

## Appendix B

### Uncertainty Analysis

Measurement uncertainty for 300 MHz to 3 GHz averaged over 1 gram

a	b	c	d	e = f(d,k)	g	i = cxg/e	k
Uncertainty Component	Section in P1528	Tol (%)	Prob. Dist.	Div.	Ci (1g)	1g ui (%)	Vi (Veff)
Probe calibration	E.2.1	6.0	N	1	1	6.00	∞
Axial isotropy	E.2.2	0.25	R	1.73	1	0.14	∞
hemispherical isotropy	E.2.2	1.3	R	1.73	1	0.75	∞
Boundary effect	E.2.3	0.4	R	1.73	1	0.23	∞
Linearity	E.2.4	0.3	R	1.73	1	0.17	∞
System detection limit	E.2.5	0.25	R	1.73	1	0.14	∞
Readout electronics	E.2.6	0.3	N	1	1	0.30	∞
Response time	E.2.7	0.8	R	1.73	1	0.46	∞
Integration time	E.2.8	2.6	R	1.73	1	1.50	∞
RF ambient Condition -Noise	E.6.1	3.0	R	1.73	1	1.73	∞
RF ambient Condition - reflections	E.6.1	3.0	R	1.73	1	1.73	∞
Probe positioning- mechanical tolerance	E.6.2	1.5	R	1.73	1	0.87	∞
Probe positioning- with respect to phantom	E.6.3	2.9	R	1.73	1	1.67	∞
Max. SAR evaluation	E.5.2	1.0	R	1.73	1	0.58	∞
Test sample positioning	E.4.2	5.84	N	1	1	5.84	9
Device holder uncertainty	E.4.1	3.6	N	1	1	3.60	∞
Output power variation -SAR drift measurement	6.62	5.0	R	1.73	1	2.89	∞
Phantom uncertainty (shape and thickness tolerances)	E.3.1	6.6	R	1.73	1	3.81	∞
Liquid conductivity - deviation from target values	E.3.2	5.0	R	1.73	0.64	1.85	∞
Liquid conductivity - measurement uncertainty	E.3.2	0.70	N	1	0.64	0.45	5
Liquid permittivity - deviation from target values	E.3.3	5.0	R	1.73	0.6	1.73	∞
Liquid permittivity - measurement uncertainty	E.3.3	0.56	N	1	0.6	0.34	5
Combined standard uncertainty				RSS		11.22	123
Expanded uncertainty (95% CONFIDENCE INTERVAL)				K=2		22.44	

## **Appendix C**

### **Calibration Certificate**

**- PROBE**

**- DAE**

**- 835 MHz, 1900 MHz, 2450 MHz DIPOLE**

**- Dielectric Assessment Kit DAK-3.5 Calibration Certificate**

## - PROBE Calibration Certificate

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Accreditation No.: **SCS 108**

Client **SGS (Dymstec)**

Certificate No: **ET3-1782\_Apr12**

### CALIBRATION CERTIFICATE

Object **ET3DV6 - SN:1782**

Calibration procedure(s) **QA CAL-01.v8, QA CAL-12.v7, QA CAL-23.v4, QA CAL-25.v4  
 Calibration procedure for dosimetric E-field probes**

Calibration date: **April 27, 2012**

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 E4419B	GB41293674	29-Mar-12 (No. 217-01508)	Apr-13
Power sensor E4412A	MY41498087	29-Mar-12 (No. 217-01508)	Apr-13
Reference 3 dB Attenuator	SN: S5054 (3c)	27-Mar-12 (No. 217-01531)	Apr-13
Reference 20 dB Attenuator	SN: S5086 (20b)	27-Mar-12 (No. 217-01529)	Apr-13
Reference 30 dB Attenuator	SN: S5129 (30b)	27-Mar-12 (No. 217-01532)	Apr-13
Reference Probe ES3DV2	SN: 3D13	29-Dec-11 (No. ES3-3013_Dec11)	Dec-12
DAE4	SN: 660	10-Jan-12 (No. DAE4-660_Jan12)	Jan-13
Secondary Standards	ID	Check Date (in house)	Scheduled Check
RF generator HP 8648C	US3642U01700	4-Aug-99 (in house check Apr-11)	in house check: Apr-13
Network Analyzer HP 8753E	US97390595	18-Oct-01 (in house check Oct-11)	in house check: Oct-12

	Name	Function	Signature
Calibrated by:	Jeton Kastali	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: April 27, 2012

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#### Glossary:

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

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

- IEEE Std 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003
- 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

#### Methods Applied and Interpretation of Parameters:

- NORM<sub>x,y,z</sub>**: Assessed for E-field polarization  $\theta = 0$  ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide). NORM<sub>x,y,z</sub> are only intermediate values, i.e., the uncertainties of NORM<sub>x,y,z</sub> does not affect the E<sup>2</sup>-field uncertainty inside TSL (see below ConvF).
- NORM(f)<sub>x,y,z</sub>** = NORM<sub>x,y,z</sub> \* frequency\_response (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCP<sub>x,y,z</sub>**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- PAR**: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- A<sub>x,y,z</sub>; B<sub>x,y,z</sub>; C<sub>x,y,z</sub>; VR<sub>x,y,z</sub>; A, B, C** are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters**: Assessed in flat phantom using E-field (or Temperature Transfer Standard for  $f \leq 800$  MHz) and inside waveguide using analytical field distributions based on power measurements for  $f > 800$  MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM<sub>x,y,z</sub> \* ConvF whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from  $\pm 50$  MHz to  $\pm 100$  MHz.
- Spherical isotropy (3D deviation from isotropy)**: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.

ET3DV6 – SN:1782

April 27, 2012

# Probe ET3DV6

## SN:1782

Manufactured: April 15, 2003  
Calibrated: April 27, 2012

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

ET3DV6- SN:1782

April 27, 2012

## DASY/EASY - Parameters of Probe: ET3DV6 - SN:1782

### Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup>	2.01	1.66	1.88	± 10.1 %
DCP (mV) <sup>B</sup>	96.2	96.7	96.7	

### Modulation Calibration Parameters

UID	Communication System Name	PAR		A dB	B dB	C dB	VR mV	Unc <sup>C</sup> (k=2)
0	CW	0.00	X	0.00	0.00	1.00	154.8	±1.9 %
			Y	0.00	0.00	1.00	185.8	
			Z	0.00	0.00	1.00	151.1	

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

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

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

<sup>C</sup> Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

ET3DV6- SN:1782

April 27, 2012

## DASY/EASY - Parameters of Probe: ET3DV6 - SN:1782

### Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) <sup>c</sup>	Relative Permittivity <sup>f</sup>	Conductivity (S/m) <sup>f</sup>	ConvF X	ConvF Y	ConvF Z	Alpha	Depth (mm)	Unct. (k=2)
450	43.5	0.87	7.17	7.17	7.17	0.23	2.35	± 13.4 %
835	41.5	0.90	6.40	6.40	6.40	0.32	3.00	± 12.0 %
1750	40.1	1.37	5.39	5.39	5.39	0.80	1.66	± 12.0 %
1900	40.0	1.40	5.12	5.12	5.12	0.80	1.98	± 12.0 %
2450	39.2	1.80	4.48	4.48	4.48	0.80	1.97	± 12.0 %

<sup>c</sup> Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

<sup>f</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

ET3DV6- SN:1782

April 27, 2012

## DASY/EASY - Parameters of Probe: ET3DV6 - SN:1782

### Calibration Parameter Determined in Body Tissue Simulating Media

f (MHz) <sup>c</sup>	Relative Permittivity <sup>f</sup>	Conductivity (S/m) <sup>f</sup>	ConvF X	ConvF Y	ConvF Z	Alpha	Depth (mm)	Unct. (k=2)
450	56.7	0.94	7.57	7.57	7.57	0.16	2.29	± 13.4 %
835	55.2	0.97	6.22	6.22	6.22	0.24	3.00	± 12.0 %
1750	53.4	1.49	4.79	4.79	4.79	0.76	2.24	± 12.0 %
1900	53.3	1.52	4.59	4.59	4.59	0.75	2.18	± 12.0 %
2450	52.7	1.95	4.11	4.11	4.11	0.76	2.25	± 12.0 %

<sup>c</sup> Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

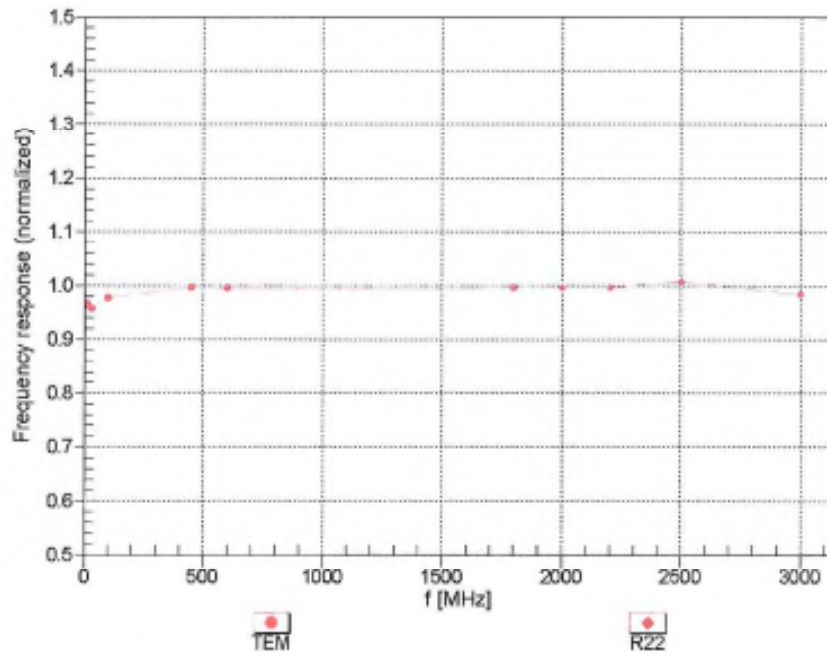
<sup>f</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.



ET3DV6- SN:1782

April 27, 2012

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



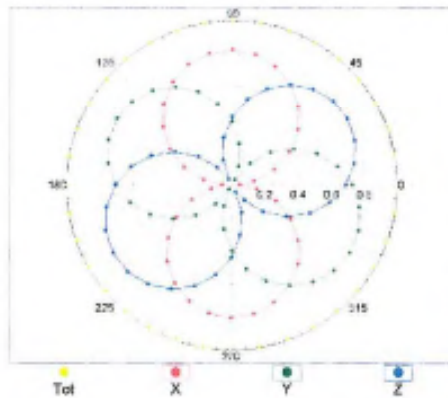
Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  (k=2)

ET3DV6-SN:1782

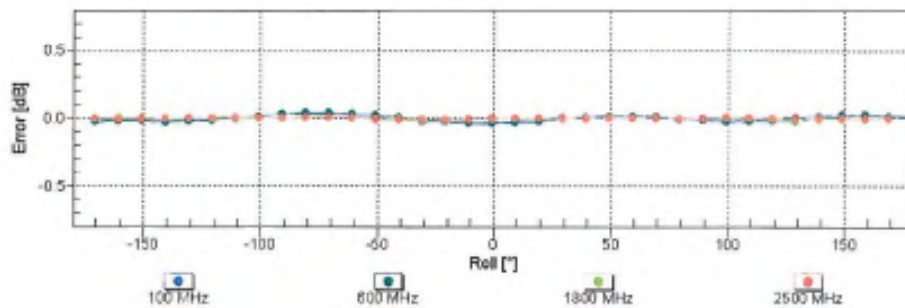
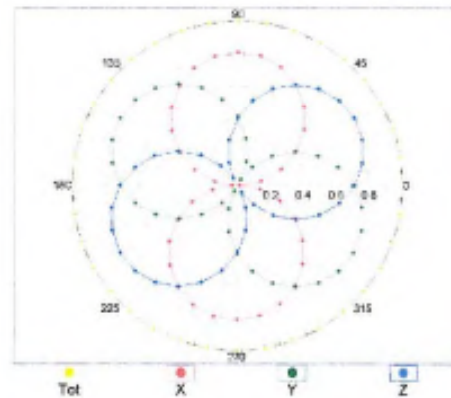
April 27, 2012

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

f=600 MHz, TEM



f=1800 MHz, R22

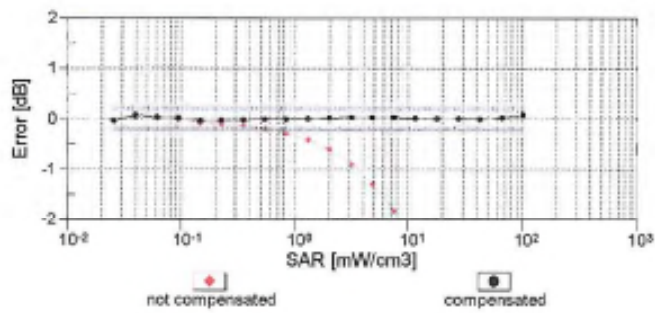
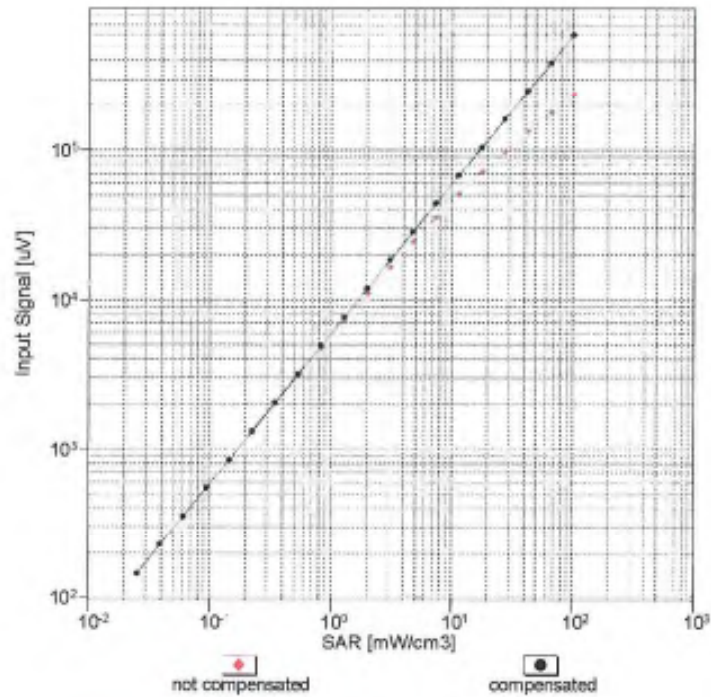


Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  (k=2)

ET3DV6- SN:1782

April 27, 2012

## Dynamic Range f(SAR<sub>head</sub>) (TEM cell , f = 900 MHz)

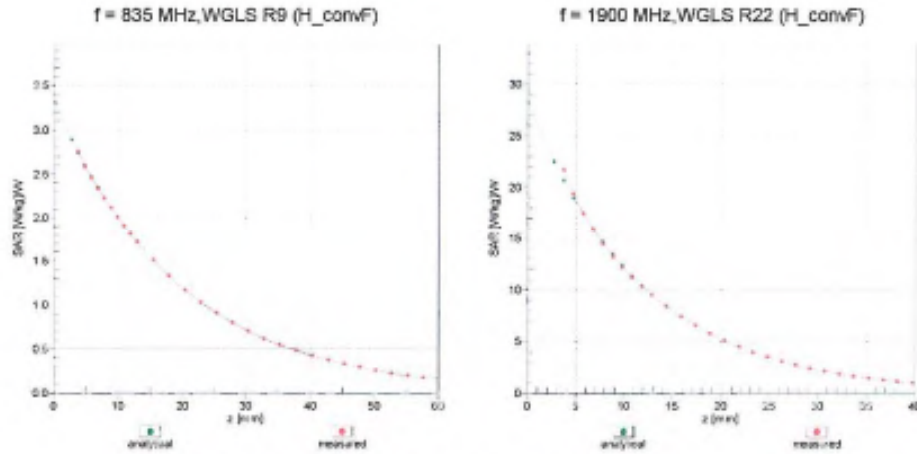


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

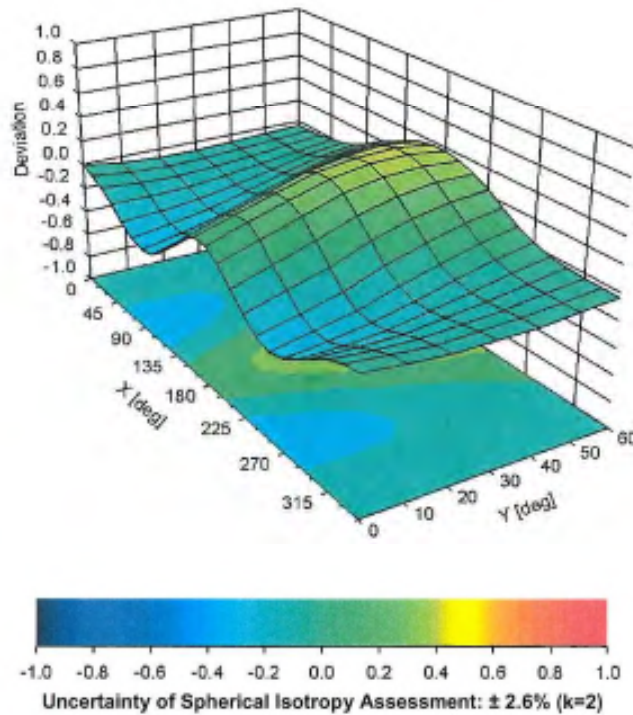
ET3DV6- SN:1782

April 27, 2012

### Conversion Factor Assessment



### Deviation from Isotropy in Liquid Error ( $\phi$ , $\theta$ ), f = 900 MHz



ET3DV6- SN:1782

April 27, 2012

## DASY/EASY - Parameters of Probe: ET3DV6 - SN:1782

### Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	49.1
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	10 mm
Tip Diameter	6.8 mm
Probe Tip to Sensor X Calibration Point	2.7 mm
Probe Tip to Sensor Y Calibration Point	2.7 mm
Probe Tip to Sensor Z Calibration Point	2.7 mm
Recommended Measurement Distance from Surface	4 mm

## - DAE3 Calibration Certificate

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Accreditation No.: **SCS 108**

Client **SGS (Dymstec)**

Certificate No: **DAE3-567\_Jan13**

### CALIBRATION CERTIFICATE

Object: **DAE3 - SD 000 D03 AA - SN: 567**

Calibration procedure(s): **QA CAL-06.v25  
 Calibration procedure for the data acquisition electronics (DAE)**


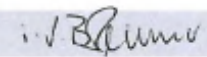
Calibration date: **January 25, 2013**

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
Keithley Multimeter Type 2001	SN: 0810278	02-Oct-12 (No:12728)	Oct-13
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	07-Jan-13 (in house check)	In house check: Jan-14
Calibrator Box V2.1	SE UMS 006 AA 1002	07-Jan-13 (in house check)	In house check: Jan-14

Calibrated by:	Name <b>R. Mayoraz</b>	Function <b>Technician</b>	Signature 
Approved by:	Name <b>Fin Bonholt</b>	Function <b>Deputy Technical Manager</b>	Signature 

Issued: January 25, 2013

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**Glossary**

**DAE** data acquisition electronics  
**Connector angle** information used in DASY system to align probe sensor X to the robot coordinate system.

**Methods Applied and Interpretation of Parameters**

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle:* The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
  - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
  - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
  - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
  - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
  - *Input Offset Measurement:* Output voltage and statistical results over a large number of zero voltage measurements.
  - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
  - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
  - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
  - *Power consumption:* Typical value for information. Supply currents in various operating modes.

**DC Voltage Measurement**

A/D - Converter Resolution nominal

 High Range: 1LSB = 6.1 $\mu$ V , full range = -100...+300 mV

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

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

Calibration Factors	X	Y	Z
High Range	404.652 $\pm$ 0.02% (k=2)	404.401 $\pm$ 0.02% (k=2)	404.491 $\pm$ 0.02% (k=2)
Low Range	3.95362 $\pm$ 1.55% (k=2)	3.97148 $\pm$ 1.55% (k=2)	3.96078 $\pm$ 1.55% (k=2)

**Connector Angle**

Connector Angle to be used in DASY system	7° $\pm$ 1°
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**Appendix**
**1. DC Voltage Linearity**

High Range	Reading ( $\mu\text{V}$ )	Difference ( $\mu\text{V}$ )	Error (%)
Channel X + Input	199995.32	-0.62	-0.00
Channel X + Input	20002.46	1.32	0.01
Channel X - Input	-19998.40	1.69	-0.01
Channel Y + Input	199997.71	1.34	0.00
Channel Y + Input	19999.63	-1.28	-0.01
Channel Y - Input	-19997.89	2.47	-0.01
Channel Z + Input	199996.03	0.01	0.00
Channel Z + Input	19998.99	-1.92	-0.01
Channel Z - Input	-19998.51	1.81	-0.01

Low Range	Reading ( $\mu\text{V}$ )	Difference ( $\mu\text{V}$ )	Error (%)
Channel X + Input	2002.18	0.83	0.04
Channel X + Input	201.83	0.08	0.04
Channel X - Input	-198.32	-0.18	0.09
Channel Y + Input	2001.92	0.81	0.04
Channel Y + Input	201.24	-0.29	-0.15
Channel Y - Input	-199.03	-0.72	0.36
Channel Z + Input	2001.88	0.72	0.04
Channel Z + Input	200.70	-0.97	-0.48
Channel Z - Input	-199.17	-0.97	0.49

**2. Common mode sensitivity**

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

	Common mode Input Voltage (mV)	High Range Average Reading ( $\mu\text{V}$ )	Low Range Average Reading ( $\mu\text{V}$ )
Channel X	200	3.30	1.64
	-200	0.20	-1.94
Channel Y	200	-0.21	-0.42
	-200	0.96	0.59
Channel Z	200	4.66	3.87
	-200	-5.94	-6.09

**3. Channel separation**

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

	Input Voltage (mV)	Channel X ( $\mu\text{V}$ )	Channel Y ( $\mu\text{V}$ )	Channel Z ( $\mu\text{V}$ )
Channel X	200	-	-0.86	-3.62
Channel Y	200	7.58	-	-0.08
Channel Z	200	5.96	5.73	-

#### 4. AD-Converter Values with inputs shorted

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

	High Range (LSB)	Low Range (LSB)
Channel X	16316	14587
Channel Y	16163	15684
Channel Z	15966	15490

#### 5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec  
Input 10M $\Omega$

	Average ( $\mu$ V)	min. Offset ( $\mu$ V)	max. Offset ( $\mu$ V)	Std. Deviation ( $\mu$ V)
Channel X	0.52	-0.92	1.43	0.45
Channel Y	-0.20	-2.46	1.17	0.46
Channel Z	-0.70	-1.79	0.17	0.39

#### 6. Input Offset Current

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

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

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

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

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

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

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

## - 835 MHz Dipole Calibration Certificate

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Accreditation No.: **SCS 108**

Client **SGS (Dymstec)**

Certificate No: **D835V2-490\_May12**

### CALIBRATION CERTIFICATE

Object: **D835V2 - SN: 490**

Calibration procedure(s): **QA CAL-05.v8  
 Calibration procedure for dipole validation kits above 700 MHz**

Calibration date: **May 16, 2012**

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	05-Oct-11 (No. 217-01451)	Oct-12
Power sensor HP 8481A	US37292783	05-Oct-11 (No. 217-01451)	Oct-12
Reference 20 dB Attenuator	SN: 5058 (20k)	27-Mar-12 (No. 217-01530)	Apr-13
Type-N mismatch combination	SN: 5047.2 / 06327	27-Mar-12 (No. 217-01533)	Apr-13
Reference Probe ES3DV3	SN: 3205	30-Dec-11 (No. ES3-3205_Dec11)	Dec-12
DAE4	SN: 601	04-Jul-11 (No. DAE4-601_Jul11)	Jul-12
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Power sensor HP 8461A	MY41092317	18-Oct-02 (in house check Oct-11)	In house check: Oct-13
RF generator R&S SMT-06	100905	04-Aug-99 (in house check Oct-11)	In house check: Oct-13
Network Analyzer HP 8753E	US37390585 S4206	18-Oct-01 (in house check Oct-11)	In house check: Oct-12

Calibrated by:	Name: <b>Israe El-Naouq</b>	Function: <b>Laboratory Technician</b>	Signature:
Approved by:	Name: <b>Katja Pokovic</b>	Function: <b>Technical Manager</b>	Signature:

Issued: May 16, 2012

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

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



**S** Schweizerischer Kalibrierdienst  
**S** Service suisse d'étalonnage  
**C** 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 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003
- 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) Federal Communications Commission Office of Engineering & Technology (FCC OET), "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields; Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions", Supplement C (Edition 01-01) to Bulletin 65

**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	V52.8.1
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	40.6 $\pm$ 6 %	0.89 mho/m $\pm$ 6 %
Head TSL temperature change during test	< 0.5 °C	---	----

### SAR result with Head TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	2.34 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	<b>9.39 mW / g <math>\pm</math> 17.0 % (k=2)</b>

SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	condition	
SAR measured	250 mW input power	1.53 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	<b>6.14 mW / g <math>\pm</math> 16.5 % (k=2)</b>

### 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	54.3 $\pm$ 6 %	1.00 mho/m $\pm$ 6 %
Body TSL temperature change during test	< 0.5 °C	---	----

### SAR result with Body TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	2.40 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	<b>9.35 mW / g <math>\pm</math> 17.0 % (k=2)</b>

SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	condition	
SAR measured	250 mW input power	1.58 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	<b>6.19 mW / g <math>\pm</math> 16.5 % (k=2)</b>

## Appendix

### Antenna Parameters with Head TSL

Impedance, transformed to feed point	49.8 $\Omega$ - 5.5 j $\Omega$
Return Loss	- 25.2 dB

### Antenna Parameters with Body TSL

Impedance, transformed to feed point	45.9 $\Omega$ - 7.3 j $\Omega$
Return Loss	- 21.2 dB

### General Antenna Parameters and Design

Electrical Delay (one direction)	1.381 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	May 19, 2003

**DASY5 Validation Report for Head TSL**

Date: 16.05.2012

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 835 MHz; Type: D835V2; Serial: D835V2 - SN: 490**

Communication System: CW; Frequency: 835 MHz

Medium parameters used:  $f = 835 \text{ MHz}$ ;  $\sigma = 0.89 \text{ mho/m}$ ;  $\epsilon_r = 40.6$ ;  $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(6.07, 6.07, 6.07); Calibrated: 30.12.2011;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 04.07.2011
- Phantom: Flat Phantom 4.9L; Type: QD000P49AA; Serial: 1001
- DASY52 52.8.1(838); SEMCAD X 14.6.5(6469)

**Dipole Calibration for Head Tissue/Pin=250 mW, d=15mm 2/Zoom Scan (7x7x7)/Cube 0:**

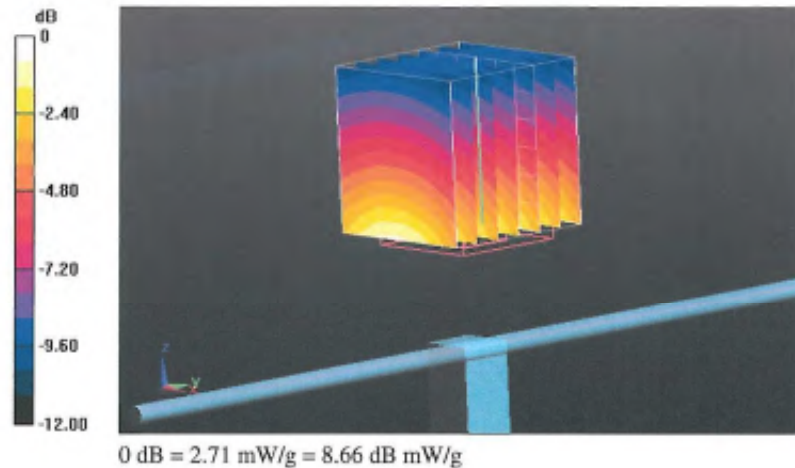
Measurement grid:  $dx=5\text{mm}$ ,  $dy=5\text{mm}$ ,  $dz=5\text{mm}$

Reference Value = 56.851 V/m; Power Drift = 0.00 dB

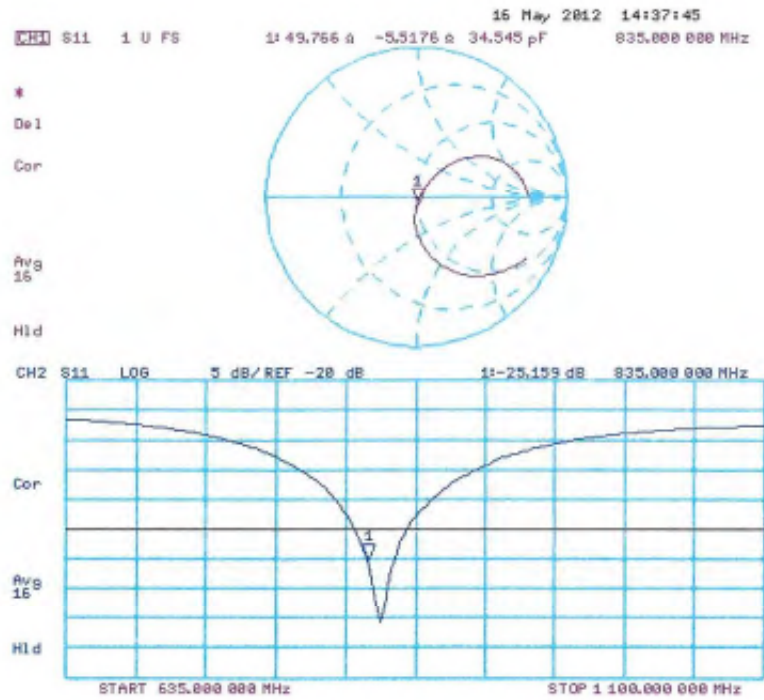
Peak SAR (extrapolated) = 3.449 mW/g

**SAR(1 g) = 2.34 mW/g; SAR(10 g) = 1.53 mW/g**

Maximum value of SAR (measured) = 2.71 mW/g



## Impedance Measurement Plot for Head TSL





**DASY5 Validation Report for Body TSL**

Date: 16.05.2012

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 835 MHz; Type: D835V2; Serial: D835V2 - SN: 490**

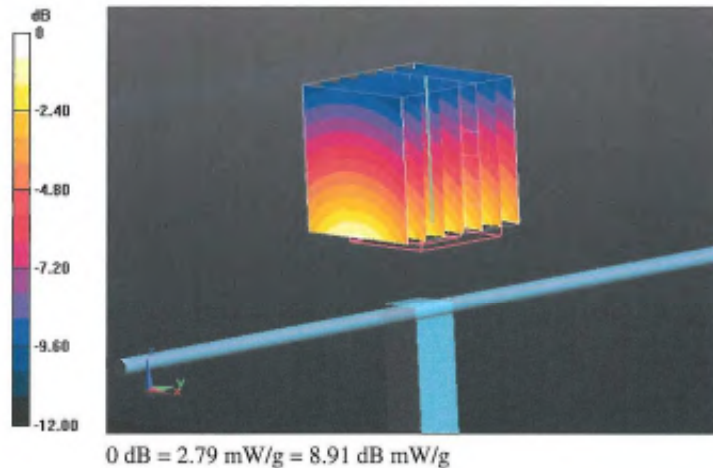
Communication System: CW; Frequency: 835 MHz  
 Medium parameters used:  $f = 835 \text{ MHz}$ ;  $\sigma = 1 \text{ mho/m}$ ;  $\epsilon_r = 54.3$ ;  $\rho = 1000 \text{ kg/m}^3$   
 Phantom section: Flat Section  
 Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

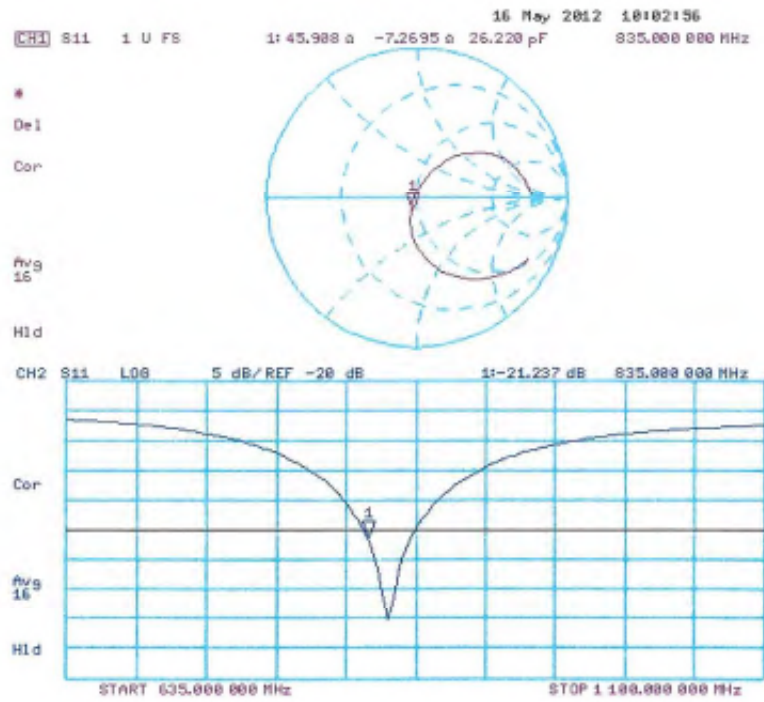
- Probe: ES3DV3 - SN3205; ConvF(6.02, 6.02, 6.02); Calibrated: 30.12.2011;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 04.07.2011
- Phantom: Flat Phantom 4.9L; Type: QD000P49AA; Serial: 1001
- DASY52 52.8.1(838); SEMCAD X 14.6.5(6469)

**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 = 54.760 V/m; Power Drift = -0.00 dB  
 Peak SAR (extrapolated) = 3.479 mW/g  
**SAR(1 g) = 2.4 mW/g; SAR(10 g) = 1.58 mW/g**  
 Maximum value of SAR (measured) = 2.79 mW/g



## Impedance Measurement Plot for Body TSL



## - 1900 MHz Dipole Calibration Certificate

**Calibration Laboratory of  
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Accredited by the Swiss Accreditation Service (SAS)  
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Accreditation No.: **SCS 108**

Client **SGS (Dymstec)**

Certificate No: **D1900V2-5d033\_May12**

CALIBRATION CERTIFICATE			
Object	D1900V2 - SN: 5d033		
Calibration procedure(s)	QA CAL-05.v8 Calibration procedure for dipole validation kits above 700 MHz		
Calibration date:	May 23, 2012		
<p>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.</p> <p>All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity &lt; 70%.</p> <p>Calibration Equipment used (M&amp;TE critical for calibration)</p>			
<b>Primary Standards</b>	<b>ID #</b>	<b>Cal Date (Certificate No.)</b>	<b>Scheduled Calibration</b>
Power meter EPM-442A	GB37480704	05-Oct-11 (No. 217-01451)	Oct-12
Power sensor HP 8481A	US37292783	05-Oct-11 (No. 217-01451)	Oct-12
Reference 20 dB Attenuator	SN: 5068 (20k)	27-Mar-12 (No. 217-01530)	Apr-13
Type-N mismatch combination	SN: 5047.2 / 06327	27-Mar-12 (No. 217-01533)	Apr-13
Reference Probe ES3DV3	SN: 3205	30-Dec-11 (No. ES3-3205_Dec11)	Dec-12
DAE4	SN: 601	04-Jul-11 (No. DAE4-601_Jul11)	Jul-12
<b>Secondary Standards</b>	<b>ID #</b>	<b>Check Date (in house)</b>	<b>Scheduled Check</b>
Power sensor HP 8481A	MY41092317	18-Oct-02 (in house check Oct-11)	In house check: Oct-13
RF generator R&S SMT-06	100005	04-Aug-99 (in house check Oct-11)	In house check: Oct-13
Network Analyzer HP 8753E	US37390585 S4205	18-Oct-01 (in house check Oct-11)	In house check: Oct-12
Calibrated by:	Name Israa El-Naouq	Function Laboratory Technician	Signature 
Approved by:	Katja Pokovic	Technical Manager	
			Issued: May 23, 2012
This calibration certificate shall not be reproduced except in full without written approval of the laboratory.			

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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 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003
- 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) Federal Communications Commission Office of Engineering & Technology (FCC OET), "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields; Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions", Supplement C (Edition 01-01) to Bulletin 65

**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	V52.8.1
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	$\Delta x, \Delta y, \Delta z = 5 \text{ mm}$	
Frequency	1900 MHz $\pm$ 1 MHz	

### Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	40.0	1.40 mho/m
Measured Head TSL parameters	(22.0 $\pm$ 0.2) °C	40.5 $\pm$ 6 %	1.37 mho/m $\pm$ 6 %
Head TSL temperature change during test	< 0.5 °C	---	---

### SAR result with Head TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	9.69 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	<b>39.4 mW / g <math>\pm</math> 17.0 % (k=2)</b>

SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	condition	
SAR measured	250 mW input power	5.13 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	<b>20.7 mW / g <math>\pm</math> 16.5 % (k=2)</b>

### 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	52.9 $\pm$ 6 %	1.52 mho/m $\pm$ 6 %
Body TSL temperature change during test	< 0.5 °C	---	---

### SAR result with Body TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	10.0 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	<b>39.9 mW / g <math>\pm</math> 17.0 % (k=2)</b>

SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	condition	
SAR measured	250 mW input power	5.31 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	<b>21.2 mW / g <math>\pm</math> 16.5 % (k=2)</b>

## Appendix

### Antenna Parameters with Head TSL

Impedance, transformed to feed point	51.8 $\Omega$ + 3.3 j $\Omega$
Return Loss	- 28.6 dB

### Antenna Parameters with Body TSL

Impedance, transformed to feed point	47.5 $\Omega$ + 3.6 j $\Omega$
Return Loss	- 27.0 dB

### General Antenna Parameters and Design

Electrical Delay (one direction)	1.196 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	March 17, 2003

**DASY5 Validation Report for Head TSL**

Date: 23.05.2012

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d033**

Communication System: CW; Frequency: 1900 MHz

Medium parameters used:  $f = 1900$  MHz;  $\sigma = 1.37$  mho/m;  $\epsilon_r = 40.5$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(5.01, 5.01, 5.01); Calibrated: 30.12.2011;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 04.07.2011
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.1(838); SEMCAD X 14.6.5(6469)

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

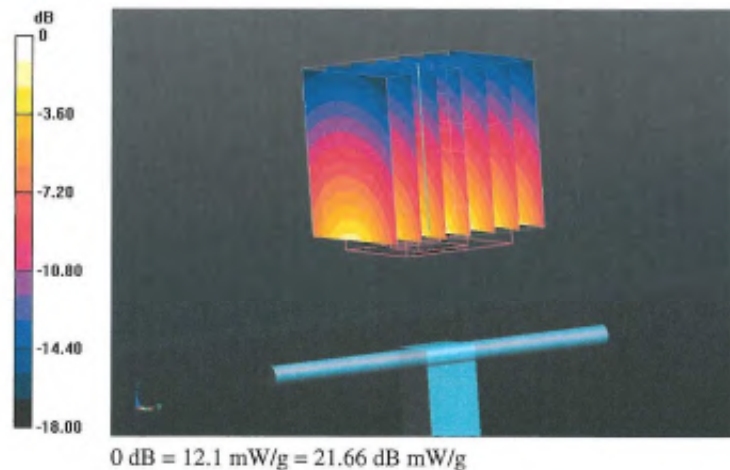
Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 97.469 V/m; Power Drift = 0.01 dB

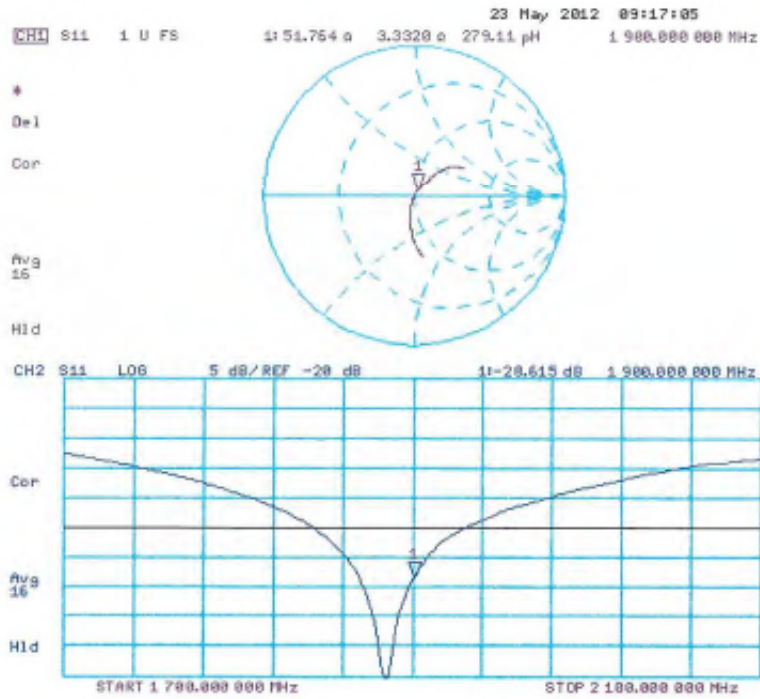
Peak SAR (extrapolated) = 17.118 mW/g

**SAR(1 g) = 9.69 mW/g; SAR(10 g) = 5.13 mW/g**

Maximum value of SAR (measured) = 12.1 mW/g



## Impedance Measurement Plot for Head TSL





**DASY5 Validation Report for Body TSL**

Date: 23.05.2012

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d033**

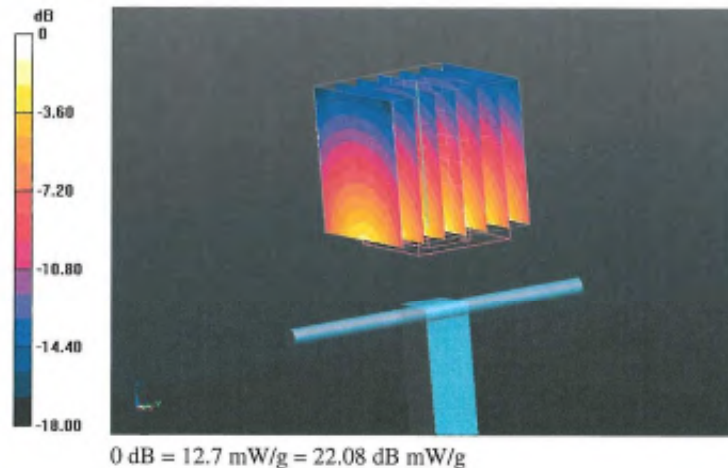
Communication System: CW; Frequency: 1900 MHz  
 Medium parameters used:  $f = 1900 \text{ MHz}$ ;  $\sigma = 1.52 \text{ mho/m}$ ;  $\epsilon_r = 52.9$ ;  $\rho = 1000 \text{ kg/m}^3$   
 Phantom section: Flat Section  
 Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

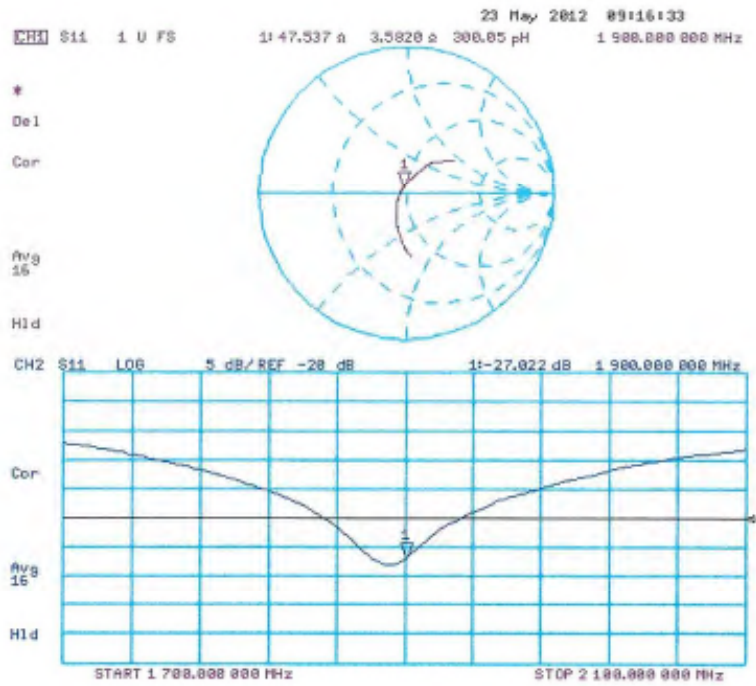
- Probe: ES3DV3 - SN3205; ConvF(4.62, 4.62, 4.62); Calibrated: 30.12.2011;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 04.07.2011
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.1(838); SEMCAD X 14.6.5(6469)

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

Measurement grid:  $dx=5\text{mm}$ ,  $dy=5\text{mm}$ ,  $dz=5\text{mm}$   
 Reference Value = 94.832 V/m; Power Drift = -0.00 dB  
 Peak SAR (extrapolated) = 17.393 mW/g  
**SAR(1 g) = 10 mW/g; SAR(10 g) = 5.31 mW/g**  
 Maximum value of SAR (measured) = 12.7 mW/g



## Impedance Measurement Plot for Body TSL



## - 2450 MHz Dipole Calibration Certificate

**Calibration Laboratory of  
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**C** Service suisse d'étalonnage  
**S** Servizio svizzero di taratura  
**S** Swiss Calibration Service

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

Accreditation No.: **SCS 108**

Client **SGS (Dymstec)**

Certificate No: **D2450V2-734\_May12**

### CALIBRATION CERTIFICATE

Object **D2450V2 - SN: 734**

Calibration procedure(s) **QA CAL-05.v8  
 Calibration procedure for dipole validation kits above 700 MHz**

Calibration date: **May 17, 2012**

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	05-Oct-11 (No. 217-01451)	Oct-12
Power sensor HP B461A	US37292783	05-Oct-11 (No. 217-01451)	Oct-12
Reference 20 dB Attenuator	SN: 5058 (20k)	27-Mar-12 (No. 217-01530)	Apr-13
Type-N mismatch combination	SN: 5047.2 / 06327	27-Mar-12 (No. 217-01533)	Apr-13
Reference Probe ES3DV3	SN: 3205	30-Dec-11 (No. ES3-3205_Dec11)	Dec-12
DAE4	SN: 601	04-Jul-11 (No. DAE4-601_Jul11)	Jul-12
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Power sensor HP B461A	MY41092317	18-Oct-02 (in house check Oct-11)	in house check: Oct-13
RF generator R&S SMT-06	100005	04-Aug-99 (in house check Oct-11)	in house check: Oct-13
Network Analyzer HP 8753E	US37390585 S4206	18-Oct-01 (in house check Oct-11)	in house check: Oct-12

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

**Signature**

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

Issued: May 17, 2012

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**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 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003
- 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) Federal Communications Commission Office of Engineering & Technology (FCC OET), "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields; Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions", Supplement C (Edition 01-01) to Bulletin 65

**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	V52.8.1
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	40.3 $\pm$ 6 %	1.85 mho/m $\pm$ 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

### SAR result with Head TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	13.3 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	<b>52.8 mW / g <math>\pm</math> 17.0 % (k=2)</b>

SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	condition	
SAR measured	250 mW input power	6.19 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	<b>24.7 mW / g <math>\pm</math> 16.5 % (k=2)</b>

### 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	52.3 $\pm$ 6 %	1.99 mho/m $\pm$ 6 %
Body TSL temperature change during test	< 0.5 °C	----	----

### SAR result with Body TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	12.7 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	<b>50.2 mW / g <math>\pm</math> 17.0 % (k=2)</b>

SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	condition	
SAR measured	250 mW input power	5.95 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	<b>23.6 mW / g <math>\pm</math> 16.5 % (k=2)</b>

**Appendix**

**Antenna Parameters with Head TSL**

Impedance, transformed to feed point	53.3 $\Omega$ + 3.6 $j\Omega$
Return Loss	- 26.4 dB

**Antenna Parameters with Body TSL**

Impedance, transformed to feed point	49.9 $\Omega$ + 5.1 $j\Omega$
Return Loss	- 25.8 dB

**General Antenna Parameters and Design**

Electrical Delay (one direction)	1.153 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	May 07, 2003

**DASY5 Validation Report for Head TSL**

Date: 17.05.2012

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 734**

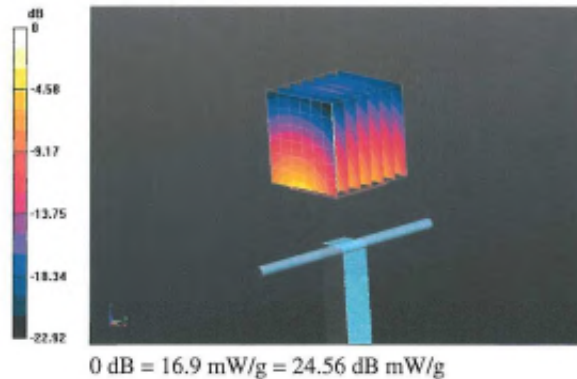
Communication System: CW; Frequency: 2450 MHz  
 Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.85$  mho/m;  $\epsilon_r = 40.3$ ;  $\rho = 1000$  kg/m<sup>3</sup>  
 Phantom section: Flat Section  
 Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

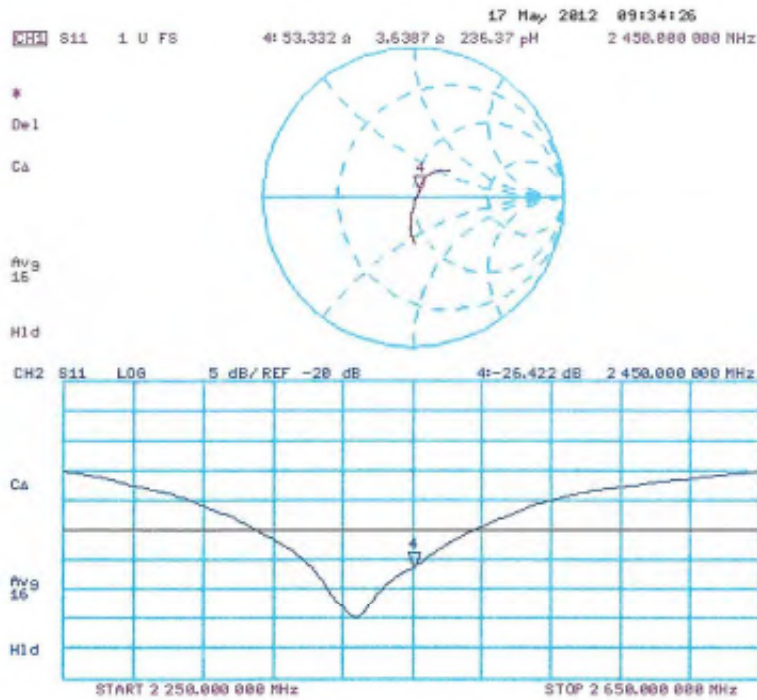
- Probe: ES3DV3 - SN3205; ConvF(4.45, 4.45, 4.45); Calibrated: 30.12.2011;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 04.07.2011
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.1(838); SEMCAD X 14.6.5(6469)

**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 = 97.190 V/m; Power Drift = 0.08 dB  
 Peak SAR (extrapolated) = 27.316 mW/g  
**SAR(1 g) = 13.3 mW/g; SAR(10 g) = 6.19 mW/g**  
 Maximum value of SAR (measured) = 16.9 mW/g



### Impedance Measurement Plot for Head TSL





**DASY5 Validation Report for Body TSL**

Date: 15.05.2012

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 734**

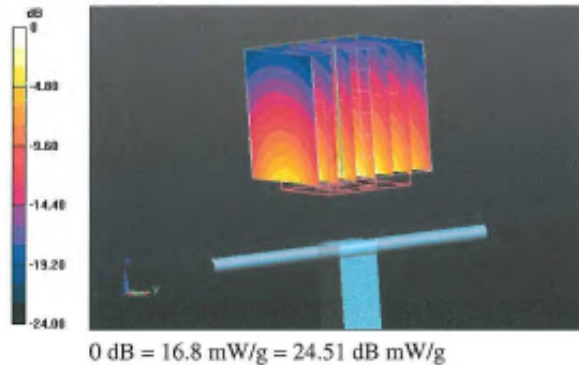
Communication System: CW; Frequency: 2450 MHz  
 Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.99$  mho/m;  $\epsilon_r = 52.3$ ;  $\rho = 1000$  kg/m<sup>3</sup>  
 Phantom section: Flat Section  
 Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

**DASY52 Configuration:**

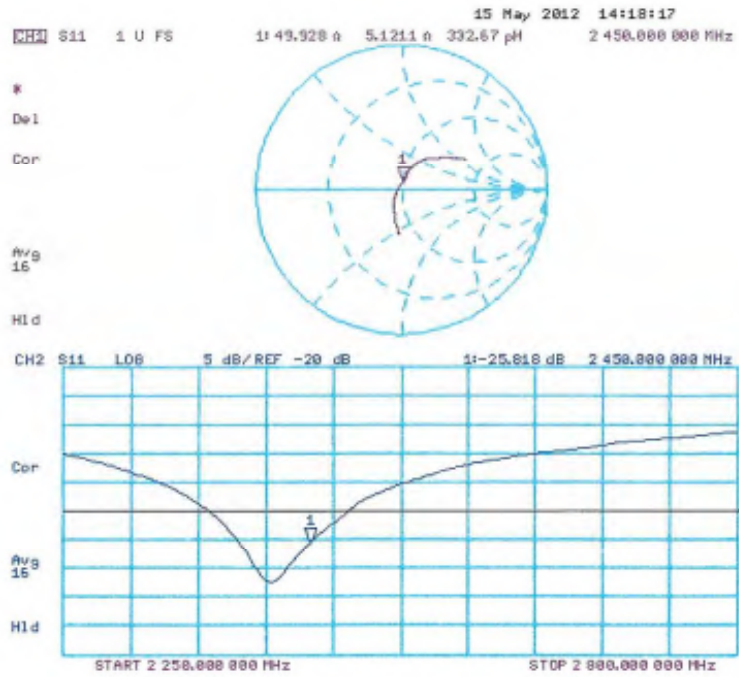
- Probe: ES3DV3 - SN3205; ConvF(4.26, 4.26, 4.26); Calibrated: 30.12.2011;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 04.07.2011
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.1(838); SEMCAD X 14.6.5(6469)

**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 = 95.201 V/m; Power Drift = 0.02 dB  
 Peak SAR (extrapolated) = 25.791 mW/g  
**SAR(1 g) = 12.7 mW/g; SAR(10 g) = 5.95 mW/g**  
 Maximum value of SAR (measured) = 16.8 mW/g



## Impedance Measurement Plot for Body TSL



## Dielectric Assessment Kit DAK-3.5 Calibration Certificate

**Calibration Laboratory of  
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Accreditation No.: **SCS 108**

Client **Dymstec**

Certificate No: **OCP-DAK3.5-1046\_Apr12**

<b>CALIBRATION CERTIFICATE</b>			
Object	DAK-3.5 - SN:1046		
Calibration procedure(s)	QA CAL-27.v7 Calibration of dielectric parameter probes		
Calibration date:	April 3, 2012		
<p>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.</p> <p>All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity &lt; 70%.</p> <p>Calibration Equipment used (M&amp;TE critical for calibration)</p>			
Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
OCP DCF035 (weighted)	SN: 2000	15-Nov-11 (OCP-DCF035-2000_Nov11)	Nov-12
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Network Analyzer HP 8753D	3410A05674	12-Oct-11 (in house check Oct-11)	Oct-12
Digital Thermometer DTM3000	T4233	21-Jul-11 (in house check Jul-11)	Jul-12
Methanol 99.9% Type 34960	SZE9306B	28-Feb-12 (batch opened)	Feb-13
Head Liquid, HSL U12	100705-3	27-Jun-11 (in house check Jun-11)	Jun-12
Muscle Liquid, MSL U12	100511-1	27-Jun-11 (in house check Jun-11)	Jun-12
Calibrated by:	Name Fin Bornholt	Function R&D Director	Signature 
Approved by:	Katja Pokovic	Laboratory Director	
			Issued: April 5, 2012
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Accreditation No.: **SCS 108**

## References

- [1] IEEE Std 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003
- [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", March 2009
- [5] Tables of the Complex Permittivity of Dielectric Reference Liquids at Frequencies up to 5 GHz
- [6] Agilent 85070E Dielectric Probe Kit, Technical Overview, document 5989-0222EN, October 2006
- [7] A. Toropainen et al, "Method for accurate measurement of complex permittivity of tissue equivalent liquids", Electronics Letters 36 (1) 2000 pp32-34
- [8] A. Peyman, C. Gabriel, E.H. Grant, "Complex Permittivity of Sodium Chloride Solutions at Microwave Frequencies", Bioelectromagnetics 28:264-274 (2007)
- [9] G. F. Hewitt, "Tables of the resistivity of aqueous sodium chloride solutions", Harwell, October 1960

## 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 and calculated as follows:  
 (Relative) permittivity  $\epsilon'$  (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/gel 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, Semi-solid / solid, MRI 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 from 20 to 300 MHz are performed in 5 MHz steps, and from 300 to 6000 MHz in 50 MHz steps.
3. Standard calibration with Air / Short / Water (optional: ethanol or provided load). If the short provided appears to have a lower contact quality, the best available short is used for this calibration. The default calibration is selected as follows (except if different calibration is required):
 

DAK and Agilent OCP:	open / short / de-ionised water (approx. 22 °C)
NPL OCP:	open / 4 shorts / pure ethanol (approx. 22 °C)

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 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.
4. Measurement of multiple shorts if not already available from the calibration in the previous step. Evaluation of the deviation (graphic presentation of the complex quantities and magnitude over the frequency range) from the previous calibration short. The specific probe short will be used if provided. This assessment shows the short quality and ability to define a short circuit at the end of the probe for the VNA calibration in the setup, which is usually most critical to obtain and influencing the results deducted from the  $S_{11}$  measurement.
5. Measurement of validation liquids Pure polar liquids are used: methanol, ethanol, water (if not used for the previous calibration). 0.5 liter quantities are measured to reduce the influence of reflections. Evaluation of the deviations from the target. The targets base on traceable data which have been determined for the specific measured temperature. These values have also been verified with precision methods. The deviation of the measurement is graphically presented for permittivity and conductivity or loss tangent (depending on the frequency range, due to the low losses at low frequencies). The validation with pure liquids of this type is possible at any time, due to the low loss parameters in comparison with lossy liquids, it is suited to give information on the calibration quality. A direct conclusion on the measurement accuracy for lossy materials is not necessarily possible due to the different  $S_{11}$  parameter range at the specific frequency.
6. SAR calibration: Measurement of lossy liquids (Head tissue and Muscle tissue simulating liquid). 0.5 liter quantities are measured to reduce the influence of reflections. Evaluation of the deviation from the target. The targets base on multiple measurements with precision reference probes or different evaluations such as transmission line or slotted line methods. Although the dielectric values are not precisely matching the target values of the SAR standards at all frequencies, they are close enough to give a direct indication on the measurement accuracy when measuring exact target values.
7. Semi-solid / solid material calibration: Measurements of lossy broadband semi-solid gel with parameters close to the head tissue target. Evaluation of the average deviation from the target. The targets base on multiple measurements (on the same material batch at identical temperature) on convex and planar surfaces with precision reference OCP. Although the dielectric values are not precisely matching the target values of the SAR standards, they are close enough to give a direct indication on the measurement accuracy for this parameter range on semi-solid and elastic homogeneous and isotropic material. Measurements of a low loss block of microwave substrate with planar surfaces (relative permittivity

- approx. 13). The target bases on multiple measurements with precision reference probes or other methods. Due to the low losses, the loss tangent is evaluated instead of the conductivity. 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. Lower parameters may result.
8. MRI material calibration: Measurement of 0.1 mol/L NaCl / water solution (typical conductivity 0.96 S/m) at 64 MHz. Evaluation of the deviation from the target. The targets base on numerically available values for specific temperature and multiple measurements with precision reference probes or different evaluations such as transmission line or slotted line methods.  
Measurement of LCM (low conductivity fat tissue simulating medium with typical relative permittivity 12, conductivity 0.04 S/m at 64 MHz). Evaluation of the deviation from the target. The targets have been evaluated from multiple measurements with precision reference probes.
  9. Representation of the uncertainty: Together with the above deviations in the graphical representation over the frequency range in Appendix A, the worst case uncertainty (k=2) of our best reference OCP measurement capability to 6 GHz is shown (7 mm precision OCP). This represents the capability of the setup and the lossy materials used, including the precision of the measured material and the influence of temperature deviations. The uncertainty of the measurement depends on the  $S_{11}$  measured which varies with multiple parameters: the probe size, the frequency and the liquid dielectric parameters. The uncertainty for a smaller probe under test is higher and may also depend on the software used, and its settings. Temperature and operator influence was minimized.
  10. Summary assessment of the measured deviations and detailed comments.

#### 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	1046
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 1.4.201.11 Calibration Type: Air / short / water (set to measured water temp.) Probe type: "DAK3.5" (software setting)
Further settings	VNA bandwidth setting: 30 Hz

##### Accessories

Cable	Huber & Suhner Sucoflex 404, SN: 1695, length 1 m, PC3.5 neg. – PC3.5 neg.
Short	DAK-3.5 shorting block, type SM DAK 200 A Contact area covered with cleaned Cu stripe

##### Additional items used during measurements

Adapter 1	PC3.5 pos. – PC7 (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

### Calibration Results

The following tables provide material-specific uncertainties for the calibrated dielectric probe

Frequency Range (MHz)	Material	P = relative permittivity within deviation for frequency range C = conductivity within deviation for frequency range					
		Deviation < 2.5 %		Deviation < 5 %		Deviation < 10 %	
200 - 400	Methanol	P	C	P	C	P	C
400 - 1000	Methanol	P	C	P	C	P	C
1000 - 2500	Methanol	P	C	P	C	P	C
2500 - 4000	Methanol	P	C	P	C	P	C
4000 - 6000	Methanol	P	C	P	C	P	C

Frequency Range (MHz)	Material	P = relative permittivity within deviation for frequency range C = conductivity within deviation for frequency range					
		Deviation < 2.5 %		Deviation < 5 %		Deviation < 10 %	
200 - 400	HSL	P	---	P	C	P	C
400 - 1000	HSL	P	---	P	C	P	C
1000 - 2500	HSL	P	(C)	P	C	P	C
2500 - 4000	HSL	P	(C)	P	C	P	C
4000 - 6000	HSL	P	C	P	C	P	C

Frequency Range (MHz)	Material	P = relative permittivity within deviation for frequency range C = conductivity within deviation for frequency range					
		Deviation < 2.5 %		Deviation < 5 %		Deviation < 10 %	
200 - 400	MSL	P	---	P	C	P	C
400 - 1000	MSL	P	---	P	C	P	C
1000 - 2500	MSL	P	(C)	P	C	P	C
2500 - 4000	MSL	P	C	P	C	P	C
4000 - 6000	MSL	P	C	P	C	P	C

### Interpretation

P: Permittivity deviation within the tolerance range

C: Conductivity deviation within the tolerance range

(P), (C): Averaged value is within, single measurements may partially exceed the tolerance range

## Appendix A: Detailed Results

### A.1 Probe appearance and calibration sequence

#### A.1.1 Appearance

The OCP appearance is fully according to the expectations:

#### 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

- Air
- Short 1 short, then immediate verification with a second short
- Water De-ionized water, temperature measured and set in the software
- Methanol Pure methanol, temperature measured and set in the software
- Liquids Measurement of further liquids (e.g. Muscle and Head simulating tissue)
- Cleaning Probe washed with water and ethanol at the end of the sequence.
- Shorts 4 additional separate short measurements to determine the deviation from the original

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, conductivity and loss tangent 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.

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### 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 at the end of 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.

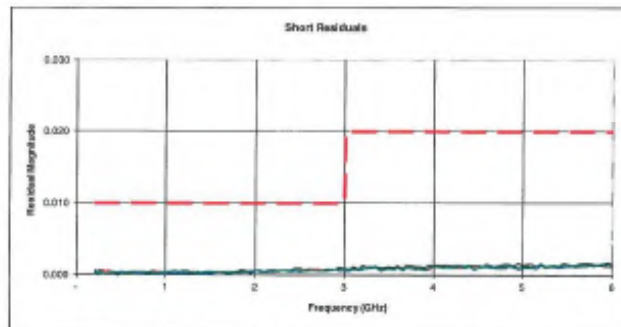


Fig. 2.1a Magnitude of the residual of the shorts, 200 MHz – 6 GHz, after calibration a)

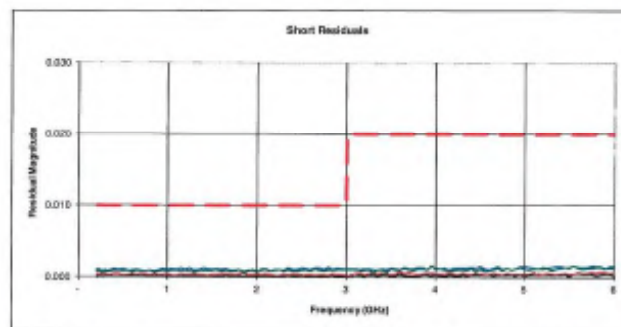


Fig. 2.1b Magnitude of the residual of the shorts, 200 MHz – 6 GHz, after calibration b)

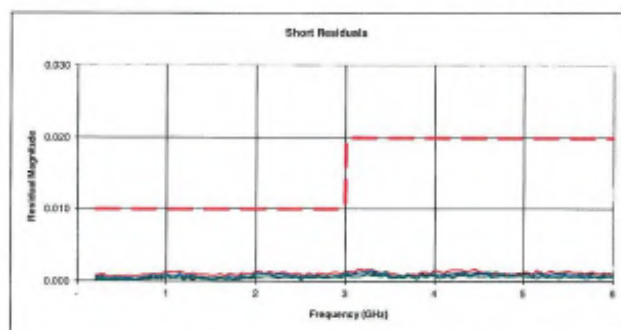


Fig. 2.1c Magnitude of the residual of the shorts, 200 MHz – 6 GHz, after calibration c)

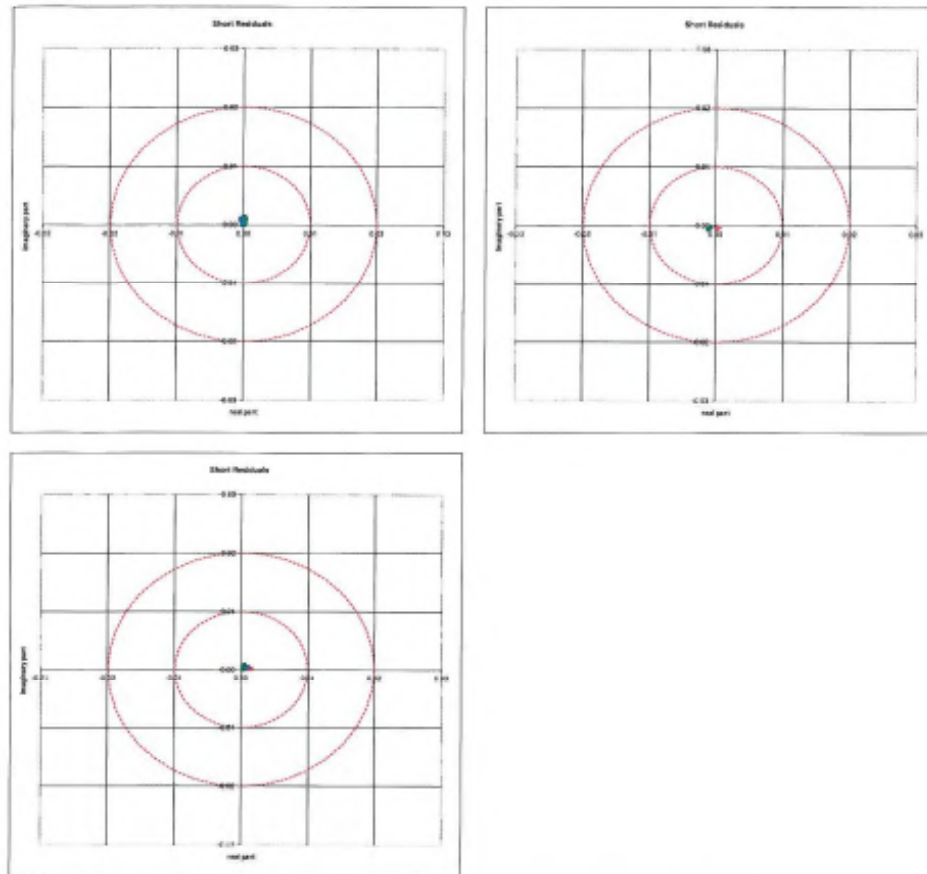


Fig. 2.2a-c Complex representation of the residuals of the shorts, 200 MHz - 6 GHz, after calibrations a)-b) in the top and c) in the bottom

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 and measured with an accuracy of 0.1 °C. Deviations are presented relative to the nominal material parameters at this temperature, calculated from NPL data for this temperature.

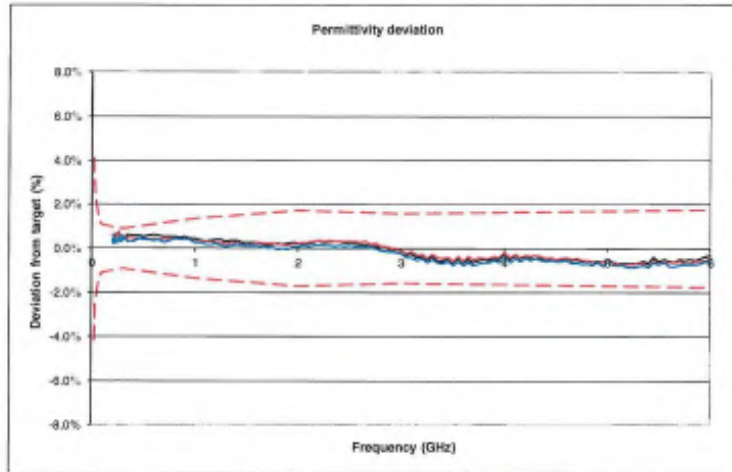


Fig. 3.1 Methanol permittivity deviation from target, 200 MHz – 6 GHz

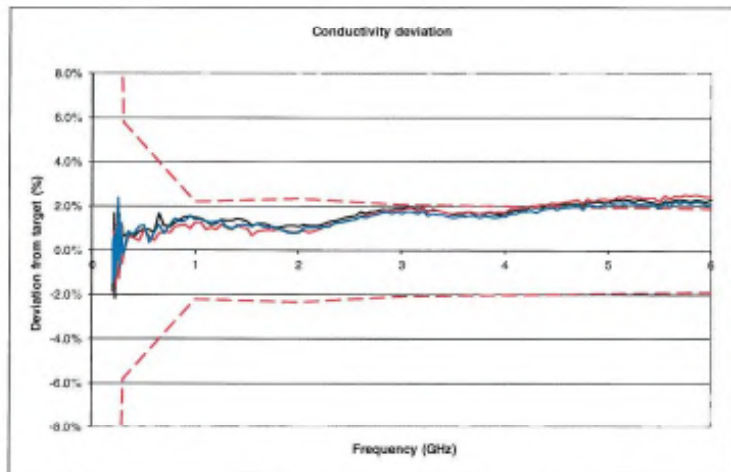


Fig. 3.2 Methanol conductivity deviation from target, 200 MHz – 6 GHz

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

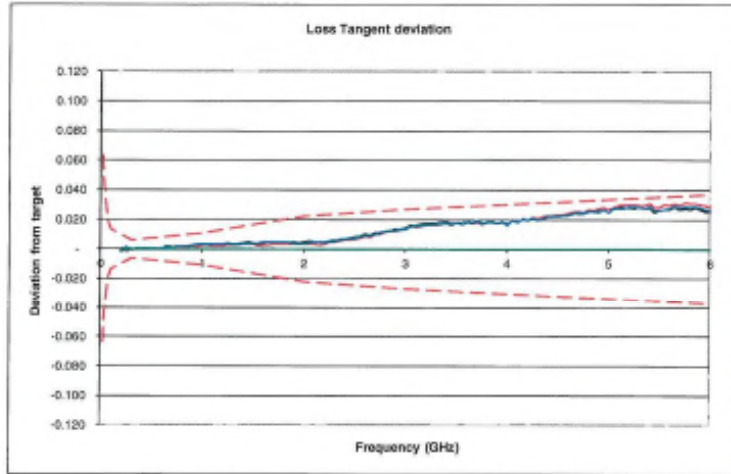


Fig. 3.3 Methanol loss tangent deviation from target, 200 MHz – 6 GHz

#### A.4 Head Tissue

Broadband head simulating liquid was measured at a temperature of 22 +/- 2 °C. The liquid temperature was stabilized and measured with an accuracy of 0.1 °C on a new sample. Deviations are presented relative to the reference data for this material. Those parameters have been evaluated from multiple measurements with a precision 7mm OCP and further methods.

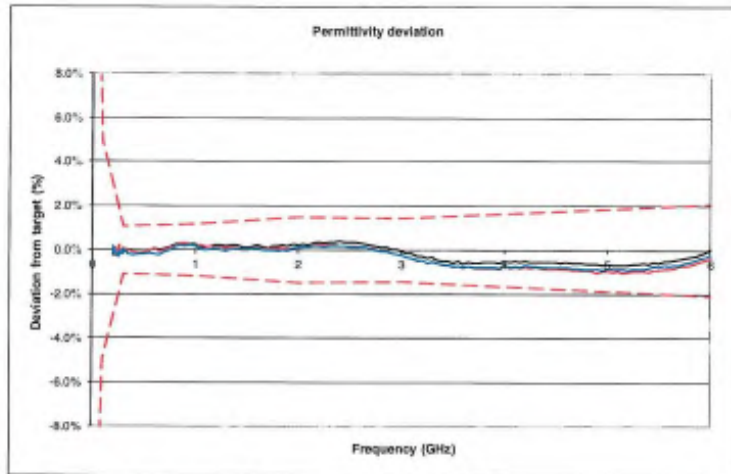


Fig. 4.1 HSL permittivity deviation from target, 200 MHz – 6 GHz

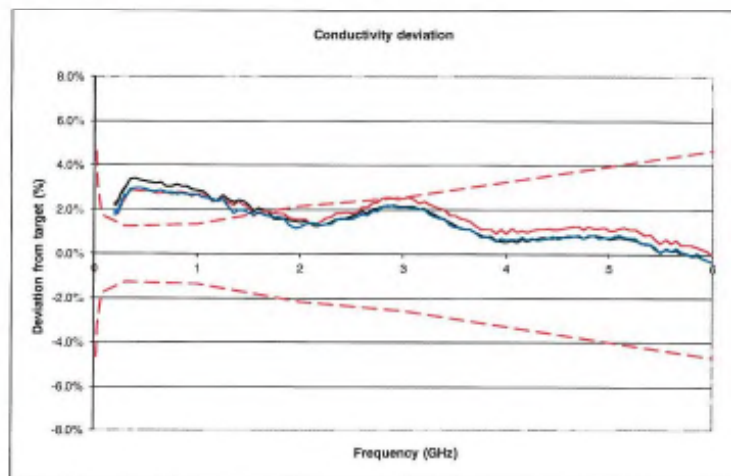


Fig. 4.2 HSL conductivity deviation from target, 200 MHz – 6 GHz

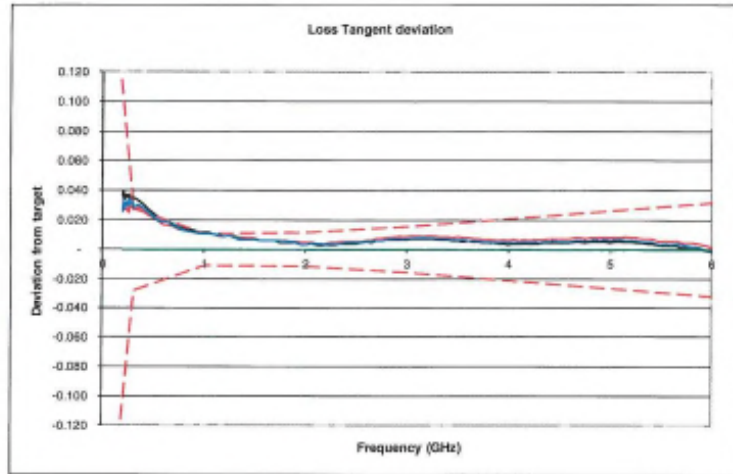


Fig. 4.3 HSL loss tangent deviation from target, 200 MHz – 6 GHz

**A.5 Muscle Tissue**

Broadband muscle simulating liquid was measured at a temperature of 22 +/- 2 °C. The liquid temperature was stabilized and measured with an accuracy of 0.1 °C on a new sample. Deviations are presented relative to the reference data for this material. Those parameters have been evaluated from multiple measurements with a precision 7mm OCP and further methods.

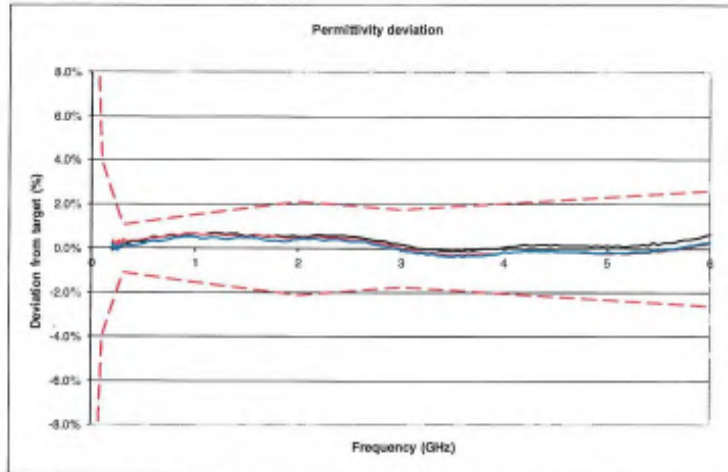


Fig. 5.1 MSL permittivity deviation from target, 200 MHz – 6 GHz

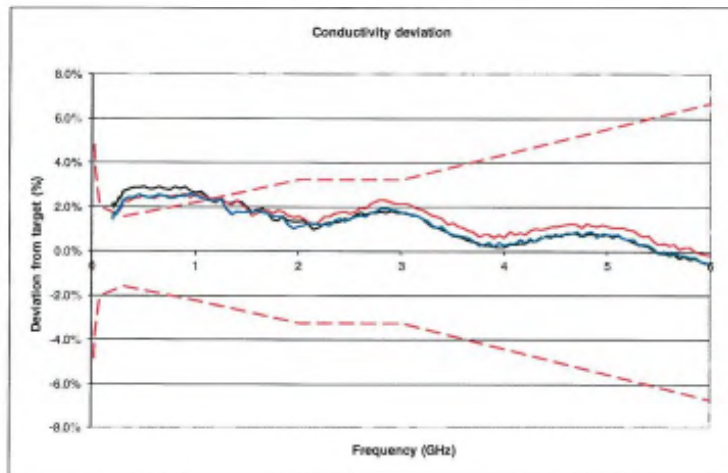


Fig. 5.2 MSL conductivity deviation from target, 200 MHz – 6 GHz

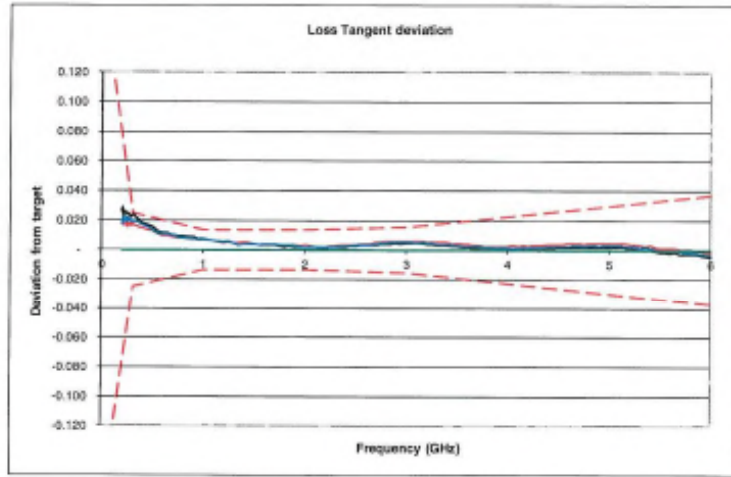


Fig. 5.3 MSL loss tangent deviation from target, 200 MHz – 6 GHz



## A.6 Uncertainty

The above quantities have been shown in the figures together with the uncertainties ( $k=2$ ) as dashed lines. These lines represent the measurement capability for a 7mm flanged OCP, including uncertainties from reference probe, its calibration, material reference data and temperature differences during the measurements. Each material is represented with the uncertainty characteristic to it. Therefore the shown limits vary with the parameters of the measured medium. The following table gives a summarized worst case overview for classes of materials.

Quantity	Frequency range	Expanded unc.	Remarks
Permittivity	300 MHz ... 6 GHz	3,0 %	Liquids
	20 MHz	4,5 %	Polar liquids, e.g. Ethanol, Methanol, Ethanediol
	30 MHz ... 6 GHz	3,2 %	
	65 MHz ... 6 GHz	3,6 %	Planar low loss substrate
	100 MHz	5,0 %	Tissue simulating liquids
Conductivity	20 MHz	4,8 %	Head and Body tissue simulating liquids
	30 MHz ... 3 GHz	3,7 %	
	3 GHz ... 6 GHz	6,7 %	
	20 MHz ... 1 GHz	7,4 %	Aqueous NaCl solutions with $\epsilon'' < 1000$
	1 GHz ... 6 GHz	2,3 %	Moderate Loss polar liquids, e.g. Ethanol, Methanol, Ethanediol
Loss Tangent	1 GHz ... 6 GHz	8,7 %	Liquids
	20 MHz ... 65 MHz	0.07	Polar liquids
	65 MHz ... 300 MHz	0.02	
	300 MHz ... 1 GHz	0.05	Liquids
	300 MHz ... 6 GHz	0.015	Planar low loss substrate, e.g. permittivity = 10

Table 6.1 Uncertainty for evaluation with 7mm OCP

For low loss media, the conductivity deviation at low frequencies is subject to a large uncertainty. In such cases, the loss tangent deviation may give a better indication on the performance of a probe.

Note: OCP with smaller diameter of the surface dielectric will have higher uncertainty. The uncertainty in practical use may change also with the operator (quality of the calibrations, temperature and homogeneity of the materials used).

**Appendix B: Nominal parameters of reference materials used for calibration**

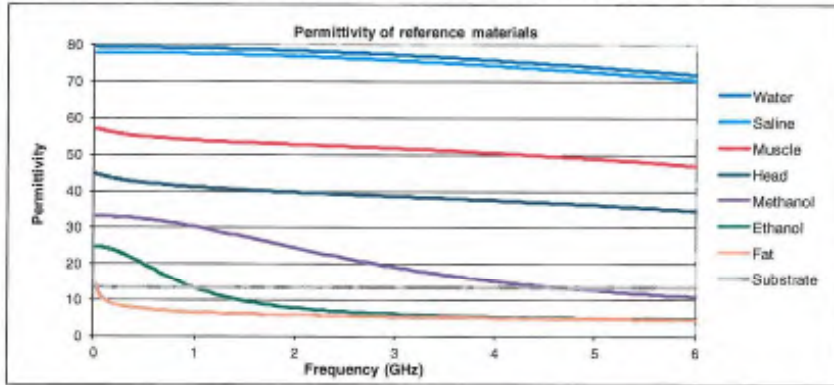


Fig. B.1 Permittivity of reference materials

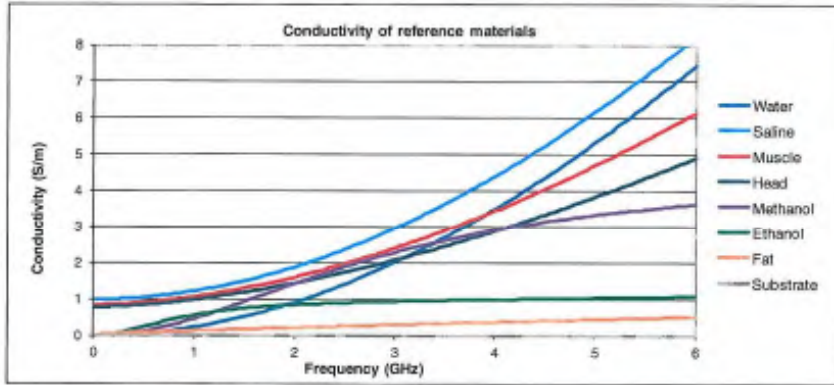


Fig. B.2 Conductivity of reference materials

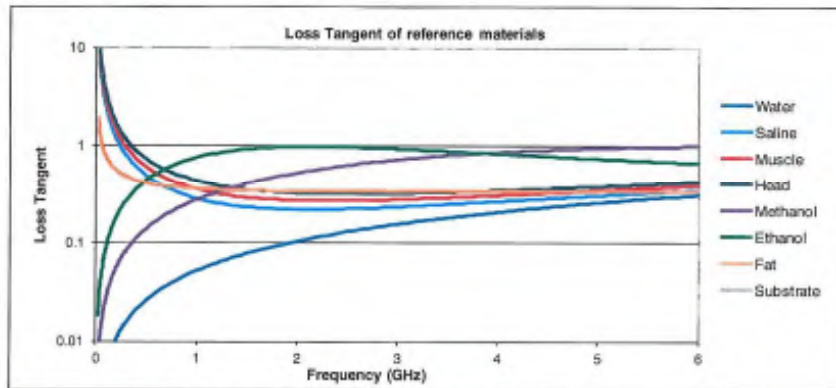


Fig. B.3 Loss tangent of reference materials

**-THE END-**