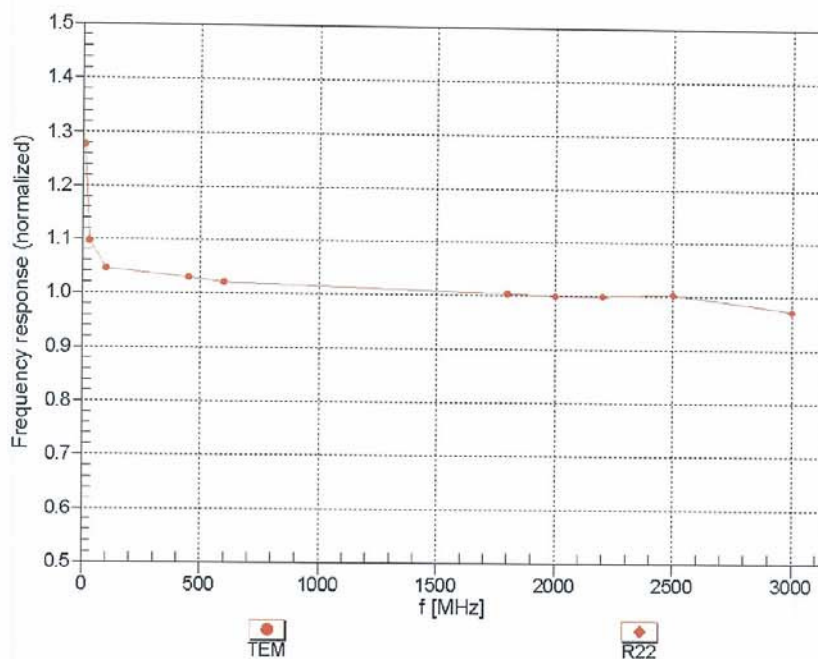


EX3DV4- SN:3666

May 26, 2015

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

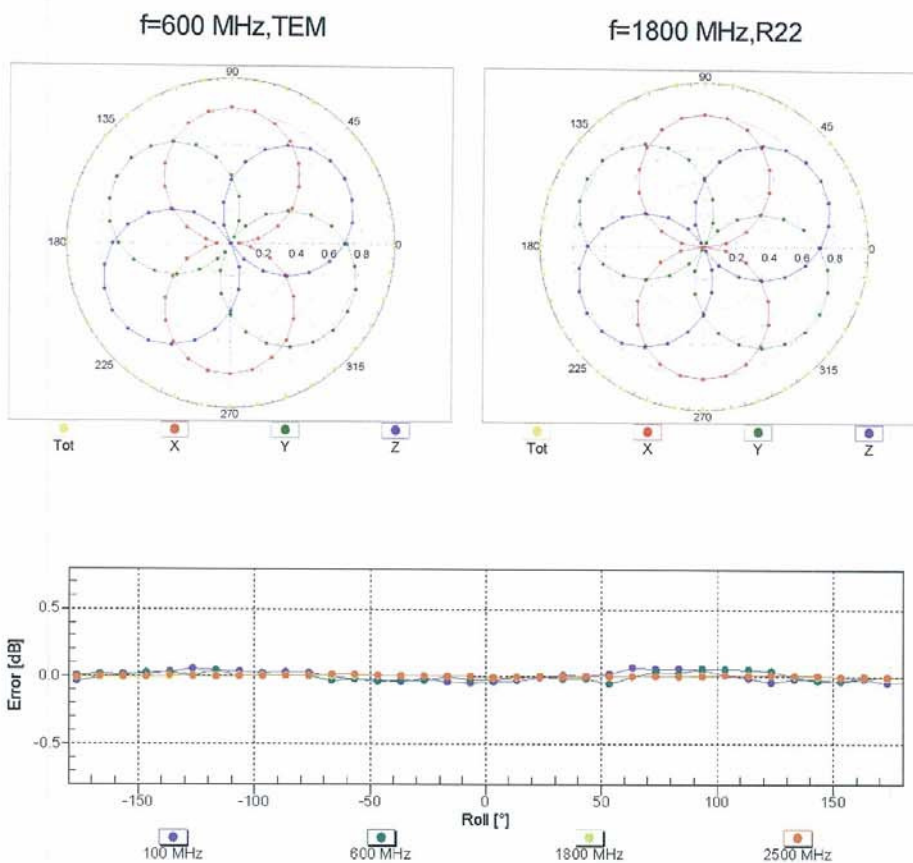


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ ($k=2$)

EX3DV4- SN:3666

May 26, 2015

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

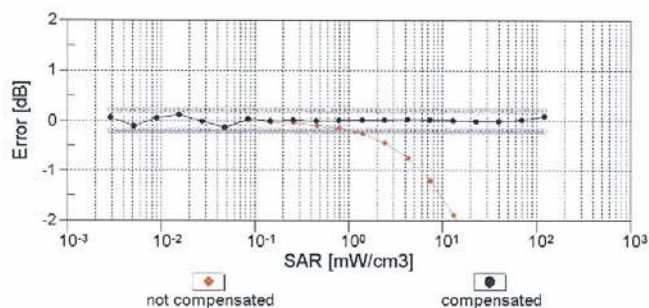
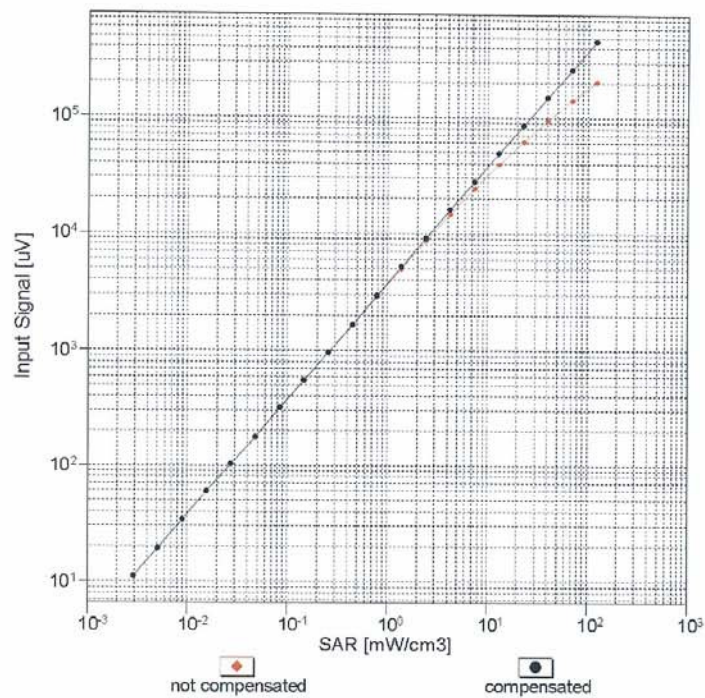


Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ ($k=2$)

EX3DV4- SN:3666

May 26, 2015

Dynamic Range $f(\text{SAR}_{\text{head}})$ (TEM cell, $f_{\text{eval}} = 1900 \text{ MHz}$)

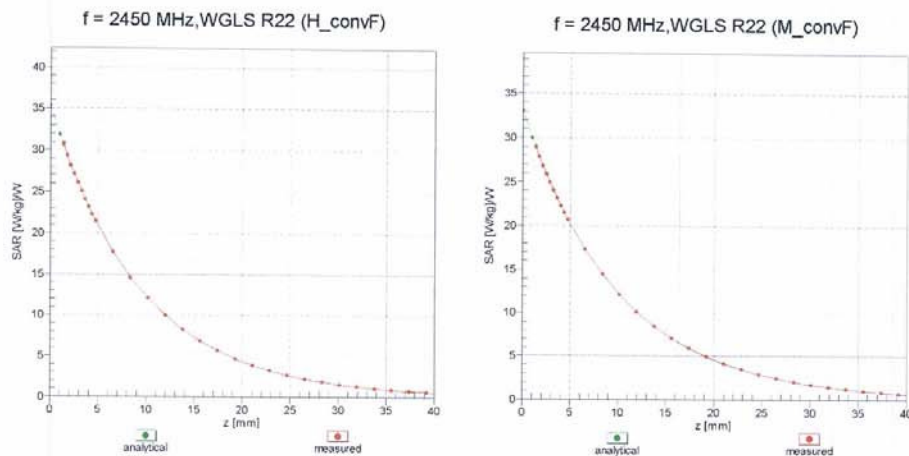


Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

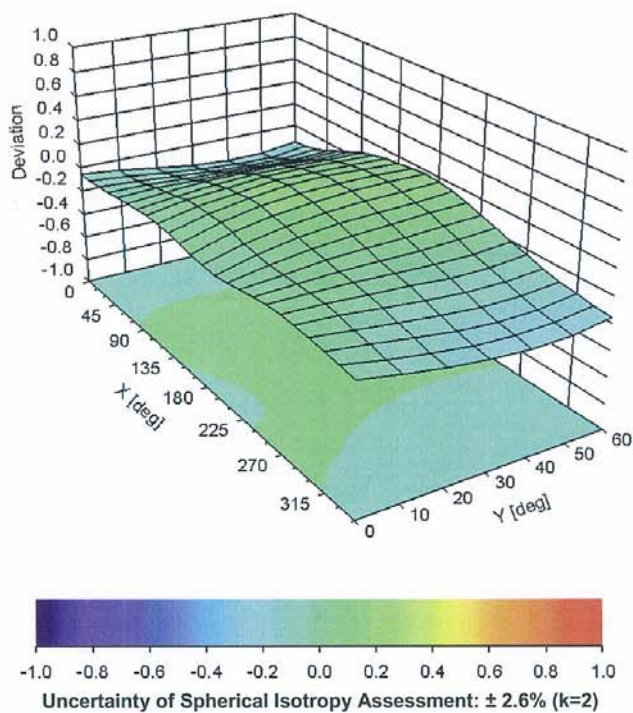
EX3DV4- SN:3666

May 26, 2015

Conversion Factor Assessment



Deviation from Isotropy in Liquid Error (ϕ , θ), f = 900 MHz



Certificate No: EX3-3666_May15

Page 10 of 11

EMC-003 (Rev.2)

HEAD OFFICE : 301-14 Daessangnyeong-ri, Chowol-eup, Gwangju-si, Gyeonggi-do 464-862 Korea (TEL: 82-31-799-9500, FAX: 82-31-799-9599)
EMC Testing Div. : 307-51 Daessangnyeong-ri, Chowol-eup, Gwangju-si, Gyeonggi-do 464-862 Korea (TEL: 82-31-765-8289, FAX: 82-31-766-2904)

EX3DV4- SN:3666

May 26, 2015

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3666

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-16.6
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

< Dipole Antenna : D835V2 – SN 4d172 >

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 108

Client **One-Tech (Dymstec)**

Certificate No: D835V2-4d172_Jul14

CALIBRATION CERTIFICATE

Object **D835V2 - SN: 4d172**

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

Calibration date: **July 10, 2014**

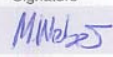
This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

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

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Power meter EPM-442A	GB37480704	09-Oct-13 (No. 217-01827)	Oct-14
Power sensor HP 8481A	US37292783	09-Oct-13 (No. 217-01827)	Oct-14
Power sensor HP 8481A	MY41092317	09-Oct-13 (No. 217-01828)	Oct-14
Reference 20 dB Attenuator	SN: 5058 (20k)	03-Apr-14 (No. 217-01918)	Apr-15
Type-N mismatch combination	SN: 5047.2 / 06327	03-Apr-14 (No. 217-01921)	Apr-15
Reference Probe ES3DV3	SN: 3205	30-Dec-13 (No. ES3-3205_Dec13)	Dec-14
DAE4	SN: 601	30-Apr-14 (No. DAE4-601_Apr14)	Apr-15

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
RF generator R&S SMT-06	100005	04-Aug-99 (in house check Oct-13)	In house check: Oct-16
Network Analyzer HP 8753E	US37390585 S4206	16-Oct-01 (in house check Oct-13)	In house check: Oct-14

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

Issued: July 11, 2014

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

Certificate No: D835V2-4d172_Jul14

Page 1 of 8

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 108**

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 62209-1, "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) 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	
Distance Dipole Center - TSL	15 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	835 MHz $\pm$ 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	41.5	0.90 mho/m
Measured Head TSL parameters	(22.0 $\pm$ 0.2) °C	41.1 $\pm$ 6 %	0.94 mho/m $\pm$ 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	2.39 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	9.23 W/kg $\pm$ 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	1.55 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	6.03 W/kg $\pm$ 16.5 % (k=2)

Body TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	55.2	0.97 mho/m
Measured Body TSL parameters	(22.0 $\pm$ 0.2) °C	53.8 $\pm$ 6 %	1.02 mho/m $\pm$ 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	2.50 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	9.58 W/kg $\pm$ 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	250 mW input power	1.63 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	6.30 W/kg $\pm$ 16.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	52.6 Ω - 2.0 j Ω
Return Loss	- 29.9 dB

Antenna Parameters with Body TSL

Impedance, transformed to feed point	47.8 Ω - 4.3 j Ω
Return Loss	- 26.1 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.393 ns
----------------------------------	----------

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.

No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

Additional EUT Data

Manufactured by	SPEAG
Manufactured on	November 11, 2013

DASY5 Validation Report for Head TSL

Date: 10.07.2014

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 835 MHz; Type: D835V2; Serial: D835V2 - SN: 4d172

Communication System: UID 0 - CW; Frequency: 835 MHz

Medium parameters used: $f = 835 \text{ MHz}$; $\sigma = 0.94 \text{ S/m}$; $\epsilon_r = 41.1$; $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(6.22, 6.22, 6.22); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.04.2014
- Phantom: Flat Phantom 4.9L; Type: QD000P49AA; Serial: 1001
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

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

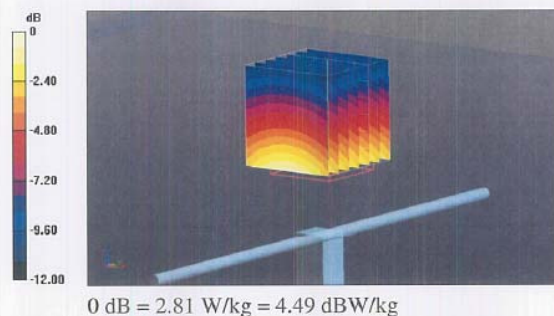
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 56.39 V/m; Power Drift = 0.01 dB

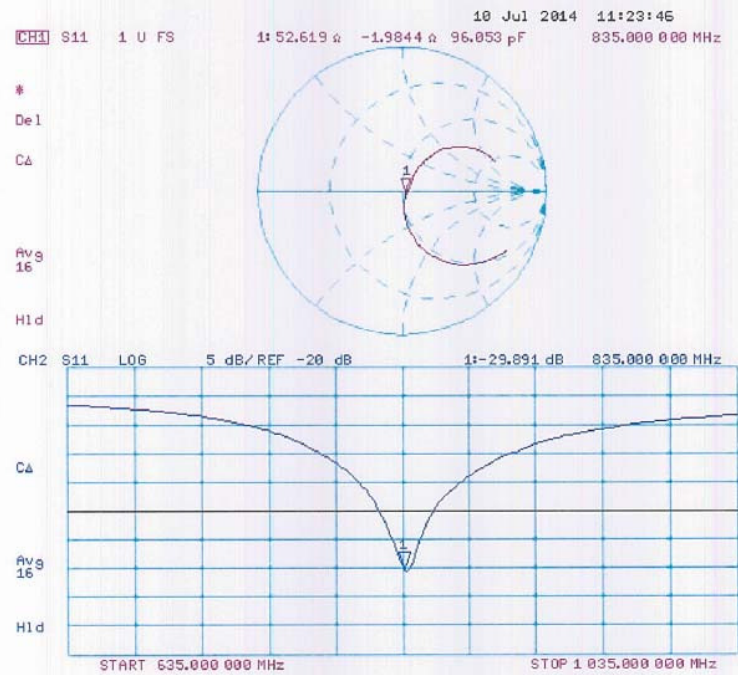
Peak SAR (extrapolated) = 3.59 W/kg

SAR(1 g) = 2.39 W/kg; SAR(10 g) = 1.55 W/kg

Maximum value of SAR (measured) = 2.81 W/kg



Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 09.07.2014

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 835 MHz; Type: D835V2; Serial: D835V2 - SN: 4d172

Communication System: UID 0 - CW; Frequency: 835 MHz

Medium parameters used: $f = 835 \text{ MHz}$; $\sigma = 1.02 \text{ S/m}$; $\epsilon_r = 53.8$; $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(6.09, 6.09, 6.09); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.04.2014
- Phantom: Flat Phantom 4.9L; Type: QD000P49AA; Serial: 1001
- DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331)

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

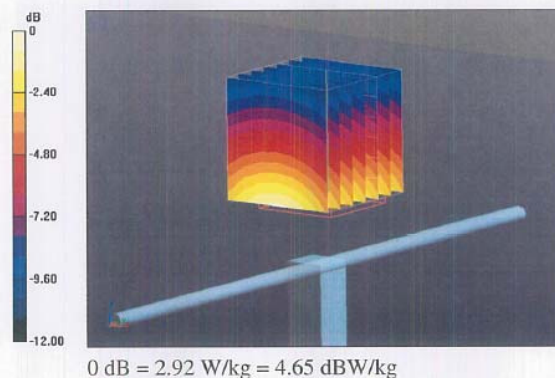
Measurement grid: $dx=5\text{mm}$, $dy=5\text{mm}$, $dz=5\text{mm}$

Reference Value = 55.24 V/m; Power Drift = -0.01 dB

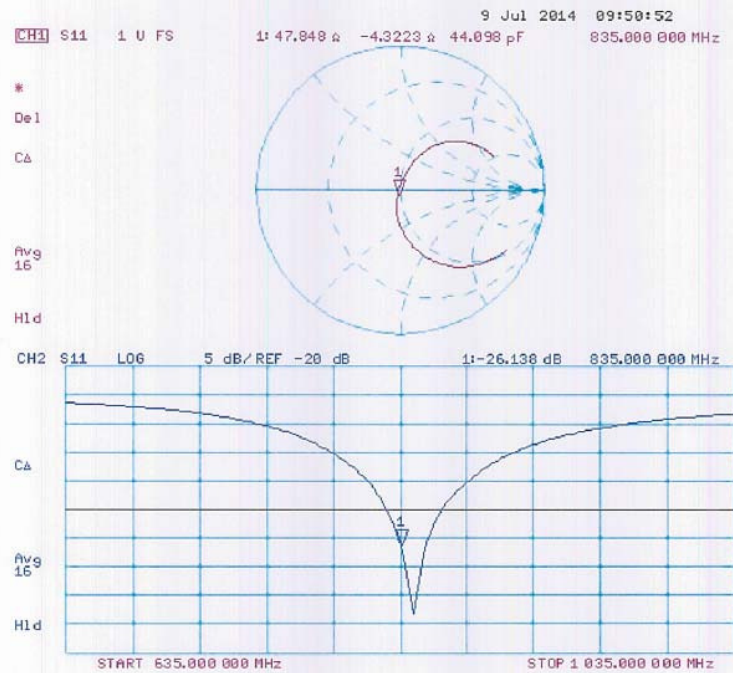
Peak SAR (extrapolated) = 3.71 W/kg

SAR(1 g) = 2.5 W/kg; SAR(10 g) = 1.63 W/kg

Maximum value of SAR (measured) = 2.92 W/kg



Impedance Measurement Plot for Body TSL



< Dipole Antenna : D1950V3 – SN 1156 >

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)

Accreditation No.: **SCS 108**

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

Client **One-Tech (Dymstec)**

Certificate No: **D1950V3-1156_Jul14**

CALIBRATION CERTIFICATE

Object **D1950V3 - SN: 1156**

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

Calibration date: **July 11, 2014**

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

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

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Power meter EPM-442A	GB37480704	09-Oct-13 (No. 217-01827)	Oct-14
Power sensor HP 8481A	US37292783	09-Oct-13 (No. 217-01827)	Oct-14
Power sensor HP 8481A	MY41092317	09-Oct-13 (No. 217-01828)	Oct-14
Reference 20 dB Attenuator	SN: 5058 (20k)	03-Apr-14 (No. 217-01918)	Apr-15
Type-N mismatch combination	SN: 5047.2 / 06327	03-Apr-14 (No. 217-01921)	Apr-15
Reference Probe ES3DV3	SN: 3205	30-Dec-13 (No. ES3-3205_Dec13)	Dec-14
DAE4	SN: 601	30-Apr-14 (No. DAE4-601_Apr14)	Apr-15

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
RF generator R&S SMT-06	100005	04-Aug-99 (in house check Oct-13)	In house check: Oct-16
Network Analyzer HP 8753E	US37390585 S4206	18-Oct-01 (in house check Oct-13)	In house check: Oct-14

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

Issued: July 14, 2014

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

Certificate No: D1950V3-1156_Jul14

Page 1 of 8

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)

Accreditation No.: **SCS 108**

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

Glossary:

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

Calibration is Performed According to the Following Standards:

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "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
- 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	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	1950 MHz $\pm$ 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	40.0	1.40 mho/m
Measured Head TSL parameters	(22.0 $\pm$ 0.2) °C	39.3 $\pm$ 6 %	1.43 mho/m $\pm$ 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	10.5 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	41.3 W/kg $\pm$ 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	5.44 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	21.5 W/kg $\pm$ 16.5 % (k=2)

Body TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	53.3	1.52 mho/m
Measured Body TSL parameters	(22.0 $\pm$ 0.2) °C	52.3 $\pm$ 6 %	1.56 mho/m $\pm$ 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	9.97 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	39.1 W/kg $\pm$ 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	250 mW input power	5.20 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	20.6 W/kg $\pm$ 16.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	49.1 Ω - 1.3 j Ω
Return Loss	- 36.2 dB

Antenna Parameters with Body TSL

Impedance, transformed to feed point	45.5 Ω - 1.5 j Ω
Return Loss	- 26.1 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.198 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	September 23, 2009

DASY5 Validation Report for Head TSL

Date: 11.07.2014

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 1950 MHz; Type: D1950V3; Serial: D1950V3 - SN: 1156

Communication System: UID 0 - CW; Frequency: 1950 MHz

Medium parameters used: $f = 1950$ MHz; $\sigma = 1.43$ S/m; $\epsilon_r = 39.3$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(4.92, 4.92, 4.92); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.04.2014
- 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, d=10mm/Zoom Scan (7x7x7)/Cube 0:

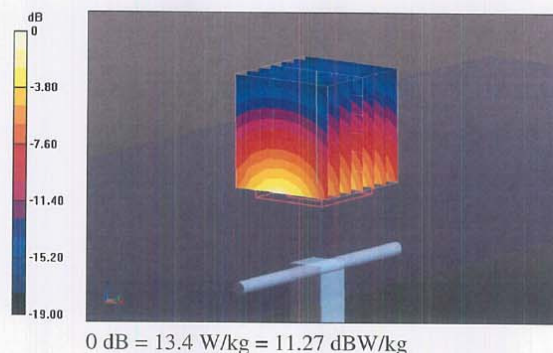
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 100.3 V/m; Power Drift = 0.01 dB

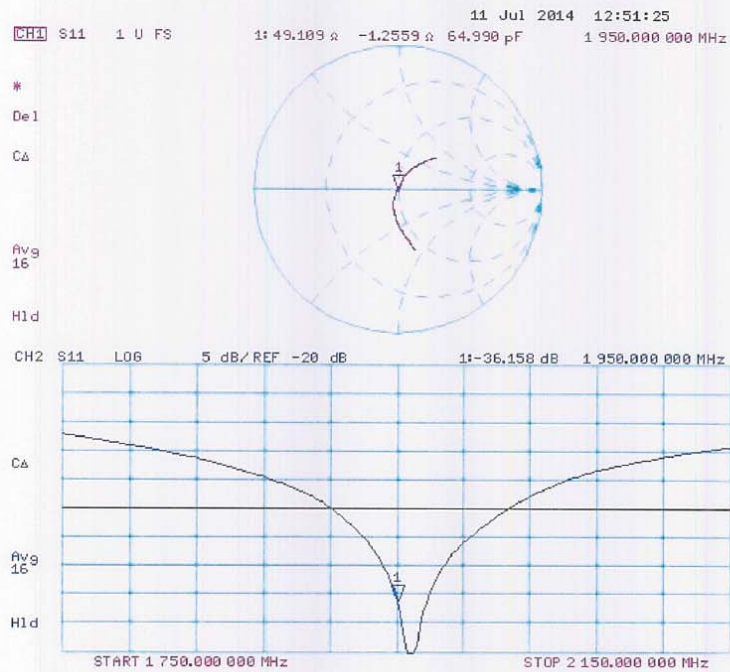
Peak SAR (extrapolated) = 19.1 W/kg

SAR(1 g) = 10.5 W/kg; SAR(10 g) = 5.44 W/kg

Maximum value of SAR (measured) = 13.4 W/kg



Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 11.07.2014

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 1950 MHz; Type: D1950V3; Serial: D1950V3 - SN: 1156

Communication System: UID 0 - CW; Frequency: 1950 MHz

Medium parameters used: $f = 1950 \text{ MHz}$; $\sigma = 1.56 \text{ S/m}$; $\epsilon_r = 52.3$; $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(4.78, 4.78, 4.78); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.04.2014
- 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:

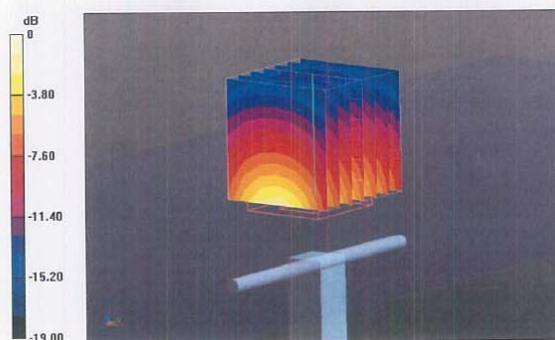
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 94.21 V/m; Power Drift = 0.01 dB

Peak SAR (extrapolated) = 17.6 W/kg

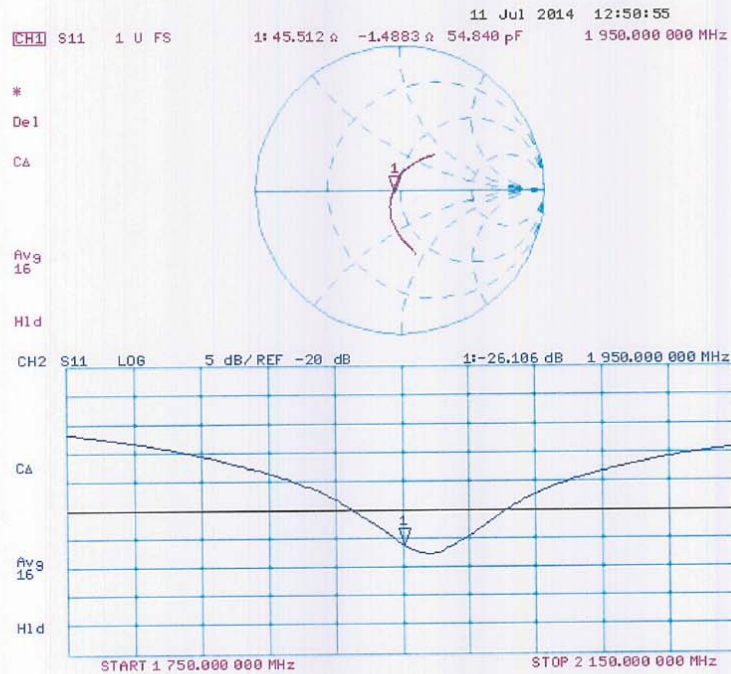
SAR(1 g) = 9.97 W/kg; SAR(10 g) = 5.2 W/kg

Maximum value of SAR (measured) = 12.7 W/kg



0 dB = 12.7 W/kg = 11.04 dBW/kg

Impedance Measurement Plot for Body TSL



< Dipole Antenna : D2450V2 – SN 923 >

**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 **Onetech (Dymstec)**

Certificate No: **D2450V2-923_Nov15**

CALIBRATION CERTIFICATE

Object **D2450V2 - SN: 923**

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

Calibration date: **November 18, 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 ± 3)°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	US37390585 S4206	18-Oct-01 (in house check Oct-15)	In house check: Oct-16

	Name	Function	Signature
Calibrated by:	Leif Klysner	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: November 19, 2015

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

Certificate No: D2450V2-923_Nov15

Page 1 of 8

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**

Glossary:

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

Calibration is Performed According to the Following Standards:

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "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 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	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	2450 MHz $\pm$ 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	39.2	1.80 mho/m
Measured Head TSL parameters	(22.0 $\pm$ 0.2) °C	38.2 $\pm$ 6 %	1.87 mho/m $\pm$ 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	13.3 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	51.9 W/kg $\pm$ 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	6.14 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	24.2 W/kg $\pm$ 16.5 % (k=2)

Body TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	52.7	1.95 mho/m
Measured Body TSL parameters	(22.0 $\pm$ 0.2) °C	52.7 $\pm$ 6 %	2.02 mho/m $\pm$ 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	13.3 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	52.3 W/kg $\pm$ 17.0 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	250 mW input power	6.22 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	24.7 W/kg $\pm$ 16.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	55.2 Ω + 0.2 j Ω
Return Loss	- 26.2 dB

Antenna Parameters with Body TSL

Impedance, transformed to feed point	50.7 Ω + 3.8 j Ω
Return Loss	- 28.2 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.158 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	September 26, 2013

DASY5 Validation Report for Head TSL

Date: 18.11.2015

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 2450 MHz ; Type: D2450V2; Serial: D2450V2 - SN: 923

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

Medium parameters used: $f = 2450$ MHz; $\sigma = 1.87$ S/m; $\epsilon_r = 38.2$; $\rho = 1000$ kg/m³

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: 1.4mm (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, d=10mm/Zoom Scan (7x7x7)/Cube 0:

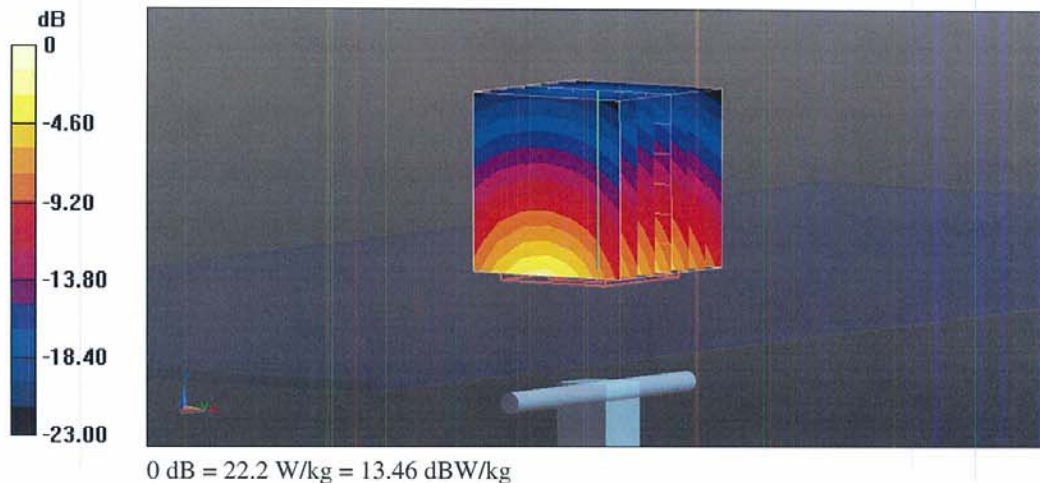
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 114.0 V/m; Power Drift = 0.04 dB

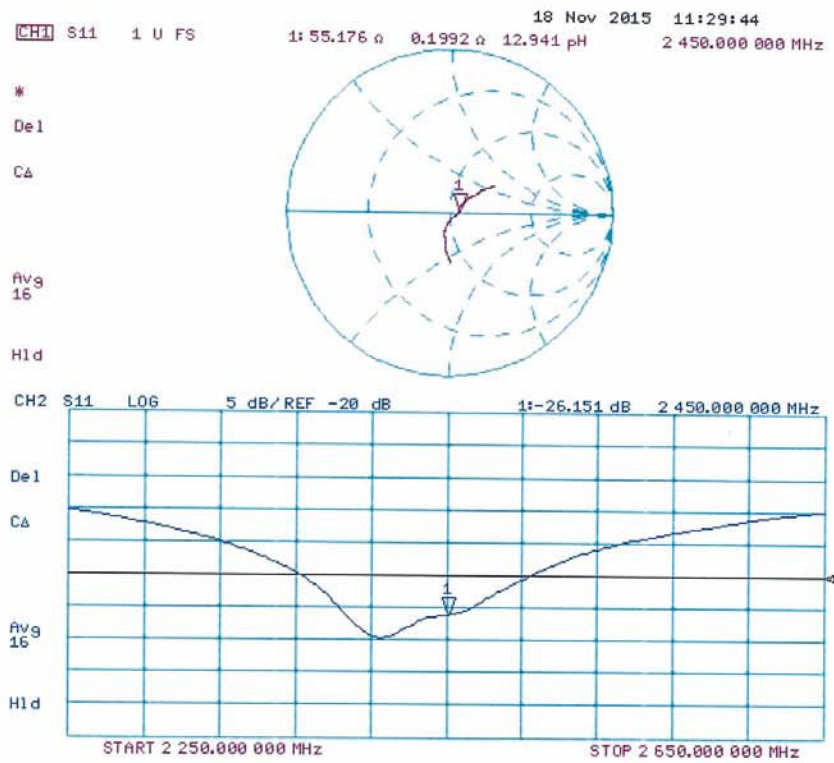
Peak SAR (extrapolated) = 27.7 W/kg

SAR(1 g) = 13.3 W/kg; SAR(10 g) = 6.14 W/kg

Maximum value of SAR (measured) = 22.2 W/kg



Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 18.11.2015

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 2450 MHz ; Type: D2450V2; Serial: D2450V2 - SN: 923

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

Medium parameters used: $f = 2450$ MHz; $\sigma = 2.02$ S/m; $\epsilon_r = 52.7$; $\rho = 1000$ kg/m³

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: 1.4mm (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:

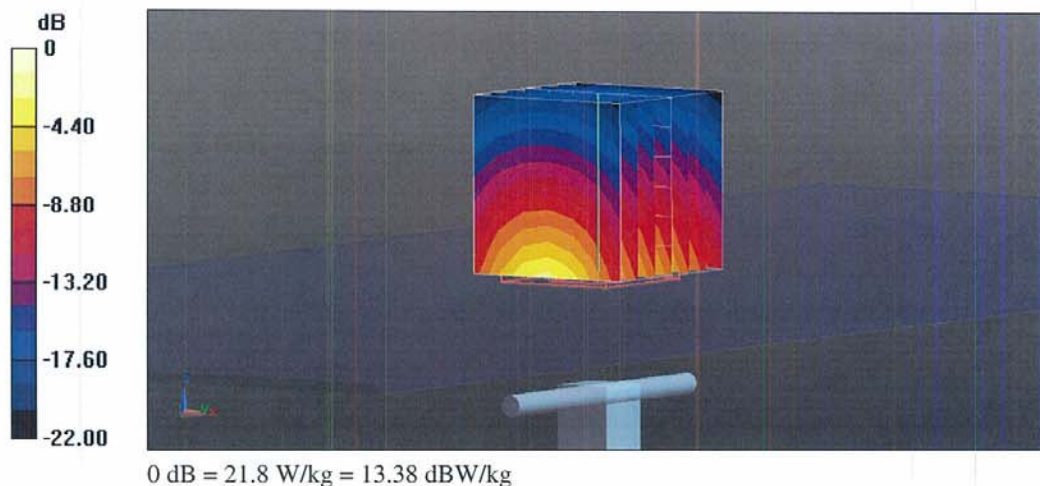
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 108.4 V/m; Power Drift = 0.03 dB

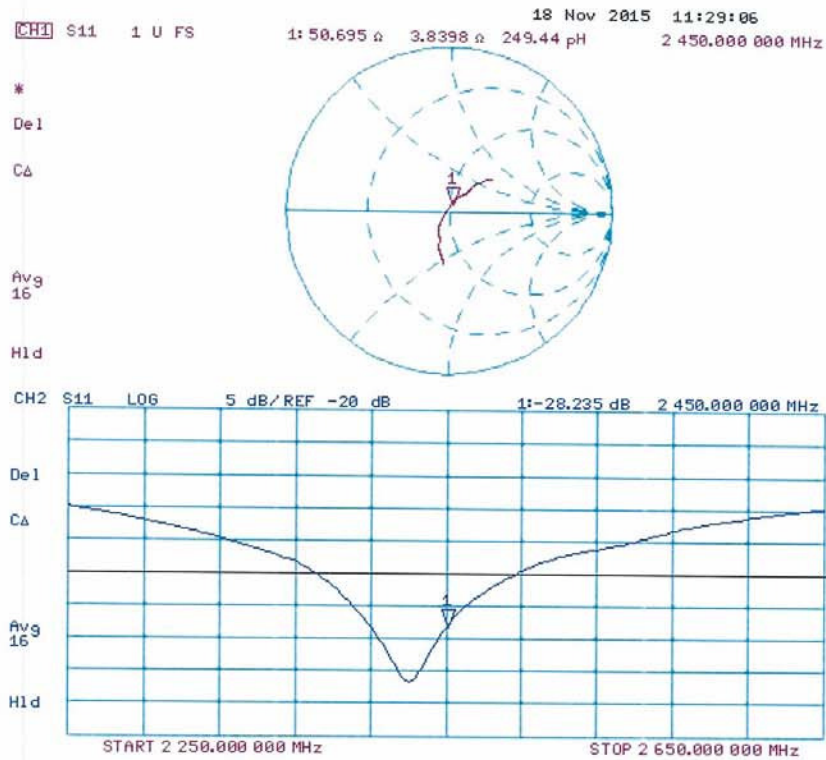
Peak SAR (extrapolated) = 26.6 W/kg

SAR(1 g) = 13.3 W/kg; SAR(10 g) = 6.22 W/kg

Maximum value of SAR (measured) = 21.8 W/kg



Impedance Measurement Plot for Body TSL



< Dipole Antenna : D5GHzV2 – SN 1094 >

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

Cient **Onetech (Dymstec)**

Certificate No: D5GHzV2-1094_Nov15

CALIBRATION CERTIFICATE

Object D5GHzV2 - SN: 1094

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

Calibration date: November 20, 2015

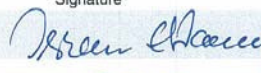
This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°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: 3503	30-Dec-14 (No. EX3-3503_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	US37390585 S4206	18-Oct-01 (in house check Oct-15)	In house check: Oct-16

Calibrated by:	Name Israe Elnaouq	Function Laboratory Technician	Signature 
Approved by:	Katja Pokovic	Technical Manager	

Issued: November 20, 2015

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

Certificate No: D5GHzV2-1094_Nov15

Page 1 of 16

EMC-003 (Rev.2)

HEAD OFFICE : 301-14 Daessangnyeong-ri, Chowol-eup, Gwangju-si, Gyeonggi-do 464-862 Korea (TEL: 82-31-799-9500, FAX: 82-31-799-9599)
EMC Testing Div. : 307-51 Daessangnyeong-ri, Chowol-eup, Gwangju-si, Gyeonggi-do 464-862 Korea (TEL: 82-31-765-8289, FAX: 82-31-766-2904)

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**

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	5200 MHz $\pm$ 1 MHz 5300 MHz $\pm$ 1 MHz 5500 MHz $\pm$ 1 MHz 5600 MHz $\pm$ 1 MHz 5800 MHz $\pm$ 1 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	34.8 $\pm$ 6 %	4.48 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 ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.13 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	80.7 W/kg $\pm$ 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.32 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	22.9 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	34.6 ± 6 %	4.57 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 ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.39 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	83.2 W / kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.40 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	23.7 W/kg ± 19.5 % (k=2)

Head TSL parameters at 5500 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.6	4.96 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	34.3 ± 6 %	4.77 mho/m ± 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

SAR result with Head TSL at 5500 MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.26 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	81.8 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.36 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	23.3 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	35.5	5.07 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	34.2 ± 6 %	4.87 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 ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.70 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	86.2 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.48 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	24.5 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	33.9 ± 6 %	5.08 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 ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.00 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	79.2 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.28 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	22.5 W/kg ± 19.5 % (k=2)

Body TSL parameters at 5200 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	49.0	5.30 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	47.1 ± 6 %	5.47 mho/m ± 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL at 5200 MHz

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.67 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	76.1 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	100 mW input power	2.15 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	21.3 W/kg ± 19.5 % (k=2)

Body TSL parameters at 5300 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.9	5.42 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	46.9 ± 6 %	5.60 mho/m ± 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL at 5300 MHz

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.66 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	76.0 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	100 mW input power	2.15 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	21.3 W/kg ± 19.5 % (k=2)

Body TSL parameters at 5500 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.6	5.65 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	46.5 ± 6 %	5.86 mho/m ± 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL at 5500 MHz

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	8.04 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	79.8 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	100 mW input power	2.24 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	22.2 W/kg ± 19.5 % (k=2)

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	46.3 ± 6 %	6.01 mho/m ± 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

SAR result with Body TSL at 5600 MHz

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	8.18 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	81.2 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	100 mW input power	2.31 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	22.9 W/kg ± 19.5 % (k=2)

Body TSL parameters at 5800 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.2	6.00 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	46.0 ± 6 %	6.28 mho/m ± 6 %
Body TSL temperature change during test	< 0.5 °C	-----	-----

SAR result with Body TSL at 5800 MHz

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.81 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	77.5 W/kg ± 19.9 % (k=2)

SAR averaged over 10 cm ³ (10 g) of Body TSL	condition	
SAR measured	100 mW input power	2.17 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	21.5 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	47.2 Ω - 5.7 j Ω
Return Loss	- 23.7 dB

Antenna Parameters with Head TSL at 5300 MHz

Impedance, transformed to feed point	48.5 Ω - 4.0 j Ω
Return Loss	- 27.4 dB

Antenna Parameters with Head TSL at 5500 MHz

Impedance, transformed to feed point	52.5 Ω - 4.4 j Ω
Return Loss	- 26.1 dB

Antenna Parameters with Head TSL at 5600 MHz

Impedance, transformed to feed point	56.8 Ω - 4.5 j Ω
Return Loss	- 22.4 dB

Antenna Parameters with Head TSL at 5800 MHz

Impedance, transformed to feed point	56.0 Ω - 8.3 j Ω
Return Loss	- 20.3 dB

Antenna Parameters with Body TSL at 5200 MHz

Impedance, transformed to feed point	47.7 Ω - 9.4 j Ω
Return Loss	- 20.1 dB

Antenna Parameters with Body TSL at 5300 MHz

Impedance, transformed to feed point	48.2 Ω - 8.1 j Ω
Return Loss	- 21.5 dB

Antenna Parameters with Body TSL at 5500 MHz

Impedance, transformed to feed point	51.1 Ω - 7.3 j Ω
Return Loss	- 22.8 dB

Antenna Parameters with Body TSL at 5600 MHz

Impedance, transformed to feed point	56.9 Ω - 6.2 j Ω
Return Loss	- 21.2 dB

Antenna Parameters with Body TSL at 5800 MHz

Impedance, transformed to feed point	55.3 Ω - 8.8 j Ω
Return Loss	- 20.3 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.203 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	September 24, 2010

DASY5 Validation Report for Head TSL

Date: 19.11.2015

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 – SN: 1094

Communication System: UID 0 - CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz

Medium parameters used: $f = 5200 \text{ MHz}$; $\sigma = 4.48 \text{ S/m}$; $\epsilon_r = 34.8$; $\rho = 1000 \text{ kg/m}^3$, Medium parameters used: $f = 5300 \text{ MHz}$; $\sigma = 4.57 \text{ S/m}$; $\epsilon_r = 34.6$; $\rho = 1000 \text{ kg/m}^3$, Medium parameters used: $f = 5500 \text{ MHz}$; $\sigma = 4.77 \text{ S/m}$; $\epsilon_r = 34.3$; $\rho = 1000 \text{ kg/m}^3$, Medium parameters used: $f = 5600 \text{ MHz}$; $\sigma = 4.87 \text{ S/m}$; $\epsilon_r = 34.2$; $\rho = 1000 \text{ kg/m}^3$, Medium parameters used: $f = 5800 \text{ MHz}$; $\sigma = 5.08 \text{ S/m}$; $\epsilon_r = 33.9$; $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.51, 5.51, 5.51); Calibrated: 30.12.2014, ConvF(5.21, 5.21, 5.21); Calibrated: 30.12.2014, ConvF(5.12, 5.12, 5.12); Calibrated: 30.12.2014, ConvF(4.92, 4.92, 4.92); Calibrated: 30.12.2014, ConvF(4.9, 4.9, 4.9); Calibrated: 30.12.2014;
- Sensor-Surface: 1.4mm (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=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 = 75.30 V/m; Power Drift = 0.00 dB

Peak SAR (extrapolated) = 29.3 W/kg

SAR(1 g) = 8.13 W/kg; SAR(10 g) = 2.32 W/kg

Maximum value of SAR (measured) = 18.1 W/kg

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5300 MHz/Zoom Scan,

dist=1.4mm (8x8x7)/Cube 0: Measurement grid: $dx=4\text{mm}$, $dy=4\text{mm}$, $dz=1.4\text{mm}$

Reference Value = 75.68 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 31.3 W/kg

SAR(1 g) = 8.39 W/kg; SAR(10 g) = 2.4 W/kg

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

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5500 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 = 74.32 V/m; Power Drift = -0.04 dB

Peak SAR (extrapolated) = 32.3 W/kg

SAR(1 g) = 8.26 W/kg; SAR(10 g) = 2.36 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 = 75.61 V/m; Power Drift = -0.02 dB

Peak SAR (extrapolated) = 34.1 W/kg

SAR(1 g) = 8.7 W/kg; SAR(10 g) = 2.48 W/kg

Maximum value of SAR (measured) = 20.1 W/kg

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:

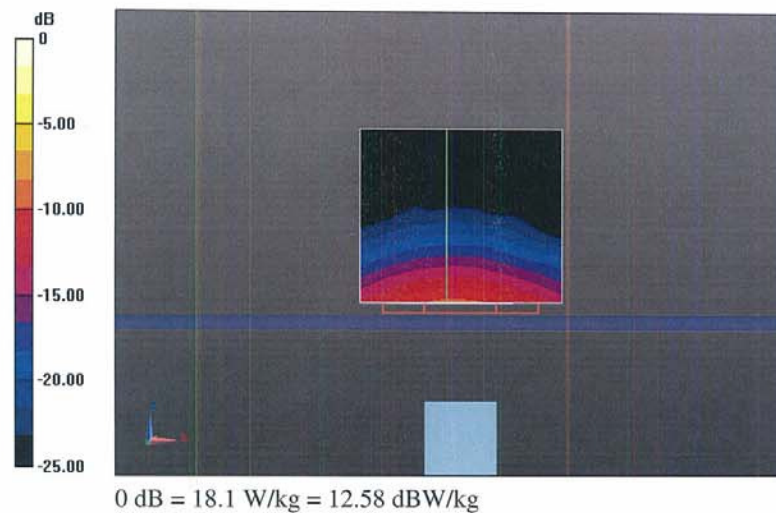
Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 71.99 V/m; Power Drift = -0.00 dB

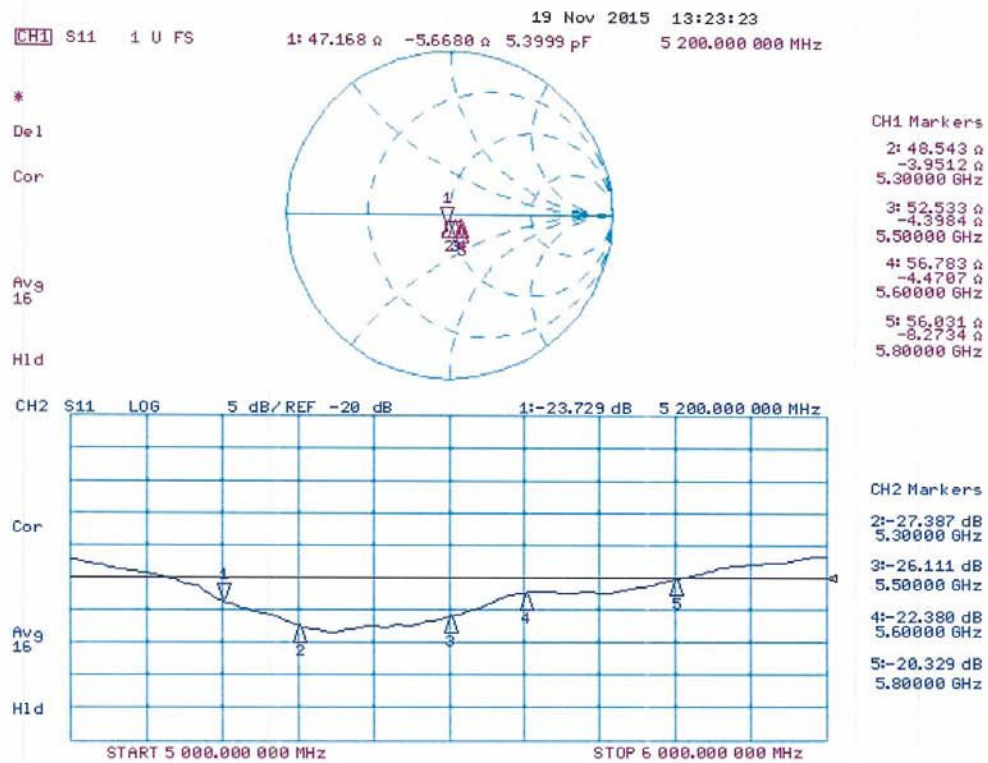
Peak SAR (extrapolated) = 32.8 W/kg

SAR(1 g) = 8 W/kg; SAR(10 g) = 2.28 W/kg

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



Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 20.11.2015

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1094

Communication System: UID 0 - CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz

Medium parameters used: $f = 5200 \text{ MHz}$; $\sigma = 5.47 \text{ S/m}$; $\epsilon_r = 47.1$; $\rho = 1000 \text{ kg/m}^3$, Medium parameters used: $f = 5300 \text{ MHz}$; $\sigma = 5.6 \text{ S/m}$; $\epsilon_r = 46.9$; $\rho = 1000 \text{ kg/m}^3$, Medium parameters used: $f = 5500 \text{ MHz}$; $\sigma = 5.86 \text{ S/m}$; $\epsilon_r = 46.5$; $\rho = 1000 \text{ kg/m}^3$, Medium parameters used: $f = 5600 \text{ MHz}$; $\sigma = 6.01 \text{ S/m}$; $\epsilon_r = 46.3$; $\rho = 1000 \text{ kg/m}^3$, Medium parameters used: $f = 5800 \text{ MHz}$; $\sigma = 6.28 \text{ S/m}$; $\epsilon_r = 46$; $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(4.95, 4.95, 4.95); Calibrated: 30.12.2014, ConvF(4.78, 4.78, 4.78); Calibrated: 30.12.2014, ConvF(4.45, 4.45, 4.45); Calibrated: 30.12.2014, ConvF(4.35, 4.35, 4.35); Calibrated: 30.12.2014, ConvF(4.32, 4.32, 4.32); Calibrated: 30.12.2014;
- Sensor-Surface: 1.4mm (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=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 = 66.84 V/m; Power Drift = -0.04 dB

Peak SAR (extrapolated) = 30.1 W/kg

SAR(1 g) = 7.67 W/kg; SAR(10 g) = 2.15 W/kg

Maximum value of SAR (measured) = 17.8 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=4mm, dy=4mm, dz=1.4mm

Reference Value = 66.62 V/m; Power Drift = -0.00 dB

Peak SAR (extrapolated) = 30.9 W/kg

SAR(1 g) = 7.66 W/kg; SAR(10 g) = 2.15 W/kg

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

Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5500 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 67.06 V/m; Power Drift = 0.02 dB

Peak SAR (extrapolated) = 34.6 W/kg

SAR(1 g) = 8.04 W/kg; SAR(10 g) = 2.24 W/kg

Maximum value of SAR (measured) = 19.4 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=4mm, dy=4mm, dz=1.4mm

Reference Value = 67.08 V/m; Power Drift = -0.01 dB

Peak SAR (extrapolated) = 35.5 W/kg

SAR(1 g) = 8.18 W/kg; SAR(10 g) = 2.31 W/kg

Maximum value of SAR (measured) = 19.7 W/kg

Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:

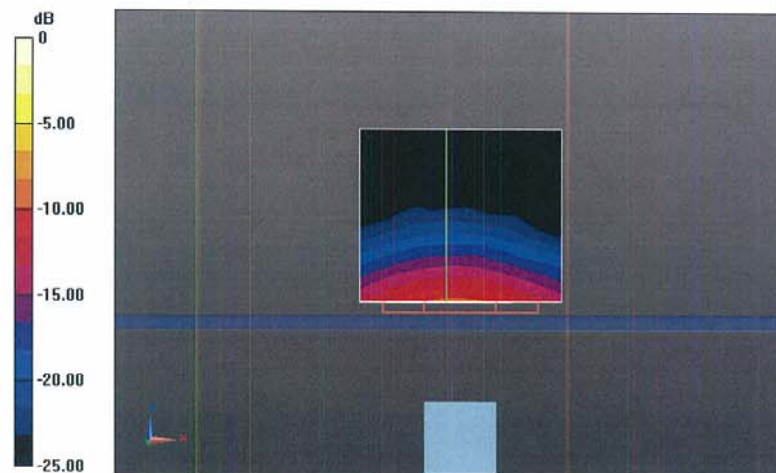
Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 64.83 V/m; Power Drift = -0.00 dB

Peak SAR (extrapolated) = 36.1 W/kg

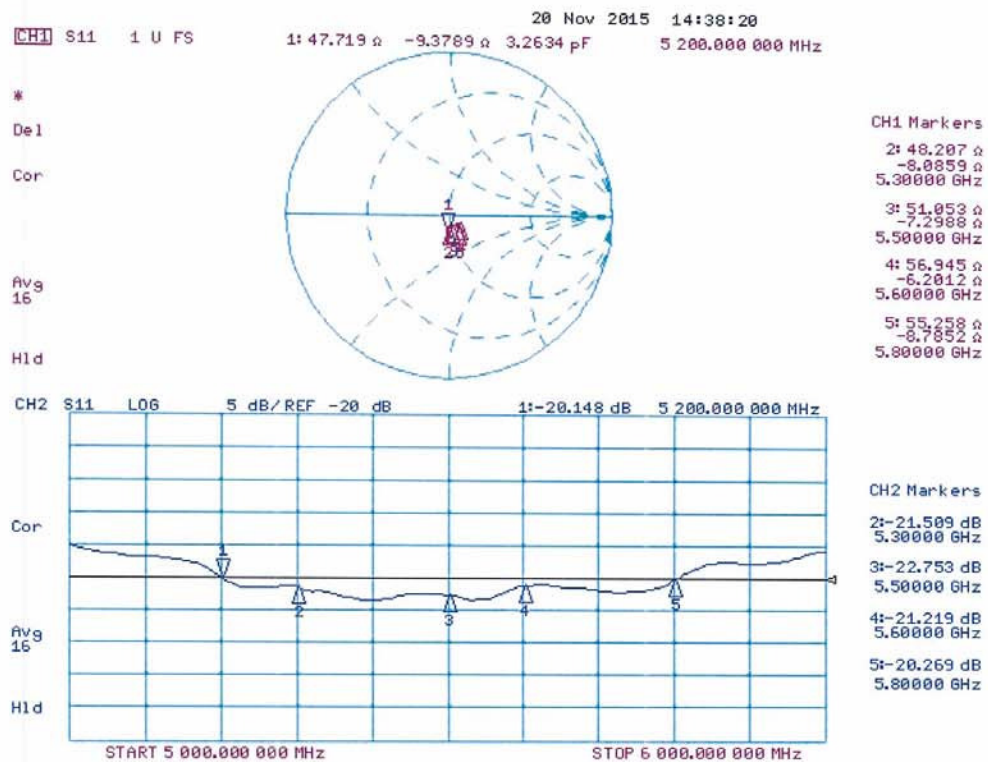
SAR(1 g) = 7.81 W/kg; SAR(10 g) = 2.17 W/kg

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



0 dB = 17.8 W/kg = 12.50 dBW/kg

Impedance Measurement Plot for Body TSL



< Dielectric Probe : DAK-3.5 SN 1140 >

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



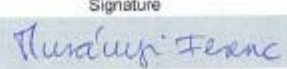
S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
S Servizio svizzero di taratura
S Swiss Calibration Service

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 **Onetech (Dymstec)**

Certificate No: **OCP-DAK3.5-1140_Nov15**

CALIBRATION CERTIFICATE																																															
Object	DAK-3.5 - SN: 1140																																														
Calibration procedure(s)	QA CAL-33.v2 Calibration of dielectric parameter probes																																														
Calibration date:	November 19, 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 ± 3)°C and humidity < 70%. Calibration Equipment used (M&TE critical for calibration) <table border="1"> <thead> <tr> <th>Primary Standards</th> <th>ID #</th> <th>Cal Date (Certificate No.)</th> <th>Scheduled Calibration</th> </tr> </thead> <tbody> <tr> <td>OCP DAK-3.5 (weighted)</td> <td>SN: 1203</td> <td>13-Oct-15 (OCP-DAK3.5-1203_Oct15)</td> <td>Oct-16</td> </tr> <tr> <th>Secondary Standards</th> <th>ID #</th> <th>Check Date (in house)</th> <th>Scheduled Check</th> </tr> <tr> <td>Rohde & Schwarz ZVA50</td> <td>T0170</td> <td>11-Jun-15 (in house check Jun-15)</td> <td>Jun-16</td> </tr> <tr> <td>Digital Thermometer DTM3000</td> <td>2148</td> <td>06-May-15 (DTM-2148_May15)</td> <td>May-16</td> </tr> <tr> <td>Methanol 99.9% Type 34860</td> <td>SZBE2308V</td> <td>21-Apr-15 (bottle opened, check Apr-15)</td> <td>Apr-16</td> </tr> <tr> <td>Head Liquid, HSL U12</td> <td>121204-1</td> <td>21-Apr-15 (in house check Apr-15)</td> <td>Apr-16</td> </tr> <tr> <td>0.1 mol/L NaCl solution Type 35275</td> <td>SZBE1570V</td> <td>15-Apr-15 (in house check Apr-15)</td> <td>Apr-16</td> </tr> <tr> <td>0.05 mol/L NaCl solution</td> <td>150421-1</td> <td>15-Apr-15 (in house check Apr-15)</td> <td>Apr-16</td> </tr> <tr> <td>Head Gel, SL AGH U08 AB-B</td> <td>150430</td> <td>11-May-15 (in house check May-15)</td> <td>Apr-16</td> </tr> <tr> <td>Solid Substrate</td> <td>AK9</td> <td>15-Apr-15 (in house check Apr-15)</td> <td>Apr-16</td> </tr> </tbody> </table>				Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration	OCP DAK-3.5 (weighted)	SN: 1203	13-Oct-15 (OCP-DAK3.5-1203_Oct15)	Oct-16	Secondary Standards	ID #	Check Date (in house)	Scheduled Check	Rohde & Schwarz ZVA50	T0170	11-Jun-15 (in house check Jun-15)	Jun-16	Digital Thermometer DTM3000	2148	06-May-15 (DTM-2148_May15)	May-16	Methanol 99.9% Type 34860	SZBE2308V	21-Apr-15 (bottle opened, check Apr-15)	Apr-16	Head Liquid, HSL U12	121204-1	21-Apr-15 (in house check Apr-15)	Apr-16	0.1 mol/L NaCl solution Type 35275	SZBE1570V	15-Apr-15 (in house check Apr-15)	Apr-16	0.05 mol/L NaCl solution	150421-1	15-Apr-15 (in house check Apr-15)	Apr-16	Head Gel, SL AGH U08 AB-B	150430	11-May-15 (in house check May-15)	Apr-16	Solid Substrate	AK9	15-Apr-15 (in house check Apr-15)	Apr-16
Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration																																												
OCP DAK-3.5 (weighted)	SN: 1203	13-Oct-15 (OCP-DAK3.5-1203_Oct15)	Oct-16																																												
Secondary Standards	ID #	Check Date (in house)	Scheduled Check																																												
Rohde & Schwarz ZVA50	T0170	11-Jun-15 (in house check Jun-15)	Jun-16																																												
Digital Thermometer DTM3000	2148	06-May-15 (DTM-2148_May15)	May-16																																												
Methanol 99.9% Type 34860	SZBE2308V	21-Apr-15 (bottle opened, check Apr-15)	Apr-16																																												
Head Liquid, HSL U12	121204-1	21-Apr-15 (in house check Apr-15)	Apr-16																																												
0.1 mol/L NaCl solution Type 35275	SZBE1570V	15-Apr-15 (in house check Apr-15)	Apr-16																																												
0.05 mol/L NaCl solution	150421-1	15-Apr-15 (in house check Apr-15)	Apr-16																																												
Head Gel, SL AGH U08 AB-B	150430	11-May-15 (in house check May-15)	Apr-16																																												
Solid Substrate	AK9	15-Apr-15 (in house check Apr-15)	Apr-16																																												
Calibrated by:	Name Ferenc Muranyi	Function External Expert	Signature 																																												
Approved by:	Katja Pokovic	Technical Manager																																													
Issued: November 19, 2015 This calibration certificate shall not be reproduced except in full without written approval of the laboratory.																																															

Certificate No: OCP-DAK3.5-1140_Nov15

Page 1 of 13

EMC-003 (Rev.2)

HEAD OFFICE : 301-14 Daessangnyeong-ri, Chowol-eup, Gwangju-si, Gyeonggi-do 464-862 Korea (TEL: 82-31-799-9500, FAX: 82-31-799-9599)
EMC Testing Div. : 307-51 Daessangnyeong-ri, Chowol-eup, Gwangju-si, Gyeonggi-do 464-862 Korea (TEL: 82-31-765-8289, FAX: 82-31-766-2904)

**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**

References

- [1] 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
- [2] IEC 62209 – 1, "Specific Absorption Rate (SAR) in the frequency range of 300 MHz to 3 GHz – Measurement Procedure, Part 1: Hand-held mobile wireless communication devices", February 2005
- [3] IEC 62209-2 Ed.1, "Human Exposure to Radio Frequency Fields from Handheld and Body-Mounted Wireless Communication Devices – Human models, Instrumentation, and Procedures Part 2: Procedure to determine the specific absorption rate (SAR) for mobile wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- [4] A. P. Gregory and R. N. Clarke, "NPL Report MAT 23", January 2012
Tables of the Complex Permittivity of Dielectric Reference Liquids at Frequencies up to 5 GHz
- [5] Agilent 85070E Dielectric Probe Kit, Technical Overview, document 5989-0222EN, October 2006
- [6] A. Toropainen et al, "Method for accurate measurement of complex permittivity of tissue equivalent liquids", Electronics Letters 36 (1) 2000 pp32-34
- [7] J. Hilland, "Simple sensor system for measuring the dielectric properties of saline solutions", Meas. Sci. Technol. 8 pp901–910 (1997)
- [8] K. Nörtemann, J. Hilland and U. Kaatz, "Dielectric Properties of Aqueous NaCl Solutions at Microwave Frequencies", J. Phys. Chem. A 101 pp6864–6869 (1997)
- [9] R. Buchner, G. T. Hefter and Peter M. May, "Dielectric Relaxation of Aqueous NaCl Solutions", J. Phys. Chem. A 103 (1) (1999)

Description of the dielectric probe

Dielectric probes are used to measure the dielectric parameters of tissue simulating media in a wide frequency range. The complex permittivity $\epsilon_r^* = (\epsilon'/\epsilon_0) - j(\epsilon''/\epsilon_0)$ is determined from the S parameters measured with a vector network analyzer (VNA) with software specific to the probe type. The parameters of interest e.g. in standards [1, 2, 3] and for other applications are presented are calculated as follows:

(Relative) permittivity ϵ' (real part of $\epsilon_r^* = (\epsilon'/\epsilon_0) - j(\epsilon''/\epsilon_0)$ where $\epsilon_0 = 8.854 \text{ pF/m}$ is the permittivity in free space)

Conductivity $\sigma = 2 \pi f \epsilon'' \epsilon_0$,

Loss Tangent $= (\epsilon''/\epsilon')$

The OCP (open ended coaxial) is a cut off section of 50 Ohm transmission line, similar to the system described in [1, 2, 3, 5], used for contact measurement. The material is measured either by touching the probe to the surface of a solid/gelly or by immersing it into a liquid media. The electromagnetic fields at the probe end fringe into the material to be measured, and its parameters are determined from the change of the S_{11} parameters. With larger diameter of the dielectrics, the probe can be used down to lower frequencies.

The flange surrounding the active area shapes the near field similar to a semi-infinite geometry and is inserted fully into the measured lossy liquid.

The probe is connected with a phase and amplitude stable cable to a VNA which is then calibrated with Open, Short and a Liquid with well-known parameters. All parts in the setup influencing the amplitude and phase of the signal are important and shall remain stable.

Handling of the item

Before usage, the active probe area has to be cleaned from any material residuals potentially contaminating the reference standards. The metal and dielectric surface must be protected to keep the precision of the critical mechanical dimensions. The connector and cable quality are critical; any movements between calibration and measurement shall be avoided. The temperature must be stable and must not differ from the material temperature.

Methods Applied and Interpretation of Parameters

The calibration of the dielectric probe system is done in the steps described below for the desired frequency range and calibration package (SAR/MRI liquids, Semi-solid/solid material). Because the standard calibration in step 3 is critical for the results in steps 4 to 8, the sequence 3 to 8 is repeated 3 times. As a result, the result from these 3 sets is represented.

1. Configuration and mechanical / optical status.
2. Measurement resolution is 5 MHz from 10 to 300 MHz, 50 MHz from 300 to 6000 MHz and 250 MHz from 6 to 20 GHz.
3. Standard calibration uses Air / Short / Liquid. 1 liter liquid quantity is used to reduce the influence the reflections. The liquid type is selected depending on the lowest frequency and probe diameter:
DAK-1.2, DAK-3.5, Agilent OCP: de-ionized water (approx. 22 °C)
DAK-12: saline solution with static conductivity 1 S/m (approx. 22 °C)
NPL OCP: pure ethanol (approx. 22 °C)
4. The cable used in the setup stays in a fixed position, i.e. the probe is fixed and measuring from the top in an angle of typ. 20° from the vertical axis. For DAK and Agilent probes, the refresh function (air standard) is used previous to the individual measurements in order to compensate for possible deviations from cable movements. After insertion of the probe into a liquid, the possible air bubbles are removed from the active surface.
5. Measurement of multiple shorts if not already available from the calibration in the previous step (NPL). Evaluation of the deviation from the previous calibration short with graphical representation of the complex quantities and magnitude over the frequency range. Probe specific short is used. This assessment shows ability to define a short circuit at the end of the probe for the VNA calibration in the setup which is essential at high frequencies and depends on the probe surface quality.
6. Measurement of validation liquids in a quantity of 1 liter at well defined temperature. Evaluation of the deviations from the target. The targets base on traceable data from reference sources. The deviation of the measurement is graphically presented for permittivity and conductivity (for lossy liquids) or loss tangent (for low losses at low frequencies).
7. Measurement of lossy liquids in a quantity of 1 liter at well defined temperature. Head tissue simulating liquid or saline solution with 0.5 S/m static conductivity are representative. The target data base on traceable data from reference sources or from multiple measurements with precision reference probes or different evaluations such as transmission line or slotted line methods. Evaluation of the deviation from the target and graphical representation for permittivity and conductivity over the frequency range
8. Semi-solid / solid material calibration:
Measurements of an elastic lossy broadband semi-solid gel with parameters close to the head tissue target. Measurements of a planar very low loss solid microwave-substrate. The average of 4 measurements of the same sample at different location is shown as a single result. The deviation of the permittivity and conductivity from the reference data is evaluated.
Measurements of a planar very low loss solid microwave-substrate. The average of 4 measurements of the same sample at different location is shown as a single result. The relative deviation of the permittivity and the absolute deviation of the loss tangent is evaluated.
The targets base on multiple measurements (on the same material batch at identical temperature) on convex and planar surfaces with precision reference OCP.

- The measurement on semi-solid / solid materials is sensitive to the quality and planarity of the probe contact area, such as air gaps due to imperfect probes (resulting lower permittivity values).
9. Table for the probe uncertainty: The uncertainty of the probe depending on probe type, size, material parameter range and frequency is given in a table. It represents the best measurement capability of the specific probe but does not include the material (deviation from the target values).
 10. Appendix with detailed results of all measurements with the uncertainties for the specific measurement. In addition to the probe uncertainty (see above), it includes the uncertainty of the reference material used for the measurement. A set of results from independent calibrations represents the capability of the setup and the lossy materials used, including the precision of the measured material and the influence of temperature deviations. Temperature and operator influence was minimized and gives a good indication of the achievable repeatability of a measurement.
 11. Summary assessment of the measured deviations and detailed comments if not typical for the probe type.

Dielectric probe identification and configuration data

Item description

Probe type	OCP Open-ended coaxial probe
Probe name	SPEAG Dielectric Assessment Kit DAK-3.5
Type No	SM DAK 040 CA
Serial No	1140
Description	Open-ended coaxial probe with flange Flange diameter: 19.0 mm Dielectric diameter: 3.5 mm Material: stainless steel
Connector 1	PC 3.5 pos.
Software version	DAK Measurement Solver 2.2.0.546 Calibration Type: Air / short / water (set to measured water temp.) Probe type: "DAK3.5" (software setting)
Further settings	VNA bandwidth setting: 50 Hz

SCS 0108 Accessories used for customer probe calibration

Cable	Huber & Suhner Sucoflex 404, SN: 3085, length 1 m, PC3.5 neg. – PC3.5 neg.
Short	DAK-3.5 shorting block, type SM DAK 200 BA Contact area covered with cleaned Cu stripe

Additional items used during measurements

Adapter 1	PC3.5 pos. – PC2.4 (VNA side)
Adapter 2	PC3.5 pos. – PC3.5 neg. (probe side)

Notes

- Before the calibration, the connectors of the probe and cable were inspected and cleaned.
- Probe visual inspection: according to requirements
- Short inspection: according to the requirements

Probe Uncertainty

The following tables provide material and frequency specific uncertainties ($k=2$) for the dielectric probe. The values in the tables represent the measurement capability for the probe when measuring a material in the indicated parameter range. They include all uncertainties of

- probe system
- possible systematic errors due to the design
- calibration
- temperature differences during the calibration and measurements, as described,
- VNA noise

Apart from the material used for the calibration (de-ionized water), material uncertainties of the reference materials used during the measurement in Appendix A are not included in these tables.

DAK-3.5				
Permittivity range		Frequency range	(sigma / LT range)	Unc. ($k=2$)
1 – 15		10 MHz - 20 MHz		---
		20 MHz - 200 MHz		---
		200 MHz - 3 GHz	LT < 0.1	2.4%
		3 GHz - 6 GHz	LT < 0.1	2.0%
		6 GHz - 20 GHz	LT < 0.1	2.1%
10 – 40		10 MHz - 20 MHz		---
		20 MHz - 200 MHz		---
		200 MHz - 3 GHz	sigma : 1 – 10 S/m	1.9%
		3 GHz - 6 GHz	sigma : 1 – 10 S/m	2.3%
		6 GHz - 20 GHz	sigma > 10 S/m	3.5%
35 – 100		10 MHz - 20 MHz		---
		20 MHz - 200 MHz		---
		200 MHz - 3 GHz	sigma : 1 – 10 S/m	1.8%
		3 GHz - 6 GHz	sigma : 1 – 10 S/m	1.9%
		6 GHz - 20 GHz	sigma > 10 S/m	2.4%
Conductivity range (S/m)		Frequency range	(epsilon / LT range)	Unc. ($k=2$)
1 – 10		10 MHz - 20 MHz		---
		20 MHz - 200 MHz		---
		200 MHz - 3 GHz	eps : 35 - 100	2.7%
		3 GHz - 6 GHz	eps : 35 - 100	3.0%
		6 GHz - 20 GHz	eps : 10 - 40	3.0%
Loss tangent range		Frequency range	(epsilon / LT range)	Unc. ($k=2$)
< 0.1		10 MHz - 20 MHz		---
		20 MHz - 200 MHz		---
		200 MHz - 3 GHz	eps : 1 - 15	0.03
		3 GHz - 6 GHz	eps : 1 - 15	0.03
		6 GHz - 20 GHz	eps : 1 - 15	0.03

Calibration Results

Uncertainty limits ($k=2$) for the material measurements in the figures of Appendix A are represented with red dashed lines. These uncertainties contain - in addition to probe uncertainty - the uncertainty of the material target parameter determination.

The measurements show the results obtained from independent calibrations for the same material. The differences between the individual measurement curves give therefore an indication for the obtainable repeatability and shall lie within the uncertainties stated in the tables.

Materials for DAK-3.5 calibration:

Appendix A with curves for Methanol, HSL, and 0.05 mol/L NaCl solution (200 MHz - 6 GHz, optional 20 GHz), HS gel and low loss solid substrate are optional.

Appendix A: Detailed Results (additional assessments outside the scope of SCS0108)

A.1 Probe appearance and calibration sequence

A.1.1 Appearance

The OCP appearance is fully according to the expectations:

- the flange surface is intact

A.1.2 Calibration sequence

The following sequence was repeated 3 times in the low frequency range from 200 – 300 MHz in 5 MHz steps and in the high frequency range from 300 to 6000 MHz in 50 MHz steps, and from 6 GHz to 20 GHz in 250 MHz steps.

- Air
- Short 1 short, then immediate verification with a second short (with eventual repetition)
- Water De-ionized water, temperature measured and set in the software (for DAK-12 0.1 mol/L saline solution, temperature measured and set in the software)
- Methanol Pure methanol, temperature measured and set in the software
- Liquids Measurement of further liquids (e.g. Head tissue simulating liquid and 0.05 mol/l saline)
- Cleaning Probe washed with water and isopropanol at the end of the sequence.
- Shorts 4 additional separate short measurements to determine the deviation from the original
- Refresh Refresh with Air
- Solid 4 separate solid low loss planar substrate measurements to determine one average (optional)
- Semisolid 4 separate head gel measurements on fresh intact surface to determine one average (optional)
- Cleaning Probe washed with water and isopropanol at the end of the sequence

Evaluation of the additional shorts from the calibrated (ideal) short point at the left edge of the Smith Chart, represented as magnitude over the frequency range (fig. 2.1.x) and in polar representation (fig. 2.2.x).

Evaluation of the Liquid measurements and representation of the permittivity and conductivity deviation from their reference data at the measurement temperature. The results of each of the 3 calibrations is shown in the appendix for each material (fig. 3ff) in black, red, blue. The red dashed line shows the uncertainty of the reference material parameter determination.

Evaluation of the Semisolid measurements (optional) by representing the 3 average deviations (each resulting from the 4 separate measurements per set), equivalent to the liquid measurement. Representation of the permittivity and conductivity deviation from their reference data at the nominal temperature.

Evaluation of the Solid measurements (optional) by representing the 3 average deviations (each resulting from the 4 separate measurements per set), equivalent to the liquid measurement. Representation of the permittivity deviation from their reference data and the loss tangent at the nominal temperature.

A.2 Short residual magnitudes

After each of the 3 calibrations with a single short (as per the DAK software), 4 additional separate, short measurements were performed after the liquid measurements and evaluated from the S11 data. The residuals in the graphs represent the deviation from the ideal short point on the polar representation on the VNA screen.

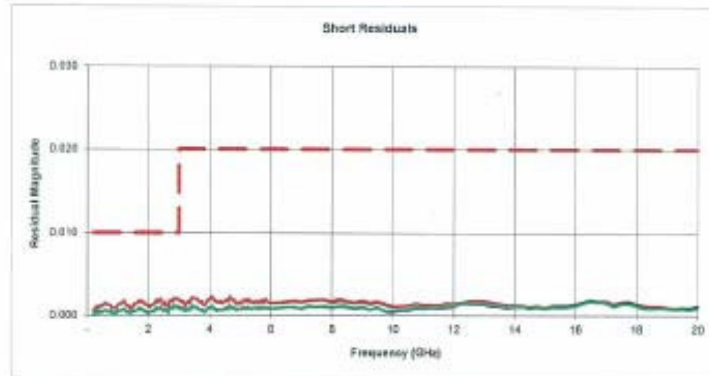


Fig. 2.1a Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration a)

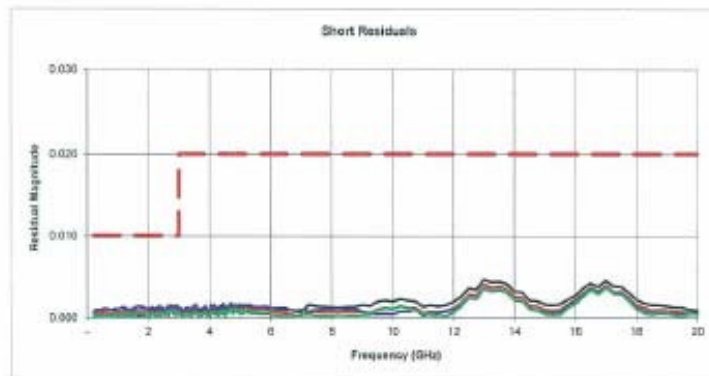


Fig. 2.1b Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration b)

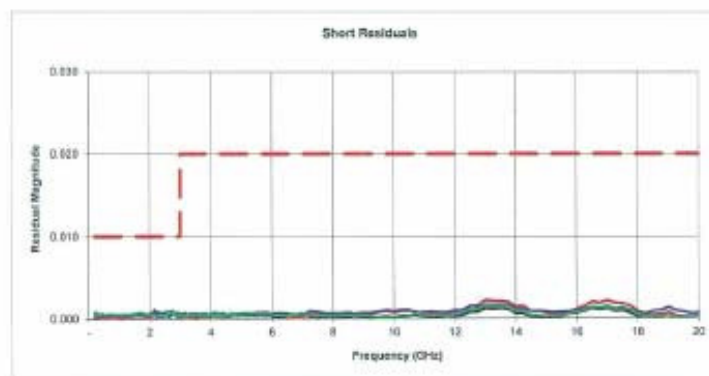


Fig. 2.1c Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration c)

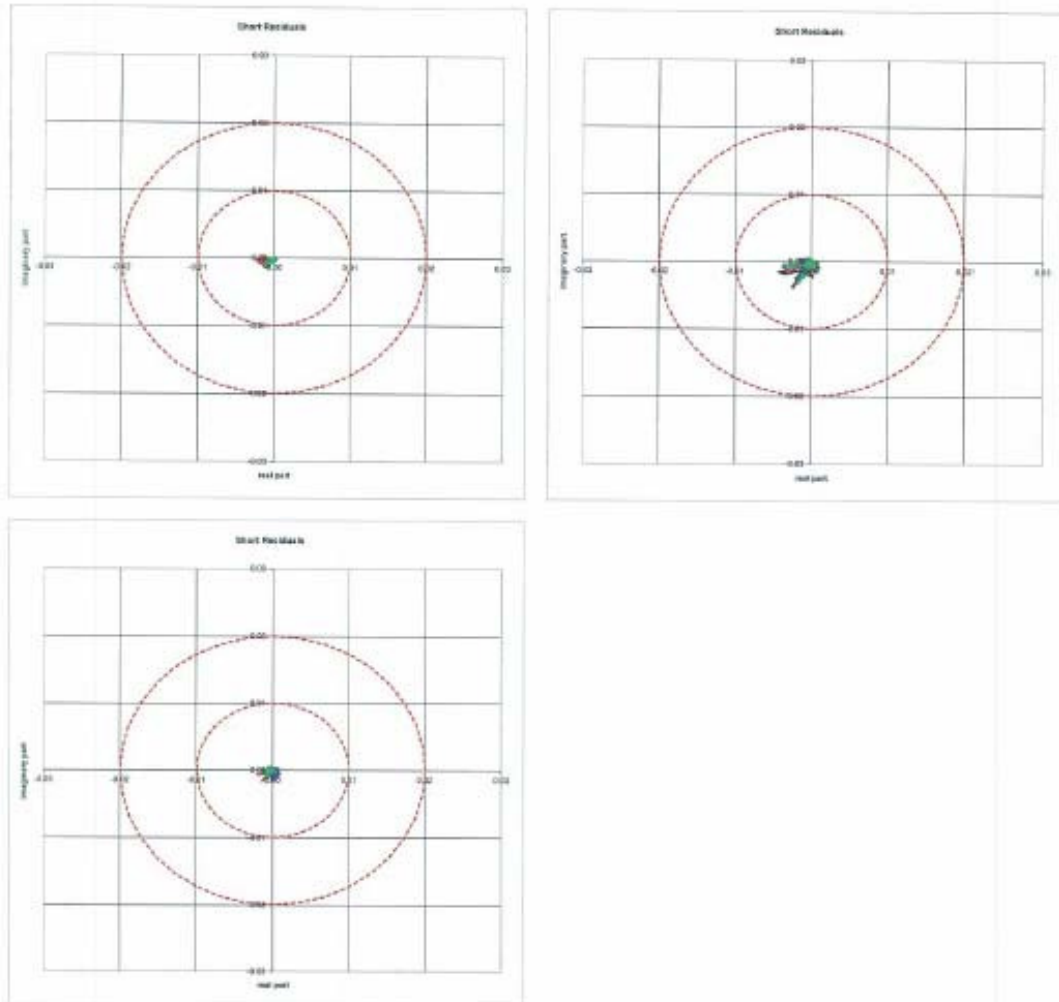


Fig. 2.2a-c Complex representation of the residuals of the shorts, 200 MHz - 20 GHz, after calibrations a)-b) in the top and c) in the bottom

All shorts have good quality. Some minor deviations might be visible from contact quality (left - right).

A.3 Methanol

Methanol (99.9% pure) was measured at a temperature of 22 ± 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the nominal material parameters at this temperature, calculated from NPL data for this temperature.

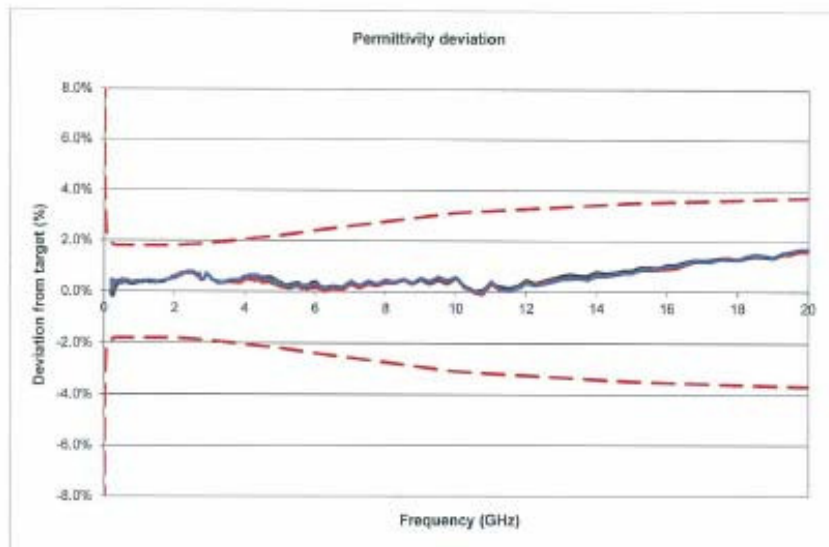


Fig. 3.1 Methanol permittivity deviation from target, 200 MHz – 20 GHz

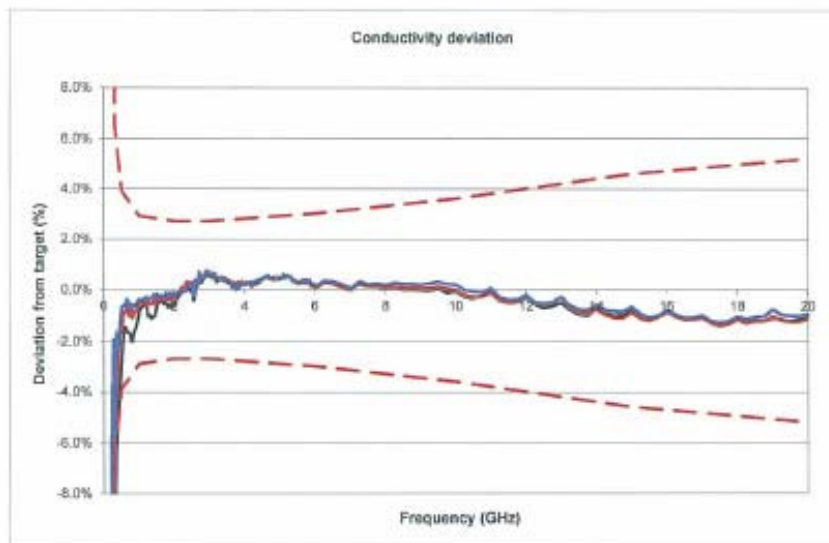


Fig. 3.2 Methanol conductivity deviation from target, 200 MHz – 20 GHz

Conductivity error can be high at low frequencies due to the low absolute conductivity values.

A.4 Head Tissue

Broadband head simulating liquid was measured at a temperature of 22 ± 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the reference data for this material. Those parameters have been evaluated from multiple measurements on the used bath with precision reference OCP and further methods.

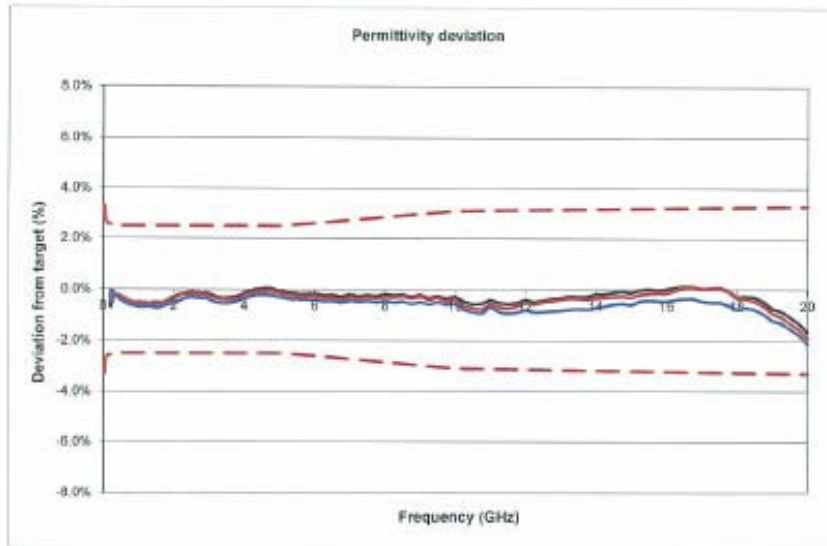


Fig. 4.1 HSL permittivity deviation from target, 200 MHz – 20 GHz

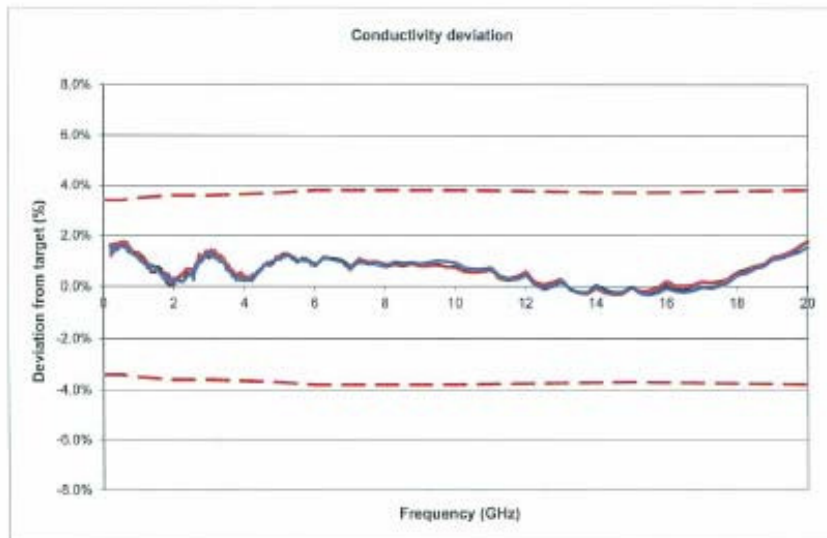


Fig. 4.2 HSL conductivity deviation from target, 200 MHz – 20 GHz

A.5 0.05 mol/L NaCl solution

0.05 mol/L NaCl / water solution has a static conductivity of 0.5 S/m, similar to MRI HCL (High Conductivity Liquid). It was measured at a temperature of 22 ± 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the reference data for this material. These parameters have been derived from the theoretical model according to [7], matched to the measurements from reference probes and other sources. A quantity of 1 liter was used for the measurement.

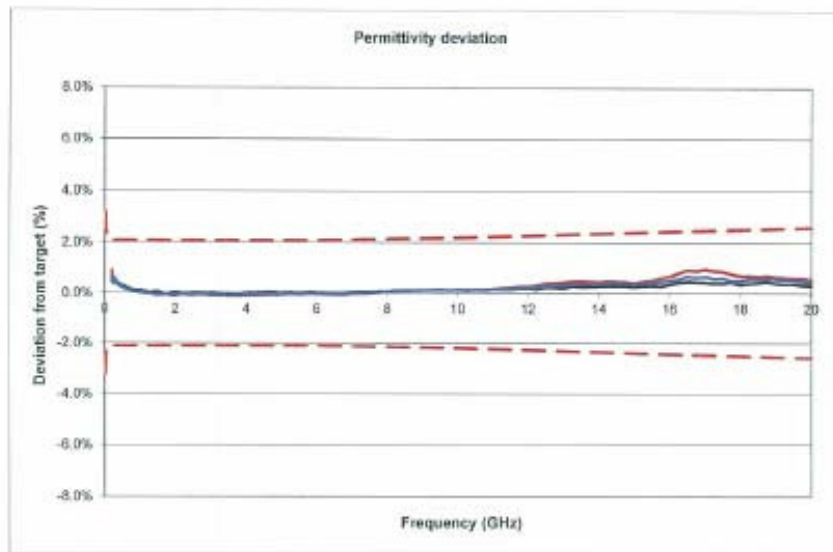


Fig. 5.1 0.05 mol/L solution permittivity deviation from target, 200 MHz – 20 GHz

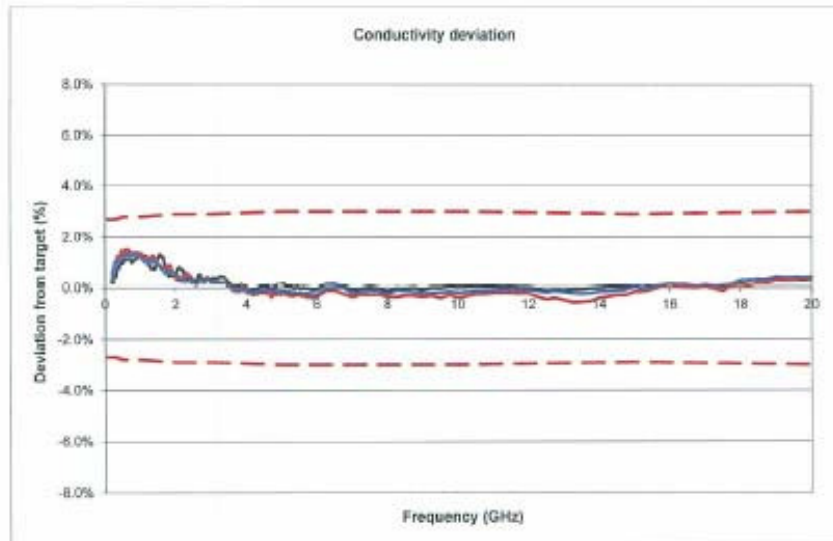


Fig. 5.2 0.05 mol/L solution conductivity deviation from target, 200 MHz – 20 GHz

Appendix B: Nominal parameters of reference materials used for calibration (additional assessments outside the scope of SCS0108)

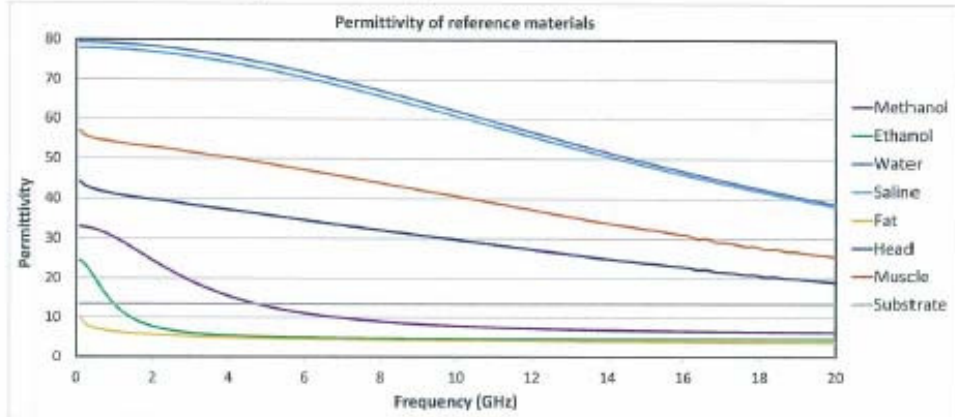


Fig. B.1 Permittivity of reference materials

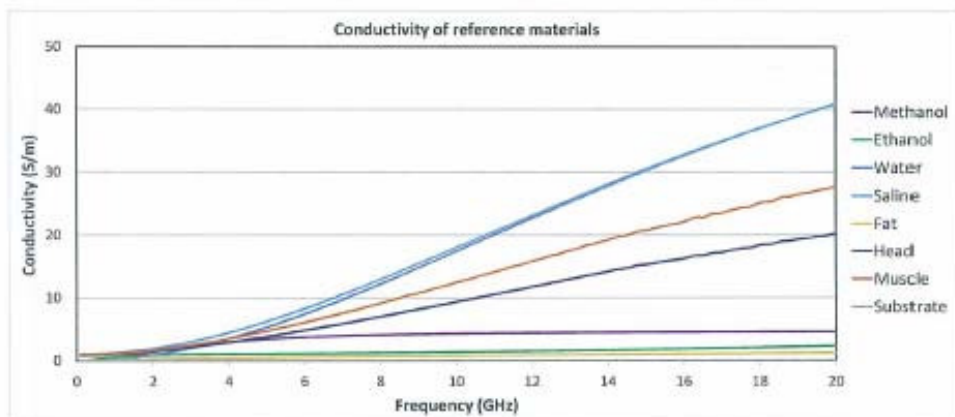


Fig. B.2 Conductivity of reference materials

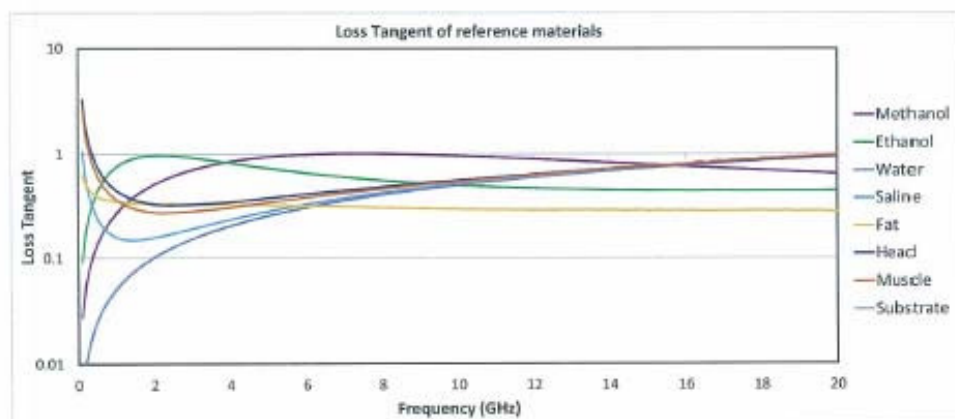


Fig. B.3 Loss tangent of reference materials