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# SAR Test Report: T300 (PY71130601)

**Date of test:** May 22 and 23, 2002

**Laboratory:** Electromagnetic Near Field and Radio Frequency Dosimetry Lab
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**Statement of Compliance**

Sonyericsson Mobile Communications AB declares under its sole responsibility that the product

***Sonyericsson Type 1130601-BV (T300); FCC ID: PY71130601***

to which this declaration relates, is in conformity with the appropriate RF exposure standards recommendations and guidelines. It also declares that the product was tested in accordance with the appropriate measurement standards, guidelines and recommended practices. Any deviations from these standards, guidelines and recommended practices are noted below:

(None)

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This test report shall not be reproduced except in full, without written approval of the laboratory.

The results and statements contained herein relate only to the items tested. The names of individuals involved may be mentioned only in connection with the statements or results from this report.

Sonyericsson encourages all feedback, both positive and negative, on this report.

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# 2 Introduction

In this test report, compliance of the Sonyericsson T300 portable telephone with RF safety guidelines is demonstrated. The applicable RF safety guidelines and the SAR measurement specifications used for the test are described in the *SAR Measurement Specifications of Wireless Handsets* [1].

# 3 Device Under Test

## 3.1 Antenna Description

| | | |
|---|---|---|
| ***Type*** | Internal antenna | |
| ***Location*** | Inside the back cover, near the top | |
| ***Dimensions*** | Max length | 38mm |
| | Max width | 17mm |
| ***Configuration*** | PIFA | |

## 3.2 Device description

| | |
|---|---|
| ***Device model*** | T300 |
| ***Serial number*** | A6101TQA85 |
| ***Mode*** | GSM 1900 |
| ***Multiple Access Scheme*** | TDMA |
| ***Maximum Output Power Setting*** | 30.0dBm |
| ***Factory Tolerance in Power Setting*** | ± 0.5dB |
| ***Maximum Peak Output Power*** | 30.5dBm |
| ***Crest Factor*** | 8 |
| ***Transmitting Frequency Range*** | 1850 – 1910 MHz |
| ***Prototype or Production Unit*** | Prototype |
| ***Device Category*** | Portable |
| ***RF exposure environment*** | General population / uncontrolled |

# 4 Test equipment

## 4.1 Dosimetric system

SAR measurements were made using the DASY3 professional system (software version 3.1c) with SAM twin phantom, manufactured by Schmid & Partner Engineering AG (SPEAG). The list of calibrated equipment is given below.

| ***Description*** | ***Serial Number*** | ***Due Date*** |
|---|---|---|
| DASY3 DAE V1 | 428 | 4/2003 |
| E-field probe ETDV6 | 1596 | 4/2003 |
| Dipole Validation Kit, D1900 V2 | 5d002 | 2/2004 |

## 4.2 Additional equipment

| ***Description*** | ***Inventory Number*** | ***Due Date*** |
|---|---|---|
| Signal generator ESG-D4000A | INV 462935 | 9/2003 |
| Directional coupler HP778D | INV 2903 | 1/2003 |
| Power meter R&S NRVD | INV 483920 | 1/2004 |
| Power sensor R&S NRV-Z5 | INV 2333 | 1/2004 |
| Power sensor R&S NRV-Z5 | INV 2334 | 1/2004 |
| Termination 65N50-0-11 | INV 2903 | 1/2003 |
| Network analyzer HP8753C | INV421671 | 8/2002 |
| S-parameter test set HP85047A | INV 421670 | 8/2002 |
| Dielectric probe kit HP8507D | INV 20000053 | 2/2004 |
| Wavetek STABILOK 4031D | INV 421578 | 7/2002 |

# 5 Electrical parameters on the tissue simulating liquid

Prior to conducting SAR measurements, the relative permittivity, $\varepsilon_r$, and the conductivity, $\sigma$, of the tissue simulating liquids were measured with the dielectric probe kit. These values are shown in the table below. The mass density, $\rho$, entered into the DASY3 software is also given. Recommended limits for permittivity $\varepsilon_r$, conductivity $\sigma$ and mass density $\rho$ are also shown.

| **f (MHz)** | **Tissue type** | **Limits / Measured** | **Dielectric Parameters** | | |
|---|---|---|---|---|---|
| | | | $\varepsilon_r$ | $\sigma$ (S/m) | $\rho$ (g/cm³) |
| **1900** | **Head** | **Measured, 05/22/02** | 37.8 | 1.45 | 1.0 |
| | | **Recommended** | 40.0 | 1.4 | 1.0 |
| | **Muscle** | **Measured, 05/23/02** | 50.1 | 1.51 | 1.0 |
| | | **Recommended** | 53.3 | 1.52 | 1.0 |

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# 6 System accuracy verification

A system accuracy verification of the DASY3 was performed using the dipole validation kit listed in section 3.1. The system verification test was conducted on the same day as the measurement of the DUT. Measurement made in ambient temperature 23.4 °C and humanity 40.6%. The obtained results are displayed in the table below.

RF noise had been measured in liquid when all RF equipment in lab was set off. Measured value was 0.00 mW/g in 1g mass.

| f (MHz) | Tissue type | Measured / Reference | SAR (W/kg) 1g mass | Dielectric Parameters | | | t (°C) |
|---|---|---|---|---|---|---|---|
| | | | | e | s (S/m) | ? (g/cm³) | |
| 1900 | Head | Measured, 05/22/02 | 43.6 | 37.8 | 1.45 | 1.0 | 23.4 |
| | | Reference | 45.2 | 39.1 | 1.47 | 1.0 | ?? |
| | Muscle | Measured, 05/23/02 | 43.6 | 50.1 | 1.51 | 1.0 | 22.9 |
| | | Reference | 44.0 | 51.9 | 1.58 | 1.0 | ?? |

# 7 SAR measurement uncertainty

*SAR measurement uncertainty evaluation for Sonyericsson T300 phone*

| Uncertainty Component | Tol. (± %) | Prob. Dist. | Div. | Measurement on Head | Measurement on Body |
|---|---|---|---|---|---|
| **Measurement System** | | | | | |
| Probe Calibration | 2.6 | N | 1 | 2.6 | 2.6 |
| Axial Isotropy | 4.7 | R | √3 | 1.9 | 1.9 |
| Hemispherical Isotropy | 9.6 | R | √3 | 3.9 | 3.9 |
| Boundary Effect | 11.0 | R | √3 | 6.4 | 6.4 |
| Linearity | 4.7 | R | √3 | 2.7 | 2.7 |
| System Detection Limits | 1.0 | R | √3 | 0.6 | 0.6 |
| Readout Electronics | 1.0 | N | 1 | 1.0 | 1.0 |
| Response Time | 0.8 | R | √3 | 0.5 | 0.5 |
| Integration Time | 1.8 | R | √3 | 1.1 | 1.1 |
| RF Ambient Conditions | 3.0 | R | √3 | 1.7 | 1.7 |
| Probe Positioned Mechanical Tolerance | 0.4 | R | √3 | 0.2 | 0.2 |
| Probe Positioning respect to Phantom Shell | 2.9 | R | √3 | 1.7 | 1.7 |
| Extrapolation, interpolation and Integration Algorithm for Max. SAR | 3.9 | R | √3 | 2.3 | 2.3 |
| *Measurement System Uncertainty* | | | | **9.4** | **9.4** |
| **Test Sample Related** | | | | | |
| Test Sample Positioning | | R | √3 | 6.7 | 6.7 |
| Device Holder Uncertainty | | R | √3 | 5.9 | 5.9 |
| Output Power Variation - Drift | 1.6 | R | √3 | 0.9 | 0.9 |
| *Test Sample Related Uncertainty* | | | | **9.0** | **9.0** |
| **Phantom and Tissue Parameters** | | | | | |
| Phantom Uncertainty(shape and thickness tolerances) | 4.0 | R | √3 | 2.3 | 2.3 |
| Liquid Conductivity-deviation from target values) | 3.6/0.7 | R | √3 | 2.1 | 0.4 |
| Liquid Conductivity-measurement uncertainty | 5 | R | √3 | 2.9 | 2.9 |
| Liquid Permitivity-deviation from target values | 5.5/6.0 | R | √3 | 3.2 | 3.5 |
| Liquid Permitivity-measurement uncertainty | 5 | R | √3 | 2.9 | 2.9 |
| *Phantom and Tissue Parameters Uncertainty* | | | | **6.1** | **5.9** |
| ***Combined Standard Uncertainty*** | | RSS | | ***14.4*** | ***14.3*** |
| ***Expanded Uncertainty*** (95% CONFIDENCE LEVEL) | | | | ***28.8*** | ***28.6*** |

# 8 Test results

The measured 1-gram averaged SAR values of the device against the head and the body are provided in Tables 1 and 2 respectively. The humidity and ambient temperature of test facility were 44.2% - 40.5% and 22.7 °C – 24.5 °C respectively. The depth of the head tissue simulating liquid was 15.1cm and of the muscle tissue simulating liquid was 15.5cm. A base station simulator was used to control the device during the SAR measurement. The phone was supplied with full-charged battery for each measurement.

For head measurement, the device was tested on the right-hand phantom (corresponding to the right side of the head) and the left-hand phantom in two phone position, cheek (touch) and tilt (cheek + 15deg). For GSM 1900 modes, the device was tested at the lowest, middle and highest frequencies in the transmit band.

| Mode | f (MHz) | Peak Output Power(dBm) | Phone Position | Liquid temp(°C) | SAR (W/kg) in 1g mass | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Right-hand | | Left-hand | |
| | | | | | Measured | Calculated | Measured | Calculated |
| 1900 GSM | 1850 | 29.3 | **Cheek** | 22.5/22.9 | 0.31 | **0.41** | 0.29 | 0.38 |
| | | | **Tilt** | 22.8/23.1 | 0.32 | 0.42 | 0.31 | 0.41 |
| | 1880 | 29.5 | **Cheek** | 22.6/22.9 | 0.27 | 0.34 | 0.25 | 0.32 |
| | | | **Tilt** | 22.8/23.1 | 0.29 | 0.37 | 0.28 | 0.35 |
| | 1910 | 29.6 | **Cheek** | 22.7/23.0 | 0.28 | 0.34 | 0.26 | 0.32 |
| | | | **Tilt** | 22.7/23.0 | 0.35 | **0.43** | 0.32 | 0.39 |

**Table1: SAR measurement result for Sonyericsson T300 telephone at highest possible output power. Measured against the head.**

For body-worn measurements, the device was tested against flat phantom representing the user body. Under measurement phone was put on in the belt holder ICT-14 and measurement provides for both front and back part the phone to the phantom.

| Mode | f (MHz) | Peak Output Power(dBm) | Phone Position | Liquid temp(°C) | SAR(W/kg) in 1g mass | |
|---|---|---|---|---|---|---|
| | | | | | Measured | Calculated |
| 1900 GSM | 1850 | 29.3 | **Back** | 22.2 | 0.28 | 0.37 |
| | | | **Front** | 22.4 | 0.1 | 0.13 |
| | 1880 | 29.5 | **Back** | 22.3 | 0.23 | 0.29 |
| | | | **Front** | 22.4 | 0.11 | 0.14 |
| | 1910 | 29.6 | **Back** | 22.3 | 0.16 | 0.2 |
| | | | **Front** | 22.5 | 0.05 | 0.06 |

**Table 2: SAR measurement result for Sonyericsson T300 telephone at highest possible output power. Measured against the body.**

# 9 References

[ 1 ] M.Douglas, “SAR Measurement Specification of Wireless Handsets”, Sonyericsson internal document EUS/CV/R-01:1061/REP

[ 2 ] FCC, “Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields: Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radio Frequency Emissions,” Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01).

[ 3 ] IEEE, “Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wirelles Communications Devices: Experimental Techniques,” Std 1528-200x, Draft 6.5 – August 20, 2001.

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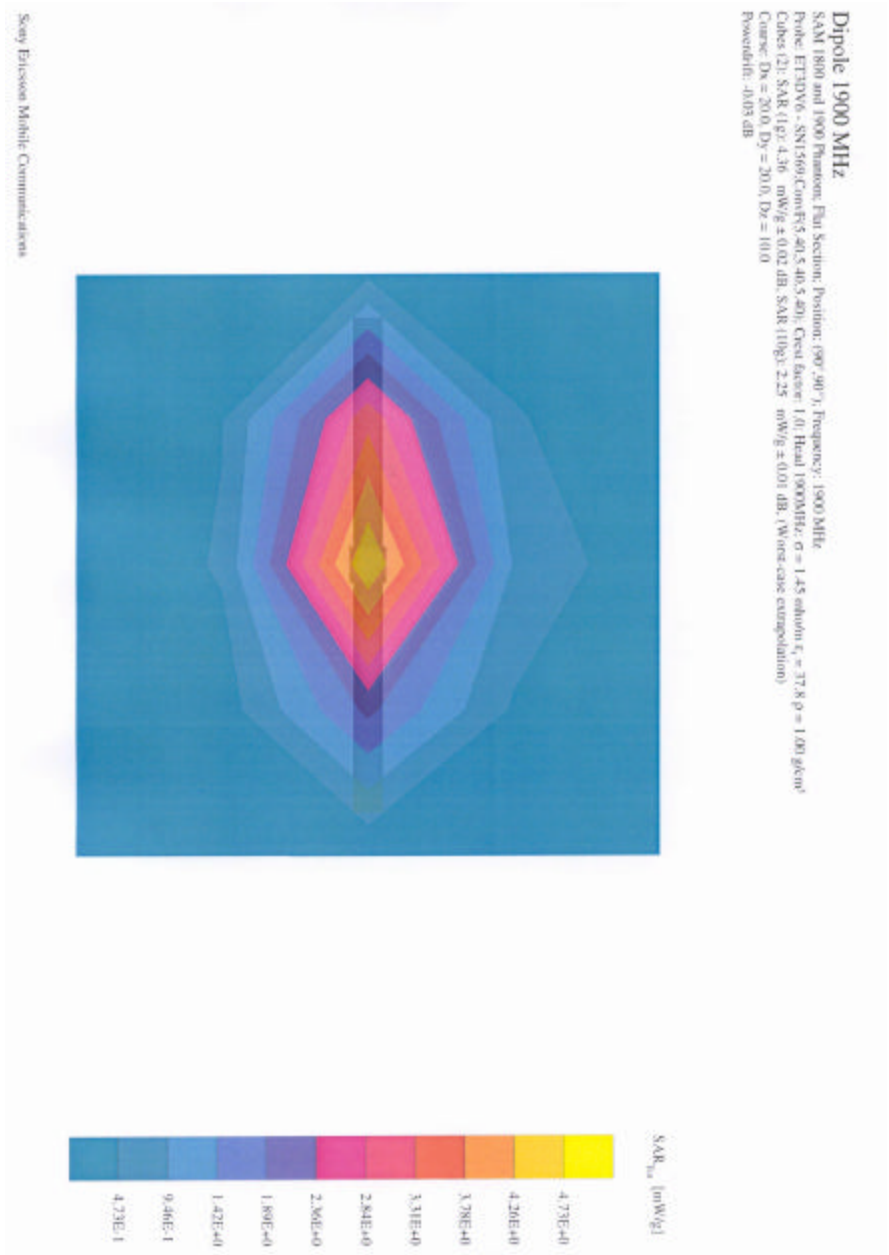
# 10 Appendix

## 10.1 SAR distribution comparison for system accuracy verification




**Validation Dipole , measured with head simulating tissue on 05/22/02**

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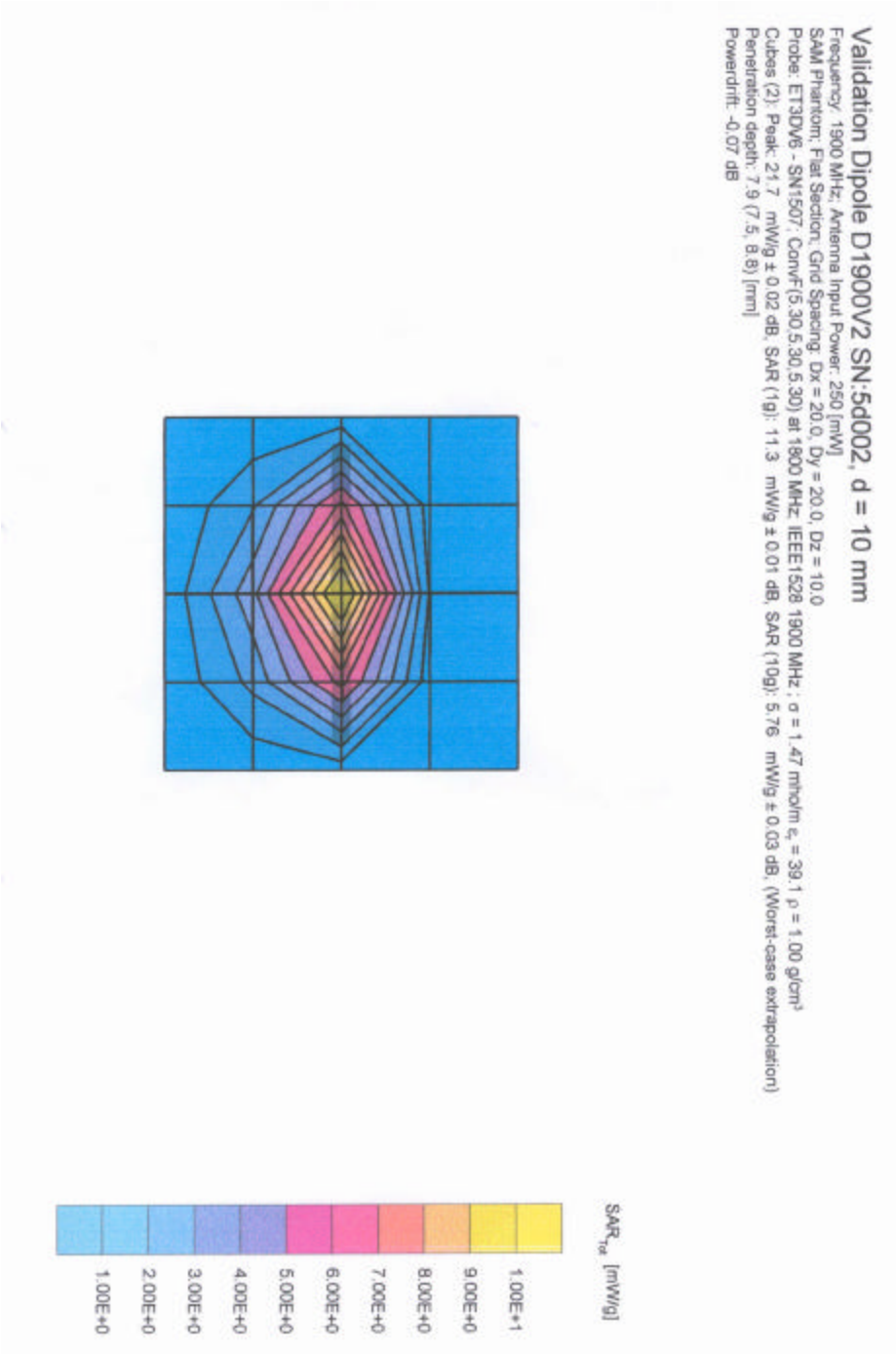


**1900MHz SAR distribution of validation dipole from reference measurement**

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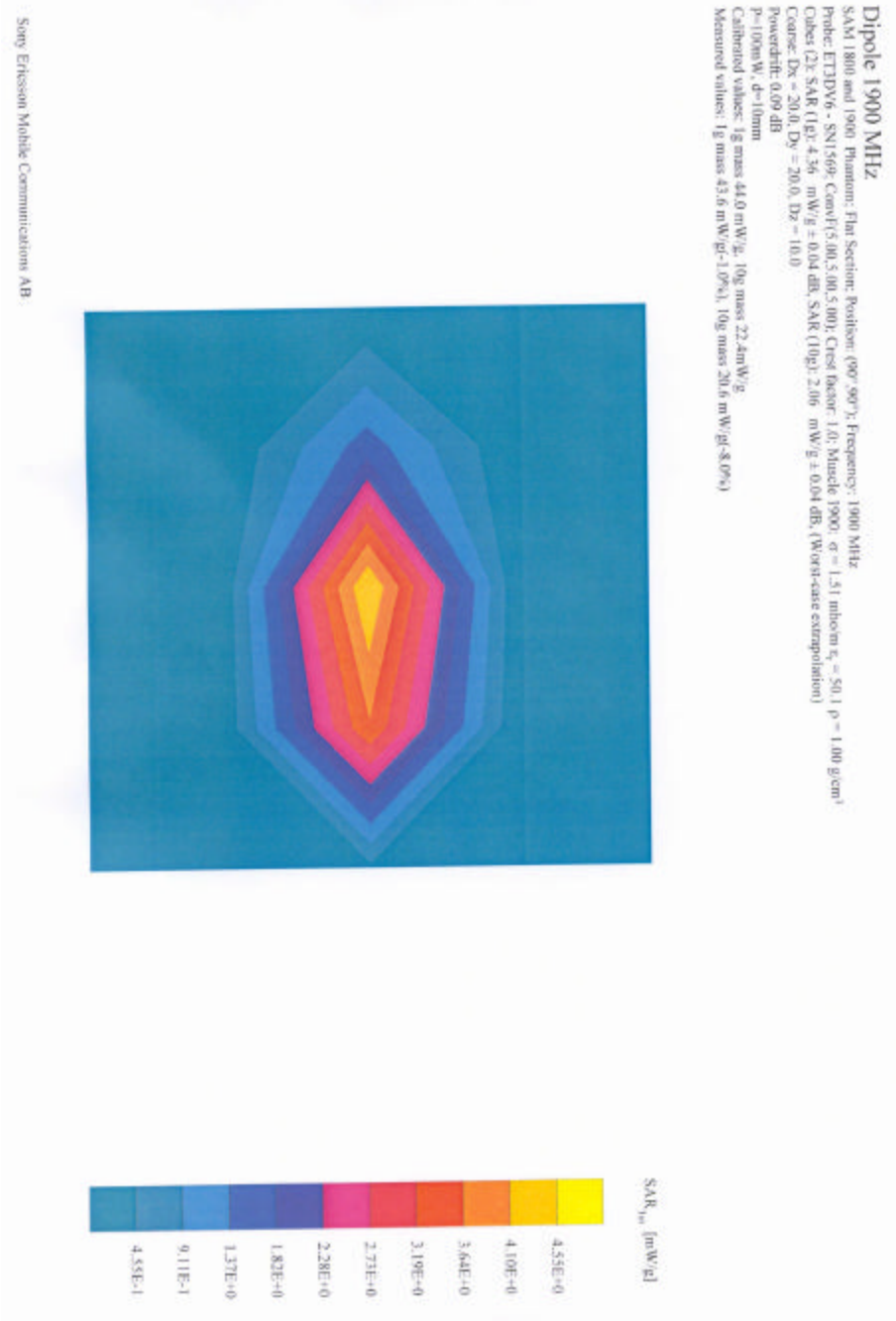


**Validation Dipole, measured with muscle simulating tissue on 05/23/02**

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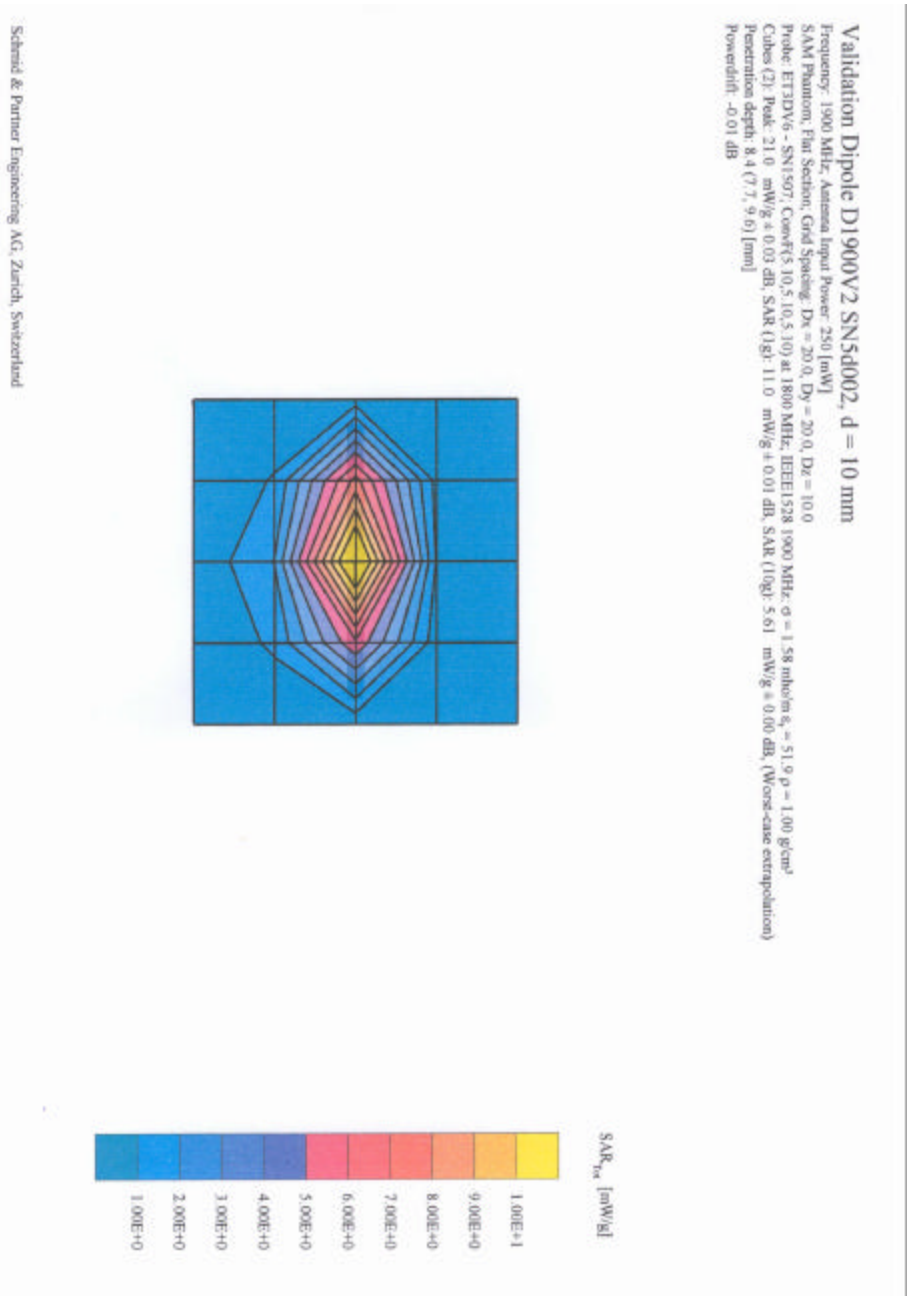


**1900MHz SAR distribution of validation dipole from reference measurement with muscle simulating tissue**

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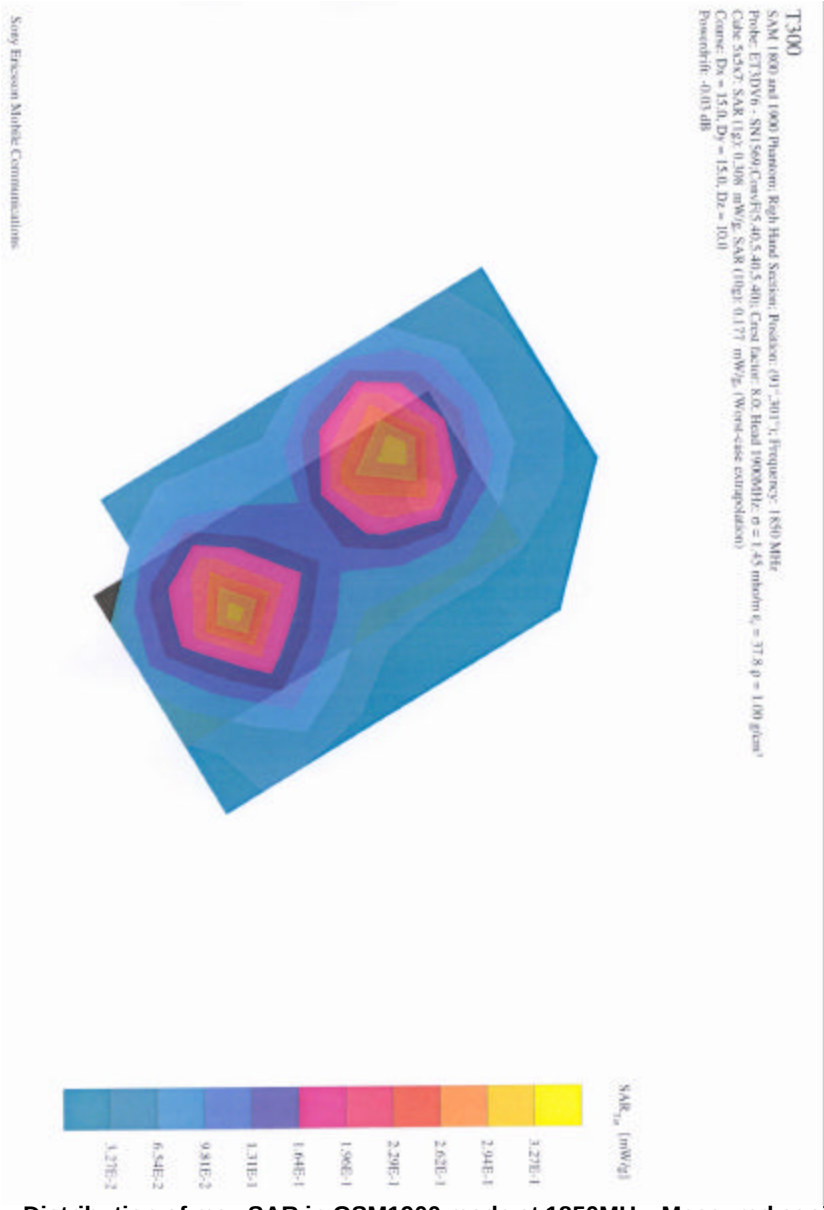
## 10.2 SAR distribution plot




**Distribution of max SAR in GSM1900 mode at 1850MHz. Measured against the head for cheek phone position**

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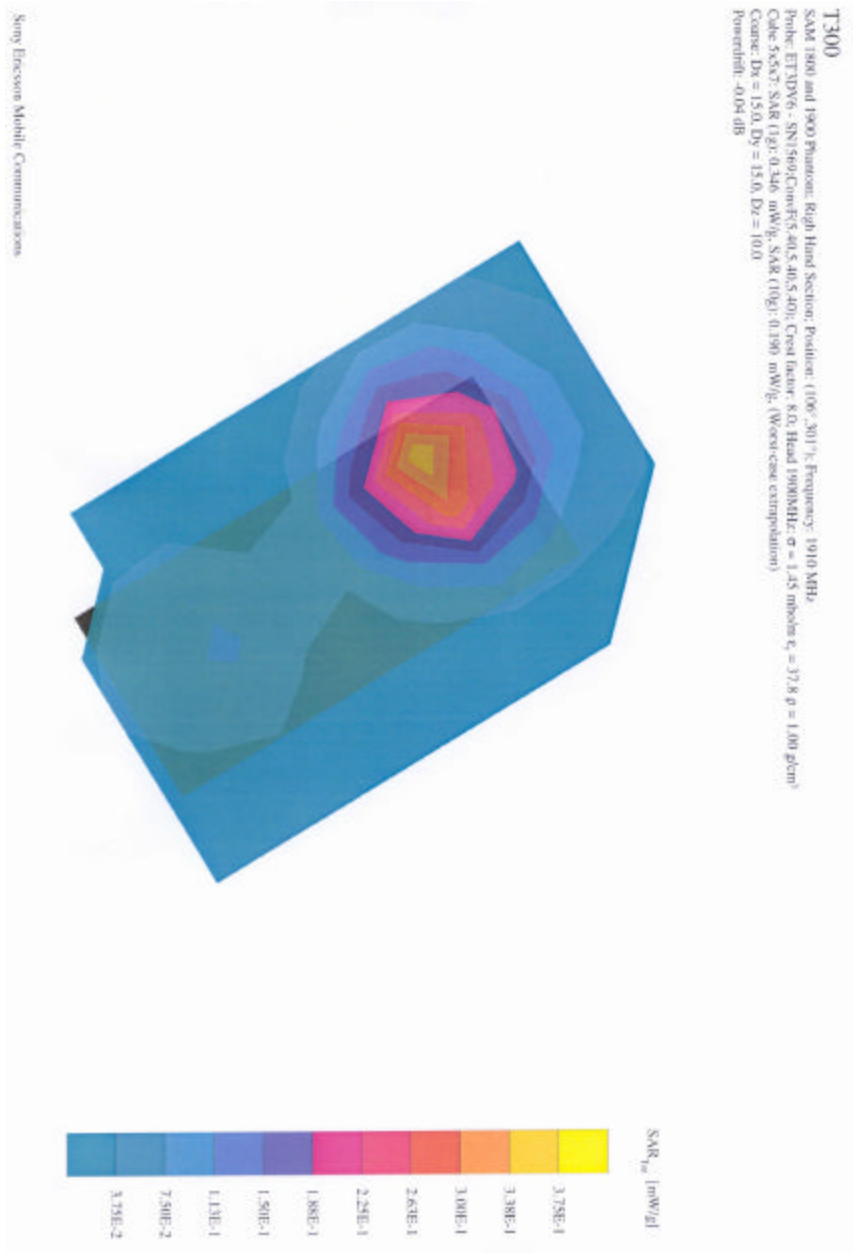


**Distribution of max SAR in GSM1900 mode at 1910MHz. Measured against the head for tilt phone position**

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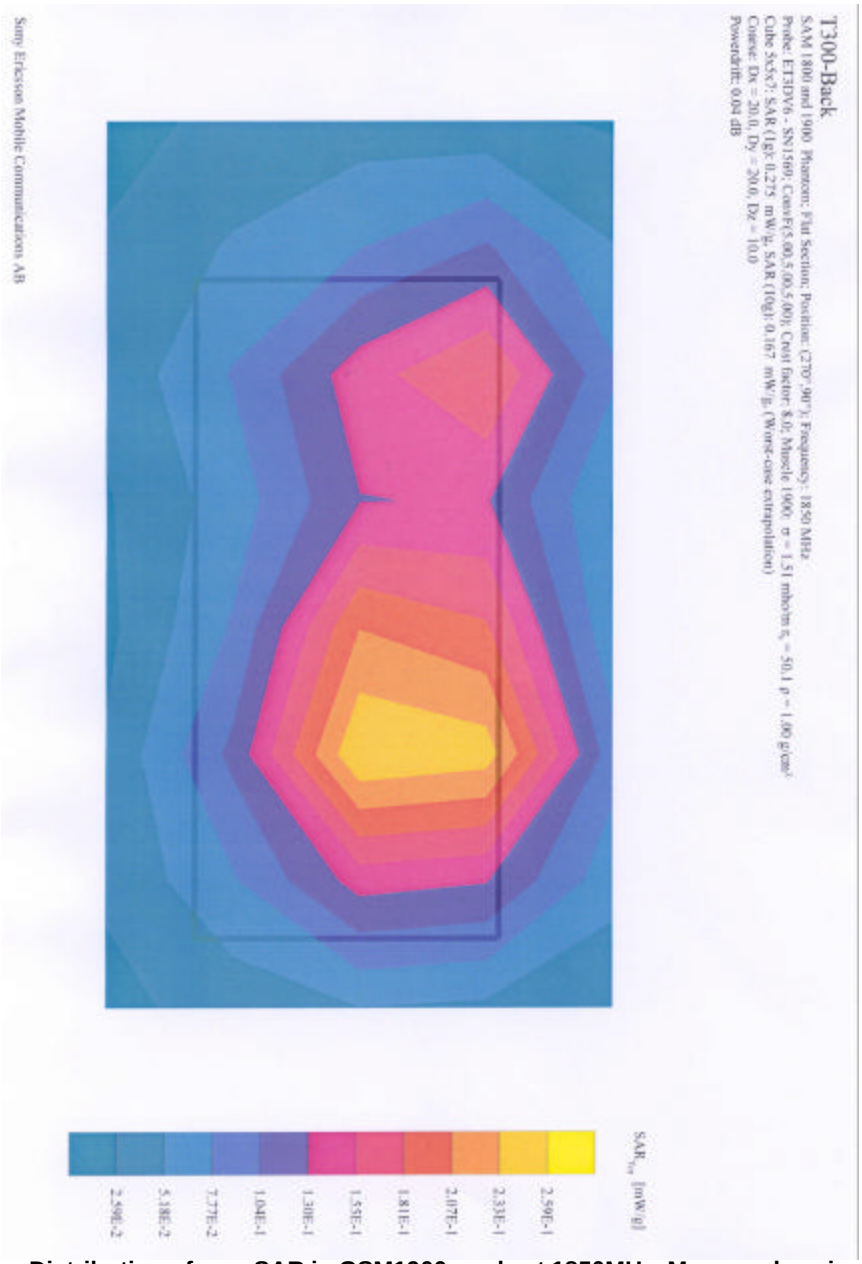


**Distribution of max SAR in GSM1900 mode at 1850MHz. Measured against the body for back phone position to the phantom**

## 10.3 Photographs of the device under test

**Front side**

**Down Connector**

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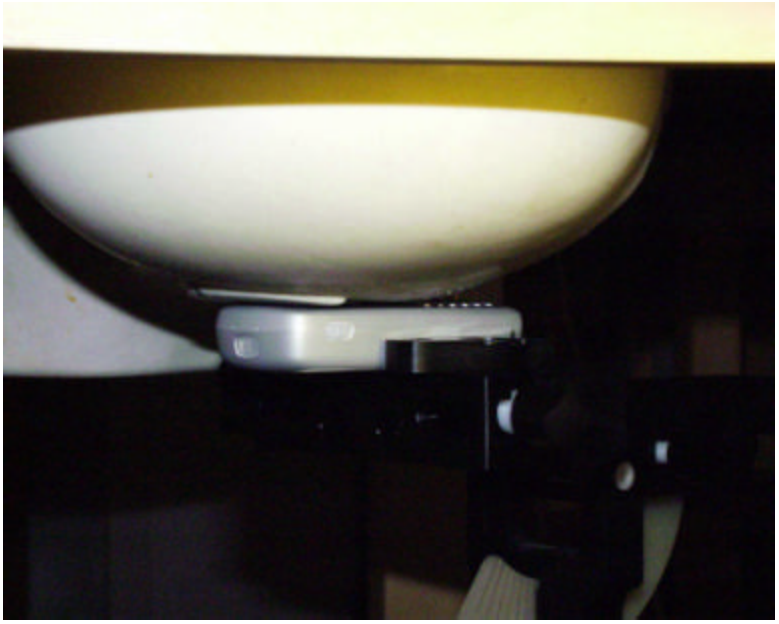
**Back side with battery**

## 10.4 Device position on SAM Twins Phantom



**Device position against the head: Cheek (touch) phone position**

**Device position against the head: Tilt (cheek+15deg) phone position**

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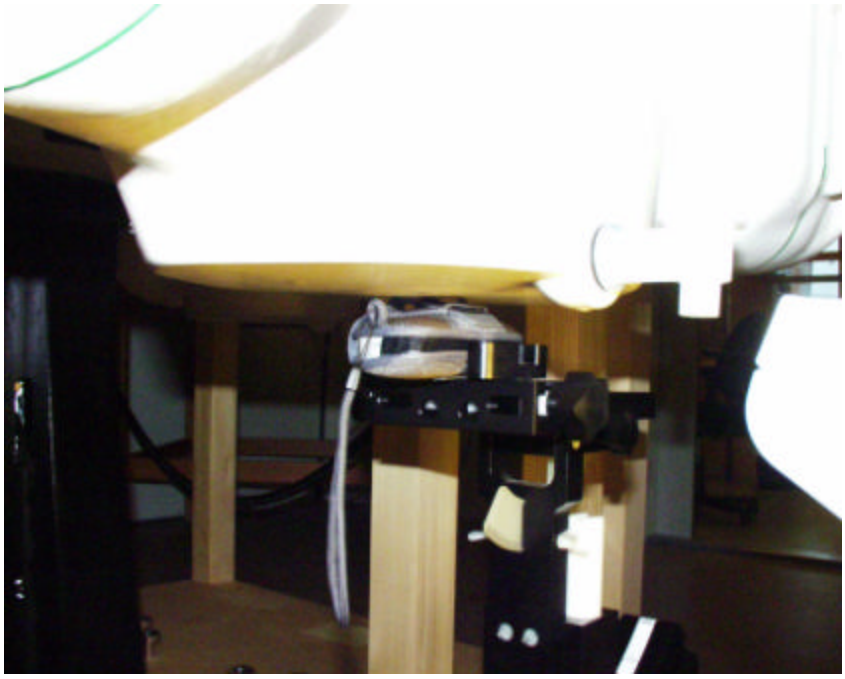

**Device position against the body: Phone in belt clip**

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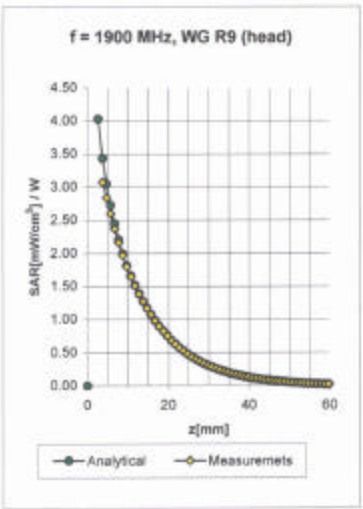
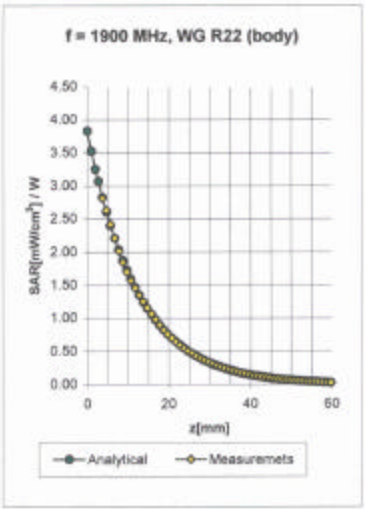
## 10.5 Probe calibration parameters

ET3DV6 SN:1569 April 25, 2002

### Conversion Factor Assessment




**Head** 1900 MHz $\varepsilon_r$ = 40.0 ± 5% $\sigma$ = 1.40 ± 5% mho/m

| | | | |
|---|---|---|---|
| ConvF X | 5.4 ± 8.9% (k=2) | Boundary effect: | |
| ConvF Y | 5.4 ± 8.9% (k=2) | Alpha | 0.47 |
| ConvF Z | 5.4 ± 8.9% (k=2) | Depth | 2.44 |

**Body** 1900 MHz $\varepsilon_r$ = 53.3 ± 5% $\sigma$ = 1.52 ± 5% mho/m

| | | | |
|---|---|---|---|
| ConvF X | 5.0 ± 8.9% (k=2) | Boundary effect: | |
| ConvF Y | 5.0 ± 8.9% (k=2) | Alpha | 0.65 |
| ConvF Z | 5.0 ± 8.9% (k=2) | Depth | 2.16 |

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| SEM/CV/PF/P Mark Douglas | MGD | 2001-11-5 | A | C:\zz_Made\SAR dokument\SAR measurement specification.doc |

# SAR Measurement Specification of Wireless Handsets

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# 1. Introduction and Scope

It is our policy that all RF transmitting products shall comply with existing recommendations, standards and regulations on human exposure to electromagnetic fields. In the reference section below, the most important RF safety guidelines are listed [4-11]. If no national standard or regulation is available in a country, the international recommendation from ICNIRP [4] shall be applied.

The RF safety guidelines specify *basic restrictions* and *reference levels*. In the frequency range of interest for mobile communications, the basic restrictions are expressed as Specific Absorption Rate (SAR) limits and the reference levels as field strength or power density limits. The reference levels are provided for the purpose of simple measurements of compliance with the basic restrictions, and they are primarily applicable in the farfield region of a RF source. Measured values greater than the reference levels do not necessarily mean that the basic restrictions are exceeded.

In the nearfield region of mobile communication devices (handsets or base station antennas), field strength values exceeding the reference levels may be observed. Compliance with the basic SAR restrictions has therefor to be verified. SAR (W/kg) is a measure of the rate of RF energy absorption in tissue. The localized SAR limits depend on whether the device is classified for use by the general public (uncontrolled environment) or workers (controlled environment). Mobile communication equipment are usually used by the general public and should consequently be in compliance with the general public limits, which are 2.0 W/kg averaged in 10 gram of tissue in the ICNIRP guidelines and 1.6 W/kg averaged in 1 gram in the ANSI/IEEE standard. Because of the lower limit and the smaller averaging mass, the ANSI/IEEE limit is slightly more conservative than the ICNIRP limit. The averaging times are also different, 6 minutes in the ICNIRP recommendations and 30 minutes in the IEEE guidelines.

This document describes the SAR measurement procedures used by the SAR Testing Laboratory of Sony Ericsson Mobile Communications, Inc. SAR measurement standardization is currently evolving. Many standards and guidelines have recently been released [1, 3] or are in progress (e.g. [2]). Sony Ericsson Mobile Communications, Inc. is firmly committed to using the latest technology and the latest standards to ensure that SAR measurements are of the highest quality.

# 2. References

**SAR measurement standards and guidelines**

The following standards and guidelines are used as a basis for the SAR measurement specification described herein. Although these documents are well harmonized, some differences exist. Reference [1] is a guideline published by the Federal Communications Commission. Reference [2] is a draft measurement standard from the IEEE. Reference [3] is an approved European standard. This measurement specification closely conforms to these documents.

[1] FCC, “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 OET Bulletin 65 (Edition 97-01), June 2001.

[2] IEEE, “Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques,” Std 1528-200X, Draft 6.5 – August 20, 2001.

[3] CENELEC, “Basic standard for the measurement of Specific Absorption Rate related to human exposure to electromagnetic fields from mobile phones (300 MHz – 3 GHz)”, European Standard EN 50361, July 2001.

**Other references**


[4] ICNIRP, “Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)”, International Commission on Non-Ionizing Radiation Protection (ICNIRP), Health Physics, vol. 74, pp 494-522, April 1998.

[5] ANSI/IEEE C95.1-1992, “Safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz”, The Institute of Electrical and Electronics Engineers Inc., New York, 1991.

[6] CENELEC ENV 50166-2, “Human exposure to electromagnetic fields: High-frequency (10 kHz – 300 GHz)”, European Prestandard, European Committee for Electrotechnical Standardization (CENELEC), January 1995.

[7] MPT, “Radio-radiation protection guidelines for human exposure to electromagnetic fields”, Telecommunications Technology Council, Ministry of Posts and Telecommunications, Japan, April 1997.

[8] AS/NZS 2772.1(Int):1998, Interim Australian/New Zealand Standard, “Radiofrequency fields, Part 1: Maximum exposure levels – 3 kHz to 300 GHz”, Standards Australia/Standards New Zealand, 1998.

[9] FCC Report and Order, ET Docket 93-62, FCC 96-326, Federal Communications Commission (FCC), August 1996.

[10] Radiocommunications (Electromagnetic Radiation Human Exposure) Standard 1999, Australian Communications Authority (ACA), May 1999.

[11] Safety code 6, Canadian Standard, Health Canada, 1999.

[12] Thomas Schmid, Oliver Egger, Niels Kuster, "Automated E-field scanning system for dosimetric assessments", *IEEE Transactions on Microwave Theory and Techniques*, vol. 44, pp. 105-113, January 1996.

[13] Schmid & Partner Engineering AG, "DASY3 User Manual", August 1999 Edition, Zurich, Switzerland.

[14] Klaus Meier, Michael Burkhardt, Thomas Schmid and Niels Kuster, "Broadband calibration of E-field probes in lossy media", *IEEE transactions on Microwave Theory and Techniques*, vol. 44, no. 10, pp. 1954-1962, October 1996.

[15] K. Pokovic, T Schmid and N. Kuster, "E-field Probe with Improved Isotropy in Brain Simulating Liquids", *Proceedings ELMAR*, Zadar, Croatia, June 23-25, 1996.

[16] NIS 81, "The treatment of uncertainty in EMC measurements", Technical Report, NAMAS Executive, National Physical Laboratory, Teddington, Middlesex, England, Edition 1, May 1994.

[17] Barry N. Taylor and Christ E. Kuyatt, "Guidelines for evaluating and expressing the uncertainty of NIST measurement results", NIST Technical Report 1297, National Institute of Standards and Technology, September 1994.

[18] T. Schmid and N. Kuster, "Preliminary uncertainty budget for SAR evaluations with DASY3," contribution to IEEE Standards Coordinating Committee 34, Subcommittee 2, July, 1998.

[19] ISO/IEC Guide Expres (1995-01),"Guide to the expression of uncertainty in measurement (1995)", Ed. 1.0 English, 1995.

[20] HP 8572C Network analyzer User’s guide. Hewlett Packard part number 08752-90157.

[21] HP 85070B Dielectric probe kit manual, Hewlett Packard part number 85070-90009.


## 3. Physical quantities, units and constants

The physical quantities, units and constants given in section 3 of [3] are applicable for this procedure document.

## 4. Definitions

The definitions given in Section 4 of [3] and Section 2 of [2] apply. If a disagreement between two definitions exist, and the disagreement is not deemed to be due to the differing context of the standard, the definition of the later document applies.

## 5. Measurement system specifications

The SAR measurement system used is the DASY3 system manufactured by Schmid & Partner Engineering, AG (SPEAG). The system includes a 6-axis robot, liquid-filled phantoms and miniature electric field probes. More information can be found in [12,13]. The specifications of the system are further described below.

### 5.1 General

Tests are performed using miniature electric field probes that are positioned by a robot whose movements are software controlled. The probes are positioned to measure the internal electric field of a liquid-filled phantom representing the human head while the phantom is exposed to electromagnetic energy from a wireless device. The software processes the electric field data to determine the SAR distribution and the highest mass-averaged SAR.

Tests are performed in a laboratory which conforms to the following environmental conditions:

- Measurements are conducted in a metal screen room which is designed to provide shielding from external radiofrequency signals and to prevent devices under test from interfering with local wireless networks [3].
- The ambient temperature is kept in the range 20 – 25°C (this simultaneously satisfies the recommendations and requirements of [1,2,3], which are 20 - 26°C, 18 - 25°C and 15 – 30°C, respectively).
- The relative humidity of the laboratory is kept within 30 – 70% (as per [1]. There are no humidity specifications in [2,3]).
- During measurements, the temperature of the liquid is kept within ±2 °C of the temperature at which the dielectric parameters were measured [1,2,3].
- The ambient noise level is kept low so that the 1-gram averaged SAR is below 12 mW/kg when the device under test (DUT) is turned off [2].
- The effects of reflections in the laboratory are kept low.

### 5.2 Phantom

The phantom used is an implementation of the Specific Anthropomorphic Mannequin (SAM) model [2, 3]. It consists of three measurement areas or sections, one section corresponding to right hand side use and an identical but mirrored section for the left hand side. In the middle of the phantom there is a flat section for tests of mobile phones when worn on the body. The flat section is also used for system verification.

The phantom shell was designed by SPEAG to meet stringent shape, thickness and material requirements [2, 3] [1]. The length and width of the flat section are at least 0.75 $\lambda_0$ and 0.6 $\lambda_0$ respectively at frequencies of 824 MHz and above ($\lambda_0$ = wavelength in air).

The phantom is filled with a tissue simulating liquid to a depth of at least 15 cm at each ear reference point [2]. The dielectric properties of the liquid conform to the requirements of [1, 2] and the tabulated values of [3]. Liquids are prepared according to Annex A and dielectric properties are measured according to Annex B.

[1] As of this writing, we have received verbal assurances but no written statement from SPEAG that the shape, thickness and material requirements have been met.

## 5.3 SAR measurement equipment

The measurement system includes dosimetric electric field probes and data acquisition electronics, which are calibrated by SPEAG at regular intervals. The equipment is calibrated in a complete system for each relevant tissue equivalent liquid at the appropriate frequency.

The ET3DV6 probe by Schmid & Partner Engineering AG is sensitive to E-fields and thus incorporates three small dipoles arranged so that the overall response is close to isotropic [14, 15]. The table below summarizes the technical data of this probe. Other probe parameters are provided in the uncertainty budget in Section 7.

| **Property** | **Data** |
|---|---|
| Frequency range | 30 MHz – 3 GHz |
| Linearity | ± 0.2 dB |
| Dynamic Range | 5 µW/kg - >100 W/kg |
| Tip diameter (including sheath) | 6.8 mm |
| Distance from probe tip to sensors | 2.7 mm |
| Optical surface detection repeatability | ± 0.2 mm |

**Table 1 The technical data for the SAR probe ET3DV6.**

The dosimetric probes are connected to the DAE3 data acquisition system which has a fiber optical link to the system controller computer. If mechanical surface detection is used, the repeatability is ± 0.05 mm [13].

## 5.4 Scanning system

The robotic scanning system is able to scan the probe over a sufficient area above the inner surface of the SAM phantom to show the SAR distribution and location of the peak SAR. Graphical output is also provided to show the SAR peak relative to the wireless device.

## 5.5 Wireless device holder

The wireless device holder is a positioning system that allows for very accurate and repeatable device postioning [13]. Tilt and rotation angles have a positioning repeatability better than 1°.

Care is taken at the laboratory to ensure that the wireless device is placed in the holder in such a way that the holder has a minimal effect on the measured results. Test personnel are trained on proper positioning techniques. In addition, prior to conducting tests, measurements were made on the flat phantom with and without the device holder. The influence of the holder was found to be small (less than 3%).

## 5.6 Other equipment

The measurement system also includes dipole antennas for system performance checking and system validation procedures at frequency bands of interest. The dipole antennas conform to the specifications of Annex F of [2]. These dipole antennas are validated yearly. Yearly validation consists of the following checks:

- dipole arms are parallel to a flat surface with a tolerance of 2°
- return loss at the center frequency is below –20 dB while the dipole is positioned under the flat phantom according to Section 7 of [2].
- current distribution along the dipole is symmetric within 5%, as measured using an H-field probe.
- SAR measurement is taken in a flat phantom and compared with reference SAR values in Table 7.1 of [2].

SAR measurement system validation requirements are described in Annex D.

# 6. Protocol for SAR assessment

## 6.1 Measurement preparation

Daily, prior to conducting SAR measurements of the DUT, the dielectric properties of the tissue simulating liquid are measured (see Annex B) and a system performance check is performed (see Annex D).

For SAR compliance measurements, the peak output power level of the mobile phone is set to the maximum power level of that device, as specified in Section 6.1.3 of [3]. The peak power level is measured with either a power meter, a sensor suitable for the carrier frequency and the duty cycle, or a digital radio tester.

Tests are conducted for each of the test configurations of the DUT (operational modes, test frequencies, and configurations) specified in Section 5.3 of [2].

If the device is intented to be used next to the ear, it is positioned next to the SAM head phantom in the “cheek” and “tilt” positions on both the left and right sides of the phantom according to Section 5.4 of [2].

If the device is intended to be used while placed against the body, the phone is tested on the flat section of the phantom. The device, with its original carry case(s) and with hands-free accessories, shall be positioned on the phantom simulating the intended use position, i.e. with the case placed against the phantom shell. Alternatively, the device can be placed against the phantom using a spacer that separates the device from the phantom by the minimum distance allowable using all carry cases. Additional guidance given in [1] on conducting body-worn measurements should be followed.

## 6.2 Tests to be performed

A wireless handset can have many test conditions (operational modes, test frequencies, configurations and test positions against the phantom). At a minimum, the steps outlined in Section 5.6.4 of [2] are followed to determine the maximum spatial-averaged SAR of the device.

## 6.3 Measurement procedure

The measurement procedure is described in detail in Annex C.

## 6.4 Post processing

Post processing of the data is described in Annex C.

# 7. Measurement uncertainty

The measurement uncertainty of the DASY has been determined according to the NIS81 [16] and NIST1297 documents [17]. The total uncertainty of the SAR assessment is composed of two main factors: measurement uncertainty and source uncertainty. Each of these uncertainties consists of a number of individual factors. A detailed breakdown of uncertainties, according to T. Schmid *et. al*. [18], is provided in the following tables. The combined uncertainty (K=1) of the SAR assessment is ±12%. The extended uncertainty (K=2) is ±24% [19].

A) Measurement uncertainty

| Uncertainty description | Error | Distrib. | Weight | Std. Dev. |
|---|---|---|---|---|
| **Probe uncertainty** | | | | |
| axial isotropy | ± 0.2dB | U-shape | 0.5 | ± 2.4% |
| spherical isotropy | ± 0.4dB | U-shape | 0.5 | ± 4.8% |
| isotropy from gradient | ± 0.5dB | U-shape | 0 | |
| spatial resolution | ± 0.5% | normal | 1 | ± 0.5% |
| linearity error | ± 0.2dB | rectang. | 1 | ± 2.7% |
| calibration error | ± 3.3% | normal | 1 | ± 3.3% |
| **SAR Evaluation Uncertainty** | | | | |
| data acquisition error | ± 1% | rectang. | 1 | ± 0.6% |
| ELF and RF disturbances | ± 0.25% | normal | 1 | ± 0.25% |
| conductivity assessment | ± 10% | rectang. | 1 | ± 5.8% |
| **Spatial Peak SAR Evaluation Uncertainty** | | | | |
| extrapol + boundary effect | ± 3% | normal | 1 | ± 3% |
| probe positioning error | ±0.1 mm[2] | normal | 1 | ± 1% |
| integrat. and cube orient | ± 3% | normal | 1 | ± 3% |
| cube shape inaccuracies | ± 2% | rectang. | 1 | ± 1.2% |
| **Total Measurement Uncertainty** | | | | **± 10.2%** |

B) Source uncertainty

| Uncertainty description | Error | Distrib. | Weight | Std. Dev. |
|---|---|---|---|---|
| device positioning | ± 6% | normal | 1 | ± 6% |
| laboratory setup | ± 3% | normal | 1 | ± 3% |
| **Total Source Uncertainty** | | | | **± 6.7%** |

C) Combined uncertainties

| Uncertainty description | Uncertainty |
|---|---|
| total measurement uncertainty | ± 10.2% |
| total source uncertainty | ± 6.7% |
| **Combined uncertainty (K=1)** | **± 12.2%** |
| **Extended uncertainty (K=2)** | **± 24.4%** |

[2] The probe positioning error is calculated from the optical surface detection accuracy of ±0.1 mm and an assumed SAR decay at 1800 MHz of 10% per mm penetration. The robot has a positioning repeatability of ±0.02 mm and a rigid probe fixture. This together with the horizontal maximum search routine of the SAR evaluation procedure ensures that SAR errors from horizontal probe or phantom positioning are negligible.

# Annex A. Tissue simulating material preparation

This section describes the preparation procedure for the tissue simulating liquids used in SAR testing.

## A.1 Preparation of liquid

**Ingredients**

| | |
|---|---|
| Water | distilled water |
| Sugar | as available in food shops |
| Salt | as available in food shops |
| Cellulose | HEC Hydroxyethyl-cellulose (Optional ingredient) |
| Propanol –2 | Purum 99.5% |
| Butanol –1 | Purum 99.5% |
| Preservative | Preventol D7 Bayer AG or Sodium Nitrate |
| DGBE | Diethylene glycol butyl ether |
| Triton X-100 | Polyethylene glycol mono [4-(1,1,3,3-tetramethylbutyl)phenyl]ether |

**Note 1:** It is important to follow the instructions provided in the Material Safety Data Sheet (MSDS) for any material, or any local regulations. It is also important to have material handling procedures (including procedures for handling, storage and disposal).

**Note 2:** Similar materials can also be substituted for the ones above (e.g. deionized water instead of distilled water). The specifications of the materials (e.g. purity) are not critical (although they may change the recipes below), because the after the tissue simulating liquid is made, its dielectric parameters must be verified to be within the target ranges.

**Preparation materials**

Scale
Stirrer with hotplate
Jars and beakers
Mixing spoon

**Recipe for tissue simulating liquid**

The tables below give common recipes for tissue simulating liquids that may be used to achieve the target dielectric parameters. These recipes are designed to meet the target dielectric parameters (as discussed in Section 5.2). Other recipes may also be used to achieve the target dielectric parameters or to satisfy the needs of regulatory agencies or other customers.

**Sugar-water recipes**

| Ingredient | 835 MHz and 900 MHz head | | 835 MHz and 900 MHz body | |
|---|---|---|---|---|
| | % weight | amount (g) | % weight | amount (g) |
| Distilled water | 40.58 % | 10549 | 56.00 % | 11800 |
| HEC | 0.90 % | 233 | 1.21 % | 256 |
| NaCl | 1.40 % | 367 | 0.76 % | 160 |
| Preservative | 0.19 % | 50 | 0.27 % | 56 |
| Sugar | 56.92 % | 14800 | 41.76 % | 8800 |
| **Total amount** | | **20 L** | | **20 L** |

**Propanol-Butanol recipes**

| Ingredient | 1800 / 1900 MHz head | |
|---|---|---|
| | % weight | amount (g) |
| Water | 51.00 % | 10263 |
| Propanol –2 | 31.00 % | 4977 |
| Butanol –1 | 18.00 % | 2836 |
| **Total amount** | | **20 L** |

**DGBE-water recipes**

| Ingredient | 1800 MHz head | | 1900 MHz head | | 1900 MHz muscle | |
|---|---|---|---|---|---|---|
| | % weight | amount (g) | % weight | amount (g) | % weight | amount (g) |
| DGBE | 47.00 % | 9204 | 44.92 % | 8798 | 30.80 % | 6078 |
| Water | 52.64 % | 10309 | 54.90 % | 10752 | 68.90 % | 13596 |
| Salt | 0.36 % | 70.5 | 0.18 % | 35.3 | 0.29 % | 57.2 |
| **Total amount** | | **20 L** | | **20 L** | | **20 L** |

**Triton X-100 recipes**

| Ingredient | 1800-3000 MHz head | |
|---|---|---|
| | % weight | amount (g) |
| DGBE | 16.33 % | 3280 |
| Triton X-100 | 17.96 % | 3607 |
| Water | 65.30 % | 13115 |
| Salt | 0.41 % | 82.3 |
| **Total amount** | | **20 L** |

## A.2 Preparation procedure

**Sugar-based liquids**

1. Add the water to a large container. Begin heating and stirring.

2. Add the cellulose, preservative and salt (if required). While keeping the container covered, leave the solution on the heating plate until the mixture becomes sufficiently transparent and homogeneous. The temperature of the mixture should be hot enough to aid in mixing the ingredients but cool enough to prevent a significant amount of water evaporation.

3. Add the sugar. Hand stirring may be necessary at the beginning until the sugar is sufficiently dissolved.

4. Keep the liquid hot and the container covered until the solids are dissolved and the liquid is homogenous.

5. Turn the hotplate off and allow the liquid to cool off to room temperature prior to performing dielectric measurements.

**Alcohol-based liquids**

1. Add all the ingredients in a large container.

2. Stir until the liquids are solved.

## A.3 Tissue liquid maintenance

A batch of tissue simulating liquid may last several months or more but regular maintenance is necessary in order to keep the dielectric properties within target ranges. The electrical parameters of the tissue simulating liquids are assessed daily prior to SAR compliance testing and checked that they are within tolerance of the specified values (see Section 5.2). The parameters are subject to small variations due to evaporation, and ingredients (e.g. water) have to be added on a regular basis in order to adjust the parameters. The amount of ingredient to add depends on the parameter deviations and the total liquid volume and is therefore not easily calculated. However, based on experience, for sugar-salt-water liquids a rule of thumb can be applied: to a 15-liter liquid with a permittivity deviation of about -10% and a conductivity deviation around -5% to -10%, 100 – 300 grams of water should be added.

It is recommended that a batch be disposed of and replaced with a new batch when it becomes difficult to keep its dielectric parameters within the ranges specified.

# Annex B. Dielectric property measurements

This annex describes the procedures used to measure the dielectric properties of the tissue simulating liquid.

## B.1 Equipment

- HP network analyzer HP8752C or similar
- HP dielectric probe kit HP85070A, HP85070B or HP85070C
- HP 85070 software (any software version)
- PC using GPIB card [20] for communication with network analyzer
- Syringe
- Small glass jars for liquid samples
- Thermometer

## B.2 Procedure for testing brain simulating liquid

1. Turn the NWA (Network analyzer) on and allow it to warm up.

2. Start the PC and run the HP 85070 software.

3. Mount dielectric probe kit so that interconnecting cable to NWA will not be moved during measurement or calibration.

4. Perform calibration according to the HP85070 B manual [21]. In short the following steps are covered
    - Inspect the probe and ensure that it is properly cleaned.
    - Pour distilled water in a sample container and measure the water temperature ( $\pm 1^{o}$C).
    - Set start and stop frequency, frequency step and water temperature.
    - Perform calibration measurement with probe in air.
    - Perform calibration measurement using the short circuiting block. Assure proper contact which requires attaching the block firmly. Monitor the polar chart on the network analyzer to assure good contact as explained in the manual.
    - Perform calibration measurement with probe in distilled water.

5. Assure that the probe is thoroughly cleaned before performing the measurement.

6. Inspect the liquid for inhomogeneities. Surface bubbles can be moved to one side, but if there are numerous bubbles throughout the liquid (e.g. as happens after a new liquid has been poured into a phantom), wait until the bubbles have floated to the surface before proceeding. Also remove any debris or lumps in the liquid.

7. Stir the liquid to be measured. Extract a sample (approximately 50 ml or more) from the liquid container.

8. Put the liquid sample into a small container.

9. Measure liquid shortly after calibration of the network analyzer and at most within an hour of this calibration. It is also important to measure the liquid sample soon after extracting it so that evaporation and temperature variation do not affect the results.

10. Immerse the dielectric probe in the liquid sample. Check that there are no air bubbles in front of the opening in the dielectric probe kit.

11. Perform measurements. Repeat measurement three times to increase reliability and use average value for comparison with target value. If a single measurement deviates substantially from the rest then redo that measurement to reject possible artifact.

12. Conductivity $s$ can be calculated from $e''$ according to

$$s = we_o e'' \cong e'' \text{f (GHz)}/18.$$

13. Clean the probe thoroughly after use.

## B.3 Dielectric parameters

If the measured dielectric parameters are not within their target ranges, ingredients may be added to adjust the parameters. For example, one can add water to increase the permittivity, sugar to reduce the permittivity or salt to increase the conductivity. Parameters should each be within a $\pm$5% range of target values. The accuracy specified by the dielectric probe kit manufacturer [21] is $\pm$5% for the dielectric constant $e'$ and $\pm$0.05 for the loss tangent $e''/e'$.

# Annex C SAR measurement protocol

The following sections describe what steps are done to evaluate the highest spatial-average SAR for a wireless device. More information is found in the user manual for the measurement system [13]. Recommendations are described in Section 5 of [2].

## C.1 Peak spatial-average SAR assessment

The measurement of the peak spatial-average SAR for each of the test conditions described in Section C.2 is performed using the following steps.

1. Surface check: the robot repeatedly moves the probe to the phantom surface at a specified point to check the repeatability of the mechanical and optical surface detection. This step may also be performed after step 5. If the repeatability is greater than ±0.1 mm, the system should be inspected (e.g. check for air bubbles trapped under the probe) and the surface check procedure should be repeated.

2. Reference check: the robot moves the probe to a fixed reference position in the tissue liquid and the E-field is recorded.

3. Coarse scan: the probe is moved in a coarse grid following the inner surface of the phantom The size of the scanned region should be large enough to guarantee that all possible SAR peaks are included. The distance between adjacent measured points should be 10 – 20 mm [1]. The specific absorption rate (SAR) is calculated from the recorded E-fields by the following expression

$$SAR = s\,\frac{E^2}{r}$$

where σ is the measured liquid conductivity (S/m), $E$ is the measured root-mean-squared E field (V/m), and ρ is the chosen tissue density (ρ = 1000 kg/m$^3$ = 1 g/cm$^3$ should always be used, according to [1,2,3]). Spline interpolation is used to determine the point of maximum SAR.

4. Fine scan: Measurements are taken on a fine grid around the position of the maximum SAR. The grid typically consists of 5x5x7 points with 8x8x5 mm between the individual points and thus contains about 31 grams of tissue. Numerical extrapolation is then used to determine the SAR values between measurement points in the cube and in the small region between the cube and the inner surface of the phantom where the E-field sensors cannot be positioned. The extrapolation distance is thus the sum of the probe tip - sensor offset, the surface detection distance and the grid offset. The extrapolation is based on fourth-order polynomial functions. Next, a 3D spline interpolation algorithm is used to get all points within the measured volume in a 1mm grid (approximately 31 000 points). Finally, the SAR is averaged over a 1g cube (1000 points). The cube is shifted throughout the fine scan area until the highest averaged SAR is found. The same procedure is repeated for a 10 gram cube (10 000 points).

5. Drift measurement: a second reference check is performed at the same location as in step 2. From this data the system drift during the SAR measurements is evaluated.

## C.2 SAR measurement procedure

This section gives a step-by-step procedure for measuring the DUT. The instructions of this section are only valid under the assumption that the measurement equipment is calibrated and verified and that the DUT has been approved for SAR testing.

### C.2.1 Initial setup

1. Ensure that the probe is mounted on the DAE.
2. Ensure that the computer, robot controller and DAE are turned on, and that the DASY software is running.
3. Press the robot button on the toolbar to set up the communications between the software and the robot. Go through the self-check procedure in the software to ensure that the system is properly running and set up for measurement.
4. Choose the appropriate test configuration in the "Setup" menu. NOTE, check that the medium parameters in the "options" window are equal to those measured previously with the dielectric probe kit for the liquid in the phantom.
5. Remove the plastic cover on the phantom.
6. Verify that the system knows the reference points on the phantom. Check the distance between the reference points and the probe tip with the plastic spacer. If it does not accurately locate one or more of the points to within ±5 mm, install the reference points. Should the installation fail to give results within the tolerances set

out in the factory settings for the phantom, the procedure will give an error and the user will have to reinstall the reference points. Afterwards, move the probe to the resting point above the flat section.

7. Stir the liquid in the phantom to ensure that it is homogeneous. Surface bubbles can be moved to one side, but if there are numerous bubbles throughout the liquid (e.g. as happens after a new liquid has been poured into a phantom), wait until the bubbles have floated to the surface before proceeding. Also remove any debris or lumps in the liquid.

### C.2.2 Measurement procedure

The following steps should be carried out for each of the test conditions described in Section 6.2.

1. Open the appropriate predefined measurement file or prepare a new measurement file by selecting jobs from the menu. Save the measurement file under an appropriate name.

2. Move the probe so that the tip is below the surface of the liquid in the selected measurement section. Stir the liquid again to remove any bubbles trapped under the probe tip.

3. Power on the DUT and set it to transmit at full power in one of the operational configurations (as described in Section 6.1). Check the signal with the spectrum analyzer.

4. Position the DUT against the phantom in one of the required test positions (as described in Section 6.1).

5. Select the desired measurement jobs and start the SAR measurement (as described in C.1).

6. Check the system drift. If the measurement data is not within ±5% (±0.2 dB), check the DUT and the DASY and repeat the measurement. If the drift cannot be maintained within 5%, add the drift to the measured SAR value.

7. Save the measurement data and enter it into the laboratory log.

### C.2.3 Post measurement procedure

When the SAR measurements are finished, do the following:

1. Power off the DUT.

2. Move the probe to the resting point and clean it with water.

3. Put the plastic cover on the phantom.

## Annex D. Measurement system validation

Measurement system validation consists of three procedures:
1. System performance checking
2. System validation
3. Interlaboratory comparison

These three procedures are defined in Section 7 of [2]. System performance checking and interlaboratory comparison are also described in Annex D of [3] (they are called Simplified performance checking and system validation, respectively). Both standards are well-harmonized.

It is recommended that the procedures of IEEE P1528 are followed, since they are the most recent and include an additional step. Following IEEE procedures will satisfy CENELEC requirements.

Note: In the system performance checking, CENELEC EN 50361 has a tighter tolerance requirement on the distance of the dipole center to the liquid surface (±0.1mm vs ±0.2mm in IEEE P1528). This tighter tolerance is inconsistent with the tolerance of the phantom shell (±0.2mm) so it does not make sense. The IEEE requirement is consistent and should be followed.