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## Ericsson SAR Measurement Specification

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## Ericsson SAR measurement specification, part 1: Introduction and purpose

### 1. Introduction

It is an Ericsson 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 [1-8]. If no national standard or regulation is available in a country, the international recommendation from ICNIRP [1] shall be applied for Ericsson products.

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 table below shows the *localized* SAR limits for the general public (uncontrolled environment) and workers (controlled environment) in the ICNIRP and ANSI/IEEE guidelines. 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.

The 2.0 W/kg (10 g) SAR limit has also been adopted in a European Prestandard from CENELEC [3] and in guidelines from the Ministry of Post and Telecommunications in Japan [4]. The 1.6 W/kg (1g) SAR limit has been adopted by the FCC as a regulation in the U.S. [6], and also as the basic restriction in preliminary Australian and Canadian standards [5,6]. The FCC requires SAR testing of mobile phones since 1997 [6,10]. Similar requirements were introduced in Australia February 1, 1999 [7] and will be introduced in Canada during 1999. In Europe and Japan regulations are expected within the next few years.

SAR test standards for mobile communication equipment are under development by IEC, CENELEC, IEEE and ARIB. In the year 2000, it is expected that the first international standard will be published. Technical documents describing SAR test methods and procedures are already available from CENELEC, ARIB, ACA and the FCC [7-10].

Standard/Guideline	Localized SAR limit (W/kg) General public (uncontrolled)	Localized SAR limit (W/kg) Workers (controlled)
ICNIRP (1998)	2.0 (10 g)	10 (10 g)
ANSI/IEEE (1992)	1.6 (1 g)	8.0 (1g)

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## 2. Purpose of the Ericsson SAR measurement specification

The purpose of the Ericsson SAR measurement specification is to describe how SAR tests shall be conducted in the three SAR test laboratories in Ericsson, which are:

- The Ericsson EMF Research Laboratory at Ericsson Research in Kista (Contacts: ERA/T/UF Christer Törnevik or ERA/T/UD Martin Siegbahn)
- The ECS SAR laboratory at Ericsson Mobile Communications in Lund (Contacts: ECS/TN/FAC Thomas Bolin or ECS/TA/FA Ramadan Plicanic)
- The EUS SAR laboratory at Ericsson Inc. in RTP (Contacts: EUS Russ Holshouser or EUS Mark Douglas)

All these laboratories are equipped with the DASY3 SAR test system from Schmid & Partner Engineering AG (SPEAG). Since there is not yet an official standard that defines and describes SAR test procedures, it is necessary to specify internal Ericsson procedures for testing of mobile communication equipment. When an international SAR test standard is available, the Ericsson SAR measurement specification will be partly or completely replaced by this standard.

The Ericsson SAR measurement specification may be submitted to agencies like the FCC (USA), ACA (Australia) and Industry Canada if requested.

## 3. Applicability of the Ericsson SAR measurement specification

The Ericsson SAR test measurement specification shall always be followed when testing for compliance with SAR limits for handheld radio products or base station antennas in any of the Ericsson SAR laboratories.

Based on results from maximum exposure calculations and experience gained from earlier SAR measurements in Ericsson, it is known that certain low-power products can not exceed the SAR limits in any operational condition. These products do not have to be SAR tested, unless required by national or international standards and regulations.

The table below gives output power levels below which SAR testing is generally not necessary.

Type of equipment	Output power level in mW, below which SAR testing is generally not required	Example of Ericsson products
Mobile terminal	20	DECT Portable Part
Base station antenna	100	DECT Radio Fixed Part DECT RLL Fixed Access Unit

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### 3. Content of the Ericsson SAR measurement specification

The Ericsson SAR test measurement specification contains the following documents:

#### **Part 1: Introduction and purpose**

The current document. It gives a short introduction to exposure limits and SAR, summarizes SAR standards and regulations and explains the purpose of the Ericsson SAR measurement specification.

#### **Part 2: Tissue liquid preparation**

This documents describes how the liquid materials used to simulate body tissue in the SAR test phantom should be prepared in order to obtain the correct dielectric properties.

#### **Part 3: Measurements of dielectric parameters**

This part describes the procedure used to experimentally verify that the dielectric properties of the tissue liquid is within the specifications given in part 2.

#### **Part 4: Test system validation**

This document describes the procedures used to validate that the SAR test system is working properly.

#### **Part 5: Calibration**

This document provides calibration information for the equipment used in Ericsson's SAR measurement laboratories.

#### **Part 6: DUT preparation and characterization**

This document gives information about how the device under test should be characterized and setup prior to a SAR test.

#### **Part 7: SAR measurement procedure**

This part of the specification describes the practical process of measuring SAR for various product types using the test equipment in the Ericsson SAR laboratories.

#### **Part 8: Result documentation**

This document describes how SAR test results should be documented and stored.

#### **Part 9: Bibliography**

This part contains copies of SAR regulation documents, references to important basic and SAR related research papers, and lists documentation that should be provided with the SAR test equipment and available in the Ericsson SAR test facilities.

#### **Part 10: Glossary of symbols and acronyms**

This document explains the meaning of symbols and acronyms used in the other parts of the Ericsson SAR measurement specifications.

#### **Annex 1: Template for SAR test report**

Contains an example of a SAR test report. All Ericsson SAR reports should have the same outline and contain the same information.

#### **Annex 2: Template for Declaration of Conformity**

Contains an example of a Declaration of Conformity, i.e. a statement that a certain product is in compliance with one or more SAR standards and regulations.

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## References

- [1] 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.
- [2] 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.
- [3] 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.
- [4] MPT, "Radio-radiation protection guidelines for human exposure to electromagnetic fields", Telecommunications Technology Council, Ministry of Posts and Telecommunications, Japan, April 1997.
- [5] 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.
- [6] FCC Report and Order, ET Docket 93-62, FCC 96-326, Federal Communications Commission (FCC), August 1996.
- [7] Radiocommunications (Electromagnetic Radiation Human Exposure) Standard 1999, Australian Communications Authority (ACA), May 1999.
- [8] Safety code 6, Draft Canadian Standard, Health Canada, 1997.
- [9] ARIB STD-T56, "Specific Absorption Rate (SAR) estimation for cellular phone", ARIB Standard Version 1.0, Association of Radio Industries and Businesses (ARIB), January 27, 1998.
- [10] FCC OET Bulletin 65, Supplement C, "Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields", Edition 97-01, Federal Communications Commission (FCC), 1997.
- [11] CENELEC ES 59005, "Considerations for evaluation of human exposure to Electromagnetic Fields (EMFs) from Mobile Telecommunication Equipment (MTE) in the frequency range 30 MHz – 6 GHz", European Specification, European Committee for Electrotechnical Standardization (CENELEC), September 1998.

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## Ericsson SAR measurement specification, part 2: Tissue liquid preparation.

### 1 Introduction

For the preparation of tissue simulating liquid to be used in the generic twin phantom with DASY3 the following preparation procedure is used. The liquid should have properties similar to the human tissue [1],[2],[3]. In total a minimum of 18 litres of liquid is required.

### 2 Preparation of liquid

#### 2.1 Ingredients

Water	distilled water
Sugar	as available in food shops
Salt	pure NaCl (>99.9%)
Cellulose	HEC Hydroxyethyl-cellulose medium viscosity (Optional ingredient) (powder 75-125 mPa s, 2% in water 20 °C )
Preservative	Preventol D7 Bayer AG or similar

#### 2.2 Preparation materials

Scale  
Stirrer with hotplate  
Glass jar 500 ml  
Glass jar 5 l  
Glass jar 10 l  
Mixing spoon (approx. 12 “)

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### 3. Recipe for tissue simulating liquid

#### 3.1 Recipe at 835 MHz and 900 MHz

Ingredient	835 MHz		900 MHz	
Distilled water	43.27 %	3725 g	40.16 %	3460 g
HEC	0.93 %	80.1 g	1.00 %	86.0 g
NaCl	0.412%	35.5 g	0.692 %	59.6 g
Preventol	0.10 %	8.5 g	0.10 %	9.0 g
Sugar	55.29 %	4760 g	58.04 %	5000 g
Total amount		6.7 l		6.7 l

#### 3.2 Recipe at 1640 MHz and 1800 MHz

Ingredient	1640 MHz		1800 MHz	
Distilled water	44.18 %	3765 g	44.97 %	3827 g
HEC	1.00 %	85.5 g	1.0 %	85.4 g
NaCl	-	-	-	-
Preventol	0.10 %	8.4 g	0.10 %	8.3 g
Sugar	54.72 %	4663 g	53.93	4589 g
Total amount		6.7 l		6.7 l

### 4. Dielectric parameters for the recipes.

Parameter	835 MHz	900 MHz	1640 MHz	1800 MHz
Dielectric constant $\epsilon'$	45.8	42.5	41.3	41.0
Conductivity $\sigma$ (S/m)	0.76	0.85	1.51	1.65

The parameters are measured according to [5].

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## 5. Preparation procedure

1. Weigh the required amount of distilled water in a large glass jar. Begin heating and stirring and ensure that the water temperature is not more than about 75 °C.
2. When adding the different ingredients check weight of residues left in weighing containers and correct if appropriate.
3. Add the cellulose. Use about 4 dl of the heated water for mixing with the cellulose in a suitable jar to allow stirring properly with a hand mixer to avoid lumps. Add the solution to the large container on the heating plate. Adjust the speed of the magnetic stirrer and keep the solution below the boiling point. Leave the solution on the heating plate for about two hours which will allow the solution to become fairly transparent.
4. Add the preservative. Add salt if included in the selected recipe.
5. Add the sugar gently in several steps. Hand stirring to some extent is necessary in the beginning in order to allow the magnetic stirrer to work properly.
6. Keep the liquid hot but below about 75 °C for at least 12 hours. Cover the jar with plastic foam or other lid in order to avoid evaporation.
7. Turn the hotplate off. Let the brain tissue simulating liquid sit for at least 3 hours prior to performing measurement of the electrical parameters. At measurement the temperature of the liquid should be maximum 25 °C.
8. Once brain tissue simulating liquid has been measured, store mixture in designated storage container/phantom. Record information about mixing procedure and results of calibration measurement.

## 6. References

- [1] Gabriel C., Gabriel S., Corthout, *The dielectric properties of biological tissue: I literature survey*, Phys. Med. Biol., vol 41, pp 2231-2249, 1996.
- [2] Gabriel S., Lau R.W., Gabriel C, *The dielectric properties of biological tissues: II measurements in the frequency range 10 Hz to 20 GHz*, Phys. Med. Biol., vol 41, pp 2251-2269, 1996
- [3] Gabriel S., Lau R.W., Gabriel C, *The dielectric properties of biological tissues: III parametric models for the dielectric spectrum of tissues*, Phys. Med. Biol., vol 41, pp 2271-2293, 1996
- [4] Federal Communications Commission, Office of Engineering & Technology, *Evaluating Compliance with FCC Guidelines for Human exposure to Radiofrequency Electromagnetic Fields*. OET bulletin 65, 1997.
- [5] Ericsson SAR measurement specification, part 3: Measurements of dielectric parameters, ERA/T/U-98:405

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## Ericsson SAR measurement specification, part 3: Measurements of dielectric parameters.

### 1. Introduction

This document describes measurement procedure using network analyzer for testing tissue simulating liquid to be used with the DASY3 system. The measurement uses coaxial probe technique for evaluating permittivity and conductivity. The tissue liquid parameters shall be measured before testing a device. If the complete test takes more than a week, the liquid parameters shall be re measured at least once per week.

### 2. Equipment

HP network analyzer HP8752C or similar  
HP dielectric probe kit HP85070B or HP85070A  
HP 85070 software  
PC using GPIB card [3] for communication with network analyzer.  
Syringe  
small glass jars for liquid samples

### 3. Procedure for testing brain simulating liquid

1. Turn the NWA (Network analyzer) on and allow at least 30 min 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. 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 ( $\pm 1^\circ\text{C}$ ).
  - Set start and stop frequency, frequency step and water temperature.
  - Perform measurement with probe in air.
  - Perform 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 measurement with probe in distilled water.
  - Save setup file.

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5. Remeasure distilled water to check calibration. Assure that the probe is thoroughly cleaned before performing the measurement. The graph of  $\epsilon'$  versus frequency should be flat. The value of  $\epsilon'$  should be about 80.1 at 20 °C and decreasing at approximately 0.4/ °C.
6. Stir the liquid to be measured. Take a sample (50 ml) with a syringe from the center of the liquid container
7. Measure liquid shortly after calibration of the network analyzer and at most within an hour of this calibration.
8. Pour the sample liquid into a small container.
9. Put the dielectric probe into the small container. Check that there are no air bubbles in front of the opening in the dielectric probe kit.
10. 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.
11. Conductivity  $\sigma$  can be calculated from  $\epsilon''$  according to  

$$\sigma = \omega \epsilon_0 \epsilon'' \approx \epsilon'' f \text{ (GHz)} / 18.$$
12. Clean the probe thoroughly after use.

#### 4. Dielectric parameters.

The value for the dielectric constant  $\epsilon'$  is allowed to deviate  $\pm 10\%$  from the target value specified in the tissue liquid preparation document [4]. The conductivity is allowed to deviate  $\pm 5\%$  from the target value specified in the same document [4].

#### 5. References

- [1] HP 8572C Network analyzer User's guide. Hewlet Packard part number 08752-90157.
- [2] HP 85070B Dielectric probe kit manual, Hewlet Packard part number 85070-90009.
- [3] National instrument GPIB-PCII/IIA card.
- [4] Ericsson SAR measurement specification , part 2:Tissue liquid preparation ERA/T/U-98:404

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# Ericsson SAR Measurement Specification, part 4:

## Test system validation

### 1. Introduction

This document is a guide for the validation of the Dosimetric Assessment System 3 (DASY3). It is a standard guide for use at all Ericsson SAR measurement laboratories. System validation must be performed at regular and frequent intervals to ensure the accuracy of the system.

The system validation test consists of measuring the SAR in a flat phantom using a standard dipole antenna and comparing the results to a reference value. Standard dipoles and reference values are provided by the manufacturer of the DASY system, Schmid & Partner Engineering AG (SPEAG). A separate validation test is necessary for each tissue simulant and frequency range.

In the remainder of this document, a list of necessary equipment is provided, and a detailed procedure for the dipole validation is given.

### 2. Equipment

- DASY3 system from SPEAG
- Flat phantom
- SPEAG Dipole antenna kit:
  - Dipole antenna (one for each tested frequency range)
  - Validation manual for that antenna
  - Antenna stand
  - Plastic dipole spacers
- 50 ohm coax line
- Coaxial connectors
- Signal generator
- Power amplifier (optional)
- Power meter

### 3. Dipole Validation Procedure

#### 3.1 Setup of the Tissue Simulant

1. Ensure that the proper tissue simulant is present in the flat phantom.
2. Stir the liquid to ensure that it is homogeneous.
3. Measure the dielectric constant and conductivity of the simulant, as described in part 3, "Measurements of dielectric parameters." The dielectric parameter values of the simulant (permittivity, conductivity) must be within the range of values specified in part 2, "Tissue liquid preparation." Also, the frequency at which the simulant parameters are satisfied must be the same as the resonant frequency of the dipole antenna used.

#### 3.2 Setup of the Validation Dipole

1. Turn on the signal generator, power meter and power amplifier (if used). Allow them sufficient time to warm up, to reduce drift.
2. Connect the dipole antenna to the antenna stand.
3. Place the proper dipole spacer over the center of the dipole antenna.

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4. Place the dipole antenna under the flat phantom and adjust the height of the stand until the spacer is touching the shell of the flat phantom. The center of the dipole antenna should be positioned under the middle of the flat phantom, as indicated by a mark on the flat phantom.
5. Connect one end of the coax line to the power meter and the other end to the output of the signal generator (or power amplifier, if used).
6. Set the signal generator to transmit in CW mode and ensure that any signal modulation is turned off. This ensures that the power amplifier will transmit a pure sinusoid.
7. Set the frequency of the signal generator to the resonant frequency of the dipole antenna.
8. Set the output power of the signal generator (and optionally adjust the gain of the power amplifier) so that one watt of power is delivered to the power meter.
9. Disconnect the coax line from the power meter and connect it to the dipole antenna.

### 3.3 Measurement Procedure

1. Turn on the robot controller and the computer.
2. Install the 3D electric field probe as shown in the SPEAG manual.
3. Power up the DAE. The LED indicates that the power is on.
4. Start the DASY3 software and set up the communications between the software and the robot.
5. Teach the robot the phantom reference positions.
6. Record the dielectric constant and conductivity of the simulant in the DASY3 software.
7. Choose the appropriate measurement configuration in the DASY3 software for the dipole validation measurement.
8. Tell the robot to move the probe tip below the surface of the liquid. Stir the liquid again to remove any bubbles trapped under the probe tip.
9. Open a measurement file. Select the predefined dipole validation test provided by SPEAG. This file includes all of the necessary measurements for the dipole validation.
10. Run the reference check.
11. Run the coarse scan, fine scan, and drift measurements.
12. Compare the one-gram and ten-gram averaged peak SAR values to the standard values provided in reference documents. If they do not agree within  $\pm 5\%$ , check the system parameters (e.g. antenna output power, dielectric parameters of the simulant, homogeneity of the liquid) and repeat the measurement.
13. Make sure that the drift measurement is below an acceptable value. If not, check the system parameters and repeat the measurement.
14. Save the measurement data and enter it into the logbook.

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## Ericsson SAR Measurement Specification, part 5: Calibration of Equipment

### 1. Introduction

This document provides calibration information for the equipment used in Ericsson's SAR measurement facilities. This document is a standard guide for use at all Ericsson SAR measurement laboratories. In this document, a list of equipment (including manufacturer and frequency of calibration) is provided, and the addresses of the manufacturers are given. It is the responsibility of Ericsson staff to keep track of calibration dates and ensure that the equipment has been sent for calibration. In some cases, the equipment may need to be sent off-site for calibration. Equipment calibration is mandatory according to ISO 9000 rules.

### 2. Equipment and Calibration Information

Equipment	Manufacturer	Calibrate every...
Network Analyzer	Hewlett-Packard	1 year
Dielectric probe kit	Hewlett-Packard	1 year
Probes (E and H field)	SPEAG	1 year
Data Acquisition Electronics	SPEAG	1 year
Dipole antennas	SPEAG	2 years
Base station simulators	WaveTek, other	1 year
Signal generator	Hewlett-Packard	1 year
Power meters	Hewlett-Packard	1 year
Power sensors	Hewlett-Packard	1 year
Robot	Stäubli	5 years or 10,000 hours of operation (whichever is greater)

### 3. Addresses of Manufacturers

Hewlett Packard Test & Measurement  
Mail Stop 51LSJ  
P.O. Box 58199  
Santa Clara, CA  
95052-9952

SPEAG (Schmid & Partner Engineering AG)  
Staffelstrasse 8  
8045 Zürich  
Switzerland  
Tel: +41 1 280 0860

WaveTek Corporation  
5808 Churchman Bypass  
Indianapolis, IN  
46203-6109

Stäubli Faverges  
Place Robert Stäubli  
F-74210 Faverges, France

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## Ericsson SAR Measurement Specification, part 6:

### DUT Preparation and Characterization

#### 1 Introduction

This part describes how the properties of the DUT should be characterized and how the DUT is prepared prior to a SAR measurement.

#### 2 DUT characterization

##### 2.1 The peak power level

The peak power level of the DUT is set to the maximum during the SAR measurement. If this is not possible for some reason, a lower peak power level can be set but the resulting SAR values must then be normalized to the maximum level after the measurement according to equation 1. The peak power level is either measured with a power meter, with a sensor suitable for the carrier frequency and the duty cycle, or a digital radio tester.

$$SAR_{norm} = SAR_{meas} \cdot \frac{P_{max}}{P_{meas}} \quad (1)$$

##### 2.2 The carrier frequency

SAR measurements shall be performed for three carrier frequencies, the lowest possible, the middle and the highest possible for each transmitter band of the DUT. The carrier frequency is measured with a spectrum analyzer. (A suitable analyzer setup for measuring GSM frequencies is: SPAN=2 MHz, RES BW=30 kHz, VBW=30 kHz and SWEEP=4 seconds).

##### 2.3 The duty-cycle

If the duty-cycle of the signal transmitted by the DUT is not known it can be measured with a spectrum analyzer with the center frequency set equal to the carrier frequency of the transmission and the span set to zero. For TDMA systems, the RF exposure assessment shall always be performed with the maximum possible duty-cycle (denoted d). In a CDMA system, on the other hand, bursting is often introduced gradually when the voice activity of the user changes but during the SAR measurement it has to be fixed and at the maximum value. If the maximum duty-cycle is not possible to obtain, the assessed SAR results have to be normalized to the used duty-cycle according to:

$$SAR_{norm} = SAR_{meas} \cdot \frac{d_{max}}{d_{meas}} \quad (2)$$

Analog mobile communications systems use continuous transmission and thus the duty-cycle is always equal to one.

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## 2.4 Antenna configuration

- For handset devices with extendable antennas, SAR measurements have to be performed both with the antenna retracted and pulled out.
- Handsets with replaceable antennas must be tested with all available antennas. Antennas that can assume different positions, for instance swivel antennas, are tested for those positions that are defined by the hinge or latch mechanism.
- Base stations with several integrated antennas, for instance micro and pico base stations, are measured for all possible antenna configurations that will be used at the base station site.
- Base station antennas are measured with the radiating elements configured so that the maximum possible exposure situation is obtained.

## 3 Preparing and setting up the DUT for a SAR measurement

### 3.1 Handset setup

The mobile phone is placed in contact with the head phantom so that the center of the ear-piece is directly below the spacer on the phantom corresponding to the position the auditory canal as shown in Fig. 1. With the ear-piece pressed against the head, the next step is to align the phone axis of symmetry with an imaginary plane consisting of the three lines joining both ears and the mouth. The phone is then gradually moved towards the cheek until any part, flip or keypad, touches the cheek. SAR measurements shall be performed for both right hand side and left hand side use.

For push-to-talk handsets, the normal use position is in front of the face and the exposure from such a device is assessed by placing it 5 cm below the flat section of the phantom.

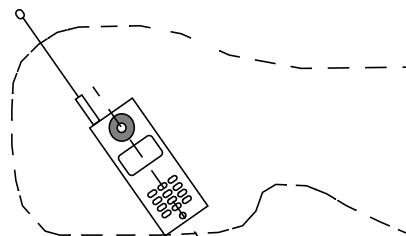


Figure 1. The placement of a handheld DUT close to the head phantom.

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### 3.2 BS antenna setup

Figure 2 shows the base station antenna setup below the flat section of the DASY generic twin phantom. This type of structure is normally too large to be positioned with the stand used for handheld test devices and therefore a larger stand or table of nonconducting material capable of supporting the whole antenna should be used. When testing base stations with integrated antennas this setup is also recommended. The test distance is dependent on the application, for indoor low power basestations a typical test distance is 5 cm.

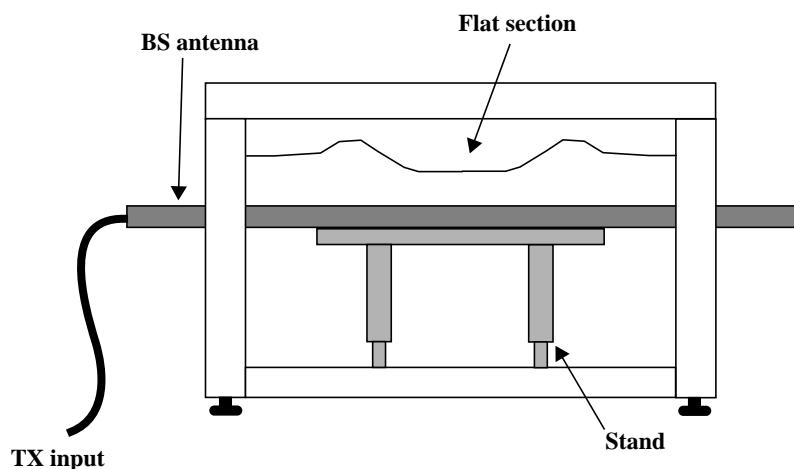


Figure 2. The setup for measurements of SAR in the flat section from base station antennas.

### 3.3 RF, power supply and control cables

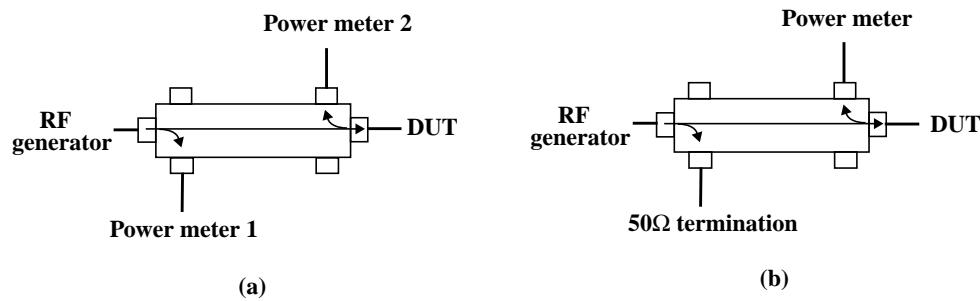
- Handsets operate on battery power and before the SAR measurements the battery must contain enough charge for the measurement time, a fully charged battery is recommended. For compliance testing, no power supply or control cable should be connected to the handset since they will interfere with the fields radiated from the antenna. RF cables connected to prototype handset with no integrated transmitter circuitry must be placed in such a way that the interference with the radiated fields is limited, ferrites on the cable close to the connectors are recommended. Section 4 describes the cable setup when testing devices supplied with external RF power.
- Base stations with integrated antennas are supplied with power from an external power line and this cable shall be connected to the DUT in such a way that interference to the radiated fields is limited. This also applies to control and transmission cables.
- Base station antennas are supplied with RF power from a signal generator and the cables should be connected via a directional coupler giving a possibility of monitoring the reflected power. This setup is explained in section 4.

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#### 4 Monitoring the DUT during the SAR measurement

Since handsets operate on batteries it is important to monitor the output signal from the DUT during the exposure assessment and a spectrum analyzer with a sensor antenna placed close to the device is recommended. If a digital radio tester is used for controlling the DUT the reported power level is easily monitored but for DUTs supplied with the RF signal from a generator the cable configurations shown in Fig. 3 should be used.

For the case of a DUT supplied with RF power through a cable, when the antenna is placed close to the phantom a load mismatch is introduced and RF power will be reflected back to the generator. A power meter monitoring this amount of power is connected through a directional coupler to the feeding cable according to Fig 3 (a) or (b). The power meter 1 in figure (a) measures the forward power from the generator, normally this power doesn't change much during a SAR measurement and a setup according to (b) is in most cases sufficient.



**Figure 3. Cable configurations for monitoring forward and reflected power with a directional coupler. (a) shows the setup for monitoring both properties and (b) the reflected power measurement setup.**

Note, before the SAR measurement is started the power delivered from the signal generator to the DUT should be measured at the end connector of the supplying cable.

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## Ericsson SAR Measurement Specification, part 7:

### SAR Measurement Procedure

## 1 Introduction

This part of the Ericsson SAR Measurement Specification describes the practical process of assessing the specific absorption rate (SAR) in the head phantom with the SPEAG dosimetric assessment system (DASY). The requirement for use of this instruction is a basic knowledge of the DASY hardware and software, including probe mounting and powering up the system.

## 2 Measurement system

### 2.1 Equipment

The main parts of the SPEAG dosimetric assessment system (DASY) are a six axis robot with controller, an E-field probe, a stand incorporating head phantoms with sections for left hand and a right hand side usage and a stand for positioning the mobile phone (DUT) close to the phantom. A computer with a PC card controls the robot and collects the data from the probe. Fig. 1 below shows an overview of the DASY.

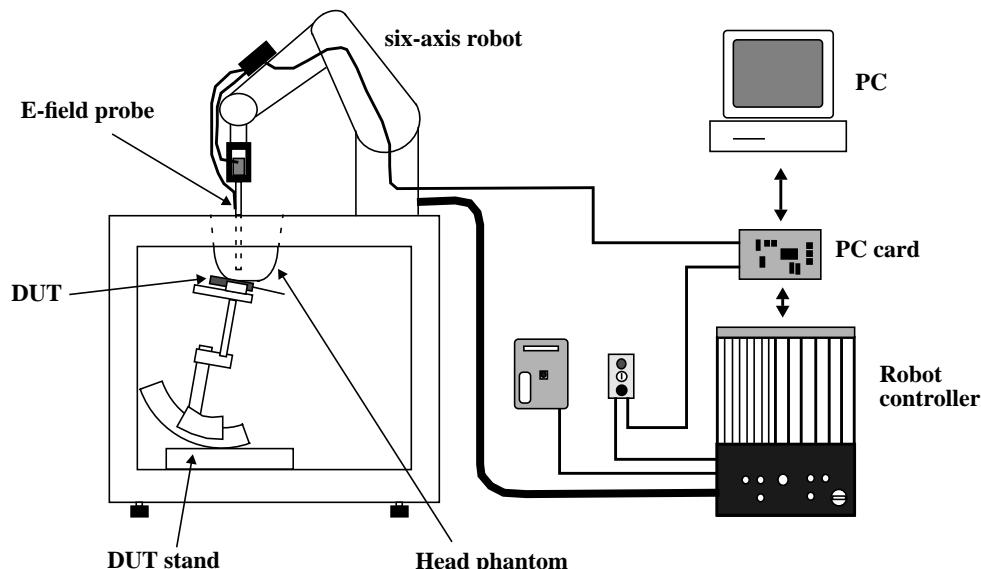


Figure 1. The dosimetric assessment system used for measuring SAR in a head phantom structure.

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### 2.1.1 Probe specification

The ET3DV5 probe by Schmid & Partner Engineering AG for measurements of SAR is sensitive to E-fields and thus incorporates three small dipoles, each only 3 mm long, arranged so that the overall response is isotropic. The table below summarizes the technical data for the probe which is used at all Ericsson SAR measurement laboratories.

Property	Data
Frequency range	30 MHz - 3 GHz
Linearity	±0.2 dB
Dynamic Range	5 mW/kg - 100 W/kg
Directivity (around probe axis)	±0.1 dB
Directivity (normal to probe axis)	±0.4 dB
Spatial resolution	< 0.125 mm <sup>3</sup>
Probe positioning repeatability	±0.2 mm

Table 1 The technical data for the SAR probe ET3DV5.

### 2.1.2 Head phantom and tissue simulating liquid

The head phantom used in the DASY has a shape that is based on anatomical data for the heads of a number of individuals. These persons were chosen so as to represent a cross-section of all mobile phone users. The phantom is a fiberglass shell with a thickness equal to 2 mm and 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. The phantom shell is filled with a liquid that simulates the brain tissue at the frequency of interest. In the middle of the phantom there is a flat section for other exposure measurements including tests of devices held close to the waist. The flat section of the phantom is also used for system validation.

## 2.2 Peak SAR determination procedure

The DUT is positioned below the head phantom according to the binder part on DUT preparation and characterization and the transmitter is powered on before the SAR measurement starts. The robot first moves the probe to a reference position in the tissue liquid and the E-field is recorded in this position for comparison with an identical measurement after the actual SAR scan; this for ensuring the power stability of the transmitter. Then the probe is moved in a coarse grid following the curved inner surface of the head phantom. In this measurement the robot is guided by the optical sensor in the tip of the probe and the size of the scanned region is selected large enough to guarantee that all possible peak SAR areas are included. The specific absorption rate (SAR) is calculated from the recorded E-fields by the following expression:

$$SAR = \sigma \frac{E^2}{\rho}$$

where  $\sigma$  is the conductivity in Siemens/meter and  $\rho$  is the density in kg/m<sup>3</sup> of the liquid.

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Measurements are then taken in a fine grid, typically 5x5x7 points with 5 mm between the individual points, around the position of the maximum SAR recorded in the coarse scan. Numerical interpolation and extrapolation are 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 which cannot be reached with the E-field probe. The 1g and 10g averaged SAR values are computed by shifting cubes with side lengths of 10mm and 21.5 mm, respectively, over the fine grid volume. The recorded peak SAR is the maximum value of all the evaluated positions. Finally, the second reference point measurement is performed.

## 2.3 Measurement uncertainty

The total SAR assessment uncertainty is 20% and includes the measurement system uncertainty, the source uncertainty and the phantom uncertainty. Each of these uncertainties consists of a number of individual factors taking into account uncertainties associated with the probe, the SAR evaluation, the positioning of the device, the device output power level, the laboratory setup, the phantom shape and material.

# 3 Measurement setup

Before the measurement is conducted the device under test and the DASY equipment have to be properly setup in order to limit the sources of error.

## 3.1 DUT setup

Depending on the DUT use the appropriate instructions, i.e either section 3.1.1 or section 3.1.2. For additional instructions see binder part on DUT preparation and characterization.

### 3.1.1 Handset setup

1. Power up the handset and set the carrier frequency, the power level and if possible the duty-cycle of the transmitter to the appropriate values.
2. Position the device under the proper section of the head phantom. SAR measurements shall be performed for both right and left hand side use.

### 3.1.2 Base station antenna setup

1. Position the base station antenna below the flat section of the phantom.
2. Connect the cable from the directional coupler and the signal generator.
3. Power up the signal generator and set the carrier frequency and the power level.
4. Let the generator warm up for about 30 minutes without the RF output activated before proceeding with the SAR measurement.

## 3.2 Additional setup

1. Power up the spectrum analyzer and set the center frequency, span and sweep time to appropriate values considering the DUT transmitter. Let the analyzer warm up for about 30 minutes before proceeding.
2. Take still pictures of the measurement setup and the DUT to be used in the documentation.

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### 3.3 DASY setup

The instructions of this section are only valid under the assumption that the equipment is calibrated and validated.

1. Mount the probe for SAR measurements on the DAE.
2. Remove the plastic cover on the phantom.
3. Power up the DAE. The LED indicates power on.
4. Power up the computer.
5. Power up the robot controller.
6. Start the DASY-software on the computer.
7. Choose the appropriate 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.
8. Power up the robot arm by pressing the robot button in the toolbar.
9. Align the probe.
10. Check that the system is properly initiated by moving the probe to the three reference points. If the probe has been removed and mounted again on the DAE, the installation process has to be repeated. Otherwise, check the distance between the reference points and the probe tip with the plastic spacer. If ok, move the probe to the resting point above the flat section.
11. Check the optical proximity sensor by moving the probe to the liquid surface.
12. Move the probe back to the resting point.
13. Move the probe to the selected measurement section.

## 4 Measurement procedure

1. Open the appropriate predefined measurement file and rename it. Or, prepare a new measurement file by selecting jobs from the menu. Do not forget to enter information on the power level and the carrier frequency of the DUT and the name of the operator in the comments window.
2. Check the setup of the DUT.
3. Start the transmitter in the DUT. Check the signal with the spectrum analyzer.
4. Select the desired measurement jobs and start the SAR measurement.
5. When the SAR measurement is finished turn the DUT transmitter off.
6. Save the measurement data.

## 5 Post measurement procedure

1. When the SAR measurements are finished, power off the DUT.
2. Move the probe to the resting point and clean it with warm water.

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3. Power off the robot arm and the DAE.
4. Power off the controller.
6. Exit the DASY software and power off the computer.
7. Power off the additional equipment, spectrum analyzers etc.
8. Enter information on the performed measurements in the laboratory log-book.

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## Ericsson SAR measurement specification, part 8: Documentation of results

### 1. Introduction

It is very important that a SAR test and the obtained results are well documented and that the data is stored in a safe way. A SAR test should be able to repeat in any of the Ericsson SAR laboratories based on the information in the documentation. Depending on the type of test, different types of reports may be issued. These are described below.

### 2. SAR test report

A SAR test report shall always be issued when a new product is tested for compliance with RF safety recommendations, standards and regulations. The SAR test report should be an internal and confidential document. If the SAR test is required for type approval, as for handheld mobile telephones in the U.S. and Australia, the SAR test may be sent to the regulator (for example the FCC or ACA) if demanded. Annex 1 shows the template for the report. All Ericsson SAR test reports should follow this template.

### 3. Declaration of conformity

A Declaration of Conformity (DOC) shall always be written when a SAR test report has been issued. This is normally the only document that is sent to the regulators that require SAR tests (FCC, ACA). The DOC is an open document that can be sent to, for example, customers and authorities that have requested information on SAR compliance test results for a product. Annex 2 shows the template for the document. All Ericsson DOCs should follow this template.

### 4. Technical report

Results from R&D related SAR measurements, for example of prototypes, modified products and non-Ericsson products, should normally not be documented in a SAR test report, but in a technical report. The format of this report may vary, depending of the type of test. The report should however include all information necessary to repeat the test later. In order to document detailed information from a SAR compliance measurement of a new product, a technical report may be issued in addition to the normal SAR test report. The technical report should be an internal and confidential document.

### 5. Storage of test data and reports

The test results (raw data) shall be stored in the SAR test laboratory. A backup of the data files shall be stored in a safe place. The SAR test reports, DOC documents and technical reports shall be stored locally where the tests have been conducted. Copies of SAR test reports and DOCS should normally also be stored in the appropriate product compliance folders and also be distributed to the other Ericsson SAR test laboratories.

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## Ericsson SAR Measurement Specification, part 9:

### Bibliography

#### Documents provided with the binder:

- [1] Federal Communications Commission Office of Engineering & Technology, OET Bulletin 65 (Edition 97-01), Supplement C, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields".
- [2] Radiocommunications (Electromagnetic Radiation Human Exposure) Standard 1999, Australian Communications Authority (ACA), May 1999.

#### Further literature:

- [3] 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.
- [4] 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.
- [5] 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.
- [6] N. Kuster, R. Kästle and T.Schmid, "Dosimetric Evaluation of Handheld Mobile Communications Equipment with Known Precision", *IEICE Transactions on Communications*, vol. E80-B, no. 5, pp. 645-652, May 1997.
- [7] S.Gabriel, R.W. Lau and C. Gabriel, "The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz", *Phys. Med. Biol.* 41 (1996), pp. 2251-2269.
- [8] G. Hartsgrove, A. Kraszewski and A. Surowiec, "Simulated biological materials for electromagnetic radiation absorption studies", *Bioelectromagnetics*, vol. 8, pp. 29-36, 1997.

#### User's manuals and system data provided with the equipment:

- [9] Schmid&Partner Engineering AG, "DASY3 User Manual", April 1999 Edition, Zurich, Switzerland.
- [10] Hewlett-Packard Company, "HP85070B Dielectric Probe Kit User's manual", HP part number 85070-90009, 1993.
- [11] Dosimetric system calibrations data.

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## Ericsson SAR Measurement Specification, part 10:

### Glossary of Symbols and Acronyms

$\sigma$	Conductivity (S/m)
$\epsilon_0$	Permittivity of free space = $8.854 \times 10^{-12}$ F/m
$\epsilon'$	Relative real part of complex permittivity (unitless)
$\epsilon''$	Relative imaginary part of complex permittivity (unitless)
$f$	Frequency (Hz)
$\omega$	Radial frequency (rad/s)
ACA	Australian Communications Authority
ANSI	American National Standards Institute (USA)
ARIB	Association of Radio Industries and Businesses (Japan)
AS/NZS	Australian Standard / New Zealand Standard
BW	Bandwidth
CDMA	Code-Division Multiple Access
CENELEC	European Committee for Electrotechnical Standardization
CW	Continuous wave
DAE	Data Acquisition Electronics
DASY	Dosimetric Assessment System
DECT	Digital Enhanced Cordless Telephone
DOC	Declaration of Conformity
DUT	Device under test
E-field	Electric field
EMF	Electromagnetic field
ES	European Standard
FCC	Federal Communications Commission (USA)
GPIB	General Purpose Interface Bus
GSM	Global System for Mobile communications
HEC	Hydroxyethyl-cellulose
HP	Hewlett-Packard
ICNIRP	International Commission on Non-Ionizing Radiation Protection (Europe)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers (USA)
LED	Light-emitting diode
MPT	Ministry of Posts and Telecommunications (Japan)
MTE	Mobile Telecommunication Equipment
NWA	Network Analyzer
OET	Office of Engineering and Technology of the FCC
PC	Personal Computer
RLL	Radio Local Loop
RF	Radio Frequency
SAR	Specific Absorption Rate (W/kg)
SPEAG	Schmid and Partner Engineering AG
TDMA	Time-Division Multiple Access

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**ANNEX 1****SAR Assessment Measurements****Test Report****for the****Ericsson R250d****Triple Mode Telephone***Electromagnetic Near Field and Radio Frequency Dosimetry Laboratory**Research Triangle Park, NC, USA***Test Equipment:**

<u>Description</u>	<u>Asset Number</u>	<u>Due Date</u>
DASY3 DAE V1	s/n 345	9911
E-field probe ETDV5	s/n 1337	0003
Dielectric probe kit HP 85070B	s/n US33020390	0002
Network analyzer HP 8752C	inv. 57248	0007
Power meter HP 437B	s/n 3125U13481	9912
Power sensor HP 8482H	s/n 3318A07097	0002
Radio Comm. Analyzer Anritsu MT8801B	s/n MB12477	9911
Dipole Validation Kit, D900V2	s/n 035	0003
Dipole Validation Kit, D1800V2	s/n 217	0001

Test approved:  
Mark Douglas, Ph.D.

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## 1. Introduction

In this test report, Specific Absorption Rate (SAR) measurements for the Ericsson R250d portable telephone are presented. The measurements were conducted at the dosimetry laboratory at Ericsson, Inc. in Research Triangle Park, North Carolina, USA. The report describes the test procedures that were used and the test results that were recorded.

## 2. Device Under Test (D.U.T.)

### 2.1 Antenna Description

<b>Type</b>	40mm dual band stub	
<b>Location</b>	Back and left	
<b>Dimensions</b>	length	40 mm
	diameter at base	12 mm
<b>Configuration</b>	Fixed helix	

### 2.2 Portable Telephone Description

<b>Device name</b>	R250d		
<b>Serial number</b>	UA2011QBN1		
<b>Certification Number</b>	AXATR-399-A2		
<b>Mode</b>	AMPS	D-AMPS 800	D-AMPS 1900
<b>Multiple Access Scheme</b>	FDMA	TDMA	TDMA
<b>Duty Cycle</b>	1	1 / 3	1 / 3
<b>Peak Power Nominal</b>	26.0 dBm	26.0 dBm	26.0 dBm
<b>Center Frequency</b>	837 MHz	837 MHz	1880 MHz

## 3. Brain tissue simulating liquid data

The electrical data used for the brain tissue simulating liquid are given in next table:

$f$ ( MHz )	835	1800
$\epsilon_r$	44.3	40.4
$\sigma$ ( S/m )	0.78	1.78

The depth of the brain tissue simulating liquid was 15.5cm. The SAR measurements were performed at a room temperature of 22.0 °C.

## 4. Validation

Immediately before measuring the SAR of the device under test, the measurement system was validated by measuring the SAR of a standard dipole antenna located a set distance underneath a flat phantom. The measured results are compared with expected values that are recorded in reference documents. The results are given below.

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Dipole	Output Power (W)	1 gram averaged SAR (W/kg)		difference (%)
		Expected	Measured	
D900V2	1	9.52	9.82	3.1
D1800V2	1	12.90	13.21	2.4

## 5. Test Results

The conducted output power and the SAR values for the low, middle and high frequencies of each mode are shown below. Results are presented for the worst-case between the right hand phantom and the left hand phantom according to [I]. The conducted output power was measured with a power meter. The SAR results shown are maximum SAR values averaged over 1 g of tissue. These SAR values are within the FCC limits for the uncontrolled RF exposure environment.

Mode	f (MHz)	Output Power (dBm)	SAR(1g) (W/kg)
AMPS	824	27.1	1.35
	837	26.2	1.25
	849	24.8	0.794
D-AMPS 800	824	26.8	0.491
	837	26.4	0.431
	849	25.7	0.256
D-AMPS 1900	1850	26.1	0.201
	1880	26.2	0.198
	1910	25.3	0.152

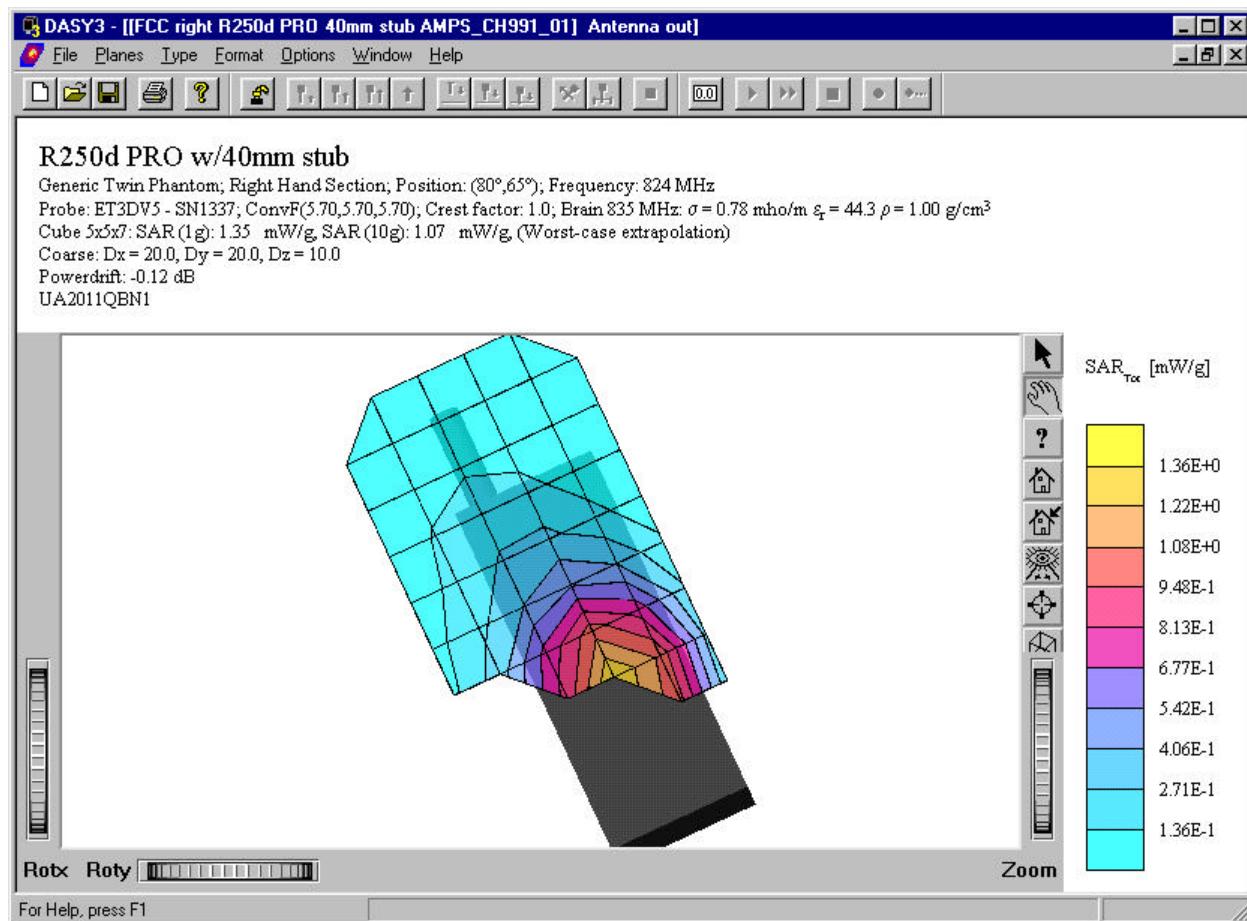
SAR measurement results for the Ericsson R250d telephone at maximum rated output power.

## Reference

[I] "Ericsson SAR Measurement Specification", C.Törnevik, M.Siegbahn, T.Persson, M.Douglas, R.Plicanic, February 1999.

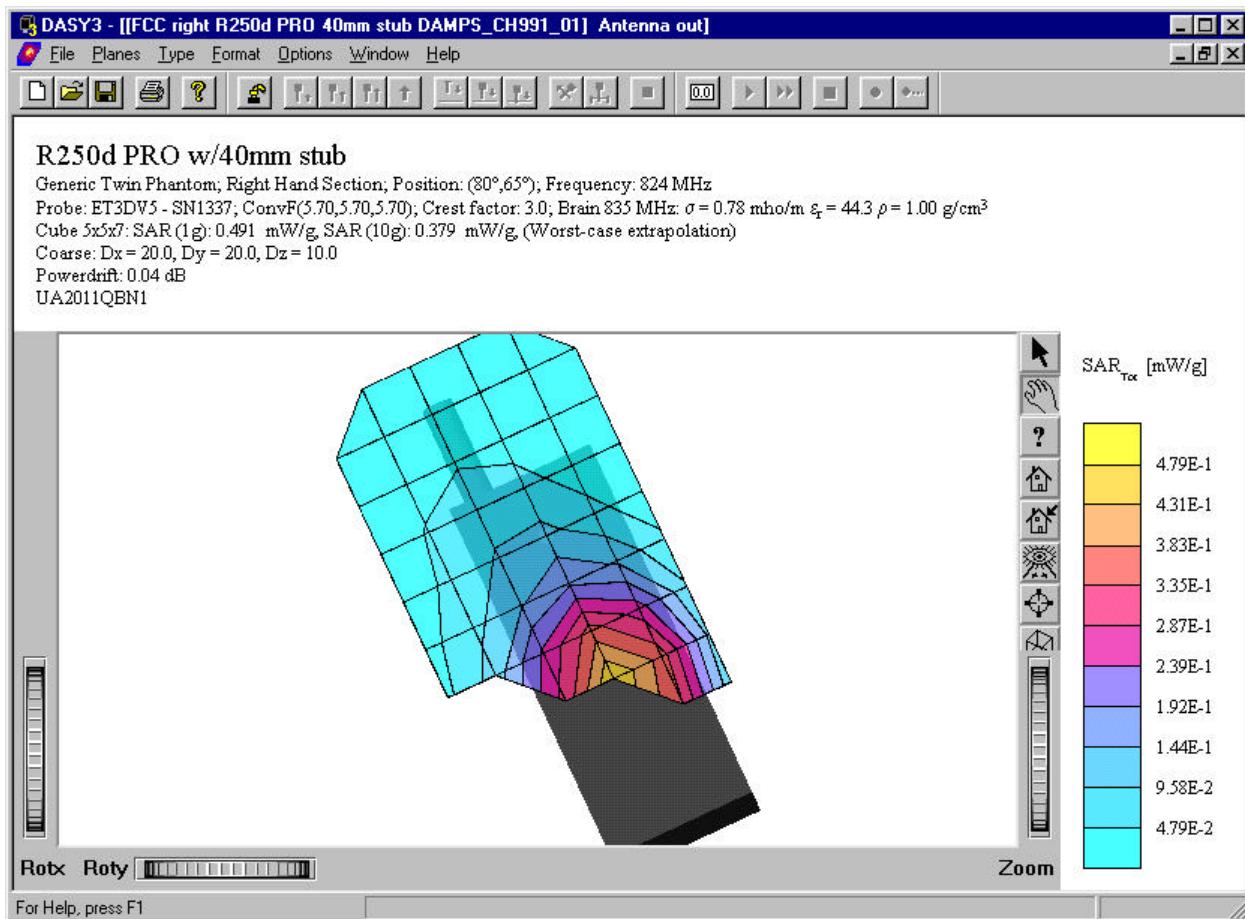
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## Appendix 1: SAR distribution plots



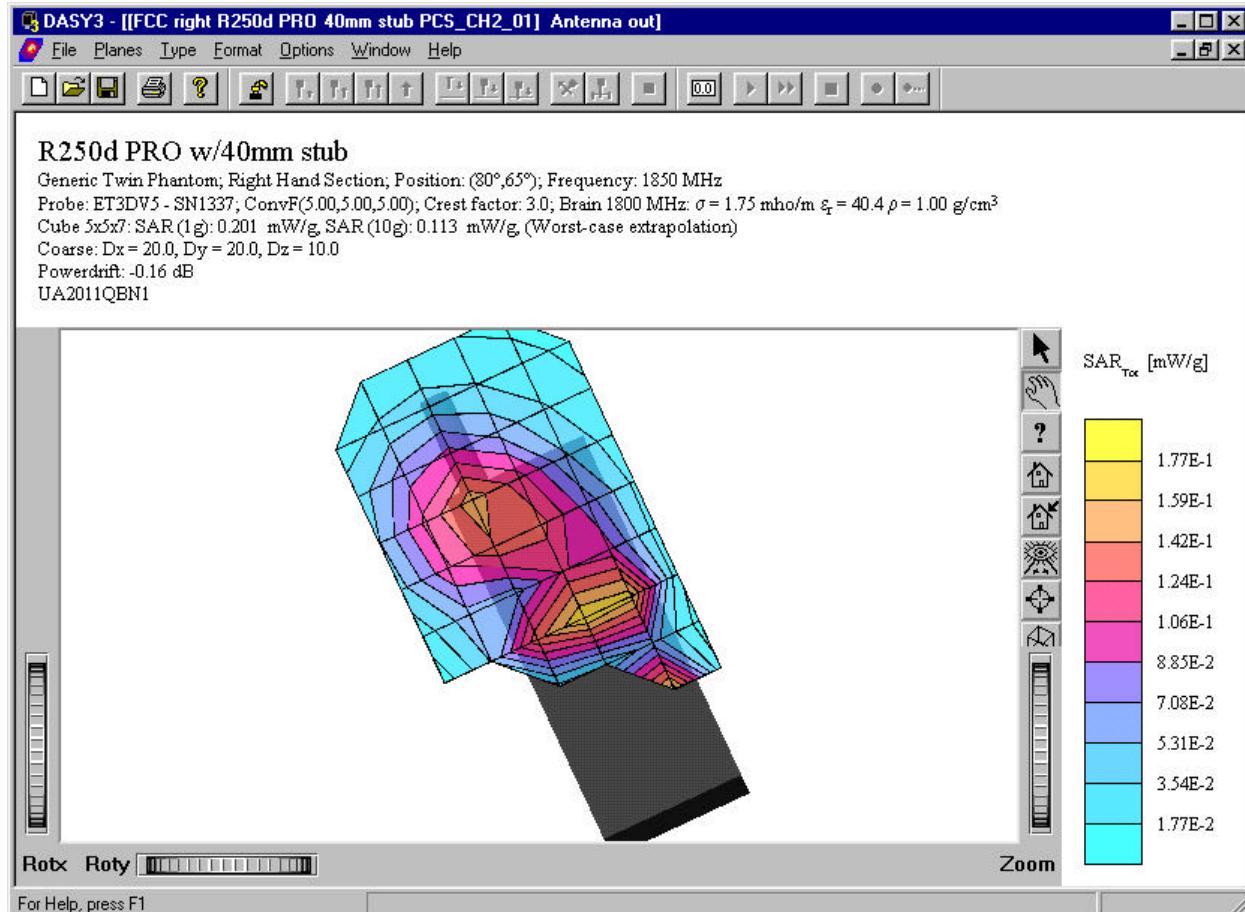
Distribution of worst-case SAR in AMPS mode.

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**Distribution of worst-case SAR in D-AMPS 800 mode.**

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**Distribution of worst-case SAR in D-AMPS 1900 mode.**

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## Appendix 2: Photographs of the device under test



**Front view of device.**

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**Side view of device.**

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## Appendix 3: Position of device on Generic Twin Phantom





Attending to this matter, name, telephone  
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Our Reference  
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## DECLARATION OF CONFORMITY

We, Ericsson Radio Systems AB of  
Torshamnsgatan 23  
164 80 Stockholm

declare under our sole responsibility that the product

*KRCNB 403 AA/N  
(Ericsson DECT BS230)*

to which this declaration relates, is in conformity with the appropriate RF exposure standards, recommendations and guidelines:

*IEEE/ANSI C95.1-1992  
FCC OET Bulletin 65 (Supplement C)  
CENELEC ENV 50166-2:1995  
AS/NZS 2772.1 (Int) - 1998  
ICNIRP (1998)*

Stockholm 1999-02-22

.....  
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Position Expert, Electromagnetic Fields