SAR Test Report

No. SAR_479_2003_FCC_1900

for the

Vitelcom

1900 MHz Mobile Phone

Model Number: TSM1

Date of Report:	**05/23/2003**
Date of issue:	**05/23/2003**
Report Copy No.:	**01**

Accredited according to
ISO/IEC 17025 by:

Deutscher Akkreditierungs Rat

TTI-P-G 81/94-A0

CTIA Authorized Testing Laborat

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Contents

1. Assessment

The Vitelcom Vitel 1900 MHz Mobile Phone is in compliance with the exposure criteria specified in Federal Communications Commission (FCC) Guidelines [FCC 2001] for uncontrolled exposure.

05/23/2003	**05/23/2003**
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2. Administrative Data

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3. Equipment under Investigation (EUI)

3.1. Identification of the Equipment under Investigation

Product Type	1900 MHz Mobile Phone
Marketing Name:	MOVISTAR
Model No:	TSM1
Serial Number:	350396010355608
FCC-ID:	TKHSP102
Frequency Range:	1850 MHz to 1910 MHz
Type(s) of Modulation:	GMSK
Number of Channels:	PCS:
Antenna Type:	Integral
Accessories:	None
Battery Options:	None
Maximum Output Power[1]:	29.0 dBm (0.749Watts) peak conducted output power

[1] For complete output power measurements see section 8.2 of this report.

3.2. Front View of the Equipment under Investigation

4. Subject of Investigation

The Vitel is a new 1900 MHz Mobile Phone from Vitelcom operating in the 1850 MHz to 1910 MHz frequency ranges. The device has an integral antenna. The objective of the measurements done by Cetecom Inc. was the dosimetric assessment of one device. The tests were performed in configurations for devices operated next to a person's ear and for body worn configurations. The examinations were carried out with the dosimetric assessment system SARA2 described below.

4.1. The IEEE Standard C95.1 and the FCC Exposure Criteria

In the USA the recent FCC exposure criteria [FCC 2001] are based upon the IEEE Standard C95.1 [IEEE 1999]. The IEEE standard C95.1 sets limits for human exposure to radio frequency electromagnetic fields in the frequency range 3 kHz to 300 GHz.

4.2. Distinction Between Exposed Population, Duration of Exposure and Frequencies

The American Standard [IEEE 1999] 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. 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.

4.3. 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:

$$SAR = \sigma \frac{E2}{\rho} = c \left. \frac{\partial T}{\partial t} \right|_{t \to 0+}$$

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.

4.4. 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

5. The FCC 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 telecom-communications devices, either by laboratory measurement techniques or by computational modeling, prior to equipment authorization or use. In 2001 the Commission's Office of Engineering and Technology has released Edition 01-01 of Supplement C to OET Bulletin 65. This revised edition, which replaces Edition 97-01, provides additional guidance and information for evaluating compliance of mobile and portable devices with FCC limits for human exposure to radiofrequency emissions [FCC 2001].

5.1. General Requirements

The test shall be performed in a laboratory with an environment which avoids influence on SAR measurements by ambient EM sources and any reflection from the environment itself. The ambient temperature shall be in the range of 20°C to 26°C and 30-70% humidity.

5.2. Device Operating Next to a Person's Ear

Phantom Requirements

The phantom is a simplified representation of the human anatomy and comprised of material with electrical properties similar to the corresponding tissues. The physical characteristics of the phantom model shall resemble the head and the neck of a user since the shape is a dominant parameter for exposure.

5.3. Test positions of device relative to head

FCC's OET Bulletin supplement C requires two test positions for the handset against the head phantom, the "cheek" position and the "tilted" position. These two test positions are defined below. The handset should be tested in both positions on the left and right sides of the SAM phantom.

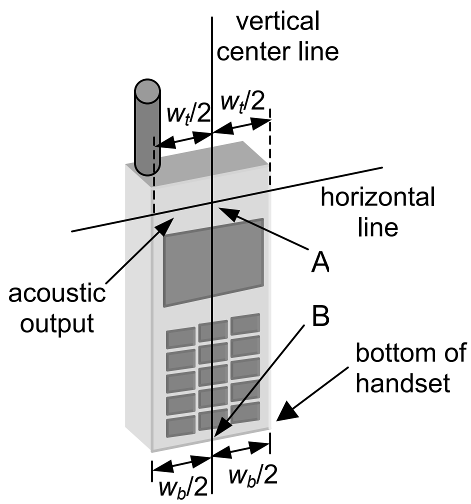


Figure 1a – Handset vertical and horizontal reference lines – fixed case

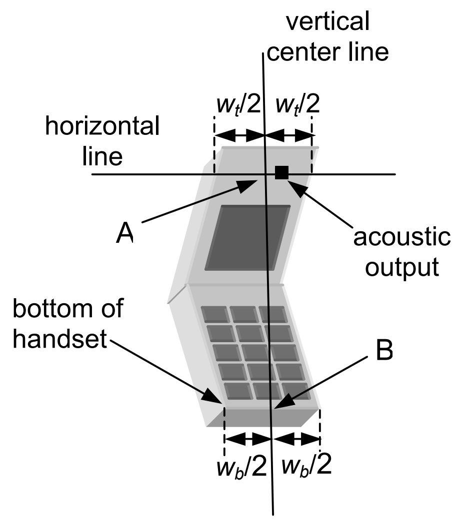


Figure 1b – Handset vertical and horizontal reference lines – "clam-shell"

Definition of the "cheek" position

The "cheek" position is defined as follows:

a) Ready the handset for talk operation.

b) Define two imaginary lines on the handset: the vertical centerline and the horizontal line. The vertical centerline passes through two points on the front side of the handset: the midpoint of the width wt of the handset at the level of the acoustic output (point A on Figures 1a and 1b), and the midpoint of the width wb of the bottom of the handset (point B). The horizontal line is perpendicular to the vertical centerline and passes through the center of the acoustic output (see Figure 1a). The two lines intersect at point A. Note that for many handsets, point A coincides with the center of the acoustic output. However, the acoustic output may be located elsewhere on the horizontal line. Also note that the vertical centerline is not necessarily parallel to the front face of the handset (see Figure 1b), especially for clamshell handsets, handsets with flip pieces, and other irregularly-shaped handsets.

c) Position the handset close to the surface of the phantom such that point A is on the (virtual) extension of the line passing through points RE and LE on the phantom (see

Figure 2), such that the plane defined by the vertical center line and the horizontal line of the handset is approximately parallel to the sagittal plane of the phantom.

d) Translate the handset towards the phantom along the line passing through RE and LE until the handset touches the pinna.

e) While maintaining the handset in this plane, rotate it around the LE-RE line until the vertical centerline is in the plane normal to MB-NF including the line MB (called the reference plane).

f) Rotate the handset around the vertical centerline until the handset (horizontal line) is symmetrical with respect to the line NF.

g) While maintaining the vertical centerline in the reference plane, keeping point A on the line passing through RE and LE and maintaining the handset contact with the pinna, rotate the handset about the line NF until any point on the handset is in contact with a phantom point below the pinna (cheek). See Figure 2. The physical angles of rotation should be noted.

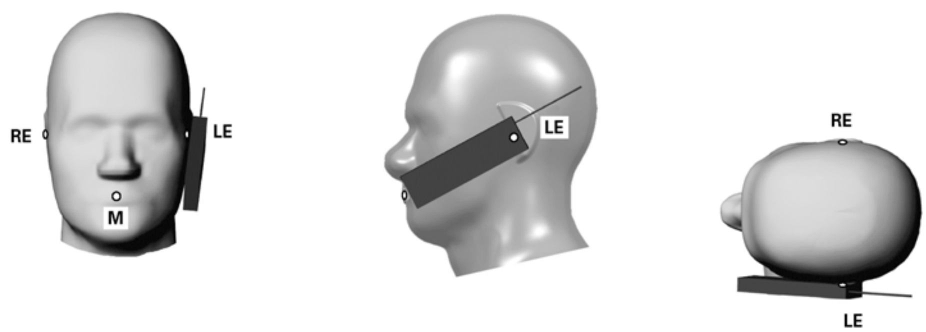


Figure 2 – Phone position 1, "cheek" or "touch" position. The reference points for the right ear (RE), left ear (LE) and mouth (M), which define the reference plane for handset positioning, are indicated.

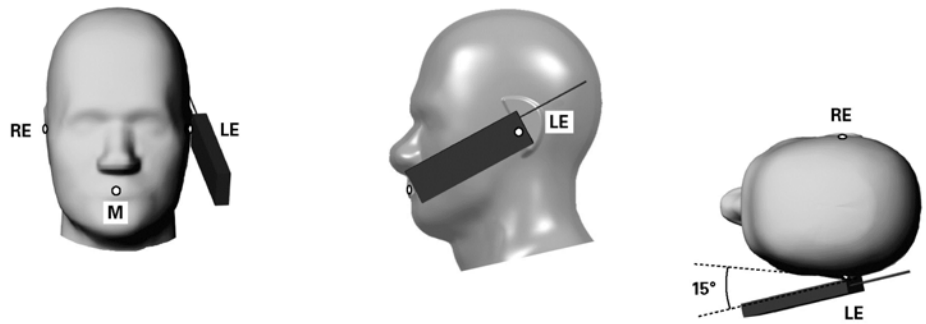


Figure 3 – Phone position 2, "tilted" position. The reference points for the right ear (RE), left ear (LE) and mouth (M), which define the reference plane for handset positioning, are indicated.

Definition of the "tilted" position

The "tilted" position is defined as follows:

a) Repeat steps (a) – (g) of cheek position section above to place the device in the "cheek position."

b) While maintaining the orientation of the handset move the handset away from the pinna along the line passing through RE and LE in order to enable a rotation of the handset by 15 degrees.

c) Rotate the handset around the horizontal line by 15 degrees.

d) While maintaining the orientation of the handset, move the handset towards the phantom on a line passing through RE and LE until any part of the handset touches the ear. The tilted position is obtained when the contact is on the pinna. If the contact is at any location other than the pinna, e.g., the antenna with the back of the phantom head, the angle of the handset should be reduced. In this case, the tilted position is obtained if any part of the handset is in contact with the pinna as well as a second part of the handset is contact with the phantom, e.g., the antenna with the back of the head.

5.4. Test to be Performed

The SAR test shall be performed with both phone positions described above, on the left and right side of the phantom. The device shall be measured for all modes operating when the device is next to the ear, even if the different modes operate in the same frequency band.

For devices with retractable antenna the SAR test shall be performed with the antenna fully extended and fully retracted. Other factors that may affect the exposure shall also be tested. For example, optional antennas or optional battery packs which may significantly change the volume, lengths, flip open/closed, etc. of the device, or any other accessories which might have the potential to considerably increase the peak spatial-average SAR value.

The SAR test shall be performed at the high, middle and low frequency channels of each operating mode. If the SAR measured at the middle channel for each test configuration is at least 2.0 dB lower than the SAR limit, testing at the high and low channels is optional.

5.5. Body-worn and Other Configurations

Phantom Requirements
For body-worn and other configurations a flat phantom shall be used which is comprised of material with electrical properties similar to the corresponding tissues.

Test Position
The body-worn configurations shall be tested with the supplied accessories (belt-clips, holsters, etc.) attached to the device in normal use configuration. Devices with a headset output shall be tested with a connected headset.

Test to be Performed
For purpose of determining test requirements, accessories may be divided into two categories: those that do not contain metallic components and those that do. For multiple accessories that do not contain metallic components, the device may be tested only with that accessory which provides the closest spacing to the body. For multiple accessories that contain metallic components, the device must be tested with each accessory that contains a unique metallic component. If multiple accessories share an identical metallic component, only the accessory that provides the closest spacing to the body must be tested. If the manufacturer provides none body-worn accessories a separation distance of 1.5 cm between the back of the device and the flat phantom is recommended. Other separation distances may be used, but they shall not exceed 2.5 cm. In these cases, the device may use body-worn accessories that provide a separation distance greater than that tested for the device provided however that the accessory contains no metallic components.

For devices with retractable antenna the SAR test shall be performed with the antenna fully extended and fully retracted. Other factors that may affect the exposure shall also be tested. For example, optional antennas or optional battery packs which may significantly change the volume, lengths, flip open/closed, etc. of the device, or any other accessories which might have the potential to considerably increase the peak spatial-average SAR value.

5.6. Procedure for assessing the peak spatial-average SAR

Step 1: Power reference measurement:

Prior to the SAR test, a local SAR measurement should be taken at a user-selected spatial reference point to monitor power variations during testing. For example, this power reference point can be spaced 10 mm or less in the normal direction from the liquid-shell interface and within ± 10 mm transverse to the normal line at the ear reference point.

Step 2: Area scan

The measurement procedures for evaluating SAR associated with wireless handsets typically start with a coarse measurement grid in order to determine the approximate location of the local peak SAR values. This is referred to as the "area scan" procedure. The SAR distribution is scanned along the inside surface of typically half of the head of the phantom but at least larger than the areas projected (normal to the phantom's surface) by the handset and antenna. An example grid is given in Figure 4. The distance between the measured points and phantom surface should be less than 8 mm, and should remain constant (variation less than ± 1 mm) during the entire scan in order to determine the locations of the local peak SAR with sufficient precision. The distance between the measurement points should enable the detection of the location of local maximum with an accuracy of better than half the linear dimension of the tissue cube after interpolation. The resolution can also be tested using the functions in Annex E (see E.5.2). The approximate locations of the peak SARs should be determined from area scan. Since a given amplitude local peak with steep gradients may produce lower spatial-average SAR than slightly lower amplitude peaks with less steep gradients, it is necessary to evaluate the other peaks as well. However, since the spatial gradients of local SAR peaks are a function of wavelength inside the tissue simulating liquid and incident magnetic field strength, it is not necessary to evaluate peaks that are less than –2dB of the local maximum. Two-dimensional spline algorithms [Press, et al, 1996], [Brishoual, 2001] are typically used to determine the peaks and gradients within the scanned area. If the peak is closer than one-half of the linear dimension of the 1 g or 10 g tissue cube to the scan border, the measurement area should be enlarged if possible, e.g., by tilting the probe or the phantom (see Figure 5).

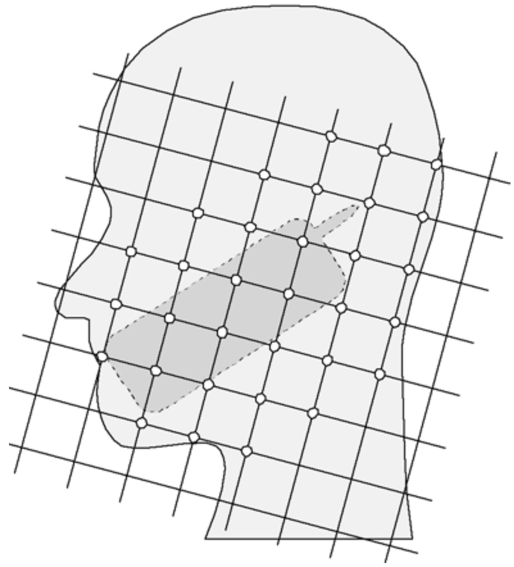


Figure 4 – Example of an area scan including the position of the handset. The scanned area (white dots) should be larger than the area projected by the handset and antenna.

Step 3: Zoom scan

In order to assess the peak spatial SAR values averaged over a 1 g and 10 g cube, fine resolution volume scans, called "zoom scans", are performed at the peak SAR locations determined during the "area scan." The zoom scan volume should have at least 1.5 times the linear dimension of either a 1 g or a 10 g tissue cube for whichever peak spatial-average SAR is being evaluated. The peak local SAR locations that were determined in the area scan (interpolated value) should be on the centerline of the zoom scans. The centerline is the line that is normal to the surface and in the center of the volume scan. If this is not possible, the zoom scan can be shifted but not by more than half the dimension of the 1 g or a 10 g tissue cube.

The maximum spatial-average SAR is determined by a numerical analysis of the SAR values obtained in the volume of the zoom scan, whereby interpolation (between measured points) and extrapolation (between surface and closest measured points) routines should be applied. A 3-D-spline algorithm [Press, et al, 1996], [Kreyszig, 1983], [Brishoual, 2001] can be used for interpolation and a trapezoidal algorithm for the integration (averaging). Scan resolutions of larger than 2 mm can be used provided the uncertainty is evaluated according to E (see E.5).

In some areas of the phantom, such as the jaw and upper head region, the angle of the probe with respect to the line normal to the surface might become large, e.g., at angles larger than ± 30º (see Figure 5), which may increase the boundary effect to an unacceptable level. In these cases, a change in the orientation of the probe and/or the phantom is recommended during the zoom scan so that the angle between the probe housing tube and the line normal to the surface is significantly reduced (<30º).

Step 4: Power reference measurement

The local SAR should be measured at exactly the same location as in Step 1. The absolute value of the measurement drift (the difference between the SAR measured in Step 4 and Step 1) should be recorded in the uncertainty budget. It is recommended that the drift be kept within ± 5%. If this is not possible, even with repeat testing, additional information may be used to demonstrate the power stability during the test. Power reference measurements can be taken after each zoom scan, if more than one zoom scan is needed. However, the drift should always be referred to the initial state with fully charged battery.

5.7. Determination of the largest peak spatial-average SAR

In order to determine the largest value of the peak spatial-average SAR of a handset, all device positions, configurations and operational modes should be tested for each frequency band according to steps 1 to 3 below.

Step 1: The tests of 6.4 should be conducted at the channel that is closest to the center of the transmit frequency band (*fc*) for:

a) all device positions (cheek and tilt, for both left and right sides of the SAM phantom,

b) all configurations for each device position in (a), e.g. antenna extended and retracted, and

c) all operational modes for each device position in (a) and configuration in (b) in each frequency band, e.g. analog and digital.

If more than three frequencies need to be tested, (i.e., Nc > 3), then all frequencies, configurations and modes must be tested for all of the above positions.

Step 2: For the condition providing highest spatial peak SAR determined in Step 1 conduct all tests of 6.4 at all other test frequencies, e.g. lowest and highest frequencies. In addition, for all other conditions (device position, configuration and operational mode) where the spatial peak SAR value determined in Step 1 is within 3dB of the applicable SAR limit, it is recommended that all other test frequencies should be tested as well[2].

Step 3: Examine all data to determine the largest value of the peak spatial-average SAR found in Steps 1 to 2.

6. The Measurement System

6.1. Robot system specification

The SAR measurement system being used is the IndexSAR SARA2 system, which consists of a Mitsubishi RV-E2 6-axis robot arm and controller, IndexSAR probe and amplifier and SAM phantom Head Shape. The robot is used to articulate the probe to programmed positions inside the phantom head to obtain the SAR readings from the DUT.

The system is controlled remotely from a PC, which contains the software to control the robot and data acquisition equipment. The software also displays the data obtained from test scans.

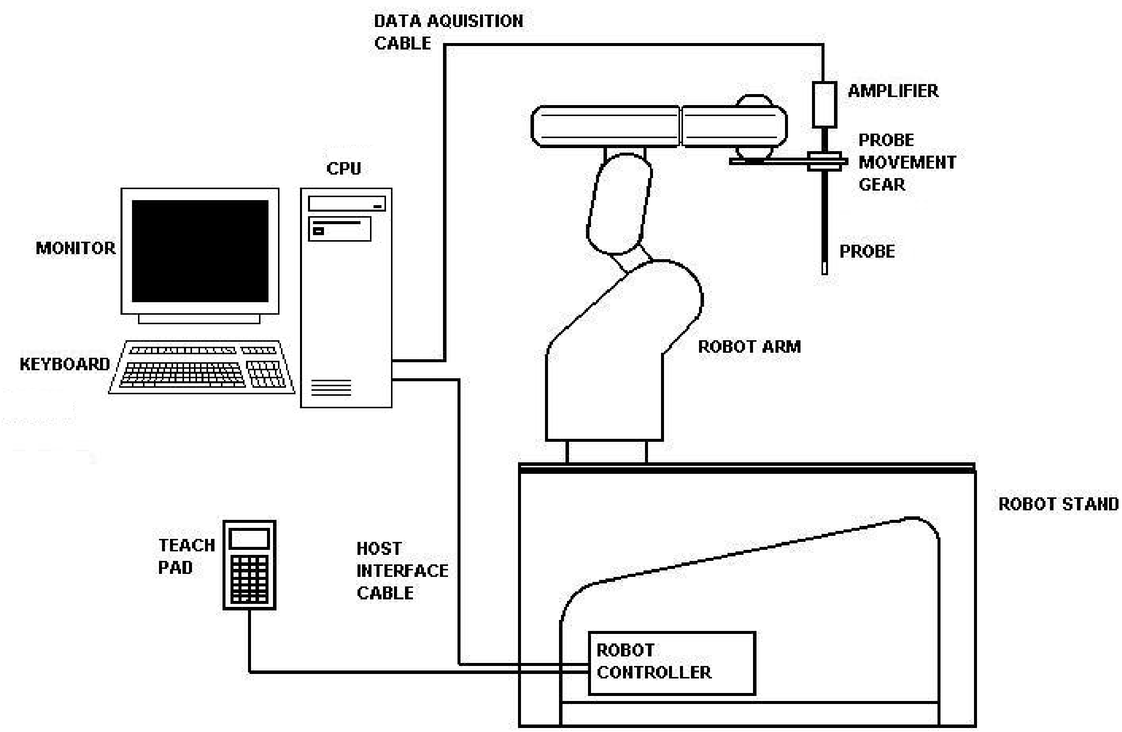


Figure 5: Schematic diagram of the SAR measurement system

The position and digitised shape of the phantom heads are made available to the software for accurate positioning of the probe and reduction of set-up time.
The SAM phantom heads are individually digitised using a Mitutoyo CMM machine to a precision of 0.001mm. The data is then converted into a shape format for the software, providing an accurate description of the phantom shell.

In operation, the system first does an area (2D) scan at a fixed depth within the liquid from the inside wall of the phantom. When the maximum SAR point has been found, the system will then carry out a 3D scan centred at that point to determine volume averaged SAR level.

6.2. Probe and amplifier specification

IXP-050 Indexsar isotropic immersible SAR probe
The probes are constructed using three orthogonal dipole sensors arranged on an interlocking, triangular prism core. The probes have built-in shielding against static charges and are contained within a PEEK cylindrical enclosure material at the tip. Probe calibration is described in the probe's calibration certificate (see appendix C.). The system uses diode compression potential (DCP) to determine SAR values for different types of modulation. Crest factor is not used for determining SAR values. The DCP for different types of modulation is determined during the probe calibration procedure. For a more detailed explanation see *IndexSAR Immesible SAR Probe Calibration Report* included in Appendix C of this report.

IXP-010 Amplifier
The amplifier unit has a multi-pole connector to connect to the probe and a multiplexer selects between the 3-channel single-ended inputs. A 16-bit AtoD converter with programmable gain is used along with an on-board micro-controller with non-volatile firmware. Battery life is around 150 hours and data are transferred to the PC via 3m of duplex optical fibre and a self-powered RS232 to optical converter.

6.3. Phantoms

The Specific Anthropomorphic Mannequin (SAM) Upright Phantom is fabricated using moulds generated from the CAD files as specified by CENELEC EN50361. It is mounted via a rotation base to a supporting table, which also holds the robotic positioner. The phantom and robot alignment is assured by both mechanical and laser registration systems. The box phantom used for body testing and for validation is manufactured from Perspex. The material is 2 mm in thickness on the test surfaces and 4 mm in thickness on the other surfaces. Its dimensions are: X=21 cm., Y=20.5 cm., Z=16 cm.

6.4. SAR measurement procedure

Figure 6: Principal components of the SAR measurement test bench

The major components of the test bench are shown in the picture above. A test set and dipole antenna control the handset via an air link and a low-mass phone holder can position the phone at either ear. Graduated scales are provided to set the phone in the 15 degree position. The upright phantom head holds approx. 7 litres of simulant liquid. The phantom is filled and emptied through a 45mm diameter penetration hole in the top of the head.

After an area scan has been done at a fixed distance of 8mm from the surface of the phantom on the source side, a 3D scan is set up around the location of the maximum spot SAR. First, a point within the scan area is visited by the probe and a SAR reading taken at the start of testing. At the end of testing, the probe is returned to the same point and a second reading is taken. Comparison between these start and end readings enables the power drift during measurement to be assessed.

6.5. SARA2 Interpolation and Extrapolation schemes

(see support document IXS-0202)

SARA2 software contains support for both 2D cubic B-spline interpolation as well as 3D cubic B-spline interpolation. In addition, for extrapolation purposes, a general n-th order polynomial fitting routine is implemented following a singular value decomposition algorithm presented in [4]. A 4th order polynomial fit is used by default for data extrapolation, but a linear-logarithmic fitting function can be selected as an option. The polynomial fitting procedures have been tested by comparing the fitting coefficients generated by the SARA2 procedures with those obtained using the polynomial fit functions of Microsoft Excel when applied to the same test input data.

6.6. Interpolation of 2D area scan

The 2D cubic B-spline interpolation is used after the initial area scan at fixed distance from the phantom shell wall. The initial scan data are collected with approx. 10mm spatial resolution and spline interpolation is used to find the location of the local maximum to within a 1mm resolution for positioning the subsequent 3D scanning.

6.7. Extrapolation of 3D scan

For the 3D scan, data are collected on a spatially regular 3D grid having (by default) 6.4 mm steps in the lateral dimensions and 3.5 mm steps in the depth direction (away from the source). SARA2 enables full control over the selection of alternative step sizes in all directions.

The digitised shape of the head is available to the SARA2 software, which decides which points in the 3D array are sufficiently well within the shell wall to be 'visited' by the SAR probe. After the data collection, the data are extrapolated in the depth direction to assign values to points in the 3D array closer to the shell wall. A notional extrapolation value is also assigned to the first point outside the shell wall so that subsequent interpolation schemes will be applicable right up to the shell wall boundary.

6.8. Interpolation of 3D scan and volume averaging

The procedure used for defining the shape of the volumes used for SAR averaging in the SARA2 software follow the method of adapting the surface of the 'cube' to conform with the curved inner surface of the phantom (see Appendix D in FCC Supplement C edition 01-01 to OET Bulletin 65 edition 97-01). This is called, here, the conformal scheme.

For each row of data in the depth direction, the data are extrapolated and interpolated to less than 1mm spacing and average values are calculated from the phantom surface for the row of data over distances corresponding to the requisite depth for 10g and 1g cubes. This results in two 2D arrays of data, which are then cubic B-spline interpolated to sub mm lateral resolution. A search routine then moves an averaging square around through the 2D array and records the maximum value of the corresponding 1g and 10g volume averages. For the definition of the surface in this procedure, the digitised position of the headshell surface is used for measurement in head-shaped phantoms. For measurements in rectangular, box phantoms, the distance between the phantom wall and the closest set of gridded data points is entered into the software. For measurements in box-shaped phantoms, this distance is under the control of the user. The effective distance must be greater than 2.5mm as this is the tip-sensor distance and to avoid interface proximity effects, it should be at least 5mm. A value of 6 or 8mm is recommended. This distance is called **dbe**.

For automated measurements inside the head, the distance cannot be less than 2.5mm, which is the radius of the probe tip and to avoid interface proximity effects, a minimum clearance distance of x mm is retained. The actual value of dbe will vary from point to point depending upon how the spatially-regular 3D grid points fit within the shell. The greatest separation is when a grid point is just not visited due to the probe tip dimensions. In this case the distance could be as large as the step-size plus the minimum clearance distance (i.e with x=5 and a step size of 3.5, **dbe** will be between 3.5 and 8.5mm).

The default step size (**dstep**) used is 3.5mm, but this is under user-control. The compromise is with time of scan, so it is not practical to make it much smaller or scan times become long and power-drop influences become larger.

The robot positioning system specification for the repeatability of the positioning (**dss**) is +/- 0.04mm.

The phantom shell is made by an industrial moulding process from the CAD files of the SAM shape, with both internal and external moulds. For the upright phantoms, the external shape is subsequently digitised on a Mitutoyo CMM machine (Euro an ultrasonic sensor indicate that the shell thickness (**dph**) away from the ear is 2.0 +/- 0.1mm. The ultrasonic measurements were calibrated using additional mechanical measurements on available cut surfaces of the phantom shells. See support document IXS-020x.

For the upright phantom, the alignment is based upon registration of the rotation axis of the phantom on its 253mm diameter baseplate bearing and the position of the probe axis when commanded to go to the axial position. A laser alignment tool is provided (procedure detailed elsewhere). This enables the registration of the phantom tip (**dmis**) to be assured to within approx. 0.2mm. This alignment is done with reference to the actual probe tip after installation and probe alignment. The rotational positioning of the phantom is variable – offering advantages for special studies, but locating pins ensure accurate repositioning at the principal positions (LH and RH ears).

7. Uncertainty Assessment

A measurement uncertainty assessment has been undertaken following guidance given in draft IEEE 1528. IndexSAR Ltd has supplied a generic uncertainty analysis for the SARA2 system in the form of a spreadsheet and the supporting assessments are documented in an Indexsar document IXS-2028. Additionally, uncertainties resulting from the probe positioning system and the upright phantom geometry are discussed in additional documents.

Some of the uncertainty contributions are site-specific and, for these, Cetecom, Inc. have assessed the uncertainty contributions arising from local environmental and procedural factors.

The resultant uncertainty budget, following the assessment template given in draft IEEE 1528 is shown below:

7.1. Measurement Uncertainty Budget

Error Sources	Description	Uncertainty			Probability Distribution	Divisor (descrip)	Divisor (value)	ci	ci^2	Standard Uncertainty (%)	Stand Uncert^2	Stand Uncert^2
		(dB)		(%)								
Measurement equipment												
Calibration	7.2.1.1			10	Normal	1 or k	2	1	1	5.00	25.00	25.00
Isotropy	7.2.1.2	0.5	12.20	5.30	Rectangular	√3	1.73	1.00	1	3.06	9.36	9.36
Linearity	7.2.1.3	0.04	0.93	2.92	Rectangular	√2	1.73	1.00	1	1.69	2.84	2.84
Probe Stability				2.50	Rectangular	√3	1.73	1.00	1	1.44	2.08	2.08
Detection limits	7.2.1.4			0	Rectangular	√3	1.73	1.00	1	0.00	0.00	0.00
Boundary effects	7.2.1.5			1.7	Rectangular	√3	1.73	1.00	1	0.98	0.96	0.96
Measurement device	7.2.1.6			0	Normal	1 or k	1.96	1.00	1	0.00	0.00	0.00
Response time	7.2.1.7			0	Normal	1	1.00	1.00	1	0.00	0.00	0.00
Noise	7.2.1.8			0	Normal	1	1.00	1.00	1	0.00	0.00	0.00
Intergration time	7.2.1.9			0.4	Normal	1	1.00	1.00	1	0.40	0.16	0.16
Mechanical Constraints												
Scanning system	7.2.2.1			0.57	Rectangular	√3	1.73	1.00	1	0.33	0.11	0.11
Phantom shell	7.2.2.2			1.43	Rectangular	√3	1.73	1.00	1	0.83	0.68	0.68
Matching between probe and phantom	7.2.2.3			2.86	Rectangular	√3	1.73	1.00	1	1.65	2.73	2.73
Positioning of the phone	7.2.2.4			10	Normal	1	1	1.00	1	10.00	100.00	100.00
Physical parameters												
Liquid conductivity (Deviation from target)	7.2.3.2			5	Rectangular	√3	1.73	0.50	0.25	1.44	2.08	0.52
Liquid conductivity (measurement error)	7.2.3.2			5	Rectangular	√3	1.73	0.50	0.25	1.44	2.08	0.52
Liquid permittivity (Deviation from target)	7.2.3.3			5	Rectangular	√3	1.73	0.50	0.25	1.44	2.08	0.52
Liquid permittivity (measurement error)	7.2.3.3			5	Rectangular	√3	1.73	0.50	0.25	1.44	2.08	0.52
Drifts in output power of the phone, probe, temperature and humidity	7.2.3.4			5	Rectangular	√3	1.73	1.00	1	2.89	8.33	8.33
Perturbation by the environment	7.2.3.5			3	Rectangular	√3	1.73	1.00	1	1.73	3.00	3.00
Post processing												
SAR interpolation and extrapolation	7.2.4.1			8	Rectangular	√3	1.73	1.00	1	4.62	21.33	21.33
Maximum SAR evaluation	7.2.4.2			2.4	Rectangular	√3	1.73	1.00	1	1.39	1.92	1.92
Other factors												
				0	Normal	1 or k	1.96	1.00	1	0.00	0.00	0.00
				0	Normal	1 or k	1.96	1.00	1	0.00	0.00	0.00
				0	Rectangular	√3	1.73	1.00	1	0.00	0.00	0.00
				0	Normal	1	1.00	1.00	1	0.00	0.00	0.00
Combined standard uncertainty	$u_c = \sqrt{\sum_{i=1}^{m} c_i^2 \cdot u_i^2}$							13.67				
Expanded uncertainty (confidence interval of 95%)				Normal	k=	1.96	**ue=k* uc**	**26.79**	%			

8. Test results summary

8.1. Description of EUT test positions and operation modes

Positions:
The EUT was tested in the positions described in section 5.3 of this report *Test positions of device relative to head*.

There is no pouch/holder or headset supplied with the EUT. Tests were performed for body worn configurations with the phone only. The EUT was tested with both its front and back surface directly against the outside edge of the flat phantom (see: *Appendix B Photos* of this report).

Operation modes:
The EUT is a GPRS class B (GPRS or voice TX), multislot class 8 device (1 timeslot uplink maximum). Testing was performed with the EUT transmitting on 1 timeslot.

8.2. Conducted Output Power

Prior to testing the conducted output power was measured. The results are shown below.

1900MHz Band:

Channel 661:	29.0 dBm
Channel 512:	29.0 dBm
Channel 810:	29.0 dBm

8.3. Head SAR results for GSM 1900MHz band for Vitel

Side	Position	Channel # / Frequency (MHz)	Max. 1g SAR (W/kg)	Area scan (See Appendix A)	Positioning photo (See Appendix B)
left	cheek	661 / 1880	0.172	1	3
left	15º tilt	661 / 1880	0.205	2	4
right	cheek	661 / 1880	0.126	3	5
right	15º tilt	661 / 1880	0.097	4	6
left	15º tilt	512 / 1850.2	0.202	5	4
left	15º tilt	810 / 1909.8	0.169	6	4

8.4. Body SAR results for GSM 1900MHz band for Vitel

Position	Channel # / Frequency (MHz)	Max. 1g SAR (W/kg)	Area scan (See Appendix A)	Positioning photo (See Appendix B)
phone front touching	661 / 1880	0.063	7	7
phone back touching	661 / 1880	1.043	8	8
phone back touching	512 / 1850.2	1.152	9	8
phone back touching	810 / 1909.8	1.062	10	8

8.5. Validation Check Results

Prior to formal testing at each frequency a system verification was performed in accordance with IEEE 1528. The balanced dipole source was placed at the specified distance in horizontal orientation. All of the testing described in this report was performed within 24 hours of the system verification. The following results were obtained:

Date	Frequency (MHz)	Input power at dipole feed (Watts)	Measured 1g SAR (W/kg)	Measured SAR normalized to 1 Watt (W/kg)	IEEE 1528 reference SAR (W/kg)	Delta between normalized and reference SAR (%)
05/22/2003	1900	0.50	20.07	40.14	39.7	+1.11

9. References

[FCC 2001] Federal Communications Commission: Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01), FCC, 2001.
[IEEE 1999] IEEE Std C95.1-1999: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, Inst. of Electrical and Electronics Engineers, Inc., 1999.
[IEEE 200x] IEEE Std 1528-200x: DRAFT Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques. Draft 6.2, Inst. of Electrical and Electronics Engineers, Inc., 2000.
[NIST 1994] NIST: Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, Technical Note 1297 (TN1297), United States Department of Commerce Technology Administration, National Institute of Standards and Technology, 1994.

Date / Time:	5/22/2003 12:11:31 PM	**Position:**	Left touch
Plot #:	1	**Phantom:**	HeadFT08.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	0
Antenna:	integral	**Test Frequency:**	1880
Shape File:	VITEL.csv	**Power Level:**	maximum

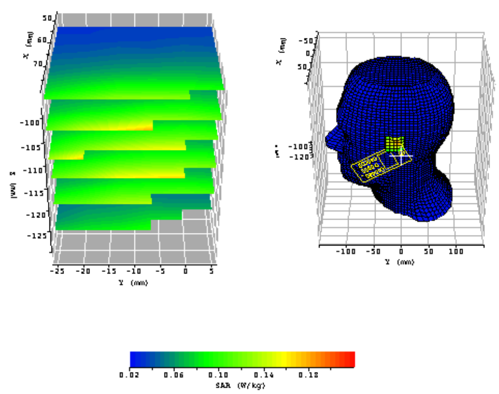
Probe:	0123
Cal File:	123_1900_HEAD_GSM

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.562	.562	.562

Amp Gain:	2
Averaging:	1
Batteries Replaced:	05/13/03

Liquid:	1900
Type:	head
Conductivity:	1.436
Relative Permittivity:	39.40
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420



ZOOM SCAN RESULTS:

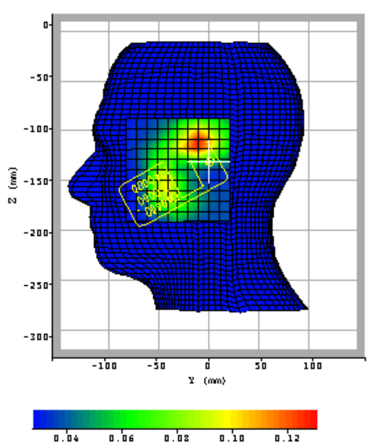
	Start Scan	End Scan
Spot SAR (W/kg):	0.073	0.073

Change during Scan (%) 0.00

Max E-field (V/m): 12.21

	1g	10g
Max SAR (W/kg)	0.172	0.109

	X	Y	Z
Location of Max (mm):	79.1	-26.0	-112.9



AREA SCAN:

		Min	Max	Steps
Scan Extent:	Y	-80.0	20.0	10.0
	Z	-190.0	-90.0	10.0

Date / Time:	5/22/2003 12:35:58 PM	**Position:**	Left tilt
Plot #:	2	**Phantom:**	HeadFT08.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	0
Antenna:	integral	**Test Frequency:**	1880
Shape File:	VITEL.csv	**Power Level:**	maximum

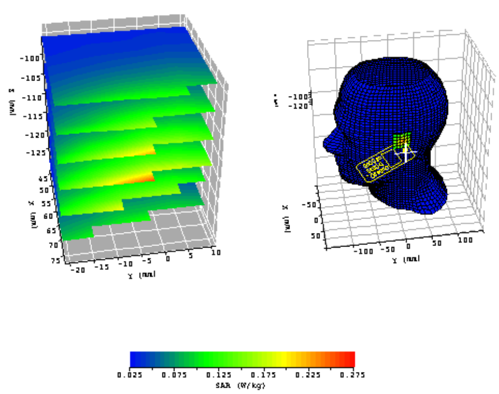
Probe:	0123
Cal File:	123_1900_HEAD_GSM

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.562	.562	.562

Amp Gain:	2
Averaging:	1
Batteries Replaced:	05/13/03

Liquid:	1900
Type:	head
Conductivity:	1.436
Relative Permittivity:	39.40
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420



ZOOM SCAN RESULTS:

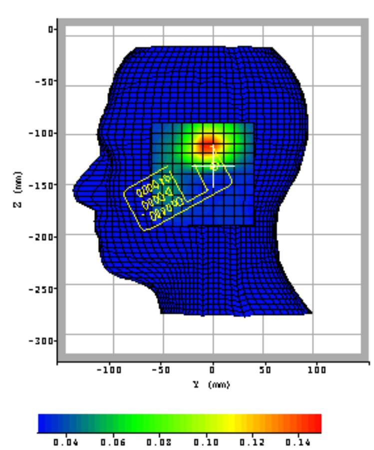
	Start Scan	End Scan
Spot SAR (W/kg):	0.082	0.082

Change during Scan (%): -0.22

Max E-field (V/m): 13.27

	1g	10g
Max SAR (W/kg)	0.205	0.126

	X	Y	Z
Location of Max (mm):	78.9	-21.0	-113.1



AREA SCAN:

		Min	Max	Steps
Scan Extent:	Y	-60.0	40.0	10.0
	Z	-190.0	-90.0	10.0

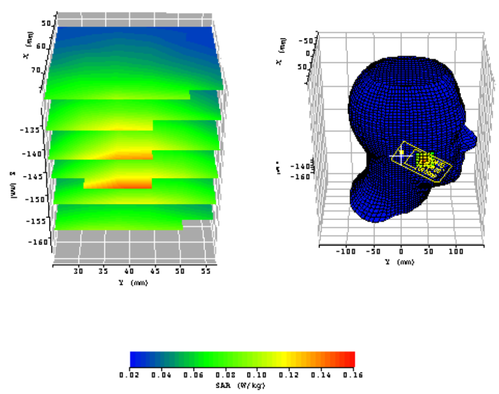
Date / Time:	5/22/2003 11:38:58 AM	**Position:**	Right touch
Plot #:	3	**Phantom:**	HeadFT08.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	180
Antenna:	integral	**Test Frequency:**	1880
Shape File:	VITEL.csv	**Power Level:**	maximum

Probe:	0123
Cal File:	123_1900_HEAD_GSM
Amp Gain:	2
Averaging:	1
Batteries Replaced:	05/13/03

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.562	.562	.562

Liquid:	1900
Type:	head
Conductivity:	1.436
Relative Permittivity:	39.40
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420

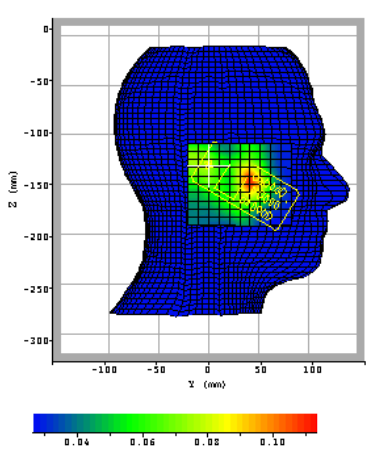


ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.072	0.071
Change during Scan (%)	-1.45	
Max E-field (V/m):	10.12	

	1g	10g
Max SAR (W/kg)	0.126	0.087

	X	Y	Z
Location of Max (mm):	75.7	25.0	-149.7



AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	80.0	-20.0	10.0
Z	-190.0	-110.0	10.0

Date / Time:	5/22/2003 10:48:57 AM	**Position:**	Right tilt
Plot #:	4	**Phantom:**	HeadFT08.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	180
Antenna:	integral	**Test Frequency:**	1880
Shape File:	VITEL.csv	**Power Level:**	maximum

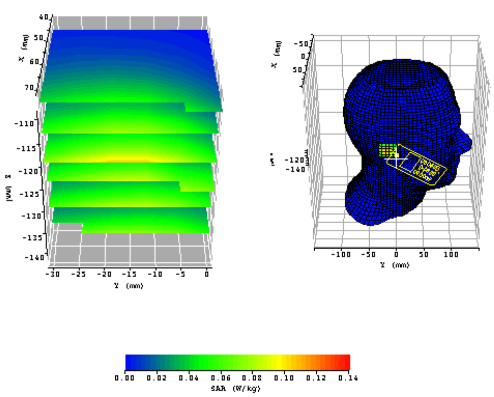
Probe:	0123
Cal File:	123_1900_HEAD_GSM

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.562	.562	.562

Amp Gain:	2
Averaging:	6
Batteries Replaced:	05/13/03

Liquid:	1900
Type:	head
Conductivity:	1.436
Relative Permittivity:	39.40
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420



ZOOM SCAN RESULTS:

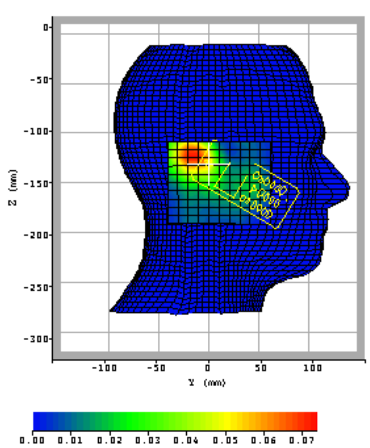
	Start Scan	End Scan
Spot SAR (W/kg):	0.033	0.034

Change during Scan (%): 1.58

Max E-field (V/m): 9.15

	1g	10g
Max SAR (W/kg)	0.097	0.058

	X	Y	Z
Location of Max (mm):	70.8	-31.0	-125.5



AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	60.0	-40.0	10.0
Z	-190.0	-110.0	10.0

Date / Time:	5/22/2003 12:59:27 PM	**Position:**	Left tilt
Plot #:	5	**Phantom:**	HeadFT08.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	0
Antenna:	integral	**Test Frequency:**	1850.2
Shape File:	VITEL.csv	**Power Level:**	maximum

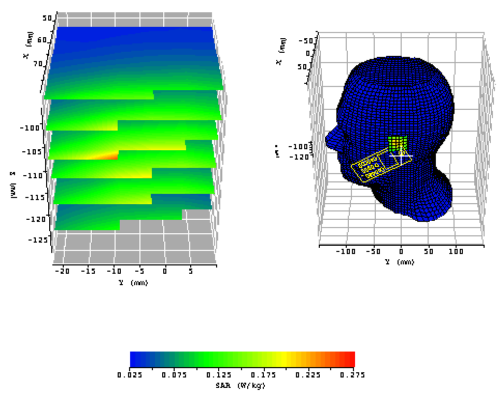
Probe:	0123
Cal File:	123_1900_HEAD_GSM

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.562	.562	.562

Amp Gain:	2
Averaging:	1
Batteries Replaced:	05/13/03

Liquid:	1900
Type:	head
Conductivity:	1.411
Relative Permittivity:	39.67
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420

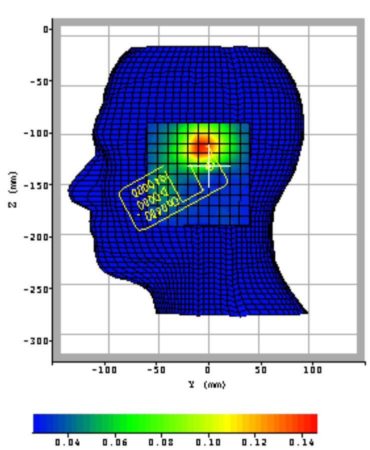


ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan** 0.086	**End Scan** 0.088
Change during Scan (%)	2.30	
Max E-field (V/m):	13.37	
Max SAR (W/kg)	**1g** 0.202	**10g** 0.125

	X	Y	Z
Location of Max (mm):	79.0	-22.0	-111.9

AREA SCAN:



Scan Extent:

	Min	Max	Steps
Y	-60.0	40.0	10.0
Z	-190.0	-90.0	10.0

Date / Time:	5/22/2003 1:28:34 PM	**Position:**	Left tilt
Plot #:	6	**Phantom:**	HeadFT08.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	0
Antenna:	integral	**Test Frequency:**	1909.8
Shape File:	VITEL.csv	**Power Level:**	maximum

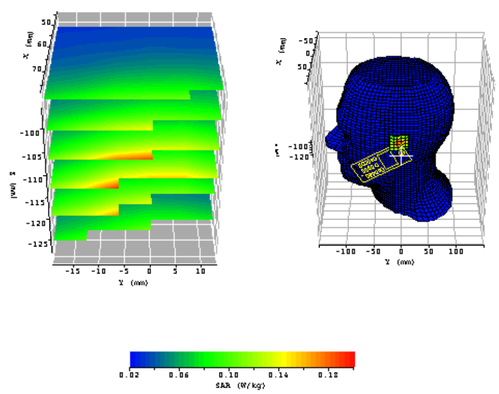
Probe: 0123
Cal File: 123_1900_HEAD_GSM

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.562	.562	.562

Amp Gain: 2
Averaging: 1
Batteries Replaced: 05/13/03

Liquid:	1900
Type:	head
Conductivity:	1.446
Relative Permittivity:	39.18
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420



ZOOM SCAN RESULTS:

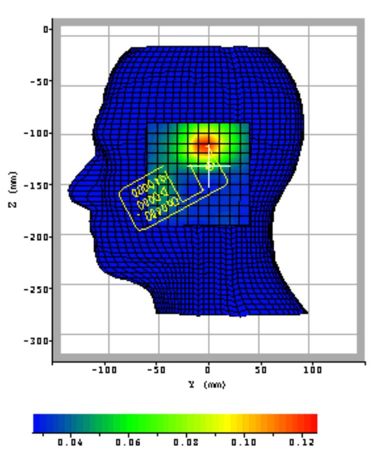
Spot SAR (W/kg):	**Start Scan**	**End Scan**
	0.068	0.071

Change during Scan (%) 4.53

Max E-field (V/m): 11.48

Max SAR (W/kg)	**1g**	**10g**
	0.169	0.106

Location of Max (mm):	**X**	**Y**	**Z**
	79.0	-19.0	-112.0



AREA SCAN:

Scan Extent:		**Min**	**Max**	**Steps**
	Y	-60.0	40.0	10.0
	Z	-190.0	-90.0	10.0

Date / Time:	5/22/2003 2:38:21 PM	**Position:**	body front of phone to phantom
Plot #:	7	**Phantom:**	HeadBox_spout.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	0
Antenna:	integral	**Test Frequency:**	1880
Shape File:	VITEL.csv	**Power Level:**	maximum

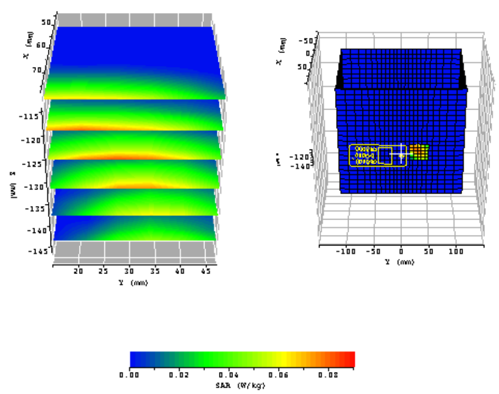
Probe:	0123
Cal File:	123_1900_BODY_GSM

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.610	.610	.610

Amp Gain:	2
Averaging:	1
Batteries Replaced:	05/13/03

Liquid:	1900
Type:	body
Conductivity:	1.572
Relative Permittivity:	53.09
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420



ZOOM SCAN RESULTS:

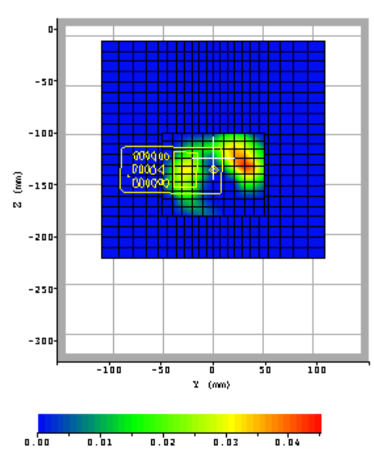
Spot SAR (W/kg):	**Start Scan**	**End Scan**
	0.005	0.005

Change during Scan (%) 0.00

Max E-field (V/m): 7.20

Max SAR (W/kg)	**1g**	**10g**
	0.063	0.032

Location of Max (mm):	**X**	**Y**	**Z**
	77.1	15.0	-127.2



AREA SCAN:

Scan Extent:

	Min	**Max**	**Steps**
Y	-50.0	50.0	10.0
Z	-180.0	-100.0	10.0

Date / Time:	5/22/2003 2:11:44 PM	**Position:**	body back of phone to phantom
Plot #:	8	**Phantom:**	HeadBox_spout.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	0
Antenna:	integral	**Test Frequency:**	1880
Shape File:	VITEL.csv	**Power Level:**	maximum

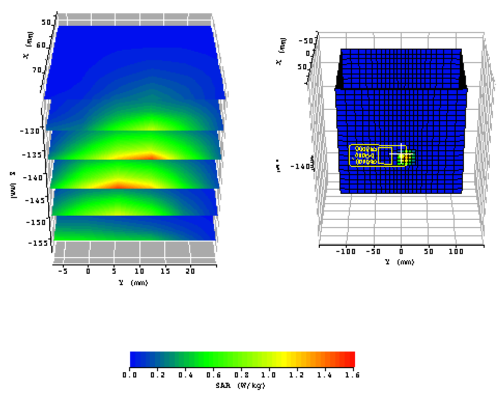
Probe: 0123
Cal File: 123_1900_BODY_GSM

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.610	.610	.610

Amp Gain: 2
Averaging: 1
Batteries Replaced: 05/13/03

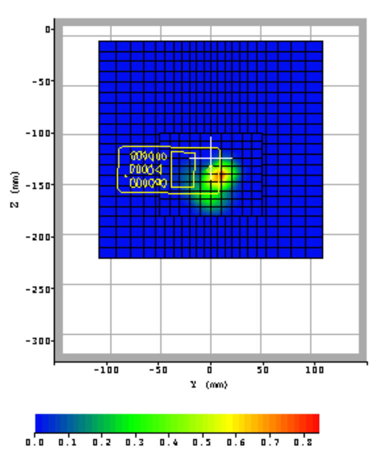
Liquid:	1900
Type:	body
Conductivity:	1.572
Relative Permittivity:	53.09
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420



ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan** 0.302	**End Scan** 0.302
Change during Scan (%)	0.00	
Max E-field (V/m):	30.80	
Max SAR (W/kg)	**1g** 1.043	**10g** 0.461

	X	Y	Z
Location of Max (mm):	77.0	-7.0	-143.5



AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-50.0	50.0	10.0
Z	-180.0	-100.0	10.0

Date / Time:	5/22/2003 3:05:59 PM	**Position:**	body back of phone to phantom
Plot #:	9	**Phantom:**	HeadBox_spout.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	0
Antenna:	integral	**Test Frequency:**	1850.2
Shape File:	VITEL.csv	**Power Level:**	maximum

Probe: 0123

Cal File: 123_1900_BODY_GSM

Cal Factors:

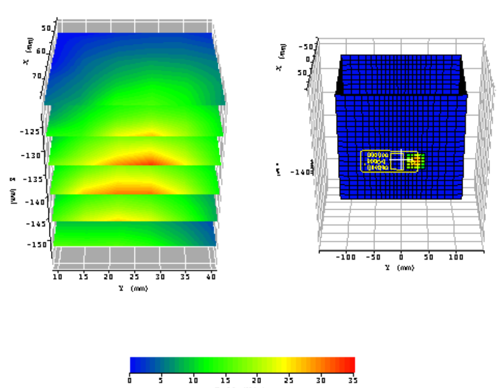
	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.610	.610	.610

Amp Gain: 2

Averaging: 1

Batteries Replaced: 05/13/03

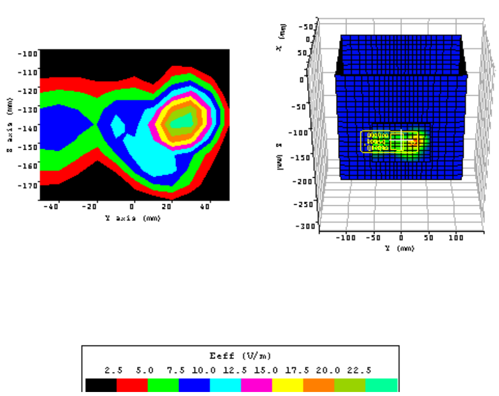
Liquid:	1900
Type:	body
Conductivity:	1.560
Relative Permittivity:	53.26
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420



ZOOM SCAN RESULTS:

	Start Scan	**End Scan**
Spot SAR (W/kg):	0.356	0.356
Change during Scan (%)	0.00	
Max E-field (V/m):	33.08	
	1g	**10g**
Max SAR (W/kg)	1.152	0.529

	X	Y	Z
Location of Max (mm):	77.1	9.0	-137.3



AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-50.0	50.0	10.0
Z	-180.0	-100.0	10.0

Date / Time:	5/22/2003 4:06:29 PM	**Position:**	body back of phone to phantom
Plot #:	10	**Phantom:**	HeadBox_spout.csv
Device Tested:	Vitel VITEL 1900	**Head Rotation:**	0
Antenna:	integral	**Test Frequency:**	1909.8
Shape File:	VITEL.csv	**Power Level:**	maximum

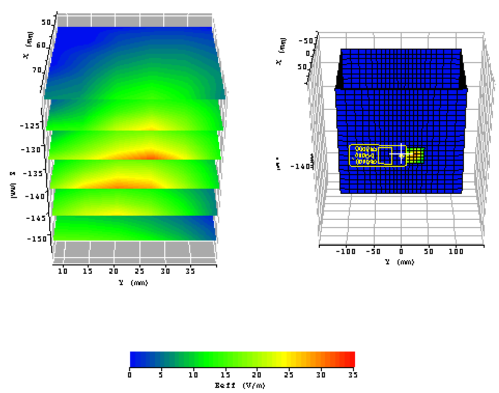
Probe:	0123
Cal File:	123_1900_BODY_GSM

Cal Factors:

	X	Y	Z
Air	346	318	386
DCP	9	13.6	8.7
Lin	.610	.610	.610

Amp Gain:	2
Averaging:	1
Batteries Replaced:	05/13/03

Liquid:	1900
Type:	body
Conductivity:	1.581
Relative Permittivity:	52.87
Liquid Temp (deg C):	22.0
Ambient Temp (deg C):	22.0
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.420

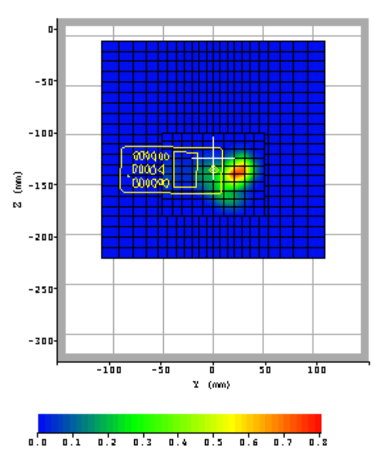


ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.312	0.304
Change during Scan (%)	-2.54	
Max E-field (V/m):	31.81	

	1g	10g
Max SAR (W/kg)	1.062	0.480

	X	Y	Z
Location of Max (mm):	43.0	8.0	-122.4



AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-50.0	50.0	10.0
Z	-180.0	-100.0	10.0

EUT Photos

Photo 1. EUT front

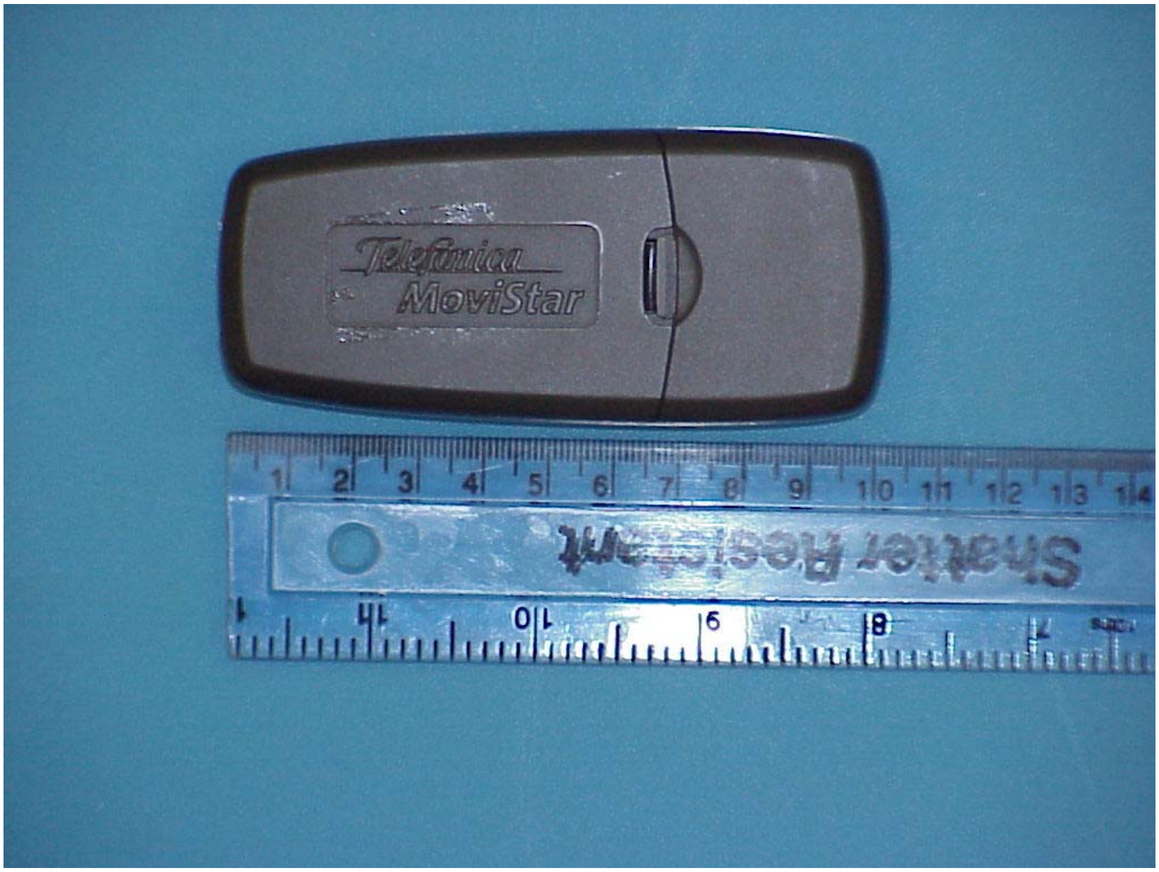


Photo 2. EUT back

Set-up Photos

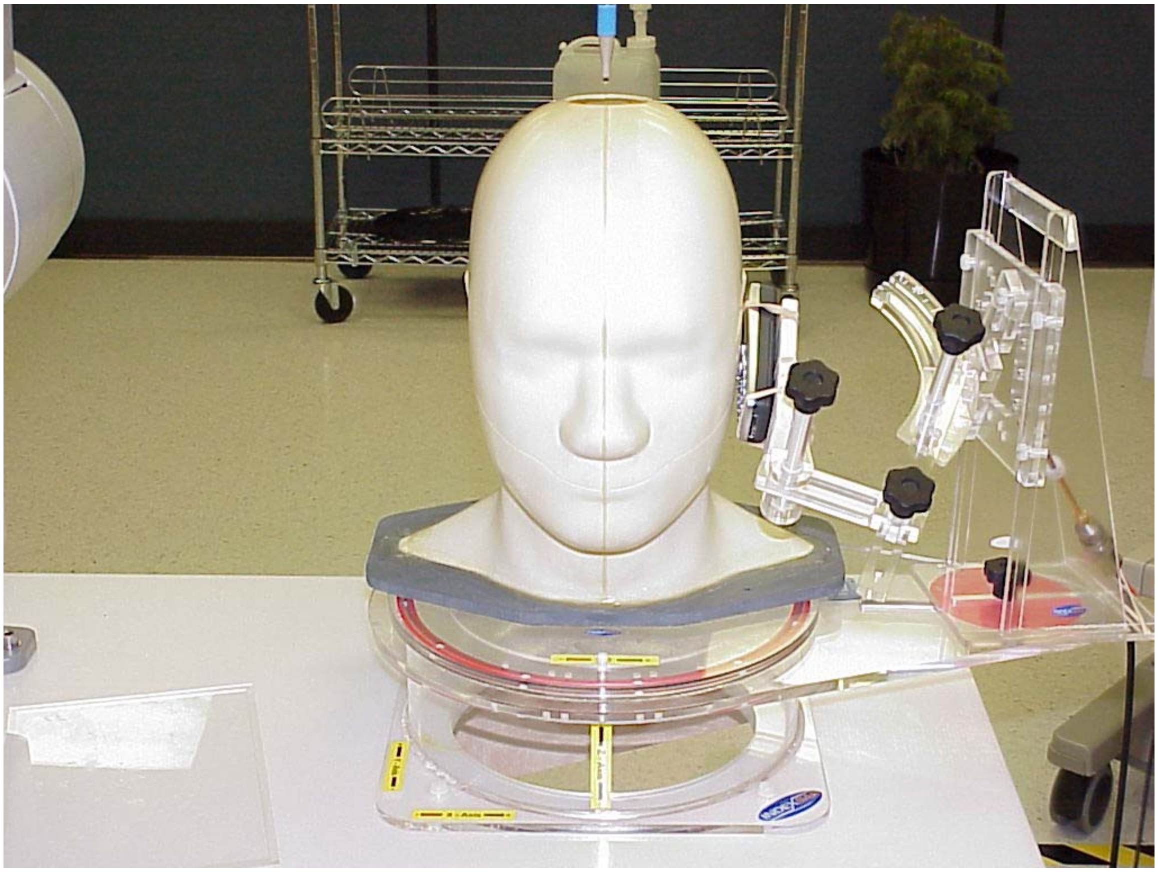


Photo 3. Left touch

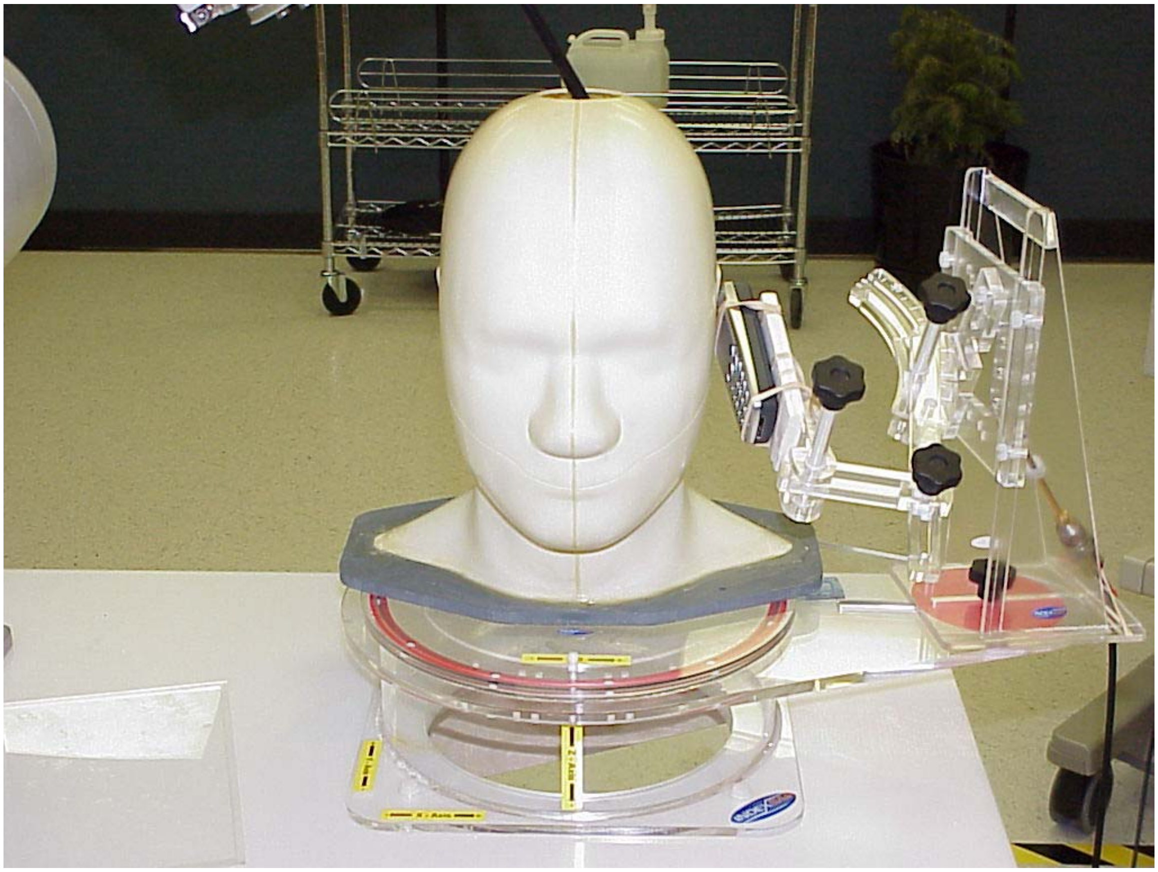


Photo 4. Left tilt

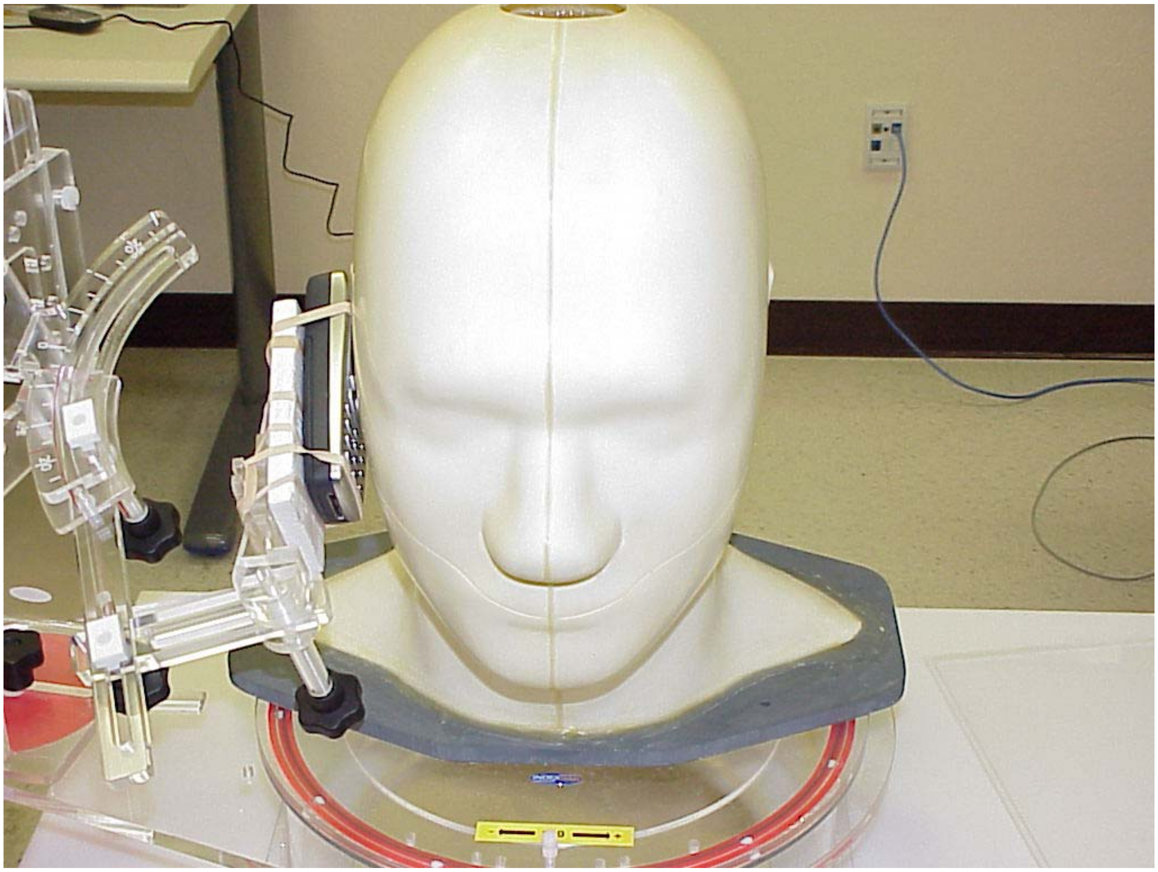


Photo 5. Right touch

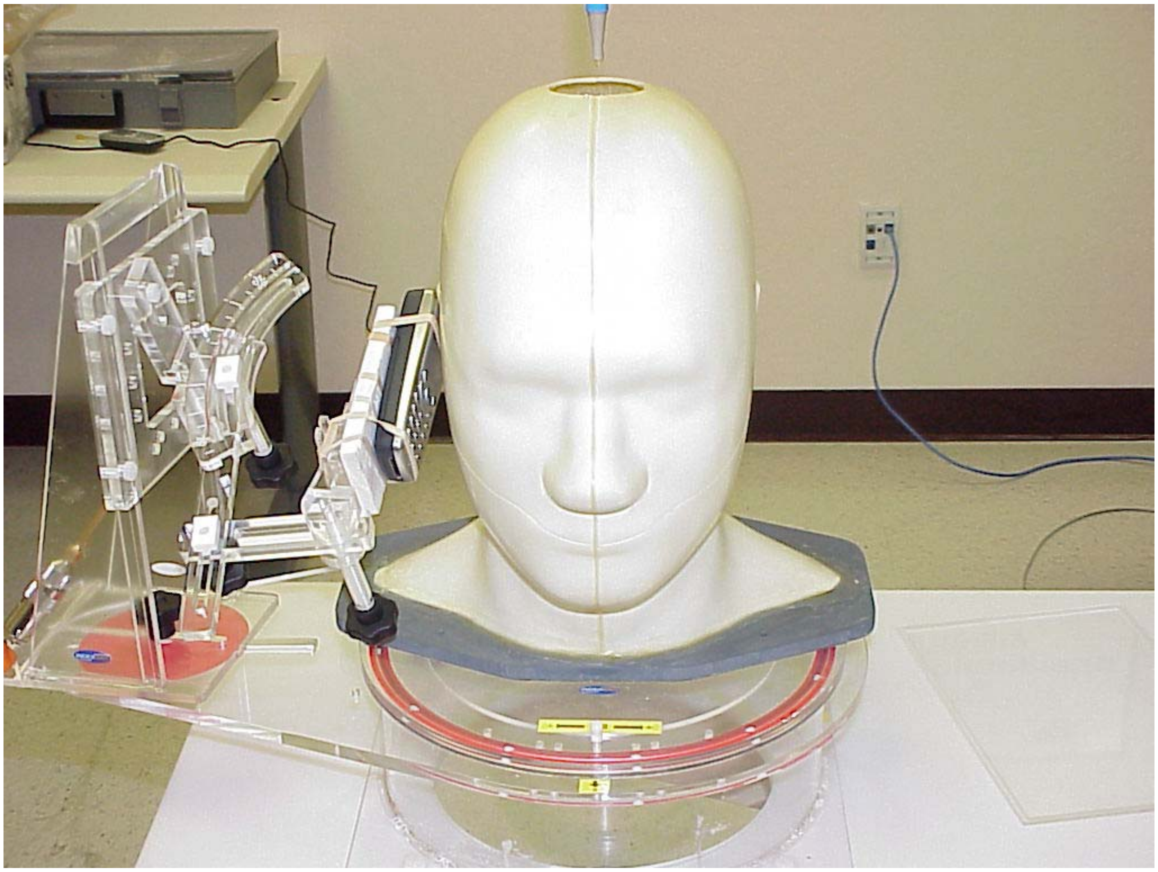


Photo 6. Right tilt

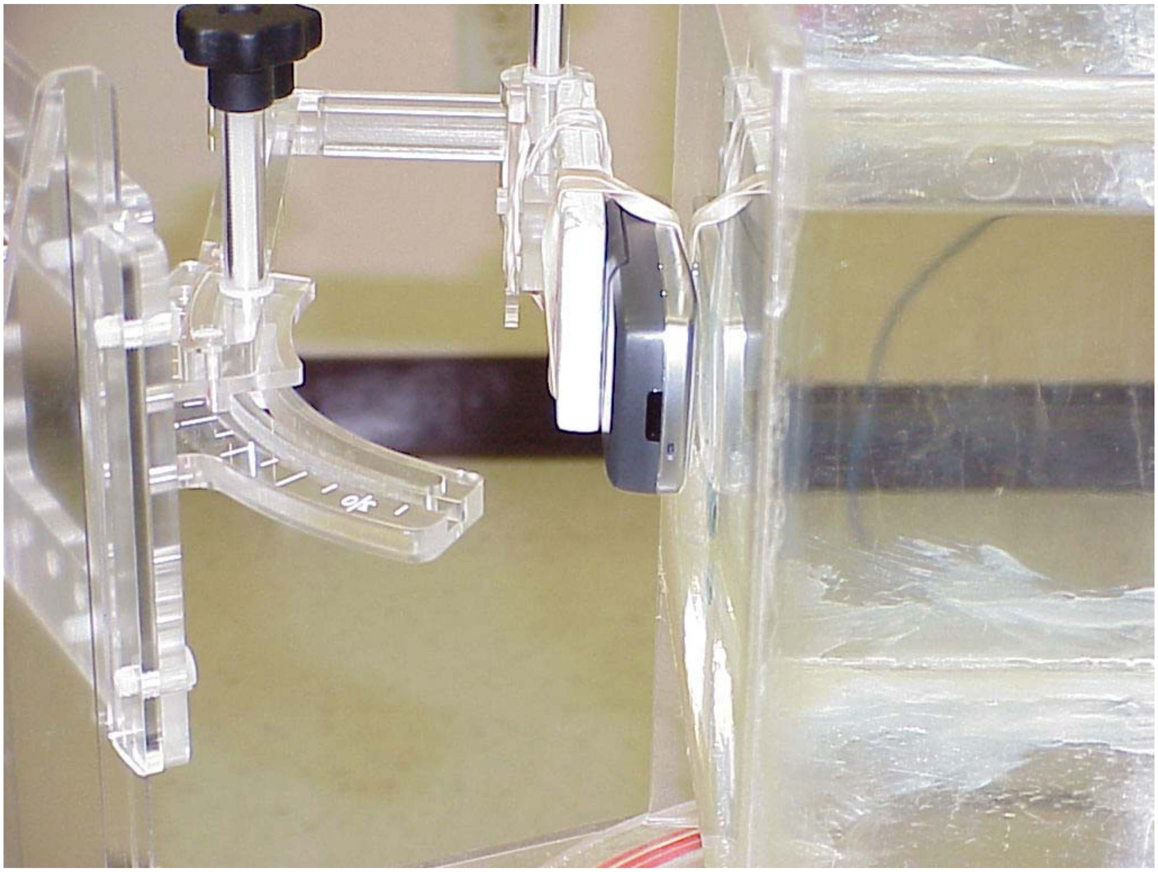


Photo 7. Body position front touching

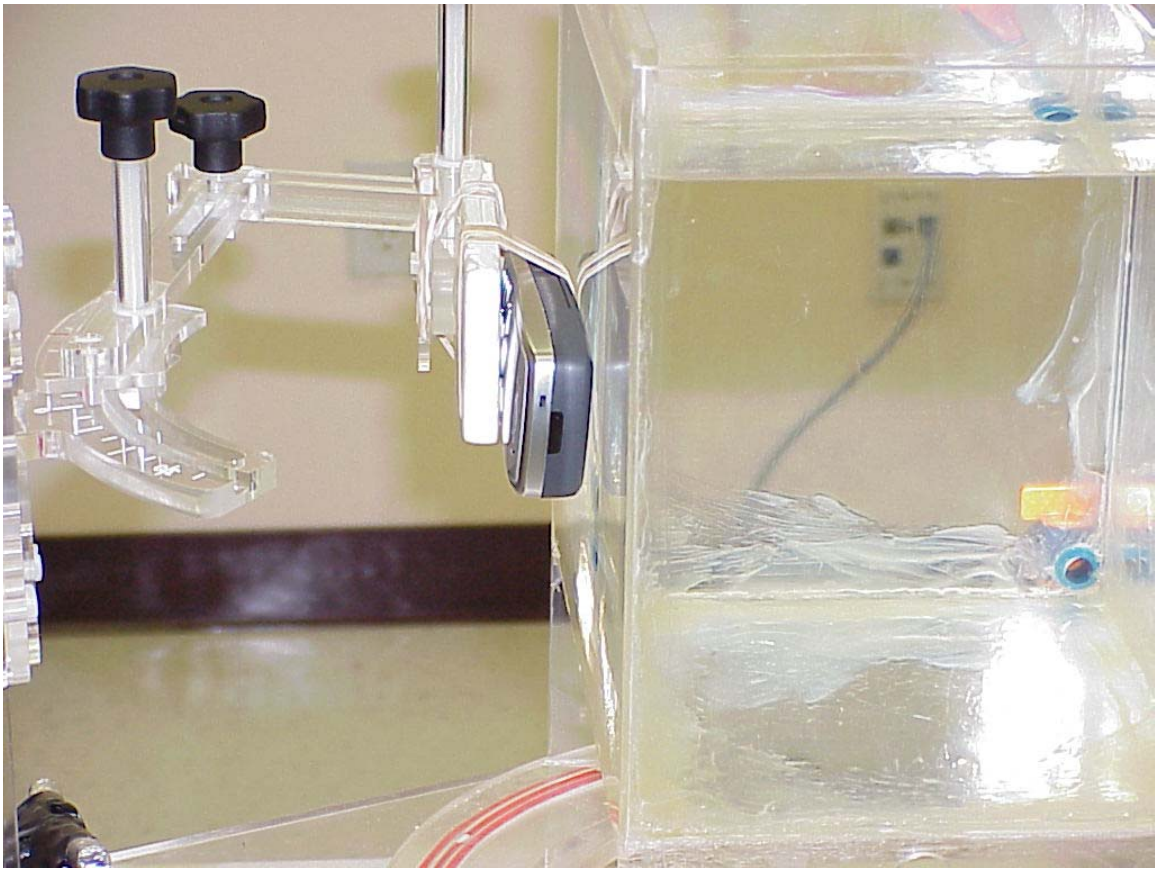


Photo 8. Body position back touching

Photo 9. Photo to demonstrate 15 cm Z-axis head phantom

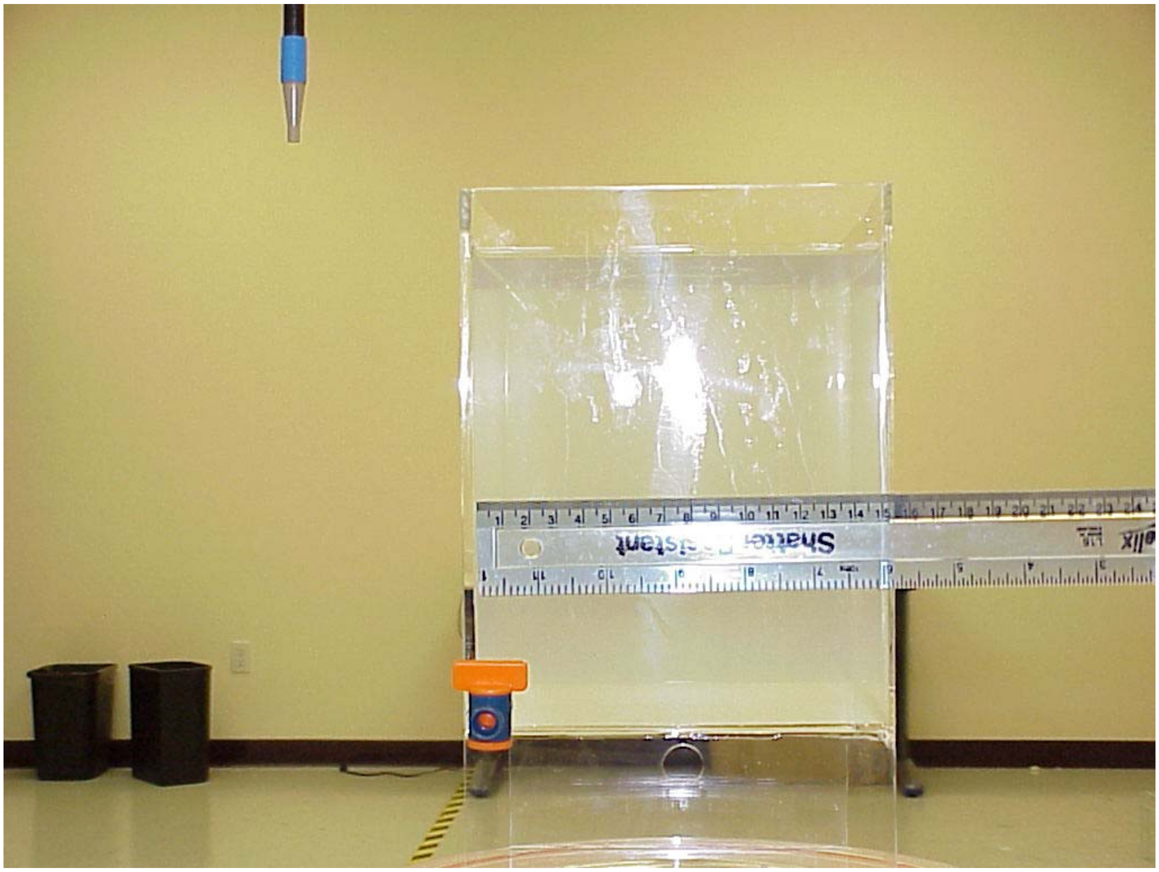


Photo 10. Photo to demonstrate 15 cm Z-axis flat phantom

Tissue Parameters

1900MHz Head liquid:

Recipe:
The following recipe is provided in percentage by weight.

54.9%	distilled water
44.92%	DGBE
0.18%	salt
0.1%	bactericide

Di-electric constants measured on 05/22/2003. SAR measurements were made within 24 hours of the measurement of liquid parameters.

Freq. (MHz)	Rel. Perm.	Condy (S/m)
1850.2	39.67	1.411
1880	39.40	1.436
1900	39.18	1.446
1909.8	39.30	1.459

1900MHz Body Liquid:

Recipe:
The following recipe is provided in percentage by weight.

69.17%	distilled water
30.29%	DGBE
0.44%	salt
0.1%	bactericide

Di-electric constants measured on 05/22/2003. SAR measurements were made within 24 hours of the measurement of liquid parameters.

Freq. (MHz)	Rel. Perm.	Condy (S/m)
1850.2	53.26	1.560
1880	53.09	1.572
1909.8	52.87	1.581

Environment 05/22/2003:

Temperature: **22.0 °C ± 2°C**
Humidity: **45% _ 55 %**

Test Equipment

Instrument description	Supplier/Manufacturer	Model	Serial No.	Calibration (date)
Bench top Robot	Mitsubishi supplied by IndexSAR	RV-E2	EA1030108	N/A
SAM Phantom	Upright shell phantom made by Antennessa digitized and mounted by IndexSAR	SAM	FT08	04/02
Flat Phantom	IndexSAR	HeadBox_Spout	N/A	N/A
Software	IndexSAR	SARA2 v0.420	N/A	N/A
1900 MHz Head Tissue Simulant	Cetecom Inc.	1900 Head	N/A	05/22/2003
1900 MHz Body Tissue Simulant	Cetecom Inc.	1900 Body	N/A	05/22/2003
1900 MHz Dipole	IndexSAR – IEEE 1528 design	IXD-190	0016	07/30/2002
Netwok Analyzer	Agilent	8753ES	US39172511	04/22/2003
Directional coupler	Werlatone	C6529	11249	N/A
RF Amplifier	Vectawave	VTL5400	N/A	N/A
Power Meter	HP	EPM-442A	GB37170232	9/04/02
Power Sensor	HP	8481A	1926A20587	8/26/2002
Power Sensor	HP	8481H	3318A15893	12/30/2002
SAR Probe	IndexSAR	IXP-050	S/N 0123	10/25/2002
Probe amplifier	IndexSAR	IXA-010	S/N 043	N/A
Thermometer	Control Company	4039	20410549	11/20/2001
Dielectric Measurement Kit	IndexSAR	Di-Line	N/A	N/A

Equipment Calibration/Performance Documents:

Please Note:
(The following pages of Appendix C show calibration documents. These calibration documents are inserted into this appendix. The header information with page numbering scheme is a part of this report and is included on all pages of the report and appendixes. This header is used to track all of the contents of this report.)

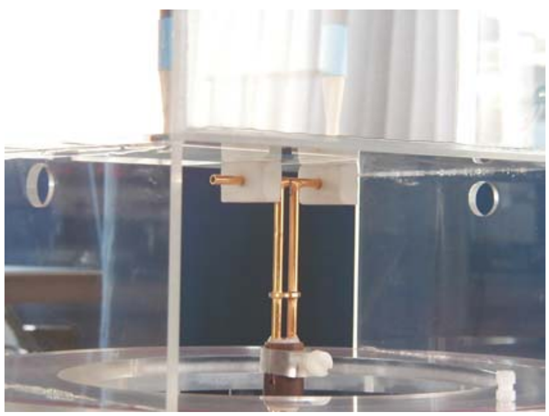
Report No. SN0016_1900

30th July 2002

INDEXSAR
1900MHz validation Dipole
Type IXD-190 **S/N 0016**

Performance measurements

MI Manning



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e-mail: enquiries@indexsar.com

1. Measurement Conditions

Measurements were performed using a box-shaped phantom made of PMMA with dimensions designed to meet the accuracy criteria for reasonably-sized phantoms that do not have liquid capacities substantially in excess of the volume of liquid required to fill the Indexsar upright SAM phantoms used for SAR testing of handsets against the ear.

An HP 8753B vector network analyser was used for the return loss measurements.
The dipole was placed in a special holder made of low-permittivity, low-loss materials. This holder enables the dipole to be positioned accurately in the centre of the base of the Indexsar box-phantom used for flat-surface testing and validation checks.

The validation dipoles are supplied with special spacers made from a low-permittivity, low-loss foam material. These spacers are fitted to the dipole arms to ensure that, when the dipole is offered up to the phantom surface, the spacing between the dipole and the liquid surface is accurately aligned according to the guidance in the relevant standards documentation. The spacers are rectangular with a central hole equal to the dipole arm diameter and dimensioned so that the longer side can be used to ensure a spacing of 15mm from the liquid in the phantom (for tests at 900MHz and below) and the shorter side can be used for tests at 1800MHz and above to ensure a spacing of 10mm from the liquid in the phantom. The spacers are made on a CNC milling machine with an accuracy of 1/40th mm but they may suffer wear and tear and need to be replaced periodically. The material used is Rohacell, which has a relative permittivity of approx. 1.05 and a negligible loss tangent.

The apparatus supplied by Indexsar for dipole validation tests thus includes:

Balanced dipoles for each frequency required are dimensioned according to the guidelines given in IEEE 1528 [1]. The dipoles are made from semi-rigid 50 Ohm co-ax, which is joined by soldering and is gold-plated subsequently. The constructed dipoles are easily deformed, if mis-handled, and periodic checks need to be made of their symmetry.

Rohacell foam spacers designed for presenting the dipoles to 2mm thick PMMA box phantoms. These components also suffer wear and tear and should be replaced when the central hole is a loose-fit on the dipole arms or if the edges are too worn to ensure accurate alignment. The standard spacers are dimensioned for use with 2mm wall thickness (additional spacers are available for 4mm wall thickness).

2. SAR Measurement

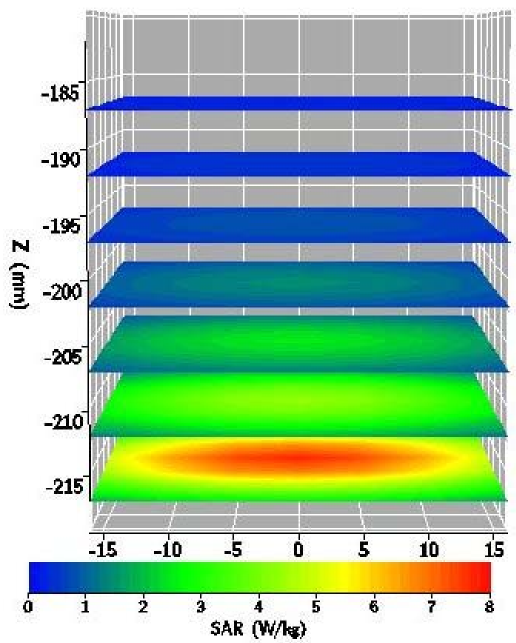
A SAR validation check was performed with the box-phantom located on the SARA2 phantom support base on the SARA2 robot system. Tests were conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 25.4°C and the relative humidity was 67% during the measurements.

The phantom was filled with a 1900MHz brain liquid using a recipe from [1], which had the following electrical parameters (measured using an Indexsar DiLine kit) at 1900MHz:

Relative Permittivity	**38.82**
Conductivity	**1.46 S/m**

The SARA2 software version 0.281 was used with an Indexsar probe previously calibrated at NPL (S/N 0071) using the NPL-supplied calibration factors [2].

The 3D measurements made using the dipole at the bottom of the phantom box are shown below:



The results, normalised to an input power of 1W (forward power) were:

Averaged over 1 cm3 (1g) of tissue	**40.068 W/kg**
Averaged over 10cm3 (10g) of tissue	**21.168 W/kg**

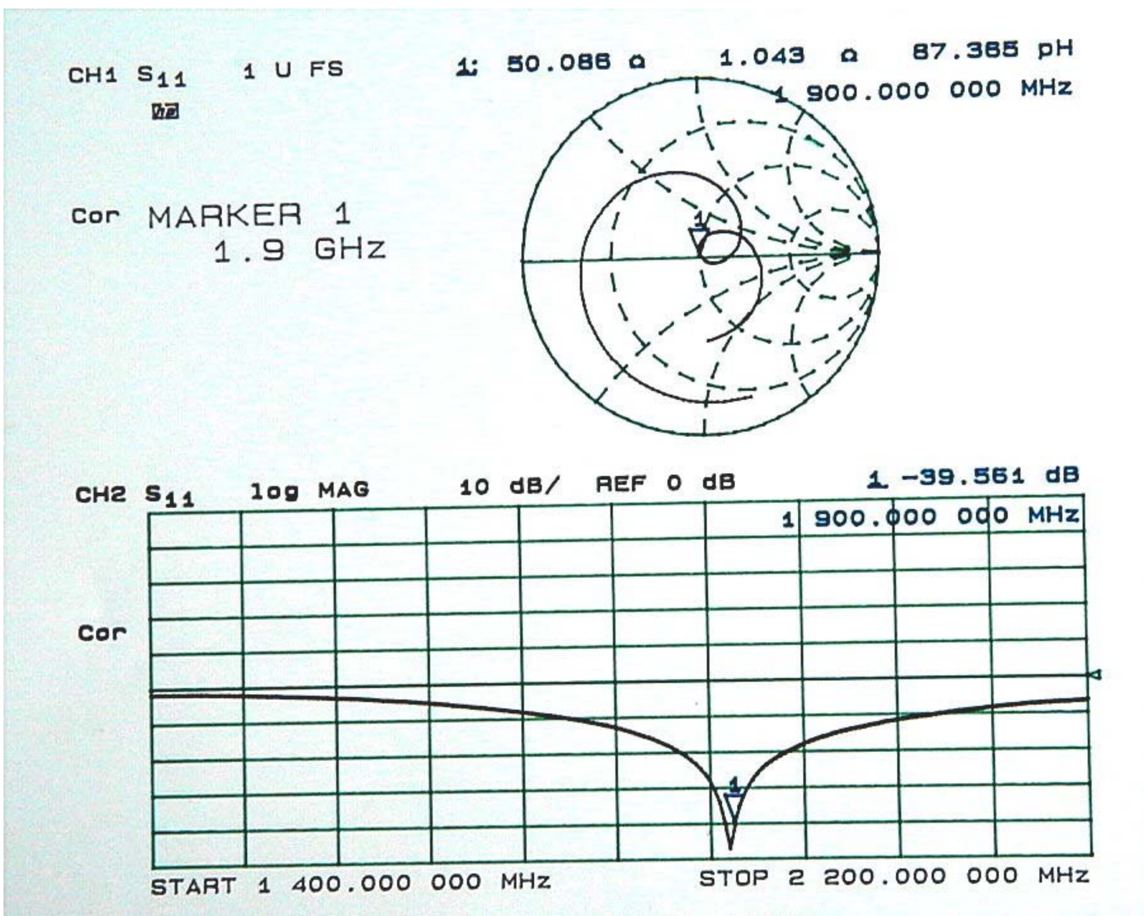
These results can be compared with Table 8.1 in [1]. The agreement is within 3%.

3. Dipole impedance and return loss

The dipoles are designed to have low return loss ONLY when presented against a lossy-phantom at the specified distance. A Vector Network Analyser (VNA) was used to perform a return loss measurement on the specific dipole when in the measurement-location against the box phantom. The distance was as specified in the standard i.e. 10mm from the liquid (for 1900MHz). The Indexsar foam spacers (described above) were used to ensure this condition during measurement.

The impedance was measured at the SMA-connector with the network analyser.
The following parameters were measured:

Dipole impedance at 1900 MHz	Re{Z} = **50.086 Ω** Im{Z} = **1.043 Ω**
Return loss at 1900MHz	**-39.561 dB**



4. Dipole handling

The dipoles are made from standard, copper-sheathed coaxial cable. In assembly, the sections are joined using ordinary soft-soldering. This is necessary to avoid excessive heat input in manufacture, which would destroy the polythene dielectric used for the cable. The consequence of the construction material and the assembly technique is that the dipoles are fragile and can be deformed by rough handling. Conversely, they can be straightened quite easily as described in this report.

If a dipole is suspected of being deformed, a normal workshop lathe can be used as an alignment jig to restore the symmetry. To do this, the dipole is first placed in the headstock of the lathe (centred on the plastic or brass spacers) and the headstock is rotated by hand (do NOT use the motor). A marker (lathe tool or similar) is brought up close to the end of one dipole arm and then the headstock is rotated by 0.5 rev. to check the opposing arm. If they are not balanced, judicious deformation of the arms can be used to restore the symmetry.

If a dipole has a failed solder joint, the dipole can be fixed down in such a way that the arms are co-linear and the joint re-soldered with a reasonably-powerful electrical soldering iron. Do not use gas soldering irons. After such a repair, electrical tests must be performed as described below.

Please note that, because of their construction, the dipoles are short-circuited for DC signals.

5. Tuning the dipole

The dipole dimensions are based on calculations that assumed specific liquid dielectric properties. If the liquid dielectric properties are somewhat different, the dipole tuning will also vary. A pragmatic way of accounting for variations in liquid properties is to 'tune' the dipole (by applying minor variations to its effective length). For this purpose, Indexsar can supply short brass tube lengths to extend the length of the dipole and thus 'tune' the dipole. It cannot be made shorter without removing a bit from the arm. An alternative way to tune the dipole is to use copper shielding tape to extend the effective length of the dipole. Do both arms equally.

It should be possible to tune a dipole as described, whilst in place in the measurement position as long as the user has access to a VNA for determining the return loss.

6. References

[1] Draft recommended practice for determining the peak spatial-average specific absorption rate (SAR) in the human body due to wireless communications devices: Experimental Techniques.

[2] Calibration report on SAR probe IXP-050 S/N 0071 from National Physical Laboratory. Test Report EF07/2002/03/IndexSAR. Dated 20 February 2002.

IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 050

S/N 0123

25th October 2002

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INTRODUCTION

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N 0123) and describes the procedures used for characterisation and calibration.

Indexsar probes are characterised using procedures that, where applicable, follow the recommendations of CENELEC [1] and IEEE [2] standards. The procedures incorporate techniques for probe linearisation, isotropy assessment and determination of liquid factors (conversion factors). Calibrations are determined by comparing probe readings with analytical computations in canonical test geometries (waveguides) using normalised power inputs.

Each step of the calibration procedure and the equipment used is described in the sections below.

CALIBRATION PROCEDURE

1. Equipment Used

For the first part of the characterisation procedure, the probe is placed in an isotropy measurement jig as pictured in Figure 1. In this position the probe can be rotated about its axis by a non-metallic belt driven by a stepper motor.

The probe is attached via its amplifier and an optical cable to a PC. A schematic representation of the test geometry is illustrated in Figure 2.

A balanced dipole (900 MHz) is inserted horizontally into the bracket attached to a second belt (Figure 1). The dipole can also be rotated about its axis. A cable connects the dipole to a signal generator, via a directional coupler and power meter. The signal generator feeds an RF amplifier at constant power, the output of which is monitored using the power meter. The probe is positioned so that its sensors line up with the rotation center of the source dipole. By recording output voltage measurements of each channel as both the probe and the dipole are rotated, data are obtained from which the spherical isotropy of the probe can be optimised and its magnitude determined.

The calibration process requires E-field measurements to be taken in air, in 900 MHz simulated brain liquid and at other frequencies/liquids as appropriate.

2. Linearising probe output

The probe channel output signals are linearised in the manner set out in Refs [1] and [2]. The following equation is utilized for each channel:

$$U_{lin} = U_{o/p} + U_{o/p}{}^{2} / DCP \qquad (1)$$

where U_{lin} is the linearised signal, $U_{o/p}$ is the raw output signal in voltage units and DCP is the diode compression potential in similar voltage units.

DCP is determined from fitting equation (1) to measurements of U_{lin} versus source feed power over the full dynamic range of the probe. The DCP is a characteristic of the schottky diodes used as the sensors. For the IXP-050 probes with CW signals the DCP values are typically 0.10V (or 20 in the voltage units used by Indexsar software, which are V*200).

3. Selecting channel sensitivity factors to optimise isotropic response

The basic measurements obtained using the calibration jig (Fig 1) represent the output from each diode sensor as a function of the presentation angle of the source (probe and dipole rotation angles). The directionality of the orthogonally-arranged sensors can be checked by analysing the data using dedicated Indexsar software, which displays the data in 3D format as in Figure 3. The left-hand side of this diagram shows the individual channel outputs after linearisation (see above). The program uses these data to balance the channel outputs and then applies an optimisation process, which makes fine adjustments to the channel factors for optimum isotropic response.

The next stage of the process is to calibrate the Indexsar probe to a W&G EMR300 E-field meter in air. The principal reasons for this are to obtain conversion factors applicable should the probe be used in air and to provide an overall measure of the probe sensitivity.

A multiplier is applied to factors to bring the magnitudes of the average E-field measurements as close as possible to those of the W&G probe.

The following equation is used (where linearised output voltages are in units of V*200):

$$E_{air}^2 \text{ (V/m)} = U_{linx} * \text{Air Factor}_x + U_{liny} * \text{Air Factor}_y + U_{linz} * \text{Air Factor}_z \qquad (2)$$

It should be noted that the air factors are not separately used for normal SAR testing. The IXP-050 probes are optimised for use in tissue-simulating liquids and do not behave isotropically in air.

4. 900 MHz Liquid Calibration

Conversion factors for use when the probes are immersed in tissue-simulant liquids at 900 MHz are determined either using a waveguide or by comparison to a reference probe that has been calibrated by NPL. Waveguide procedures are described later. The summary sheet indicates the method used for the probe S/N 0123.

The conversion factor, referred to as the 'liquid factor' is also applied to the measurements of each channel. The following equation is used (where output voltages are in units of V*200):

$$\begin{aligned} E_{liq}^2\ (V/m) = \quad & U_{linx} * \text{Air Factor}_x * \text{Liq Factor}_x \\ & + U_{liny} * \text{Air Factor}_y * \text{Liq Factor}_y \\ & + U_{linz} * \text{Air Factor}_z * \text{Liq Factor}_z \qquad (3) \end{aligned}$$

A 3D representation of the spherical isotropy for probe S/N 0123 using these factors is shown in Figure 3.

The rotational isotropy can also determined from the calibration jig measurements and is reported as the 900MHz isotropy in the summary table. Note that waveguide measurements can also be used to determine rotational isotropy (Fig. 5).

The design of the cells used for determining probe conversion factors are waveguide cells is shown in Figure 4. The cells consist of a coax to waveguide transition and an open-ended section of waveguide containing a dielectric separator. Each waveguide cell stands in the upright positition and is filled with liquid within 10 mm of the open end. The seperator provides a liquid seal and is designed for a good electrical transition from air filled guide to liquid filled guide. The choice of cell depends on the portion of the frequency band to be examined and the choice of liquid used. The depth of liquid ensures there is negligible radiation from the waveguide open top and that the probe calibration is not influenced by reflections from nearby objects. The return loss at the coaxial connector of the filled waveguide cell is measured initially using a network analyser and this information is used subsequently in the calibration procedure. The probe is positioned in the centre of the waveguide and is adjusted vertically or rotated using stepper motor arrangements. The signal generator is connected to the waveguide cell and the power is monitored with a coupler and a power meter. A fuller description of the waveguide method is given below.

The liquid dielectric parameters used for the probe calibrations are listed in the Tables below. The final calibration factors for the probe are listed in the summary chart.

WAVEGUIDE MEASUREMENT PROCEDURE

The calibration method is based on setting up a calculable specific absorption rate (SAR) in a vertically-mounted WG8 (R22) waveguide section [1]. The waveguide has an air-filled, launcher section and a liquid-filled section separated by a matching window that is designed to minimise reflections at the liquid interface. A TE_{01} mode is launched into the waveguide by means of a N-type-to-waveguide adapter. The power delivered to the liquid section is calculated from the forward power and reflection coefficient measured at the input to the waveguide. At the centre of the cross-section of the waveguide, the local spot SAR in the liquid as a function of distance from the window is given by functions set out in IEEE1528 as below:

Because of the low cutoff frequency, the field inside the liquid nearly propagates as a TEM wave. The depth of the medium (greater than three penetration depths) ensures that reflections at the upper surface of the liquid are negligible. The power absorbed in the liquid is determined by measuring the waveguide forward and reflected power. Equation (4) shows the relationship between the SAR at the cross-sectional center of the lossy waveguide and the longitudinal distance (*z*) from the dielectric separator

$$SAR(z) = \frac{4\left(P_f - P_b\right)}{\rho ab\delta} e^{-2z/\delta} \quad (4)$$

where the density ρ is conventionally assumed to be 1000 kg/m^3, *ab* is the cross-sectional area of the waveguide, P_f and P_b are the forward and reflected power inside the lossless section of the waveguide, respectively. The penetration depth δ, which is the reciprocal of the waveguide-mode attenuation coefficient, is determined from a scan along the *z*-axis and compared with the theoretical value determined from Equation (5) using the measured dielectric properties of the lossy liquid.

$$\delta = \left[\mathrm{Re}\left\{ \sqrt{\left(\pi / a\right)^2 + j\omega\mu_o\left(\sigma + j\omega\varepsilon_o\varepsilon_r\right)} \right\} \right]^{-1}. \quad (5)$$

Table A.1 of [1] can be used for designing calibration waveguides with a return loss greater than 30 dB at the most important frequencies used for personal wireless communications. Values for the penetration depth for these specific fixtures and tissue-simulating mixtures are also listed in Table A.1.

According to [1], this calibration technique provides excellent accuracy, with standard uncertainty of less than 3.6% depending on the frequency and medium. The calibration itself is reduced to power measurements traceable to a standard calibration procedure. The practical limitation to the frequency band of 800 to 2500 MHz because of the waveguide size is not severe in the context of compliance testing.

CALIBRATION FACTORS MEASURED FOR PROBE S/N 0123

The probe was calibrated at 900, 1800, 1900 and 2450MHz MHz in liquid samples representing both brain liquid and body fluid at these frequencies. The calibration was for CW signals only, and the axis of the probe was parallel to the direction of propagation of the incident field i.e. end-on to the incident radiation. The axial isotropy of the probe was measured by rotating the probe about its axis in 10 degree steps through 360 degrees in this orientation.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 2.7 m from the probe tip in the direction of the probe amplifier. A value of 2.7 mm should be used for the tip to sensor offset distance in the software.

It is important that the diode compression point and air factors used in the software are the same as those quoted in the results tables, as these are used to convert the diode output voltages to a SAR value.

DIELECTRIC PROPERTIES OF LIQUIDS

The dielectric properties of the brain and body tissue-simulant liquids employed for calibration are listed in the tables below. The measurements were performed prior to each waveguide test using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2].

AMBIENT CONDITIONS

Measurements were made in the open laboratory at 22 $\pm$ 2.0^{o}C. The temperature of the liquids in the waveguide used was measured using a mercury thermometer.

RESPONSE TO MODULATED SIGNALS

To measure the response of the probe and amplifier to modulated signals, the probe is held vertically in a liquid-filled waveguide.

An RF amplifier is allowed to warm up and stabilise before use. A spectrum analyser is used to demonstrate that the peak power of the RF amplifier for the CW signals and the pulsed signals are within 0.1dB of each other when the signal generator is switched from CW to modulated output. Subsequently, the power levels recorded are read from a power meter when a CW signal is being transmitted.

The test sequence involves manually stepping the power up in regular (e.g. 2 dB) steps from the lowest power that gives a measurable reading on the SAR probe up to the maximum that the amplifiers can deliver.

At each power level, the individual channel outputs from the SAR probe are recorded at CW and then recorded again with the modulation setting. The results are entered into a spreadsheet. Using the spreadsheets, the modulated power is calculated by applying a factor to the measured CW power (e.g. for GSM, this factor is 9.03dB). This process is repeated 3 times with the response maximised for each channel sensor in turn.

The probe channel output signals are linearised in the manner set out in Section 1 above using equation (1) with the DCPs determined from the linearisation procedure. Calibration factors for the probe are used to determine the E-field values corresponding to the probe readings using equation (3). SAR is determined from the equation

$$SAR\ (W/kg) = E_{liq}^{2}\ (V/m) * \sigma(S/m) / 1000 \qquad (6)$$

Where σ is the conductivity of the simulant liquid employed.

Using the spreadsheet data, the DCP value for linearising each of the individual channels (X, Y and Z) is assessed separately. The corresponding DCP values are listed in the summary page of the calibration factors for each probe.

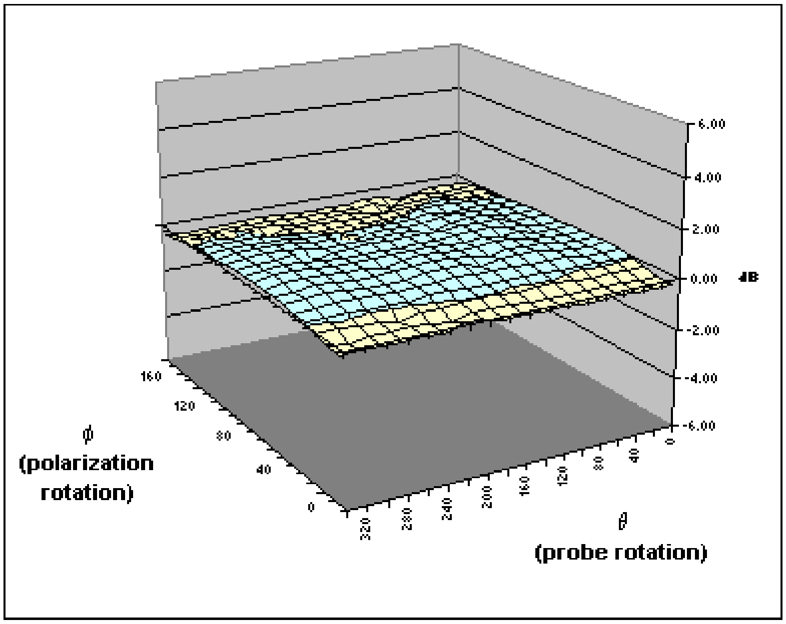
Figure 7 shows the linearised probe response to GSM signals, Figure 8 the response to GPRS signals (GSM with 2 timeslots) and Figure 9 the response to CDMA IS-95A and W-CDMA signals.

Additional tests have shown that the modulation response is similar at 1800MHz and is not affected by the orientation between the source and the probe.

SUMMARY OF CALIBRATION FACTORS FOR PROBE IXP-050 S/N 0123

IXP-050 **S/N0123** 25/10/2002

Spherical isotropy measured at 900 MHz 0.44 (+/-) dB



	X	Y	Z	
Air factors	346	318	386	(V*200)
DCPs	20	20	20	(V*200)
GSM	9	13.6	8.7	(V*200)
GPRS	17.9	18	13.6	(V*200)
CDMA	20	20	20	(V*200)

f (MHz)	Axial isotropy (+/- dB) BRAIN	BODY	SAR conversion factors (liq/air) BRAIN	BODY	Notes
835	0.15	0.18	0.401	0.466	4
900	0.14	0.16	0.480	0.509	4
1800	0.14	0.14	0.542	0.600	4
1900	0.14	0.14	0.562	0.610	4
2000	0.14	-	0.6	-	4
2450	0.15	0.15	0.768	0.816	4

Notes

1) Extrapolated values in italics

2) Calibrations done at 22C +/- 2C

3) Probe calibration by substitution against NPL-calibrated probe (Probe IXP-050 S/N0071; NPL Cal Rept. No: EF07/2002/03/IndexSAR

4) Waveguide calibration

(the graph shows a simple, spreadsheet representation of surface shown in 3D in Figure 3 below)

PROBE SPECIFICATIONS

Indexsar probe 0123, along with its calibration, is compared with CENELEC and IEEE standards recommendations (Refs [1] and [2]) in the Tables below. A listing of relevant specifications is contained in the tables below:

Dimensions	S/N 0123	CENELEC [1]	IEEE [2]
Overall length (mm)	350		
Tip length (mm)	10		
Body diameter (mm)	12		
Tip diameter (mm)	5.2	8	8
Distance from probe tip to dipole centers (mm)	2.7		

Dynamic range	S/N 0123	CENELEC [1]	IEEE [2]
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg) N.B. only measured to 35 W/kg	>35	>100	100

Linearity of response	S/N 0123	CENELEC [1]	IEEE [2]
Over range 0.01 – 100 W/kg (+/- dB)	0.125	0.50	0.25

Isotropy (measured at 900MHz)	S/N 0123	CENELEC [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB) at 835, 900, 1800, 1900 and 2450 MHz	Max. 0.18 (see summary table)	0.5	0.25
Spherical isotropy covering all orientations to source (+/- dB)	0.44	1.0	0.50

Construction	Each probe contains three orthogonal dipole sensors arranged on a triangular prism core, protected against static charges by built-in shielding, and covered at the tip by PEEK cylindrical enclosure material. No adhesives are used in the immersed section. Outer case materials are PEEK and heat-shrink sleeving.
Chemical resistance	Tested to be resistant to glycol and alcohol containing simulant liquids but probes should be removed, cleaned and dried when not in use.

REFERENCES

[1] CENELEC, EN 50361, July 2001. Basic Standard for the measurement of specific absorption rate related to human exposure to electromagnetic fields from mobile phones.

[2] IEEE 1528, Recommended practice for determining the spatial-peak specific absorption rate (SAR) in the human body due to wireless communications devices: Experimental techniques.

[3] Calibration report on SAR probe IXP-050 S/N 0071 from National Physical Laboratory. Test Report EF07/2002/03/IndexSAR. Dated 20 February 2002.

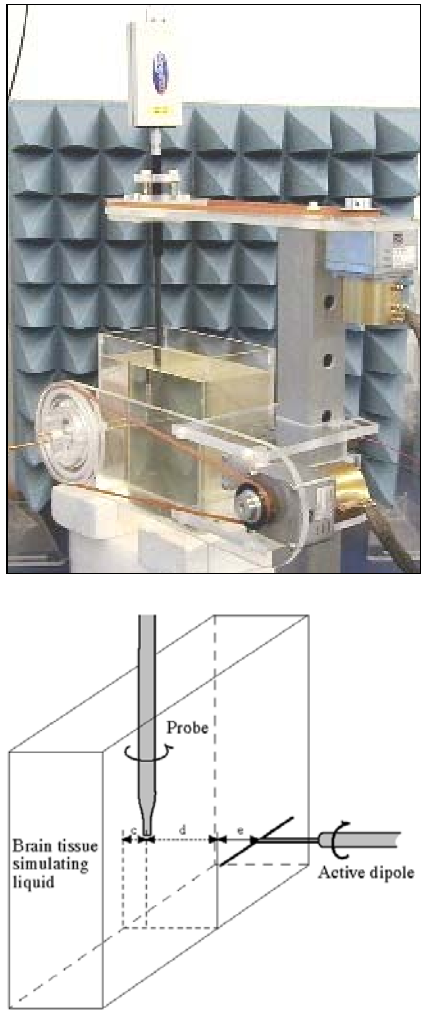


Figure 1. Spherical isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

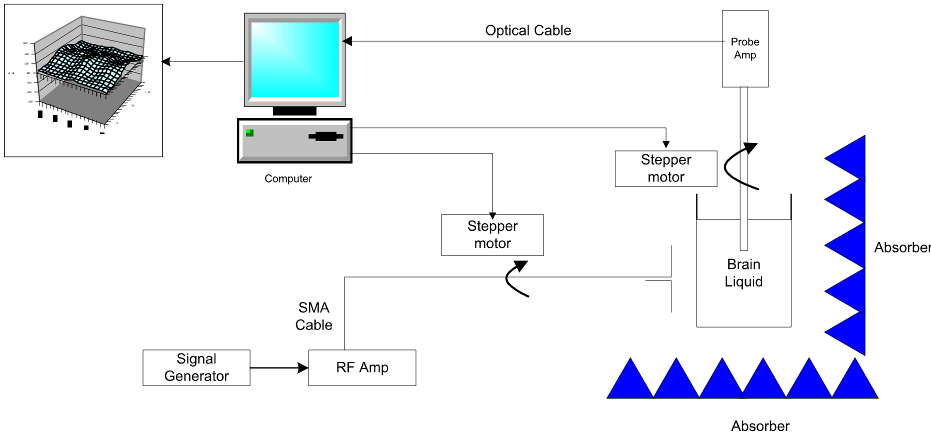


Figure 2. Schematic diagram of the test geometry used for isotropy determination

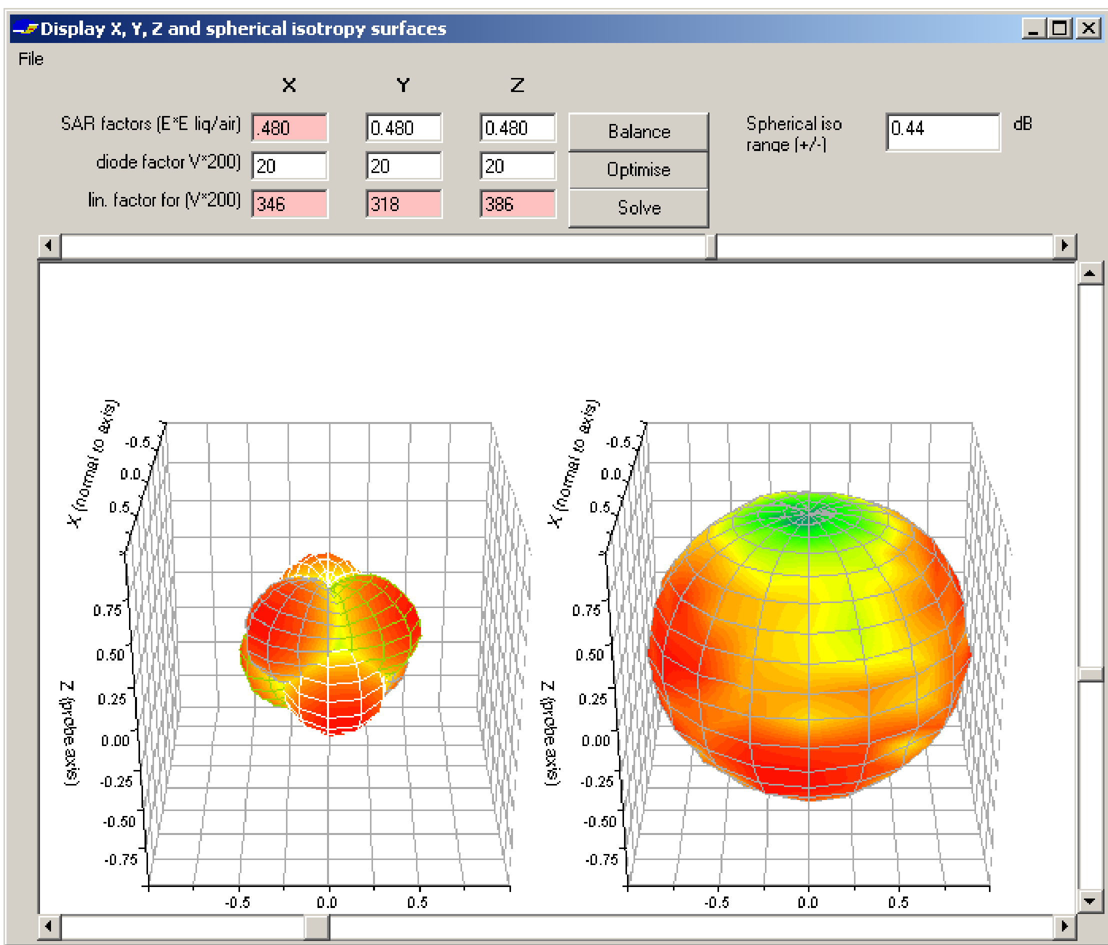


Figure 3. Graphical representation of the probe response to fields applied from each direction. The diagram on the left shows the individual response characteristics of each of the three channels and the diagram on the right shows the resulting probe sensitivity in each direction. The colour range in the figure images the lowest values as blue and the maximum values as red. For the probe S/N 0123, this range is (+/-) 0.44 dB. The probe is more sensitive to fields parallel to the axis and less sensitive to fields normal to the probe axis.

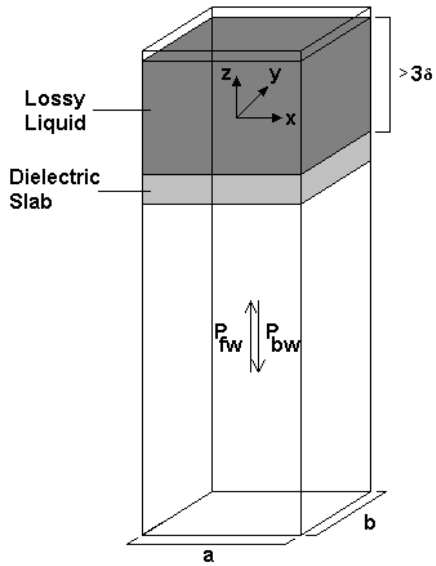
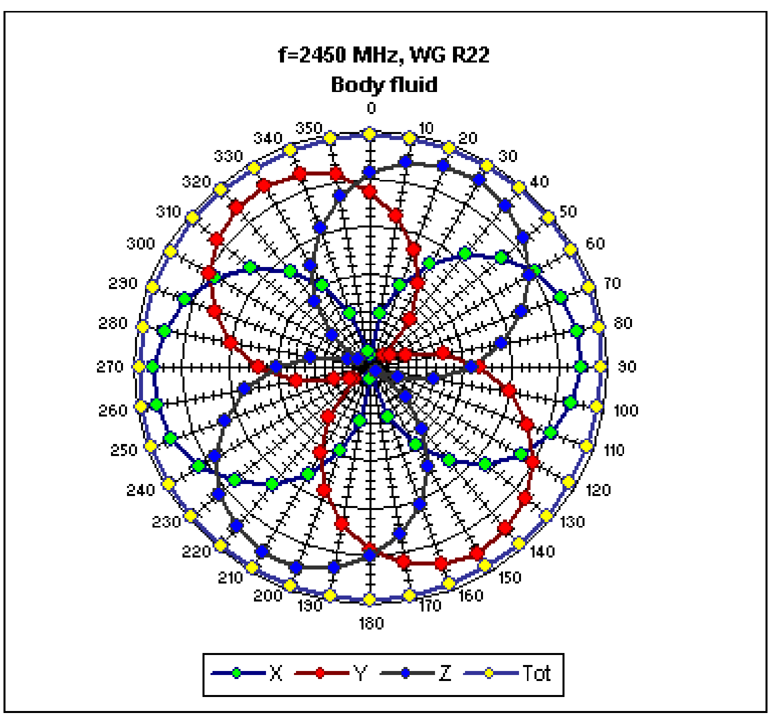


Figure 4. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

IXP-050 S/N 0123 **25-Oct-02**



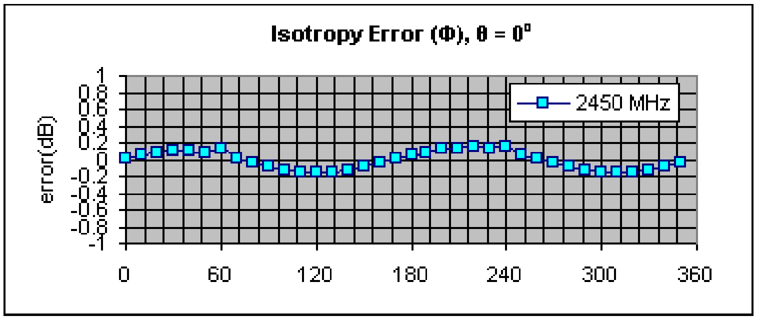


Figure 5. Example of the rotational isotropy of probe S/N 0123 obtained by rotating the probe in a liquid-filled waveguide at 2450 MHz. Similar distributions are obtained at the other test frequencies (1800 and 1900 MHz) both in brain liquids and body fluids (see summary table)

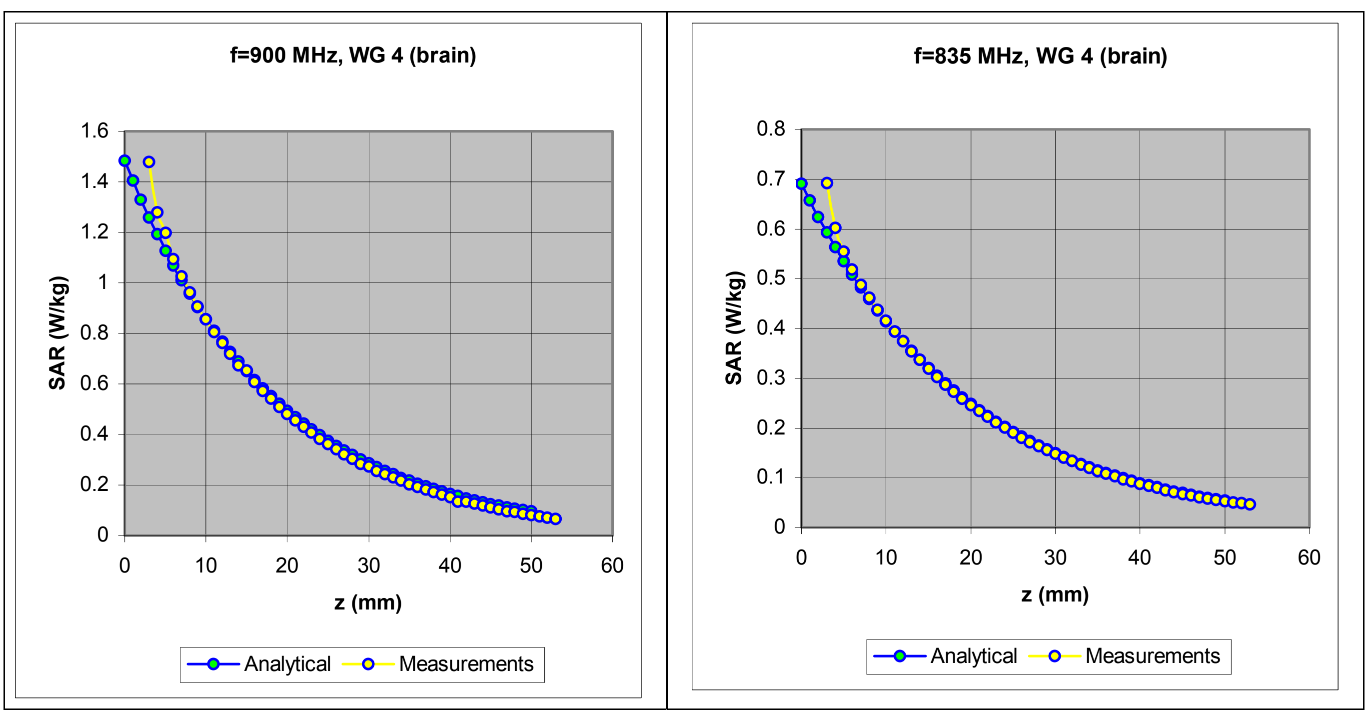


Figure 6. The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

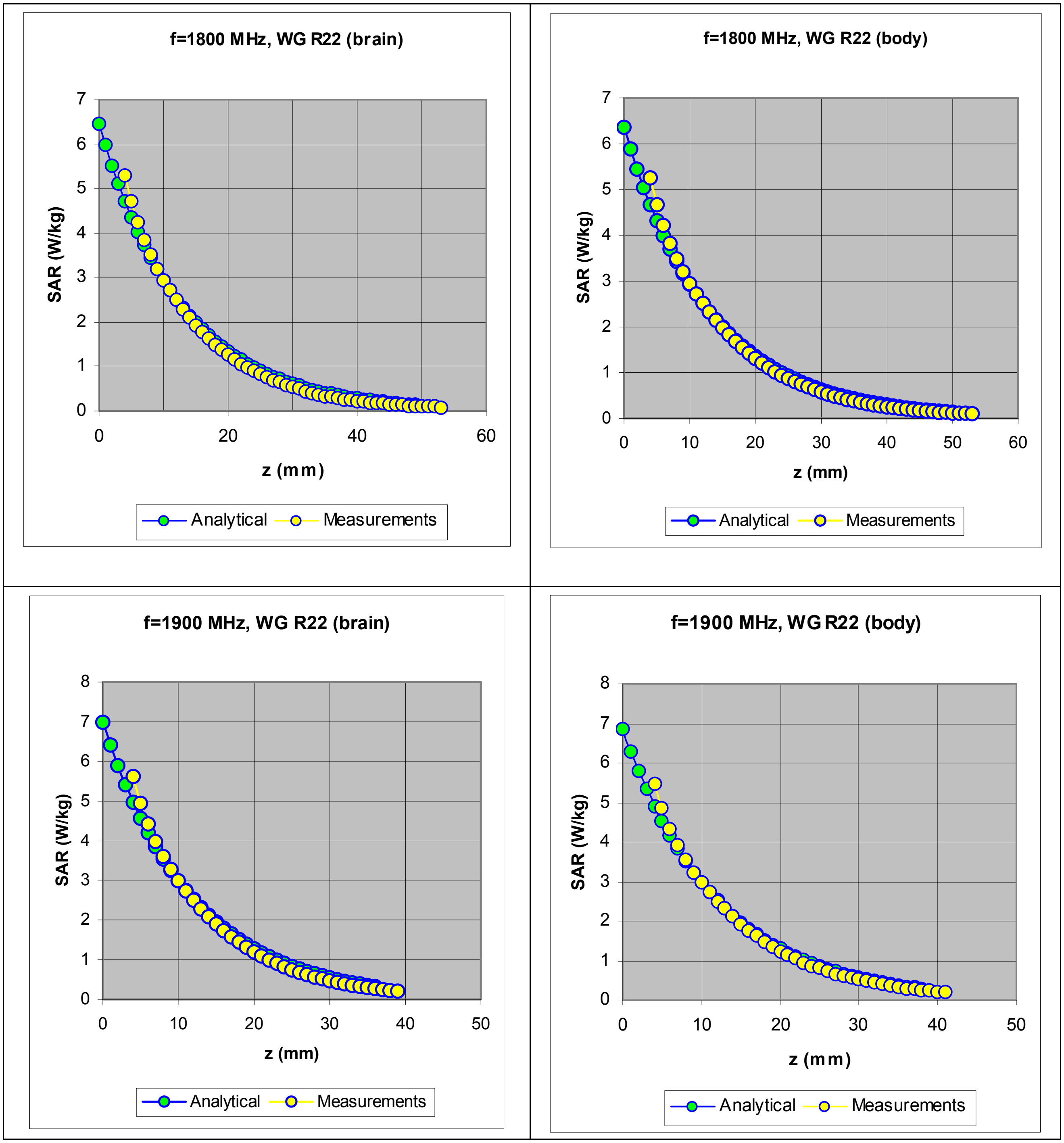


Figure 7. The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

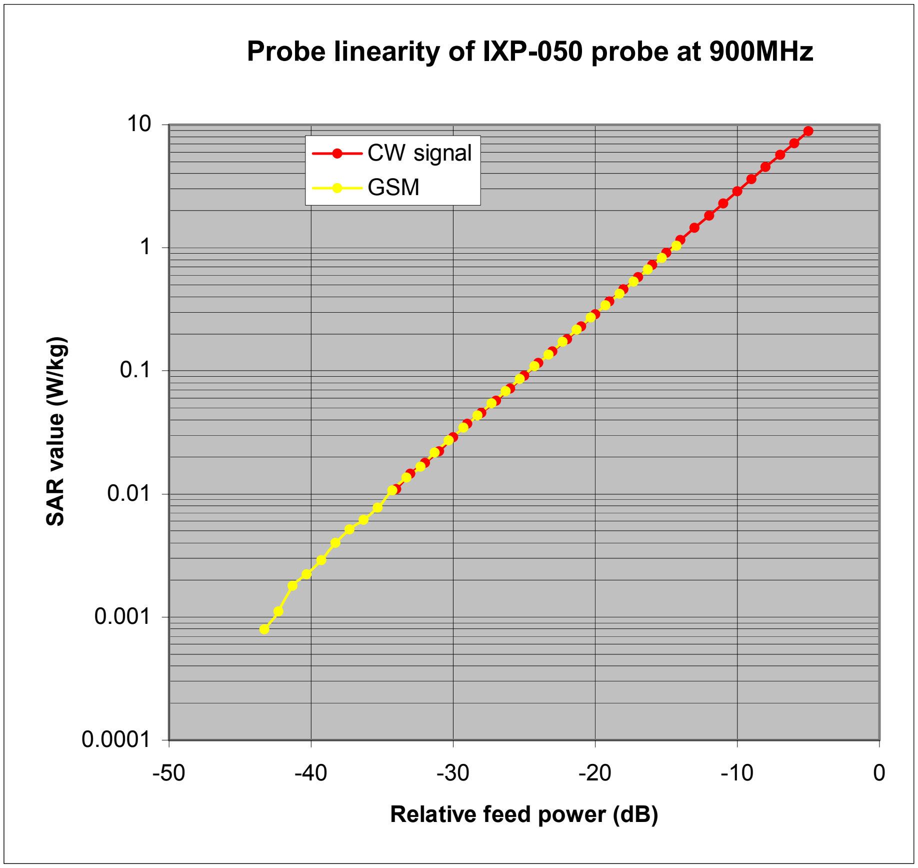


Figure 8. The GSM response of an IXP-050 probe at 900MHz.

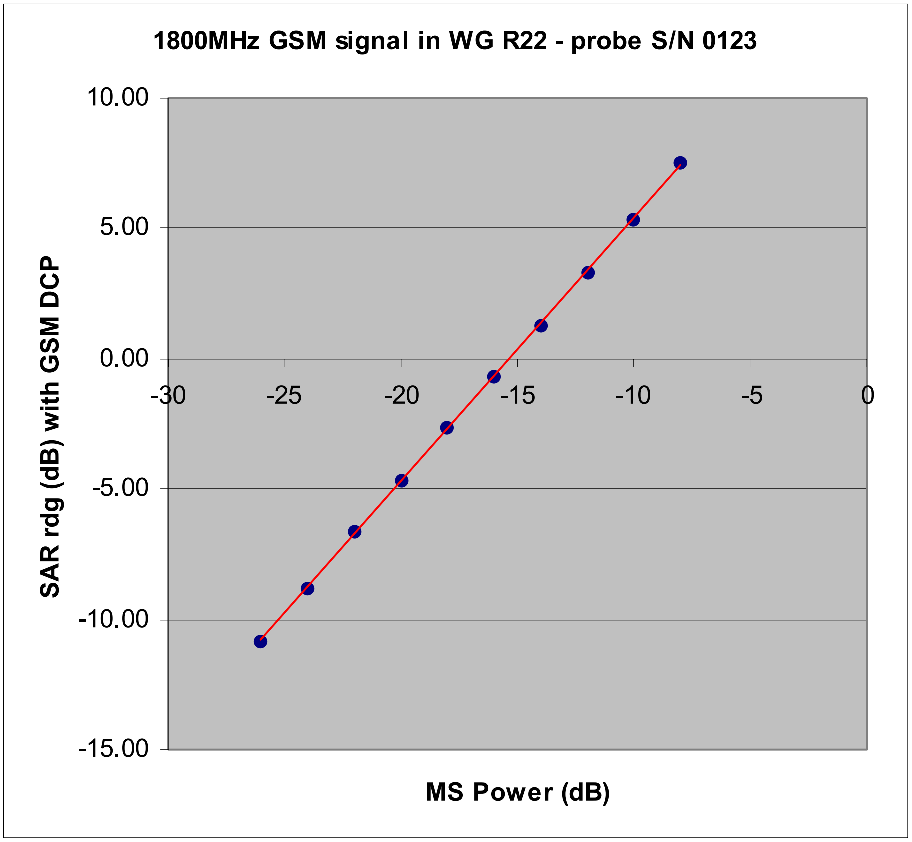


Figure 8a. The actual GSM response of IXP-050 probe S/N 0123 at 1800MHz

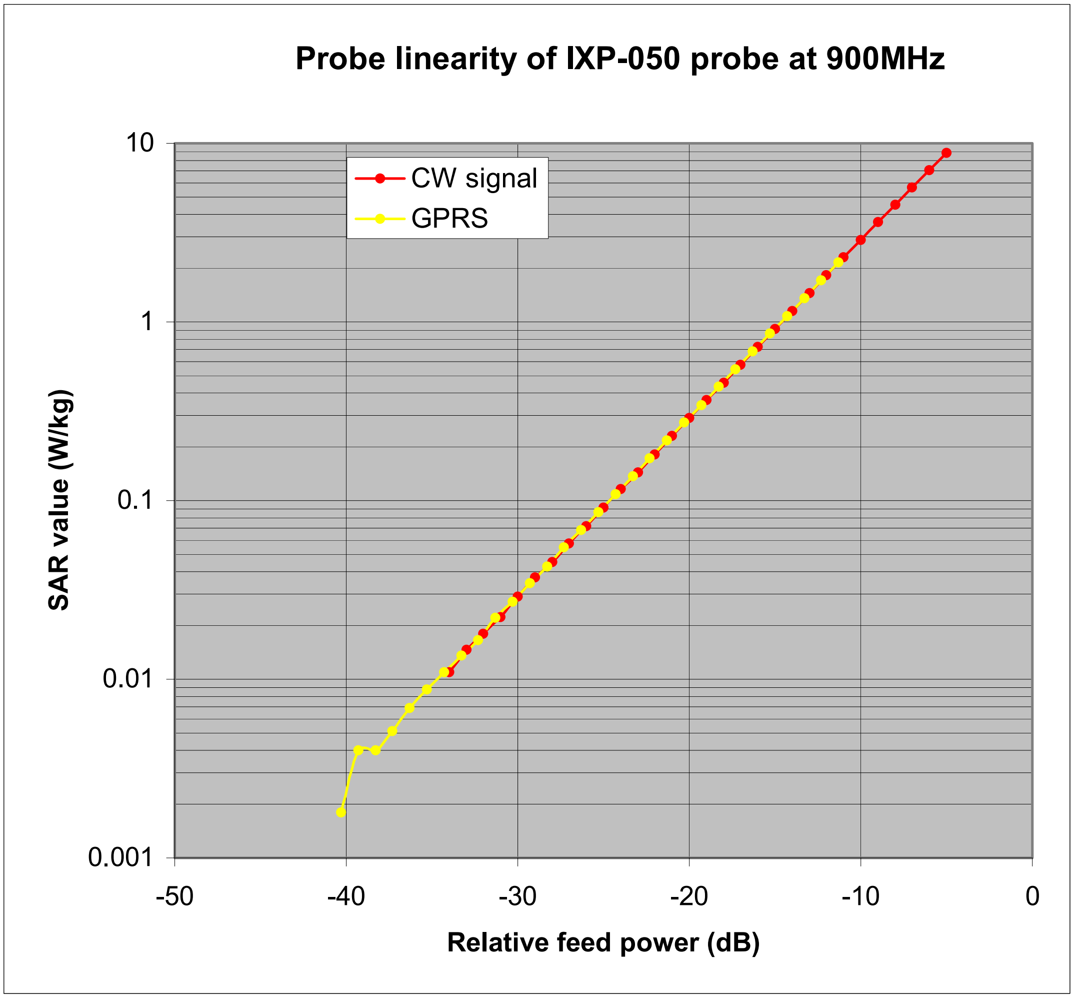
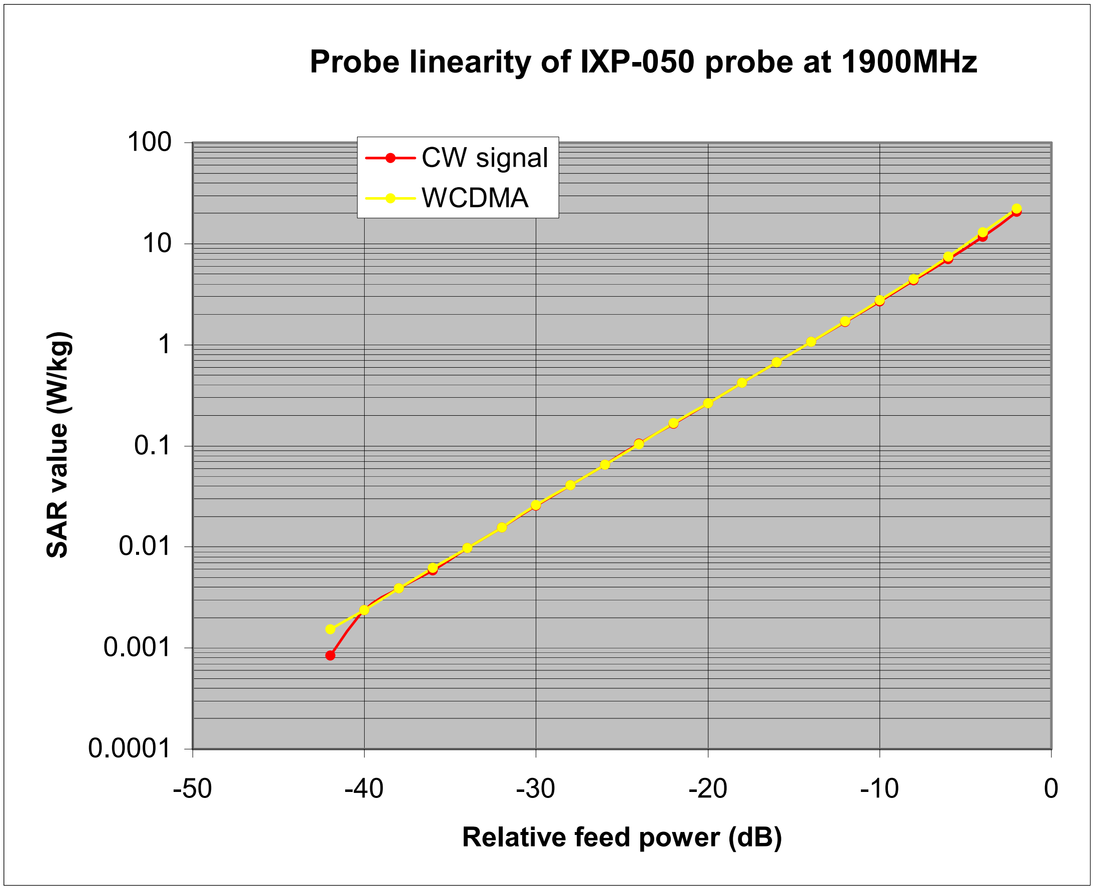


Figure 9. The GPRS response of an IXP-050 probe at 900MHz.


Probe linearity of IXP-050 probe at 1900MHz
CW signal
WCDMA
SAR value (W/kg)
100
10
1
0.1
0.01
0.001
0.0001
-50
-40
-30
-20
-10
0
Relative feed power (dB)

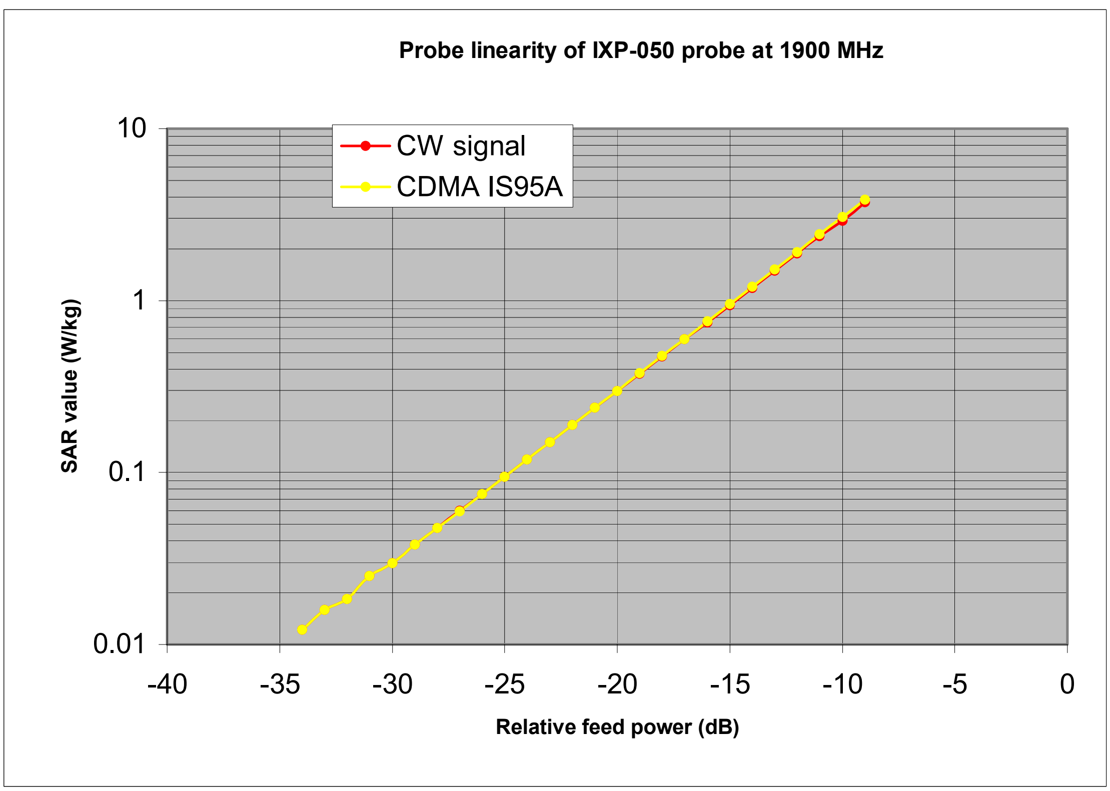

Probe linearity of IXP-050 probe at 1900 MHz
CW signal
CDMA IS95A
SAR value (W/kg)
10
1
0.1
0.01
-40
-35
-30
-25
-20
-15
-10
-5
0
Relative feed power (dB)

Figure 10. The CDMA response of an IXP-050 probe at 1900MHz.

Table indicating the dielectric parameters of the liquids used for calibrations at each frequency

Liquid used	Relative permittivity (measured)	Conductivity (S/m) (measured)
835 MHz BRAIN	43.3	0.911
835 MHz BODY	58.9	0.985
900 MHz BRAIN	42.5	0.97
900 MHz BODY	58.45	1.044
1800 MHz BRAIN	38.97	1.33
1800 MHz BODY	52.53	1.51
1900 MHz BRAIN	38.43	1.429
1900 MHz BODY	52.02	1.62
2000 MHz BRAIN	37.42	1.36
2450 MHz BRAIN	39.29	1.737
2450 MHz BODY	62.9	2.08

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Calibration Certificate
Dosimetric E-field Probe

Type:	**IXP-050**
Manufacturer:	**IndexSAR, UK**
Serial Number:	**0123**
Place of Calibration:	**IndexSAR, UK**

IndexSAR Limited hereby declares that the IXP-050 Probe named above has been calibrated for conformity to the IEEE 1528 and CENELEC En 50361 standards on the date shown below.

Date of Initial Calibration:	**25th October 2002**

The probe named above will require a calibration check on the date shown below.

Next Calibration Date:	**October 2003**

The calibration was carried out using the methods described in the calibration document. Where applicable, the standards used in the calibration process are traceable to the UK's National Physical Laboratory.

Calibrated By:

Approved By:

Please keep this certificate with the calibration document. When the probe is sent for a calibration check, please include the calibration document.