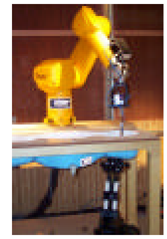
PCTEST Engineering Laboratory, Inc.

6660-B Dobbin Road • Columbia, MD 21045 • U.S.A.

TEL (410) 290-6652 • FAX (410) 290-6654

http://www.pctestlab.com



CERTIFICATE OF COMPLIANCE (SAR EVALUATION)

DENSO INTERNATIONAL AMERICA, INC.	**Dates of Tests: May 09, 2000**
5770 Armada Drive	**Test Report S/N: SAR.200509209.LXC**
Carlsbad, CA 92008-4608	**Test Site: PCTEST Lab, Columbia, MD USA**
Attention: Steve Burrington, Test & Verification Group	

FCC ID	**LXC-E220**
APPLICANT	**DENSO INTERNATIONAL AMERICA, INC.**

EUT Type:	**Dual-Band Analog/PCS Phone (AMPS/CDMA)**
Tx Frequency:	**824.04 – 848.97 MHz (AMPS) / 1851.25 – 1908.75 MHz (CDMA)**
Rx Frequency:	**869.04 – 893.97 MHz (AMPS) / 1931.25 – 1988.75 MHz (CDMA)**
Max. RF Output Power:	**0.6 W ERP AMPS (27.8 dBm)**
Trade Name/Model(s):	***DENSO E220***
FCC Classification:	**Licensed Portable Transmitter Held to Ear (PCE)**
Application Type:	**Class II Permissive Change**
Serial Number:	**n/a (pre production)**
FCC Rule Part(s):	**2.1093; ET Docket 96.326; 24(E); 22(H)**
Original Grant Date:	**April 06, 2000**
Class II Change(s):	**Increase conducted power level to 26.7 dBm (470 mW)**

This wireless portable device, with the Class II Permissvie Change(s), has been shown to be capable of continued compliance for localized specific absorption rate (SAR) for uncontrolled environment/general population exposure limits specified in ANSI/IEEE Std. C95.1-1992 and had been tested in accordance with the measurement procedures specified in ANSI/IEEE Std. C95.3-1992. (See Test Report).

I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

NVLAP accreditation does not constitute any product endorsement by NVLAP or any agency of the United States Government.

PCTEST certifies that no party to this application has been denied the FCC benefits pursuant to Section 5301 of the Anti-Drug Abuse Act of 1988, 21 U.S.C. 862.

Randy Ortanez
President & Chief Engineer

200509209.LXC

NVLAP LAB CODE 100431-0

Table of Contents

SAR MEASUREMENT REPORT

1.1 Scope

Environmental evaluation measurements of specific absorption rate[1] (SAR) distributions in simulated human head and body tissues exposed to radiofrequency (RF) radiation from wireless portable devices for compliance with the rules and regulations of the U.S. Federal Communications Commission (FCC).[2]

Company Name:	**DENSO INTERNATIONAL AMERICA, INC.**
Address:	**5770 Armada Drive**
	Carlsbad, CA 92008-4608
Attention:	**Steve Burrington, Test & Verification Group**

- EUT Type: Dual-Band Analog/PCS Phone
- Trade Name: ***DENSO***
- Model(s): ***E220***
- FCC IDENTIFIER: **LXC-E220**
- Tx Frequency: 824.04 – 848.97 MHz (AMPS)
1851.25 – 1908.75 MHz (CDMA)
- Rx Frequency: 869.04 – 893.97 MHz (AMPS)
1931.25 – 1988.75 MHz (CDMA)
- Application Type: Class II Permissive Change
- FCC Classification: Licensed Portable Transmitter
Held to Ear (PCE)
- Modulation(s): AMPS / CDMA
- FCC Rule Part(s): § 2.1093, Docket 96-326; § 24(E); § 22(H)
- Max. RF Output Power: 0.6W ERP AMPS (27.8 dBm)
- Antenna Type: Helical (λ/2)
- Antenna Dimensions: 2.0 cm. (Length)
- Original Grant Date: April 06, 2000
- Dates of Tests: May 09, 2000
- Class II Change(s): Increase conducted power to 26.7dBm (470mW)
- Place of Tests: PCTEST Engineering Lab.
Columbia, MD, U.S.A.
- Report Serial No.: SAR.200509209.LXC

Fig. 1 SAR Test Setup

NVLAP Lab Code 100431-0

[1] *Specific Absorption Rate (SAR) is a measure of the rate of energy absorption due to exposure to an RF transmitting source (wireless portable device).*
[2] *IEEE/ANSI Std. C95.1-1992 limits are used to determine compliance with FCC ET Docket 93-62.*

2.1 INTRODUCTION

The FCC has adopted the guidelines for evaluating the environmental effects of radiofrequency radiation in ET Docket 93-62 on Aug. 6, 1996 to protect the public and workers from the potential hazards of RF emissions due to FCC-regulated portable devices.[1]

The safety limits used for the environmental evaluation measurements are based on the criteria published by the American National Standards Institute (ANSI) for localized specific absorption rate (SAR) in *IEEE/ANSI C95.1-1992 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*. (c) 1992 by the Institute of Electrical and Electronics Engineers, Inc., New York, New York 10017.[2] The measurement procedure described in *IEEE/ANSI C95.3-1992 Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave*[3] is used for guidance in measuring SAR due to the RF radiation exposure from the Equipment Under Test (EUT). These criteria for SAR evaluation are similar to those recommended by the National Council on Radiation Protection and Measurements (NCRP) in *Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields,"* NCRP Report No. 86 (c) NCRP, 1986, Bethesda, MD 20814.[4] SAR is a measure of the rate of energy absorption due to exposure to an RF transmitting source. SAR values have been related to threshold levels for potential biological hazards.

2.2 SAR Definition

Specific Absorption Rate (SAR) is defined as the time derivative (rate) of the incremental energy (dU) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given density (r). It is also defined as the rate of RF energy absorption per unit mass at a point in an absorbing body (see Fig. 2).

$$SAR = \frac{d}{dt}\left(\frac{dU}{dm}\right) = \frac{d}{dt}\left(\frac{dU}{r\,dv}\right)$$

Figure 1. SAR Mathematical Equation

SAR is expressed in units of Watts per Kilogram (W/kg).

$$SAR = s E^2 / r$$

where:

s	=	conductivity of the tissue-simulant material (S/m)
r	=	mass density of the tissue-simulant material (kg/m^3)
E	=	Total RMS electric field strength (V/m)

NOTE: The primary factors that control rate of energy absorption were found to be the wavelength of the incident field in relations to the dimensions and geometry of the irradiated organism, the orientation of the organism in relation to the polarity of field vectors, the presence of reflecting surfaces, and whether conductive contact is made by the organism with a ground plane.[4]

3.1 SAR MEASUREMENT SET-UP

These measurements are performed using the DASY3 automated dosimetric assessment system. It is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland. It consists of high precision robotics system (Staubli), robot controller, Pentium III computer, near-field probe, probe alignment sensor, and the generic twin phantom containing the brain equivalent material. The robot is a six-axis industrial robot performing precise movements to position the probe to the location (points) of maximum electromagnetic field (EMF) (see Fig. 2).

A cell controller system contains the power supply, robot controller, teach pendant (Joystick), and remote control, is used to drive the robot motors. The PC consists of the Micron Pentium III 500 MHz computer with Windows NT system and SAR Measurement Software DASY3, A/D interface card, monitor, mouse, and keyboard. The Staubli Robot is connected to the cell controller to allow software manipulation of the robot. A data acquisition electronic (DAE) circuit performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. is connected to the Electro-optical coupler (EOC). The EOC performs the conversion from the optical into digital electric signal of the DAE and transfers data to the PC plug-in card.

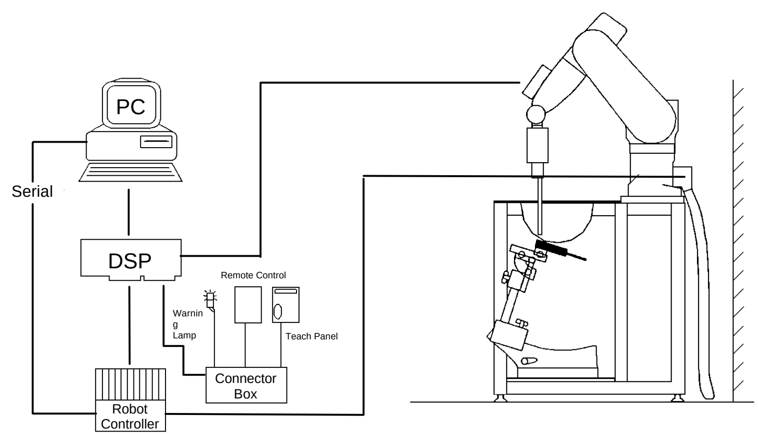


Figure 2. PCTEST SAR Lab II Test Measurement Set-up

The DAE3 consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the PC-card is accomplished through an optical downlink for data and status information and an optical uplink for commands and clock lines. The mechanical probe mounting device includes two different sensor systems for frontal and sidewise probe contacts. They are also used for mechanical surface detection and probe collision detection. The robot uses its own controller with a built in VME-bus computer. The system is described in detail in [5].

4.1 DASY3 E-FIELD PROBE SYSTEM

4.2 ET3DV5 Probe Specification

Construction	Symmetrical design with triangular core Built-in optical fiber for surface detection System Built-in shielding against static charges
Calibration	In air from 10 MHz to 2.5 GHz In brain and muscle simulating tissue at Frequencies of 450 MHz, 900 MHz and 1.8 GHz (accuracy ± 8%)
Frequency	10 MHz to > 6 GHz; Linearity: ± 0.2 dB (30 MHz to 3 GHz)
Directivity	± 0.2 dB in brain tissue (rotation around probe axis) ± 0.4 dB in brain tissue (rotation normal probe axis)
Dynamic Range	5 µW/g to > 100 mW/g; Linearity: ± 0.2 dB
Surface Detection	± 0.2 mm repeatability in air and clear liquids over diffuse reflecting surfaces.
Dimensions	Overall length: 330 mm Tip length: 16 mm Body diameter: 12 mm Tip diameter: 6.8 mm Distance from probe tip to dipole centers: 2.7 mm
Application	General dosimetry up to 3 GHz Compliance tests of mobile phones Fast automatic scanning in arbitrary phantoms

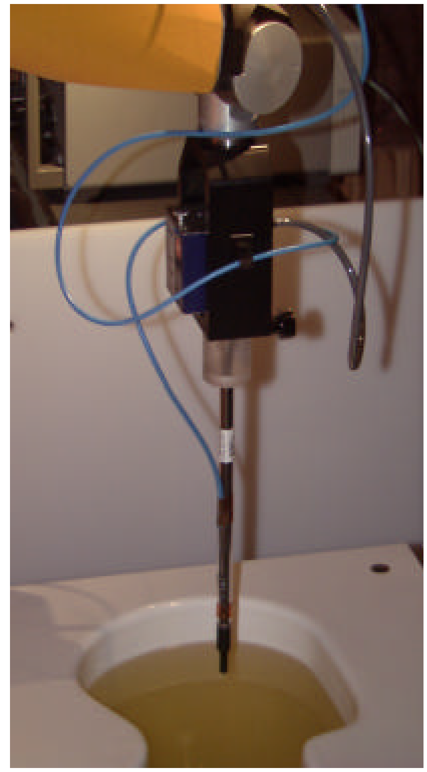


Figure 4. Photograph of the Probe and the Phantom

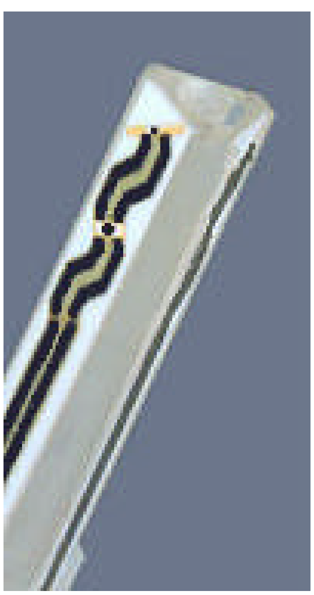


Fig. 5. ET3DV5 E-field Probe

The SAR measurements were conducted with the dosimetric probe ET3DV5, designed in the classical triangular configuration [5] and optimized for dosimetric evaluation. The probe is constructed using the thick film technique; with printed resistive lines on ceramic substrates. The probe is equipped with an optical multifiber line ending at the front of the probe tip. It is connected to the EOC box on the robot arm and provides an automatic detection of the phantom surface. Half of the fibers are connected to a pulsed infrared transmitter, the other half to a synchronized receiver. As the probe approaches the surface, the reflection from the surface produces a coupling from the transmitting to the receiving fibers. This reflection increases first during the approach, reaches a maximum and then decreases. If the probe is flatly touching the surface, the coupling is zero. The distance of the coupling maximum to the surface is independent of the surface reflectivity and largely independent of the surface to probe angle. The DASY3 software reads the reflection during a software approach and looks for the maximum using a 2nd order fitting. The approach is stopped at reaching the maximum.

5.1 E-FIELD PROBE CALIBRATION PROCESS

5.2 E-Probe Calibration

dosimetric assessment procedure described in [6] with an

and found to be better than +/-0.25dB. The sensitivity parameters (NormX, NormZ), the diode compression parameter (DCP) and the conversion factor (

The free space E-field from amplified probe outputs is determined in a test chamber. This is performed in a TEM cell for frequencies bellow 1 GHz, and in a
space calibration, the probe is placed in the volumetric center of the cavity and at the proper orientation with the field. The probe is then rotated 360 degrees.

simulated brain tissue. The measured free space E-field in the medium correlates to temperature rise in a dielectric medium. For temperature correlation calibration a RF transparent
probe is used in conjunction with the E-field probe.

$$\text{SAR} = C\frac{\Delta T}{\Delta t}$$

where:

Δt = exposure time (30 seconds),

C = heat capacity of tissue (brain or muscle),

ΔT = temperature increase due to RF exposure.

SAR is proportional to $\Delta T / \Delta$, the initial rate of tissue

possible to quantify the electric field in the simulated tissue by equating the thermally derived SAR to the E- field

$$\text{SAR} = \frac{|E|^2 \cdot s}{r}$$

where:

σ = simulated tissue conductivity,

ρ = Tissue density (1.25 g/cm^3 for brain tissue)

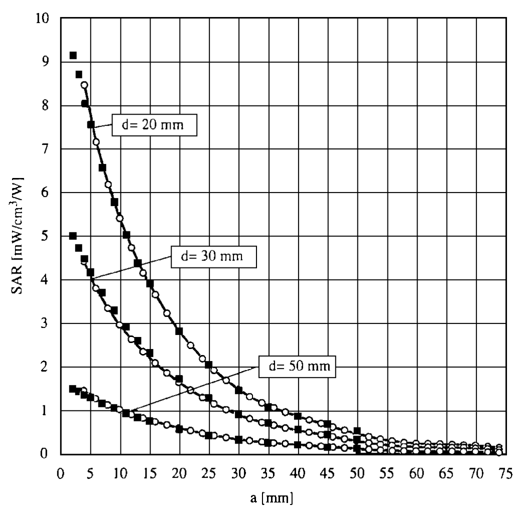


Figure 6. E-Field and Temperature measurements at 900MHz [5]

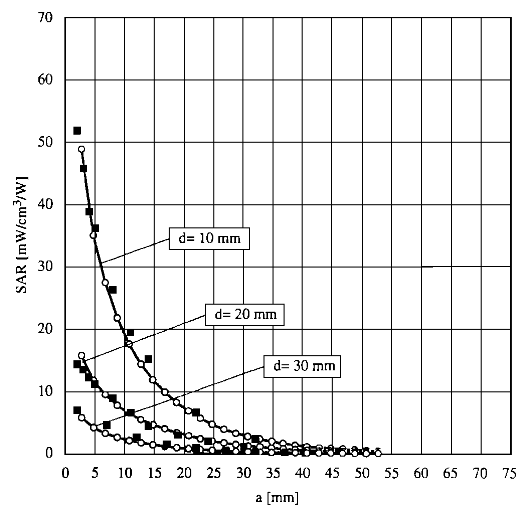


Figure 7. E-Field and temperature

5.3 Data Extrapolation

The DASY3 software automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC-transmission factor from the diode to the evaluation electronics. If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given as [8]:

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

with
V_i = compensated signal of channel i (i=x,y,z)
U_i = input signal of channel i (i=x,y,z)
cf = crest factor of exciting field (DASY parameter)
dcp_i = diode compression point (DASY parameter)

From the compensated input signals the primary field data for each channel can be evaluated:

E-field probes:

$$E_i = \sqrt{\frac{V_i}{Norm_i \cdot ConvF}}$$

with
V_i = compensated signal of channel i (i = x,y,z)
$Norm_i$ = sensor sensitivity of channel i (i = x,y,z) $\mu V/(V/m)^2$ for E-field probes
ConvF = sensitivity of enhancement in solution
E_i = electric field strength of channel i in V/m

The RSS value of the field components gives the total field strength (Hermetian magnitude):

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

The primary field data are used to calculate the derived field units.

$$SAR = E_{tot}^2 \cdot \frac{s}{r \cdot 1000}$$

with
SAR = local specific absorption rate in W/g
E_{tot} = total field strength in V/m
σ = conductivity in [mho/m] or [Siemens/m]
ρ = equivalent tissue density in g/cm^3

The power flow density is calculated assuming the excitation field to be a free space field.

$$P_{pwe} = \frac{E_{tot}^2}{3770}$$

with
P_{pwe} = equivalent power density of a plane wave in W/cm^2
E_{tot} = total electric field strength in V/m

6.1 PHANTOM & EQUIVALENT TISSUES

6.2 Generic Twin Phantom

is constructed of a fiberglass shell integrated in a

designed to determine the maximum exposure in at least 90% of all users [9][10]. It enables the
as well as body mounted usage at the flat phantom region. A cover prevents the evaporation of the liquid. Reference markings on the Phantom allow the

manually teaching three points in the robot. See Figure 8.

Shell Thickness ± 0.1 mm
Volume Volume Approx. 20 liters
810 x 1000 x 500 mm (H x L x W)

Fig. 8 Generic Twin Phantom

6.3 Brain & Muscle Simulating Mixture Characterization

hydroxethylcellullose (HEC) gelling agent and saline solution (see Table 1). Preservation with a
bubbles are not trapped during the mixing process. The mixture is calibrated to obtain proper dielectric constant (
tissue simulating liquids are according to the data by C. Gabriel and G. Hartsgrove [11].

%	FREQUENCY 800 - 850 MHz	FREQUENCY 800 - 850 MHz	FREQUENCY 1850 -1910 MHz	FREQUENCY 1850 -1910 MHz
WATER		52.4	45.0	
SUGAR	56.0		53.9	58.0
	2.5	1.4		0.5
BACTERIACIDE		0.2	0.1	
HEC	1.0		1.0	1.0

1. Composition of the Brain & Muscle Tissue Equivalent Matter

In combination with the Generic Twin Phantom V3.0, the Mounting Device (POM) enables the rotation of the mounted transmitter in spherical coordinates whereby the
repeatably
positioned according to the FCC and CENELEC specifications. The device holder can be

Fig. 9. Device Holder

* Note:
structure of the hand that may produced infinite number of configurations [10]. To produce the worst-case condition (the hand absorbs antenna output power), the hand is omitted during the

7.1 SYSTEM SPECIFICATIONS

7.2 Robotic System Specifications

Specifications

	Stäubli Unimation Corp. Robot Model: RX60L
	0.02 mm
No.	6

Data Acquisition Electronic (DAE) System

Processor:	Pentium III
	450 MHz
Operating System:	
Data Card:	DASY3 PC-Board
Features:	Signal Amplifier,
Software:	DASY3 software
	Optical downlink for data and status info.

PC Interface Card

Function:	
	Link to DAE3
	16 bit
	serial link to robot
	direct emergency stop output for robot

Model:	ET3DV5	S/N: 1370
Construction:		
Frequency:	10 MHz to 6 G	
Linearity:	±	

Phantom

Phantom:	
Shell Material:	Fiberglass
	2.0 ±

Tissue Parameters	**800-850 MHz**	**800-850 MHz (Muscle)**	**(Brain)**	**1850-1910 MHz**
Dielectric Constant: ε	42.5		40.4	54.2
σ	0.86	0.95		1.85

8.1 MEASUREMENT PROCESS

8.2 System Verification

Prior to assessment, the sytem is verified to the ±5% of the specifications by using the system validation kit. System verification is performed with 800 MHz brain equivalent material. Once system verification is complete, the fluid is replaced with 800 MHz muscle equivalent material. (Graphics Plots Attached)

Validation Kit D835V2, S/N: 406	835MHz Brain	Targeted SAR_{1g} (mW/g) 2.11	Measured SAR_{1g} (mW/g) 2.15
Validation Kit D835V2, S/N: 406	835MHz Muscle	Targeted SAR_{1g} (mW/g) 2.11	Measured SAR_{1g} (mW/g) 2.16

8.3 Dosimetric Assessment Setup

The evaluation was performed with the following procedure:

1. The SAR value at a fixed location above the ear point was measured and was used as a reference value for assessing the power drop.
2. The SAR distribution at the exposed side of the head was measured at a distance of 3.9mm from the inner surface of the shell. The area covered the entire dimension of the head and the horizontal grid spacing was 20mm x 20mm. Based on this data, the area of the maximum absorption was determined by spline interpolation.
3. Around this point, a volume of 32mm x 32mm x 34mm was assessed by measuring 5 x 5 x 7 points. On this basis of this data set, the spatial peak SAR value was evaluated with the following procedure:
   a. The data at the surface were extrapolated, since the center of the dipoles is 2.7mm away from the tip of the probe and the distance between the surface and the lowest measuring point is 1.2mm. The extrapolation was based on a least square algorithm [13]. A polynomial of the fourth order was calculated through the points in z-axes. This polynomial was then used to evaluate the points between the surface and the probe tip.
   b. The maximum interpolated value was searched with a straight-forward algorithm. Around this maximum the SAR values averaged over the spatial volumes (1g or 10g) were computed using the 3D-Spline interpolation algorithm. The 3D-spline is composed of three one-dimensional splines with the "Not a knot" condition (in x,y, and z directions) [13][14]. The volume was integrated with the trapezoidal algorithm. One thousand points (10 x 10 x 10) were interpolated to calculate the average.
   c. All neighboring volumes were evaluated until no neighboring volume with a higher average value was found.
4. The SAR value, at the same location as procedure #1, was re-measured. If the value changed by more than 5%, the evaluation is repeated.

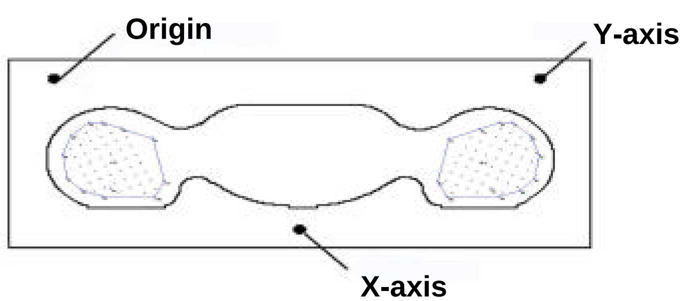


Fig 10. SAR Measurement Points in Area Scan

9.1 TEST POSITION OF THE PHONE

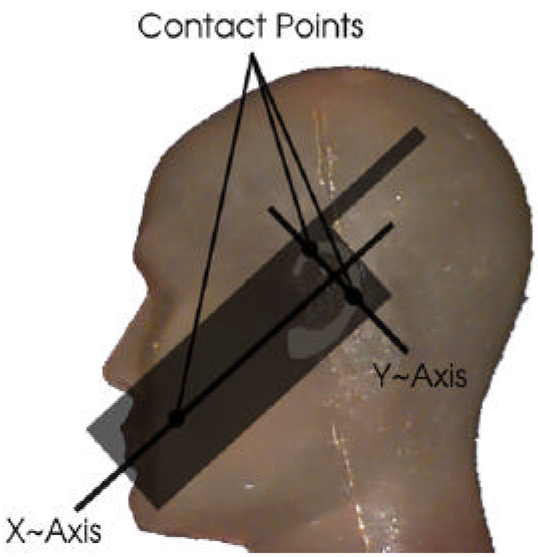


Figure 11. Diagram showing Typical Alignment & Contact Points

9.2 HANDSET TEST POSITION

The device was placed in a normal operating position with the center of its ear-piece aligned with the location of the ear canal on the phantom (See Fig. 11). With the ear-piece pressed against the head, the vertical center line of the body of the handset was aligned 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 was gradually moved towards the cheek until any point on the mouth-piece or keypad contacted the cheek [15]. An upper right-hand corner antenna requires the left-hand phantom while handsets with an upper left antenna requires the right-hand phantom. The handset was tested both with its antenna extended (out) and retracted (in). A sample diagram of a typical handset shows the earpiece at the center of the X and Y axis, placed at the center of the ear canal of the phantom (see Fig. 12 and 13).

Fig 12. Sample of Handset Alignment with the Ear Canal of the Phantom

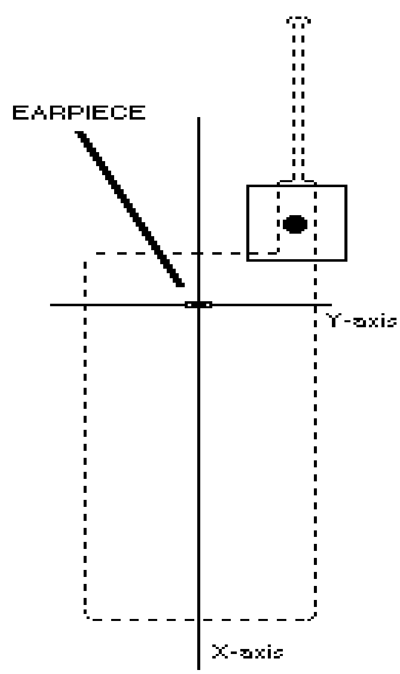


Figure 13. Origin of Axis at Earpiece Position

10.1 BODY-WORN TEST SETUP

10.2 Ear-Microphone

Portable transmitting devices that have an Ear-Microphone jack must be evaluated for RF exposure in a body-worn configuration. The testing is performed with the use of a torso phantom filled with muscle equivalent tissue. The EUT is positioned with the keypad facing away from the phantom, and the Ear-Microphone wire attached to the phone jack, simulating the device placed in a shirt pocket or attached to a body holster. The SAR tests are then performed in both the antenna in and antenna out positions using the low, middle, and high channels to investigate the worst case SAR value (see Figure 11). Please note that body-worn configurations which have not been SAR tested may result in operating conditions that could exceed FCC RF exposure limits, therefore, users are cautioned to use tested and/or approved accessories.

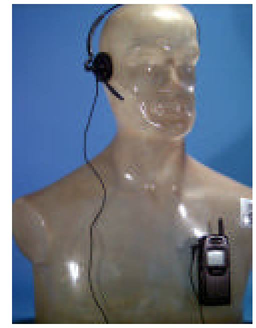


Figure 11.
Ear-Microphone Jack

A. Shirt Pocket Configuration

The shirt pocket configuration is used for devices designed to be body-worn, and small enough to be placed inside a shirt pocket. To simulate the worst-case configuration, the EUT is placed in a torso position on the phantom with the keypad facing away from the phantom, and the Ear-Microphone wire connected to the phone to simulate hands-free operation in a shirt-pocket configuration (see Figure 12).

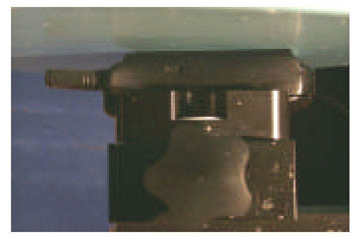


Figure 12.
Shirt Pocket Configuration

B. Body Holster Configuration

The body holster configuration is used for body-worn devices that have a body holster accessory. Typically, a holster or carrying case is provided or available as an accessory item for supporting headset and body-worn operations. SAR may vary depending on the body separation distance provided by the type of holster and batteries supplied for a phone. In most cases, the antenna may become closer to the user's body than next to the head. The design of the holster permits the phone to be positioned only with the keypad facing away from the phantom. Proper usage of the holster restricts the antenna to a specified distance away from the surface of the body. For this test the EUT is placed into the holster and the holster is positioned against the torso of the phantom in a normal operating position. The Ear-Microphone wire is then connected to the phone to simulate hands-free operation in a body holster configuration (see Figure 13).

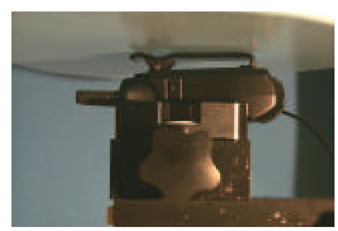


Figure 13.
Body Holster Configuration

C. Other Configurations

If other operating configurations are possible (i.e.: pants pocket, car adapter kit, etc), it will be indicated to users in the instruction manual about untested conditions and the possibility of exceeding FCC RF exposure limits for such use or the use of third-party accessories. If there is a high potential for exceeding limits in certain unintended configurations, a warning statement will be included in the manual, warning the user to avoid such operating conditions.

11.1 NSI/IEEE C95.1 - 1992 RF EXPOSURE LIMITS

HUMAN EXPOSURE	UNCONTROLLED ENVIRONMENT General Population (W/kg) or (mW/g)	CONTROLLED ENVIRONMENT Occupational (W/kg) or (mW/g)
SPATIAL PEAK SAR * (Brain)	1.60	8.00
SPATIAL AVERAGE SAR ** (Whole Body)	0.08	0.40
SPATIAL PEAK SAR *** (Hands / Feet / Ankle / Wrist)	4.00	20.00

Table 2. Safety Limits for Partial Body Exposure [2]

NOTES:

* The Spatial Peak value of the SAR averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

** The Spatial Average value of the SAR averaged over the whole-body.

******* The Spatial Peak value of the SAR averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure.

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation).

12.1 MEASUREMENT UNCERTAINTIES

Measurement uncertainties in SAR measurements are difficult to quantify due to several variables including biological, physiological, and environmental. However, we estimate the measurement uncertainties in SAR to be less than 15-25 % [16].

According to ANSI/IEEE C95.3, the overall uncertainties are difficult to assess and will vary with the type of meter and usage situation. However, accuracy's of ± 1 to 3 dB can be expected in practice, with greater uncertainties in near-field situations and at higher frequencies (shorter wavelengths), or areas where large reflecting objects are present. Under optimum measurement conditions, SAR measurement uncertainties of at least ± 2dB can be expected.[3]

According to CENELEC [17], typical worst-case uncertainty of field measurements is ± 5 dB. For well-defined modulation characteristics the uncertainty can be reduced to ± 3 dB.

Uncertainty Description	Error	Distribution	Weight	Std. Deviation	Offset
Probe Uncertainty					
Axial isotropy	±0.2 dB	U-Shaped	0.5	±2.4 %	
Spherical isotropy	±0.4 dB	U-Shaped	0.5	±4.8 %	
Isotropy from gradient	±0.5 dB	U-Shaped	0	±	
Spatial resolution	±0.5 %	Normal	1	±0.5 %	
Linearity error	±0.2 dB	Rectangle	1	±2.7 %	
Calibration error	±3.3 %	Normal	1	±3.3 %	
SAR Evaluation Uncertainty					
Data acquisition error	±1 %	Rectangle	1	±0.6 %	
ELF and RF disturbances	±0.25 %	Normal	1	±0.25 %	
Conductivity assessment	±10 %	Rectangle	1	±5.8 %	
Spatial Peak SAR Evaluation Uncertainty					
Extrapolated boundary effect	±3 %	Normal	1	±3 %	±5 %
Probe positioning error	±0.1 mm	Normal	1	±1 %	
Integrated and cube orientation	±3 %	Normal	1	±3 %	
Cube Shape inaccuracies	±2 %	Rectangle	1	±1.2 %	
Device positioning	±6 %	Normal	1	±6 %	
Combined Uncertainties				±11.7 %	±5 %

Table 3. Breakdown of Errors [18]

13.1 SAR TEST DATA SUMMARY

Ambient TEMPERATURE (°C) 24.0
Relative HUMIDITY (%) 55.0
Atmospheric PRESSURE (kPa) 100.0

Mixture Type: **800MHz Brain**

Dielectric Constant: **42.5**

Conductivity: **0.86**

Closest Distance (between E-Probe & Phone): 1.5 cm

13.2 Measurement Results (Head SAR)

FREQUENCY		Modulation	POWER	Phantom	Antenna	SAR
MHz	Ch.		(dBm)	Position	Position	(W/kg)
824.04	991	AMPS	26.7	Left Ear	Fixed	1.23
836.49	383	AMPS	26.7	Left Ear	Fixed	1.44
848.97	799	AMPS	26.7	Left Ear	Fixed	1.17
ANSI / IEEE C95.1 1992 - SAFETY LIMIT Spatial Peak Uncontrolled Exposure/General Population				**Brain 1.6 W/kg (mW/g)**		

NOTES:
1. The test data reported are the worst-case SAR value with the antenna-head position set in a typical configuration.
2. All modes of operation were investigated and the worst-case are reported.
3. Battery Type ☒ Standard ☐ Extended
   Radiated measurements indicate that the extended-life battery produces a lower ERP and EIRP, therefore the standard-life battery is used.
4. Power Measured ☒ Conducted ☐ EIRP ☐ ERP
5. SAR Measurement System ☒ SPEAG ☐ IDX
6. SAR Configuration ☒ Head ☐ Body ☐ Hand

Randy Ortanez
President & Chief Engineer

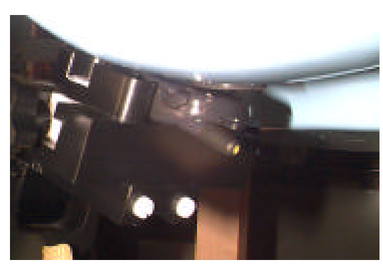


Figure 14. Head SAR Test Setup

13.1 SAR TEST DATA SUMMARY (Continued)

Ambient TEMPERATURE (°C)	24.0
Relative HUMIDITY (%)	55.0
Atmospheric PRESSURE (kPa)	100.0

Mixture Type: **800MHz Muscle**

Dielectric Constant: **56.2**

Conductivity: **0.95**

13.3 Measurement Results (Body SAR with Belt Clip)

FREQUENCY MHz	Ch.	Modulation	POWER * (dBm)	Separation Distance (cm)**	Antenna Position	SAR (W/kg)
824.04	991	AMPS	26.7	2.5	Fixed	0.544
836.49	383	AMPS	26.7	2.5	Fixed	0.518
848.97	799	AMPS	26.7	2.5	Fixed	0.476
ANSI / IEEE C95.1 1992 - SAFETY LIMIT Spatial Peak Uncontrolled Exposure/General Population				**Muscle 1.6 W/kg (mW/g)**		

NOTES:
1. All modes of operation were investigated and the worst-case are reported.
2. Battery condition is fully charged for all readings.
3. Battery Type ☒ Standard ☐ Extended
4. * Power Measured ☒ Conducted ☐ EIRP ☐ ERP
5. SAR Measurement System ☒ SPEAG ☐ IDX
6. SAR Configuration ☐ Head ☒ Body ☐ Hand
7. ** Test Configuration ☒ Body Holster ☐ Without Body Holster
   Note: Body holster (Model SBC-200) contains metallic clip.

Randy Ortanez
President & Chief Engineer

Figure 15. Body SAR Test Setup with Belt Clip

14.1 Test Data

14.2 Effective Radiated Power Output

A. POWER: **Low (Analog Mode)**

Freq. Tuned (MHz)	LEVEL (dBm)	POL (H/V)	ERP (W)	ERP (dBm)
824.04	-33.876	H	0.005505	7.40
836.49	-33.311	H	0.006499	8.12
848.97	-34.930	H	0.004640	6.65

A. POWER: **High (Analog Mode)**

Freq. Tuned (MHz)	LEVEL (dBm)	POL (H/V)	ERP (W)	ERP (dBm)	BATTERY
824.04	-12.439	H	0.76459	28.834	Standard
836.49	-12.522	H	0.77748	28.907	Standard
848.97	-12.439	H	0.82147	29.146	Standard
836.49	-12.555	H	0.77160	28.874	Extended

NOTES:

ERP Measurements by Substitution Method:
The EUT was placed on a wooden turn table 3-meters from the receive antenna. The receive antenna height and turntable rotation was adjusted for the highest reading on the receive spectrum analyzer. A half-wave dipole was substituted in place of the EUT. This dipole antenna was driven by a signal generator and the level of the signal generator was adjusted to obtain the same receive spectrum analyzer reading. This ERP level is recorded. For readings above 1GHz, the above procedure is repeated using horn antennas and the difference between the gain of the horn and an isotropic antenna are taken into consideration.

15.1 SAR TEST EQUIPMENT

15.2 Type / Model	Calib. Date	S/N:
Stäubli Robot RX60L	Feb. 00	599131-01
Stäubli Robot Controller	Feb. 00	PCT592
Stäubli Teach Pendant (Joystick)	Feb. 00	3323-00161
Micron Computer 450 MHz Pentium III, Windows NT	Feb. 00	PCT577
SPEAG EDC3	Feb. 00	321
SPEAG DAE3	Feb. 00	330
SPEAG E-Field Probe ET3DV5	Feb. 00	1368
SPEAG E-Field Probe ET3DV5	Feb. 00	1370
SPEAG Dummy Probe	Feb. 00	PCT583
SPEAG Generic Twin Phantom	Feb. 00	PCT587
SPEAG Light Alignment Sensor	Feb. 00	205
SPEAG Validation Dipole D1900V2	Feb. 00	PCT593
Brain Equivalent Matter (800MHz)	Apr. 00	PCTBEM03
Brain Equivalent Matter (1900MHz)	Apr. 00	PCTBEM04
Muscle Equivalent Matter (800MHz)	Apr. 00	PCTMEM05
Muscle Equivalent Matter (1900MHz)	Apr. 00	
Robot Table		PCT586
Phone Holder		PCT588
A/B Power Indicator		PCT589
Remote Power Switch		PCT590
Phantom Cover		PCT591
HP Spectrum Analyzer	Dec. 99	PCT200
IFI TEM Cell Model: CC110EXX (DC - 2000 MHz)	Jan. 00	A427-0697
Microwave Amp. Model: 5S1G4 (800MHz - 4.2GHz, 5 Watts)	Jan. 00	22332

NOTE:
The E-field probe was calibrated by SPEAG, by temperature measurement procedure. Dipole Validation measurement is performed by PCTEST Lab. before each test. The brain simulating material is calibrated by PCTEST using the dielectric probe system and network analyzer to determine the conductivity and permittivity (dielectric constant) of the brain-equivalent material.

The following list of equipment was used to calibrate the brain equivalent material:

Power Meter	Gigatronics 85422
Signal Generator	HP-8648D (9kHz ~ 4GHz)
Power Amp	Amplifier Research 5S1G4 (5 Watts, 800MHz ~ 4.2GHz)
Network Analyzer	HP-8753E (30kHz ~ 3GHz)
Dielectric Probe Kit	HP85070B

16.1 CONCLUSION

The SAR measurement indicates that the EUT complies with the RF radiation exposure limits of the FCC. These measurements are taken to simulate the RF effects exposure under worst-case conditions. Precise laboratory measures were taken to assure repeatability of the tests.

Please note that the absorption and distribution of electromagnetic energy in the body are very complex phenomena that depend on the mass, shape, and size of the body, the orientation of the body with respect to the field vectors, and the electrical properties of both the body and the environment. Other variables that may play a substantial role in possible biological effects are those that characterize the environment (e.g. ambient temperature, air velocity, relative humidity, and body insulation) and those that characterize the individual (e.g. age, gender, activity level, debilitation, or disease). Because innumerable factors may interact to determine the specific biological outcome of an exposure to electromagnetic fields, any protection guide shall consider maximal amplification of biological effects as a result of field-body interactions, environmental conditions, and physiological variables.[3]

17.1 REFERENCES:

[1] Federal Communications Commission, ET Docket 93-62, Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation, Aug. 1996.

[2] ANSI/IEEE C95.1 - 1991, *American National Standard safety levels with respect to human exposure to radio frequency electromagnetic fields, 300kHz to 100GHz*, New York: IEEE, Aug. 1992

[3] ANSI/IEEE C95.3 - 1991, *IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave*, New York: IEEE, 1992.

[4] NCRP, National Council on Radiation Protection and Measurements, *Biological Effects and Exposure Criteria for RadioFrequency Electromagnetic Fields*, NCRP Report No. 86, 1986. Reprinted Feb. 1995.

[5] T. Schmid, O. Egger, N. Kuster, *Automated E-field scanning system for dosimetric assessments*, IEEE Transaction on Microwave Theory and Techniques, vol. 44, Jan. 1996, pp. 105-113.

[6] K. Pokovic, T. Schmid, N. Kuster, *Robust setup for precise calibration of E-field probes in tissue simulating liquids at mobile communications frequencies*, ICECOM97, Oct. 1997, pp. 120-124.

[7]K. Pokovic, T. Schmid, and N. Kuster, *E-field Probe with improved isotropy in brain simulating liquids*, Proceedings of the ELMAR, Zadar, Croatia, June 23-25, 1996, pp. 172-175.

[8] Schmid & Partner Engineering AG, Application Note: Data Storage and Evaluation, June 1998, p2.

[9] V. Hombach, K. Meier, M. Burkhardt, E. Kuhn, N. Kuster, *The Dependence of EM Energy Absorption upon Human Head Modeling at 900 MHz*, IEEE Transaction on Microwave Theory and Techniques, vol. 44 no. 10, Oct. 1996, pp. 1865-1873.

[10] N. Kuster and Q. Balzano, *Energy absorption mechanism by biological bodies in the near field of dipole antennas above 300MHz*, IEEE Transaction on Vehicular Technology, vol. 41, no. 1, Feb. 1992, pp. 17-23.

[11] G. Hartsgrove, A. Kraszewski, A. Surowiec, *Simulated Biological Materials for Electromagnetic Radiation Absorption Studies*, University of Ottawa, Bioelectromagnetics, Canada: 1987, pp. 29-36.

[12] Q. Balzano, O. Garay, T. Manning Jr., *Electromagnetic Energy Exposure of Simulated Users of Portable Cellular Telephones*, IEEE Transactions on Vehicular Technology, vol. 44, no.3, Aug. 1995.

[13] W. Gander, *Computermathematick*, Birkhaeuser, Basel, 1992.

[14] W.H. Press, S.A. Teukolsky, W.T. Vetterling, and B.P. Flannery, *Numerical Recepies in C,* The Art of Scientific Computing, Second edition, Cambridge University Press, 1992.

[15] Federal Communications Commission, OET Bulletin 65*, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*. Supplement C, Dec. 1997.

[16] N. Kuster, R. Kastle, T. Schmid, *Dosimetric evaluation of mobile communications equipment with known precision*, IEEE Transaction on Communications, vol. E80-B, no. 5, May 1997, pp. 645-652.

[17] CENELEC CLC/SC111B, European Prestandard (prENV 50166-2), *Human Exposure to Electromagnetic Fields High-frequency: 10kHz-300GHz*, Jan. 1995.

[18] Prof. Dr. Niels Kuster, ETH, Eidgenössische Technische Hoschschule Zürich, *Dosimetric Evaluation of the Cellular Phone*.

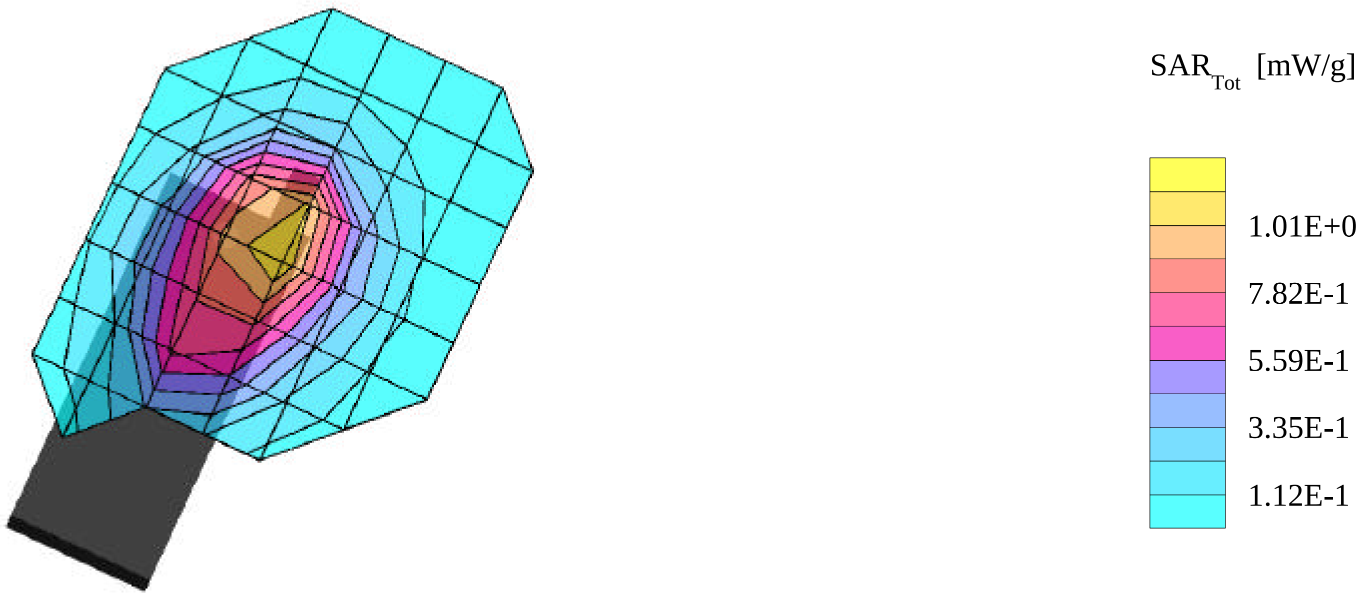
DENSO FCC ID:LXC-E220 -- FM Brain SAR [Class II Permissive Change]

Generic Twin Phantom; Left Hand Section; Probe: ET3DV5 - SN1370 -- Probe Cal Date 02/00

Med. Parameters 835 MHz Brain: σ = 0.86 mho/m ε_r = 42.5 ρ = 1.00 g/cm^3; Antenna Position -- Out; Crest Factor 1.0

SAR (1g): 1.23 mW/g, SAR (10g): 0.792 mW/g

DENSO Dual-Band Model: E220
FM Mode, Ch.0991 [824.04MHz]
Conducted Power = 26.7dBm
Test Date: 05/09/2000



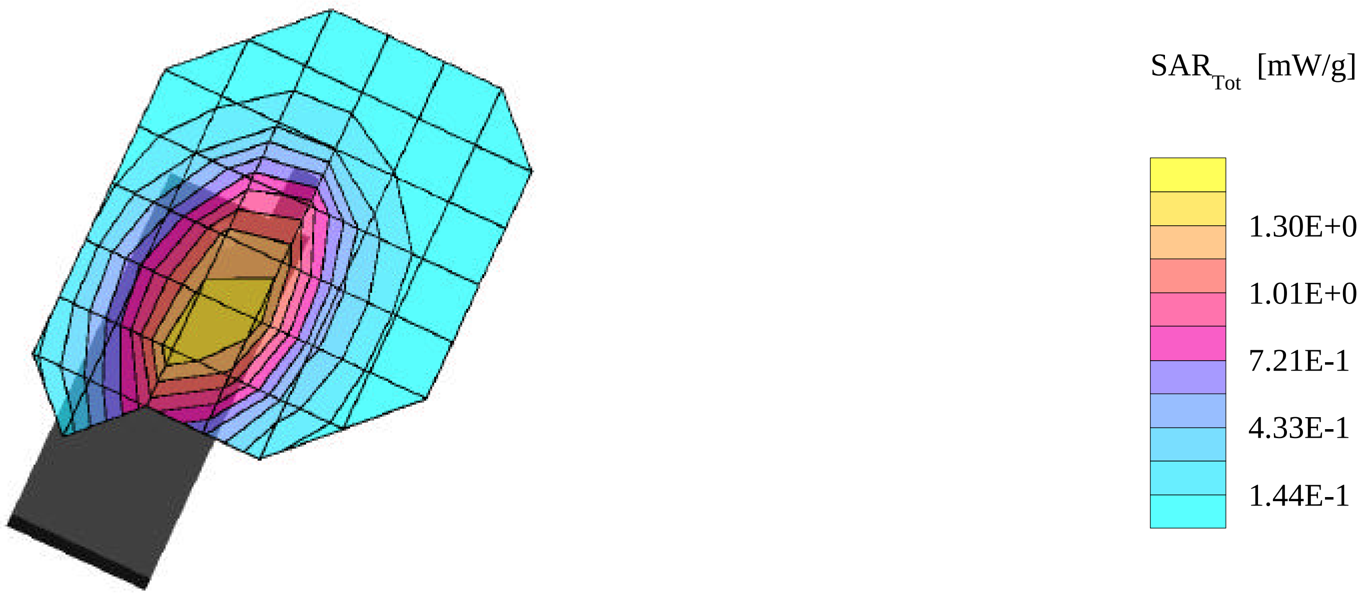
DENSO FCC ID:LXC-E220 -- FM Brain SAR [Class II Permissive Change]

Generic Twin Phantom; Left Hand Section; Probe: ET3DV5 - SN1370 -- Probe Cal Date 02/00

Med. Parameters 835 MHz Brain: σ = 0.86 mho/m ε_r = 42.5 ρ = 1.00 g/cm^3; Antenna Position -- Out; Crest Factor 1.0

SAR (1g): 1.44 mW/g, SAR (10g): 1.04 mW/g

DENSO Dual-Band Model: E220
FM Mode, Ch.0383 [836.49MHz]
Conducted Power = 26.7dBm
Test Date: 05/09/2000



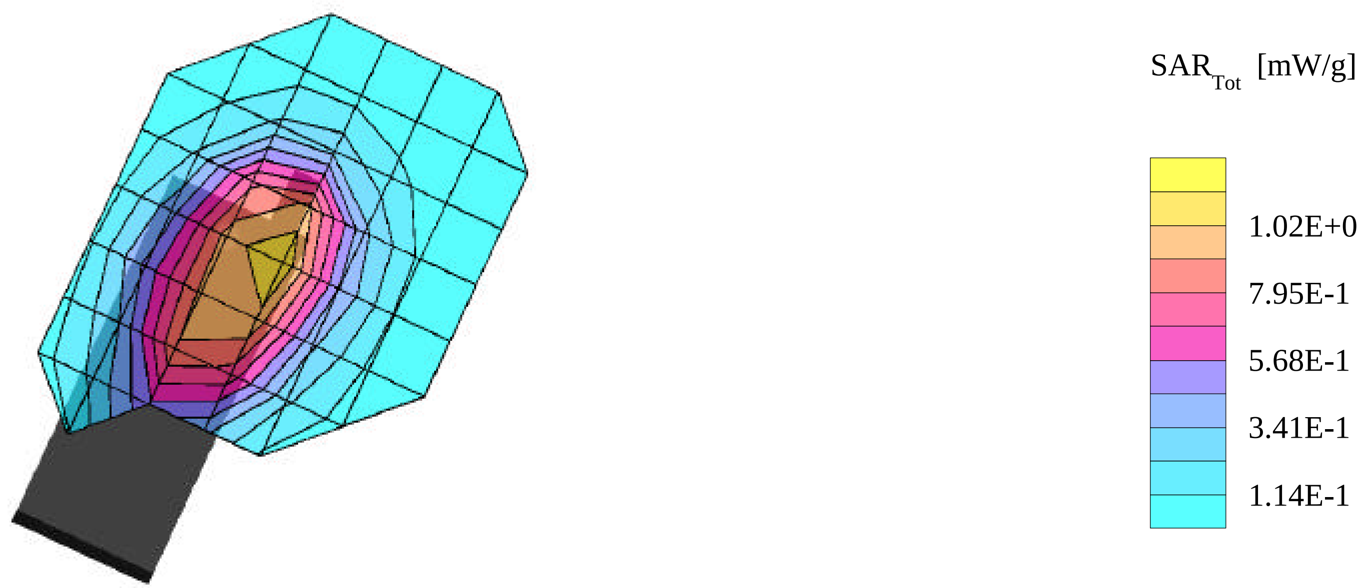
DENSO FCC ID:LXC-E220 -- FM Brain SAR [Class II Permissive Change]

Generic Twin Phantom; Left Hand Section; Probe: ET3DV5 - SN1370 -- Probe Cal Date 02/00

Med. Parameters 835 MHz Brain: σ = 0.86 mho/m ε_r = 42.5 ρ = 1.00 g/cm³; Antenna Position -- Out; Crest Factor 1.0

SAR (1g): 1.17 mW/g, SAR (10g): 0.766 mW/g

DENSO Dual-Band Model: E220
FM Mode, Ch.0799 [848.97MHz]
Conducted Power = 26.7dBm
Test Date: 05/09/2000



DENSO FCC ID:LXC-E220 -- FM Body SAR [Class II Permissive Change]

Generic Twin Phantom; Flat Section; Probe: ET3DV5 - SN1370 -- Probe Cal Date 02/00

Med. Parameters 835 MHz Muscle: σ = 0.95 mho/m ε_r = 56.2 ρ = 1.00 g/cm^3; Antenna Position -- Out; Crest Factor 1.0

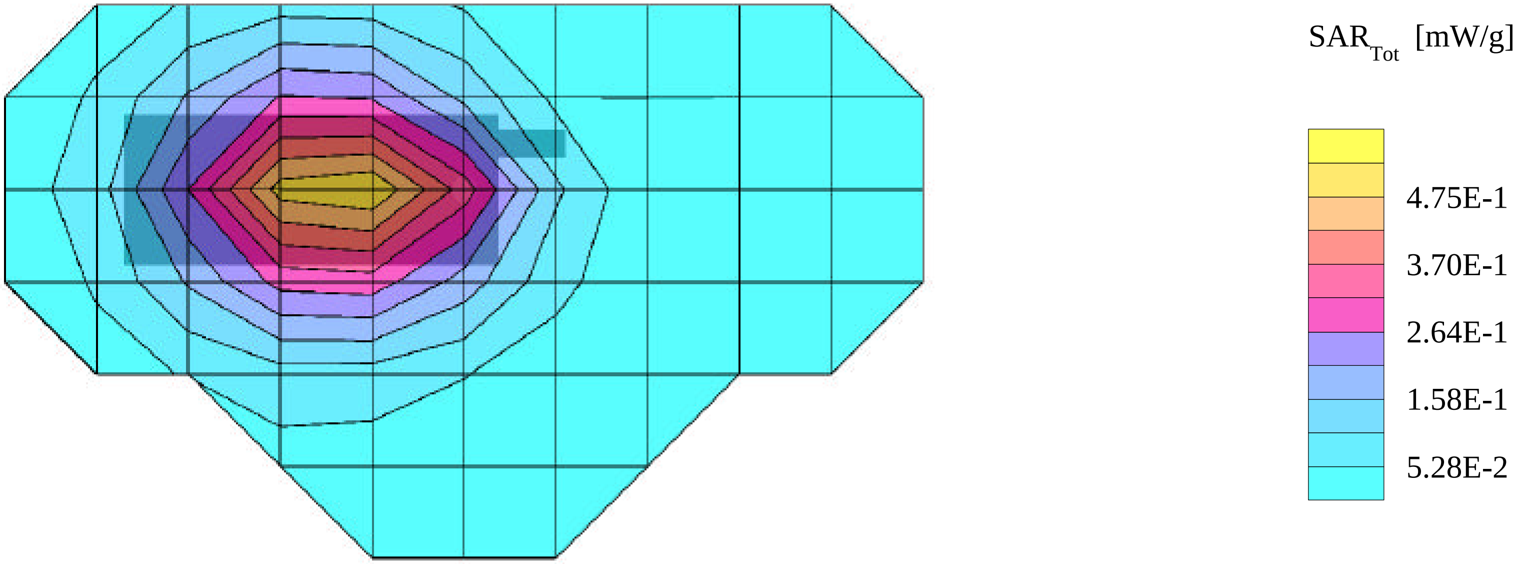
SAR (1g): 0.544 mW/g, SAR (10g): 0.388 mW/g

DENSO Dual-Band Model: E220

FM Mode, Ch.0991 [824.04MHz]

Conducted Power = 26.7dBm; Spacing = 2.5cm w/Denso beltclip Model:SBC-200

Test Date: 05/09/2000



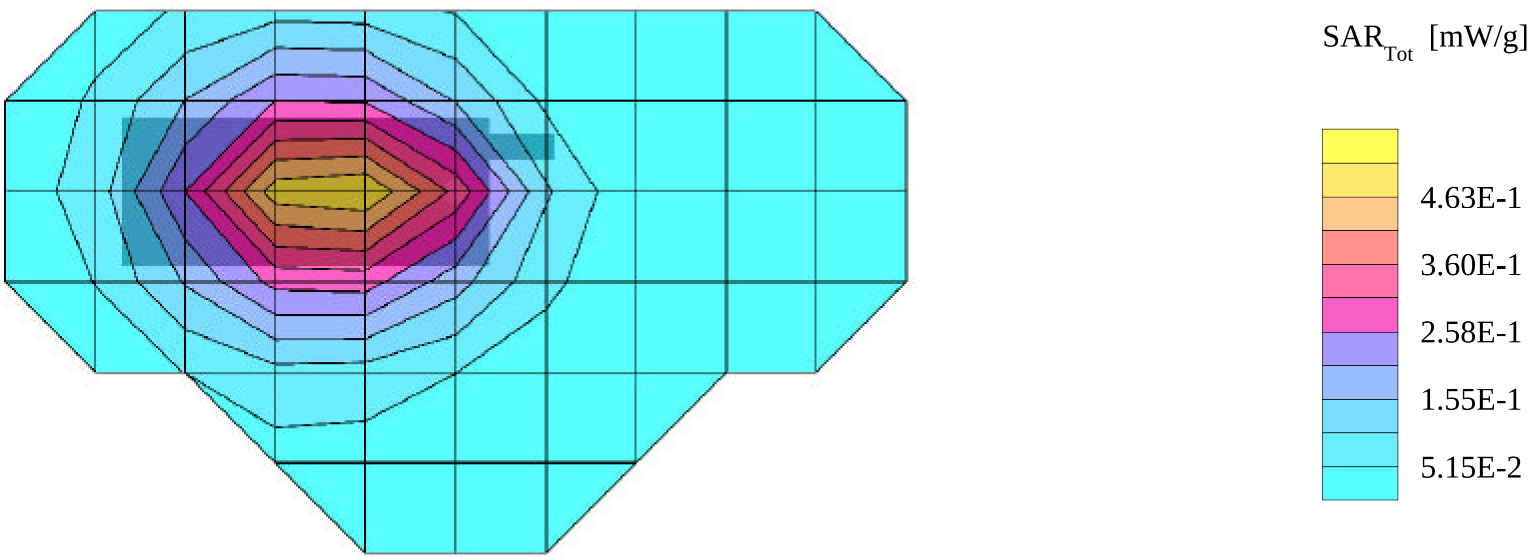
DENSO FCC ID:LXC-E220 -- FM Body SAR [Class II Permissive Change]

Generic Twin Phantom; Flat Section; Probe: ET3DV5 - SN1370 -- Probe Cal Date 02/00

Med. Parameters 835 MHz Muscle: σ = 0.95 mho/m ε_r = 56.2 ρ = 1.00 g/cm^3; Antenna Position -- Out; Crest Factor 1.0

SAR (1g): 0.518 mW/g, SAR (10g): 0.370 mW/g

DENSO Dual-Band Model: E220
FM Mode, Ch.0383 [836.49MHz]
Conducted Power = 26.7dBm; Spacing = 2.5cm w/Denso beltclip Model:SBC-200
Test Date: 05/09/2000



DENSO FCC ID:LXC-E220 -- FM Body SAR [Class II Permissive Change]

Generic Twin Phantom; Flat Section; Probe: ET3DV5 - SN1370 -- Probe Cal Date 02/00

Med. Parameters 835 MHz Muscle: σ = 0.95 mho/m ε_r = 56.2 ρ = 1.00 g/cm^3; Antenna Position -- Out; Crest Factor 1.0

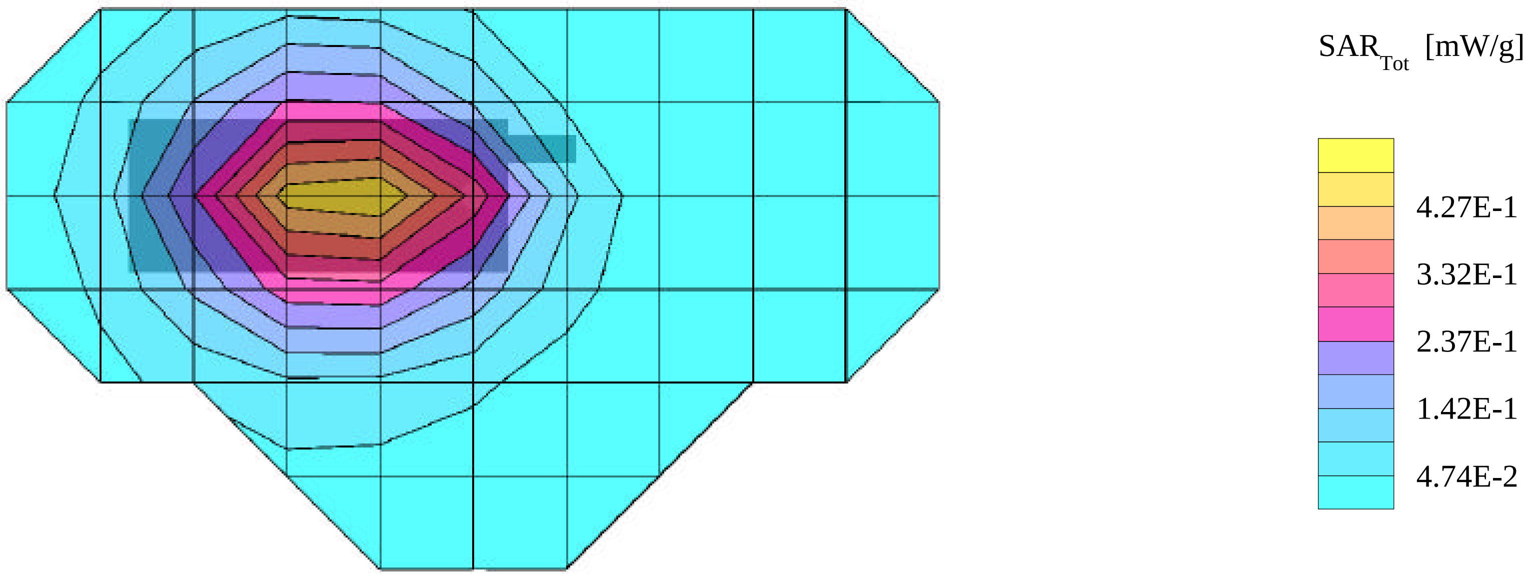
SAR (1g): 0.476 mW/g, SAR (10g): 0.338 mW/g

DENSO Dual-Band Model: E220

FM Mode, Ch.0799 [848.97MHz]

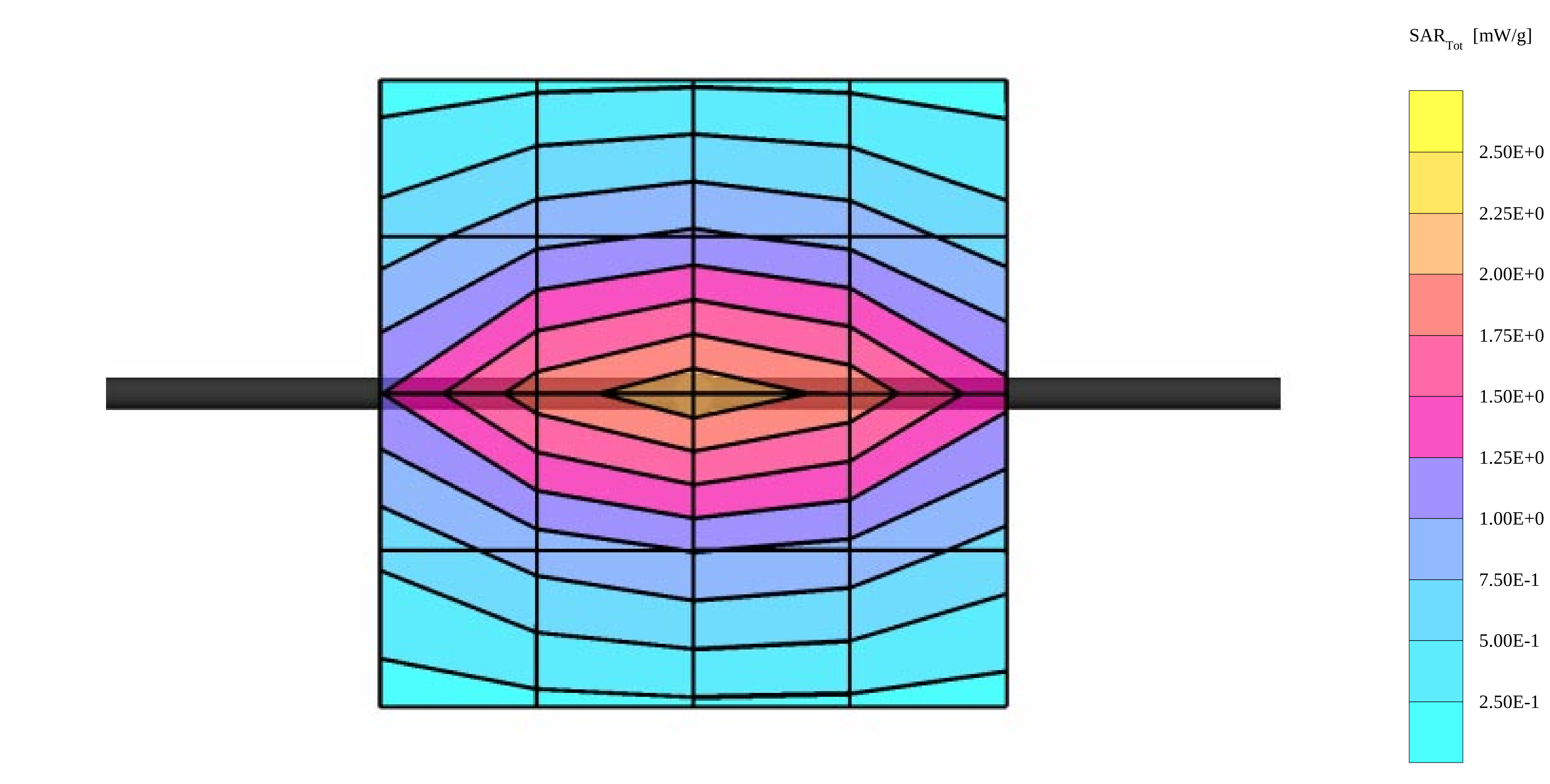
Conducted Power = 26.7dBm; Spacing = 2.5cm w/Denso beltclip Model:SBC-200

Test Date: 05/09/2000



Validation Dipole D835V2 SN:406, d = 15mm

Frequency: 835 MHz; Antenna Input Power: 250 [mW]
Generic Twin Phantom; Flat Section; Grid Spacing: Dx = 20.0, Dy = 20.0, Dz = 10.0
Probe: ET3DV5 - SN1342/DAE3; ConvF(5.75,5.75,5.75); Brain 835 MHz: σ = 0.79 mho/m ε_r = 41.9 ρ = 1.00 g/cm^3
Cubes (2): Peak: 3.17 mW/g ± 0.03 dB, SAR (1g): 2.11 mW/g ± 0.03 dB, SAR (10g): 1.41 mW/g ± 0.04 dB, (Worst-case extrapolation)
Penetration depth: 13.4 (12.3, 14.9) [mm]
Powerdrift: -0.01 dB



835MHz Brain Dipole Validation

Generic Twin Phantom; Flat Section; Probe: ET3DV5 - SN1370 -- Probe Cal Date 02/00

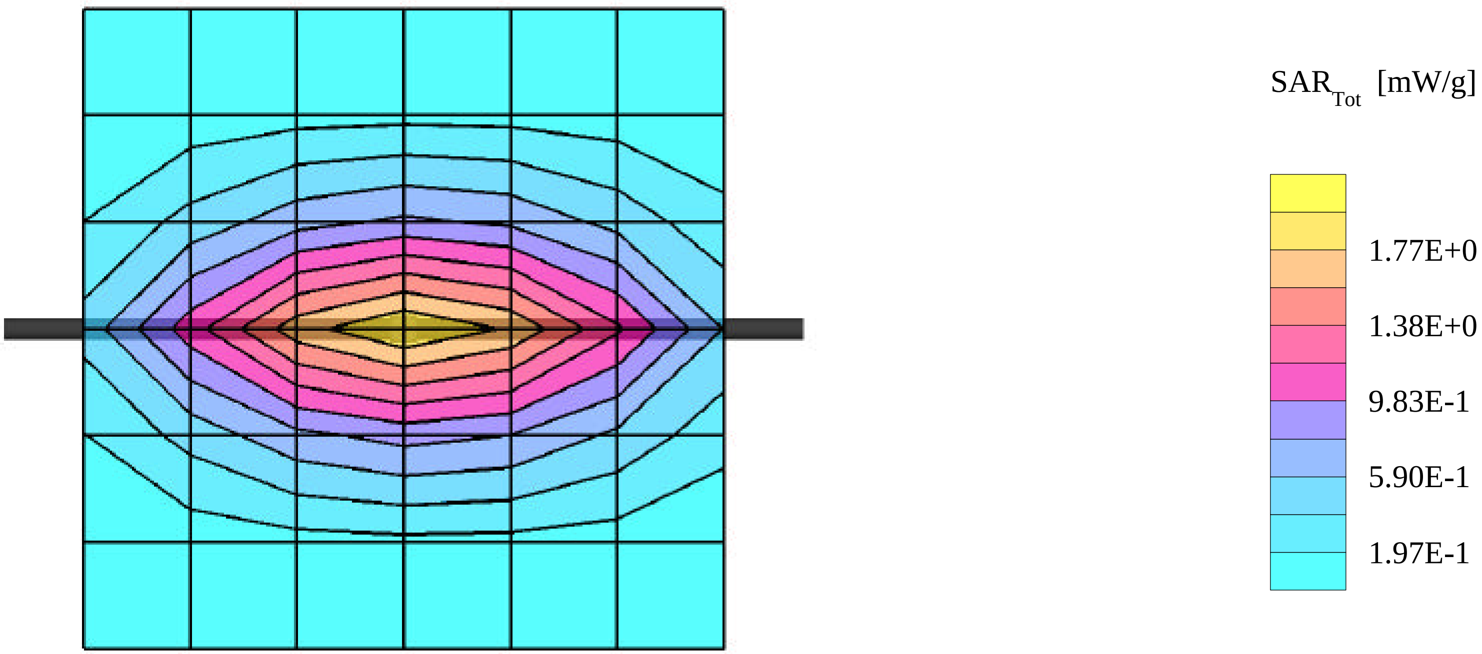
Med. Parameters 835 MHz Brain: σ = 0.86 mho/m ε_r = 42.5 ρ = 1.00 g/cm^3; Antenna Position -- Out; Crest Factor 1.0

SAR (1g): 2.16 mW/g, SAR (10g): 1.41 mW/g

835MHz Dipole Validation (D835V2 S/N: 406)

Frequency: 835 MHz; Antenna Input Power: 250 [mW]

PCTEST Brain Tissue Simulating Liquid



835MHz Muscle Dipole Validation

Generic Twin Phantom; Flat Section; Probe: ET3DV5 - SN1370 -- Probe Cal Date 02/00

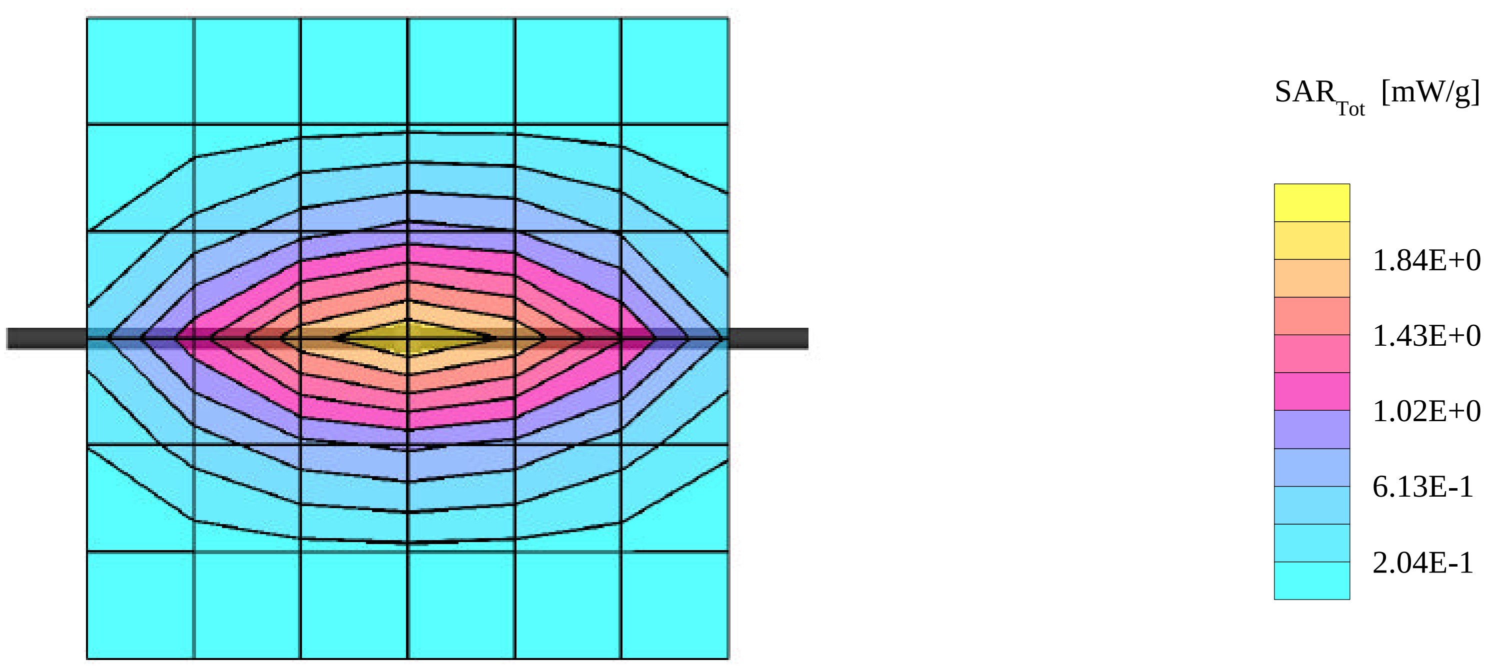
Med. Parameters 835 MHz Muscle: σ = 0.95 mho/m ε_r = 56.2 ρ = 1.00 g/cm^3; Antenna Position -- Out; Crest Factor 1.0

SAR (1g): 2.15 mW/g, SAR (10g): 1.40 mW/g

835MHz Muscle Dipole Validation (D835V2 S/N: 406)

Frequency: 835 MHz; Antenna Input Power: 250 [mW]

PCTEST Muscle Tissue Simulating Liquid



Probe ET3DV5

SN:1370

Manufactured:	February 1999
Calibrated:	February 2000

Calibrated for System DASY3

Introduction

The performance of all probes is measured before delivery. This includes an assessment of the characteristic parameters, receiving patterns as a function of frequency, frequency response and relative accuracy. Furthermore, each probe is tested in use according to a dosimetric assessment protocol. The sensitivity parameters (NormX, NormY, NormZ), the diode compresion parameter (DCP) and the conversion factor (ConvF) of the probe and some of the measurement diagrams are given in the following.

The performance of the individual probes varies slightly due to tolerances arising from the manufacturing process. Since the lines are highly resistive (several MOhms), the offset and noise problem is greatly increased if signals in the low μV range are measured. Accurate measurement below 10 μW/g are possible if the following precautions are taken. 1) check the current grounding with the *multimeter*[1], i.e., low noise levels, 2) compensate the current *offset*[1], 3) use long integration time (approx. 10 seconds), 4) *calibrate*[1] before each measurement, 5) persons should avoid moving around the lab while measuring.

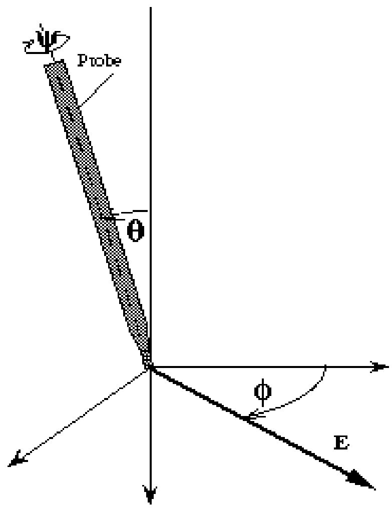


Fig 1: Due to the field distortion caused by the supporting material, the probe has two characteristic directions, referred to as angle ψ and θ.

Since the field distortion caused by the supporting material and the sheath is quite high in the θ direction, the receiving pattern is poor in air. However, the distortion in tissue equivalent material is much less because of its high dielectricity. In addition, the fields induced in the phantoms by dipole structures close to the body are dominently parallel to the surface. Thus, the error due to non-isotropy is much better than 1 dB for dosimetric assessments.

The probes are calibrated in the TEM cell ifi 110 although the field distribution in the cell is not very uniform and the frequency response is not very flat. To ensure consistency, a strict protocol is followed. The conversion factor (ConF) between this calibration and the measurement in the tissue simulation solution is performed by comparison with temperature measurements and computer simulations. This conversion factor is only valid for the specified tissue simulating liquids at the specified frequencies. If measurements have to be performed in solutions with other electrical properties or at other frequencies, the conversion factor has to be assessed by the same procedure.

As the probes have been constructed with printed resistive lines on ceramic substrates (thick film technique), the probe is very delicate with respect to mechanical shocks.

Attention:

Do not drop the probe or let the probe collide with any solid object. Never let the robot move without first activating the emergency stop feature (i.e., without first turning the data acquisition electronics on).

[1] Feature of the DASY Software Tool.

DASY3 - Parameters of Probe: ET3DV5 SN:1370

Sensitivity in Free Space

NormX	**1.58**	$\mu V/(V/m)^2$
NormY	**1.64**	$\mu V/(V/m)^2$
NormZ	**1.80**	$\mu V/(V/m)^2$

Diode Compression

DCP X	**96**	mV
DCP Y	**96**	mV
DCP Z	**96**	mV

Sensitivity in Tissue Simulating Liquid

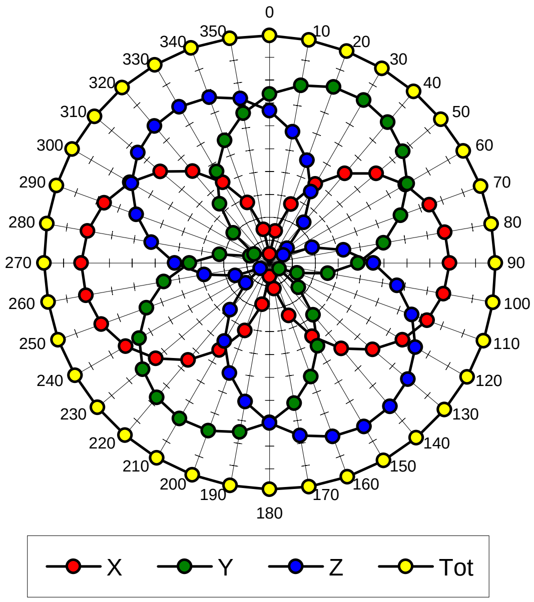
450 MHz	ConvF X	**6.5**	extrapolated	ε_r =	48 ± 5%
	ConvF Y	**6.5**	extrapolated	σ =	0.50 ± 10% mho/m
	ConvF Z	**6.5**	extrapolated	(brain tissue simulating liquid)	
900 MHz	ConvF X	**6.0**	± 10%	ε_r =	42.5 ± 5%
	ConvF Y	**6.0**	± 10%	σ =	0.86 ± 10% mho/m
	ConvF Z	**6.0**	± 10%	(brain tissue simulating liquid)	
1500 MHz	ConvF X	**5.4**	interpolated	ε_r =	41 ± 5%
	ConvF Y	**5.4**	interpolated	σ =	1.32 ± 10% mho/m
	ConvF Z	**5.4**	interpolated	(brain tissue simulating liquid)	
1800 MHz	ConvF X	**5.1**	± 10%	ε_r =	41 ± 5%
	ConvF Y	**5.1**	± 10%	σ =	1.69 ± 10% mho/m
	ConvF Z	**5.1**	± 10%	(brain tissue simulating liquid)	

Sensor Offset

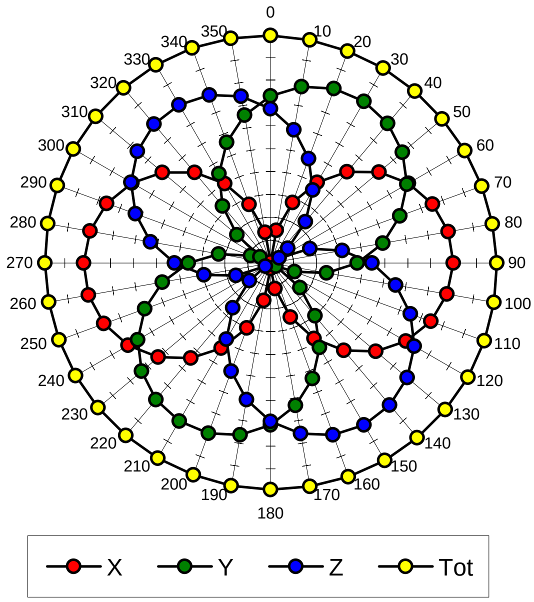
Probe Tip to Sensor Center	**2.7**	mm
Surface to Probe Tip	**1.6 ± 0.2**	mm

Receiving Pattern (ϕ), θ = 0°

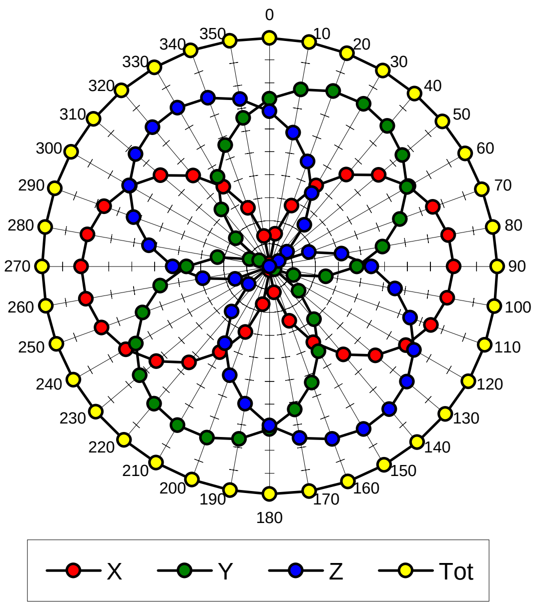
f = 30 MHz, TEM cell ifi110



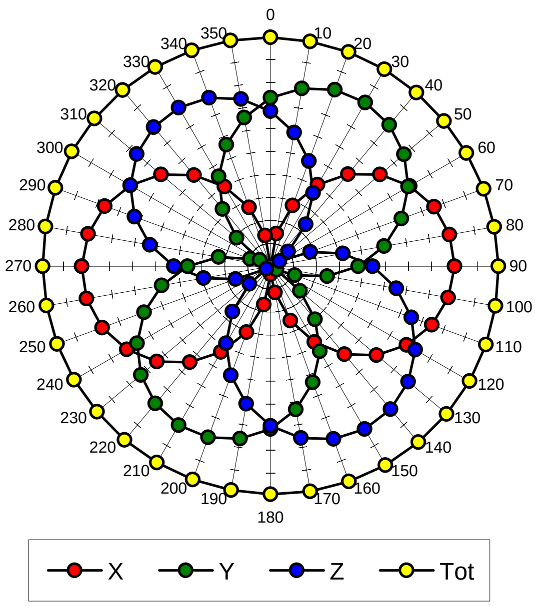
f = 100 MHz, TEM cell ifi110

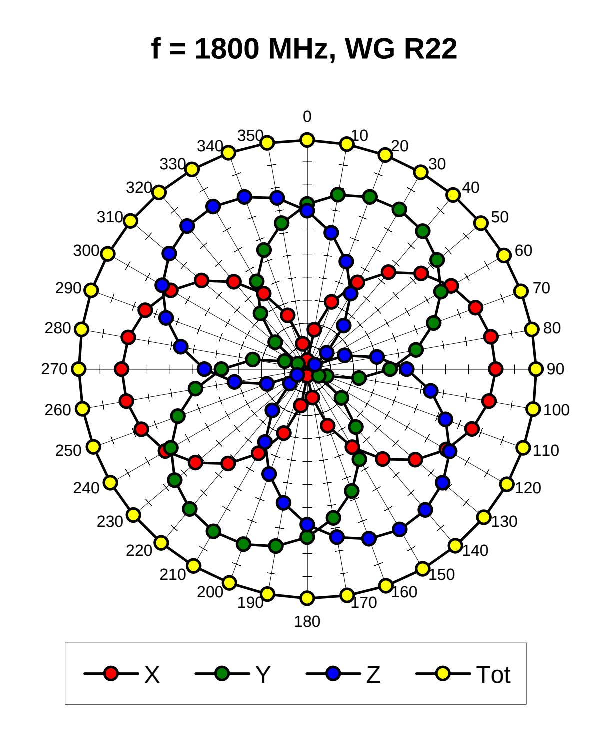


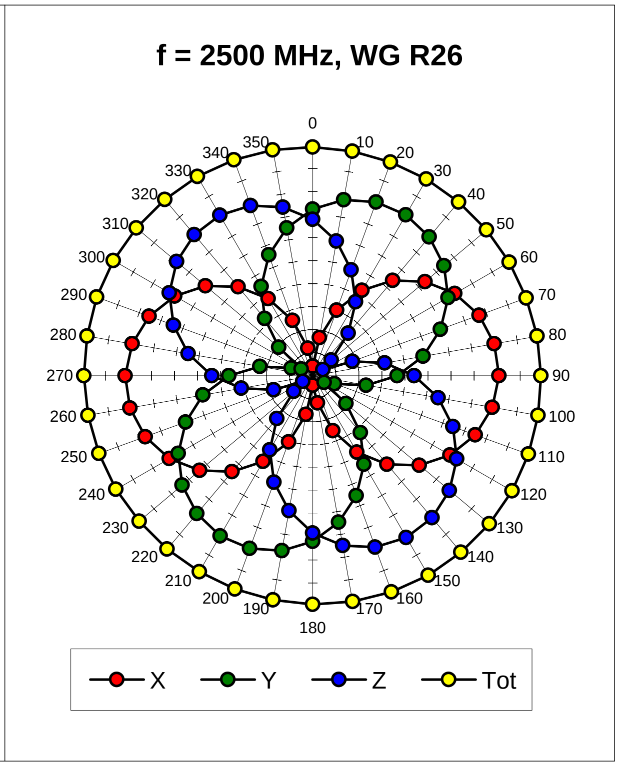
f = 300 MHz, TEM cell ifi110



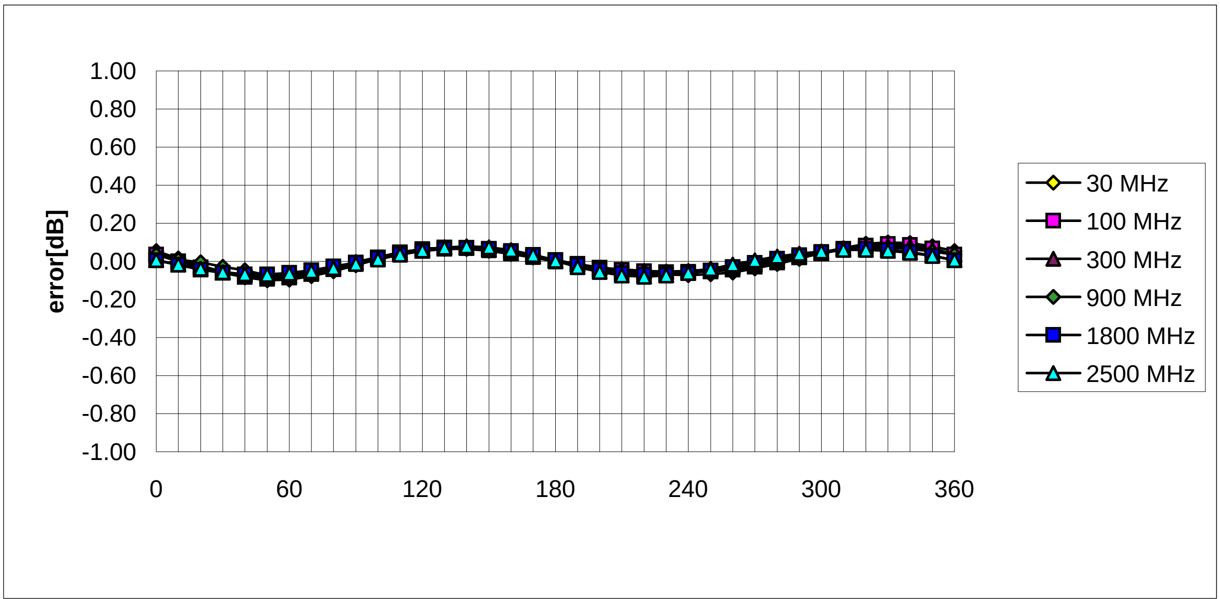
f = 900 MHz, TEM cell ifi110





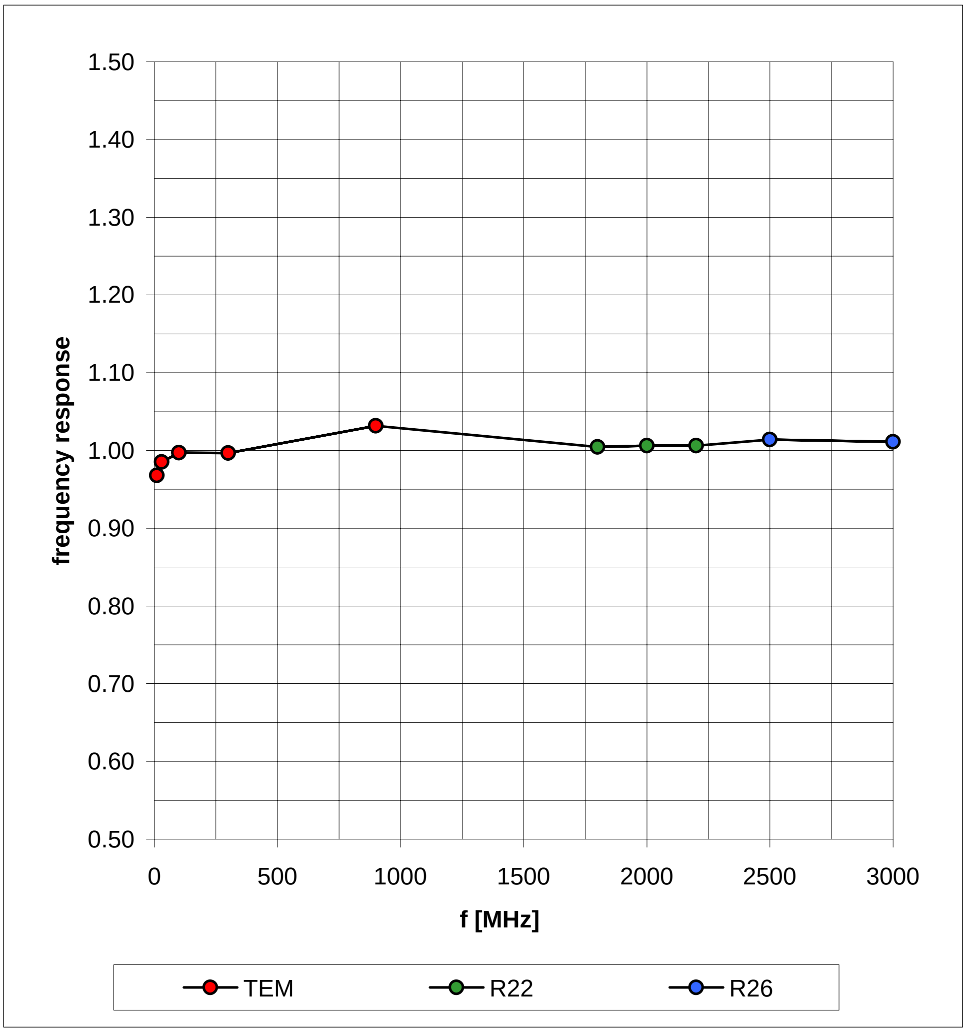


Isotropy Error (ϕ), θ = 0°



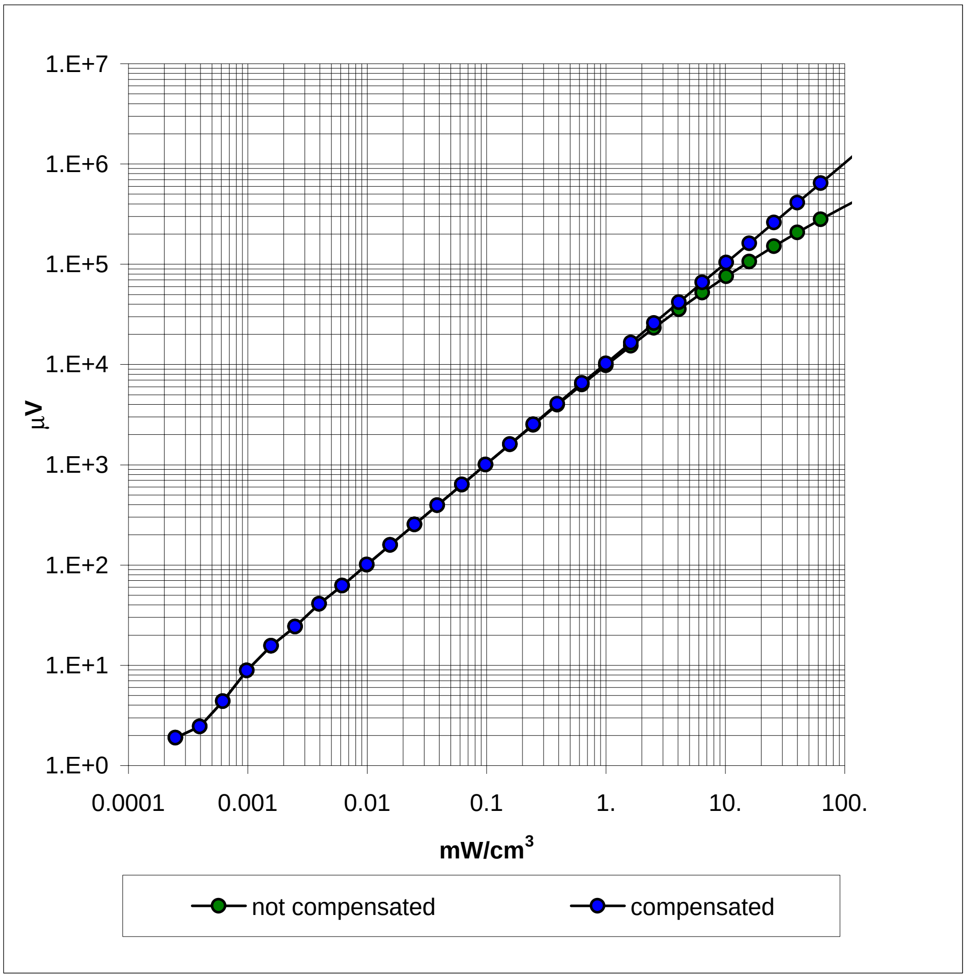
Frequency Response of E-Field

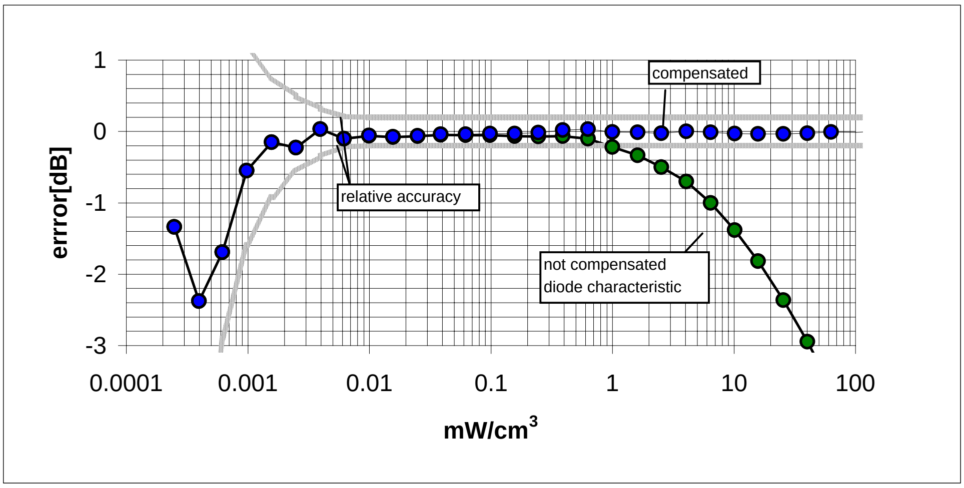
(TEM-Cell:ifi110, Waveguide R22, R26)



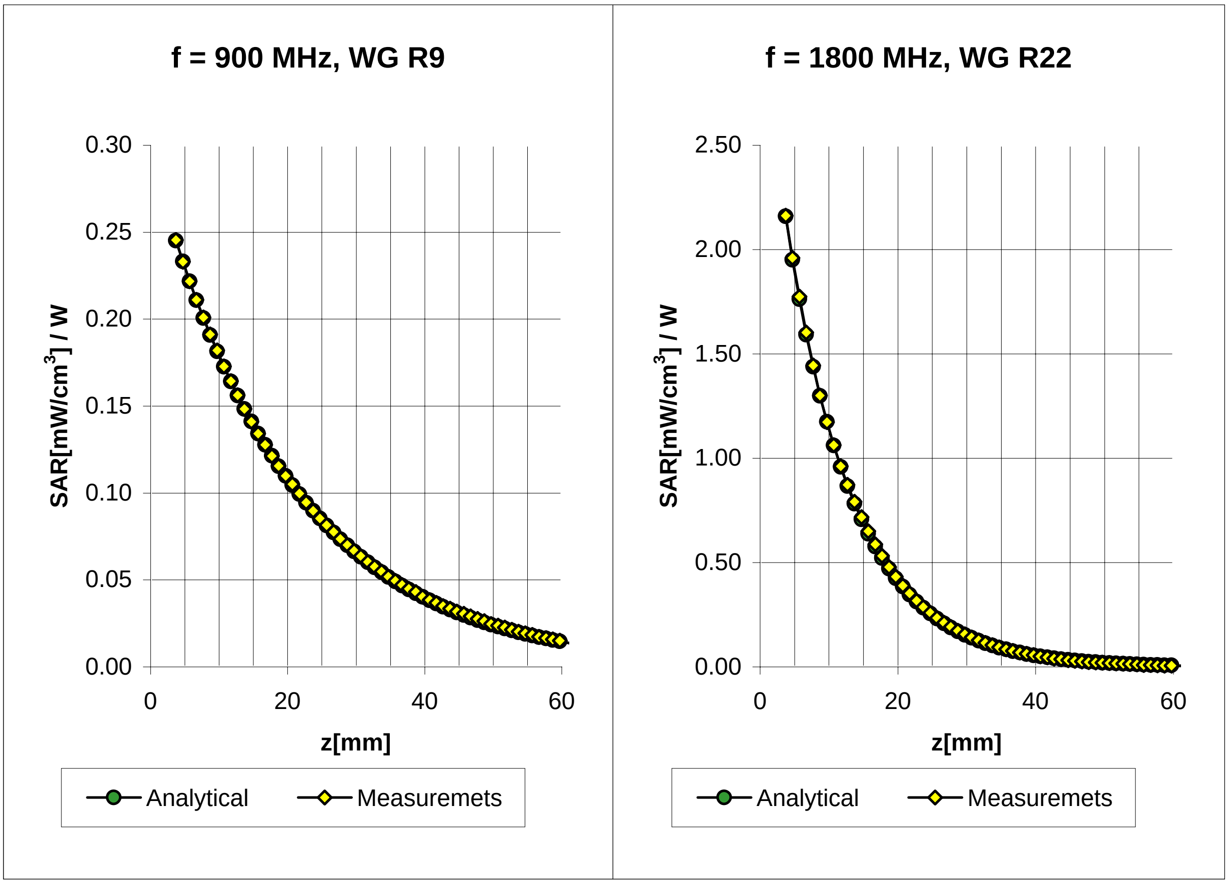
Dynamic Range f(SAR_{brain})

(TEM-Cell:ifi110)





Conversion Factor Assessment



Receiving Pattern (ϕ)

(in brain tissue, z = 5 mm)