

# ***Specific Absorption Rate (SAR) Test Report***

for

**Quanta Computer Inc.**

on the

Notebook Personal Computer (with WLAN Mini-PCI module RM8 inside)

**Model Number: ZI 3**

Test Report: EME-031135

Date of Report: Oct. 20, 2003

Date of test: Oct. 17, 2003

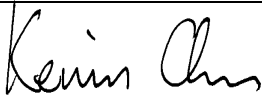

Total No of Pages Contained in this Report: 66



0597

ILAC MRA

Accredited for testing to FCC Part 15

Tested by: Kevin Chen	
Reviewed by: Elton Chen	

Review Date: Oct. 21, 2003

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### STATEMENT OF COMPLIANCE

The Quanta sample device, model # ZI 3 was evaluated in accordance with the requirements for compliance testing defined in FCC OET Bulletin 65, Supplement C (Edition 01-01). Testing was performed at the Intertek Testing Services facility in Hsinchu, Taiwan.

For the evaluation, the dosimetric assessment system INDEXSAR SARA2 was used. The phantom employed was the box phantom of 2mm thick in one wall. The total uncertainty for the evaluation of the spatial peak SAR values averaged over a cube of 1g tissue mass had been assessed for this system to be  $\pm 27.6\%$ .

The device was tested at their maximum output power declared by the Quanta.

In summary, the maximum spatial peak SAR value for the sample device averaged over 1g was found to be:

<b>Phantom</b>	<b>Position</b>	<b>SAR<sub>1g</sub>, mW/g</b>
2mm thick box phantom wall	EUT perpendicular rear to the phantom, 0 mm separation.	0.202 mW/g.

In conclusion, the tested Sample device was found to be in compliance with the requirements defined in OET Bulletin 65, Supplement C (Edition 01-01) for body configurations.

## 1.0 Job Description

### 1.1 Client Information

The ZI 3 has been tested at the request of:

**Company:** **Quanta Computer Inc.**  
**No. 188, Wen-Hwa 2<sup>nd</sup> Road, Kuei-Shan Hsiang**  
**Tao Yuan Shien, Taiwan**

### 1.2 Equipment under test (EUT)

#### Product Descriptions:

<b>Equipment</b>	<b>Notebook Personal Computer (with WLAN Mini-PCI module RM8 inside)</b>		
<b>Trade Name</b>	Quanta	<b>Model No:</b>	ZI 3
<b>FCC ID</b>	HFSZI3RM8	<b>S/N No.</b>	Not Labeled
<b>Category</b>	Portable	<b>RF Exposure</b>	Uncontrolled Environment
<b>Frequency Band</b>	2412 – 2462 MHz	<b>System</b>	DSSS, OFDM

<b>EUT Antenna Description</b>			
<b>Type</b>	PCB Printed	<b>Configuration</b>	Fixed
<b>Dimensions</b>	332 x 278 mm	<b>Gain</b>	2.02 dBi
<b>Location</b>	Embedded		

The series model, Aspire 1450 is identical to ZI3, the different model for different brand serves as marketing purpose.

**Use of Product :** **Wireless Data Communication**

**Manufacturer:** Quanta

**Production is planned:** [X] Yes, [ ] No

**EUT receive date:** Oct. 6, 2003

**EUT received condition:** Good operating condition prototype

**Test start date:** Oct. 17, 2003

**Test end date:** Oct. 17, 2003

### 1.3 Test plan reference

FCC Rule: Part 2.1093, FCC's OET Bulletin 65, Supplement C (Edition 01-01)

### 1.4 System test configuration

#### 1.4.1 System block diagram & Support equipment

Support Equipment			
Item #	Equipment	Model No.	S/N
1	N/A	N/A	N/A



### 1.4.2 Test Position

See the photographs as section 2.2

### 1.4.3 Test Condition

During tests the worst-case data (max RF coupling) was determined with following conditions:

<b>Usage</b>	Operates with a portable computer	<b>Distance between antenna axis at the joint and the liquid surface:</b>	Laptop is touching the Phantom in perpendicular, separating 0mm and 15mm in left and rear position, 0mm in bottom position.	
<b>Simulating human Head/ Body/Hand</b>	Body	<b>EUT Battery</b>	Device is powered from host computer through battery.	
<b>802.11b Conducted output Power</b>	<b>Channel</b>	<b>Frequency MHz</b>	<b>Before SAR Test (dBm)</b>	<b>After SAR Test (dBm)</b>
	Low Channel - 1	2412	17.55	-
	Mid Channel - 6	2437	16.84	-
	High Channel- 11	2462	16.29	-
<b>802.11g Conducted output Power</b>	<b>Channel</b>	<b>Frequency MHz</b>	<b>Before SAR Test (dBm)</b>	<b>After SAR Test (dBm)</b>
	Low Channel - 1	2412	19.48	-
	Mid Channel - 6	2437	19.86	19.87
	High Channel- 11	2462	19.34	-

The spatial peak SAR values were assessed for lowest, middle and highest operating channels, defined by the manufacturer.

The conducted output power was measured before and after the test using a diode detector, oscilloscope and signal generator.

The EUT contains 802.11b and 802.11g function, due to the worst case output power was found in 802.11g function, we only performed the 802.11g for SAR testing.

Run the test program “.BAT” under MFGTEST of Windows OS.

The EUT was transmitted continuously during the test.

After verifying the maximum output power, we found the maximum output power was occurred at 6Mbps data rate.

All the test data were performed under the above transmission rate.

### **1.5 Modifications required for compliance**

Intertek Testing Services implemented no modifications.

### **1.6 Additions, deviations and exclusions from standards**

The phantom employed was the box phantom of 2mm thick in vertical wall.

## 2.0 SAR Evaluation

### 2.1 SAR Limits

The following FCC limits for SAR apply to devices operate in General Population/Uncontrolled Exposure environment:

<b>EXPOSURE (General Population/Uncontrolled Exposure environment)</b>	<b>SAR (W/kg)</b>
Average over the whole body	0.08
Spatial Peak (1g)	1.60
Spatial Peak for hands, wrists, feet and ankles (10g)	4.00



**2.2 Configuration Photographs**

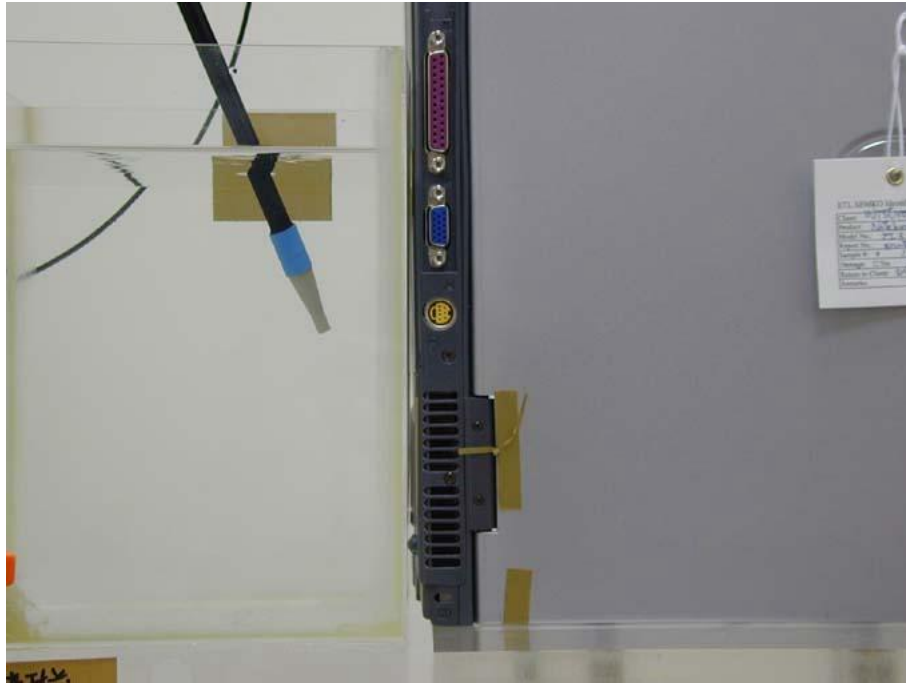
**SAR Measurement Test Setup**

**Test System**



**SAR Measurement Test Setup**

**Bottom side of Laptop facing phantom touching**



**Bottom side of Laptop facing phantom touching – Zoom In**



**SAR Measurement Test Setup  
EUT perpendicular in left position to phantom, 0 mm separation**



**EUT perpendicular in left position to phantom, 0 mm separation – Zoom In**



**SAR Measurement Test Setup**  
**EUT perpendicular in left position to phantom, 15 mm separation**



**EUT perpendicular in left position to phantom, 15 mm separation– Zoom In**



**SAR Measurement Test Setup**  
**EUT perpendicular in rear position to phantom, 0 mm separation**



**EUT perpendicular in rear position to phantom, 0 mm separation - Zoom In**



**SAR Measurement Test Setup  
EUT perpendicular in rear position to phantom, 15 mm separation**



**EUT perpendicular in rear position to phantom, 15 mm separation - Zoom In**



## 2.3 SAR measurement system

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### 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.

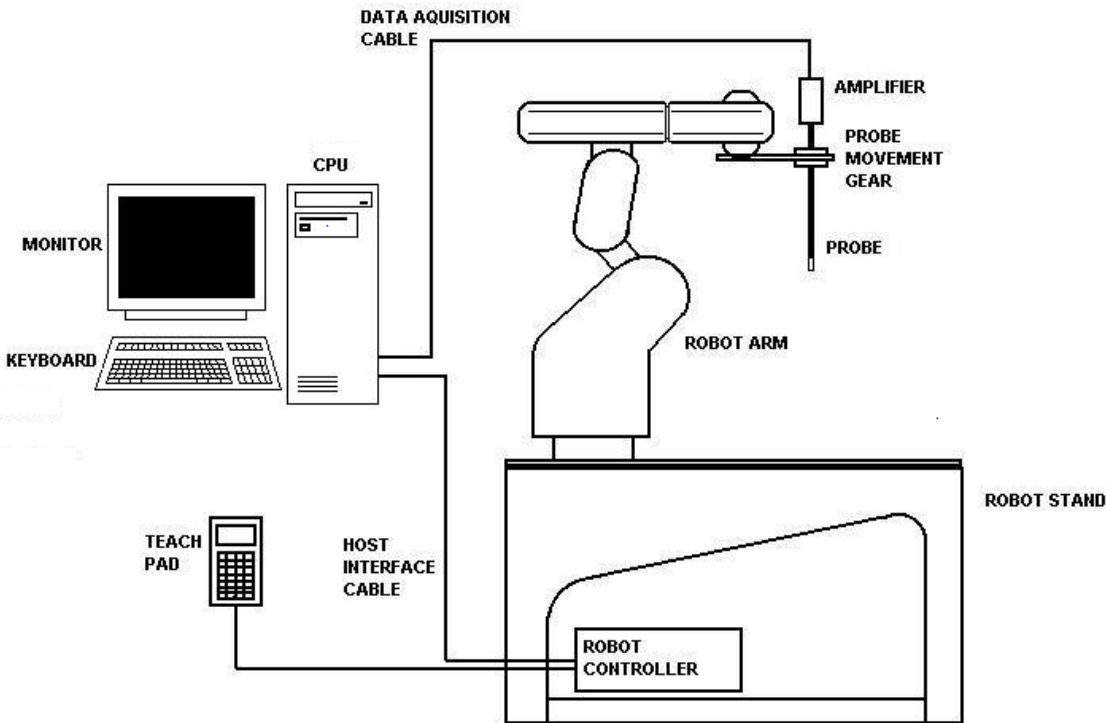


Figure 1: Schematic diagram of the SAR measurement system

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 0.02mm. 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.

## 2.4 SAR measurement system validation

Prior to the assessment, the system was verified to the  $\pm 10\%$  of the specifications by using the system validation equipments. The validation was performed at 2450 MHz on the bottom side of box phantom.

### Procedures

The SAR evaluation was performed with the following procedures:

- a. The SAR distribution was measured at the exposed side of the bottom of the box phantom and was measured at a distance of 8 mm from the inner surface of the shell. The feed power was 1/4W.
- b. The dimension for this cube is 32 mm x 32 mm x 34 mm was assessed by measuring 5 x 5 x 7 points. On the basis of this data set, the spatial peak SAR value was evaluated with the following procedure:
  - i) The data at the surface were extrapolated, since the center of the dipoles is 2.7 mm away from the tip of the probe and the distance between the surface and the lowest measurement point is 5 mm. The extrapolation was based on a least square algorithm. A polynomial of the fourth order was calculated through the points in Z-axis. This polynomial was then used to evaluate the points between the surface and the probe tip.
  - ii) The maximum interpolated value was searched with a straightforward algorithm. Around this maximum, the SAR values averaged over the spatial volumes (1g or 10g) were computed using the 3-D spline interpolation algorithm. The 3-D spline is composed of three one-dimensional splines with the “Not a knot” condition (in x, y and z directions). The volume was integrated with the trapezoidal algorithm. 1000 points (10 x 10 x 10) were interpolated to calculate the average.
  - iii) All neighboring volumes were evaluated until no neighboring volume with a higher average value was found.

System Validation (2450 MHz Head)					
Frequency MHz	Operating Mode	Target SAR <sub>1g</sub> (mW/g)	Measured SAR <sub>1g</sub> (mW/g)	Deviation ( $\pm 10\%$ )	Plot Number
2450	CW	52.4	54.688	4.37%	1

System performance check (2450 MHz Head)					
Frequency MHz	Operating Mode	Target SAR <sub>1g</sub> (mW/g)	Measured SAR <sub>1g</sub> (mW/g)	Deviation ( $\pm 10\%$ )	Plot Number
2450	CW	52.4	54.648	4.29%	2



## **2.5 Test Result**

The results on the following page(s) were obtained when the device was tested in the condition described in this report. Detailed measurement data and plots, which reveal information about the location of the maximum SAR with respect to the device, are reported in Appendix A.

### Measurement Results

<b>Trade Name:</b>	Quanta	<b>Model No.:</b>	ZI 3
<b>Serial No.:</b>	Not Labeled	<b>Test Engineer:</b>	Kevin Chen
<b>TEST CONDITIONS</b>			
<b>Ambient Temperature</b>	24 °C	<b>Relative Humidity</b>	50 %
<b>Test Signal Source</b>	Test Mode	<b>Signal Modulation</b>	OFDM
<b>Output Power Before SAR Test</b>	See page 6	<b>Output Power After SAR Test</b>	See page 6
<b>Test Duration</b>	22 min. each scan	<b>Number of Battery Change</b>	1

<b>EUT Position</b>						
<b>Channel (MHz)</b>	<b>Operating Mode</b>	<b>Crest Factor</b>	<b>Description</b>	<b>Distance (mm)</b>	<b>Measured SAR<sub>1g</sub> (mW/g)</b>	<b>Plot Number</b>
2437	OFDM	1	Perpendicular in rear position	0	0.202	3
2437	OFDM	1	Perpendicular in rear position	15	0.024	4
2437	OFDM	1	Perpendicular in left position	0	Note 2	5
2437	OFDM	1	Perpendicular in left position	15	Note 2	6
2437	OFDM	1	Bottom of EUT	15	Note 2	7

Note:

1. Configuration at middle channel with more than -3dB of applicable limit.
2. The measurement was only performed in Area Scan due to scanning system couldn't continue performing Zoom Scan with such a low SAR distribution.

### 3.0 Test Equipment

#### 3.1 Equipment List

The Specific Absorption Rate (SAR) tests were performed with the INDEXSAR SARA2 SYSTEM.

The following major equipment/components were used for the SAR evaluations:

SAR Measurement System			
EQUIPMENT	SPECIFICATIONS	S/N #	LAST CAL. DATE
Balanced Validation dipole	2450MHz	0048	N/A
Controller	Mitsubishi CR-E116	F1008007	N/A
Robot	Mitsubishi RV-E2	EA009002	N/A
	Repeatability: ± 0.04mm; Number of Axes: 6		
E-Field Probe	IXP-050	0136	09/10/2003
	Frequency Range: Probe outer diameter: 5.2 mm; Length: 350 mm; Distance between the probe tip and the dipole center: 2.7 mm		
Data Acquisition	SARA2	N/A	N/A
	Processor: Pentium 4; Clock speed: 1.5GHz; OS: Windows XP; I/O: two RS232; Software: SARA2 ver. 0.421N		
Phantom	2mm wall thickness box phantom	N/A	N/A
	Shell Material: clear Perspex; Thickness: 2 ± 0.1 mm; Capacity: 152.5 x 215.5 x 200 (W x L x D) mm <sup>3</sup> ; Dielectric constant: less than 2.85 above 500MHz;		
Device holder	Material: clear Perspex; Dielectric constant: less than 2.85 above 500MHz	N/A	N/A
Simulated Tissue	Mixture	N/A	N/A
	Please see section 3.2 for details		
RF Power Meter	Boonton 4231A with 51011-EMC power sensor	79401-32482	03/21/2003
	Frequency Range: 0.03 to 8 GHz, <24dBm		
RF Power Amplifier	INDEXSAR VTL5400	0302	01/23/2003
	10MHz to 2.5GHz, Gain >30dB		
Directional Coupler	INDEXSAR VDC0830-20	0302	05/19/2003
	0.8 to 3 GHz, Max. Power<500W		
Vector Network Analyzer	HP 8753B HP 85046A	2807J04037 2729A01958	07/04/2003
	300k to 3GHz		
Signal Generator	R&S SMR27	100036	09/19/2003
	10M to 27GHz, <120dBuV		
Crystal Detector	Agilent 8472B	MY42240243	N/A
	10MHz to 18GHz		
Two Channel Digital Storage Oscilloscope	Tektronix TDS1012	C031679	Aug. 16, 2003

### 3.2 Body Tissue Simulating Liquid for evaluation test

The dielectric parameters were verified prior to assessment using the HP 85046A dielectric probe kit and the HP 8753B network Analyzer. The dielectric parameters were:

Frequency (MHz)	Temp. (°C)	e <sub>r</sub> / Relative Permittivity			s / Conductivity (mho/m)			r *(kg/m <sup>3</sup> )
		measured	target	Δ(±5%)	measured	target	Δ(±5%)	
2450	22.4	50.69	52.7	-3.81%	1.98	1.95	1.54%	1000

\* *Worst-case assumption*

Test data is included in Appendix B.

### 3.3 Head Tissue Simulating Liquid for System performance Check test

The dielectric parameters were verified prior to assessment using the HP 85046A dielectric probe kit and the HP 8753B network Analyzer. The dielectric parameters were:

Frequency (MHz)	Temp. (°C)	e <sub>r</sub> / Relative Permittivity			s / Conductivity (mho/m)			r *(kg/m <sup>3</sup> )
		measured	target	Δ(±5%)	measured	target	Δ(±5%)	
2450	23.2	38.12	39.2	-2.76%	1.803	1.80	0.17	1000

\* *Worst-case assumption*

### 3.4 E-Field Probe Calibration

Probe calibration factors are included in Appendix C.

### 3.5 Measurement Uncertainty

The uncertainty budget has been determined for the INDEXSAR SARA2 measurement system according to IEEE P1528 documents [3] and is given in the following table. The extended uncertainty (95% confidence level) was assessed to be 27.6 %

Uncertainty Component	Sec.	(dB)	Tol.(+/-)	(%)	Prob. Dist.	Divisor (descript)	Divisor (value)	c1	Standard Uncertainty (%)
<b>Measurement System</b>									
Probe Calibration	E 2.1			2.5	N	1 or k	1	1	2.50
Axial Isotropy	E 2.2	0.25	5.93	5.93	R	$\sqrt{3}$	1.73	0	0.00
Hemispherical Isotropy	E 2.2	0.45	10.92	10.92	R	$\sqrt{3}$	1.73	1	6.30
Boundary effects	E 2.3		4	4.00	R	$\sqrt{3}$	1.73	1	2.31
Linearity	E 2.4	0.04	0.93	0.93	R	$\sqrt{3}$	1.73	1	0.53
System Detection Limits	E 2.5		1	1.00	R	$\sqrt{3}$	1.73	1	0.58
Readout Electronics	E 2.6		1	1.00	N	1 or k	1.00	1	1.00
Response time	E 2.7		0	0.00	R	$\sqrt{3}$	1.73	1	0.00
Integration time	E 2.8		1.4	1.40	R	$\sqrt{3}$	1.73	1	0.81
RF Ambient Conditions	E 6.1		3	3.00	R	$\sqrt{3}$	1.73	1	1.73
Probe Positioner Mechanical Tolerance	E 6.2		0.6	0.60	R	$\sqrt{3}$	1.73	1	0.35
Probe Position wrt. Phantom Shell	E 6.3		3	3.00	R	$\sqrt{3}$	1.73	1	1.73
SAR Evaluation Algorithms	E 5		8	8.00	R	$\sqrt{3}$	1.73	1	4.62
<b>Test Sample Related</b>									
Test Sample Positioning	E 4.2		2	2.00	N	1	1.00	1	2.00
Device Holder Uncertainty	E 4.1		2	2.00	N	1	1.00	1	2.00
Output Power Variation	E 6.6.2		5	5.00	R	$\sqrt{3}$	1.73	1	2.89
<b>Phantom and tissue Parameters</b>									
Phantom Uncertainty (shape and thickness)	E 3.1		4	4.00	R	$\sqrt{3}$	1.73	1	2.31
Liquid conductivity (Deviation from target)	E 3.2		5	5.00	R	$\sqrt{3}$	1.73	0.64	1.85
Liquid conductivity (Meas. Uncertainty)	E 3.3		1.1	1.10	N	1	1.00	0.64	0.70
Liquid permittivity (Deviation from target)	E 3.2		5	5.00	R	$\sqrt{3}$	1.73	0.6	1.73
Liquid permittivity (Meas. Uncertainty)	E 3.3		1.1	1.10	N	1	1.00	0.6	0.66
<b>Combined standard uncertainty</b>	<b>RSS</b>								<b>10.5</b>

### **3.6 Measurement Traceability**

All measurements described in this report are traceable to Chinese National Laboratory Accreditation (CNLA) standards or appropriate national standards.



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#### **4.0 WARNING LABEL INFORMATION - USA**

See user manual.

## 5.0 REFERENCES

- [1] ANSI, *ANSI/IEEE C95.1-1999: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300 GHz*, The Institute of electrical and Electronics Engineers, Inc., New York, NY 10017, 1999
- [2] Federal Communications Commission, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", OET Bulletin 65, FCC, Washington, D.C. 20554, 1997
- [3] IEEE Standards Coordinating Committee 34, "DRAFT Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Measurement Techniques", IEEE Std 1528-200X, Draft CD 1.2 – April 21, 2003



**6.0 DOCUMENT HISTORY**

<b>Revision/ Job Number</b>	<b>Writer Initials</b>	<b>Date</b>	<b>Change</b>
N/A	J.C.	Oct. 20, 2003	Original document

## **APPENDIX A - SAR Evaluation Data**

**Power drift** is the measurement of power drift of the device over one complete SAR scan.

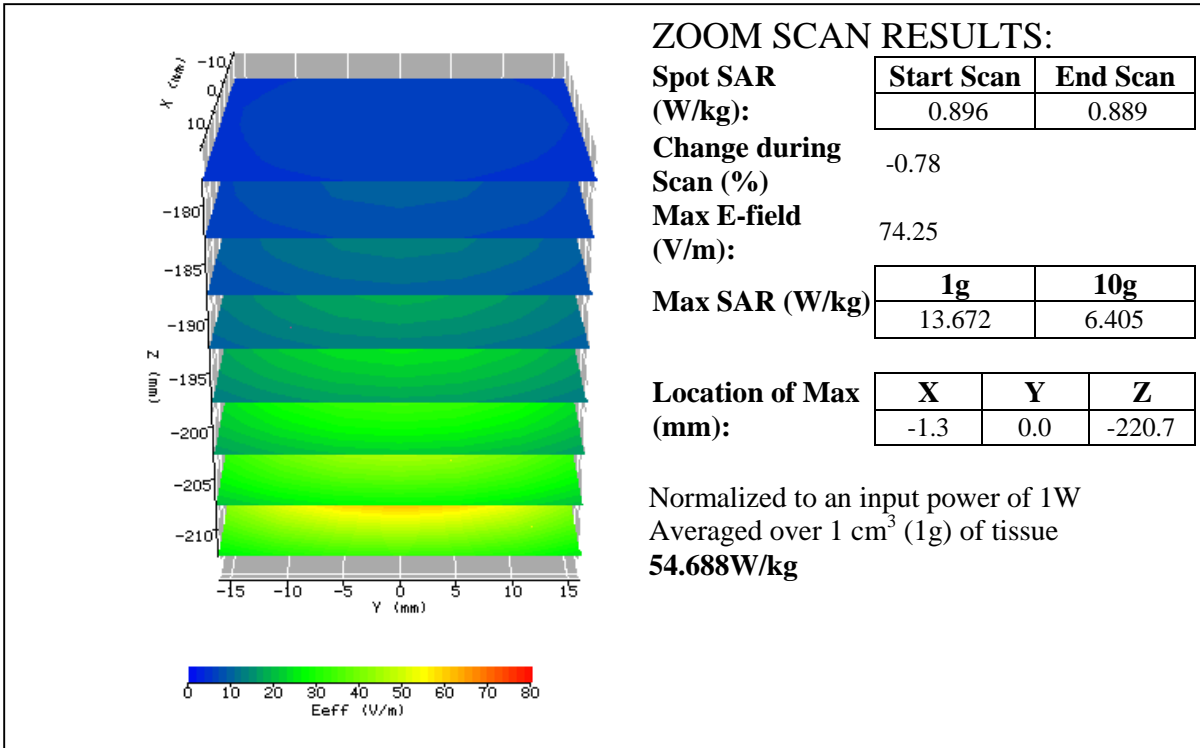
To assess the drift of the power of the device under test, a SAR measurement was made in the middle of the zoom scan volume at the start of the scan and a measurement at this point was then also made after the measurement scan. The difference between the two measurements should be less than 5%.

Plot #1

<b>Date:</b> 2003/10/15	<b>Position:</b> Bottom
<b>Filename:</b> 2450val10-15.txt	<b>Phantom:</b> Box1.csv
<b>Device Tested:</b> SARA2 system	<b>Head Rotation:</b> 0
<b>Antenna:</b> 2450dipole	<b>Test Frequency:</b> 2450MHz
<b>Shape File:</b> none.csv	<b>Power Level:</b> 24dBm /CW

<b>Probe:</b> 0136				
<b>Cal File:</b> SN0136_2450_CW_HEAD				
<b>Cal Factors:</b>	<b>X</b>	<b>Y</b>	<b>Z</b>	
	Air	490	405	405
	DCP	20	20	20
	Lin	.453	.453	.453
<b>Amp Gain:</b>	2			
<b>Averaging:</b>	1			
<b>Batteries Replaced:</b>	-			

<b>Liquid:</b> 15.5cm	
<b>Type:</b> 2450MHz Head	
<b>Conductivity:</b> 1.80379	
<b>Relative Permittivity:</b> 38.1223	
<b>Liquid Temp (deg C):</b> 23.3	
<b>Ambient Temp (deg C):</b> 24	
<b>Ambient RH (%):</b> 50	
<b>Density (kg/m3):</b> 1000	
<b>Software Version:</b> 0.421N	

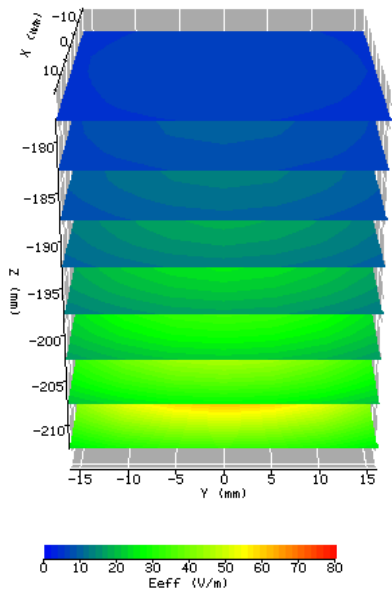


Plot #2

<b>Date / Time:</b>	2003/10/16	<b>Position:</b>	bottom of box phantom
<b>Filename:</b>	2450 performance check.txt	<b>Phantom:</b>	HeadBox1.csv
<b>Device Tested:</b>	2450 performance check	<b>Head Rotation:</b>	0
<b>Antenna:</b>	2450 dipole antenna	<b>Test Frequency:</b>	2450MHz
<b>Shape File:</b>	none.csv	<b>Power Level:</b>	24dBm

<b>Probe:</b>	0136			
<b>Cal File:</b>	SN0136_2450_CW_HEAD			
<b>Cal Factors:</b>		<b>X</b>	<b>Y</b>	<b>Z</b>
	<b>Air</b>	490	405	405
	<b>DCP</b>	20	20	20
	<b>Lin</b>	.453	.453	.453
<b>Amp Gain:</b>	2			
<b>Averaging:</b>	1			
<b>Batteries Replaced:</b>	-			

<b>Liquid:</b>	15.5cm
<b>Type:</b>	2450MHz Head
<b>Conductivity:</b>	1.80379
<b>Relative Permittivity:</b>	38.1223
<b>Liquid Temp (deg C):</b>	23.3
<b>Ambient Temp (deg C):</b>	24
<b>Ambient RH (%):</b>	50
<b>Density (kg/m3):</b>	1000
<b>Software Version:</b>	0.421N
Crest Factor=1	



### ZOOM SCAN RESULTS:

<b>Spot SAR (W/kg):</b>	<b>Start Scan</b>	<b>End Scan</b>
	0.895	0.889
<b>Change during Scan (%):</b>	-0.79	
<b>Max E-field (V/m):</b>	75.25	
<b>Max SAR (W/kg)</b>	<b>1g</b>	<b>10g</b>
	13.662	6.415
<b>Location of Max (mm):</b>	<b>X</b>	<b>Y</b>
	-1.3	0.0
	<b>Z</b>	-220.5

Normalized to an input power of 1W  
Averaged over 1 cm<sup>3</sup> (1g) of tissue  
**54.648 W/kg**

Plot #3 (1/2)

<b>Date / Time:</b>	2003/10/17	<b>Position:</b>	per-rear0
<b>Filename:</b>	2437per0-rear.txt	<b>Phantom:</b>	HeadBox1.csv
<b>Device Tested:</b>	ZI3	<b>Head Rotation:</b>	0
<b>Antenna:</b>	PCB Printed	<b>Test Frequency:</b>	2437MHz
<b>Shape File:</b>	ZI3per-rear.csv	<b>Power Level:</b>	19.86 dBm

<b>Probe:</b>	0136																
<b>Cal File:</b>	SN0136_2450_CW_BODY																
<b>Cal Factors:</b>	<table border="1"> <thead> <tr> <th></th> <th>X</th> <th>Y</th> <th>Z</th> </tr> </thead> <tbody> <tr> <td><b>Air</b></td> <td>490</td> <td>405</td> <td>405</td> </tr> <tr> <td><b>DCP</b></td> <td>20</td> <td>20</td> <td>20</td> </tr> <tr> <td><b>Lin</b></td> <td>.486</td> <td>.486</td> <td>.486</td> </tr> </tbody> </table>		X	Y	Z	<b>Air</b>	490	405	405	<b>DCP</b>	20	20	20	<b>Lin</b>	.486	.486	.486
		X	Y	Z													
	<b>Air</b>	490	405	405													
	<b>DCP</b>	20	20	20													
<b>Lin</b>	.486	.486	.486														
<b>Amp Gain:</b>	2																
<b>Averaging:</b>	1																
<b>Batteries Replaced:</b>	1																

<b>Liquid:</b>	15.5cm
<b>Type:</b>	2450MHz Body
<b>Conductivity:</b>	1.97944
<b>Relative Permittivity:</b>	50.691438
<b>Liquid Temp (deg C):</b>	22.1
<b>Ambient Temp (deg C):</b>	21
<b>Ambient RH (%):</b>	50
<b>Density (kg/m3):</b>	1000
<b>Software Version:</b>	0.421N
Crest Factor=1	

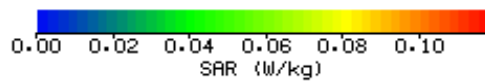
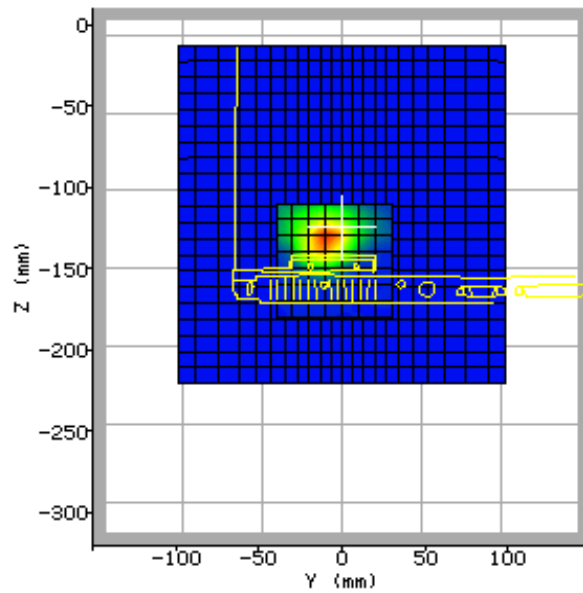
Plot #3 (2/2)

ZOOM SCAN RESULTS:

<b>Spot SAR (W/kg):</b>	<b>Start Scan</b>	<b>End Scan</b>		
	0.029	0.028		
<b>Change during Scan (%)</b>	-4.91			
<b>Max E-field (V/m):</b>	12.62			
<b>Location of Max (mm):</b>	<b>X</b>	<b>Y</b>	<b>Z</b>	
	75.1	-25.0	-133.1	

AREA SCAN:

	Min	Max	Steps
<b>Scan Extent:</b>			
<b>Y</b>	-40.0	30.0	7.0
<b>Z</b>	-180.0	-110.0	7.0



Plot #4 (1/2)

<b>Date / Time:</b>	2003/10/17	<b>Position:</b>	per-rear15
<b>Filename:</b>	2437per15-rear.txt	<b>Phantom:</b>	HeadBox1.csv
<b>Device Tested:</b>	ZI3	<b>Head Rotation:</b>	0
<b>Antenna:</b>	PCB Printed	<b>Test Frequency:</b>	2437MHz
<b>Shape File:</b>	ZI3per-rear.csv	<b>Power Level:</b>	19.86 dBm

<b>Probe:</b>	0136																
<b>Cal File:</b>	SN0136_2450_CW_BODY																
<b>Cal Factors:</b>	<table border="1"> <thead> <tr> <th></th> <th>X</th> <th>Y</th> <th>Z</th> </tr> </thead> <tbody> <tr> <td><b>Air</b></td> <td>490</td> <td>405</td> <td>405</td> </tr> <tr> <td><b>DCP</b></td> <td>20</td> <td>20</td> <td>20</td> </tr> <tr> <td><b>Lin</b></td> <td>.486</td> <td>.486</td> <td>.486</td> </tr> </tbody> </table>		X	Y	Z	<b>Air</b>	490	405	405	<b>DCP</b>	20	20	20	<b>Lin</b>	.486	.486	.486
		X	Y	Z													
	<b>Air</b>	490	405	405													
	<b>DCP</b>	20	20	20													
<b>Lin</b>	.486	.486	.486														
<b>Amp Gain:</b>	2																
<b>Averaging:</b>	1																
<b>Batteries Replaced:</b>	1																

<b>Liquid:</b>	15.5cm
<b>Type:</b>	2450MHz Body
<b>Conductivity:</b>	1.97944
<b>Relative Permittivity:</b>	50.691438
<b>Liquid Temp (deg C):</b>	22.1
<b>Ambient Temp (deg C):</b>	21
<b>Ambient RH (%):</b>	50
<b>Density (kg/m3):</b>	1000
<b>Software Version:</b>	0.421N
Crest Factor=1	

Plot #4 (2/2)

**ZOOM SCAN RESULTS:**

<b>Spot SAR (W/kg):</b>	<b>Start Scan</b>	<b>End Scan</b>
	0.009	0.010

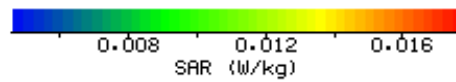
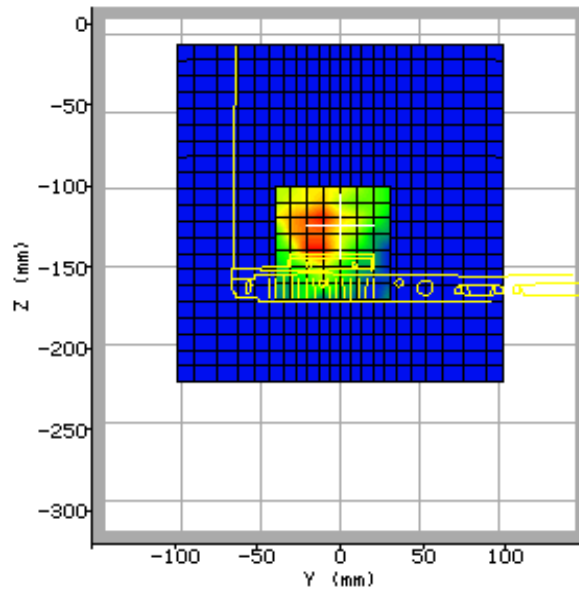
**Change during Scan (%)** 3.49

**Max E-field (V/m):** 3.84

<b>Location of Max (mm):</b>	<b>X</b>	<b>Y</b>	<b>Z</b>
	75.1	-30.0	-131.7

**AREA SCAN:**

	<b>Min</b>	<b>Max</b>	<b>Steps</b>
<b>Scan Extent:</b>			
<b>Y</b>	-40.0	30.0	7.0
<b>Z</b>	-170.0	-100.0	7.0





Plot #5 (1/2)

<b>Date / Time:</b>	2003/10/17	<b>Position:</b>	per-left0
<b>Filename:</b>	2437per0-lefta.txt	<b>Phantom:</b>	HeadBox1.csv
<b>Device Tested:</b>	ZI3	<b>Head Rotation:</b>	0
<b>Antenna:</b>	PCB Printed	<b>Test Frequency:</b>	2437MHz
<b>Shape File:</b>	ZI3per-left.csv	<b>Power Level:</b>	19.86dBm

<b>Probe:</b>	0136																
<b>Cal File:</b>	SN0136_2450_CW_BODY																
<b>Cal Factors:</b>	<table border="1"> <thead> <tr> <th></th> <th>X</th> <th>Y</th> <th>Z</th> </tr> </thead> <tbody> <tr> <td><b>Air</b></td> <td>490</td> <td>405</td> <td>405</td> </tr> <tr> <td><b>DCP</b></td> <td>20</td> <td>20</td> <td>20</td> </tr> <tr> <td><b>Lin</b></td> <td>.486</td> <td>.486</td> <td>.486</td> </tr> </tbody> </table>		X	Y	Z	<b>Air</b>	490	405	405	<b>DCP</b>	20	20	20	<b>Lin</b>	.486	.486	.486
		X	Y	Z													
	<b>Air</b>	490	405	405													
	<b>DCP</b>	20	20	20													
<b>Lin</b>	.486	.486	.486														
<b>Amp Gain:</b>	2																
<b>Averaging:</b>	1																
<b>Batteries Replaced:</b>	1																

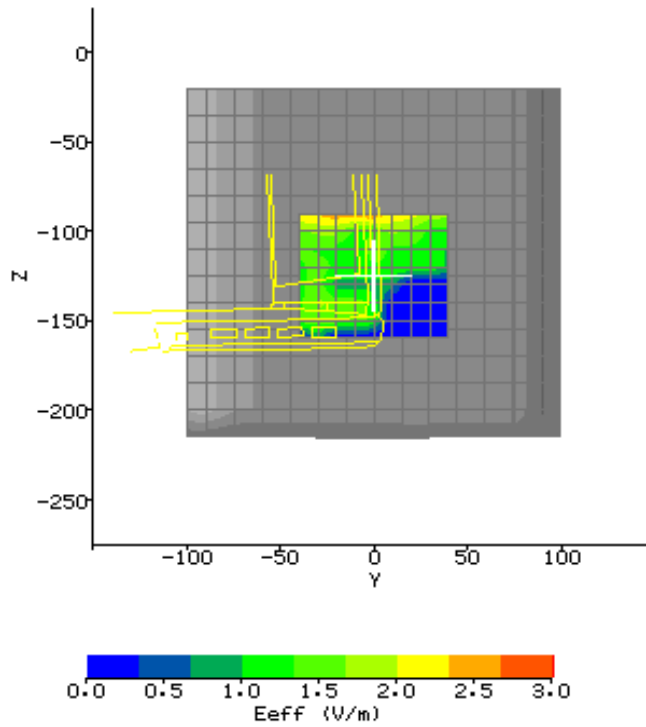
<b>Liquid:</b>	15.5cm
<b>Type:</b>	2450MHz Body
<b>Conductivity:</b>	1.97944
<b>Relative Permittivity:</b>	50.691438
<b>Liquid Temp (deg C):</b>	22.1
<b>Ambient Temp (deg C):</b>	21
<b>Ambient RH (%):</b>	50
<b>Density (kg/m3):</b>	1000
<b>Software Version:</b>	0.421N
Crest Factor=1	

Plot #5 (2/2)

### AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-40.0	40.0	8.0
Z	-160.0	-90.0	7.0



Plot #6 (1/2)

<b>Date / Time:</b>	2003/10/17	<b>Position:</b>	per-left15
<b>Filename:</b>	2437per15-lefta.txt	<b>Phantom:</b>	HeadBox1.csv
<b>Device Tested:</b>	ZI3	<b>Head Rotation:</b>	0
<b>Antenna:</b>	PCB Printed	<b>Test Frequency:</b>	2437MHz
<b>Shape File:</b>	ZI3per-left.csv	<b>Power Level:</b>	19.86dBm

<b>Probe:</b>	0136			
<b>Cal File:</b>	SN0136_2450_CW_BODY			
<b>Cal Factors:</b>		<b>X</b>	<b>Y</b>	<b>Z</b>
	<b>Air</b>	490	405	405
	<b>DCP</b>	20	20	20
	<b>Lin</b>	.486	.486	.486
<b>Amp Gain:</b>	2			
<b>Averaging:</b>	1			
<b>Batteries Replaced:</b>	1			

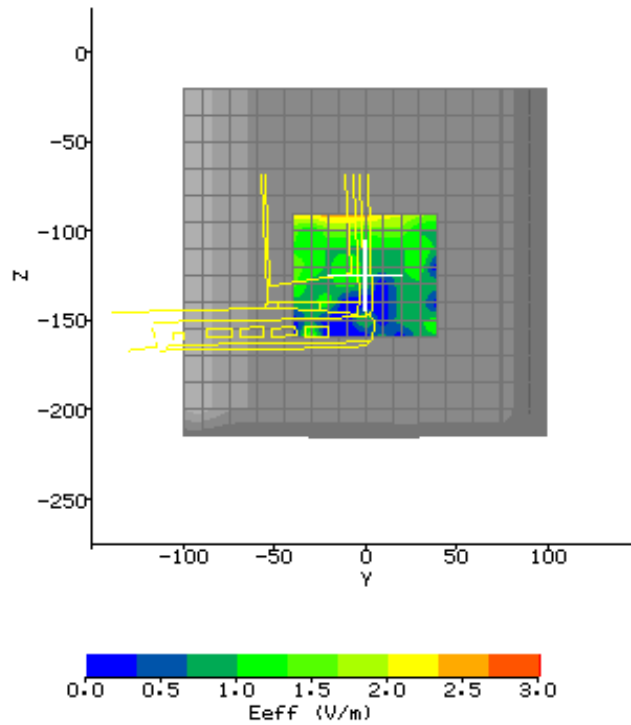
<b>Liquid:</b>	15.5cm
<b>Type:</b>	2450MHz Body
<b>Conductivity:</b>	1.97944
<b>Relative Permittivity:</b>	50.691438
<b>Liquid Temp (deg C):</b>	22.1
<b>Ambient Temp (deg C):</b>	21
<b>Ambient RH (%):</b>	50
<b>Density (kg/m3):</b>	1000
<b>Software Version:</b>	0.421N
Crest Factor=1	

Plot #6 (2/2)

### AREA SCAN:

**Scan Extent:**

	Min	Max	Steps
<b>Y</b>	-40.0	40.0	8.0
<b>Z</b>	-160.0	-90.0	7.0



Plot #7 (1/2)

<b>Date / Time:</b>	2003/10/17	<b>Position:</b>	bottom0
<b>Filename:</b>	2437bot0a.txt	<b>Phantom:</b>	HeadBox1.csv
<b>Device Tested:</b>	ZI3	<b>Head Rotation:</b>	0
<b>Antenna:</b>	PCB Printed	<b>Test Frequency:</b>	2437MHz
<b>Shape File:</b>	ZI3bottom.csv	<b>Power Level:</b>	19.86dBm

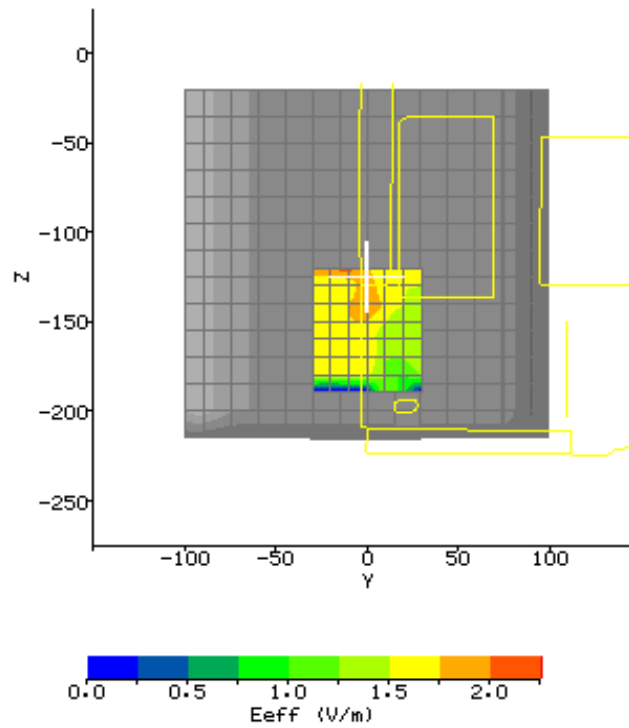
<b>Probe:</b>	0136	<b>Liquid:</b>	15.5cm	
<b>Cal File:</b>	SN0136_2450_CW_BODY	<b>Type:</b>	2450MHz Body	
<b>Cal Factors:</b>		<b>Conductivity:</b>	1.97944	
	<b>Air</b>	490	405	405
	<b>DCP</b>	20	20	20
	<b>Lin</b>	.486	.486	.486
<b>Amp Gain:</b>	2	<b>Relative Permittivity:</b>	50.691438	
<b>Averaging:</b>	1	<b>Liquid Temp (deg C):</b>	22.1	
<b>Batteries Replaced:</b>	1	<b>Ambient Temp (deg C):</b>	21	
		<b>Ambient RH (%):</b>	50	
		<b>Density (kg/m3):</b>	1000	
		<b>Software Version:</b>	0.421N	
		Crest Factor=1		

Plot #7 (2/2)

### AREA SCAN:

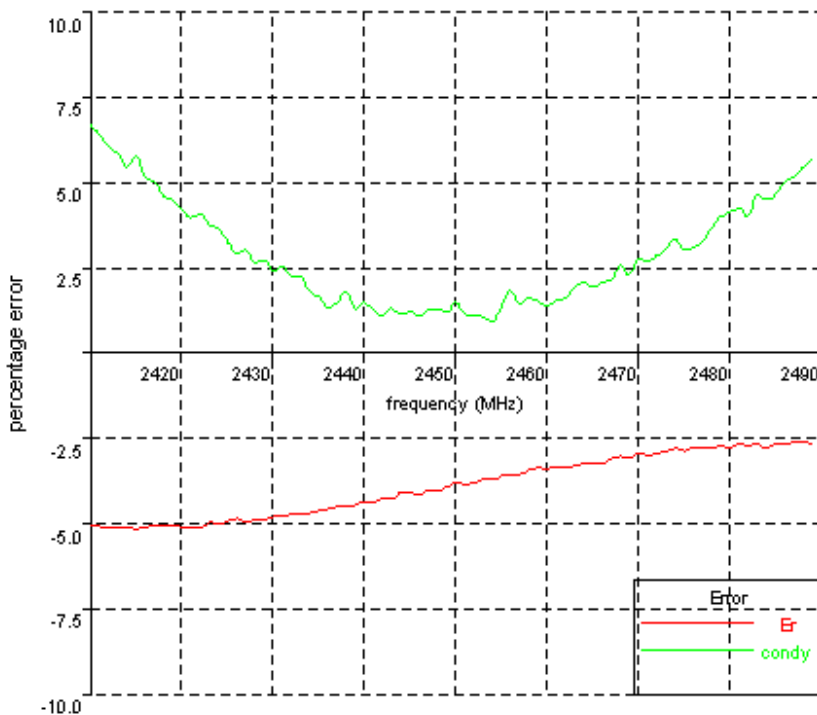
**Scan Extent:**

	Min	Max	Steps
<b>Y</b>	-30.0	30.0	6.0
<b>Z</b>	-190.0	-120.0	7.0



**APPENDIX B – 2450MHz body liquid Calibration Data**

Date: 15 Oct. 2003	Temperature: 22.4°C	Type: 2450MHz/body (FCC)	Tested by: Kevin
2410, 50.0943039867, -2.0397879056		<b>2450, 50.6914384342, -1.9794437433</b>	
2411, 50.0738793804, -2.0354621302		2451, 50.6800242908, -1.9738745564	
2412, 50.0549470735, -2.029494356		2452, 50.6894169163, -1.9744473102	
2413, 50.047567855, -2.0267501134		2453, 50.7415863085, -1.9749527149	
2414, 50.0461570517, -2.0199222901		2454, 50.7395641333, -1.9738164615	
2415, 50.0340754998, -2.0273257983		2455, 50.801718296, -1.9841210889	
2416, 50.0571193099, -2.0160648618		2456, 50.8196572476, -1.9947031142	
2417, 50.0703932255, -2.0153049641		2457, 50.821904787, -1.9884903053	
2418, 50.063692915, -2.0078563704		2458, 50.893392466, -1.9931353974	
2419, 50.0762384409, -2.0063108215		2459, 50.9176577531, -1.9931923882	
2420, 50.0553833139, -2.0024162655		2460, 50.9086668334, -1.9911949867	
2421, 50.0570861626, -1.9989498341		2461, 50.9254307597, -1.9963053702	
2422, 50.0362390119, -2.0019776637		2462, 50.9203978235, -1.9989423537	
2423, 50.1250373997, -1.996974849		2463, 50.9519383281, -2.0056129087	
2424, 50.0874196415, -1.9958747876		2464, 50.9811866596, -2.0106322582	
2425, 50.1383743686, -1.9894221584		2465, 50.9948909474, -2.0094445956	
2426, 50.1737953527, -1.9832033431		2466, 50.9841518249, -2.013620505	
2427, 50.1154790466, -1.9864897961		2467, 51.0511209709, -2.0165985142	
2428, 50.1672771754, -1.9805251488		2468, 51.0826851884, -2.0262043557	
2429, 50.1532634184, -1.9825777513		2469, 51.0736651285, -2.0220842157	
2430, 50.1961237835, -1.9778366073		2470, 51.1296839521, -2.0329025499	
2431, 50.2059634688, -1.9811128232		2471, 51.100335394, -2.033025821	
2432, 50.2326352501, -1.976357224		2472, 51.1271841299, -2.0379089051	
2433, 50.2457359334, -1.977016129		2473, 51.1547928094, -2.042833168	
2434, 50.2526301436, -1.9701116744		2474, 51.1992555544, -2.0506803727	
2435, 50.2862010557, -1.9678164643		2475, 51.1605332421, -2.0455768802	
2436, 50.3197943945, -1.9623835486		2476, 51.2166473447, -2.0482344264	
2437, 50.3405233655, -1.9658837253		2477, 51.2023404561, -2.0536654486	
2438, 50.3488987554, -1.9737870193		2478, 51.1915576463, -2.0634354534	
2439, 50.3711085159, -1.9646324492		2479, 51.2325590673, -2.0707009959	
2440, 50.4246412181, -1.9693904267		2480, 51.2088752505, -2.0748986128	
2441, 50.4080260036, -1.9664568351		2481, 51.2650423758, -2.0786853667	
2442, 50.4752194418, -1.9641635698		2482, 51.2230316258, -2.0753731823	
2443, 50.4722512178, -1.9688237355		2483, 51.2706083511, -2.0896624563	
2444, 50.5504283011, -1.9666128108		2484, 51.1888759123, -2.0882559374	
2445, 50.5467186619, -1.9691361342		2485, 51.2540714138, -2.0927247688	
2446, 50.5206019573, -1.9677475037		2486, 51.2575338819, -2.1010692675	
2447, 50.5916658144, -1.9719324357		2487, 51.2736651072, -2.106295633	
2448, 50.5839124687, -1.9733677635		2488, 51.2852114722, -2.1128009998	
2449, 50.630157372, -1.9725560789		2489, 51.2600085733, -2.1185981923	
		2490, 51.2708043347, -2.1155623925	



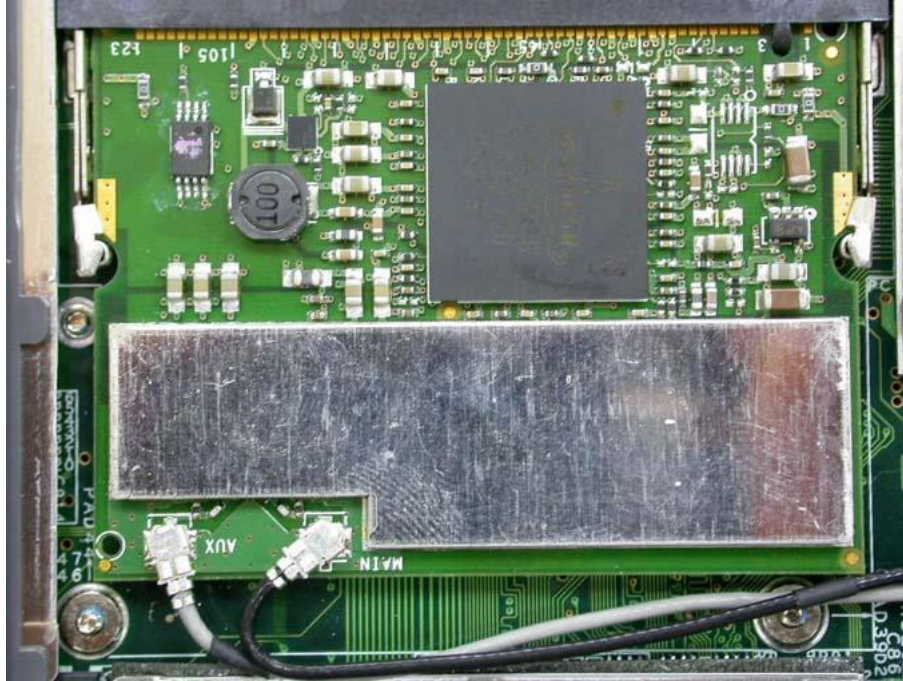


**Photographs**

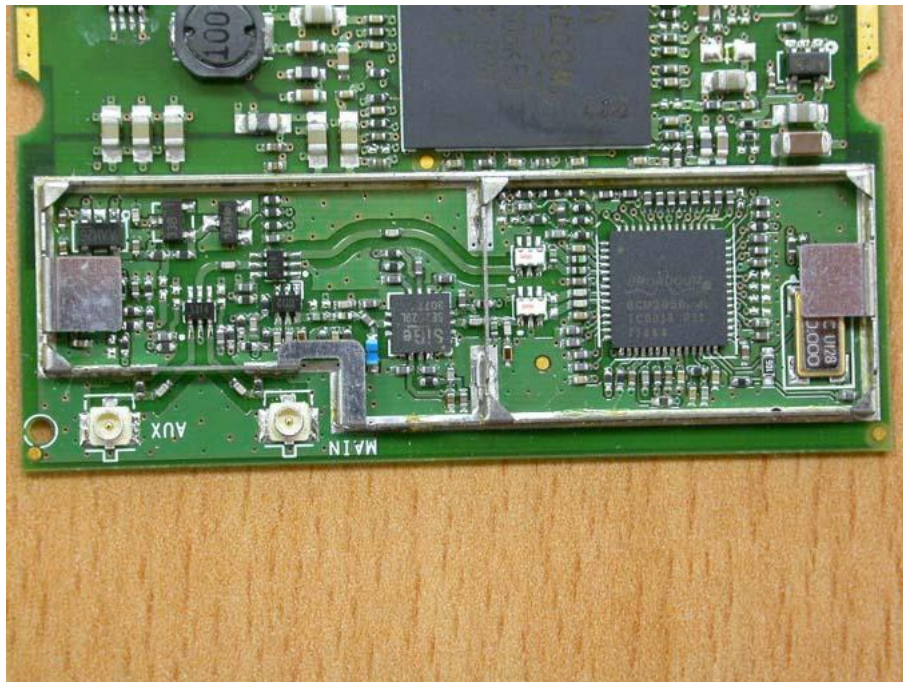
External photo



Internal photo 1



Internal photo 2



Internal photo 3



Antenna photo





FCC ID. : HFSZI3RM8

Report No.: EME-031135  
Page 46 of 66

**APPENDIX C - E-Field Probe Certificate and Calibration Data**  
Validation dipole certificate and performance measurements



**Indexsar Limited**  
Oakfield House  
Cudworth Lane  
Newdigate  
Surrey RH5 5DR  
Tel: +44 (0) 1306 631 233  
Fax: +44 (0) 1306 631 834  
e-mail: [enquiries@indexsar.com](mailto:enquiries@indexsar.com)  
**Calibration Certificate**  
**Dosimetric E-field Probe**

Type:	<b>IXP-050</b>
Manufacturer:	<b>IndexSAR, UK</b>
Serial Number:	<b>0136</b>
Place of Calibration:	<b>IndexSAR, UK</b>


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:	<b>10<sup>th</sup> September 2003</b>
------------------------------	---------------------------------------

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

Next Calibration Date:	<b>September 2004</b>
------------------------	-----------------------

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.



**IMMERSIBLE SAR PROBE**

**CALIBRATION REPORT**

**Part Number: IXP – 050**

**S/N 0136**

**10<sup>th</sup> September 2003**



**Indexsar Limited  
Oakfield House  
Cudworth Lane  
Newdigate  
Surrey RH5 5DR  
Tel: +44 (0) 1306 631 233  
Fax: +44 (0) 1306 631 834  
e-mail: [enquiries@indexsar.com](mailto:enquiries@indexsar.com)**



## INTRODUCTION

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N 0136) 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:

$$U_{lin} = U_{op} + U_{op}^2 / DCP \quad (1)$$

where  $U_{lin}$  is the linearised signal,  $U_{op}$  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):

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

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 0136.

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):

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

A 3D representation of the spherical isotropy for probe S/N 0136 using these factors is shown in Figure 3.

The rotational isotropy can also be 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 position and is filled with liquid within 10 mm of the open end. The separator 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

$$SAR(z) = \frac{4(P_f - P_b)}{rabd} e^{-2z/d} \quad (4)$$

where the density  $r$  is conventionally assumed to be  $1000 \text{ kg/m}^3$ ,  $ab$  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  $d$ , 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.

$$d = \left[ \text{Re} \left\{ \sqrt{(p/a)^2 + jwm_o(s + jwe_o e_r)} \right\} \right]^{-1} \quad (5)$$

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 0136**

*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  $22 \pm 2.0^{\circ}\text{C}$ . 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

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

Where  $\sigma$  is the conductivity of the simulant liquid employed.

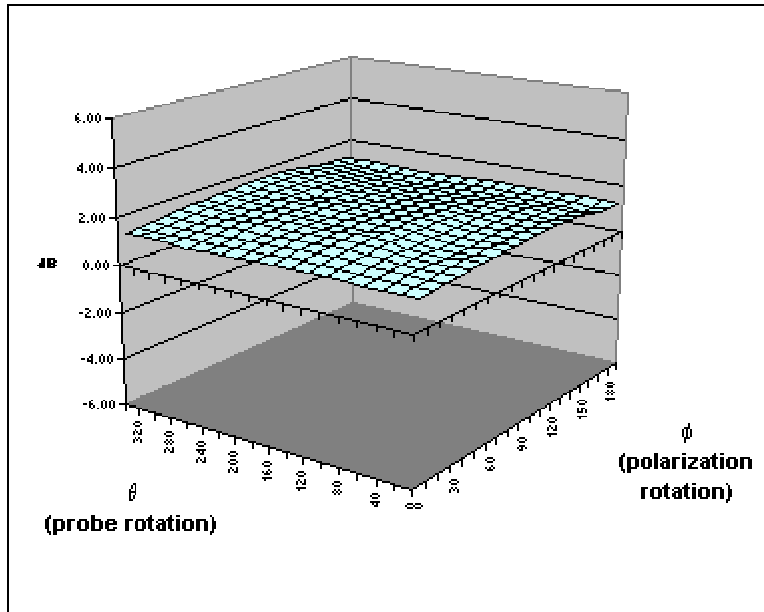
Using the spreadsheet data, the DCP value for linearising each of the individual channels (X, Y and Z) is assessed separately. The corresponding DCP values are listed in the summary page of the calibration factors for each probe.

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 0136

Spherical isotropy measured at 900 MHz 0.24 (+/-) dB



	X	Y	Z	
Air factors	490	405	405	(V*200)
DCPs	20	20	20	(V*200)
DSSS	20	20	20	(V*200)
GSM	8	9.5	11.2	(V*200)
CDMA	20	20	20	(V*200)

f (MHz)	Axial isotropy (+/- dB)		SAR conversion factors (liq/air)		Notes
	BRAIN	BODY	BRAIN	BODY	
450					
835	0.05	0.04	0.257	0.272	1,2,3
900	0.05	0.04	0.261	0.282	1,2,3
1800	0.06	0.06	0.315	0.339	1,2,3
1900	0.06	0.06	0.327	0.351	1,2,3
2450	0.05	0.10	0.453	0.486	1,2,3

### Notes

- 1) Calibrations done at 22C +/- 2C
- 2) Waveguide calibration
- 3) Checked using box-phantom validation test

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

**PROBE SPECIFICATIONS**

Indexsar probe 0136, 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 0136	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 0136	CENELEC [1]	IEEE [2]
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg)	>35	>100	100
N.B. only measured to 35 W/kg			

Linearity of response	S/N 0136	CENELEC [1]	IEEE [2]
Over range 0.01 – 100 W/kg (+/- dB)	0.125	0.50	0.25

Isotropy (measured at 900MHz)	S/N 0136	CENELEC [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB) at 835, 900, 1800, 1900 and 2450 MHz	Max. 0.10 (see summary table)	0.5	0.25
Spherical isotropy covering all orientations to source (+/- dB)	0.24	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.



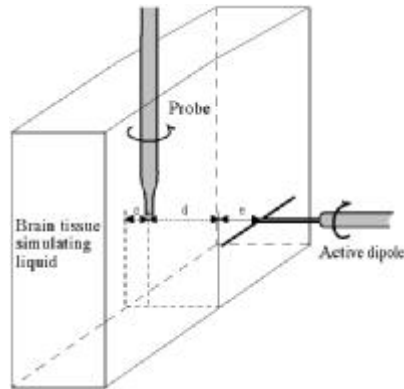
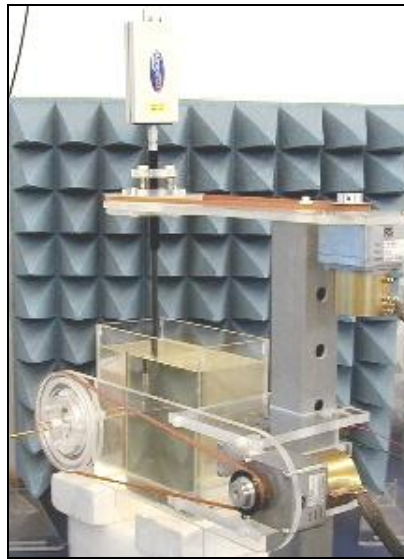


Figure 1. Spherical isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

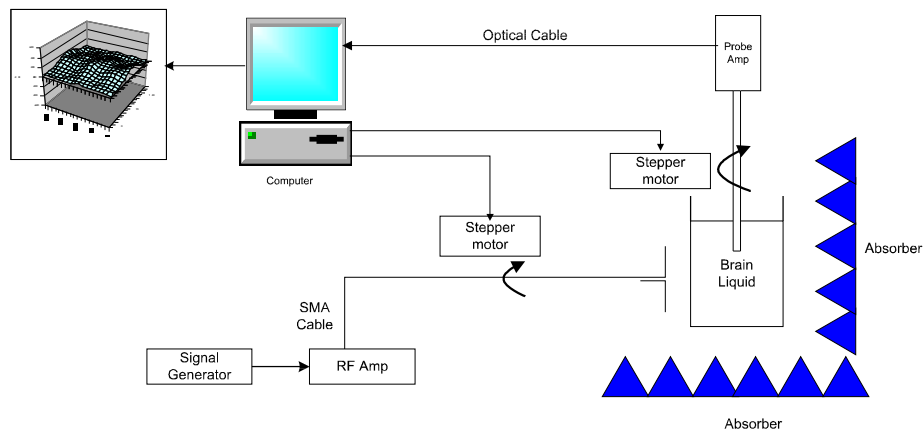


Figure 2. Schematic diagram of the test geometry used for isotropy determination

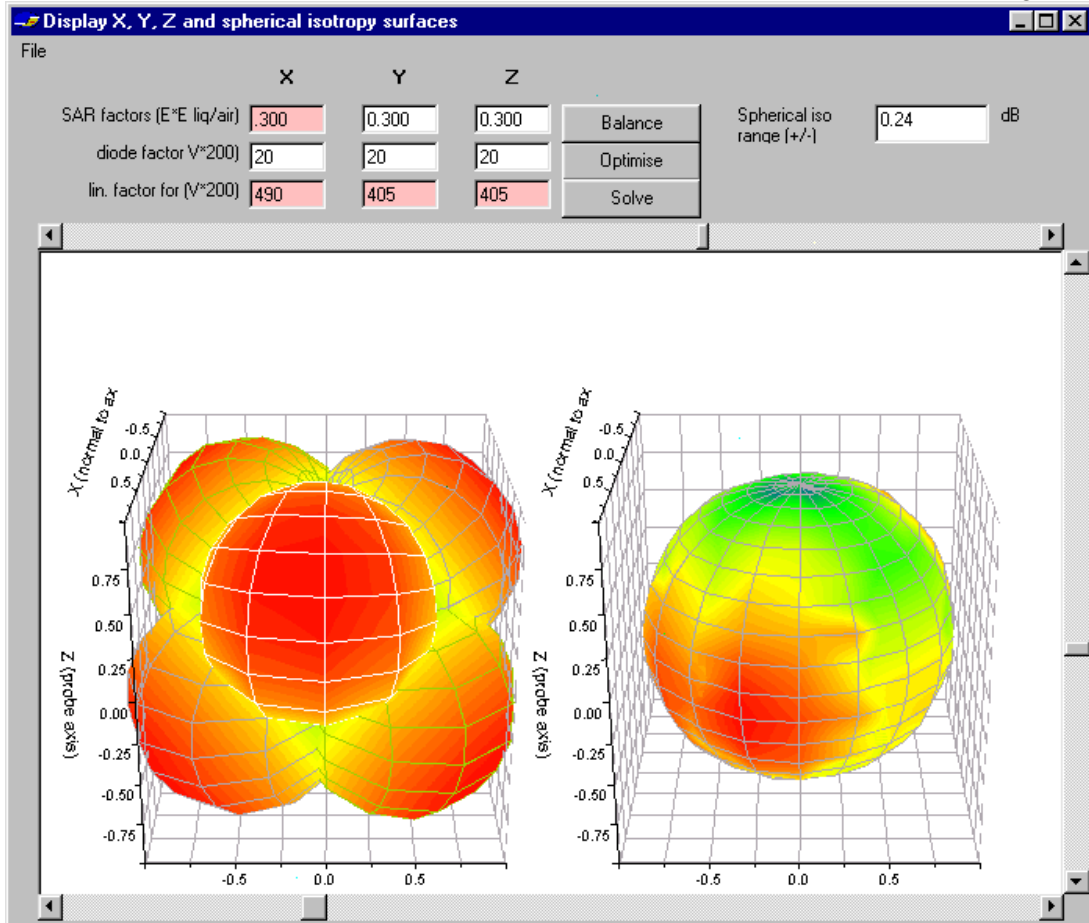


Figure 3. Graphical representation of the probe response to fields applied from each direction. The diagram on the left shows the individual response characteristics of each of the three channels and the diagram on the right shows the resulting probe sensitivity in each direction. The colour range in the figure images the lowest values as blue and the maximum values as red. For the probe S/N 0136, this range is (+/-) 0.24 dB. The probe is more sensitive to fields parallel to the axis and less sensitive to fields normal to the probe axis.

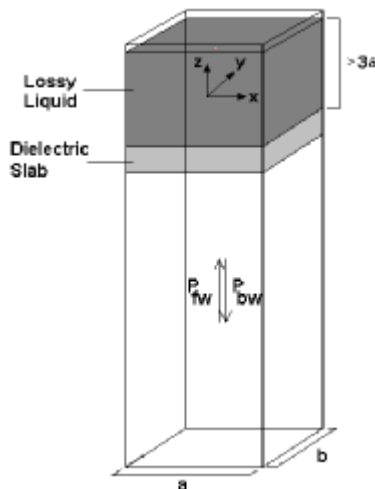


Figure 4. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

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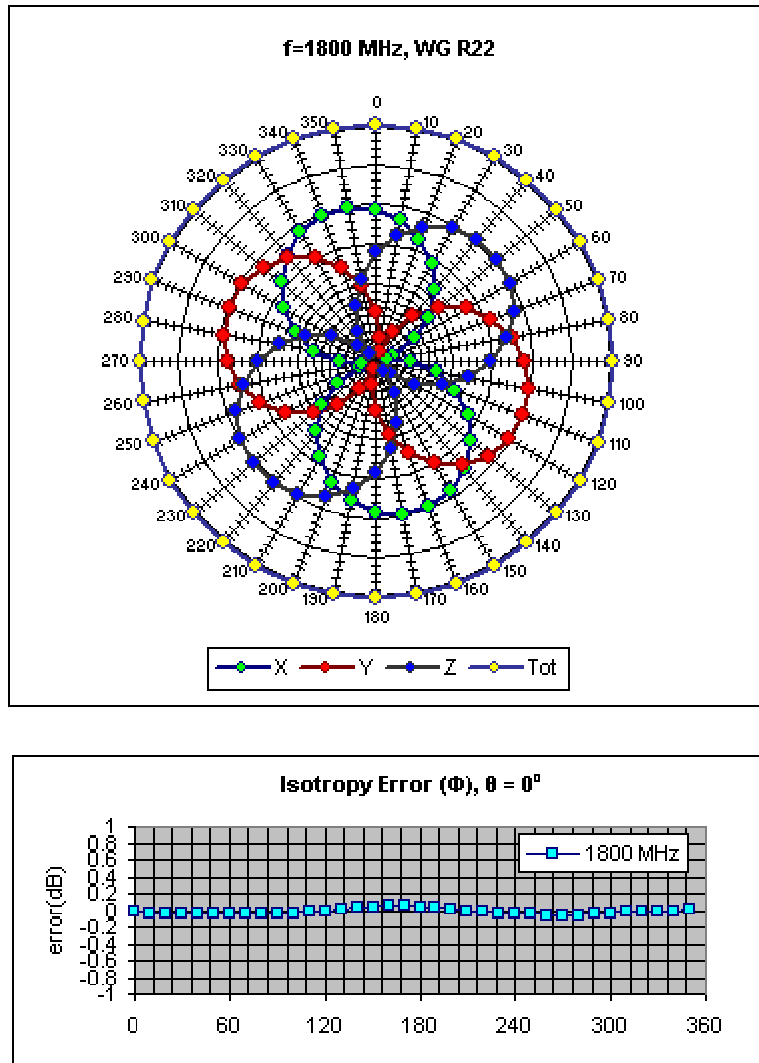


Figure 5. Example of the rotational isotropy of probe S/N 0136 obtained by rotating the probe in a liquid-filled waveguide at 2450 MHz. Similar distributions are obtained at the other test frequencies (1800 and 1900 MHz) both in brain liquids and body fluids (see summary table)

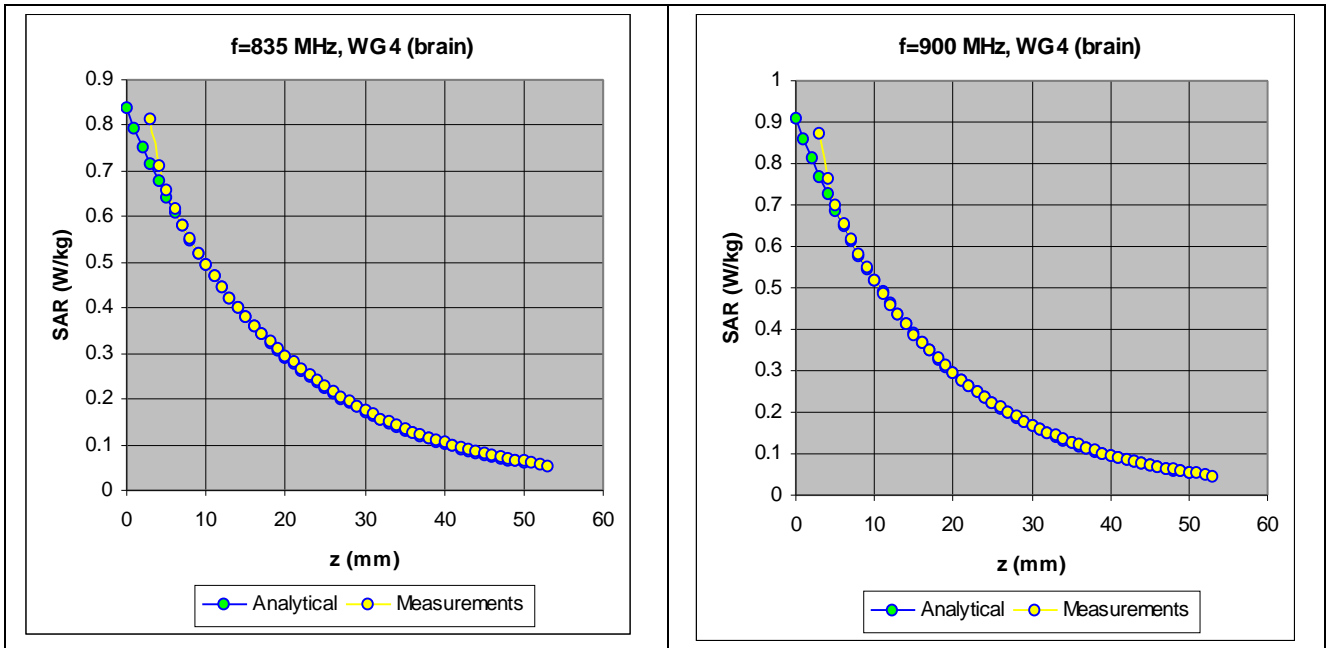


Figure 6. The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

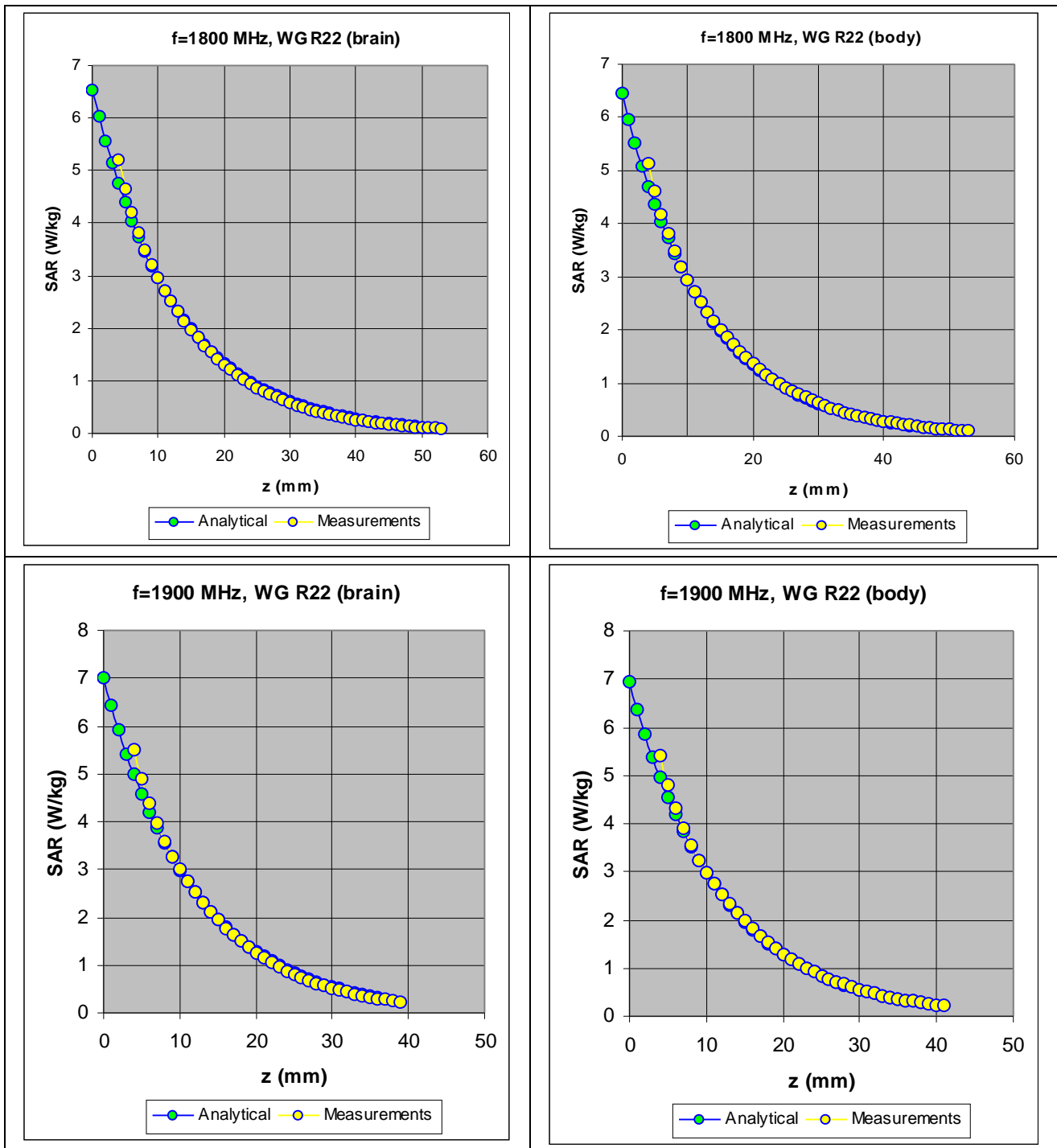


Figure 7. The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

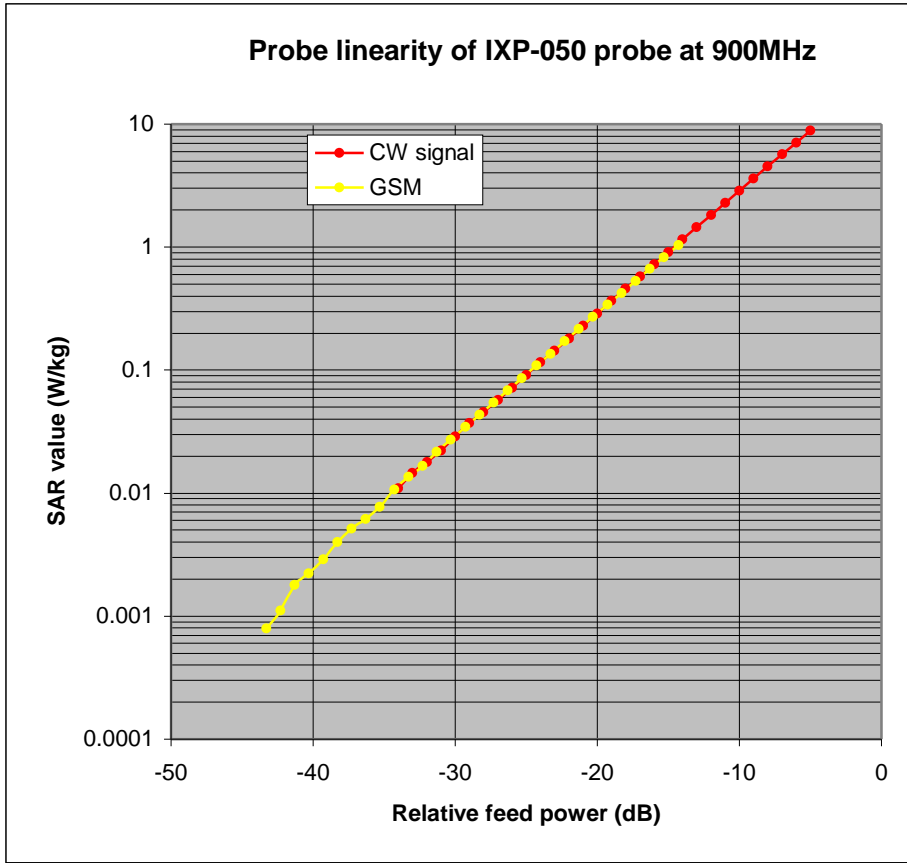


Figure 8. The GSM response of an IXP-050 probe at 900MHz.

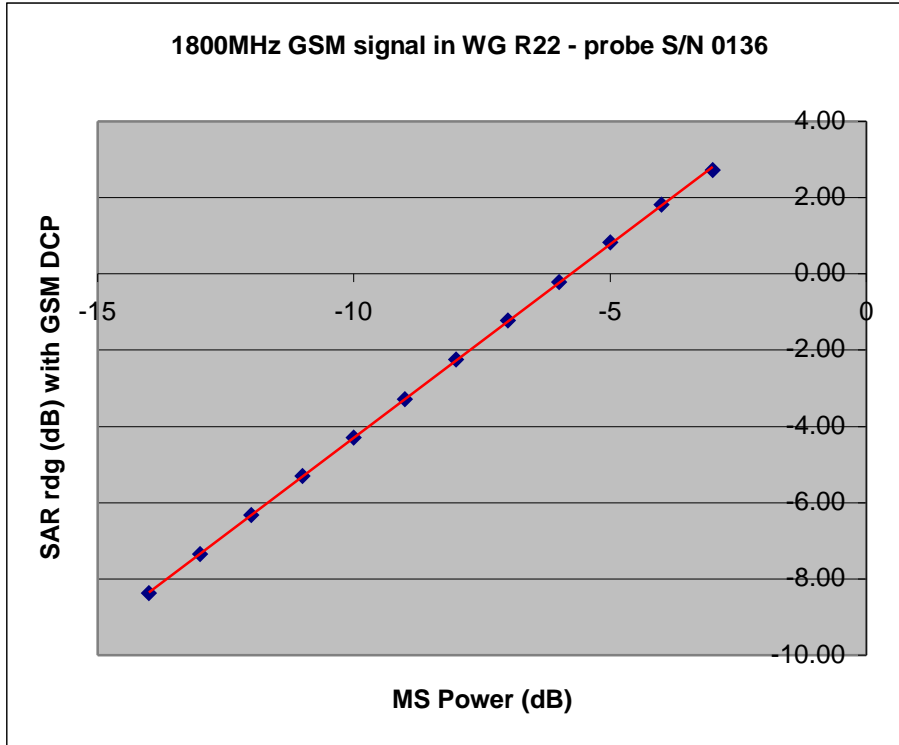


Figure 8a. The actual GSM response of IXP-050 probe S/N 0136 at 1800MHz

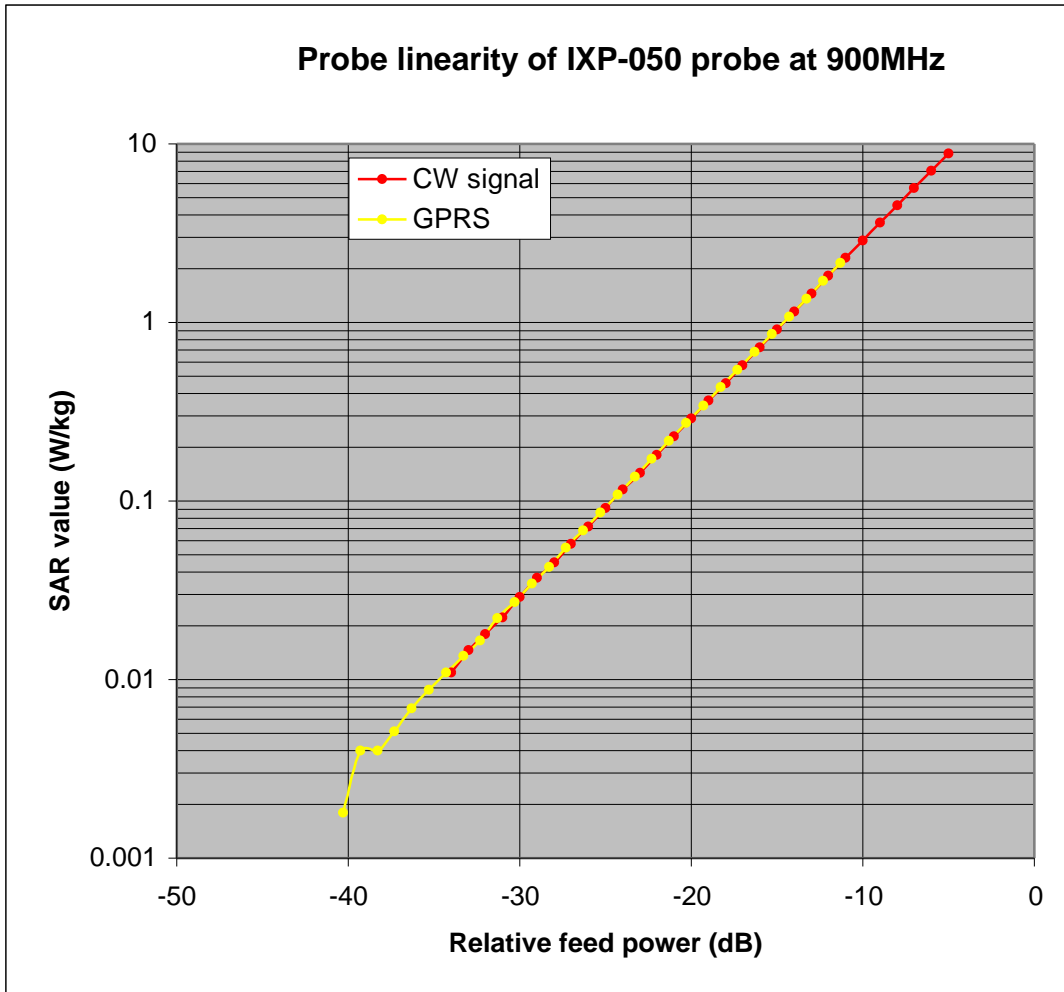
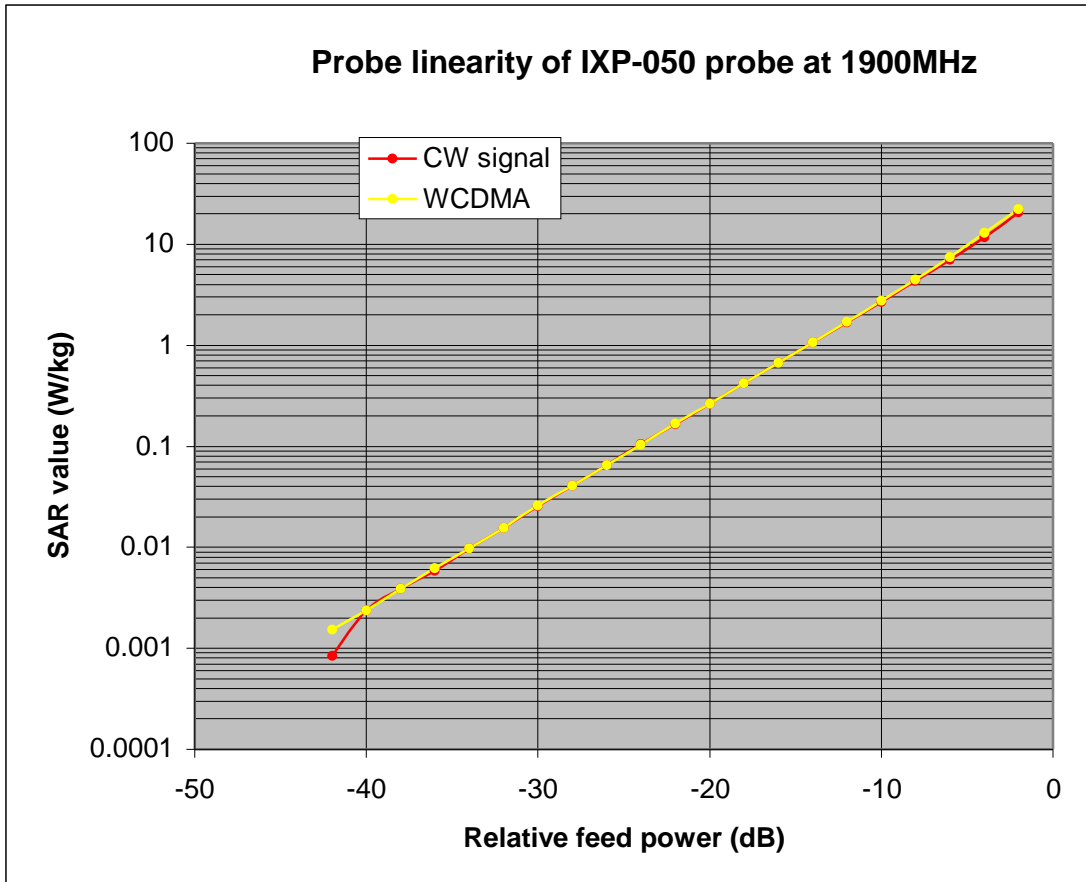


Figure 9. The GPRS response of an IXP-050 probe at 900MHz.





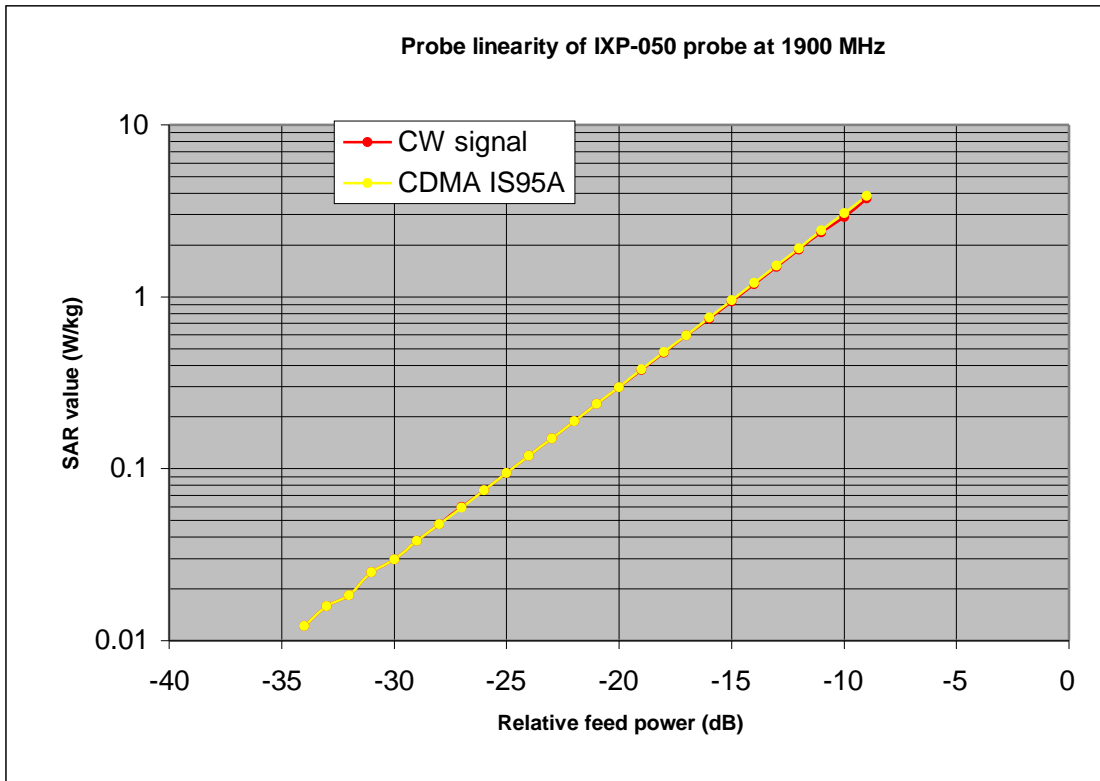


Figure 10. The CDMA response of an IXP-050 probe at 1900MHz.

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

<i>Liquid used</i>	<i>Relative permittivity (measured)</i>	<i>Conductivity (S/m) (measured)</i>
835 MHz BRAIN	43.18	0.935
835 MHz BODY	59.19	0.992
900 MHz BRAIN	42.47	0.998
900 MHz BODY	58.7	1.056
1800 MHz BRAIN	38.72	1.34
1800 MHz BODY	52.5	1.53
1900 MHz BRAIN	38.31	1.43
1900 MHz BODY	52.06	1.64
2450 MHz BRAIN	38.9	1.87
2450 MHz BODY	52.59	2.08