TTI-P-G 158

Report

Dosimetric Assessment of the Mobile Telephone Siemens S40 According to the American FCC Requirements In Body worn configuration

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Executive Summary

The device S40 is a new mobile phone from Siemens operating in the 1900 MHz frequency range. The device has an integrated antenna. The system concept used is the PCS 1900 standard.

The objective of the measurements done by IMST was the dosimetric assessment of one device. The examinations have been carried out with the dosimetric assessment system „DASY3“.

The measurements were made according to the Federal Communications Commission (FCC) Guidelines [FCC 1997] for evaluating compliance of mobile phones with the IEEE Standard C95.1 [IEEE 1999]. In [IEEE 1999] limits are defined to prevent harmful effects in human beings exposed to electromagnetic fields.

The Siemens S40 mobile phone (IMEI: 004513-67-000001-5) is in compliance with the IEEE Standard C95.1 [IEEE 1999].

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1 Subject of Investigation

The device S40 shown in Fig. 1 is a new mobile phone from Siemens operating in the 1900 MHz frequency range. The device has an integrated antenna. The system concept used is the PCS 1900 standard.

Fig. 1: Picture of the device under test.

The objective of the measurements done by IMST was the dosimetric assessment of one device. The examinations have been carried out with the dosimetric assessment system „DASY“ described below.

2 The IEEE Standard C95.1

In the USA the recent IEEE Standard C95.1 was published in April 1999 [IEEE 1999]. It sets limits for human exposure to radiofrequency fields in the frequency range 3 kHz to 300 GHz.

2.1 Distinction Between Exposed Population, Duration of Exposure and Frequencies

The American standard distinguishes between controlled and uncontrolled environment. Controlled environments are locations where there is exposure that may be incurred by persons who are aware of the potential for exposure as a concomitant of employment or by other cognizant persons. Uncontrolled environments are locations where there is the exposure of individuals who have no knowledge or control of their exposure. The exposures may occur in living quarters or workplaces. For exposure in controlled environments higher field strengths are admissible. In addition the duration of exposure is considered.

The code of Federal Regulations [CFR 47] also distinguishes between fixed and mobile respectively portable transmitters. A mobile device is defined as a device which is designed to be used in other than fixed locations and a separation distance of at least 20 cm between its radiation structure and the body of the user. On the other hand a portable devise (mobile telephone) is defined with a separation distance within 20 cm.

Due to the influence of frequency on important parameters, as the penetration depth of the electromagnetic fields into the human body and the absorption capability of different tissues, the limits in general vary with frequency.

2.2 Distinction between Maximum Permissible Exposure and SAR Limits

The biological relevant parameter describing the effects of electromagnetic fields in the frequency range of interest is the specific absorption rate SAR (dimension: power/mass). It is a measure of the power absorbed per unit mass. The SAR may be spatially averaged over the total mass of an exposed body or its parts. The SAR is calculated from the r.m.s. electric field strength E inside the human body, the conductivity σ and the mass density ρ of the biological tissue:

$$SAR = \sigma \frac{E^2}{\rho} = c \left. \frac{\partial T}{\partial t} \right|_{t \to 0+} \quad . \tag{1}$$

The specific absorption rate describes the initial rate of temperature rise $\partial T / \partial t$ as a function of the specific heat capacity c of the tissue. A limitation of the specific absorption rate prevents an excessive heating of the human body by electromagnetic energy.

As it is sometimes difficult to determine the SAR directly by measurement (e.g. whole body averaged SAR), the standard specifies more readily measurable maximum permissible exposures in terms of external electric E and magnetic field strength H and power density S, derived from the SAR limits. The limits for E, H and S have been fixed so that even under worst case conditions, the limits for the specific absorption rate SAR are not exceeded.

For the relevant frequency range the maximum permissible exposure may be exceeded if the exposure can be shown by appropriate techniques to produce SAR values below the corresponding limits.

2.3 SAR Limit

In this report the comparison between the American exposure limits and the measured data is made using the spatial peak SAR; the power level of the device under test guarantees that the whole body averaged SAR is not exceeded.

Having in mind a worst case consideration, the SAR limit is valid for uncontrolled environment and mobile respectively portable transmitters. According to Table 1 the SAR values have to be averaged over a mass of 1 g (SAR_{1g}) with the shape of a cube.

Standard	Status	SAR limit [W/kg]
IEEE C95.1	In force	1.6

Table 1: Relevant spatial peak SAR limit averaged over a mass of 1 g.

3 The American Measurement Procedure

The Federal Communications Commission (FCC) has published a report and order on the 1st of August 1996 [FCC 1996], which requires routine dosimetric assessment of mobile telecommunications devices, either by laboratory measurement techniques or by computational modeling, prior to equipment authorization or use. In 1997 the FCC has published additional information for evaluating compliance of mobile and portable devices with FCC limits for human exposure to radiofrequency emissions [FCC 1997]. This supplement is not intended, however, to establish mandatory procedures, and other methods and procedures may be acceptable if based on sound engineering practice.

3.1 Test Conditions

The device under test has to operate at maximum power level with a fully charged battery during the measurement. The SAR test has to be performed with the mobile phone transmitting at three different frequencies in the allocated frequency band: lowest frequency, center frequency, and highest frequency. For devices with retractable antenna the tests shall be performed with the antenna fully extended and fully retracted.

3.2 Test Position

The lack of standardized test positions for evaluating handsets can result in difficulties in determining RF compliance with SAR limits. Therefore the FCC recommends one test position (other test positions representing normal operating positions are also acceptable):

First the device is positioned in a normal operating position with the center of its ear-piece aligned with the location of the ear canal on a simulated head model. With the ear-piece pressed against the head, the next step is to align the vertical center-line of the body of the handset with an imaginary plane consisting of the three lines joining both ears and the tip of the mouth. While maintaining these alignments, the body of the handset is gradually moved towards the cheek until any point on the mouth-piece or keypad is in contact with the cheek.

If the mobile phone provides a jack to use a headset and thus using of the mobile in any positions is possible, dosimetric assessment in a body-worn configuration is required. In the most cases the antenna may become closer to the users body then next to the head. This testing is performed with the use of the flat section of the generic twin phantom. The mobile is placed with the keypad facing away from the phantom with connected headset.

In that case a holster, carrying case or a belt clip are provided or are available as an accessory a dosimetric assessment with this configuration is also required. The mobile is placed with the keypad facing away from the phantom.

4 The Measurement System

DASY is an abbreviation of „Dosimetric Assessment System“ and describes a system which is able to determine the SAR distribution inside a phantom of a human being according to different standards. It consists of a robot, several field probes calibrated for use in liquids, a shell phantom, tissue simulating liquid and software. The software controls the robot and processes the measured data to compare them with safety levels with respect to human exposure to radio frequency electromagnetic fields. Fig. 2 shows the equipment, similar to the installations in other laboratories [DASY 1995].

Fig. 2: The measurement setup with a phantom containing tissue simulating liquid and a device under test.

A mobile phone operating at the maximum power level is placed by a non metallic device holder in a well-defined position at a shell phantom of a human being. The distribution of the electric field strength E is measured in the tissue simulating liquid within the shell phantom. For this miniaturized field probes with high sensitivity and low field disturbance are used. Afterwards the corresponding SAR values are calculated with the known electrical conductivity σ and the mass density ρ of the tissue. The system software is able to determine the averaged SAR values (averaging region 1 g or 10 g) for compliance testing.

This is done by two scans: first a coarse scan determines the region of the maximum SAR, afterwards the 1 g or 10 g averaged SAR is measured in a second fine scan. The measurement time takes about 20 minutes.

The phantom (generic twin phantom) is a fiberglass shell integrated in a wooden table. The thickness of the phantom amounts to 2 mm ± 0.1 mm. It enables the dosimetric evaluation of left

and right hand phone usage. The phantom setup includes a coverage (polyethylene) which prevents the evaporation of the liquid. The ear is simulated by ensuring a space of 4 mm thickness between the tissue simulating liquid and the speaker of the phone.

4.1 Technical Parameters of the Measurement System

Parameter	DASY
Spatial resolution	5 mm
Repeatability of probe position	± 0.1 mm
Dynamic range	5 mW/kg - 100 W/kg

Table 2: DASY system specification.

Parameter	Accuracy
Frequency linearity	± 0.2 dB
Deviation from isotropy (in air)	± 0.8 dB
Surface detection	± 0.2 mm

Table 3: Probe specification.

Parameter	Noise floor
SAR values	< 0.005 W/kg
Electric field strength *E*	< 1 V/m

Table 4: Sensitivity of DASY.

Accuracy influencing conditions	Accuracy of SAR values
Isotropy, calibration, noise floor	< 13 % @ 1 W/kg
Extrapolation of SAR values	< 7 %
Dielectric parameters	< 5 %

Table 5: Accuracy of the SAR values determined by measurements [Kuster 1997].

5 SAR Results

The Tables below contains the measured SAR values averaged over a mass of 1 g.

Hip position	channel	SAR(1g) W/kg	File
lowest freq.	0512	0.191 ± 0.052	s40phl_2.da3
center freq.	0661	0.192 ± 0.052	s40phm_2.da3
highest freq.	0810	0.167 ± 0.046	s40phh_2.da3

Table 6: Measurement results for PCS 1900 for the Siemens S40, in hip position. (The display is oriented towards to the phantom. The SAR measurement is performed in the flat part of the phantom (representing the trunk of the body).)

Hip position	channel	SAR(1g) W/kg	File
lowest freq.	0512	1.540 ± 0.382	s40phl_1.da3
center freq.	0661	1.190 ± 0.297	s40phm_1.da3
highest freq.	0810	1.010 ± 0.252	s40phh_1.da3

Table 7: Measurement results for PCS 1900 for the Siemens S40, in hip position. (The display is oriented towards to the ground. The SAR measurement is performed in the flat part of the phantom (representing the trunk of the body).)

6 Evaluation

In Fig. 3 and Fig 4 the SAR results for PCS 1900 given in Table 6 - 7 are summarized and compared to the limit.

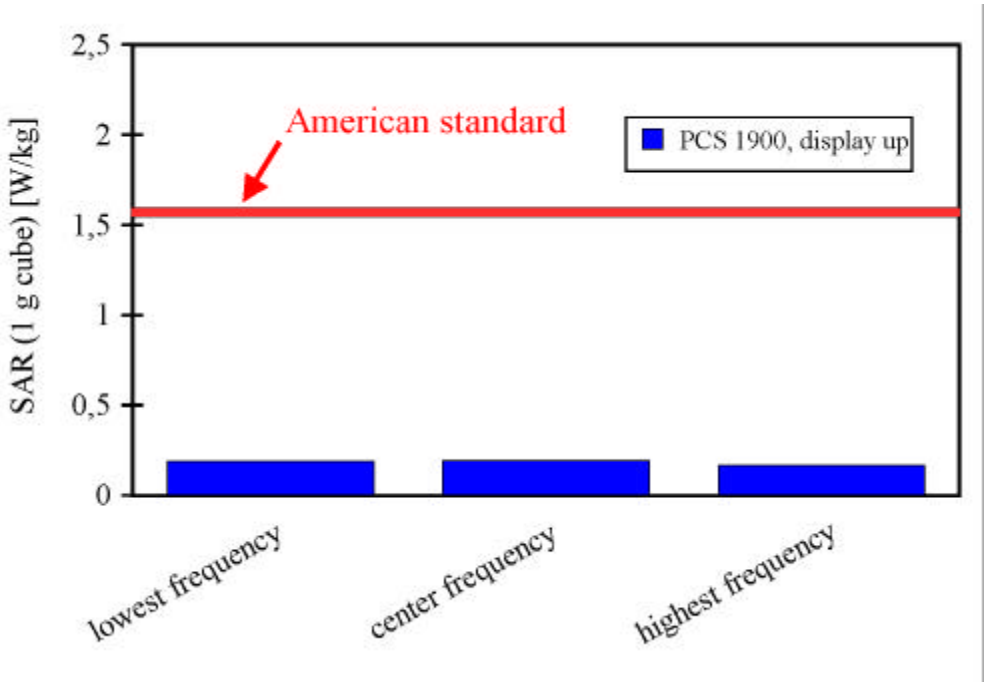


Fig. 3: The measured SAR values for PCS 1900 using the Siemens S40 in comparison to the American standard.

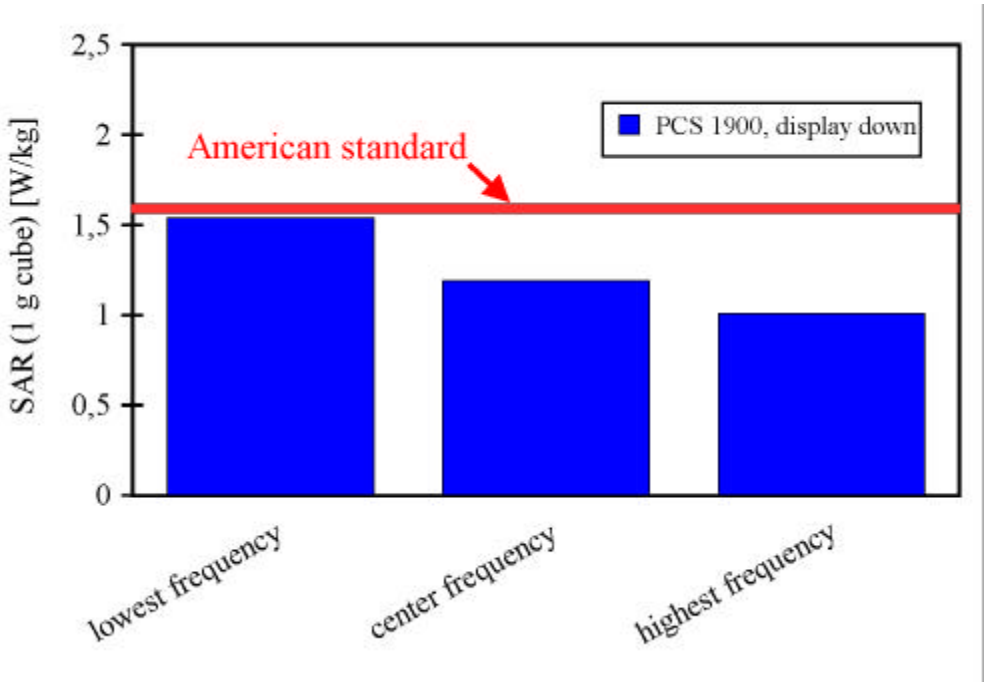


Fig. 4: The measured SAR values for PCS 1900 using the Siemens S40 in comparison to the American standard.

Fig. 5 show the SAR distribution plots with the maximum local SAR for PCS 1900 respectively.

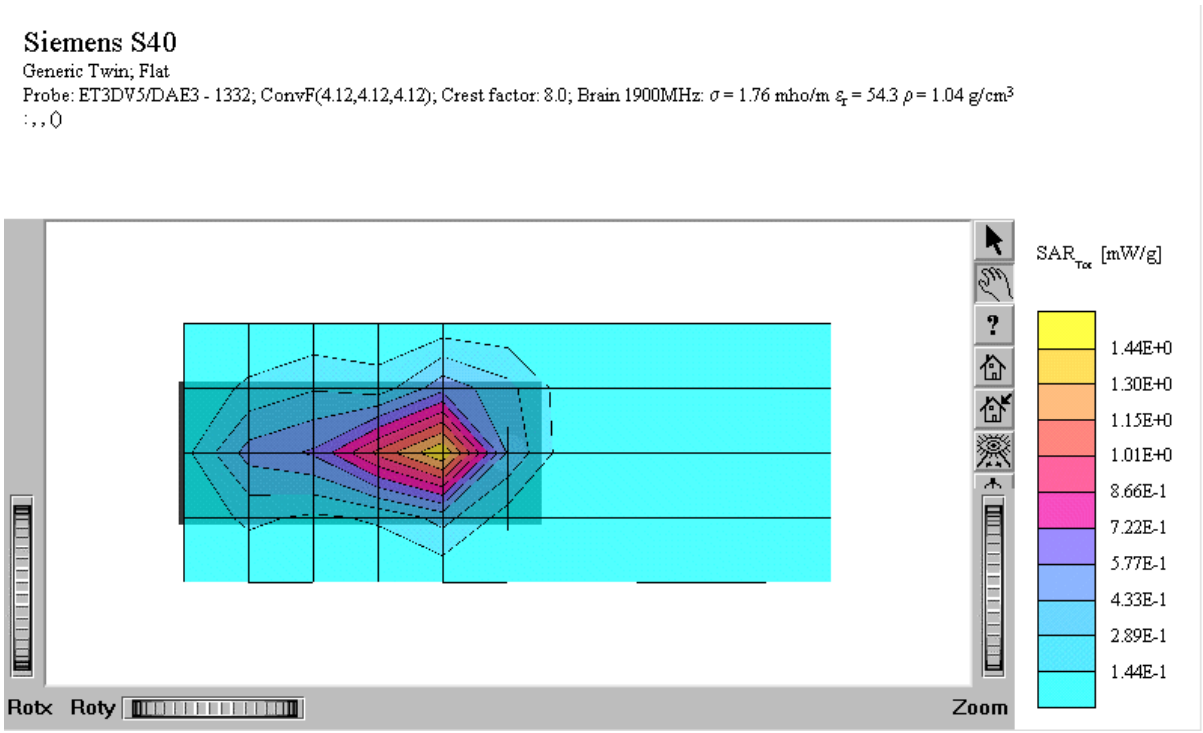


Fig. 5: SAR distribution plot with maximum local SAR value for PCS 1900 (channel 0512, hip position, the display is oriented towards to the ground. The SAR measurement is performed in the flat part of the phantom (representing the trunk of the body).)

The mobile phone Siemens S40 complies with the IEEE Standard C95.1 [IEEE 1999]. The tests were performed according to the Federal Communications Commission (FCC) Guidelines [FCC 1997] in body worn configuration.

Note: The measured SAR values depend on the material parameters. Therefore the material parameters must be enclosed in all copies and publications of these results.

7 Appendix

7.1 Administrative Data

Date of measurement:	November 27, 2000 by: André van den Bosch
Data stored:	Siemens_6575_135

7.2 Device under Test and Test Conditions

MTE:	Siemens S40
IMEI:	004513-67-000001-5
Date of receipt of MTE:	November 20, 2000
Standard:	PCS 1900
Modulation:	GMSK
Frequency Tx:	PCS 1900, low end: ch. 0512, center: ch. 0661, high end: ch. 810
MS Pwr TCH:	30 dBm
Battery status:	charged batteries (3.7 V), battery status checked with the battery status bar of the MTE at the end of each measurement
Base station (BS):	Wavetek STABILOK 4032 GSM

7.3 DASY Options

Software version:	DASY V3.1c
Probe:	ET3DV5 SN: 1332
Phantom:	Schmid & Partner generic twin phantom, left and right hand position

7.4 Validation

Validation date:	PCS 1900: November 27, 2000
Dipole validation kit:	D1800V2 S/N: 206
Signal Generator:	Network Analyzer HP 8753D, S/N: 3410A06555
Power Meter:	Gigatronics 8541B, S/N: 1830892
Power Sensor:	Gigatronics 80401A, S/N: 1829437

7.5 Test Position

In the body worn condition two configurations have been investigated: mobile phone with the display towards the phantom and mobile phone with the display towards the ground. The configuration is shown in Fig. 5 and Fig. 6, respectively.

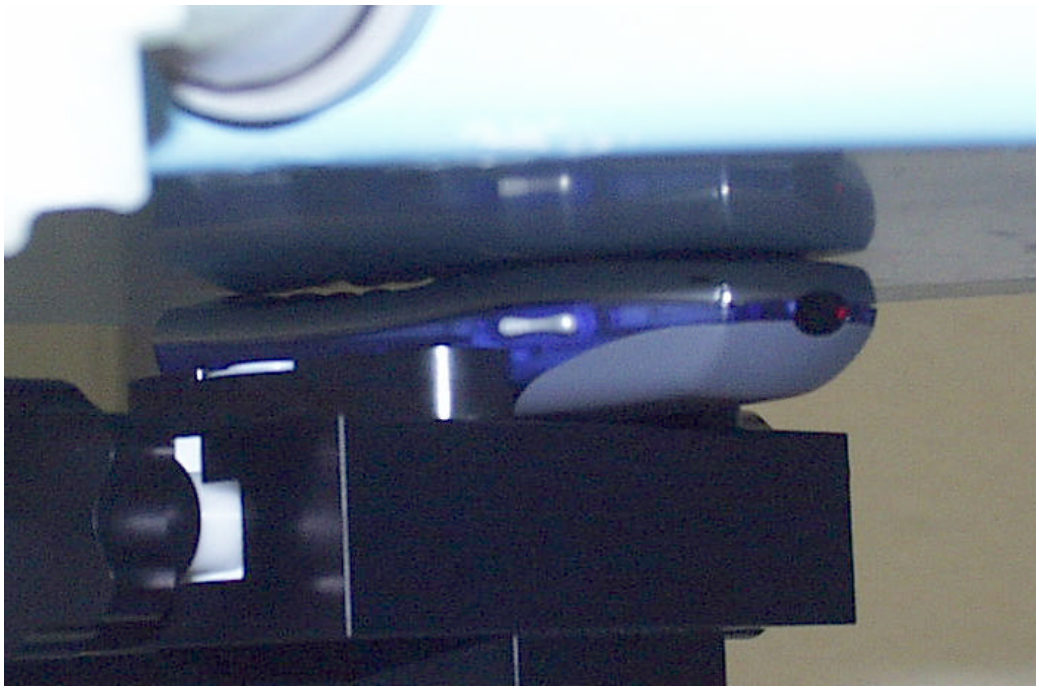


Fig. 6: Body worn configuration, display towards to the phantom.

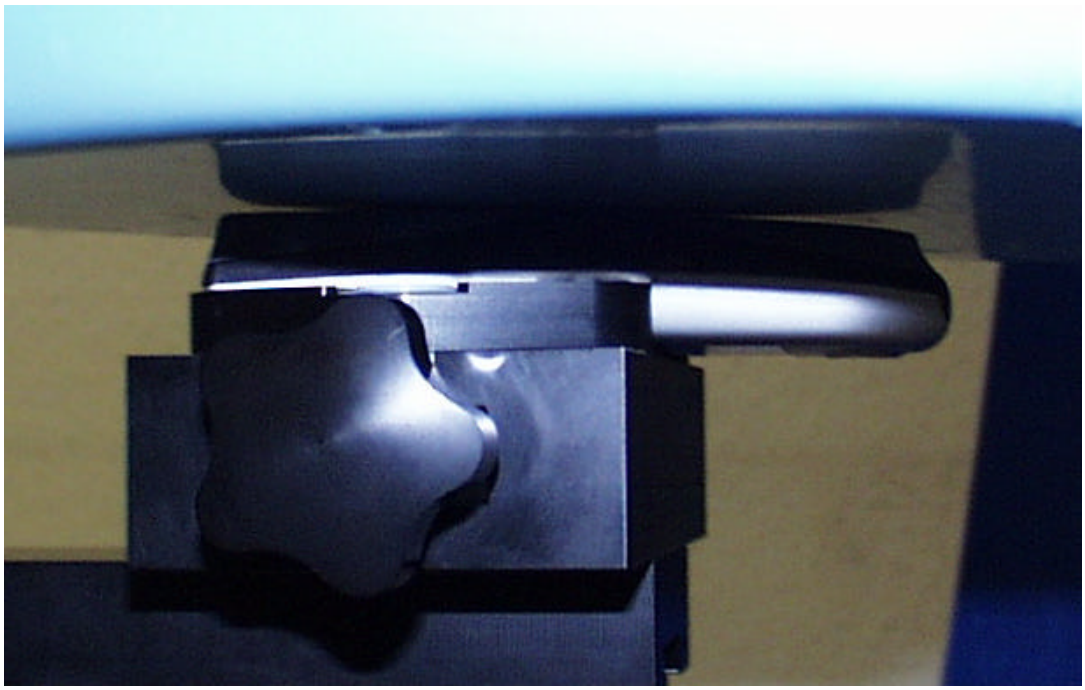


Fig. 7: Body worn configuration, display towards to the ground.

7.6 Material Measurement System

Type: HP85070B Dielectric Probe Kit, S/N:US33020263
Software version: HP85070 Rev. B.01.05 1993
Network Analyzer: HP8753D (6 GHz option), S/N: 3410A06555

Material parameters:

	FCC recommended (brain tissue)	FCC recommended (muscle tissue)	measured
Relative permittivity ε_r	43.4	54.3	54.3 ± 4.4
Conductivity σ	1.20 S/m	1.45 S/m	(1.76 ± 0.14) S/m
Mass density ρ	1.03 g/cm^3	1.04 g/cm^3	1.04 g/cm^3

Table 8: Parameters of the tissue simulating liquid in the 1.9 GHz frequency range.

Note: The measured SAR values depend on the material parameters. If the target values do not match with the actual dielectric parameters of the tissue simulating liquid, the following rules apply:

1. If the measured permittivity is lower than the recommended permittivity the measured SAR will be always higher than the real SAR.
2. If the measured conductivity is higher than the recommended conductivity the measured SAR will be always higher than the real SAR.

7.7 Environment

Ambient temperature: 20-23 °C
Tissue simulating liquid: 20-23 °C

7.8 Datasheets

Schmid & Partner
Engineering AG

Staffelstrasse 8, 8045 Zurich, Switzerland, Telefon +41 1 280 08 60, Fax +41 1 280 08 64

Calibration Certificate

Dosimetric E-Field Probe

Type:	**ET3DV5**
Serial Number:	**1332**
Place of Calibration:	**Zurich**
Date of Calibration:	**December 18, 1999**
Calibration Interval:	**12 months**

Schmid & Partner Engineering AG hereby certifies, that this device has been calibrated on the date indicated above. The calibration was performed in accordance with specifications and procedures of Schmid & Partner Engineering AG.

Whereever applicable, the standards used in the calibration process are traceable to international standards. In all other cases the standards of the Laboratory for EMF and Microwave Electronics at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland have been applied.

Calibrated by: 

Approved by: 

Schmid & Partner
Engineering AG

Staffelstrasse 8, 8045 Zurich, Switzerland, Telefon +41 1 280 08 60, Fax +41 1 280 08 64

Probe ET3DV5

SN:1332

Manufactured:	December 20, 1997
Last calibration:	January 12, 1999
Recalibrated:	December 18, 1999

Calibrated for System DASY3

ET3DV5 SN:1332

DASY3 - Parameters of Probe: ET3DV5 SN:1332

Sensitivity in Free Space

NormX	1.29 $\mu V/(V/m)^2$
NormY	1.17 $\mu V/(V/m)^2$
NormZ	1.25 $\mu V/(V/m)^2$

Diode Compression

DCP X	102 mV
DCP Y	102 mV
DCP Z	102 mV

Sensitivity in Tissue Simulating Liquid

Brain **450 MHz** $\varepsilon_r = 48 \pm 5\%$ $\sigma = 0.50 \pm 10\%$ mho/m

ConvF X	5.05 extrapolated	Boundary effect:	
ConvF Y	5.05 extrapolated	Alpha	0.46
ConvF Z	5.05 extrapolated	Depth	1.77

Brain **900 MHz** $\varepsilon_r = 42.5 \pm 5\%$ $\sigma = 0.86 \pm 10\%$ mho/m

ConvF X	4.75 ± 7% (k=2)	Boundary effect:	
ConvF Y	4.75 ± 7% (k=2)	Alpha	0.54
ConvF Z	4.75 ± 7% (k=2)	Depth	1.85

Brain **1500 MHz** $\varepsilon_r = 41 \pm 5\%$ $\sigma = 1.32 \pm 10\%$ mho/m

ConvF X	4.36 interpolated	Boundary effect:	
ConvF Y	4.36 interpolated	Alpha	0.64
ConvF Z	4.36 interpolated	Depth	1.95

Brain **1800 MHz** $\varepsilon_r = 41 \pm 5\%$ $\sigma = 1.69 \pm 10\%$ mho/m

ConvF X	4.16 ± 7% (k=2)	Boundary effect:	
ConvF Y	4.16 ± 7% (k=2)	Alpha	0.70
ConvF Z	4.16 ± 7% (k=2)	Depth	2.01

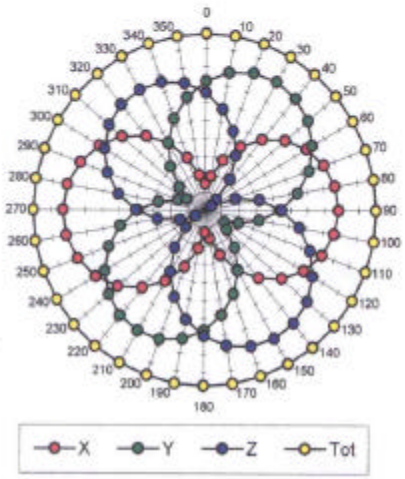
Sensor Offset

Probe Tip to Sensor Center	2.7	mm
Optical Surface Detection	1.9 ± 0.2	mm

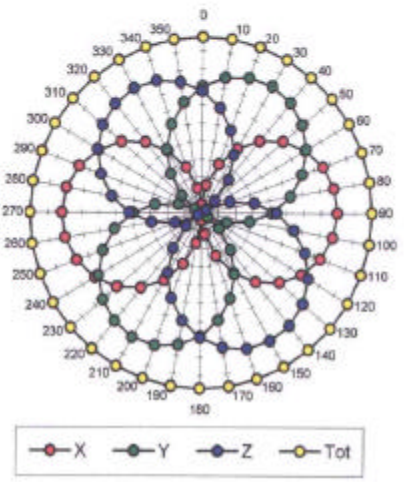
ET3DV5 SN:1332

Receiving Pattern (ϕ), θ = 0°

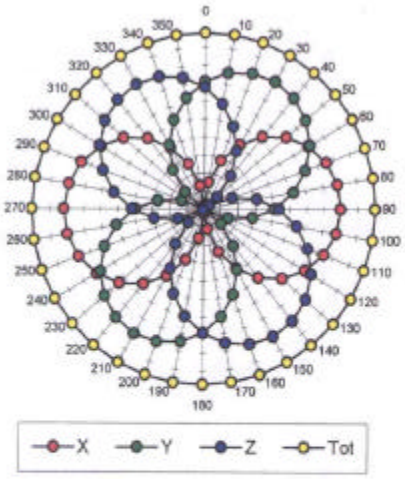
f = 30 MHz, TEM cell ifi110



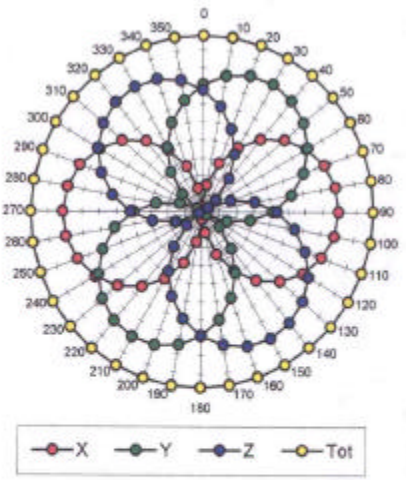
f = 100 MHz, TEM cell ifi110



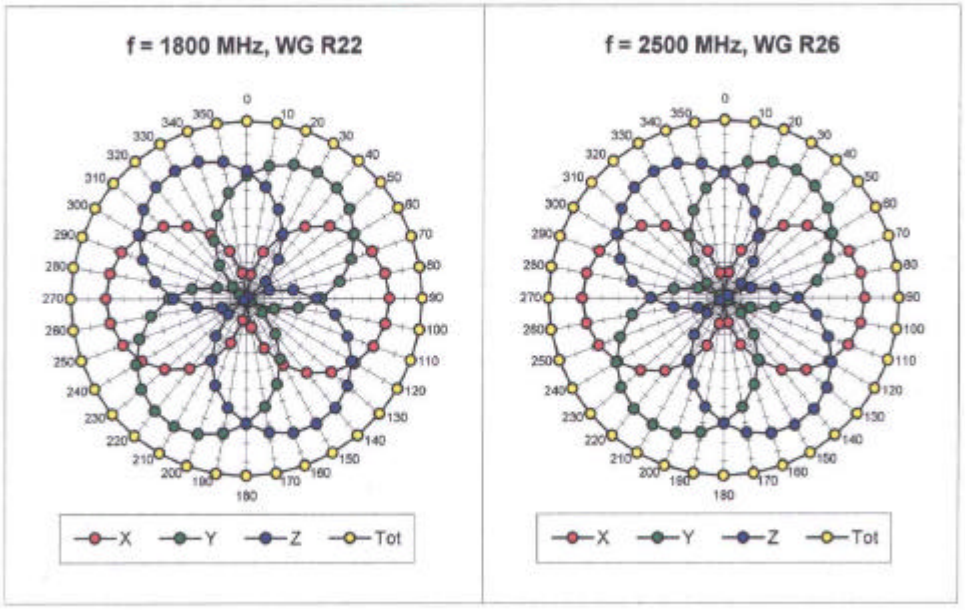
f = 300 MHz, TEM cell ifi110



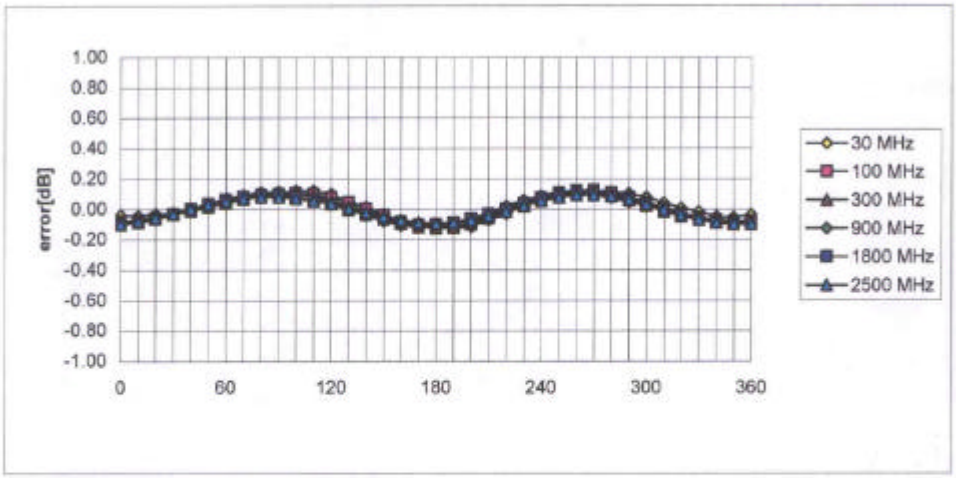
f = 900 MHz, TEM cell ifi110



ET3DV5 SN:1332



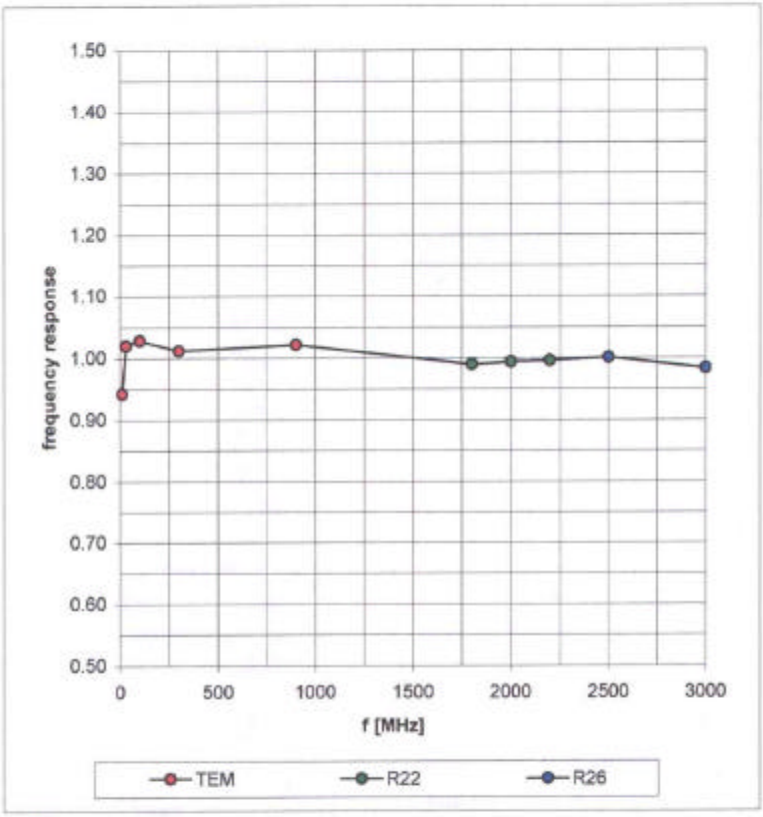
Isotropy Error (ϕ), θ = 0°



ET3DV5 SN:1332

Frequency Response of E-Field

(TEM-Cell:ifi110, Waveguide R22, R26)



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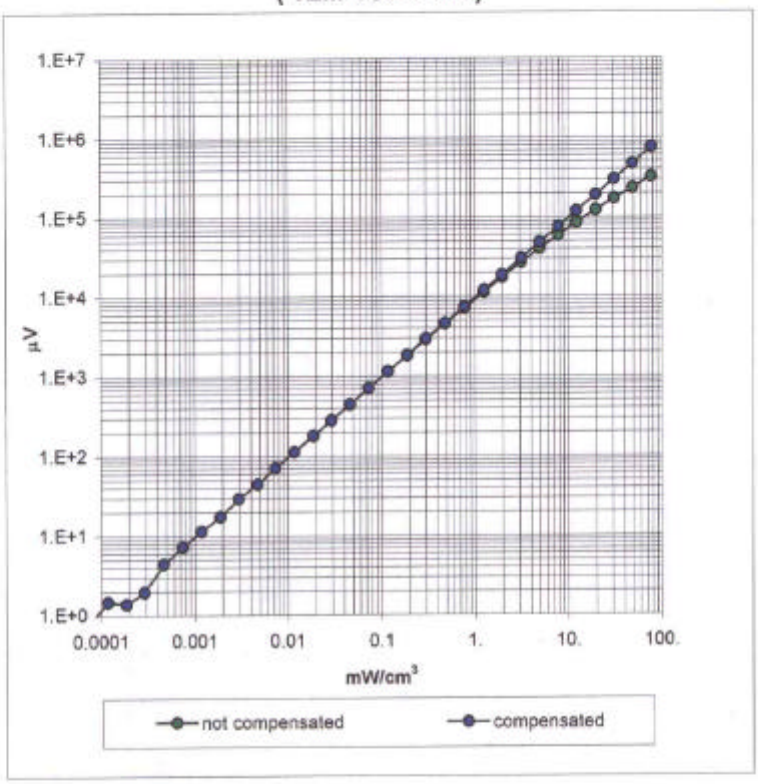
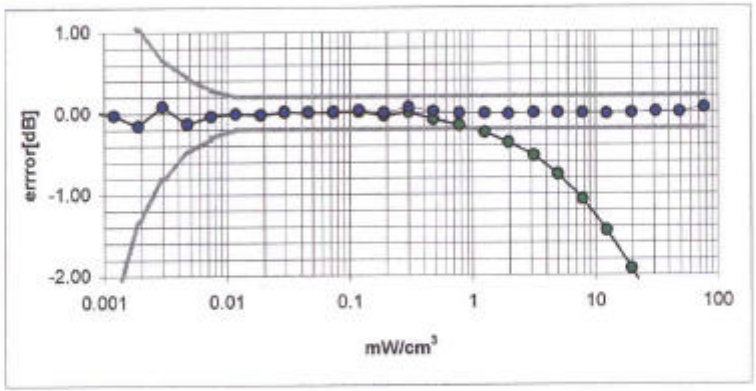
Dynamic Range f(SAR_{brain})

(TEM-Cell:ifi110)





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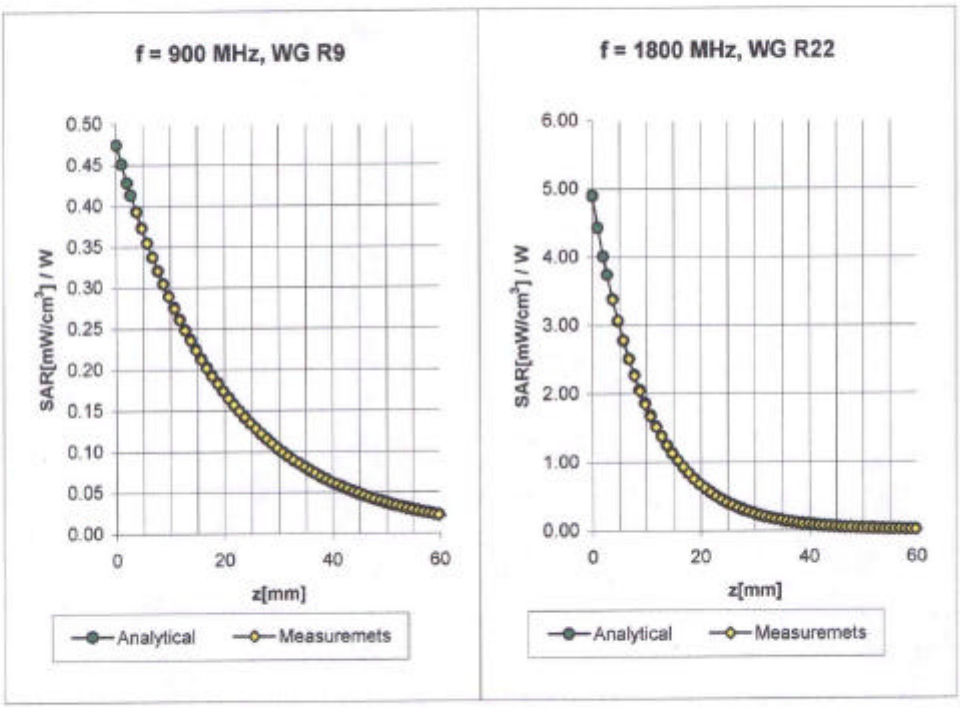
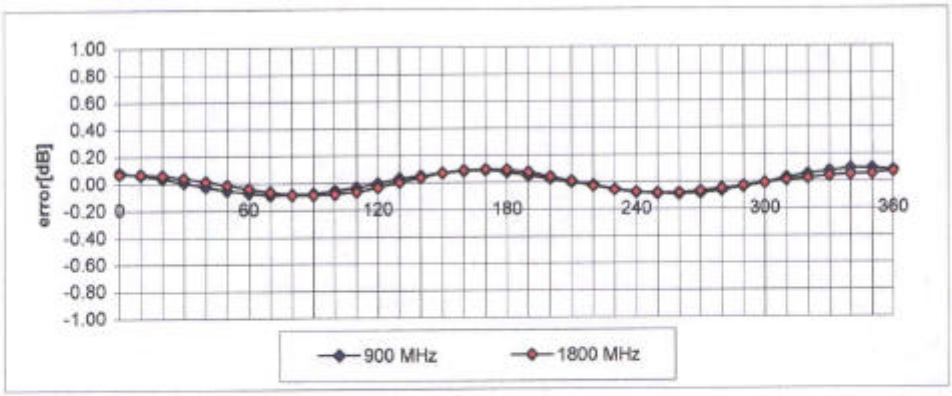
Conversion Factor Assessment



Receiving Pattern (ϕ)

(in brain tissue, z = 5 mm)



8 References

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