Specific Absorption Rate (SAR) Test Report

for

Giant Electronics Ltd.

on the

Two Way Radio With GMRS and FRS

Model Number: R1050

Test Report: EME-050881
Issue date: Sep. 12, 2005

Total No of Pages Contained in this Report: 78

Tested by: Kevin Chen	Kevin Chen
Reviewed by: Jerry Liu	Jerry Liu

Review Date: Sep. 12, 2005

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1.0 General information

The Giant sample device, model # R1050 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. The maximum output power declared by the Giant.

The EUT was evaluated in a face-held configuration with the front of the radio placed parallel to the outer surface of the planar. A 2.5cm separation distance was maintained between the front side of the EUT and the outer surface of the planar phantom for the duration of the test.

The EUT was tested in a body-worn configuration with the rear of the radio placed parallel to outer surface of the planar phantom. The attached plastic belt-clip was touching the planar phantom. The EUT was evaluated for body-worn SAR with the microphone accessory.

For the evaluation, the dosimetric assessment system INDEXSAR SARA2 was used. The phantom employed was the box phantom of 6 mm 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 ±20.6%.

The device was tested in unmodulated continuous transmit operation (Continuous Wave at 100% duty cycle) with the transmit key constantly depressed. For a push-to-talk device, the 50% duty cycle compensation reported assumes a transmit/ receive cycle of equal time base.

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

Phantom	Position (Worst case)	SAR_{1g}, W/kg
6 mm thick box phantom wall for face-held evaluation	For head used: EUT front to the phantom, 25 mm separation. 462MHz band _channel 4 with general alkaline batteries	0.337 W/kg

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.

1.1 Client Information

The R1050 has been tested at the request of:

Applicant: **Giant Electronics Ltd.**
9/F., Elite Industrial Bldg., 135-137 Hoi Bun Road, Kwun Tong, Kowloon, Hong Kong

1.2 Equipment under test (EUT)

Product Descriptions:

Equipment	**Two Way Radio with FRS and GMRS**		
Trade Name	RCA	**Model No:**	R1050
FCC ID	K7GR1050	**S/N No.**	Not Labeled
Category	Portable	**RF Exposure**	Uncontrolled Environment
Frequency Band	462.5625 – 462.7125 MHz for FRS 467.5625 – 467.7125 MHz for FRS 462.5625 – 462.7125 MHz for GMRS 462.5500 – 462.7250 MHz for GMRS	**System**	F3E

EUT Antenna Description			
Type	Integral/ helix	**Configuration**	Fixed
Dimensions	82 mm length	**Gain**	-2.0 dBi
Location	Embedded		

Use of Product : **Two Way Radio With GMRS and FRS**

Manufacturer: RCA

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

EUT receive date: Aug. 11, 2005

EUT status: Normal operating condition

Test start date: Sep. 2, 2005

Test end date: Sep. 2, 2005

1.3 Test plan reference

FCC Rule: Part 2.1093, FCC's OET Bulletin 65, Supplement C (Edition 01-01) and IEEE 1528

1.4 Test configuration

Please refer to section 2.2 figure 2 ~ 5

1.4.1 Support equipment & EUT antenna position

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

1.4.2 Test Condition

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

Usage	Operates with a built-in test mode by client	**Distance between antenna axis at the joint and the liquid surface:**	For head, EUT front to phantom, 25 mm separation. For body, EUT rear with belt-clip to phantom, 0 mm separation	
Simulating human Head/ Body	Head and Body	**EUT Battery**	Fully-charged with 1 Nickel-Metal batteries Brand-new with 4 general alkaline batteries	
E.R.P. for 462MHz Band	**Channel**	**Frequency MHz**	**Before SAR Test (dBm)**	**After SAR Test (dBm)**
	Mid Channel – 4	462.6375	32.0	31.9
E.R.P. for 467MHz Band	**Channel**	**Frequency MHz**	**Before SAR Test (dBm)**	**After SAR Test (dBm)**
	Mid Channel – 11	467.6375	25.7	25.6

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

The EUT has built-in test mode that used to evaluate SAR.

The EUT was transmitted continuously during the test (Continuous Wave at 100% duty cycle). For a push-to-talk device, the 50% duty cycle compensation reported assumes a transmit/ receive cycle of equal time base.

The EUT take Nickel-Metal and general alkaline batteries as its power source. Each test was proceeded with fully-charged batteries.

1.5 Modifications required for compliance

The EUT has no modifications during test.

2.0 SAR Evaluation

The evaluation of the result analysis was based on software: SARA2 Version 2.33VPM (**V**irtual **P**robe **M**iniaturization).

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

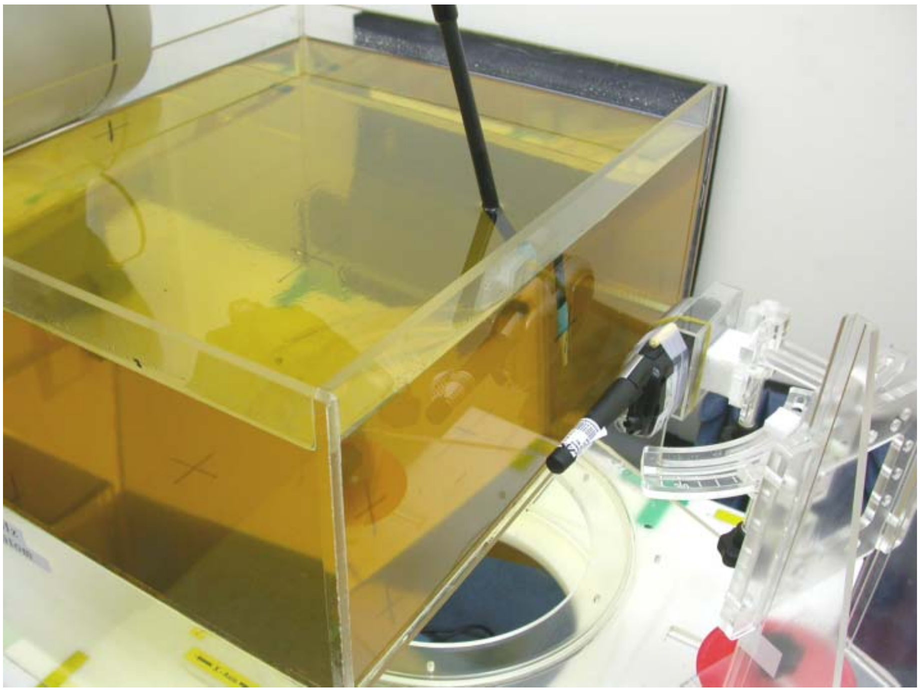
2.2 Configuration Photographs

SAR Measurement Test Setup

Figure 1: Test System

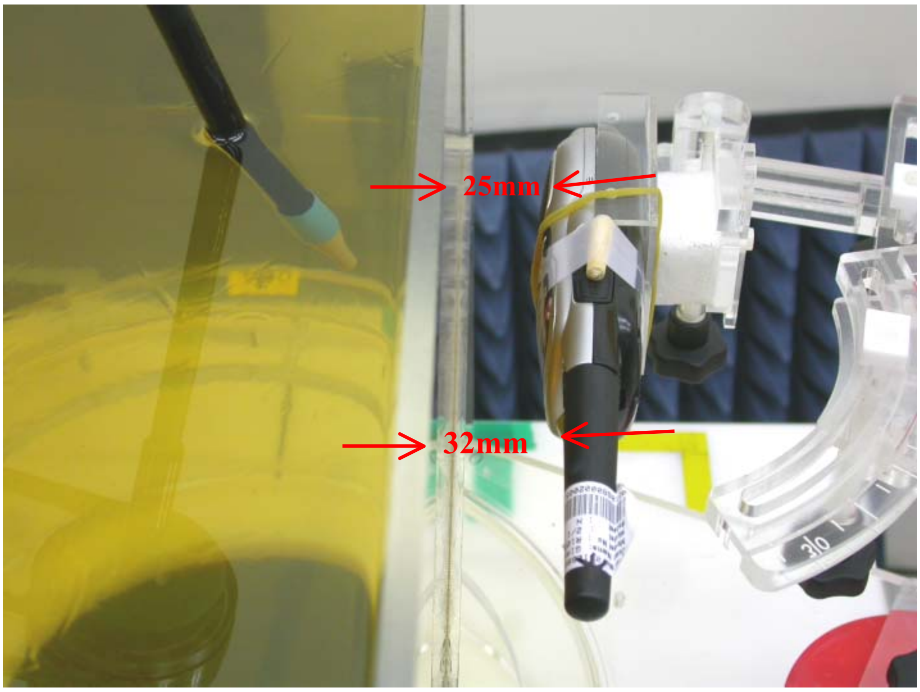
SAR Measurement Test Setup

Figure 2: For head, EUT front to phantom, 25 mm separation



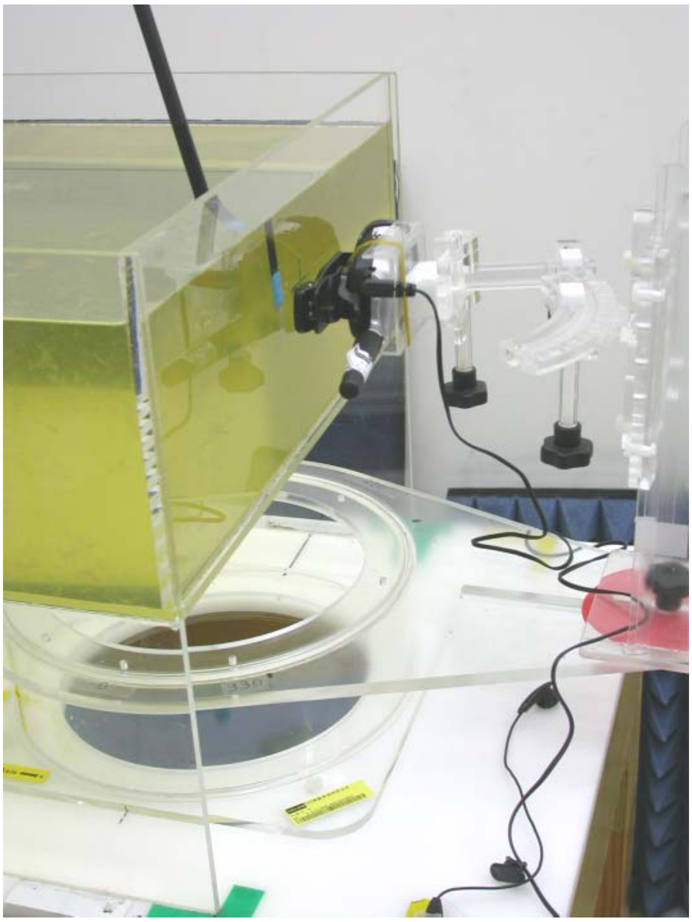
SAR Measurement Test Setup

Figure 3: For head, EUT front to phantom, 25 mm separation – Zoom In



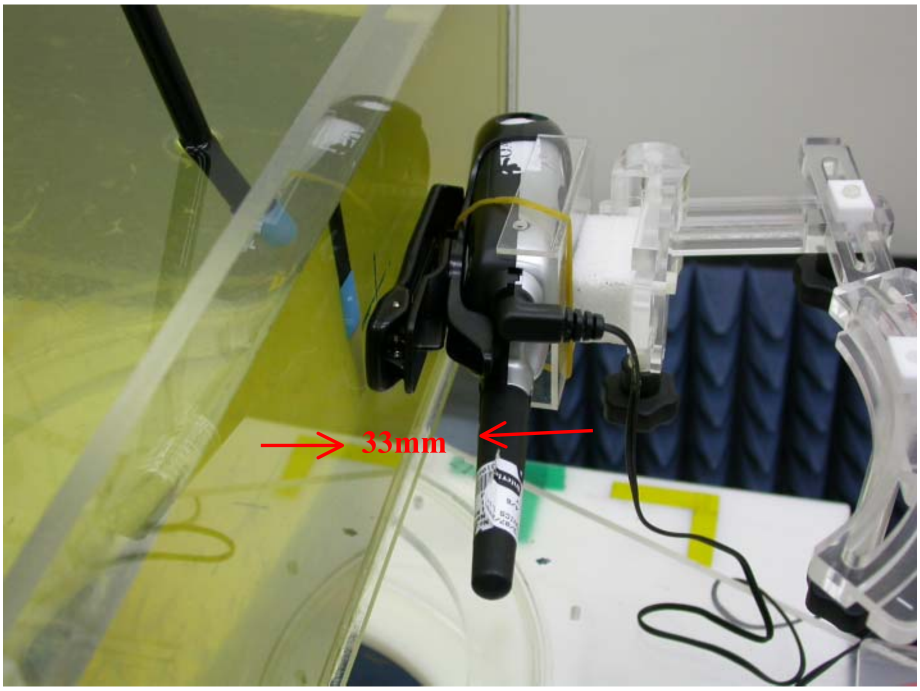
SAR Measurement Test Setup

Figure 4: For body, EUT rear with belt-clip and microphone to phantom, 0 mm separation



SAR Measurement Test Setup

Figure 5: For body, EUT rear with belt-clip and microphone to phantom, 0 mm separation-Zoon In



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.

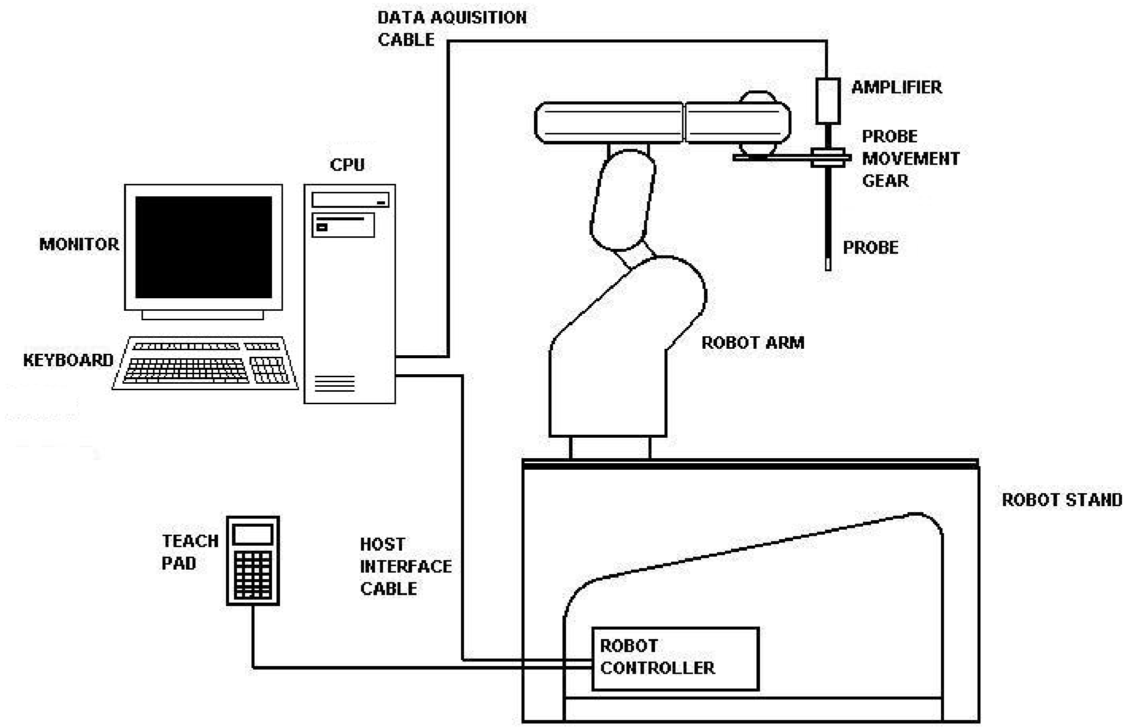


Figure 1: Schematic diagram of the SAR measurement system

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.

The first 2 measurements points in a direction perpendicular to the surface of the phantom during the zoom scan and closest to the phantom surface, were only 3.5mm and the probe is kept at greater than half a diameter from the surface.

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 450 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 15 mm for 300 ~ 1000 MHz and 10 mm for 1000 ~ 3000 MHz from the inner surface of the shell. The feed power was 1/5W.

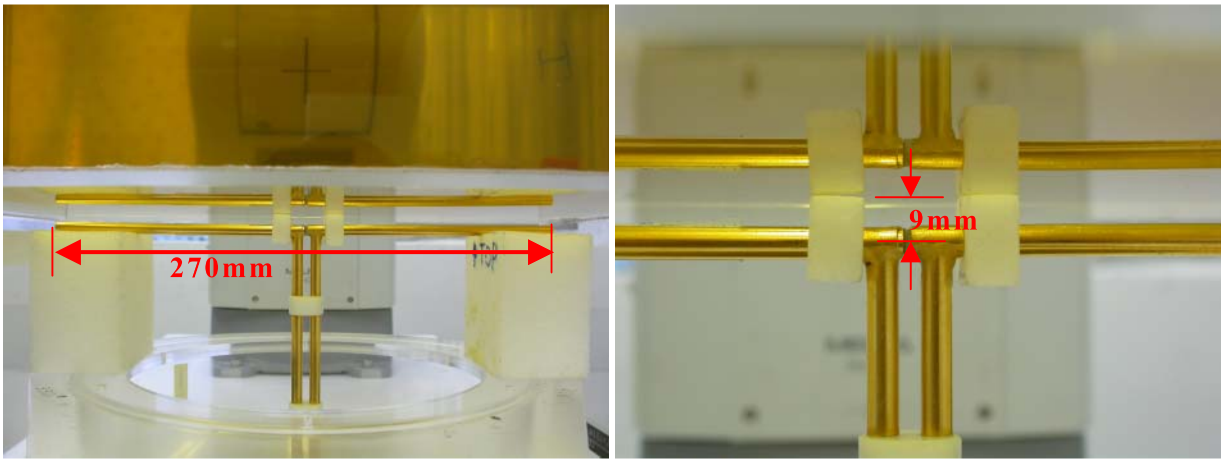
b. The dimension for this cube is 32 mm x 32 mm x 34 mm was assessed by measuring 5 x 5 x 7 points. On the basis of this data set, the spatial peak SAR value was evaluated with the following procedure:

   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-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.

The test scan procedure for system validation also apply to the general scan procedure except for the set-up position. For general scan, the EUT was placed at the side of phantom. For validation scan, the dipole antenna was placed at the bottom of phantom



2.4.1 System Validation result

System Validation (450 MHz Head)				
Frequency MHz	**Operating Mode**	**Target SAR_{1g} (W/kg)**	**Measured SAR_{1g} (W/kg)**	**Deviation** (±10%)
450	CW	4.9	5.055	3.16%

Please see the plot below:

Date:	2005/7/25	**Position:**	bottom to the Phantom
Filename:	450per. check.txt	**Phantom:**	HeadBox3-450-val..csv
Device Tested:	450 performance check	**Head Rotation:**	0
Antenna:	450 Dipole Antenna	**Test Frequency:**	450MHz
Shape File:	none.csv	**Power Level:**	23 dBm

Probe: 0114
Cal File: SN0114_450_CW_HEAD

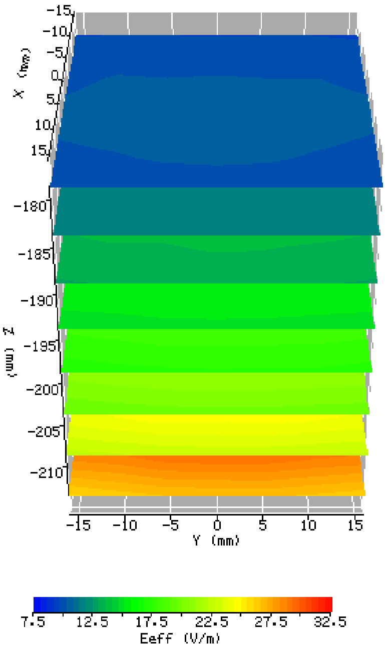
Cal Factors:

	X	Y	Z
Air	438	359	403
DCP	20	20	20
Lin	.424	.424	.424

Amp Gain: 2
Averaging: 1
Batteries Replaced: -

Liquid:	15.5cm
Type:	450 MHz Head
Conductivity:	0.8709
Relative Permittivity:	43.9376
Liquid Temp (deg C):	22.5
Ambient Temp (deg C):	23
Ambient RH (%):	55
Density (kg/m3):	1000
Software Version:	2.33VPM

Crest Factor = 1



ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.253	0.254

Change during Scan (%): 0.21

Max E-field (V/m): 30.52

	1g	10g
Max SAR (W/kg)	1.011	0.690

	X	Y	Z
Location of Max (mm):	2.7	2.7	-221.7

Normalized to an input power of 1W Averaged over 1 cm^3 (1g) of tissue
5.055W/kg

2.4.2 System Performance Check result

System performance check (450 MHz Head)				
Frequency MHz	**Operating Mode**	**Target SAR_{1g} (W/kg)**	**Measured SAR_{1g} (W/kg)**	**Deviation (±10%)**
450	CW	4.9	4.99	1.84%

Please see the plot below:

Date:	2005/9/1	**Position:**	bottom to the Phantom
Filename:	450per. check.txt	**Phantom:**	HeadBox3-450-val..csv
Device Tested:	450 performance check	**Head Rotation:**	0
Antenna:	450 Dipole Antenna	**Test Frequency:**	450MHz
Shape File:	none.csv	**Power Level:**	23 dBm

Probe: 0114

Cal File: SN0114_450_CW_HEAD

Cal Factors:

	X	Y	Z
Air	438	359	403
DCP	20	20	20
Lin	.424	.424	.424

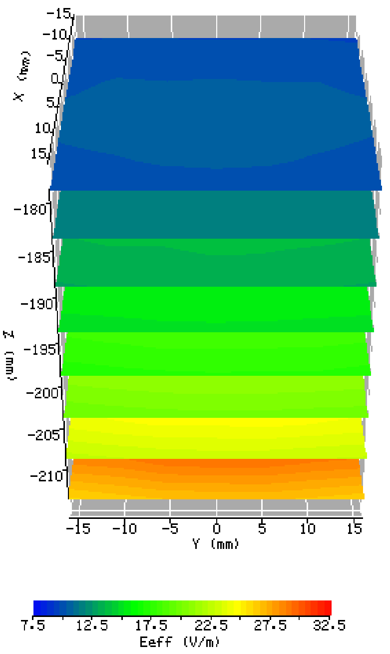
Amp Gain: 2

Averaging: 1

Batteries Replaced: -

Liquid:	15.5cm
Type:	450 MHz Head
Conductivity:	0.871
Relative Permittivity:	43.938
Liquid Temp (deg C):	22.5
Ambient Temp (deg C):	23
Ambient RH (%):	55
Density (kg/m3):	1000
Software Version:	2.33VPM

Crest Factor = 1



ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.254	0.254

Change during Scan (%) 0.11

Max E-field (V/m): 30.55

	1g	10g
Max SAR (W/kg)	0.998	0.681

	X	Y	Z
Location of Max (mm):	2.7	2.7	-221.5

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

4.99W/kg

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

Trade Name:	RCA	**Model No.:**	R1050
Serial No.:	Not Labled	**Test Engineer:**	Kevin Chen
TEST CONDITIONS			
Ambient Temperature	22.5°C	**Relative Humidity**	58 %
Test Signal Source	Test Mode	**Signal Modulation**	F3E
Output Power Before SAR Test	See section 1.4.2	**Output Power After SAR Test**	See section 1.4.2
Test Duration	23 min. each scan	**Number of Battery Change**	Fully Charged battery for each Scan

Test Mode: Head evaluation with general alkaline battery

EUT Position							
Channel (MHz)	**Operating Mode**	**Crest Factor**	**Description**	**Distance (mm)**	**Measured SAR_{1g} (W/kg) Duty Cycle**		**Plot Number**
					100%	**50%**	
462.6375 (CH4)	F3E	1	Front to phantom	25	0.674	0.337	1
467.6375 (CH11)	F3E	1	Front to phantom	25	0.592	0.296	2

Note: Duty Cycle 100% is the measured value, and 50% is the half of the measured value

Test Mode: Head evaluation with Nickel-Metal battery

EUT Position							
Channel (MHz)	**Operating Mode**	**Crest Factor**	**Description**	**Distance (mm)**	**Measured SAR_{1g} (W/kg) Duty Cycle**		**Plot Number**
					100%	**50%**	
462.6375 (CH4)	F3E	1	Front to phantom	25	0.580	0.290	3
467.6375 (CH11)	F3E	1	Front to phantom	25	0.511	0.2555	4

Note: Duty Cycle 100% is the measured value, and 50% is the half of the measured value

Test Mode: Body evaluation with belt-clip and microphone with general alkaline battery

EUT Position							
Channel (MHz)	**Operating Mode**	**Crest Factor**	**Description**	**Distance (mm)**	**Measured SAR_{1g} (W/kg)**		**Plot Number**
					Duty Cycle		
					100%	**50%**	
462.6375 (CH4)	F3E	1	Rear to phantom	0	0.345	0.1725	5
467.6375 (CH11)	F3E	1	Rear to phantom	0	0.309	0.1545	6

Note: Duty Cycle 100% is the measured value, and 50% is the half of the measured value

Test Mode: Body evaluation with belt-clip and microphone with Nickel-Metal battery

EUT Position							
Channel (MHz)	**Operating Mode**	**Crest Factor**	**Description**	**Distance (mm)**	**Measured SAR_{1g} (W/kg)**		**Plot Number**
					Duty Cycle		
					100%	**50%**	
462.6375 (CH4)	F3E	1	Rear to phantom	0	0.362	0.181	7
467.6375 (CH11)	F3E	1	Rear to phantom	0	0.242	0.121	8

Note: Duty Cycle 100% is the measured value, and 50% is the half of the measured value

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**	Intertek ID No.	LAST CAL. DATE
Balanced Validation dipole	**450MHz**	EC381-1	10/2003
Controller	**Mitsubishi CR-E116**	EP320-1	N/A
Robot	**Mitsubishi RV-E2**	EP320-2	N/A
	Repeatability: ± 0.04mm; Number of Axes: 6		
E-Field Probe	**IXP-050**	EC356	03/2005
	Frequency Range: 450MHz ~ 2450MHz 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. 2.33VPM (**V**irtual **P**robe **M**inaturisation)		
Phantom	**6 mm wall thickness box phantom**	N/A	N/A
	Shell Material: clear Perspex; Thickness: 5.6 ± 0.1 mm; Capacity: 333 x 400 x 170 (W x L x D) mm^3; Dielectric constant: less than 2.85 above 500MHz;		
Device holder	**Material: clear Perspex**	N/A	N/A
	Dielectric constant: less than 2.85 above 500MHz		
Simulated Tissue	**Mixture**	N/A	09/01/2005
	Please see section 3.2 for details		
Vector Network Analyzer	**HP 8753B** **HP 85046A**	EC375	08/19/2005
	300k to 3GHz		
Signal Generator	**R&S SMR27**	EC354	08/16/2005
	10M to 27GHz, <120dBuV		
Wideband Peak Power Meter/ Sensor	**Anritsu ML2497A with MA2491A Power sensor**	EC396	10/19/2004
	Frequency Range: 100MHz~18GHz		

3.2 Tissue Simulating Liquid

The head and body tissue parameters should be used to test operating frequency band of transmitters. When a transmission band overlaps with one of the target frequencies, the tissue dielectric parameters of the tissue medium at the middle of a device transmission band should be within ±5% of the parameters specified at that target frequency.

3.2.1 Body Tissue Simulating Liquid for evaluation test

Body Ingredients Frequency (450 MHz)	
Water	51.16%
Salt	1.49%
Sugar	46.78%
HEC (Hydroxyethyl Cellulose)	0.52%
Bactericide	0.05%

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. (℃)	ε_r / Relative Permittivity			σ / Conductivity (mho/m)			ρ *(kg/m^3)
		measured	target	△(±5%)	measured	target	△(±5%)	
450	21.5	57.428	56.7	1.28%	0.945	0.94	0.53%	1000

* *Worst-case assumption*

3.2.2 Head Tissue Simulating Liquid for System performance Check and evaluation test

Head Ingredients Frequency (450 MHz)	
Water	38.56%
Salt	3.95%
Sugar	56.32%
HEC (Hydroxyethyl Cellulose)	0.98%
Bactericide	0.19%

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. (℃)	ε_r / Relative Permittivity			σ / Conductivity (mho/m)			ρ *(kg/m^3)
		measured	target	△(±5%)	measured	target	△(±5%)	
450	22.6	43.938	43.5	1.01%	0.871	0.87	0.11%	1000

* *Worst-case assumption*

3.2.3 Body Liquid results

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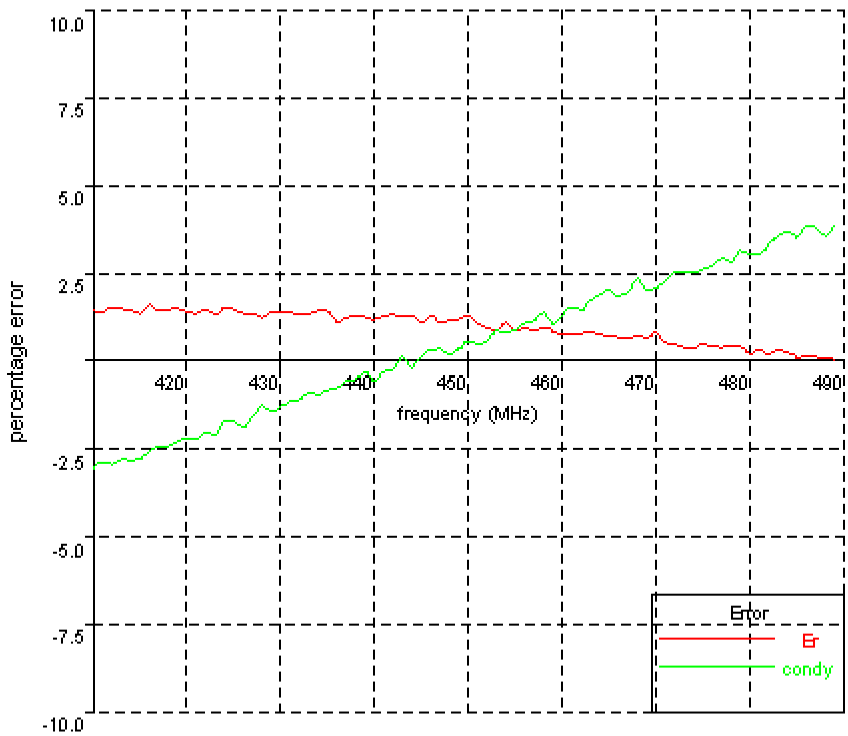
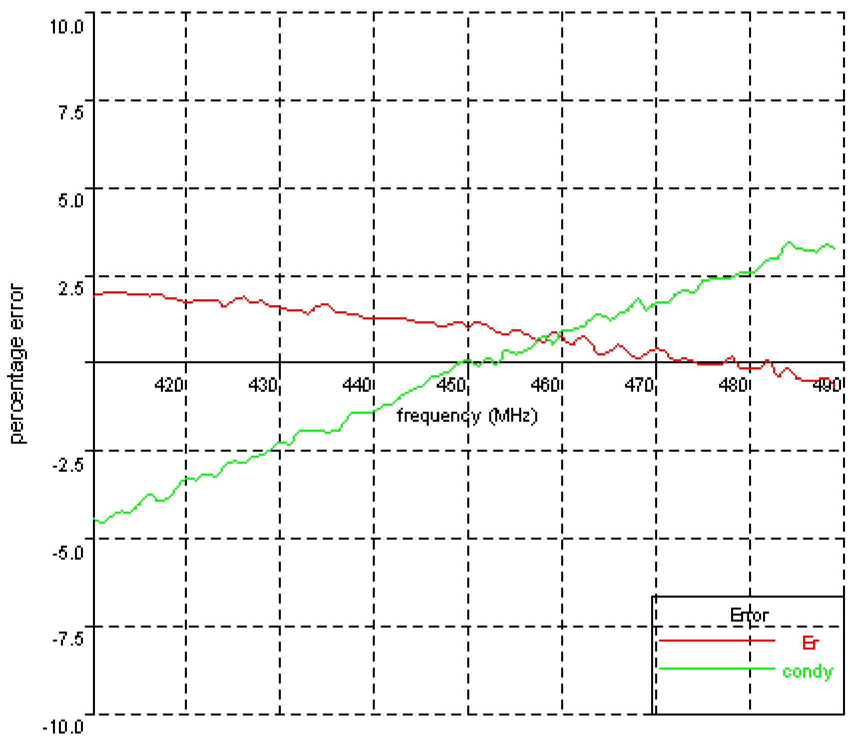


3.2.4 Head Liquid results

Date: 01 Sep. 2005	Temperature: 22.6 ℃	Type: 450 MHz/ head	Tested by: Kevin
410, 44.8214404351, -0.8315216002		450, 43.9375513667, -0.8709447739	
411, 44.8434065273, -0.8304108699		451, 44.0047789246, -0.8694636642	
412, 44.839592397, -0.8321952991		452, 43.9469742818, -0.8713279971	
413, 44.8320199384, -0.8332735022		453, 43.8677389057, -0.869974197	
414, 44.7928943316, -0.8330933059		454, 43.8278573749, -0.8736694081	
415, 44.7737739856, -0.8352466506		455, 43.8783115424, -0.8728303504	
416, 44.7572719502, -0.8375983831		456, 43.8352246953, -0.8736420412	
417, 44.7518339417, -0.8358640536		457, 43.7599128336, -0.8753521785	
418, 44.7002838434, -0.8363985226		458, 43.7254413266, -0.877374198	
419, 44.6721084598, -0.8393895362		459, 43.8382212091, -0.8755811717	
420, 44.6101750133, -0.8414950818		460, 43.768221392, -0.8790292285	
421, 44.6266154347, -0.8410441751		461, 43.669847328, -0.8791771421	
422, 44.6320375685, -0.8424920951		462, 43.7693624471, -0.8799696183	
423, 44.6210085661, -0.8420925614		463, 43.6925711469, -0.8817993071	
424, 44.5162102633, -0.844455957		464, 43.5280415123, -0.883082795	
425, 44.5873170698, -0.8457191612		465, 43.5776219416, -0.8820106837	
426, 44.6129083866, -0.8453666496		466, 43.6385720762, -0.8834099456	
427, 44.5264668771, -0.8467768532		467, 43.5463461015, -0.8846936593	
428, 44.5445000961, -0.8473428841		468, 43.4646644746, -0.8874254193	
429, 44.4553534963, -0.8488033175		469, 43.5196399186, -0.8847783291	
430, 44.4357293368, -0.8505406415		470, 43.5676227962, -0.8865894353	
431, 44.3920951265, -0.8498693243		471, 43.5140928254, -0.8866188577	
432, 44.3867014869, -0.85336773		472, 43.4107898652, -0.8887531221	
433, 44.3158258697, -0.8534102762		473, 43.4299541992, -0.8898263686	
434, 44.4099777103, -0.8533505157		474, 43.3920521972, -0.8896457421	
435, 44.406200445, -0.8529937178		475, 43.3441758812, -0.8923321067	
436, 44.2986256643, -0.8532850579		476, 43.3409631953, -0.8930664391	
437, 44.2757887682, -0.8559021796		477, 43.3516679998, -0.8933724941	
438, 44.2508667412, -0.8578294968		478, 43.4277738797, -0.8935335743	
439, 44.1948863309, -0.8576761911		479, 43.2875566753, -0.8947770463	
440, 44.1660635965, -0.8581529935		480, 43.2859788438, -0.89488705	
441, 44.1644537435, -0.8597549993		481, 43.2791420152, -0.8964644475	
442, 44.1487122719, -0.8601195736		482, 43.3763609414, -0.8982517922	
443, 44.1345851752, -0.862201712 5		483, 43.1568614324, -0.8988674644	
444, 44.1042194221, -0.8632763488		484, 43.2593070359, -0.9027080026	
445, 44.0641228995, -0.8645075832		485, 43.1295888522, -0.9012763413	
446, 44.0578055433, -0.8663039718		486, 43.1035547042, -0.9010938052	
447, 43.9884171048, -0.8670963478		487, 43.0949968165, -0.900723819	
448, 44.0078364409, -0.8682460928		488, 43.1213547849, -0.9024965867	
449, 44.0256596147, -0.8700043978		489, 43.0221203877, -0.9015246407	
		490, 43.0802002502, -0.9042543973	



3.3 E-Field Probe and 450 Balanced Dipole Antenna Calibration

Probe calibration factors and dipole antenna calibration are included in Appendix C.

4.0 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 20.6 % for SAR measurement, and the extended uncertainty (95% confidence level) was assessed to be 20.2 % for system performance check.

Table 1 Exposure Assessment Uncertainty

Example of measurement uncertainty assessment SAR measurement

(blue entries are site-specific)

a	b			c	d	e		f	g	h	I
Uncertainty Component	Sec.	Tol. (+/-)			Prob. Dist.	Divisor (descrip)	Divisor (value)	c1 (1g)	c1 (10g)	Standard Uncertainty (%) 1g	Standard Uncertainty (%) 10g
		(dB)		(%)							
Measurement System											
Probe Calibration	E2.1			2.5	N	1 or k	1	1	1	2.50	2.50
Axial Isotropy	E2.2	0.25	5.93	5.93	R	√3	1.73	0	0	0.00	0.00
Hemispherical Isotropy	E2.2	0.45	10.92	10.92	R	√3	1.73	1	1	6.30	6.30
Boundary effect	E2.3		4	4.00	R	√3	1.73	1	1	2.31	2.31
Linearity	E2.4	0.04	0.93	0.93	R	√3	1.73	1	1	0.53	0.53
System Detection Limits	E2.5		1	1.00	R	√3	1.73	1	1	0.58	0.58
Readout Electronics	E2.6		1	1.00	N	1 or k	1.00	1	1	1.00	1.00
Response time	E2.7		0	0.00	R	√3	1.73	1	1	0.00	0.00
Integration time	E2.8		1.4	1.40	R	√3	1.73	1	1	0.81	0.81
RF Ambient Conditions	E6.1		3	3.00	R	√3	1.73	1	1	1.73	1.73
Probe Positioner Mechanical Tolerance	E6.2		0.6	0.60	R	√3	1.73	1	1	0.35	0.35
Probe Position wrt. Phantom Shell	E6.3		3	3.00	R	√3	1.73	1	1	1.73	1.73
SAR Evaluation Algorithms	E5		8	8.00	R	√3	1.73	1	1	4.62	4.62
Test Sample Related											
Test Sample Positioning	E4.2		2	2.00	N	1	1.00	1	1	2.00	2.00
Device Holder Uncertainty	E4.1		2	2.00	N	1	1.00	1	1	2.00	2.00
Output Power Variation	6.6.2		5	5.00	R	√3	1.73	1	1	2.89	2.89
Phantom and Tissue Parameters											
Phantom Uncertainty (shape and thickness)	E3.1		4	4.00	R	√3	1.73	1	1	2.31	2.31
Liquid conductivity (Deviation from target)	E3.2		5	5.00	R	√3	1.73	0.64	0.43	1.85	1.24
Liquid conductivity (measurement uncert.)	E3.3		1.1	1.10	N	1	1.00	0.64	0.43	0.70	0.47
Liquid permittivity (Deviation from target)	E3.2		5	5.00	R	√3	1.73	0.6	0.49	1.73	1.41
Liquid permittivity (measurement uncert.)	E3.3		1.1	1.10	N	1	1.00	0.6	0.49	0.66	0.54
Combined standard uncertainty					RSS					10.5	10.3
Expanded uncertainty	(95% Confidence Level)				k=2					**20.6**	**20.3**

Table 2 System Check (Verification)

Example of measurement uncertainty assessment for system performance check

(blue entries are site-specific)

a	b			c	d	e		f	g	h	I
Uncertainty Component	Sec.	Tol. (+/-)			Prob. Dist.	Divisor (descrip)	Divisor (value)	c1 (1g)	c1 (10g)	Standard Uncertainty (%) 1g	Standard Uncertainty (%) 10g
		(dB)		(%)							
Measurement System											
Probe Calibration	E2.1			2.5	N	1 or k	1	1	1	2.50	2.50
Axial Isotropy	E2.2	0.25	5.93	5.93	R	√3	1.73	0	0	0.00	0.00
Hemispherical Isotropy	E2.2	0.45	10.92	10.92	R	√3	1.73	1	1	6.30	6.30
Boundary effect	E2.3		4	4.00	R	√3	1.73	1	1	2.31	2.31
Linearity	E2.4	0.04	0.93	0.93	R	√3	1.73	1	1	0.53	0.53
System Detection Limits	E2.5		1	1.00	R	√3	1.73	1	1	0.58	0.58
Readout Electronics	E2.6		1	1.00	N	1 or k	1.00	1	1	1.00	1.00
Response time	E2.7		0	0.00	R	√3	1.73	1	1	0.00	0.00
Integration time	E2.8		1.4	1.40	R	√3	1.73	1	1	0.81	0.81
RF Ambient Conditions	E6.1		3	3.00	R	√3	1.73	1	1	1.73	1.73
Probe Positioner Mechanical Tolerance	E6.2		0.6	0.60	R	√3	1.73	1	1	0.35	0.35
Probe Position wrt. Phantom Shell	E6.3		3	3.00	R	√3	1.73	1	1	1.73	1.73
SAR Evaluation Algorithms	E5		8	8.00	R	√3	1.73	1	1	4.62	4.62
Dipole											
Dipole axis to liquid distance	8, E4.2		2	2.00	N	1	1.00	1	1	2.00	2.00
Input power and SAR drift measurement	8, 6.6.2		5	5.00	R	√3	1.73	1	1	2.89	2.89
Phantom and Tissue Parameters											
Phantom Uncertainty (thickness)	E3.1		4	4.00	R	√3	1.73	1	1	2.31	2.31
Liquid conductivity (Deviation from target)	E3.2		5	5.00	R	√3	1.73	0.64	0.43	1.85	1.24
Liquid conductivity (measurement uncert.)	E3.3		1.1	1.10	N	1	1.00	0.64	0.43	0.70	0.47
Liquid permittivity (Deviation from target)	E3.2		5	5.00	R	√3	1.73	0.6	0.49	1.73	1.41
Liquid permittivity (measurement uncert.)	E3.3		1.1	1.10	N	1	1.00	0.6	0.49	0.66	0.54
Combined standard uncertainty					**RSS**					10.3	10.1
Expanded uncertainty	(95% Confidence Level)				k=2					**20.2**	**19.9**

5.0 Warning Label Information - USA

See user manual.

6.0 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", Supplement C to OET Bulletin 65, Washington, D.C. 20554, 1997

[3] IEEE Standards Coordinating Committee 34, "IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", IEEE Std 1528™-2003

[4] Industry Canada, "Evaluation Procedure for Mobile and Portable Radio Transmitters with respect to Health Canada's Safety Code 6 for Exposure of Humans to Radio Frequency Fields", Radio Standards Specification RSS-102 Issue 1 (Provisional): September 1999.

7.0 Document History

Revision/ Job Number	Writer Initials	Date	Change
N/A	S.L.	Sep. 12, 2005	Original document

APPENDIX A - SAR Evaluation Data

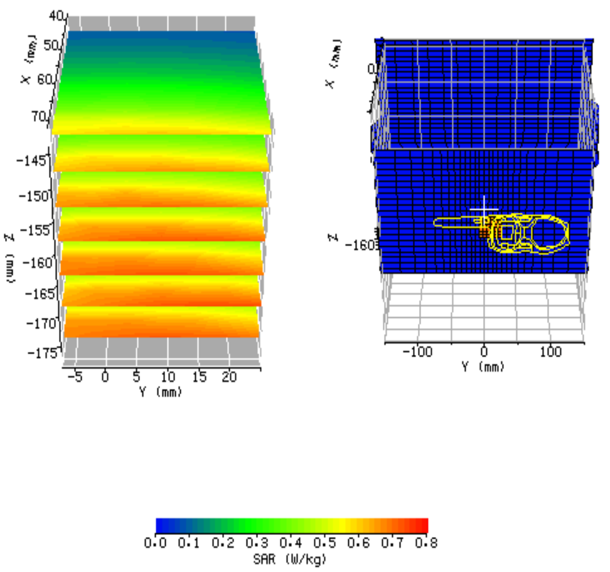
Power drift is the measurement of power drift of the device over one complete SAR scan.
To assess the drift of the power of the device under test, a SAR measurement was made in the middle of the zoom scan volume at the start of the scan and a measurement at this point was then also made after the measurement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

Plot #1(1/2)

Date:	2005/9/2	**Position:**	Front side 25mm to Phantom
Filename:	R1050-head_ch4 with GB.txt	**Phantom:**	HeadBox4-450-newtest.csv
Device Tested:	R1050	**Head Rotation:**	0
Antenna:	Integral Antenna	**Test Frequency:**	CH4_462.6375MHz
Shape File:	R1050-F.csv	**Power Level:**	32.0 dBm

Probe:	0114			
Cal File:	SN0114_450_CW_HEAD			
Cal Factors:		**X**	**Y**	**Z**
	Air	438	359	403
	DCP	20	20	20
	Lin	.424	.424	.424
Amp Gain:	2			
Averaging:	1			
Batteries Replaced:	-			

Liquid:	15.5cm
Type:	450 MHz Head
Conductivity:	0.871
Relative Permittivity:	43.938
Liquid Temp (deg C):	22.5
Ambient Temp (deg C):	22
Ambient RH (%):	58
Density (kg/m3):	1000
Software Version:	2.33VPM



ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.387	0.345

Change during Scan (%) -3.70

Max E-field (V/m): 29.06

	1g	10g
Max SAR (W/kg)	0.674	0.511

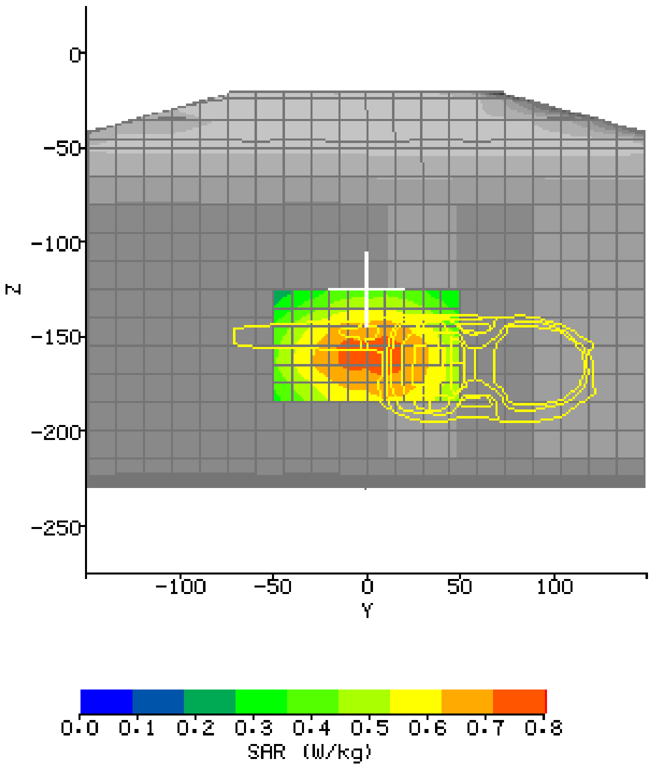
	X	Y	Z
Location of Max (mm):	71.5	-7.0	-168.0

Plot #1(2/2)

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-50.0	50.0	10.0
Z	-185.0	-125.0	6.0



Plot #2(1/2)

Date:	2005/9/2	**Position:**	Front side 25mm to Phantom
Filename:	R1050-head_ch11 with GB.txt	**Phantom:**	HeadBox4-450-newtest.csv
Device Tested:	R1050	**Head Rotation:**	0
Antenna:	Integral Antenna	**Test Frequency:**	CH11_467.6375MHz
Shape File:	R1050-F.csv	**Power Level:**	25.7 dBm

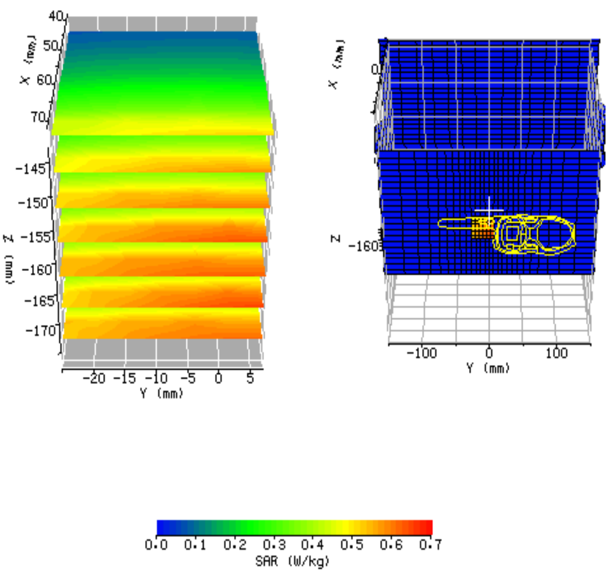
Probe:	0114
Cal File:	SN0114_450_CW_HEAD

Cal Factors:

	X	Y	Z
Air	438	359	403
DCP	20	20	20
Lin	.424	.424	.424

Amp Gain:	2
Averaging:	1
Batteries Replaced:	-

Liquid:	15.5cm
Type:	450 MHz Head
Conductivity:	0.871
Relative Permittivity:	43.938
Liquid Temp (deg C):	22.5
Ambient Temp (deg C):	22
Ambient RH (%):	58
Density (kg/m3):	1000
Software Version:	2.33VPM



ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan**	**End Scan**
	0.336	0.301

Change during Scan (%) -3.96

Max E-field (V/m): 27.42

Max SAR (W/kg)	**1g**	**10g**
	0.592	0.451

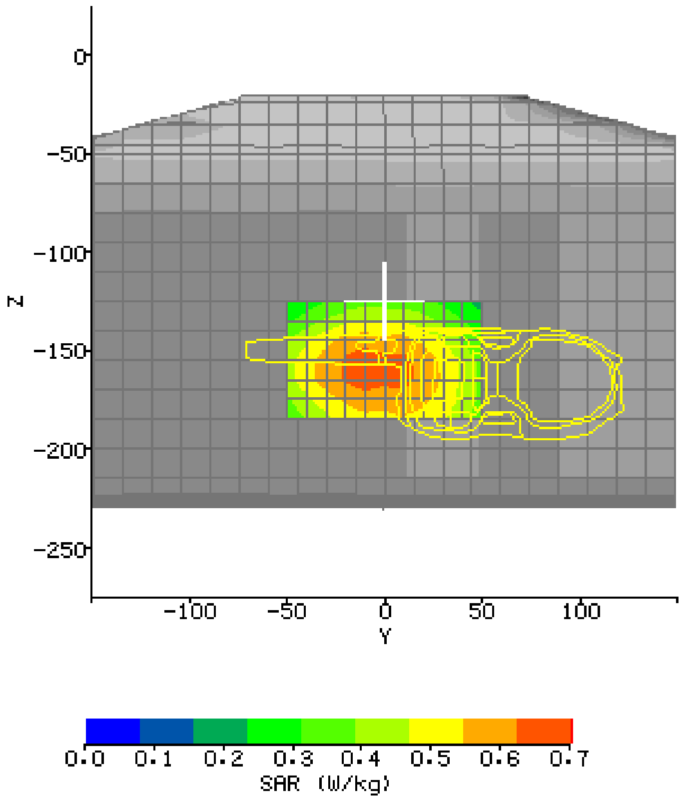
Location of Max (mm):	**X**	**Y**	**Z**
	71.5	-25.0	-166.1

Plot #2(2/2)

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-50.0	50.0	10.0
Z	-185.0	-125.0	6.0



Plot #3(1/2)

Date:	2005/9/2	**Position:**	Front side 25mm to Phantom
Filename:	R1050-head_ch4 with NB.txt	**Phantom:**	HeadBox4-450-newtest.csv
Device Tested:	R1050	**Head Rotation:**	0
Antenna:	Integral Antenna	**Test Frequency:**	CH4_462.6375MHz
Shape File:	R1050-F.csv	**Power Level:**	32.0 dBm

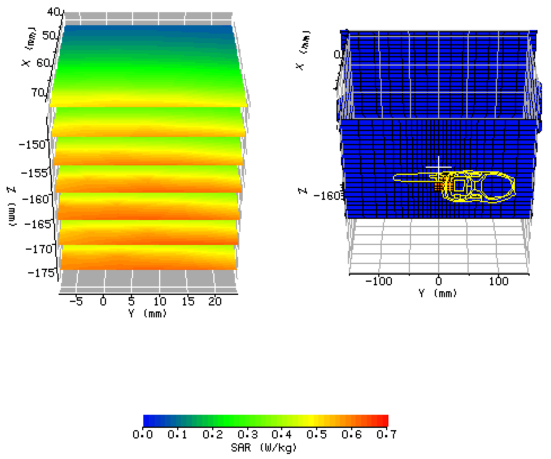
Probe: 0114
Cal File: SN0114_450_CW_HEAD

Cal Factors:

	X	Y	Z
Air	438	359	403
DCP	20	20	20
Lin	.424	.424	.424

Amp Gain: 2
Averaging: 1
Batteries Replaced: -

Liquid:	15.5cm
Type:	450 MHz Head
Conductivity:	0.871
Relative Permittivity:	43.938
Liquid Temp (deg C):	22.5
Ambient Temp (deg C):	22
Ambient RH (%):	58
Density (kg/m3):	1000
Software Version:	2.33VPM



ZOOM SCAN RESULTS:

Spot SAR (W/kg):

Start Scan	End Scan
0.324	0.298

Change during Scan (%) -4.38

Max E-field (V/m): 26.92

Max SAR (W/kg)

1g	10g
0.580	0.442

Location of Max (mm):

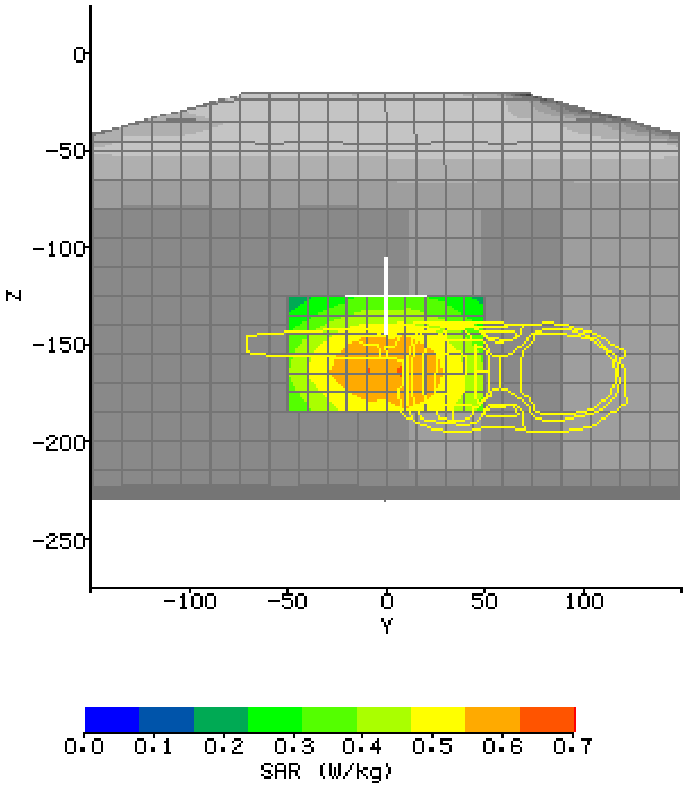
X	Y	Z
71.6	-8.0	-170.9

Plot #3(2/2)

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-50.0	50.0	10.0
Z	-185.0	-125.0	6.0

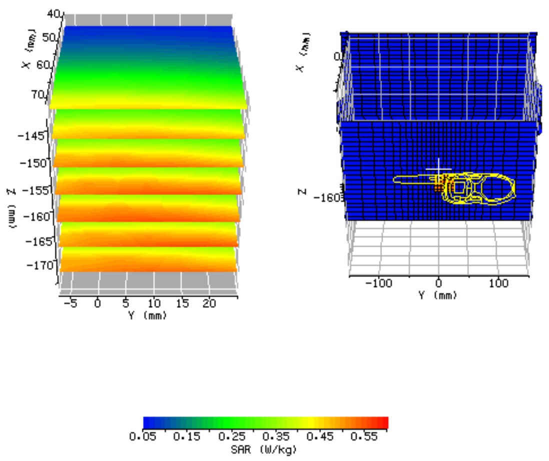


Plot #4(1/2)

Date:	2005/9/2	**Position:**	Front side 25mm to Phantom
Filename:	R1050-head_ch11 with NB.txt	**Phantom:**	HeadBox4-450-newtest.csv
Device Tested:	R1050	**Head Rotation:**	0
Antenna:	Integral Antenna	**Test Frequency:**	CH11_467.6375MHz
Shape File:	R1050-F.csv	**Power Level:**	25.7 dBm

Probe:	0114			
Cal File:	SN0114_450_CW_HEAD			
Cal Factors:		**X**	**Y**	**Z**
	Air	438	359	403
	DCP	20	20	20
	Lin	.424	.424	.424
Amp Gain:	2			
Averaging:	1			
Batteries Replaced:	-			

Liquid:	15.5cm
Type:	450 MHz Head
Conductivity:	0.871
Relative Permittivity:	43.938
Liquid Temp (deg C):	22.5
Ambient Temp (deg C):	22
Ambient RH (%):	58
Density (kg/m3):	1000
Software Version:	2.33VPM



ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan**	**End Scan**
	0.280	0.257

Change during Scan (%) -3.35

Max E-field (V/m): 25.27

Max SAR (W/kg)	**1g**	**10g**
	0.511	0.384

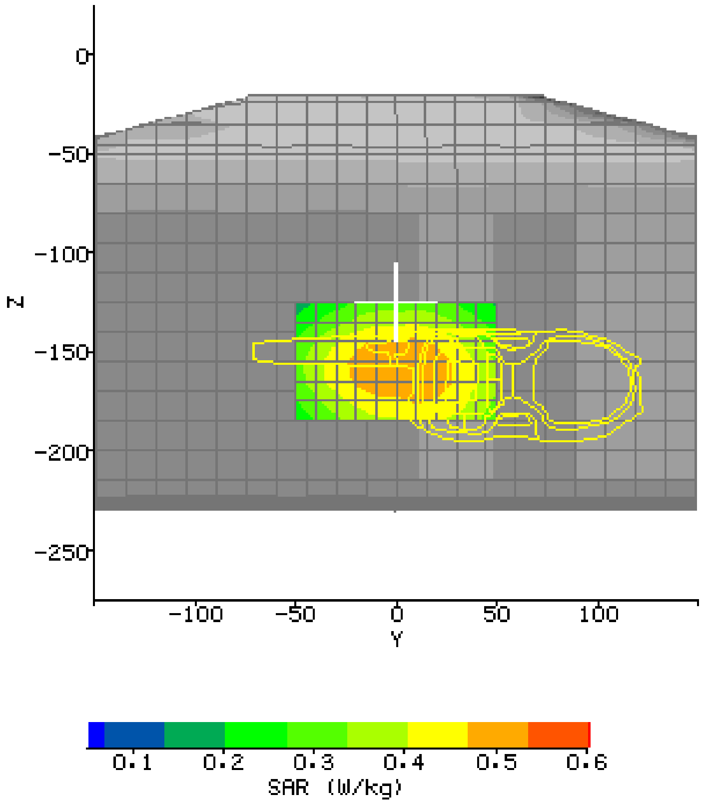
Location of Max (mm):	**X**	**Y**	**Z**
	71.5	-7.0	-164.3

Plot #4(2/2)

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-50.0	50.0	10.0
Z	-185.0	-125.0	6.0



Plot #5(1/2)

Date:	2005/9/2	**Position:**	rear side 0mm to Phantom
Filename:	R1050-body_ch4 with GB.txt	**Phantom:**	HeadBox4-450-newtest.csv
Device Tested:	R1050	**Head Rotation:**	0
Antenna:	Integral Antenna	**Test Frequency:**	CH4_462.6375MHz
Shape File:	R1050-R.csv	**Power Level:**	32.0 dBm

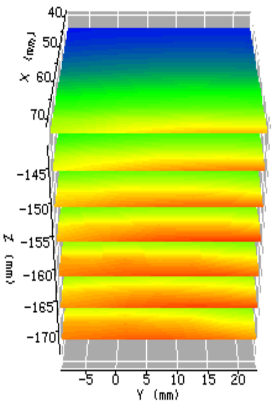
Probe:	0114
Cal File:	SN0114_450_CW_BODY

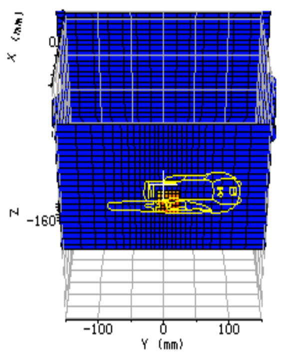
Cal Factors:

	X	Y	Z
Air	438	359	403
DCP	20	20	20
Lin	.397	.397	.397

Amp Gain:	2
Averaging:	1
Batteries Replaced:	-

Liquid:	15.5cm
Type:	450 MHz Body
Conductivity:	0.945
Relative Permittivity:	57.428
Liquid Temp (deg C):	22
Ambient Temp (deg C):	22
Ambient RH (%):	58
Density (kg/m3):	1000
Software Version:	2.33VPM





ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan**	**End Scan**
	0.203	0.189

Change during Scan (%) -4.37

Max E-field (V/m): 20.00

Max SAR (W/kg)	**1g**	**10g**
	0.345	0.262

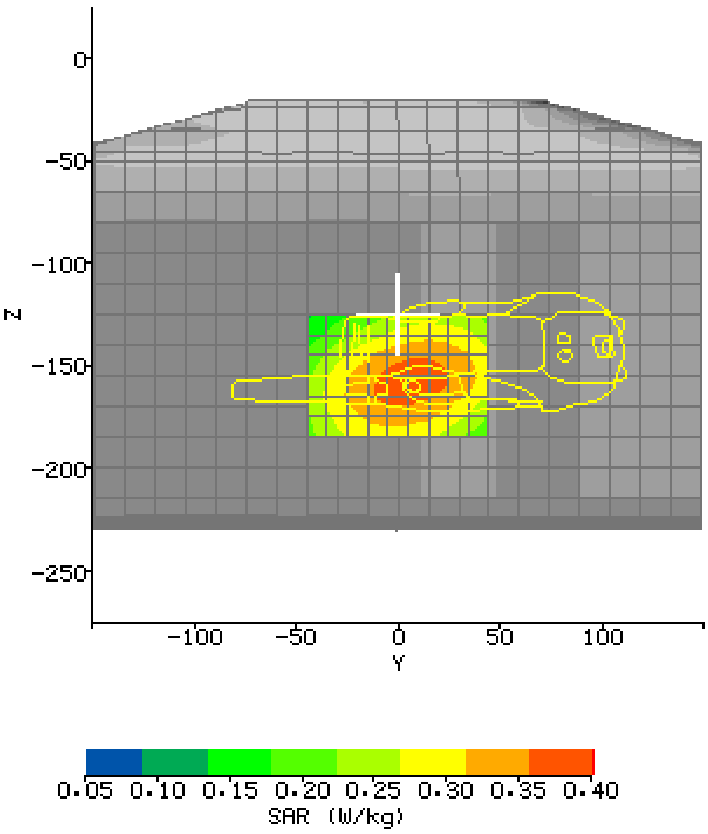
Location of Max (mm):	**X**	**Y**	**Z**
	71.6	-9.0	-163.3

Plot #5(2/2)

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-45.0	45.0	9.0
Z	-185.0	-125.0	6.0



Plot #6(1/2)

Date:	2005/9/2	**Position:**	rear side 0mm to Phantom
Filename:	R1050-body_ch11 with GB.txt	**Phantom:**	HeadBox4-450-newtest.csv
Device Tested:	R1050	**Head Rotation:**	0
Antenna:	Integral Antenna	**Test Frequency:**	CH11_467.6375MHz
Shape File:	R1050-R.csv	**Power Level:**	25.7 dBm

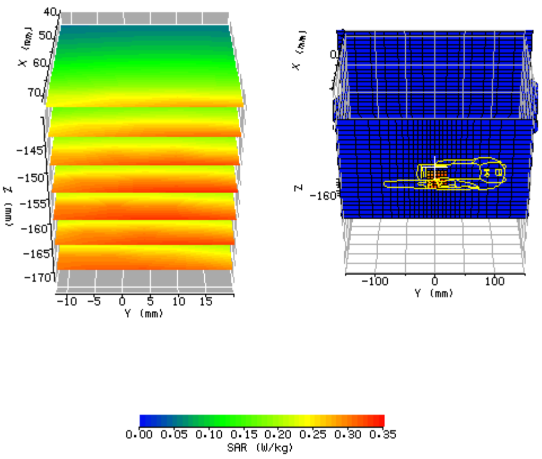
Probe:	0114
Cal File:	SN0114_450_CW_BODY

Cal Factors:

	X	Y	Z
Air	438	359	403
DCP	20	20	20
Lin	.397	.397	.397

Amp Gain:	2
Averaging:	1
Batteries Replaced:	-

Liquid:	15.5cm
Type:	450 MHz Body
Conductivity:	0.945
Relative Permittivity:	57.428
Liquid Temp (deg C):	22
Ambient Temp (deg C):	22
Ambient RH (%):	58
Density (kg/m3):	1000
Software Version:	2.33VPM



ZOOM SCAN RESULTS:

	Start Scan	End Scan
Spot SAR (W/kg):	0.179	0.159

Change during Scan (%) -4.34

Max E-field (V/m): 18.88

	1g	10g
Max SAR (W/kg)	0.309	0.232

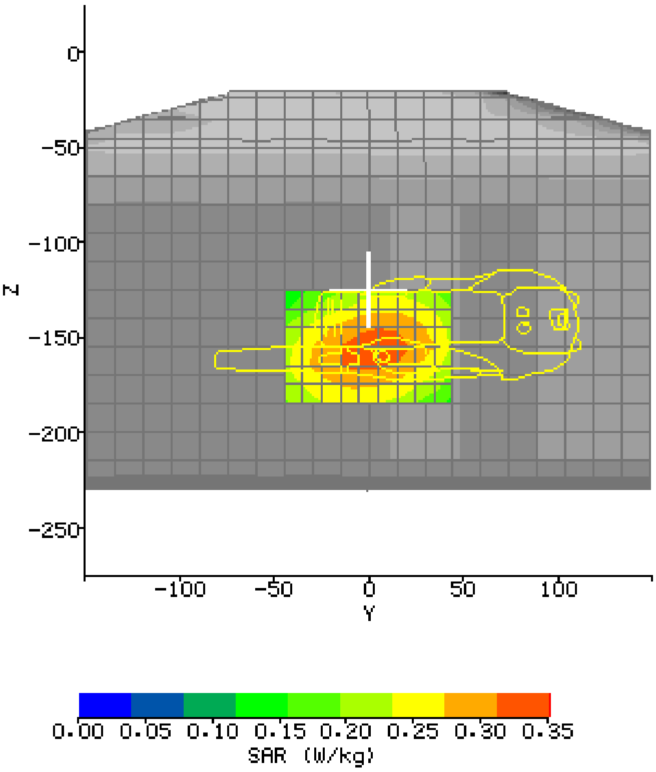
	X	Y	Z
Location of Max (mm):	71.5	-12.0	-159.6

Plot #6(2/2)

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-45.0	45.0	9.0
Z	-185.0	-125.0	6.0

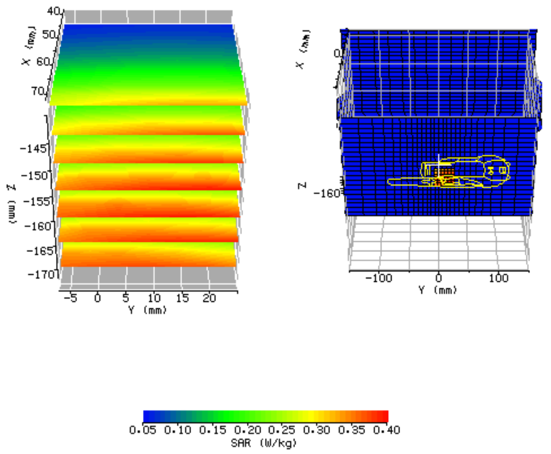


Plot #7(1/2)

Date:	2005/9/2	**Position:**	rear side 0mm to Phantom
Filename:	R1050-body_ch4 with NB.txt	**Phantom:**	HeadBox4-450-newtest.csv
Device Tested:	R1050	**Head Rotation:**	0
Antenna:	Integral Antenna	**Test Frequency:**	CH4_462.6375MHz
Shape File:	R1050-R.csv	**Power Level:**	32.0 dBm

Probe:	0114			
Cal File:	SN0114_450_CW_BODY			
		X	**Y**	**Z**
Cal Factors:	**Air**	438	359	403
	DCP	20	20	20
	Lin	.397	.397	.397
Amp Gain:	2			
Averaging:	1			
Batteries Replaced:	-			

Liquid:	15.5cm
Type:	450 MHz Body
Conductivity:	0.945
Relative Permittivity:	57.428
Liquid Temp (deg C):	22
Ambient Temp (deg C):	22
Ambient RH (%):	58
Density (kg/m3):	1000
Software Version:	2.33VPM



ZOOM SCAN RESULTS:

Spot SAR (W/kg):	**Start Scan**	**End Scan**
	0.205	0.180
Change during Scan (%)	-3.93	
Max E-field (V/m):	20.51	
Max SAR (W/kg)	**1g**	**10g**
	0.362	0.270

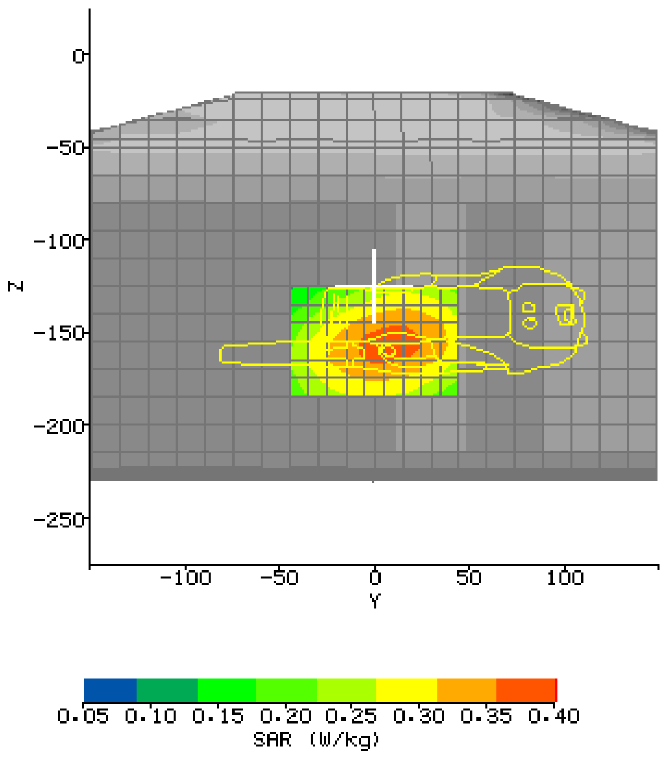
Location of Max (mm):	**X**	**Y**	**Z**
	71.5	-7.0	-159.6

Plot #7(2/2)

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-45.0	45.0	9.0
Z	-185.0	-125.0	6.0



Plot #8(1/2)

Date:	2005/9/2	**Position:**	rear side 0mm to Phantom
Filename:	R1050-body_ch11 with NB.txt	**Phantom:**	HeadBox4-450-newtest.csv
Device Tested:	R1050	**Head Rotation:**	0
Antenna:	Integral Antenna	**Test Frequency:**	CH11_467.6375MHz
Shape File:	R1050-R.csv	**Power Level:**	25.7 dBm

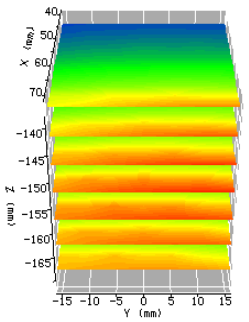
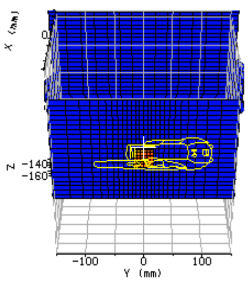
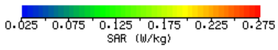
Probe: 0114
Cal File: SN0114_450_CW_BODY

Cal Factors:

	X	Y	Z
Air	438	359	403
DCP	20	20	20
Lin	.397	.397	.397

Amp Gain: 2
Averaging: 1
Batteries Replaced: -

Liquid:	15.5cm
Type:	450 MHz Body
Conductivity:	0.945
Relative Permittivity:	57.428
Liquid Temp (deg C):	22
Ambient Temp (deg C):	22
Ambient RH (%):	58
Density (kg/m3):	1000
Software Version:	2.33VPM

ZOOM SCAN RESULTS:

Spot SAR (W/kg):

Start Scan	End Scan
0.130	0.118

Change during Scan (%) -4.47

Max E-field (V/m): 16.73

Max SAR (W/kg)

1g	10g
0.242	0.181

Location of Max (mm):

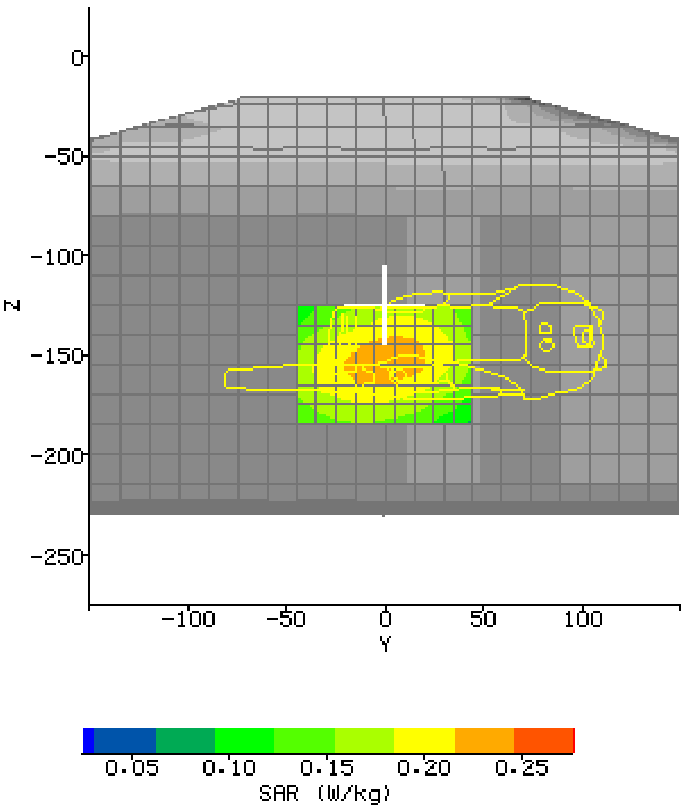
X	Y	Z
71.6	-16.0	-154.0

Plot #8(2/2)

AREA SCAN:

Scan Extent:

	Min	Max	Steps
Y	-45.0	45.0	9.0
Z	-185.0	-125.0	6.0



APPENDIX B - Photographs

(External)

(External)

(External)

(External)

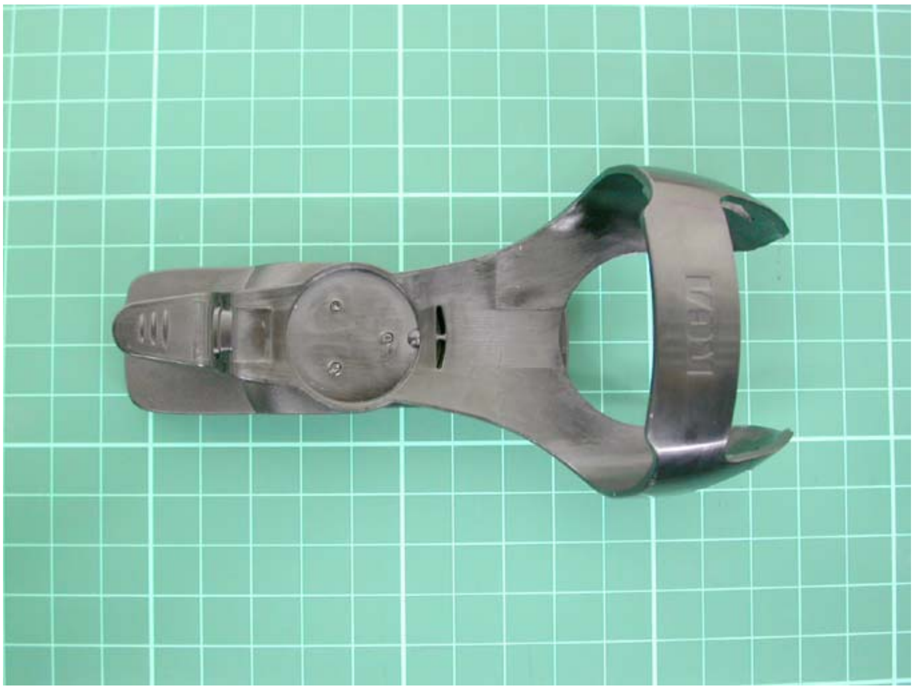
(Battery)

(Battery)

(Belt-clip)

(Belt-clip)

(Belt-clip)



(Belt-clip)

(earphone)

(Charger)

(Charger)

(Adapter)

(Adapter)


DVE®
AC ADAPTOR
MODEL NO.: DV-6540
INPUT: 120VAC 60Hz
OUTPUT1: 6.5VDC 200mA
OUTPUT2:6.5VDC 200mA
MADE IN CHINA
1
2

APPENDIX C - E-Field Probe and 450MHz Balanced Dipole Antenna Calibration Data

IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 050

S/N 0114

March 2005

Indexsar Limited
Oakfield House
Cudworth Lane
Newdigate
Surrey RH5 5BG
Tel: +44 (0) 1306 632 870
Fax: +44 (0) 1306 631 834
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) using normalized power inputs.

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

CALIBRATION PROCEDURE

1. Objectives

The calibration process comprises the following stages

1) Determination of the channel sensitivity factors which optimise the probe's overall rotational isotropy in 1800MHz brain fluid
2) At each frequency of interest, application of these channel sensitivity factors to model the exponential decay of SAR in a sensitivity factors to model the exponential decay of SAR in a at that frequency
3) Determination of the effective tip radius and angular offset of the X channel which together optimise the probe's spherical isotropy in 900MHz brain fluid
4) If requested by the Customer, determination of the probe's response to GSM pulsed modulation

2. 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).

In turn, measurements of E-field are determined using the following equation (where output voltages are also in units of V*200):

E_{liq}^2 (V/m) = U_{linx} * Air $Factor_x$* Liq $Factor_x$
+ U_{liny} * Air $Factor_y$* Liq $Factor_y$
+ U_{linz} * Air $Factor_z$* Liq $Factor_z$ (3)

Here, "Air Factor" represents each channel's sensitivity, while "Liq Factor" represents the enhancement in signal level when the probe is immersed in tissue-simulant liquids at each frequency of interest.

3. Selecting channel sensitivity factors to optimise isotropic response

After manufacture, the first stage of the calibration process is to balance the three channels' Air Factor values, thereby optimising the probe's overall axial response ("rotational isotropy").

To do this, an 1800MHz waveguide containing head-fluid simulant is selected.
Like all waveguides used during probe calibration, this particular waveguide contains two distinct sections: an air-filled launcher section, and a liquid cell section, separated by a dielectric matching window designed to minimize reflections at the air-liquid interface.

The waveguide stands in an upright position and the liquid cell section is filled with 1800MHz brain fluid to within 10 mm of the open end. 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.

During the measurement, a TE_{01} mode is launched into the waveguide by means of an N-type-to-waveguide adapter. The probe is then lowered vertically into the liquid until the tip is exactly 10mm above the centre of the dielectric window. This particular separation ensures that the probe is operating in a part of the waveguide where boundary corrections are not necessary.

Care must also be taken that the probe tip is centred while rotating.

The exact power applied to the input of the waveguide during this stage of the probe calibration is immaterial since only relative values are of interest while the probe rotates. However, the power must be sufficiently above the noise floor and free from drift.

The dedicated Indexsar calibration software rotates the probe in 10 degree steps about its axis, and at each position, an Indexsar 'Fast' amplifier samples the probe channels 500 times per second for 0.4 s. The raw $U_{o/p}$ data from each sample are packed into 10 bytes and transmitted back to the PC controller via an optical cable. U_{linx}, U_{liny} and U_{linz} are derived from the raw $U_{o/p}$ values and written to an Excel template.

Once data have been collected from a full probe rotation, the Air Factors are adjusted using a special Excel Solver routine to equalise the output from each channel and hence minimise the rotational isotropy. This automated approach to optimisation removes the effect of human bias.

Figure 5 represents the output from each diode sensor as a function of probe rotation angle. 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, a representative image of which is shown 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.

4. Determination of Conversion ("Liquid") Factors at each frequency of interest

A lookup table of conversion factors for a probe allows a SAR value to be derived at the measured frequencies, and for either brain or body fluid-simulant.

The method by which the conversion factors are assessed is based on the comparison between measured and analytical rates of decay of SAR with height above a dielectric window. This way, not only can the conversion factors for that frequency/fluid combination be determined, but an allowance can also be made for the scale and range of boundary layer effects.

The theoretical relationship between the SAR at the cross-sectional centre of the lossy waveguide as a function of the longitudinal distance (z) from the dielectric separator is given by Equation 4:

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

Here, the density ρ is conventionally assumed to be 1000 kg/m^3, ab is the cross-sectional area of the waveguide, and P_f and P_b are the forward and reflected power inside the lossless section of the waveguide, respectively.
The penetration depth δ (which is the reciprocal of the waveguide-mode attenuation coefficient) is a property of the lossy liquid and is given by Equation (5).

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

where σ is the conductivity of the tissue-simulant liquid in S/m, ε_r is its relative permittivity, and ω is the radial frequency (rad/s). Values for σ and ε_r are obtained prior to each waveguide test using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2]. σ and ε_r are both temperature- and fluid-dependent, so are best measured using a sample of the tissue-simulant fluid immediately prior to the actual calibration.

Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at 22 ±2.0°C; if this is not possible, the values of σ and ε_r should reflect the actual temperature. Values employed for calibration are listed in the tables below.

By ensuring the liquid height in the waveguide is at least three penetration depths, reflections at the upper surface of the liquid are negligible. The power absorbed in the liquid is therefore determined solely from the waveguide forward and reflected power.

Different waveguides are used for 835/900MHz, 1800/1900MHz, 2450MHz and 5200/5800MHz measurements. Table A.1 of [1] can be used for designing calibration waveguides with a return loss greater than 20 dB at the most important frequencies used for personal wireless communications, and better than 15dB for frequencies greater than 5GHz. 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 5800 MHz because of the waveguide size is not severe in the context of compliance testing.

During calibration, the probe is lowered carefully until it is just touching the cross-sectional centre of the dielectric window. 200 samples are then taken and written to an Excel template file before moving the probe vertically upwards. This cycle is repeated 50 times. The vertical separation between readings is determined from practical considerations of the expected SAR decay rate, and range from 1mm steps at low frequency, through 0.5mm at 2450MHz, down to 0.2mm at 5GHz.

Once the data collection is complete, a Solver routine is run which optimizes the measured-theoretical fit by varying the conversion factor, and the boundary correction size and range.

5. Measurement of Spherical Isotropy

The setup for measuring the probe's spherical isotropy is shown in Figure 2.

A box phantom containing 900MHz head fluid is irradiated by a vertically- polarised, tuned dipole, mounted to the side of the phantom on the robot's seventh axis. During calibration, the spherical response is generated by rotating the probe about its axis in 20 degree steps and changing the dipole polarisation in 10 degree steps.

By using the VPM technique discussed below, an allowance can also be made for the effect of E-field gradient across the probe's spatial extent. This permits values for the probe's effective tip radius and X-channel angular offset to be modelled until the overall spherical isotropy figure is optimised.

The dipole is connected to a signal generator and amplifier via a directional coupler and power meter. As with the determination of rotational isotropy, the absolute power level is not important as long as it is stable.

The probe is positioned within the fluid so that its sensors are at the same vertical height as the centre of the source dipole. The line joining probe to dipole should be perpendicular to the phantom wall, while the horizontal separation between the two should be small enough for VPM corrections to be applicable, without encroaching near the boundary layer of the phantom wall.
VPM corrections require a knowledge of the fluid skin depth. This is measured during the calibration by recording the E-field strength while systematically moving the probe away from the dipole in 2mm steps over a 20mm range.

6. Response to Modulated Signals

To measure the response of the probe and amplifier to quickly-changing, modulated signals, the probe is mounted vertically in air, approximately 50mm from a vertically-polarised 900MHz dipole.

The test sequence involves manually stepping the power fed to the dipole 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. Theresults are entered into a spreadsheet also containing channel sensitivity factors for the probe. Equations (1) and (3) relate the channel output voltages to the three components of E-field, and Equation (6), below, converts these E-field values to measured SAR values.

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

Where σ is the conductivity of the simulant liquid employed.

In the spreadsheet, it is possible to derive an optimum DCP value for each channel which yields a SAR value 1/8 of the CW value (for GSM modulation).
The ratio of " GSM SAR " to " CW SAR " is shown in Figure 7 as a function of input power. At the optimum DCP value for modulated signals, this response remains flat for SAR values approaching 2 W/kg. The corresponding DCP values are listed in the summary page of the calibration factors for each probe.

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.

VPM (Virtual Probe Miniaturisation)

SAR probes with 3 diode-sensors in an orthogonal arrangement are designed to display an isotropic response when exposed to a uniform field. However, the probes are ordinarily used for measurements in non-uniform fields and isotropy is not assured when the field gradients are significant compared to the dimensions of the tip containing the three orthogonally-arranged dipole sensors.

It becomes increasingly important to assess the effects of field gradients on SAR probe readings when higher frequencies are being used. For Indexsar IXP-050 probes, which are of 5mm tip diameter, field gradient effects are minor at GSM frequencies, but are major above 5GHz. Smaller probes are less affected by field gradients and so probes, which are significantly less than 5mm diameter, would be better for applications above 5GHz.

The IndexSAR report IXS0223 describes theoretical and experimental studies to evaluate the issues associated with the use of probes at arbitrary angles to surfaces and field directions. Based upon these studies, the procedures and uncertainty analyses referred to in P1528 are addressed for the full range of probe presentation angles.

In addition, generalized procedures for correcting for the finite size of immersible SAR probes are developed. Use of these procedures enables application of schemes for virtual probe miniaturization (VPM) – allowing probes of a specific size to be used where physically-smaller probes would otherwise be required.

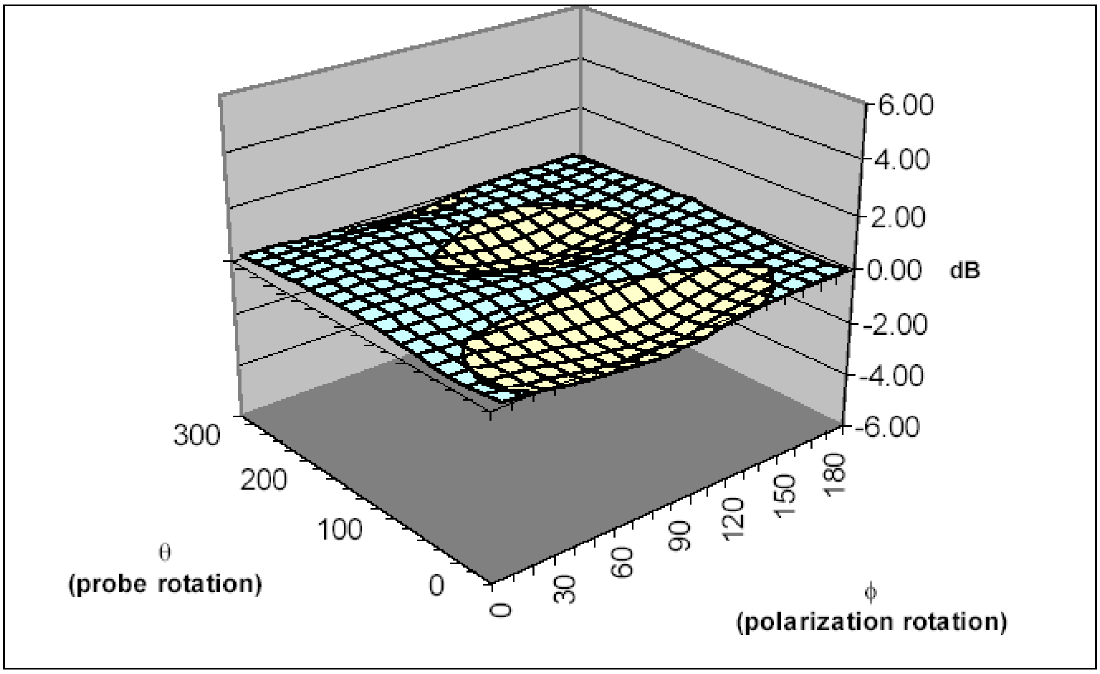
Given the typical dimensions of 3-channel SAR probes presently available, use of the VPM technique extends the satisfactory measurement range to higher frequencies.

CALIBRATION FACTORS MEASURED FOR PROBE S/N 0114

The probe was calibrated at 835, 900, 1800, 1900, 2450, 5200 and 5800 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 mm 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. The distance of 2.7mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 8).

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.



Surface Isotropy diagram of IXP-050 Probe S/N 0114 at 900MHz after VPM (rotational isotropy at side +/-0.07dB, spherical isotropy +/-0.38dB)

Probe tip radius	1.24
X Ch. Angle to red dot	20

	Head		Body	
Frequency	Bdy. Corrn. – f(0)	Bdy. Corrn. – d(mm)	Bdy. Corrn. – f(0)	Bdy. Corrn. – d(mm)
900	0.49	3.0	1.00	1.3
1800	0.63	1.8	0.51	2.3
1900	0.66	1.7	0.46	2.5
2450	0.91	1.4	0.59	2.0

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

Spherical isotropy measured at 900MHz	0.38	(+/-) dB

	X	Y	Z	
Air Factors	438	359	403	(V*200)
CW DCPs	20	20	20	(V*200)
GSM DCPs	3.5	5.3	3.6	(V*200)

Freq (MHz)	Axial Isotropy (+/- dB)		SAR ConvF (liq/air)		Notes
	Head	Body	Head	Body	1,2
450	-	-	0.424	0.397	1,2
835	-	-	0.424	0.397	1,2
900	-	-	0.424	0.397	1,2
1800	0.07	-	0.467	0.501	1,2
1900	-	-	0.472	0.524	1,2
2450	-	-	0.508	0.585	1,2

Notes	
1)	Calibrations done at 22°C +/-2°C
2)	Waveguide calibration

PROBE SPECIFICATIONS

Indexsar probe 0114, 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)	2.7		

Dimensions	S/N 0114	CENELEC [1]	IEEE [2]
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg) N.B. only measured to > 100 W/kg on representative probes	>100	>100	100

Isotropy (measured at 900MHz)	S/N 0114	CENELEC [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB)	0.07 Max (See table above)	0.5	0.25
Spherical isotropy covering all orientations to source (+/- dB)	0.38	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.

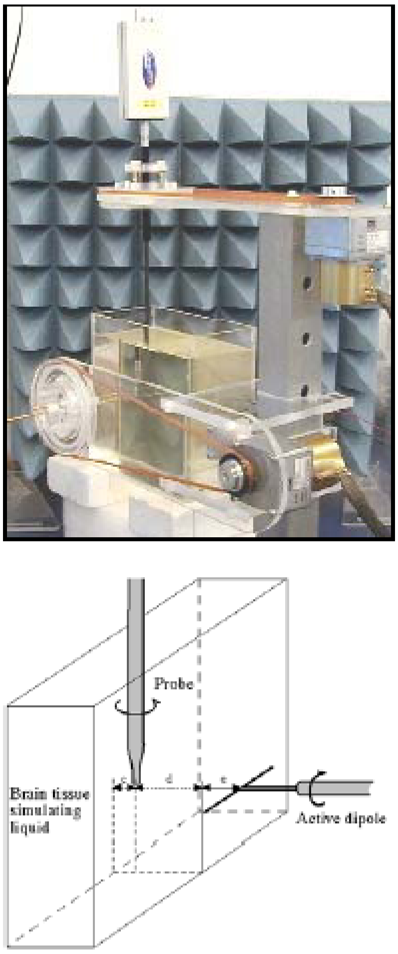


Figure 1. Spherical isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

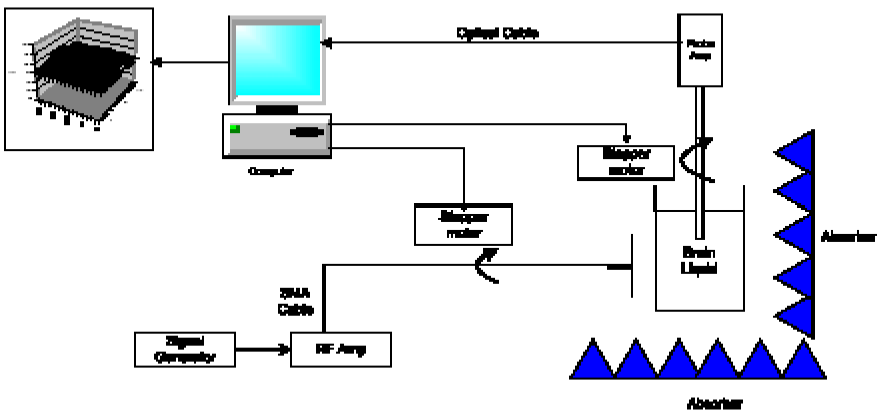


Figure 2. Schematic diagram of the test geometry used for isotropy determination

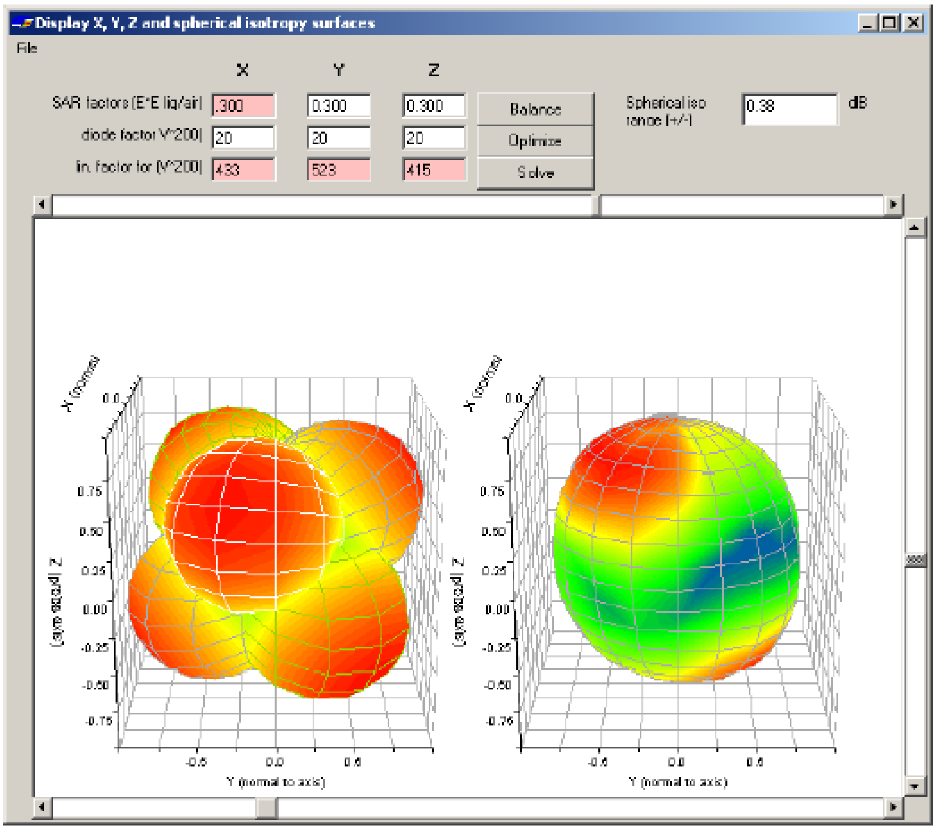


Figure 3. Graphical representation of a probe ' s response to fields applied from each direction. The diagram on the left shows the individual response characteristics of each of the three channels and the diagram on the right shows the resulting probe sensitivity in each direction. The colour range in the figure images the lowest values as blue and the maximum values as red. For the probe S/N 0114, this range is (+/-) 0.38 dB.

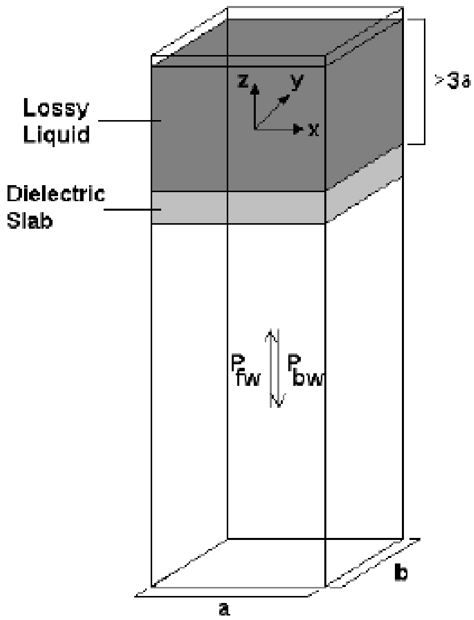


Figure 4. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

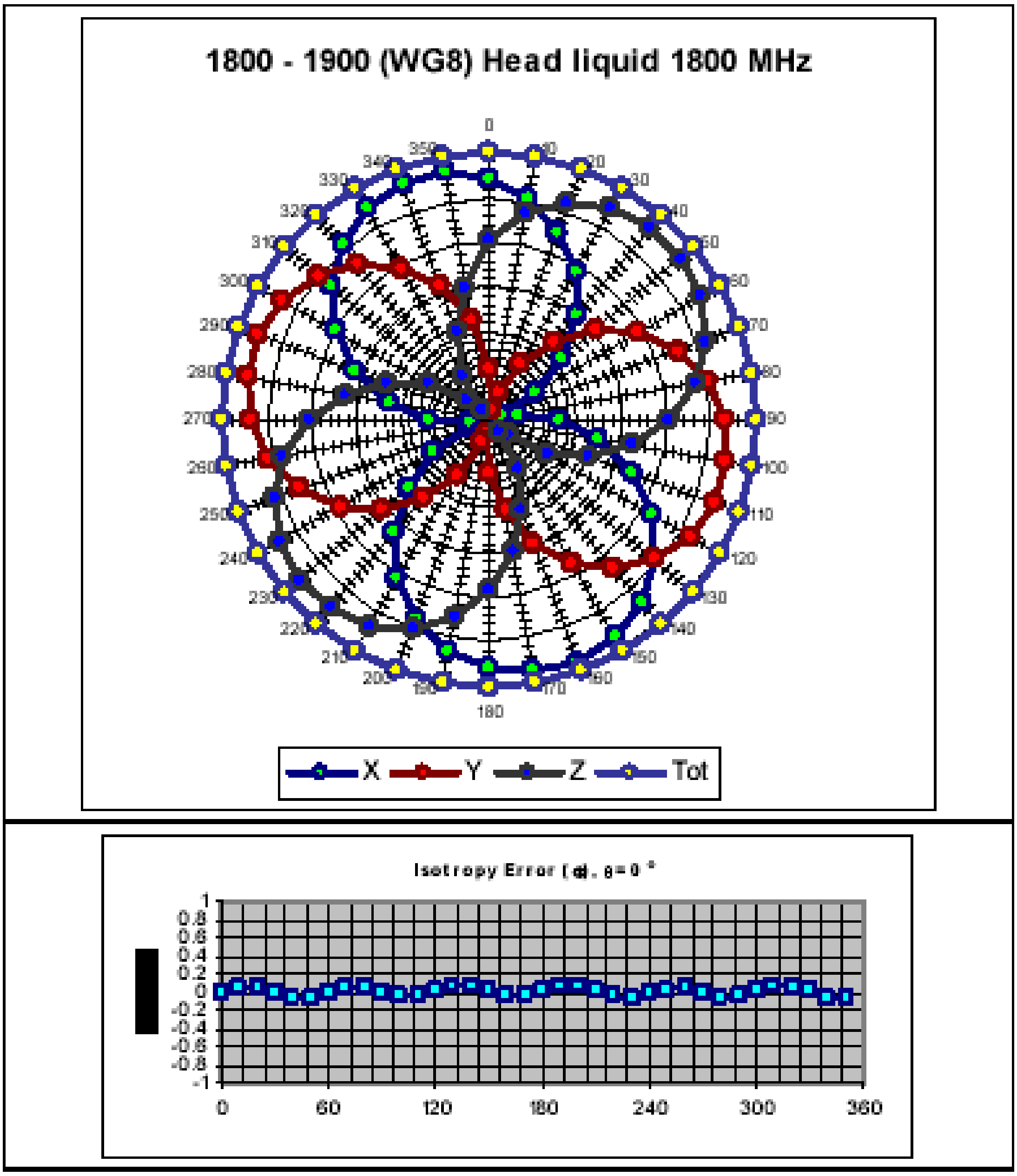
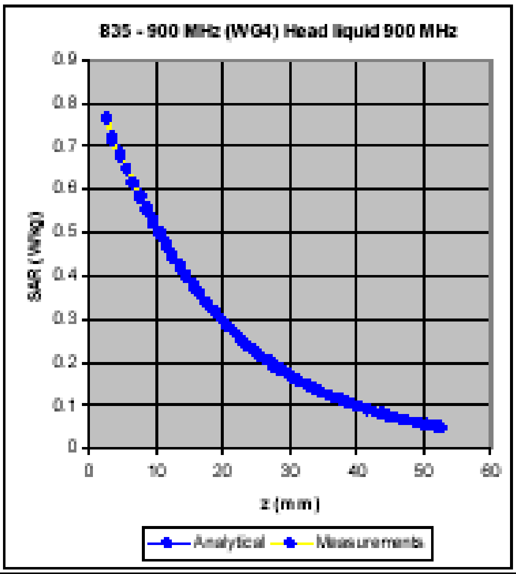
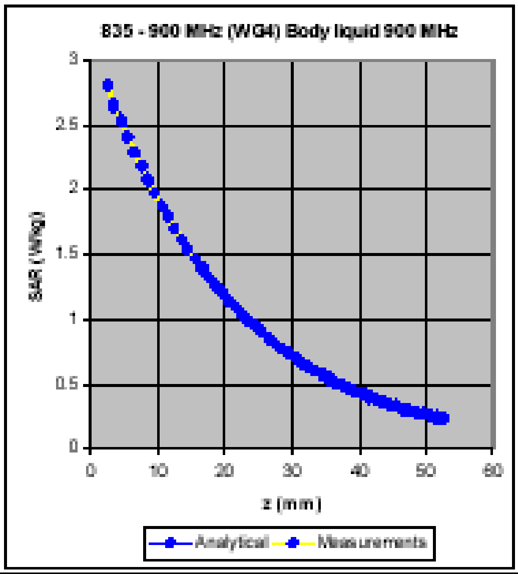
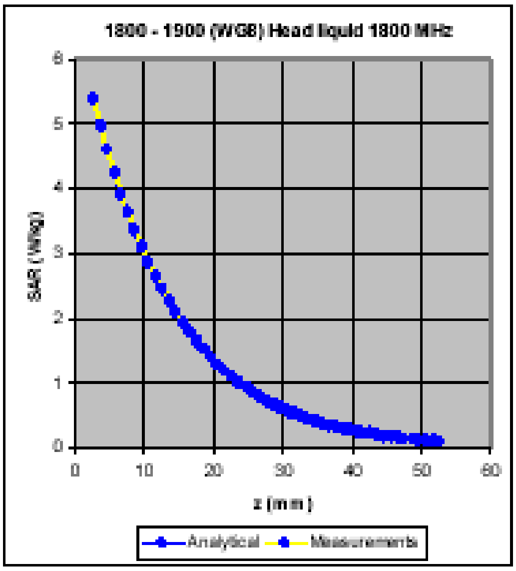
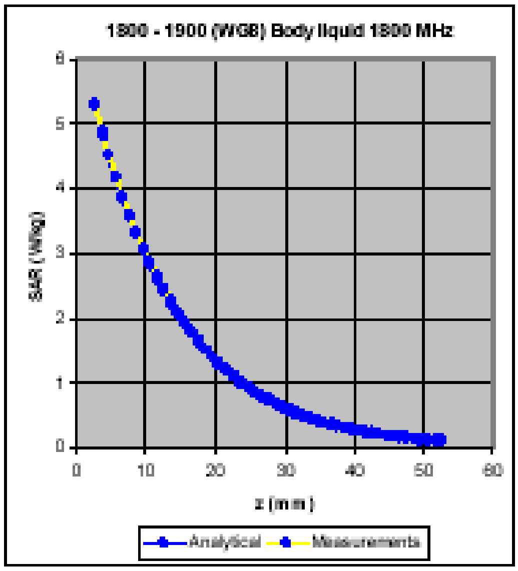


Figure 5. The rotational isotropy of probe S/N 0114 obtained by rotating the probe in a liquid-filled waveguide at 1800 MHz.


835 - 900 MHz (WG4) Head liquid 900 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements


835 - 900 MHz (WG4) Body liquid 900 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements


1800 - 1900 (WG8) Head liquid 1800 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements


1800 - 1900 (WG8) Body liquid 1800 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements

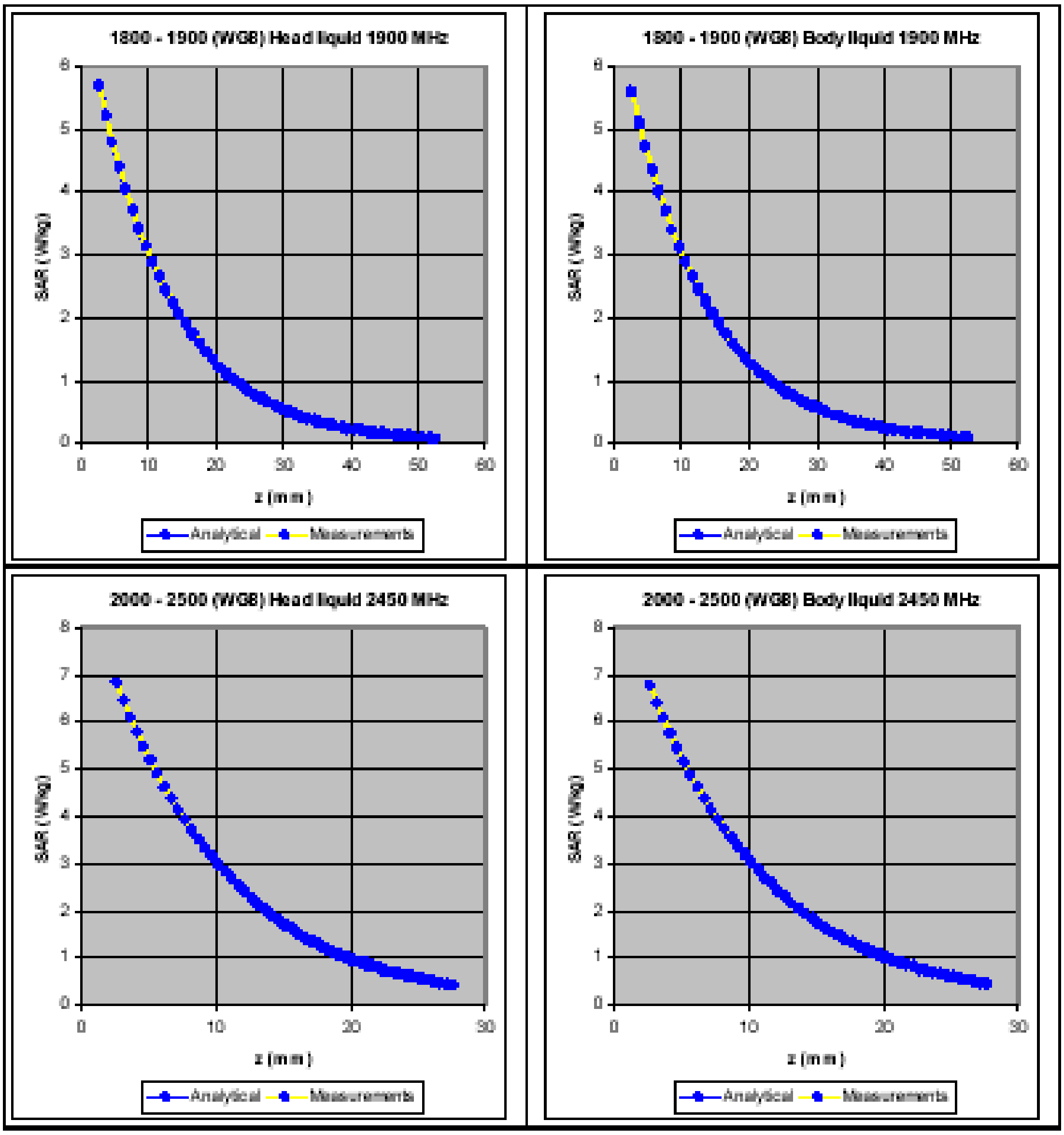


Figure 6. The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

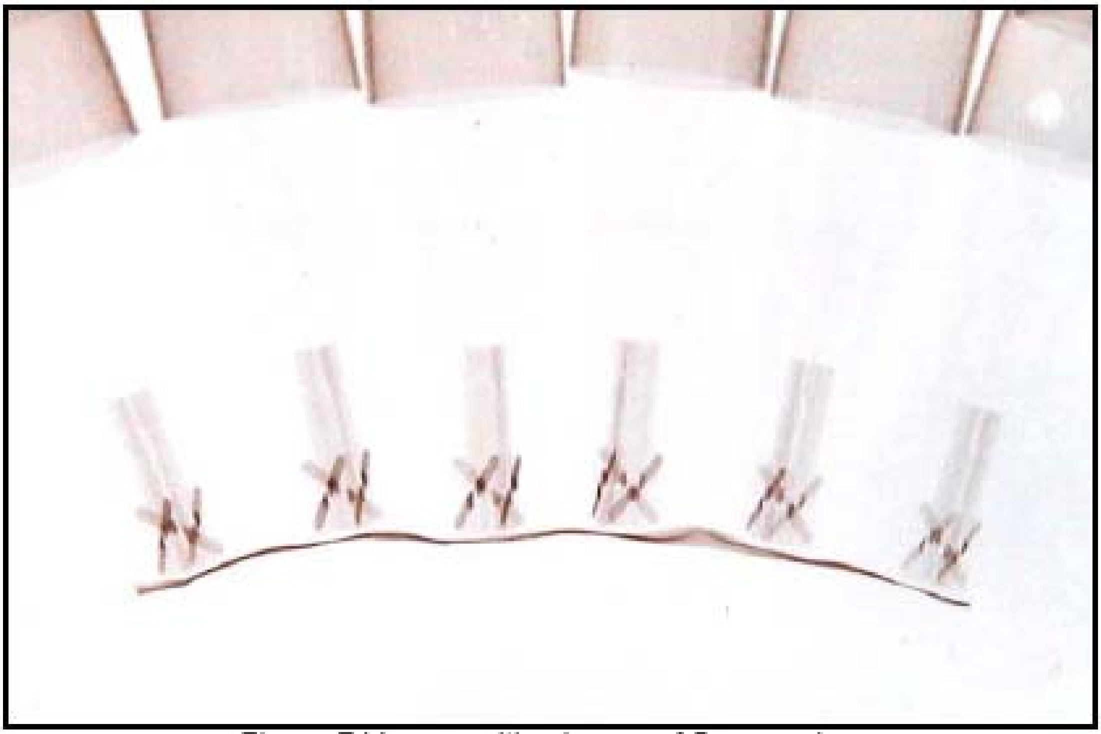


Figure 7 X-ray positive image of 5mm probes

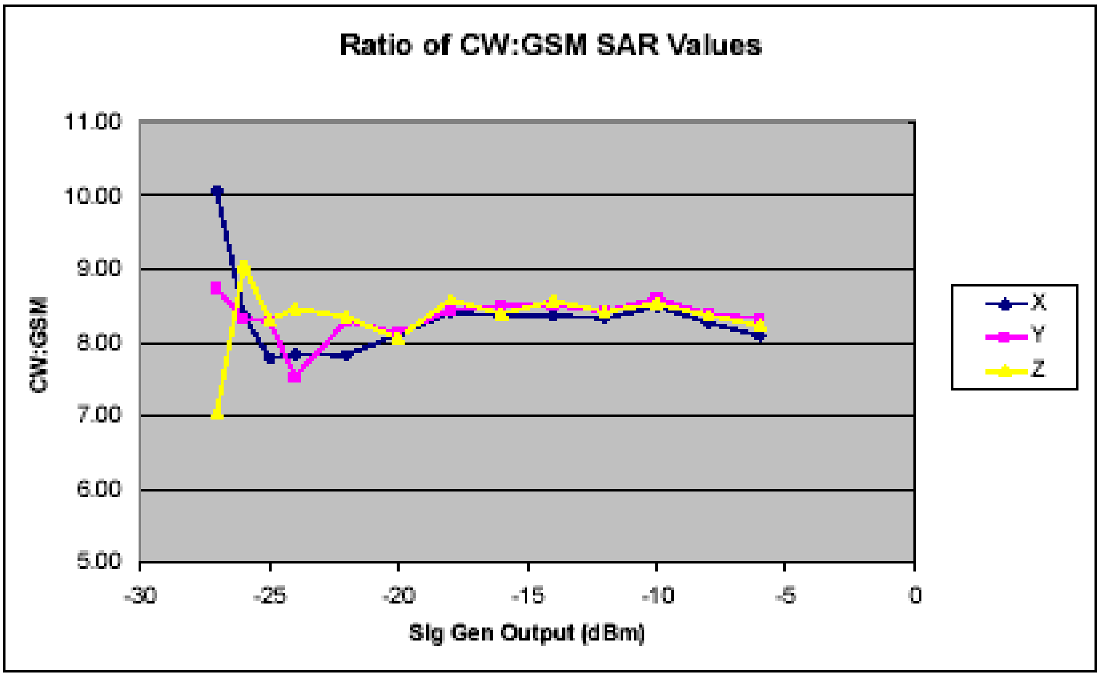


Figure 8 Response of probe to GSM-modulated signals over a range of powers

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

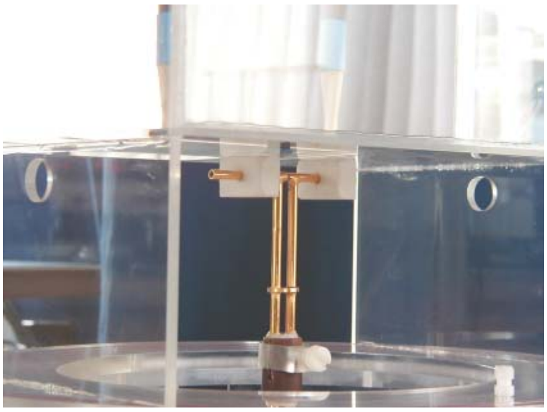
Liquid used	Relative permittivity (measured)	Conductivity (S/m) (measured)
900 MHz BRAIN	39.40	0.93
900 MHz BODY	56.33	1.01
1800 MHz BRAIN	40.10	1.36
1800 MHz BODY	54.39	1.55
1900 MHz BRAIN	39.70	1.46
1900 MHz BODY	54.07	1.65
2450 MHz BRAIN	39.38	1.89
2450 MHz BODY	54.00	2.14

Report No. SN0065_450
October 2003

INDEXSAR
450MHz validation Dipole
Type IXD-045 S/N 0065

Performance measurements

- **MI Manning**



Indexsar, Oakfield House, Cudworth Lane,
Newdigate, Surrey RH5 5DR. UK.
Tel: +44 (0) 1306 631233 Fax: +44 (0) 1306 631834
e-mail: enquiries@indexsar.com

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 / Conformance statement
Balanced Validation dipole

Type:	**IXD-045 450MHz**

Manufacturer:	**IndexSAR, UK**

Serial Number:	**0065**

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:	**October 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:	**October 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:

Approved By:

1. Measurement Conditions

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

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

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

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

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

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

2. Typical SAR Measurement

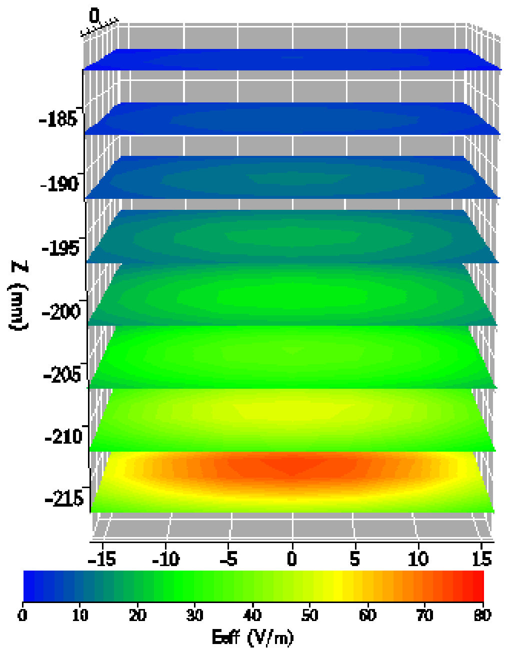
A SAR validation check is performed with the box-phantom located on the SARA2 phantom support base on the SARA2 robot system. Tests are then conducted at a feed power level of approx. 0.25W. The actual power level is recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature is 23°C +/- 1°C and the relative humidity is around 67% during the measurements.

The phantom is filled with a 450MHz brain liquid using a recipe from [1], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 450MHz +/-10%:

Relative Permittivity	**43.5**
Conductivity	**0.87 S/m**

The SARA2 software version 0.421N is used with an Indexsar probe previously calibrated using waveguides.

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



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

Averaged over 1 cm3 (1g) of tissue	**4.9 W/kg**
Averaged over 10cm3 (10g) of tissue	**3.3 W/kg**

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

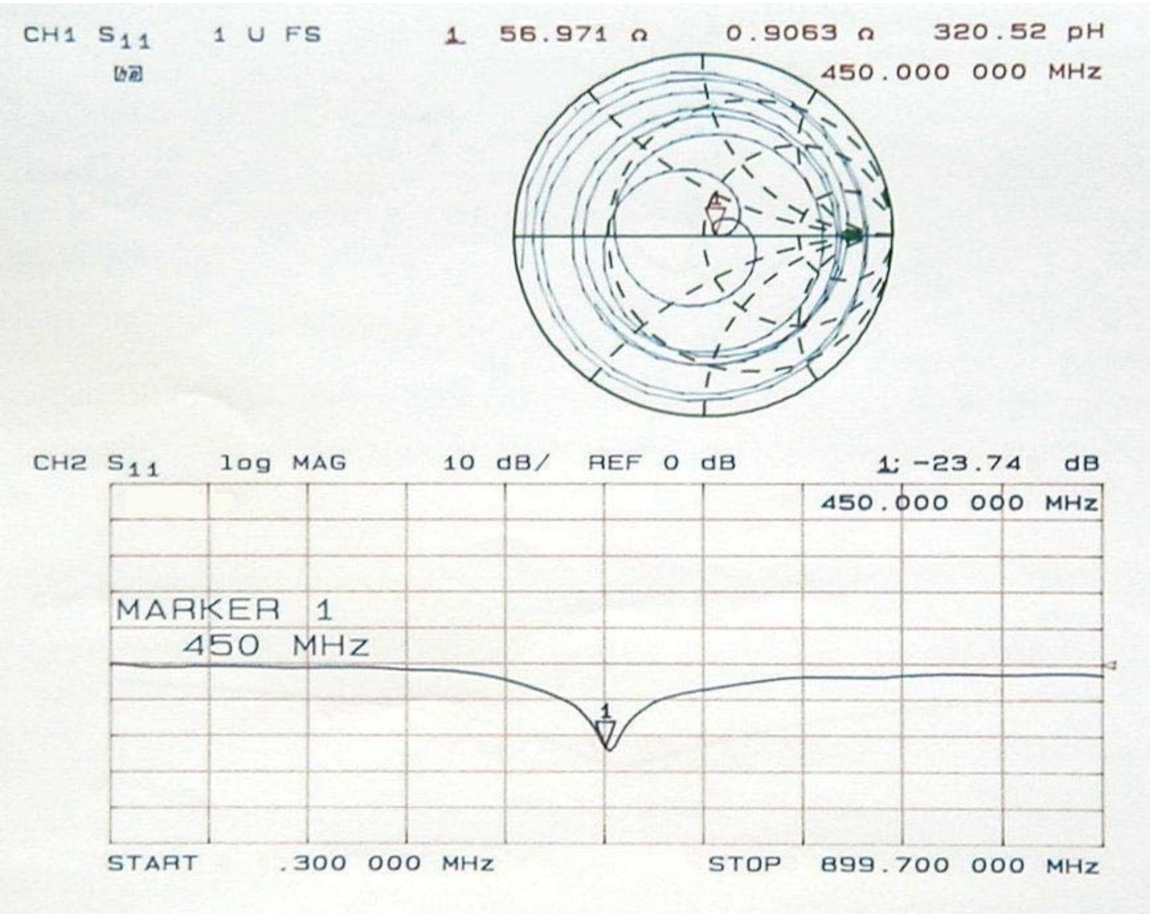
3. Dipole impedance and return loss

The dipoles are designed to have low return loss ONLY when presented against a lossy-phantom at the specified distance. A Vector Network Analyser (VNA) was used to perform a return loss measurement on the specific dipole when in the measurement-location against the box phantom. The distance was as specified in the standard i.e. 10mm from the liquid (for 450MHz). 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 450 MHz Re{Z} = **56.971 Ω**
Im{Z} = **0.9063 Ω**

Return loss at 450MHz **-23.74 dB**



4. Dipole handling

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

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

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

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

5. Tuning the dipole

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

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

6. References

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

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