| Network Analyzer HP 8753E $\mid$ US37390585 S4206 18-Oct-01 (in house check Oct-15) In house check: Oct-16 |  |  |  |
| Name Function Signature |  |  |  |
| Calibrated by: | Israe Elnaouq | Laboratory Technician |  |
| Approved by: | Katja Pokovic | Technical Manager | 7 |
|  |  |  | Issued: December 10, 2 |

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Multilateral Agreement for the recognition of calibration certificates
Glossary:
TSL tissue simulating liquid
ConvF sensitivity in TSL / NORM $x, y, z$
N/A not applicable or not measured

## Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak SpatialAveraged 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 $\mathrm{k}=2$, 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 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 | $\mathrm{dx}, \mathrm{dy}, \mathrm{dz}=5 \mathrm{~mm}$ |  |
| Frequency | $2450 \mathrm{MHz} \pm 1 \mathrm{MHz}$ |  |

## Head TSL parameters

The following parameters and calculations were applied.

|  | Temperature | Permittivity | Conductivity |
| :--- | :---: | :---: | :---: |
| Nominal Head TSL parameters | $22.0^{\circ} \mathrm{C}$ | 39.2 | $1.80 \mathrm{mho} / \mathrm{m}$ |
| Measured Head TSL parameters | $(22.0 \pm 0.2)^{\circ} \mathrm{C}$ | $37.9 \pm 6 \%$ | $1.88 \mathrm{mho} / \mathrm{m} \pm 6 \%$ |
| Head TSL temperature change during test | $<0.5^{\circ} \mathrm{C}$ | ---- | ---- |

## SAR result with Head TSL

| SAR averaged over $\mathbf{1} \mathbf{c m}^{\mathbf{3}} \mathbf{( 1 \mathbf { g } ) \text { of Head TSL }}$ | Condition |  |
| :--- | :---: | :---: |
| SAR measured | 250 mW input power | $13.4 \mathrm{~W} / \mathrm{kg}$ |
| SAR for nominal Head TSL parameters | normalized to 1 W | $\mathbf{5 2 . 1} \mathbf{W} / \mathbf{k g} \pm \mathbf{1 7 . 0} \%(\mathbf{k}=\mathbf{2})$ |


| SAR averaged over $\mathbf{1 0} \mathbf{c m}^{\mathbf{3}} \mathbf{( \mathbf { 1 0 } \mathbf { g } ) \text { of Head TSL }}$ | condition |  |
| :--- | :---: | :---: |
| SAR measured | 250 mW input power | $6.15 \mathrm{~W} / \mathbf{k g}$ |
| SAR for nominal Head TSL parameters | normalized to 1 W | $\mathbf{2 4 . 2} \mathbf{W} / \mathbf{k g} \pm \mathbf{1 6 . 5} \%(\mathbf{k}=\mathbf{2})$ |

## Body TSL parameters

The following parameters and calculations were applied.

|  | Temperature | Permittivity | Conductivity |
| :--- | :---: | :---: | :---: |
| Nominal Body TSL parameters | $22.0^{\circ} \mathrm{C}$ | 52.7 | $1.95 \mathrm{mho} / \mathrm{m}$ |
| Measured Body TSL parameters | $(22.0 \pm 0.2)^{\circ} \mathrm{C}$ | $52.2 \pm 6 \%$ | $2.03 \mathrm{mho} / \mathrm{m} \pm 6 \%$ |
| Body TSL temperature change during test | $<0.5^{\circ} \mathrm{C}$ | ---- | ---- |

## SAR result with Body TSL

| SAR averaged over $\mathbf{1} \mathbf{c m}^{\mathbf{3}} \mathbf{( 1 \mathbf { g } ) \text { of Body TSL }}$ | Condition |  |
| :--- | :---: | :---: |
| SAR measured | 250 mW input power | $13.4 \mathrm{~W} / \mathrm{kg}$ |
| SAR for nominal Body TSL parameters | normalized to 1 W | $\mathbf{5 2 . 5} \mathrm{~W} / \mathbf{k g} \pm \mathbf{1 7 . 0} \%(\mathbf{k}=\mathbf{2})$ |


| SAR averaged over $\mathbf{1 0} \mathbf{c m}^{\mathbf{3}} \mathbf{( 1 0 ~ \mathbf { g } ) \text { of Body TSL }}$ | condition |  |
| :--- | :---: | :---: |
| SAR measured | 250 mW input power | $6.22 \mathrm{~W} / \mathrm{kg}$ |
| SAR for nominal Body TSL parameters | normalized to 1 W | $\mathbf{2 4 . 6} \mathbf{W} / \mathbf{k g} \pm \mathbf{1 6 . 5} \%(\mathbf{k}=\mathbf{2})$ |

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

## Antenna Parameters with Head TSL

| Impedance, transformed to feed point | $55.3 \Omega+4.5 \mathrm{j} \Omega$ |
| :--- | :---: |
| Return Loss | -23.7 dB |

## Antenna Parameters with Body TSL

| Impedance, transformed to feed point | $52.4 \Omega+6.2 \mathrm{j} \Omega$ |
| :--- | :---: |
| Return Loss | -23.8 dB |

## General Antenna Parameters and Design



After long term use with 100 W 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 | September 26, 2013 |

## DASY5 Validation Report for Head TSL

Test Laboratory: SPEAG, Zurich, Switzerland
DUT: Dipole 2450 MHz ; Type: D2450V2; Serial: D2450V2 - SN: 925
Communication System: UID 0 - CW; Frequency: 2450 MHz
Medium parameters used: $\mathrm{f}=2450 \mathrm{MHz} ; \sigma=1.88 \mathrm{~S} / \mathrm{m} ; \varepsilon_{\mathrm{r}}=37.9 ; \rho=1000 \mathrm{~kg} / \mathrm{m}^{3}$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)
DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.67, 7.67, 7.67); Calibrated: 30.12.2014;
- Sensor-Surface: 1.4 mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 17.08.2015
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

Dipole Calibration for Head Tissue/Pin=250 mW, $\mathbf{d = 1 0 m m / Z o o m ~ S c a n ~ ( 7 x 7 x 7 ) / C u b e ~ 0 : ~}$
Measurement grid: $\mathrm{dx}=5 \mathrm{~mm}, \mathrm{dy}=5 \mathrm{~mm}, \mathrm{dz}=5 \mathrm{~mm}$
Reference Value $=112.6 \mathrm{~V} / \mathrm{m}$; Power Drift $=0.08 \mathrm{~dB}$
Peak SAR $($ extrapolated $)=27.8 \mathrm{~W} / \mathrm{kg}$
$\operatorname{SAR}(1 \mathrm{~g})=13.4 \mathrm{~W} / \mathrm{kg} ; \operatorname{SAR}(10 \mathrm{~g})=6.15 \mathrm{~W} / \mathrm{kg}$
Maximum value of SAR $($ measured $)=22.0 \mathrm{~W} / \mathrm{kg}$


## Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Test Laboratory: SPEAG, Zurich, Switzerland

## DUT: Dipole 2450 MHz ; Type: D2450V2; Serial: D2450V2 - SN: 925

Communication System: UID 0 - CW; Frequency: 2450 MHz
Medium parameters used: $\mathrm{f}=2450 \mathrm{MHz} ; \sigma=2.03 \mathrm{~S} / \mathrm{m} ; \varepsilon_{\mathrm{r}}=52.2 ; \rho=1000 \mathrm{~kg} / \mathrm{m}^{3}$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)
DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.53, 7.53, 7.53); Calibrated: 30.12.2014;
- Sensor-Surface: 1.4 mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 17.08.2015
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

Dipole Calibration for Body Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:
Measurement grid: $\mathrm{dx}=5 \mathrm{~mm}, \mathrm{dy}=5 \mathrm{~mm}, \mathrm{dz}=5 \mathrm{~mm}$
Reference Value $=108.2 \mathrm{~V} / \mathrm{m}$; Power Drift $=0.05 \mathrm{~dB}$
Peak SAR (extrapolated) $=26.6 \mathrm{~W} / \mathrm{kg}$
$\operatorname{SAR}(1 \mathrm{~g})=13.4 \mathrm{~W} / \mathrm{kg} ; \operatorname{SAR}(10 \mathrm{~g})=\mathbf{6 . 2 2} \mathbf{W} / \mathrm{kg}$
Maximum value of SAR $($ measured $)=21.8 \mathrm{~W} / \mathrm{kg}$


## Impedance Measurement Plot for Body TSL



## Attachment 3. SAR system validation

## SAR System Validation

Per FCC KDB 865664 D02v01r02, SAR system validation status should be documented to confirm measurement accuracy. The SAR systems (including SAR probes, system components and software versions) used for this device were validated against its performance specifications prior to the SAR measurements. Reference dipoles were used with the required tissue- equivalent media for system validation, according to the procedures outlined in IEEE 1528-2013 and FCC KDB 865664 D01v01r04. Since SAR probe calibrations are frequency dependent, each probe calibration point was validated at a frequency within the valid frequency range of the probe calibration point, using the system that normally operates with the probe for routine SAR measurements and according to the required tissue-equivalent media. A tabulated summary of the system validation status including the validation date(s), measurement frequencies, SAR probes and tissue dielectric parameters has been included.

Table Attachment 3.1 SAR System Validation Summary

| SAR <br> System | Freq. <br> [MHz] | Data | Probe <br> Type | Probe CAL. Point |  | PERM. | COND. | CW Validation |  |  | MOD. Validation |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  | (Er) | ( $\sigma$ ) | Sensi- <br> tivity | Probe <br> Linearity | Probe <br> Isotropy | $\begin{aligned} & \text { MOD. } \\ & \text { Type } \end{aligned}$ | Duty <br> Factor | PAR |
| E | 750 | 2016-09-05 | 3957 | 750 | Head | 42.01 | 0.933 | PASS | PASS | PASS | QPSK | PASS | N/A |
| E | 835 | 2016-09-09 | 3957 | 835 | Head | 41.98 | 0.917 | PASS | PASS | PASS | GMSK | PASS | N/A |
| E | 835 | 2016-09-12 | 3957 | 835 | Head | 41.59 | 0.907 | PASS | PASS | PASS | GMSK | PASS | N/A |
| E | 1900 | 2016-09-08 | 3957 | 1900 | Head | 39.73 | 1.392 | PASS | PASS | PASS | GMSK | PASS | N/A |
| E | 2450 | 2016-08-31 | 3957 | 2450 | Head | 37.96 | 1.852 | PASS | PASS | PASS | OFDM | N/A | PASS |
| E | 750 | 2016-09-05 | 3957 | 750 | Body | 55.01 | 0.990 | PASS | PASS | PASS | QPSK | PASS | N/A |
| E | 835 | 2016-09-06 | 3957 | 835 | Body | 54.62 | 1.005 | PASS | PASS | PASS | GMSK | PASS | N/A |
| E | 1900 | 2016-09-07 | 3957 | 1900 | Body | 52.59 | 1.528 | PASS | PASS | PASS | GMSK | PASS | N/A |
| E | 1900 | 2016-10-25 | 3957 | 1900 | Body | 52.92 | 1.506 | PASS | PASS | PASS | GMSK | PASS | N/A |
| E | 2450 | 2016-08-31 | 3957 | 2450 | Body | 51.14 | 1.951 | PASS | PASS | PASS | OFDM | N/A | PASS |

