Specific Absorption Rate (SAR) Test Report

for

ZyXEL Communications Corporation

on the

11Mbps Wireless USB Stick

Model Number: ZyAIR B-220

Test Report: EME-030565

Date of Report: June 10, 2003

Date of test: May 15, 2003

Total No of Pages Contained in this Report: 66

0597

ILAC MRA

Accredited for testing to FCC Part 15

Tested by: Kevin Chen	Kevin Chen
Reviewed by: Elton Chen	Elton Chen

Review Date: June 18, 2003

STATEMENT OF COMPLIANCE

The ZyXEL sample device, model # ZyAIR B-220 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 ±27.5%.

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

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

Phantom	Position	SAR_{1g}, mW/g
2mm thick box phantom wall	The EUT inserted into the left side of notebook PC, with EUT bottom touching the phantom.	0.652 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 ZyAIR B-220 has been tested at the request of:

Company: ZyXEL Communications Corporation
No. 6, Innovation Rd II, Science-Based Industrial Park,
Hsin-Chu, Taiwan

1.2 Equipment under test (EUT)

Product Descriptions:

Equipment	11Mbps Wireless USB Stick		
Trade Name	ZyXEL	**Model No:**	ZyAIR B-220
FCC ID	I88B220	**S/N No.**	Not Labeled
Category	Portable	**RF Exposure**	Uncontrolled Environment
Frequency Band	2412 – 2462 MHz	**System**	DSSS

EUT Antenna Description			
Type	Ceramic antenna	**Configuration**	Fixed
Dimensions	30 x 93mm	**Gain**	-3 dBi
Location	Embedded		

Note: The serial models, Lantech WL-555, Lantech 8800-555, B-220, Telefonica B-220 are identical to the basic model, 11Mbps Wireless USB Stick, for marketing purpose only.

Use of Product : **Wireless Data Communication**

Manufacturer: ZyXEL Communications Corporation

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

EUT receive date: May 8, 2003

EUT received condition: Good operating condition prototype.

Test start date: May 15, 2003

Test end date: May 15, 2003

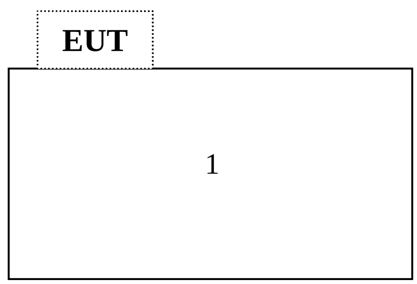
1.3 Test plan reference

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	hp Laptop Computer	XE_3	TW20705468



1.4.3 Test Condition

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

Usage	Operates with a portable computer	**Distance between antenna axis at the joint and the liquid surface:**	Laptop is touching the Phantom in bottom position	
Simulating human Head/ Body/Hand	Body	**EUT Battery**	Device is powered from host computer through battery.	
Conducted output Power	**Channel**	**Frequency MHz**	**Before SAR Test (dBm)**	**After SAR Test (dBm)**
	Low Channel - 1	2412	17.85	17.81
	Mid Channel - 6	2437	17.74	17.73
	High Channel- 11	2462	17.88	17.89

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 an average power meter.

Plug the EUT into notebook, and turn on the power, then run the test program “ZDGonfig” under Windows OS.

The EUT was transmitted continuously during the test.

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:

EXPOSURE (General Population/Uncontrolled Exposure environment)	**SAR (W/kg)**
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

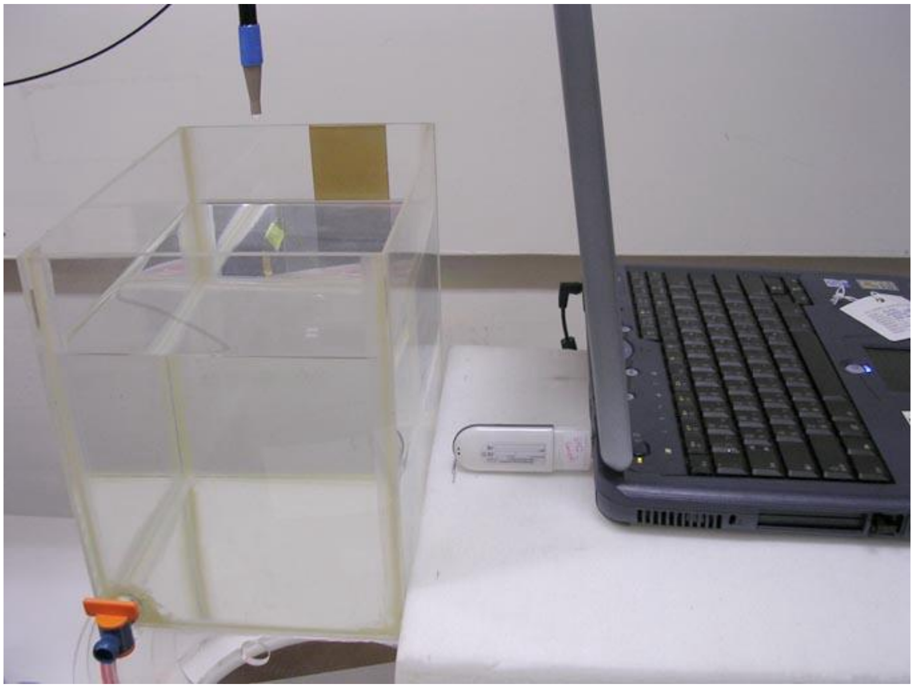
Test System

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 to phantom, 15 mm separation



EUT perpendicular to phantom, 15 mm separation – Zoom In

SAR Measurement Test Setup
EUT perpendicular to phantom, 0 mm separation

2.3 SAR measurement system

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.

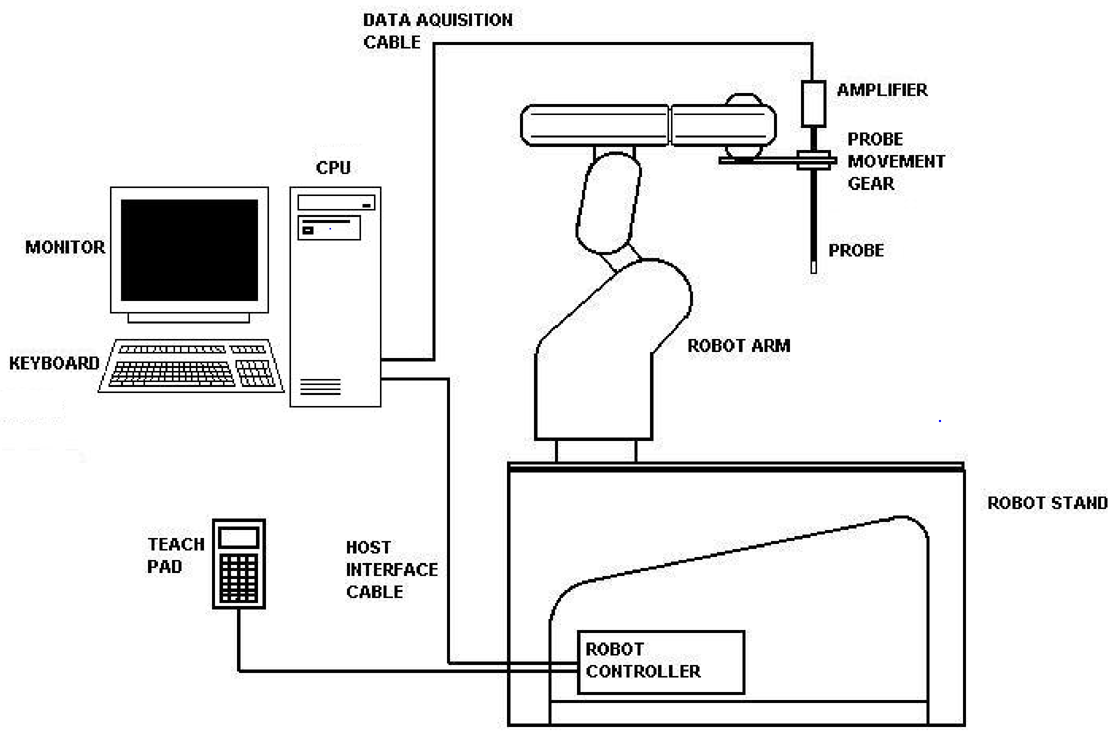


Figure 1: Schematic diagram of the SAR measurement system

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 ±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 3 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-axes. 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_{1g} (mW/g)**	**Measured SAR_{1g} (mW/g)**	**Deviation (±10%)**	**Plot Number**
2450	CW	52.4	50.16	-5.92%	7

Test Results

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.

System performance check (2450 MHz Head)					
Frequency MHz	**Operating Mode**	**Target SAR_{1g} (mW/g)**	**Measured SAR_{1g} (mW/g)**	**Deviation (±10%)**	**Plot Number**
2450	CW	52.4	53.928	2.92%	8

Note: a) Worst case data were reported
b) Uncertainty of the system is not included

Measurement Results

Trade Name:	ZyXEL	**Model No.:**	ZyAIR B-220
Serial No.:	Not Labled	**Test Engineer:**	Kevin Chen
TEST CONDITIONS			
Ambient Temperature	23.3 ^{o}C	**Relative Humidity**	50 %
Test Signal Source	Test Mode	**Signal Modulation**	DSSS
Output Power Before SAR Test	See page 7	**Output Power After SAR Test**	See page 7
Test Duration	22 min. each scan	**Number of Battery Change**	1

EUT Position						
Channel (MHz)	**Operating Mode**	**Crest Factor**	**Description**	**Distance (mm)**	**Measured SAR_{1g} (mW/g)**	**Plot Number**
2437	DSSS	1	Bottom of NoteBook PC	0	0.506	1
2412	DSSS	1	Bottom of NoteBook PC	0	0.652	2
2462	DSSS	1	Bottom of Note Book PC	0	0.533	3
2437	DSSS	1	Perpendicular to phantom	0	0.062	4
2412	DSSS	1	Perpendicular to phantom	0	0.103	5
2462	DSSS	1	Perpendicular to phantom	0	0.099	6
2437	DSSS	1	Perpendicular to phantom	15	Note	9
2412	DSSS	1	Perpendicular to phantom	15	Note	10
2462	DSSS	1	Perpendicular to phantom	15	Note	11

Note: The measurement was only performed in Area Scan due to scanning system couldn't continue performing Zoom Scan with such a low SAR distribution.

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	Mar. 26, 2003
Robot	**Mitsubishi RV-E2**	EA009002	N/A
	Repeatability: ± 0.04mm; Number of Axes: 6		
E-Field Probe	**IXP-050**	0114	09/06/2002
	Frequency Range: Probe outer diameter: 5 mm; Length: 350 mm; Distance between the probe tip and the dipole center: 3 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. 0.401N;		
Phantom	**2mm wall thickness box phantom**	N/A	N/A
	Shell Material: clear Perspex; Thickness: 2 ± 0.1 mm; Capacity: 154 x 200 x 200 (W x L x D) mm^3; 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	**Boonton 4231A with 51011-EMC power sensor**	79401-32482	03/21/2003
Power Meter	Frequency Range: 0.03 to 8 GHz, <24dBm		
RF	**INDEXSAR VTL5400**	0302	01/23/2003
Power Amplifier	10MHz to 2.5GHz, Gain >30dB		
Directional	**INDEXSAR VDC0830-20**	0302	05/19/2003
Coupler	0.8 to 3 GHz, Max. Power<500W		
Vector Network Analyzer	**HP 8753B** **HP 85046A**	2807J04037 2729A01958	12/13/2002
	300k to 3GHz		
Signal Generator	**Rohde & Schwarz SMR27**	1104.0002.27	08/16/2002
	10M to 27GHz, <120dBuV		

3.2 Body Tissue Simulating Liquid for evaluation test

Body Ingredients Frequency (2.45 GHz)	
DGBE Dilethylene Glycol Butyl Ether	26.7%
Salt	0.04%
Water	73.2%

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. (℃)**	e $_r$ / **Relative Permittivity**			s / **Conductivity (mho/m)**			r ***(kg/m^3)**
2450	23.1	measured	target	Δ(±5%)	measured	target	Δ(±5%)	1000
		50.76	52.7	-3.68%	1.897	1.95	-2.72%	

* *Worst-case assumption*

Test data is included in Appendix B.

Head Tissue Simulating Liquid for System performance Check test

Head Ingredients Frequency (2.45 GHz)	
DGBE Dilethylene Glycol	53.3%
Water	46.7%

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. (℃)**	e $_r$ / **Relative Permittivity**			s / **Conductivity (mho/m)**			r ***(kg/m^3)**
2450	23.1	measured	target	Δ(±5%)	measured	target	Δ(±5%)	1000
		38.221	39.2	-2.5%	1.88	1.80	4.44%	

* *Worst-case assumption*

3.3 E-Field Probe Calibration

Probe calibration factors are included in Appendix C.

3.4 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 27.5 %

Uncertainty Component	Sec.	(dB)	Tol.(+/-)	(%)	Prob. Dist.	Divisor (descript)	Divisor (value)	c1	Standard Uncertainty (%)	
Measurement System										
Probe Calibration	E 1.1			10	N	1 or k	2	1	5.00	25.00
Axial Isotropy	E 1.2	0.25	5.93	5.93	R	$\sqrt{3}$	1.73	0	0.00	0.00
Hemispherical Isotropy	E 1.2	0.45	10.92	10.92	R	$\sqrt{3}$	1.73	1	6.30	39.73
Boundary effects	E 1.3		4	4.00	R	$\sqrt{3}$	1.73	1	2.31	5.33
Linearity	E 1.4	0.04	0.93	0.93	R	$\sqrt{3}$	1.73	1	0.53	0.29
System Detection Limits	E 1.5		1	1.00	R	$\sqrt{3}$	1.73	1	0.58	0.33
Readout Electronics	E 1.6		1	1.00	N	1 or k	1.73	1	1.00	1.00
Response time	E 1.7		0	0.00	R	$\sqrt{3}$	1.73	1	0.00	0.00
Integration time	E 1.8		1.8	1.80	R	$\sqrt{3}$	1.73	1	1.04	1.08
RF Ambient Conditions	E 5.1		3	3.00	R	$\sqrt{3}$	1.73	1	1.73	3.00
Probe Positioner Mechanical Tolerance	E 5.2		0.6	0.60	R	$\sqrt{3}$	1.73	1	0.35	0.12
Probe Position wrt. Phantom Shell	E 5.3		5	5.00	R	$\sqrt{3}$	1.73	1	2.89	8.33
SAR Evaluation Algorithms	E 4.2		8	8.00	R	$\sqrt{3}$	1.73	1	4.62	21.33
Test Sample Related										
Test Sample Positioning	E 3.2.1		10	10.00	R	$\sqrt{3}$	1.73	1	5.77	33.33
Device Holder Uncertainty	E 3.1.1		10	10.00	R	$\sqrt{3}$	1.73	1	5.77	33.33
Output Power Variation	E 5.6.2		5	4.00	R	$\sqrt{3}$	1.73	0.5	2.89	8.33
Phantom and tissue Parameters										
Phantom Uncertainty (shape and thickness)	E 2.1		4	4.00	R	$\sqrt{3}$	1.73	0.5	1.15	1.33
Liquid conductivity (Deviation from target)	E 2.2		5	5.00	R	$\sqrt{3}$	1.73	0.5	1.44	2.08
Liquid conductivity (Meas. Uncertainty)	E 2.2		10	10.00	R	$\sqrt{3}$	1.73	0.5	2.89	8.33

Combined standard uncertainty **RSS** **14.0**

3.5 Measurement Traceability

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

4.0 WARNING LABEL INFORMATION - USA

See user manual.

5.0 REFERENCES

[1] ANSI, *ANSI/IEEE C95.1-1991: 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, 1992

[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: Experimental Techniques", IEEE Std 1528-200X, Draft CD 1.0 – September 15, 2002

6.0 DOCUMENT HISTORY

Revision/ Job Number	Writer Initials	Date	Change
TC0300445	J.C.	June 10, 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 (1/2)

Date / Time:	2003/5/15	**Position:**	bottom 0mm
Filename:	B-220 bot2437.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2437MHz
Shape File:	B-220 bottom(HP NB)-1.csv	**Power Level:**	17.74dBm

Probe: 0114

Cal File: SN0114_2450_CW_BODY

Cal Factors:

	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.528	.528	.528

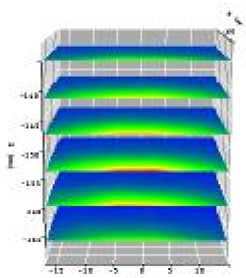
Amp Gain: 2

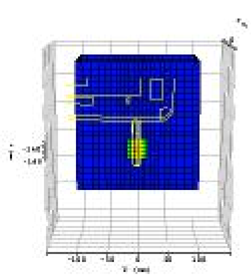
Averaging: 1

Batteries Replaced: May 15

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1





ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan**	**End Scan**
	0.143	0.146

Change during Scan (%): 2.03

Max E-field (V/m): 18.58

Max SAR (W/kg)	**1g**	**10g**
	0.506	0.254

Location of Max (mm):	**X**	**Y**	**Z**
	75.1	-17.0	-152.1

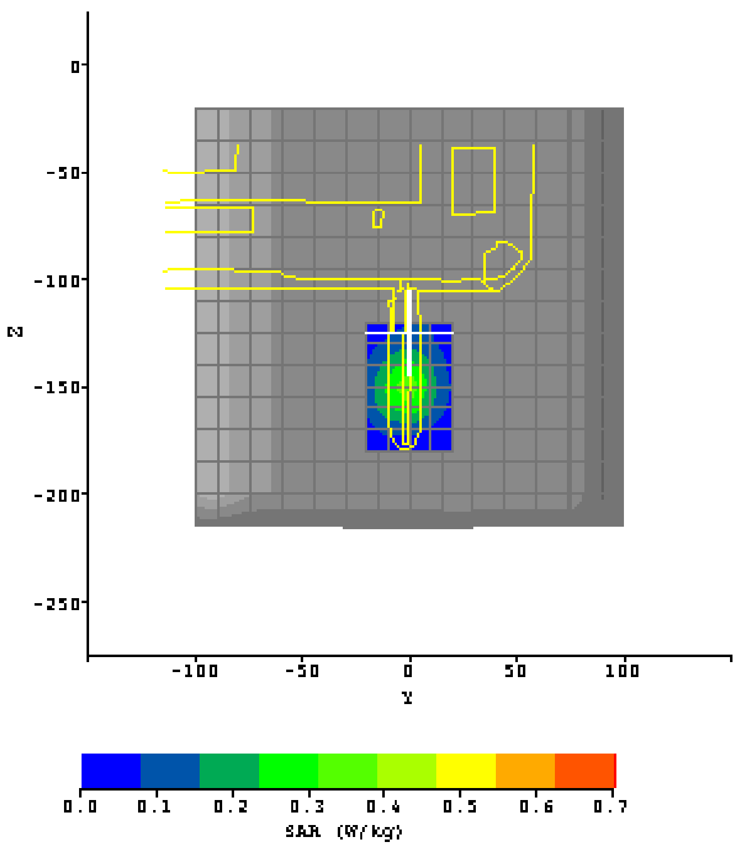
Plot #1 (2/2)

Date / Time:	2003/5/15	**Position:**	bottom 0mm
Filename:	B-220 bot2437.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2437MHz
Shape File:	B-220 bottom(HP NB)-1.csv	**Power Level:**	17.74dBm

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-20.0	20.0	4.0
Z	-180.0	-120.0	6.0



Plot #2 (1/2)

Date / Time:	2003/5/15	**Position:**	bottom 0mm
Filename:	B-220 bot2412.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2412MHz
Shape File:	B-220 bottom(HP NB)-1.csv	**Power Level:**	17.85dBm

Probe: 0114

Cal File: SN0114_2450_CW_BODY

Cal Factors:

	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.528	.528	.528

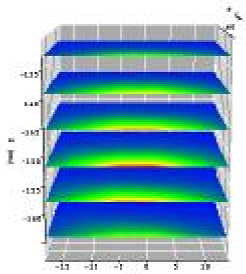
Amp Gain: 2

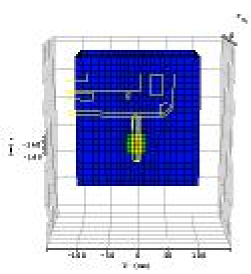
Averaging: 1

Batteries Replaced: May 15

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1





ZOOM SCAN RESULTS:

Spot SAR (W/kg):

Start Scan	End Scan
0.156	0.160

Change during Scan (%) 2.71

Max E-field (V/m): 21.17

Max SAR (W/kg)

1g	10g
0.652	0.306

Location of Max (mm):

X	Y	Z
75.1	-18.0	-150.1

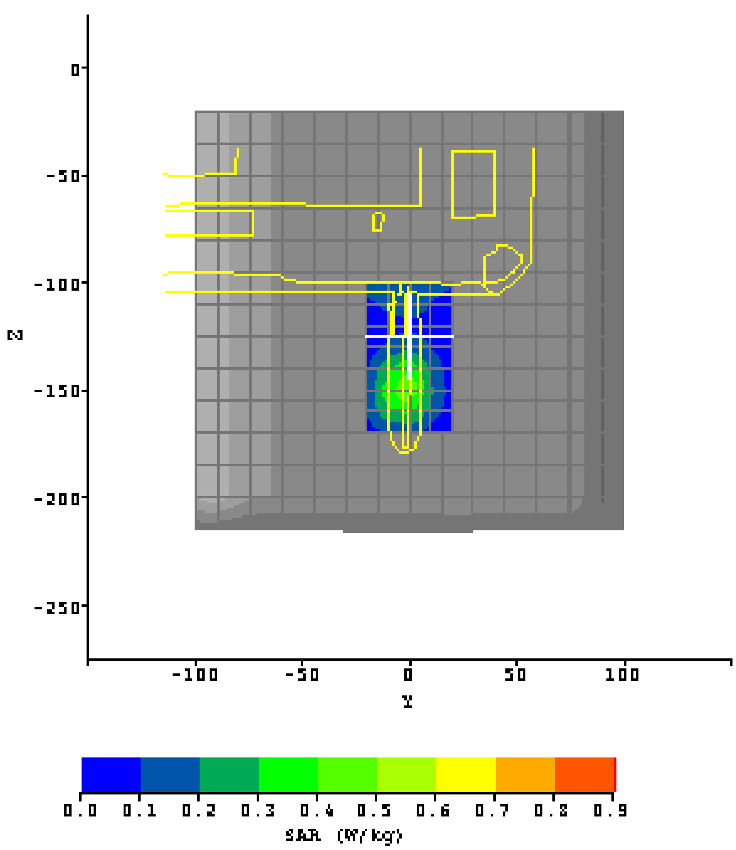
plot #2 (2/2)

Date / Time:	2003/5/15	**Position:**	bottom 0mm
Filename:	B-220 bot2412.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2412MHz
Shape File:	B-220 bottom(HP NB)-1.csv	**Power Level:**	17.85dBm

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-20.0	20.0	4.0
Z	-170.0	-100.0	7.0



plot #3 (1/2)

Date / Time:	2003/5/15	**Position:**	bottom 0mm
Filename:	B-220 bot2462.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2462MHz
Shape File:	B-220 bottom(HP NB)-1.csv	**Power Level:**	17.88dBm

Probe: 0114

Cal File: SN0114_2450_CW_BODY

Cal Factors:

	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.528	.528	.528

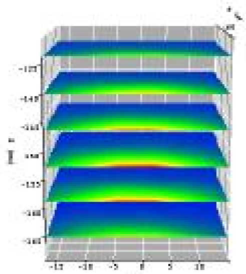
Amp Gain: 2

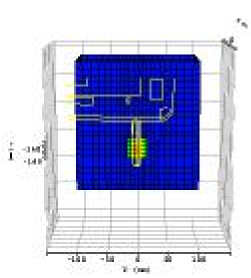
Averaging: 1

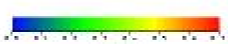
Batteries Replaced: May 15

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1







ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.147	0.139

Change during Scan (%): -4.88

Max E-field (V/m): 19.08

	1g	10g
Max SAR (W/kg)	0.533	0.263

	X	Y	Z
Location of Max (mm):	75.1	-17.0	-152.1

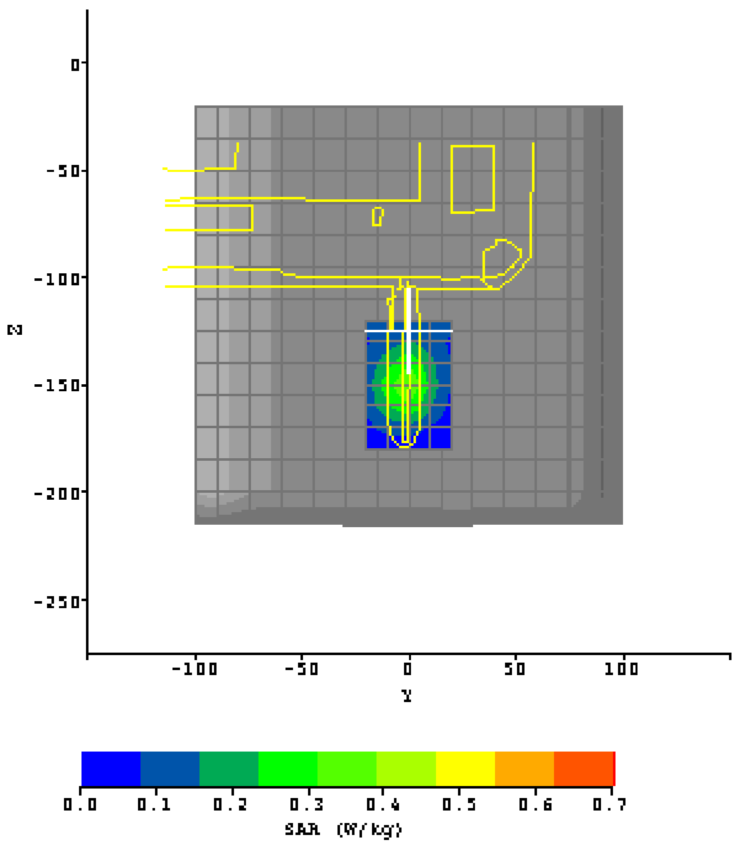
plot #3 (2/2)

Date / Time:	2003/5/15	**Position:**	bottom 0mm
Filename:	B-220 bot2462.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2462MHz
Shape File:	B-220 bottom(HP NB)-1.csv	**Power Level:**	17.88dBm

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-20.0	20.0	4.0
Z	-180.0	-120.0	6.0



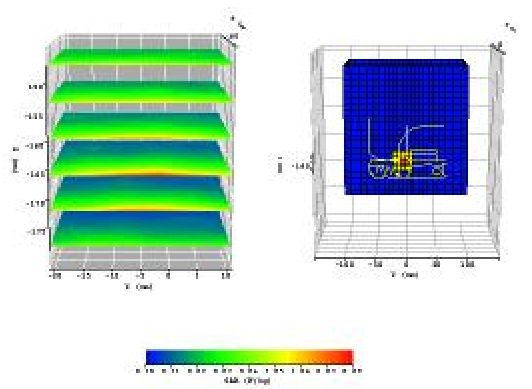
plot #4 (1/2)

Date / Time:	2003/5/15	**Position:**	perpendicular 0mm
Filename:	B-220_per2437.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2437MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.74dBm

Probe:	0114			
Cal File:	SN0114_2450_CW_BODY			
Cal Factors:		**X**	**Y**	**Z**
	Air	532	494	450
	DCP	20	20	20
	Lin	.528	.528	.528
Amp Gain:	2			
Averaging:	1			
Batteries Replaced:	May 15			

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1



ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan**	**End Scan**
	0.022	0.023
Change during Scan (%)	2.29	
Max E-field (V/m):	6.36	
Max SAR (W/kg)	**1g**	**10g**
	0.062	0.038

Location of Max (mm):	**X**	**Y**	**Z**
	75.0	-21.0	-165.5

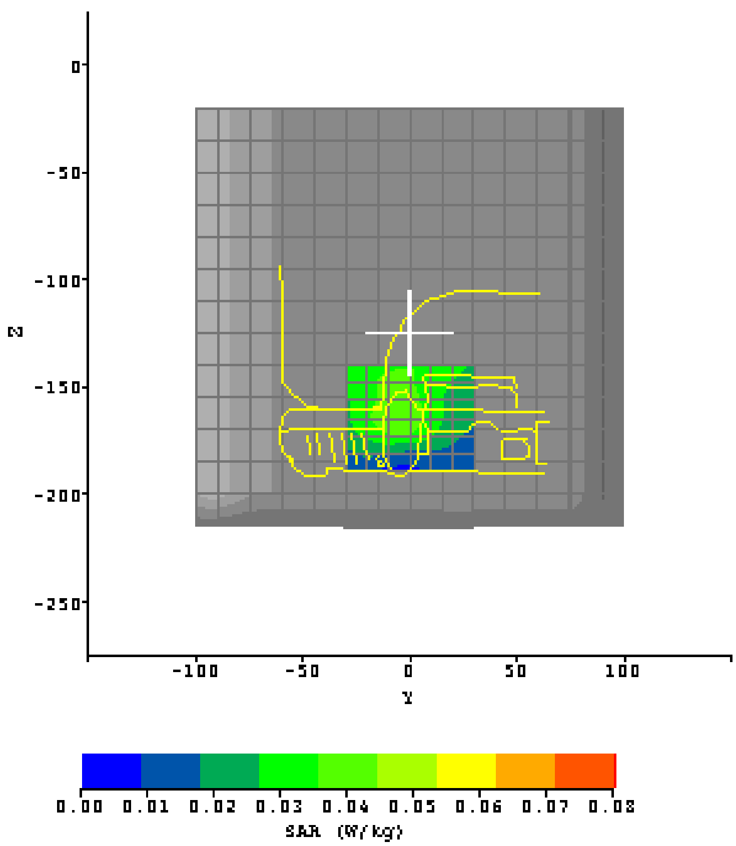
plot #4 (2/2)

Date / Time:	2003/5/15	**Position:**	perpendicular 0mm
Filename:	B-220_per2437.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2437MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.74dBm

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-30.0	30.0	6.0
Z	-190.0	-140.0	6.0



plot #5 (1/2)

Date / Time:	2003/5/15	**Position:**	perpendicular 0mm
Filename:	B-220_per2412.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2412MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.85dBm

Probe:	0114
Cal File:	SN0114_2450_CW_BODY

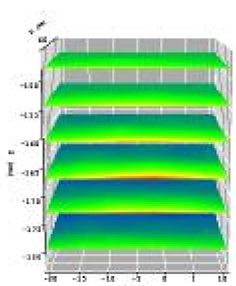
Cal Factors:

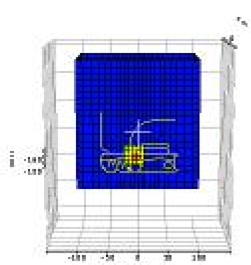
	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.528	.528	.528

Amp Gain:	2
Averaging:	1
Batteries Replaced:	May 15

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1





ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.037	0.037

Change during Scan (%)	0.27
Max E-field (V/m):	8.39

	1g	10g
Max SAR (W/kg)	0.103	0.064

	X	Y	Z
Location of Max (mm):	75.0	-21.0	-167.4

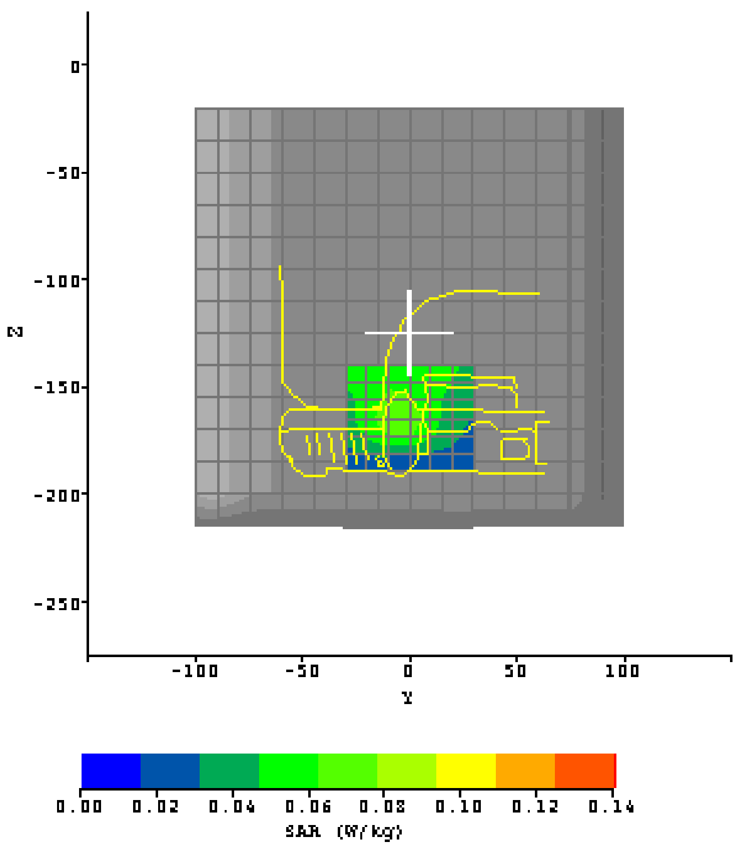
plot #5 (2/2)

Date / Time:	2003/5/15	**Position:**	perpendicular 0mm
Filename:	B-220_per2412.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2412MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.85dBm

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-30.0	30.0	6.0
Z	-190.0	-140.0	6.0



plot #6 (1/2)

Date / Time:	2003/5/15	**Position:**	perpendicular 0mm
Filename:	B-220_per2462.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2462MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.88dBm

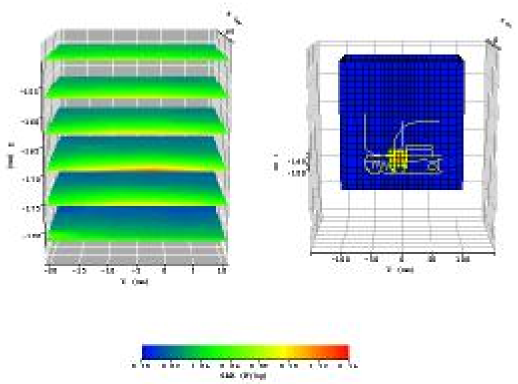
Probe:	0114
Cal File:	SN0114_2450_CW_BODY
Amp Gain:	2
Averaging:	1
Batteries Replaced:	May 15

Cal Factors:

	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.528	.528	.528

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1



ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.039	0.037

Change during Scan (%): -5.79

Max E-field (V/m): 8.19

	1g	10g
Max SAR (W/kg)	0.099	0.062

	X	Y	Z
Location of Max (mm):	75.0	-21.0	-167.7

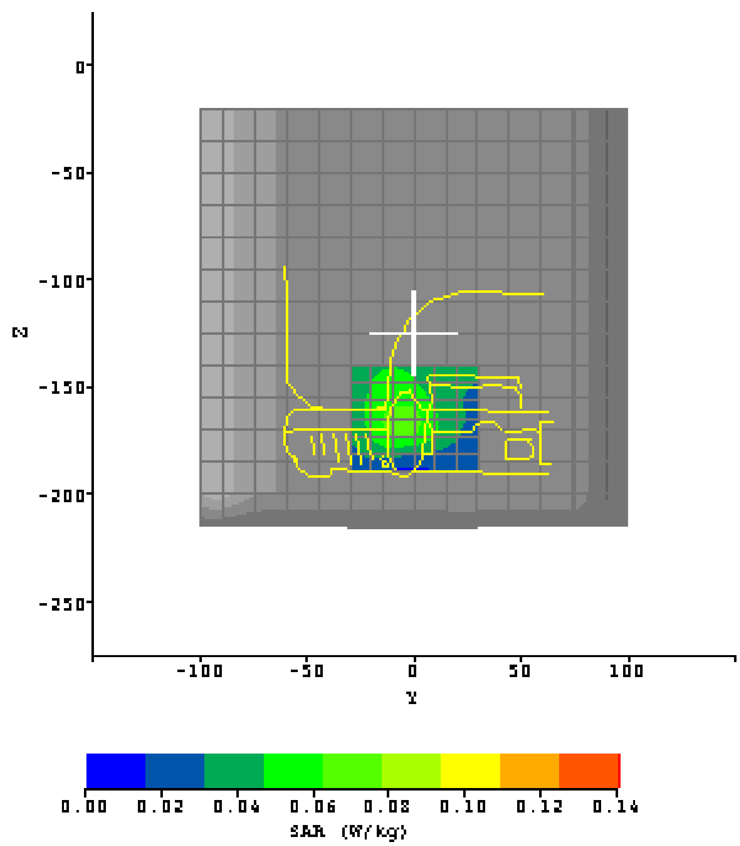
plot #6 (2/2)

Date / Time:	2003/5/15	**Position:**	perpendicular 0mm
Filename:	B-220_per2462.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2462MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.88dBm

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-30.0	30.0	6.0
Z	-190.0	-140.0	6.0



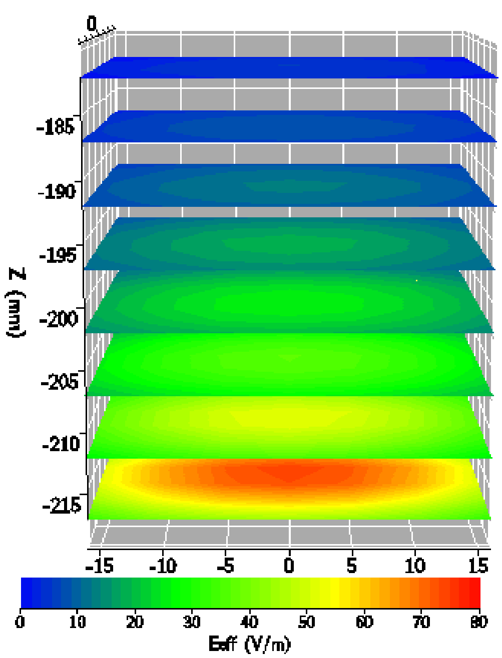
Plot #7

Date:	2003/3/7	**Position:**	Bottom
Filename:	2450val5-15.txt	**Phantom:**	Box1.csv
Device Tested:	SARA2 system	**Head Rotation:**	0
Antenna:	2450dipole	**Test Frequency:**	2450MHz
Shape File:	none.csv	**Power Level:**	24dBm /CW

Probe:	0114			
Cal File:	SN0114_2450_CW_HEAD			
		X	**Y**	**Z**
Cal Factors:	**Air**	532	494	450
	DCP	20	20	20
	Lin	.495	.495	.495
Amp Gain:	2			
Averaging:	1			
Batteries Replaced:	N/a			

Liquid:	15.1cm
Type:	2450MHz Head
Conductivity:	1.88
Relative Permittivity:	38.221
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	22.1
Ambient RH (%):	62
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor = 1



ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan**	**End Scan**
Change during Scan (%)		
Max E-field (V/m):	76.31	
Max SAR (W/kg)	**1g**	**10g**
	12.54	6.23

Location of Max (mm):	**X**	**Y**	**Z**
	1.5	1.2	-220.0

Normalized to an input power of 1W
Averaged over 1 cm^3 (1g) of tissue
50.16 W/kg

Plot #8

Date / Time:	2003/5/15	**Position:**	bottom of box phantom
Filename:	2450 performance check	**Phantom:**	HeadBox1.csv
Device Tested:	SARA2 system	**Head Rotation:**	0
Antenna:	2.45GHz dipole	**Test Frequency:**	2450MHz
Shape File:	Dipole2450.csv	**Power Level:**	24 dBm /CW

Probe: 0114

Cal File: SN0114_2450_CW_HEAD

Cal Factors:

	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.495	.495	.495

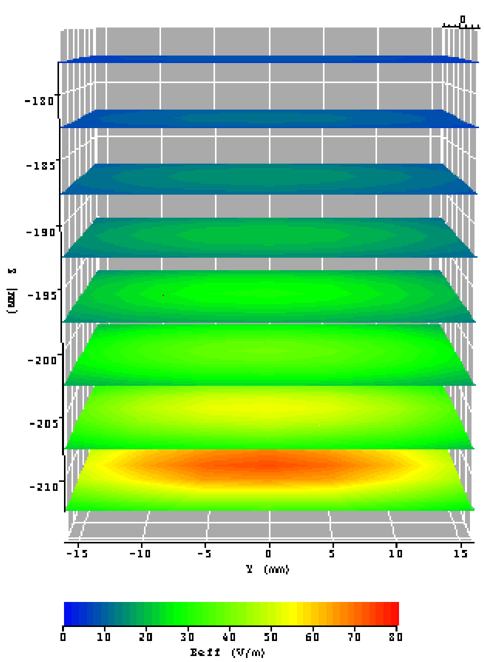
Amp Gain: 2

Averaging: 3

Batteries Replaced: -

Liquid:	15.2cm
Type:	2450MHz head
Conductivity:	1.882
Relative Permittivity:	38.952
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	22.5
Ambient RH (%):	60
Density (kg/m3):	1000
Software Version:	0.421N

Crest factor = 1



ZOOM SCAN RESULTS:

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

Change during Scan (%)

Max E-field (V/m): 73.42

Max SAR (W/kg)	**1g**	**10g**
	13.482	6.255

Location of Max (mm):	**X**	**Y**	**Z**
	0.0	0.0	-220.5

Normalized to an input power of 1W
Averaged over 1 cm^3 (1g) of tissue
53.928 W/kg

plot #9

Date / Time:	2003/5/15	**Position:**	perpendicular 15mm
Filename:	ZyAIR B-220a 2437 for 15mm per.a.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2437MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.74dBm

Probe: 0114

Cal File: SN0114_2450_CW_BODY

Cal Factors:

	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.528	.528	.528

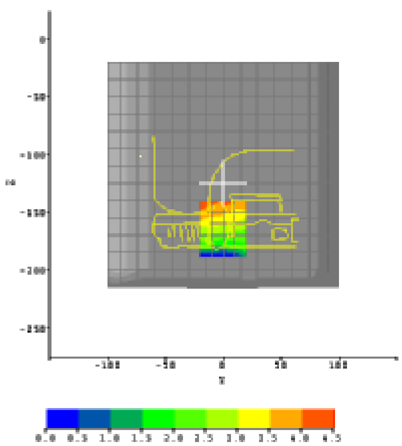
Amp Gain: 1

Averaging: 1

Batteries Replaced: May 15

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1



AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-20.0	20.0	4.0
Z	-190.0	-140.0	5.0

plot #10

Date / Time:	2003/5/15	**Position:**	perpendicular 15mm
Filename:	ZyAIR B-220a 2412 for 15mm per.a.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2412MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.85dBm

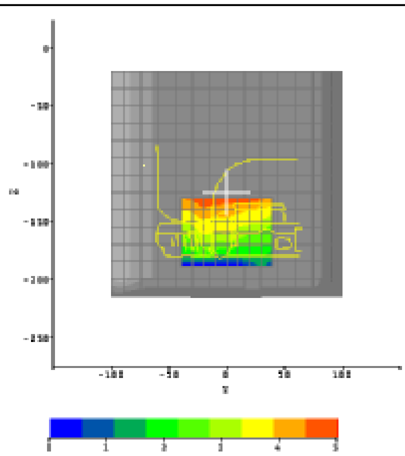
Probe:	0114
Cal File:	SN0114_2450_CW_BODY
Amp Gain:	1
Averaging:	1
Batteries Replaced:	May 15

Cal Factors:

	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.528	.528	.528

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1



AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-40.0	40.0	8.0
Z	-190.0	-130.0	6.0

plot #11

Date / Time:	2003/5/15	**Position:**	perpendicular 15mm
Filename:	ZyAIR B-220a 2462 for 15mm per.a.txt	**Phantom:**	HeadBox1.csv
Device Tested:	ZyAIR B-220	**Head Rotation:**	0
Antenna:	Ceramic	**Test Frequency:**	2462MHz
Shape File:	B-220 perpendicular(HP NB).csv	**Power Level:**	17.88dBm

Probe: 0114

Cal File: SN0114_2450_CW_BODY

Cal Factors:

	X	Y	Z
Air	532	494	450
DCP	20	20	20
Lin	.528	.528	.528

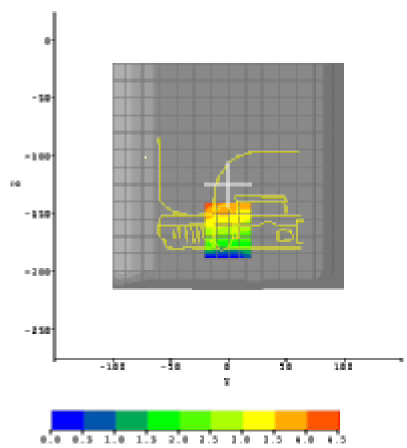
Amp Gain: 1

Averaging: 1

Batteries Replaced: May 15

Liquid:	15.3cm
Type:	2450MHz body
Conductivity:	1.89659
Relative Permittivity:	50.756798
Liquid Temp (deg C):	23.1
Ambient Temp (deg C):	20
Ambient RH (%):	50
Density (kg/m3):	1000
Software Version:	0.421N

Crest Factor=1



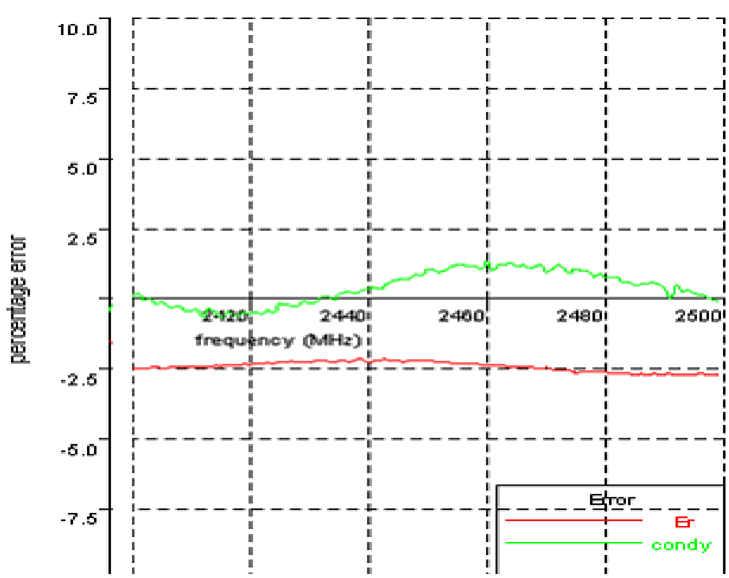
AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-20.0	20.0	4.0
Z	-190.0	-140.0	5.0

APPENDIX B – 2450MHz body liquid Calibration Data

Date	27 Mar 2003	Temperature	23.2℃	Tested by	Bruce
2400, 51.4561731074, -1.9042983162			**2450, 51.5399962214, -1.9709742142**		
2401, 51.4618622908, -1.9074318666			2451, 51.5253820963, -1.9714888178		
2402, 51.4491455736, -1.9032053975			2452, 51.5138376197, -1.9712764191		
2403, 51.4597447905, -1.9053580588			2453, 51.506264452, -1.9744307721		
2404, 51.47733312, -1.9024853703			2454, 51.4797118628, -1.9781930314		
2405, 51.4521081981, -1.9049122745			2455, 51.4815882983, -1.9809404159		
2406, 51.4604603699, -1.9024956108			2456, 51.4810253471, -1.9823596219		
2407, 51.4627300203, -1.9028876489			2457, 51.4658651578, -1.9825321803		
2408, 51.473688404, -1.9052446327			2458, 51.4696792746, -1.9842363434		
2409, 51.4764838923, -1.9021558305			2459, 51.4526469091, -1.9834798983		
2410, 51.4664137477, -1.9036953101			2460, 51.4261219609, -1.9905032004		
2411, 51.4688525043, -1.9056549894			2461, 51.4433050331, -1.9855396115		
2412, 51.473792562, -1.9010364732			2462, 51.4351797909, -1.991614928		
2413, 51.4703336505, -1.9080418825			2463, 51.4192833694, -1.9926441596		
2414, 51.4853170469, -1.9075814689			2464, 51.3935248988, -1.9951662021		
2415, 51.4777480721, -1.9039314052			2465, 51.4067807362, -1.9940377601		
2416, 51.4975077921, -1.9081039443			2466, 51.3973497372, -1.9965390767		
2417, 51.4910256185, -1.9076696526			2467, 51.4035945152, -1.996413623		
2418, 51.4910256185, -1.9077555336			2468, 51.3752221594, -1.9983473438		
2419, 51.5205793847, -1.9110002928			2469, 51.3657334963, -2.0013612312		
2420, 51.5015907146, -1.9112969669			2470, 51.3821659658, -1.9975422712		
2421, 51.5186299965, -1.913333299			2471, 51.3494044323, -2.000827518		
2422, 51.5199444738, -1.9132995662			2472, 51.3316014489, -2.005838666		
2423, 51.5383678105, -1.9164616343			2473, 51.3302917026, -2.0041845906		
2424, 51.507022345, -1.9159470284			2474, 51.327048332, -2.0023612572		
2425, 51.5535636155, -1.9228209833			2475, 51.2809460611, -2.0067604224		
2426, 51.5434783921, -1.9230193922			2476, 51.3079480027, -2.00626195		
2427, 51.5567729067, -1.9234357151			2477, 51.2992831757, -2.0084710545		
2428, 51.5440327361, -1.9242282308			2478, 51.2936112023, -2.0054399112		
2429, 51.5459115161, -1.9284002105			2479, 51.3011522711, -2.0090308719		
2430, 51.5489798728, -1.9284127939			2480, 51.2836148761, -2.0073938227		
2431, 51.5508588331, -1.9293915476			2481, 51.2549164139, -2.0088742591		
2432, 51.5495434924, -1.9344271731			2482, 51.2473813108, -2.0109721385		
2433, 51.5483972892, -1.9357711193			2483, 51.2577708094, -2.0088889846		
2434, 51.5280836418, -1.9339312378			2484, 51.2502352867, -2.0101724366		
2435, 51.5634320839, -1.938072836			2485, 51.2319064707, -2.0091094983		
2436, 51.5596101838, -1.9410064722			2486, 51.241119396, -2.0114765135		
2437, 51.519783227, -1.9421099893			2487, 51.2241626656, -2.0136195162		
2438, 51.5708848449, -1.9422852073			2488, 51.2399895297, -2.0157126805		
2439, 51.5708848449, -1.9456341184			2489, 51.23507108, -2.0150913632		
2440, 51.520244181, -1.9474993194			2490, 51.2307133103, -2.0143129528		
2441, 51.545493223, -1.9493233493			2491, 51.24467433, -2.0083690716		
2442, 51.5619831997, -1.9490242373			2492, 51.2165763995, -2.0189383173		
2443, 51.5688118794, -1.9535325295			2493, 51.2193393653, -2.0165741161		
2444, 51.53784239, -1.956085257			2494, 51.2198994488, -2.0185948185		
2445, 51.5581514216, -1.9585172362			2495, 51.2248156116, -2.0178354949		
2446, 51.5285668156, -1.9596063202			2496, 51.23616024, -2.0181454203		
2447, 51.5383078584, -1.9614054013			2497, 51.2234992958, -2.0182098569		
2448, 51.5287890744, -1.9649943839			2498, 51.207276331, -2.0180287515		
2449, 51.5361768938, -1.9651226896			2499, 51.2179937402, -2.0181685351		
			2500, 51.2208313603, -2.0196352693		



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

Calibration Certificate
Dosimetric E-field Probe

Type:	**IXP-050**
Manufacturer:	**IndexSAR, UK**
Serial Number:	**0114**
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:	**6th September 2002**

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

Next Calibration Date:	**September 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.

IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 050

S/N 0114

6th September 2002

Indexsar Limited
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Tel: +44 (0) 1306 631 233
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e-mail: ***enquiries@indexsar.com***

INTRODUCTION

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N 0114) 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, boxes and spheres) 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 calibration procedure, the probe is placed in a calibration 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. When it is necessary to place the probe in liquid, a rectangular box made from PMMA (200mm internal width, 200mm internal height and 100mm internal depth; wall thickness 4mm) is filled with the appropriate liquid and positioned on the stand so that the probe tip is positioned within the liquid (Figure 1). The box is positioned so that its outer surface is 2mm from the dipole. The procedure follows that described in Ref [2]. Section A.5.2.1.

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 0114.

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):

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

A 3D representation of the spherical isotropy for probe S/N 0114 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).

For other frequencies, probe conversion factors are determined using waveguide cells as 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 posititition 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

$$SAR(z) = \frac{4\left(P_f - P_b\right)}{r\,abd} e^{-2z/d} \qquad (4)$$

where the density r 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 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.

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

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 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 0114

The probe was calibrated at 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 2.5 mm from the probe tip in the direction of the AD converter. A value of 2.5 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 using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2].

AMBIENT CONDITIONS

Measurements were made in the open laboratory laboratory at 23 $\pm$ 0.5^{o}C. The temperature of the liquids in the waveguide used was measured using a mercury thermometer.

GSM RESPONSE

SAR probes are required to measure the effective value (RMS value) of the electric field strength. The averaging time is defined in the standards as being over 6 minutes but with most of the signals that occur in the real world, such a long averaging time is unnecessary since the fluctuations are eliminated with significantly shorter averaging times. With most signals, a much shorter averaging time is sufficient. For example the GSM frame rate is 120mS and averaging over this time period will remove the fluctuations.

In diode probes, a single Schottky diode is used as the detector for each of the three channels (X, Y and Z). For small field strengths, these offer a very good approximation to a true RMS rectifier. For higher field strengths, higher or lower values than the RMS value can be displayed - depending on the modulation frequency.

The theoretical maximum deviation from the RMS value can be derived based on the behavior of the two extremes [4]:

An average-value rectifier

- displays a value proportional to the average value of the magnitude of a measured quantity.

A peak-value rectifier

- displays a value proportional to the peak value of the magnitude of a measured quantity

The proportionality factor for a practical probe is chosen so that the probe reads the true RMS value for a continuous (CW) signal.

For pulsed signals, a diode rectifier must deliver a value lying somewhere between the two extremes of an average value rectifier and a peak value rectifier. By way of example, for a GSM signal with a 1 in 8 duty cycle (ratio of ‘on’ time to total time), the power measurement at higher powers can vary between being a factor of 8 too low (average value extreme) and a factor of 8 too high (peak-value extreme).

The actual behaviour is complex as it depends on the period of the modulation in relation to various time constants in the measuring system. These include the holding time of the diode (typically 50 uS), the time constant of the high-resistance leads and the time constant and integration periods of the measurement electronics. Also, the modulation periods are complex – GSM has a basic burst rate of 4.615mS, but the full modulation scheme only repeats every 120mS.

To correct for the errors due to the diode response to pulsed signals, a multiplier can be added to the second term of Equation 1 (see earlier). In principle, this multiplier can have a range for a GSM signal of between 8 and 1/8. The correction scheme will

$$U_{lin} = U_{o/p} + U_{o/p}^{2} * PCF/ DCP \qquad (4)$$

Where PCF is a pulse correction factor ranging between the duty cycle and the reciprocal of the duty cycle.

Indexsar SAR probes show a qualitatively similar behaviour in response to GSM signals, but with a much lesser degree of over or underestimation than indicated by the possible ranges above. Indeed, for many Indexsar probes, the PCF has been established by measurement to be close to unity. A probe with a unity PCF reads true RMS for a pulsed signal without correction.

The PCF has the effect of altering the effective diode compression potential and a modification to the DCP value is how the GSM correction is implemented in the Indexsar probe calibration scheme.

The modified DCP values for GSM are included in the summary page. The value has been determined by finding the modified DCP required to linearise the probe response as indicated in Figure 7.

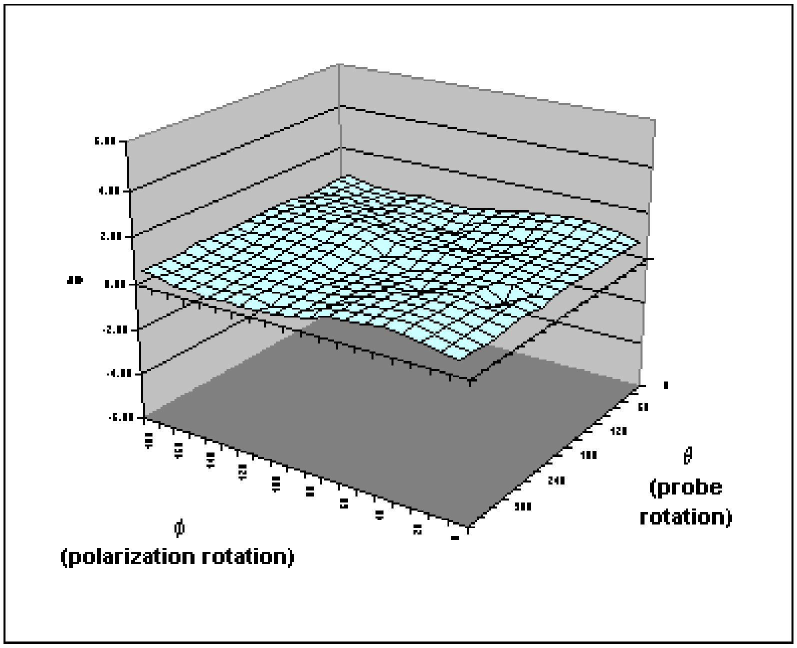
Non-amplitude modulated carriers can be considered as CW as far as the probe calibration is concerned.

The effects of amplitude modulation of the CDMA signal on SAR measurements has been considered in a draft paper [see ref. 4] submitted to IEEE SCC-34.

SUMMARY OF CALIBRATION FACTORS FOR PROBE IXP-050 S/N 0114

IXP-050 **S/N0114** 06/08/2002

Spherical isotropy measured at 900 MHz	0.50	(+/-) dB



	X	Y	Z	
Air factors	532	494	450	(V*200)
DCPs CW	20	20	20	(V*200)
DCPs GSM	7	7	7	(V*200)

f (MHz)	Axial isotropy (+/- dB) BRAIN	BODY	SAR conversion factors (liq/air) BRAIN	BODY	Notes
900	0.10	*0.10*	0.340	*0.374*	3, 1
1800	0.08	0.08	0.381	0.417	
1900	0.09	0.08	0.387	0.417	
2450	0.08	0.08	0.495	0.528	

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
5) 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 0106, 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 0114	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)	3.0		

Dynamic range	S/N 0114	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 0114	CENELEC [1]	IEEE [2]
Over range 0.01 – 100 W/kg (+/- dB)	0.125	0.50	0.25

Isotropy (measured at 900MHz)	S/N 0114	CENELEC [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB) at 900, 1800, 1900 and 2450 MHz	Max. 0.10 (see summary table)	0.5	0.25
Spherical isotropy covering all orientations to source (+/- dB)	0.50	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.

[4] The response of Indexsar SAR probes to amplitude modulated (pulsed) RF signals, Indexsar Support document IXS211.

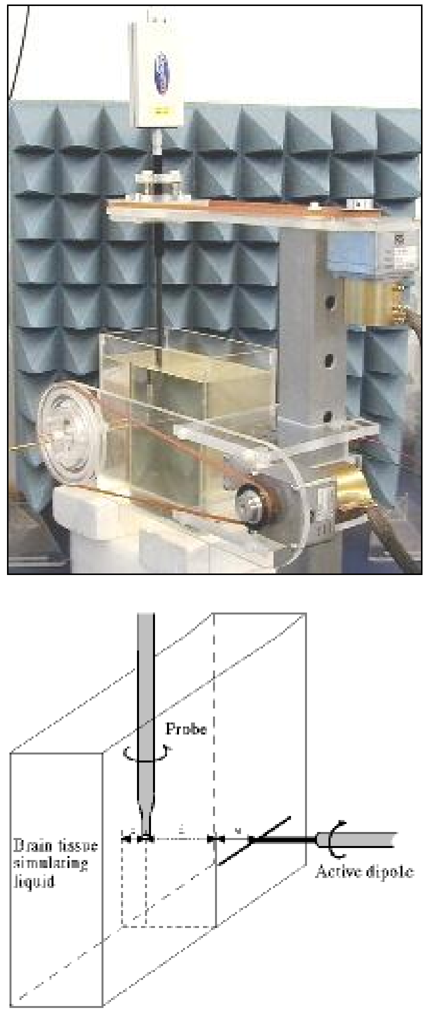


Figure 1. Calibration jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

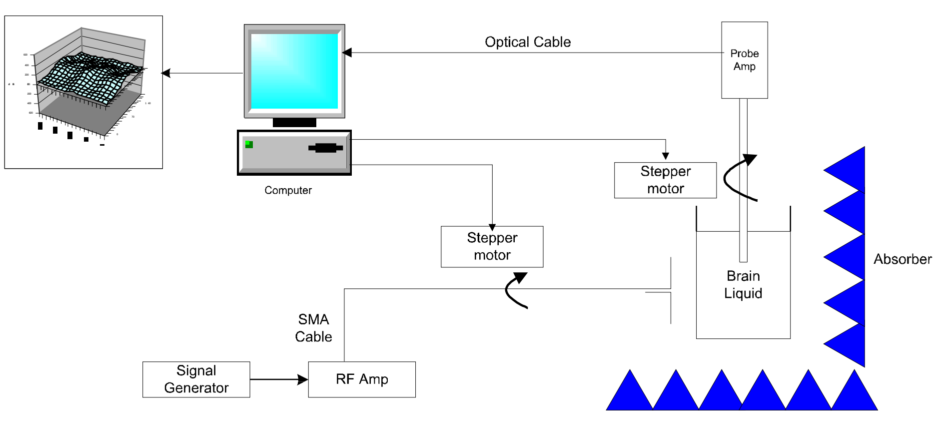


Figure 2. Schematic diagram of the test geometry used for isotropy determination

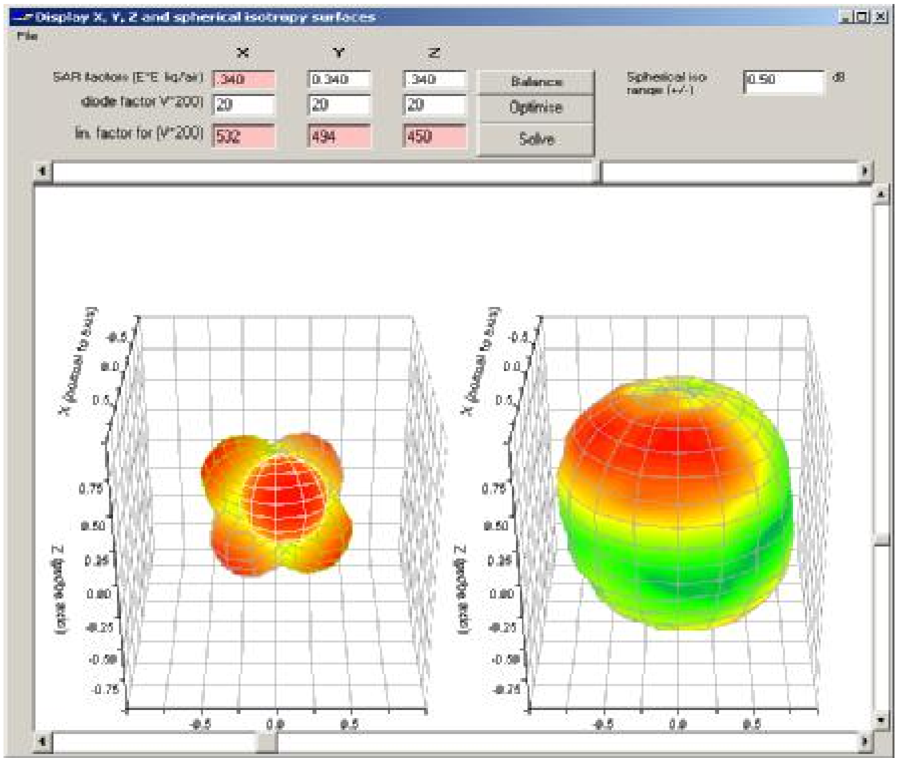


Figure 3. Graphical representation of the probe response to fields applied from each direction. The diagram on the left shows the individual response characteristics of each of the three channels and the diagram on the right shows the resulting probe sensitivity in each direction. The colour range in the figure images the lowest values as blue and the maximum values as red. For the probe S/N 0114, this range is (+/-) 0.50 dB. The probe is more sensitive to fields parallel to the axis and less sensitive to fields normal to the probe axis.

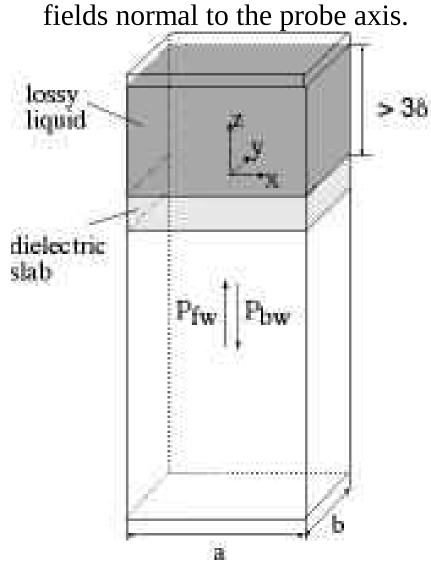
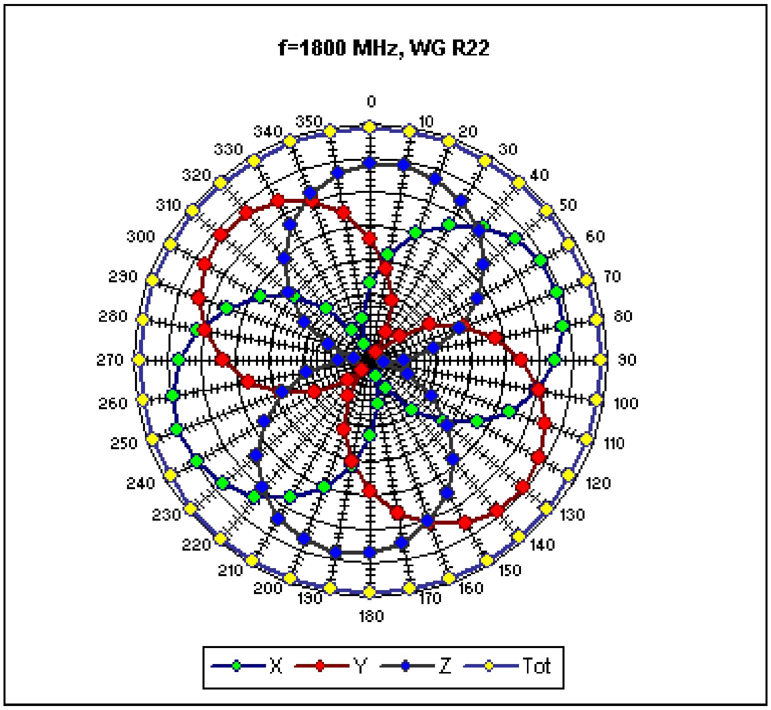


Figure 4. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

IXP-050 S/N 0114 **08-Aug-02**



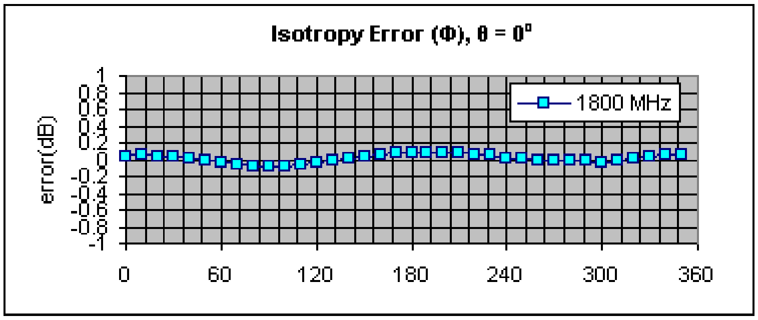


Figure 5. Example of the rotational isotropy of probe S/N 0114 obtained by rotating the probe in a liquid-filled waveguide at 1800 MHz. Similar distributions are obtained at the other test frequencies (1900 and 2450 MHz) both in brain liquids and body fluids (see summary table)

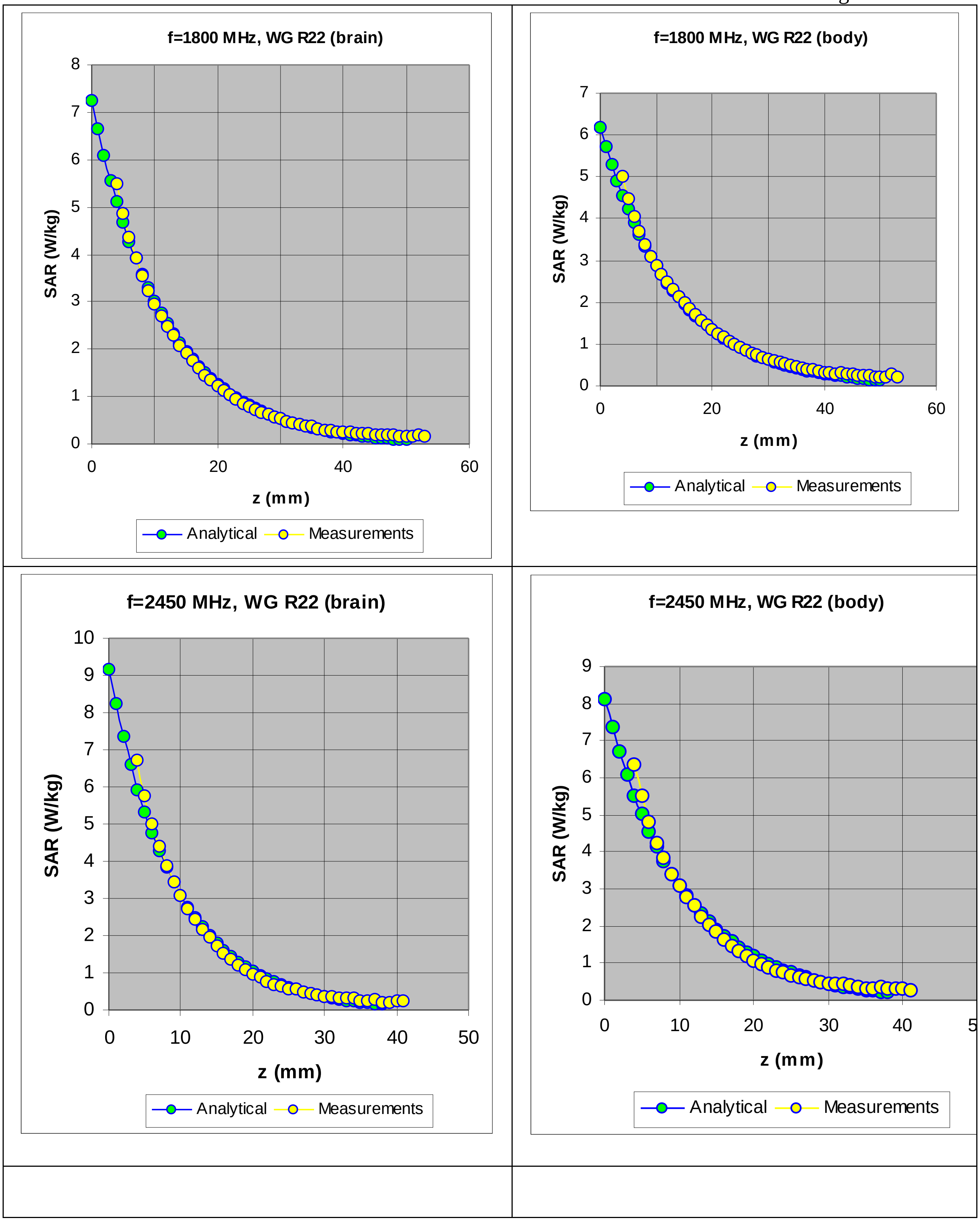


Figure 6. The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

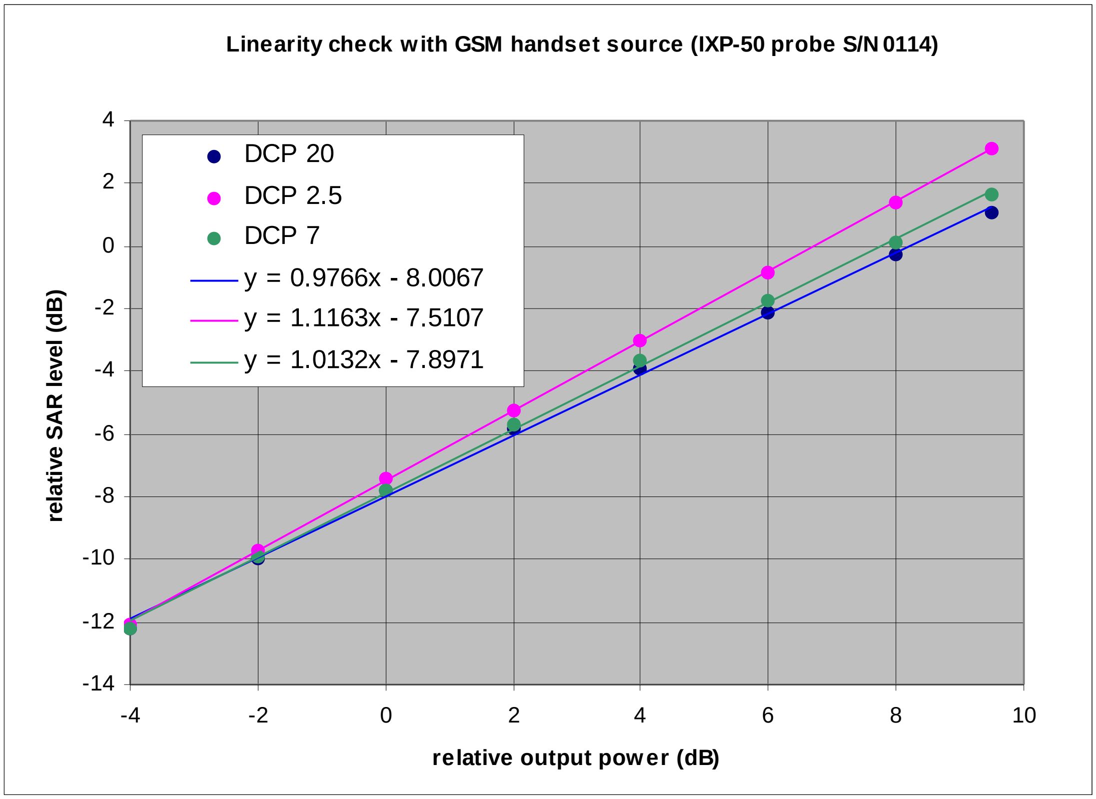


Figure 7. The GSM response of IXP-050 probe S/N 0114 at 1800MHz (max. SAR level 1.6 W/kg)

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

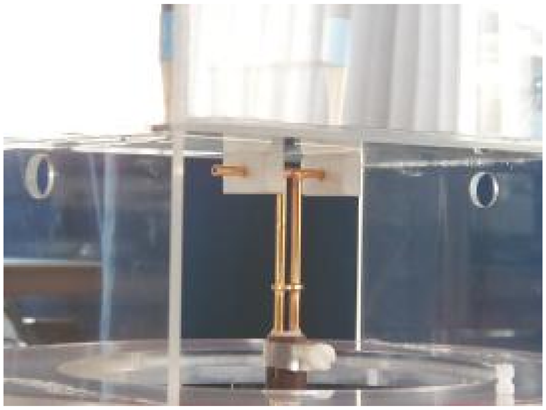
Liquid used	*Relative permittivity (measured)*	*Conductivity (S/m) (measured)*
835 MHz BRAIN	*42.85*	*0.90*
900 MHz BRAIN	*42.43*	*1.01*
1800 MHz BRAIN	*39.09*	*1.37*
1800 MHz BODY	*52.53*	*1.49*
1900 MHz BRAIN	*38.6*	*1.48*
1900 MHz BODY	*52.21*	*1.60*
2450 MHz BRAIN	*38.13*	*1.82*
2450 MHz BODY	*55.28*	*1.92*

Report No. SN0048_2450
26th March 2003

INDEXSAR
2450MHz validation Dipole
Type IXD-245 **S/N 0048**

Performance measurements

- ***MI Manning***



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Calibration / Conformance statement
Balanced Validation dipole

Type:	**IXD-245 2450MHz**

Manufacturer:	**IndexSAR, UK**

Serial Number:	**0048**

Place of Calibration:	**IndexSAR, UK**

IndexSAR Limited hereby declares that the IXD series dipole named above has been checked for conformity to the specifications given in the draft IEEE 1528 and CENELEC En 50361 standards on the date shown below.

Date of Calibration/Check:	**26th March 2003**

The dipole named above should be periodically re-checked using the procedures set out in the dipole calibration document. It is important that the cautions regarding handling of the dipoles (given in the calibration document) are adhered to.

Next Calibration Date:	**March 2005**

The calibration measurements were 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: kmLadley

Approved By: M.J.Manif

1. Tests on Validation Dipole

Tests have been performed on a balanced dipole made for 2450MHz application according to the construction guidelines, dimensions and tolerances given in the draft IEEE1528 standard [1]. Measurements have been made of the impedance and return loss when positioned against the liquid-filled phantom and a validation test has been performed according to the procedures set out in IEEE 1528 [1].

2. 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).

3. SAR Validation Measurement

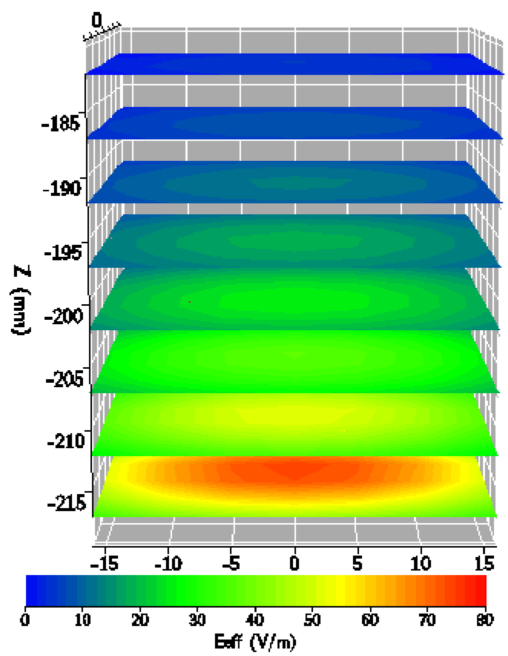
A SAR validation check was performed with the box-phantom located on the SARA2 phantom support base on the SARA2 robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 24^{o}C.

The phantom was filled with a 2450MHz brain liquid using a recipe from [1], which was measured using an Indexsar DiLine kit at 2450MHz. Measurements were taken at 23°C and 30°C and interpolation was used to find the properties at 24°C which were as below:

Relative Permittivity **39.221**
Conductivity **1.8714 S/m**

The SARA2 software version 0.420N was used with an Indexsar probe previously calibrated using waveguide techniques.

The 3D measurement made using the dipole at the bottom of the phantom box is shown below:



The volume-averaged SAR results, normalised to an input power of 1W (forward power) are:

Averaged over 1 cm^3 (1g) of tissue **51.376 W/kg**
Averaged over $10cm^3$ (10g) of tissue **23.888 W/kg**

These results can be compared with Table 8.1 in [1]. The agreement is within 10%.

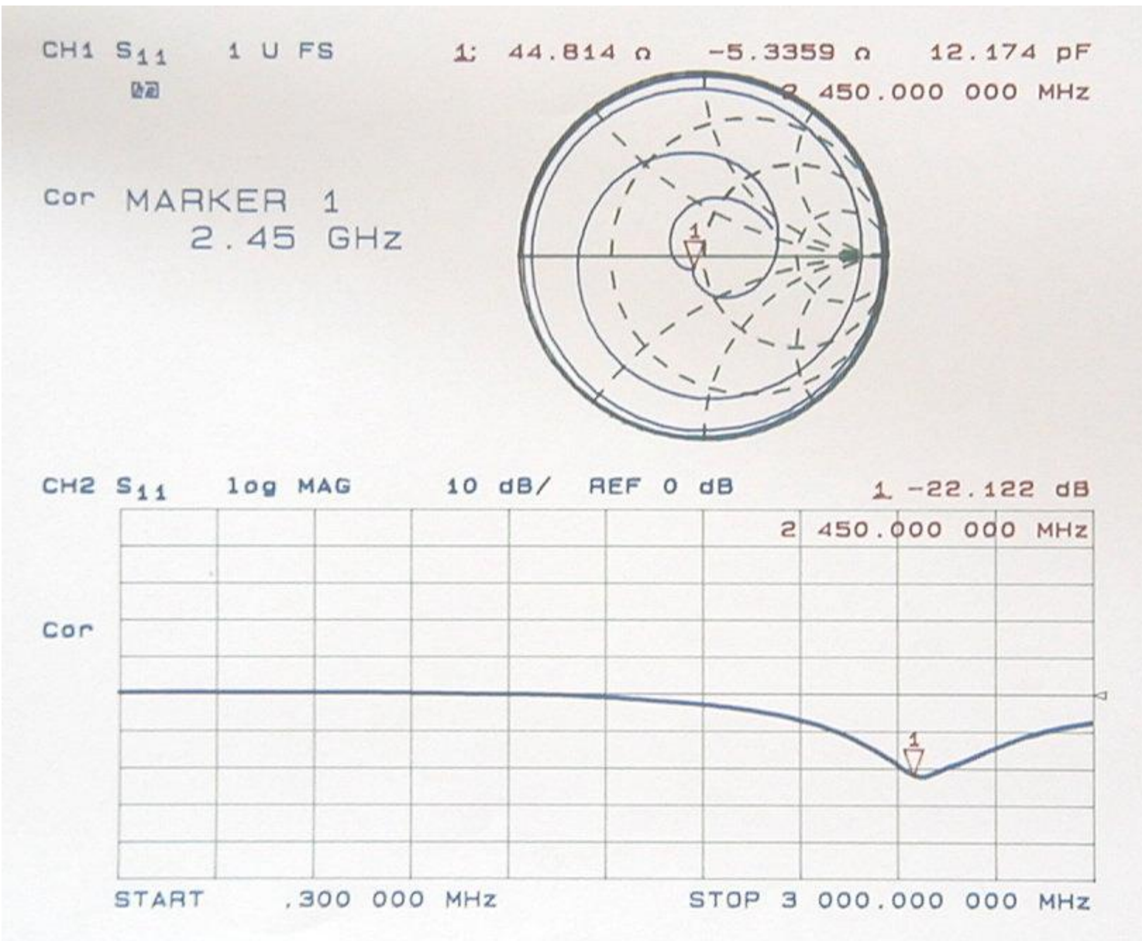
4. Dipole impedance and return loss

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 2450MHz). 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 2450 MHz Re{Z} = **44.814 Ω**
Im{Z} = **-5.3359 Ω**

Return loss at 2450MHz **-22.122 dB**



5. 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.

6. 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.

7. Reference

[1] Draft recommended practice for determining the peak spatial-average specific absorption rate (SAR) in the human body due to wireless communications devices: Measurement Techniques. Draft CD1.1 – December 29, 2002.