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## REPORT ON

Specific Absorption Rate Testing of the SHL Telemedicine International Ltd  
River ECG Cardiograph (Recorder/Transmitter)

FCC ID: U6VRV911

Doc Number 75900645 Report 01 Issue 2

March 2007

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**REPORT ON** Specific Absorption Rate Testing of the SHL Telemedicine International Ltd  
River ECG Cardiograph (Recorder/Transmitter)

Doc Number 75900645 Report 01 Issue 2

**FCC ID** U6VRV911

**PREPARED FOR** SHL Telemedicine Global Trading Ltd  
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Ireland

**ATTESTATION** The wireless portable device described within this report has been shown  
to be capable of compliance for localised specific absorption rate (SAR) for  
General Population/Uncontrolled Exposure Limits as defined in the FCC  
standard Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-  
01) of 1.6 W/kg.

The measurements shown in this report were made in accordance with  
the procedures specified in Supplement C (Edition 01-01) to OET  
Bulletin 65 (Edition 97-01) and IEEE 1528-2003

All reported testing was carried out on a sample of equipment to  
demonstrate compliance with the above standards. The sample tested  
was found to comply with the requirements in the applied rules.

**PREPARED BY**   
A. Miller  
Principal Engineer

**APPROVED BY**   
M. Jenkins  
Authorised Signatory

**DATED** 11<sup>th</sup> April 2007

*Note: The test results reported herein relate only to the item tested  
as identified above and on the Status Page.*

**This report has been up-issued to include FCC ID**

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## SECTION 1

### REPORT SUMMARY

Specific Absorption Rate Testing of the SHL Telemedicine International Ltd  
River ECG Cardiograph (Recorder/Transmitter)

Max 1g SAR (W/kg)	0.258
The maximum 1g volume averaged SAR level measured for all the tests performed did not exceed the limits for General Population/Uncontrolled Exposure (W/kg) Partial Body of 1.6 W/kg. Level defined in Supplement C (Edition 01-01) to OET Bulletin 65 (97-01).	

## 1.1 STATUS

<b>MANUFACTURING DESCRIPTION</b>	ECG Cardiograph (Recorder/Transmitter)
<b>STATUS OF TEST</b>	Specific Absorption Rate Testing
<b>POWER CLASS</b>	GSM 850 Class 4 / GSM 900 Class 4 GSM DCS 1800 / PCS 1900 Class 1
<b>GPRS CLASS</b>	Class B
<b>GPRS MULTI-SLOT CLASS</b>	10 (4Dn; 2Up; Sum5)
<b>MANUFACTURER</b>	SHL Telemedicine International Ltd
<b>TYPE OR MODEL NUMBER</b>	River
<b>HARDWARE VERSION</b>	V2.0
<b>FIRMWARE VERSION</b>	V2.0
<b>FCC ID</b>	U6VRV911
<b>SERIAL NUMBER</b>	01000014
<b>IMEI NUMBER</b>	3570230000645900
<b>BATTERY MODEL</b>	Cell Model No.: AE683466P6H Part No.: AE17-99 3.7V Nom; 1600mAh Capacity
<b>BATTERY MANUFACTURER</b>	AEnergy

## TEST SPECIFICATIONS:

1. Federal Communications Commission (FCC) OET Bulletin 65c, Edition 01-01, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields – Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions.

## REFERENCES:

2. US Federal Government, Code of Federal Regulations, Title 47 Telecommunication, Chapter I Federal Communications Commission, part 2, section 1093.
3. IEEE 1528 – 2003: Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques.

<b>TUV REGISTRATION NUMBER:</b>	75900645
<b>RECEIPT OF TEST SAMPLES:</b>	19 <sup>th</sup> February 2007
<b>START OF TEST:</b>	19 <sup>th</sup> February 2007
<b>FINISH OF TEST:</b>	20 <sup>th</sup> February 2007

## 1.2 SUMMARY

The unit supplied for testing is a SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter), which offers Quad-Band (GPRS 850/900/1800/1900) connectivity.

For Body SAR assessment, the device was tested for typical body-worn operation. Flat Phantom dimensions 220mmx200mmx150mm and with a sidewall thickness of 2.0mm. The phantom was filled to a depth of 150mm with the appropriate Body simulant liquid. The dielectric properties were in accordance with the requirements for the dielectric properties specified in Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01).

For Body SAR assessment the device was placed into a GPRS Multislot Class 10 configuration, with 2 timeslots transmitting at maximum power for both the GSM850 and GSM1900 bands. This was achieved using a Universal Radio Communication Tester (CMU200), which controlled the number of transmit slots and the handset power at level 5 (GSM850), and power level 0 (GSM1900) respectively. The River ECG Cardiograph (Recorder/Transmitter) was first configured with the rear of the device with belt clip placed to the 'side to phantom' (body). The device was then positioned in its intended user position whilst SAR assessment was carried out in the bottom, middle and top channel for each band assessed.

During the Body SAR assessment the River ECG Cardiograph (Recorder/Transmitter), was connected to the power supply unit, to enable the device to continuously operate in GPRS Multislot Class 10 with both transmit channels transmitting at full power for the duration of the SAR assessment.

The maximum 1g volume averaged SAR level measured for all the tests performed did not exceed the limits for General Population/Uncontrolled Exposure (W/kg) Partial Body of 1.6 W/kg. Level defined in Supplement C (Edition 01-01) to OET Bulletin 65 (97-01).

### 1.3 TEST RESULT SUMMARY

#### SYSTEM PERFORMANCE / VALIDATION CHECK RESULTS

Prior to formal testing being performed a System Check was performed in accordance with OET 65 Supplement C (Edition 01-01) [1] and the results were compared against published data in Standard IEEE 1528-2003 [3]. The following results were obtained: -

Date	Dipole Used	Frequency (MHz)	Max 1g SAR (W/kg)*	Percentage Drift on Reference (%)	Max 10g SAR (W/kg)*	Percentage Drift on Reference (%)
19/02/2007	850	844.4	9.94*	4.60%	6.49*	4.66%
20/02/2007	1900	1883.6	40.70*	2.51%	21.45*	4.65%

\*Normalised to a forward power of 1W

#### GPRS 850MHz BODY Specific Absorption Rate (Maximum SAR) 1g & 10g Results for the SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter)

Position		Channel Number	Frequency (MHz)	Max Spot SAR (W/kg)	Max 1g SAR (W/kg)	Max 10g SAR (W/kg)	SAR Drift (%)	Area scan (Figure number)
Spacing From Phantom	Device Position to Phantom							
0mm	Belt Clip Facing	189	836.4	0.03	0.033	0.021	1.660	Figure 4
0mm	Belt Clip Facing	128	824.2	0.02	0.023	0.015	-5.040	Figure 5
0mm	Belt Clip Facing	251	848.8	0.03	0.031	0.020	1.750	Figure 6
Limit for General Population (Uncontrolled Exposure) 1.6 W/kg (1g) & 2.0 W/kg (10g)								

#### GPRS 1900MHz BODY Specific Absorption Rate (Maximum SAR) 1g & 10g Results for the SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter)

Position		Channel Number	Frequency (MHz)	Max Spot SAR (W/kg)	Max 1g SAR (W/kg)	Max 10g SAR (W/kg)	SAR Drift (%)	Area scan (Figure number)
Spacing From Phantom	Device Position to Phantom							
0mm	Belt Clip Facing	661	1880.0	0.16	0.199	0.123	0.720	Figure 7
0mm	Belt Clip Facing	512	1850.2	0.21	0.258	0.168	-3.480	Figure 8
0mm	Belt Clip Facing	810	1909.8	0.16	0.192	0.118	0.270	Figure 9
Limit for General Population (Uncontrolled Exposure) 1.6 W/kg (1g) & 2.0 W/kg (10g)								

## SECTION 2

### TEST DETAILS

Specific Absorption Rate Testing of the SHL Telemedicine International Ltd  
River ECG Cardiograph (Recorder/Transmitter)

## 2.1 SAR MEASUREMENT SYSTEM

### 2.1.1 ROBOT SYSTEM SPECIFICATION

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

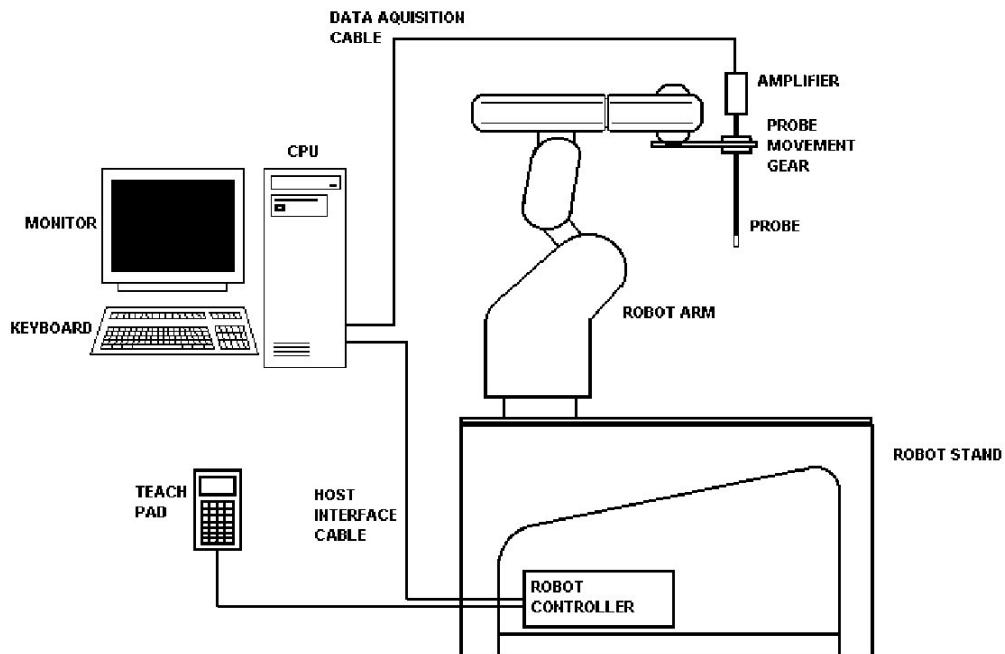


Figure 1: Schematic diagram of the SAR measurement system

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.

The position and digitised shape of the phantom heads are made available to the software for accurate positioning of the probe and reduction of set-up time.

The SAM phantom heads are individually digitised using a Mitutoyo CMM machine to a precision of 0.001mm. The data is then converted into a shape format for the software, providing an accurate description of the phantom shell.

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

## 2.1 SAR MEASUREMENT SYSTEM - Continued

### 2.1.2 PROBE AND AMPLIFIER SPECIFICATION

#### IXP-050 IndexSAR Isotropic Immersible SAR probe

The probes are constructed using three orthogonal dipole sensors arranged on an interlocking, triangular prism core. The probes have built-in shielding against static charges and are contained within a PEEK cylindrical enclosure material at the tip.

Probe calibration is described in the following section.

#### IFA-010 Fast Amplifier

Technical description of IndexSAR IFA-010 Fast probe amplifier

A block diagram of the fast probe amplifier electronics is shown below.

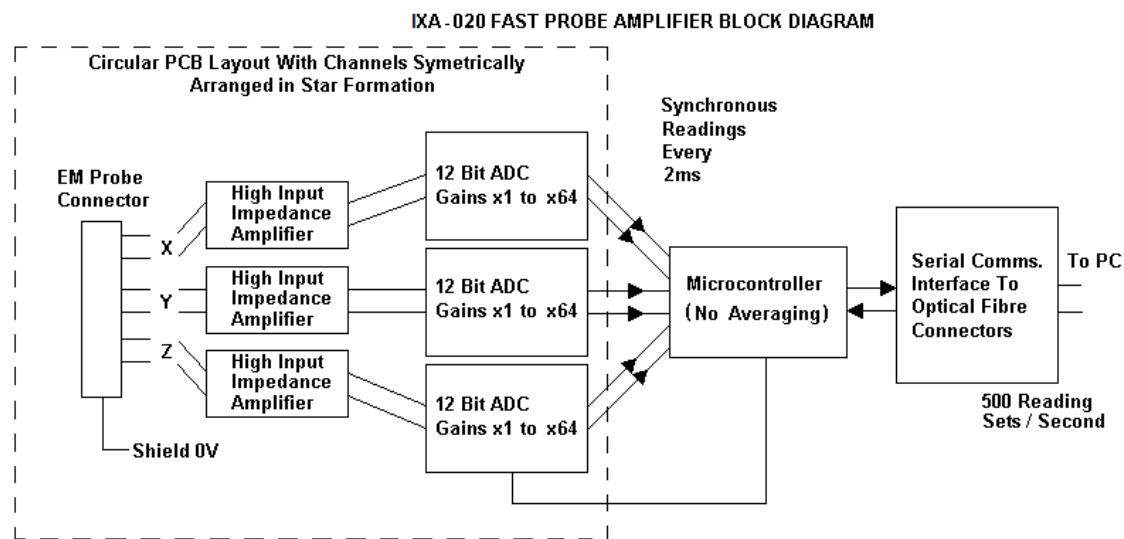


Figure 2: Block diagram of the fast probe amplifier electronic

This amplifier has a time constant of approx. 50 $\mu$ s, which is much faster than the SAR probe response time. The overall system time constant is therefore that of the probe (<1ms) and reading sets for all three channels (simultaneously) are returned every 2ms to the PC. The conversion period is approx. 1  $\mu$ s at the start of each 2ms period. This enables the probe to follow pulse modulated signals of periods  $>>2$ ms. The PC software applies the linearization procedure separately to each reading, so no linearization corrections for the averaging of modulated signals are needed in this case. It is important to ensure that the probe reading frequency and the pulse period are not synchronised and the behaviour with pulses of short duration in comparison with the measurement interval need additional consideration.

#### Phantoms

The Cube phantom used is a Perspex Box IndexSAR item IXB-070. Dimensions of 200w x 200d x 200h (mm). This phantom is used with IndexSAR side bench IXM-030.

The Flat phantom used is a Rectangular Perspex Box IndexSAR item. Dimensions of 210w x 150d x 200h (mm). This phantom is used with IndexSAR upright bench. The phantom and robot alignment is assured by both mechanical and laser registration systems.

## 2.1 SAR MEASUREMENT SYSTEM - Continued

### 2.1.3 SAR MEASUREMENT PROCEDURE

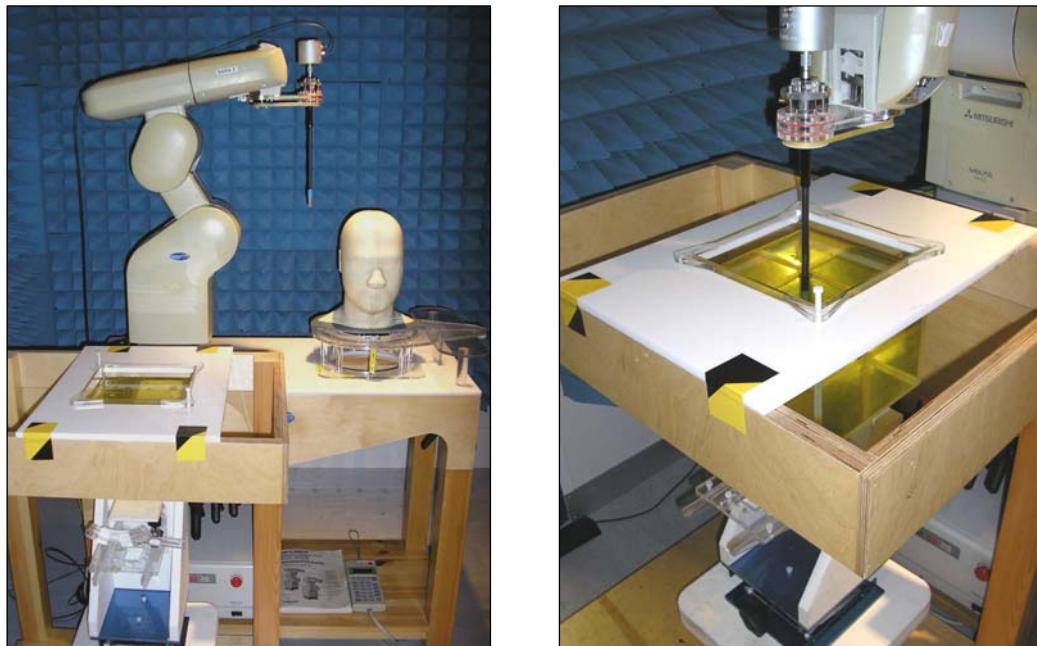


Figure 3: Principal components of the SAR measurement test bench

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

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

#### SARA2 Interpolation and Extrapolation schemes

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

#### Interpolation of 2D area scan

The 2D cubic B-spline interpolation is used after the initial area scan at fixed distance from the phantom shell wall. The initial scan data are collected with approx. 115mm spatial resolution and spline interpolation is used to find the location of the local maximum to within a 1mm resolution for positioning the subsequent 3D scanning.

## 2.1 SAR MEASUREMENT SYSTEM - Continued

### 2.1.3 SAR MEASUREMENT PROCEDURE

#### Extrapolation of 3D scan

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

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

#### Interpolation of 3D scan and volume averaging

The procedure used for defining the shape of the volumes used for SAR averaging in the SARA2 software follow the method of adapting the surface of the 'cube' to conform with the curved inner surface of the phantom (see Appendix C.2.2.1 in EN 50361:2001). This is called, here, the conformal scheme.

For each row of data in the depth direction, the data are extrapolated and interpolated to less than 1mm spacing and average values are calculated from the phantom surface for the row of data over distances corresponding to the requisite depth for 10g and 1g cubes. This results in two 2D arrays of data, which are then cubic B-spline interpolated to sub mm lateral resolution. A search routine then moves an averaging square around through the 2D array and records the maximum value of the corresponding 1g and 10g volume averages. For the definition of the surface in this procedure, the digitised position of the headshell surface is used for measurement in head-shaped phantoms. For measurements in rectangular, box phantoms, the distance between the phantom wall and the closest set of gridded data points is entered into the software.

For measurements in box-shaped phantoms, this distance is under the control of the user. The effective distance must be greater than 2.5mm as this is the tip-sensor distance and to avoid interface proximity effects, it should be at least 5mm. A value of 6 or 8mm is recommended. This distance is called **dbe** in EN 50361:2001.

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

The default step size (**dstep** in EN 50361:2001) used is 3.5mm, but this is under user-control. The compromise is with time of scan, so it is not practical to make it much smaller or scan times become long and power-drop influences become larger.

The robot positioning system specification for the repeatability of the positioning (**dss** in EN50361:2001) is +/- 0.04mm.

## 2.1 SAR MEASUREMENT SYSTEM - Continued

### 2.1.3 SAR MEASUREMENT PROCEDURE

The phantom shell is made by an industrial moulding process from the CAD files of the SAM shape, with both internal and external moulds. For the upright phantoms, the external shape is subsequently digitised on a Mitutoyo CMM machine (Euro C574) to a precision of 0.001mm. Wall thickness measurements made non-destructively with an ultrasonic sensor indicate that the shell thickness (**dph**) away from the ear is 2.0 +/- 0.1mm. The ultrasonic measurements were calibrated using additional mechanical measurements on available cut surfaces of the phantom shells.

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

## 2.2 850MHz GPRS BODY SAR TEST RESULT INCLUDING COURSE AREA SCAN – 2D

SYSTEM / SOFTWARE:	SARA2 / 2.39 VPM	INPUT POWER DRIFT:	0.0dB
DATE / TIME:	19/02/2007 16:15:40	DUT BATTERY MODEL/NO:	AE683466P6H
FILENAME:	75900645_01.txt	PROBE SERIAL NUMBER:	0171
AMBIENT TEMPERATURE:	21.3°C	LIQUID SIMULANT:	835 Body
DEVICE UNDER TEST:	River	RELATIVE PERMITTIVITY:	57.28
RELATIVE HUMIDITY:	36.5%	CONDUCTIVITY:	0.98
PHANTOM S/NO:	HeadBox170.csv	LIQUID TEMPERATURE:	20.9°C
PHANTOM ROTATION:	0°	MAX SAR X-AXIS LOCATION:	8.00 mm
DUT POSITION:	Belt Clip Facing 0mm	MAX SAR Y-AXIS LOCATION:	-26.00 mm
ANTENNA CONFIGURATION:	Fixed (Integral)	MAX E FIELD:	5.63 V/m
TEST FREQUENCY:	836.4MHz	SAR 1g:	0.033 W/kg
AIR FACTORS:	344 / 473 / 382	SAR 10g:	0.021 W/kg
CONVERSION FACTORS:	0.267 / 0.267 / 0.267	SAR START:	0.008 W/kg
TYPE OF MODULATION:	GMSK	SAR END:	0.008 W/kg
MODN. DUTY CYCLE:	25%	SAR DRIFT DURING SCAN:	1.66 %
DIODE COMPRESSION FACTORS (V*200):	20 / 20 / 20	PROBE BATTERY LAST CHANGED:	16/02/2007
INPUT POWER LEVEL:	33dBm X 2	EXTRAPOLATION:	poly4

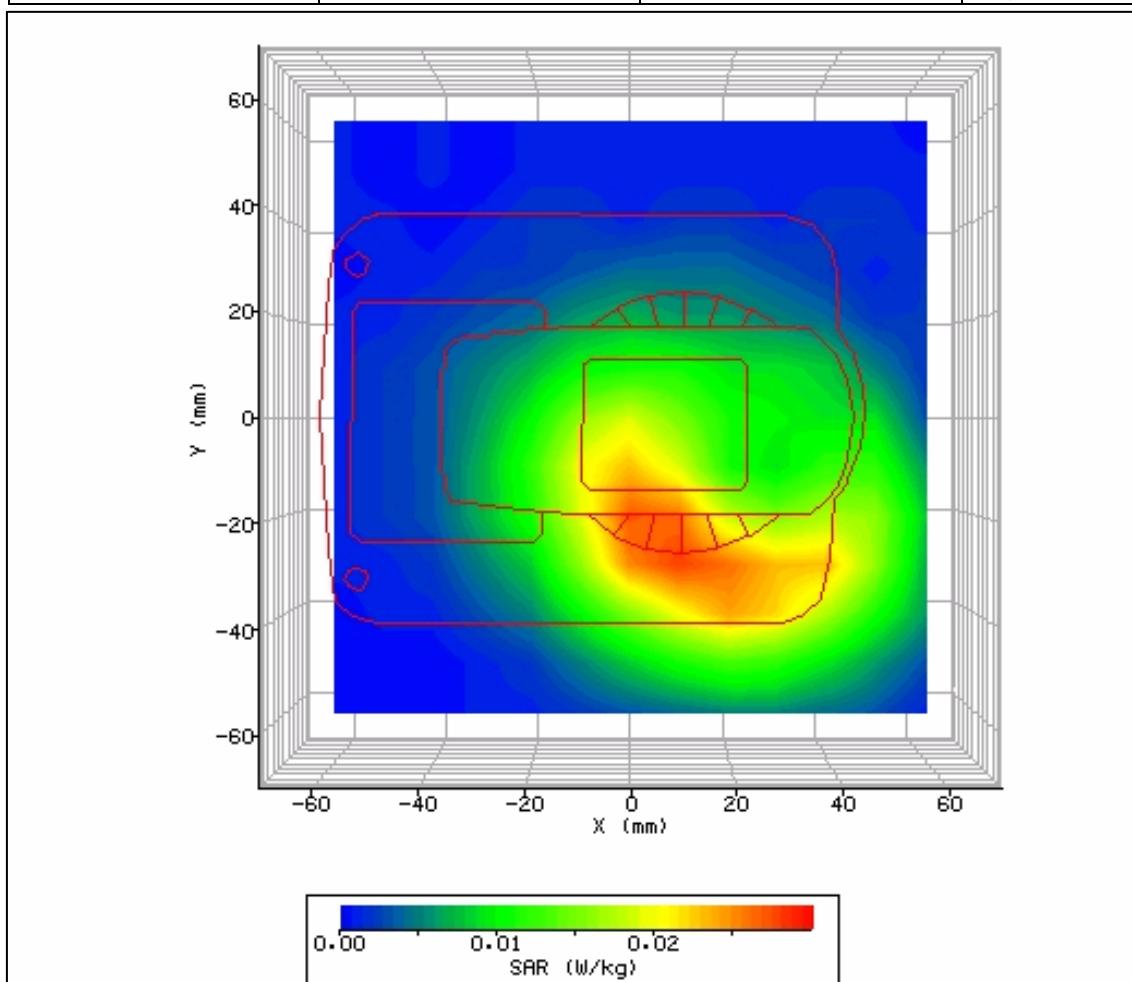


Figure 4: SAR Body Testing Results for the SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter) in Belt Clip Facing Phantom Position; Tested at 836.4MHz (850MHz GSM Middle Channel) with 0.0mm Separation.

## 2.2 850MHz GPRS BODY SAR TEST RESULT INCLUDING COURSE AREA SCAN – 2D

SYSTEM / SOFTWARE:	SARA2 / 2.39 VPM	INPUT POWER DRIFT:	0.0dB
DATE / TIME:	19/02/2007 16:39:23	DUT BATTERY MODEL/NO:	AE683466P6H
FILENAME:	75900645_02.txt	PROBE SERIAL NUMBER:	0171
AMBIENT TEMPERATURE:	22.8°C	LIQUID SIMULANT:	835 Body
DEVICE UNDER TEST:	River	RELATIVE PERMITTIVITY:	57.28
RELATIVE HUMIDITY:	36.2%	CONDUCTIVITY:	0.98
PHANTOM S/NO:	HeadBox170.csv	LIQUID TEMPERATURE:	21.0°C
PHANTOM ROTATION:	0°	MAX SAR X-AXIS LOCATION:	9.00 mm
DUT POSITION:	Belt Clip Facing 0mm	MAX SAR Y-AXIS LOCATION:	-26.00 mm
ANTENNA CONFIGURATION:	Fixed (Integral)	MAX E FIELD:	4.58 V/m
TEST FREQUENCY:	824.2MHz	SAR 1g:	0.023 W/kg
AIR FACTORS:	344 / 473 / 382	SAR 10g:	0.015 W/kg
CONVERSION FACTORS:	0.267 / 0.267 / 0.267	SAR START:	0.006 W/kg
TYPE OF MODULATION:	GMSK	SAR END:	0.005 W/kg
MODN. DUTY CYCLE:	25%	SAR DRIFT DURING SCAN:	-5.04 %
DIODE COMPRESSION FACTORS (V*200):	20 / 20 / 20	PROBE BATTERY LAST CHANGED:	16/02/2007
INPUT POWER LEVEL:	33dBm X 2	EXTRAPOLATION:	poly4

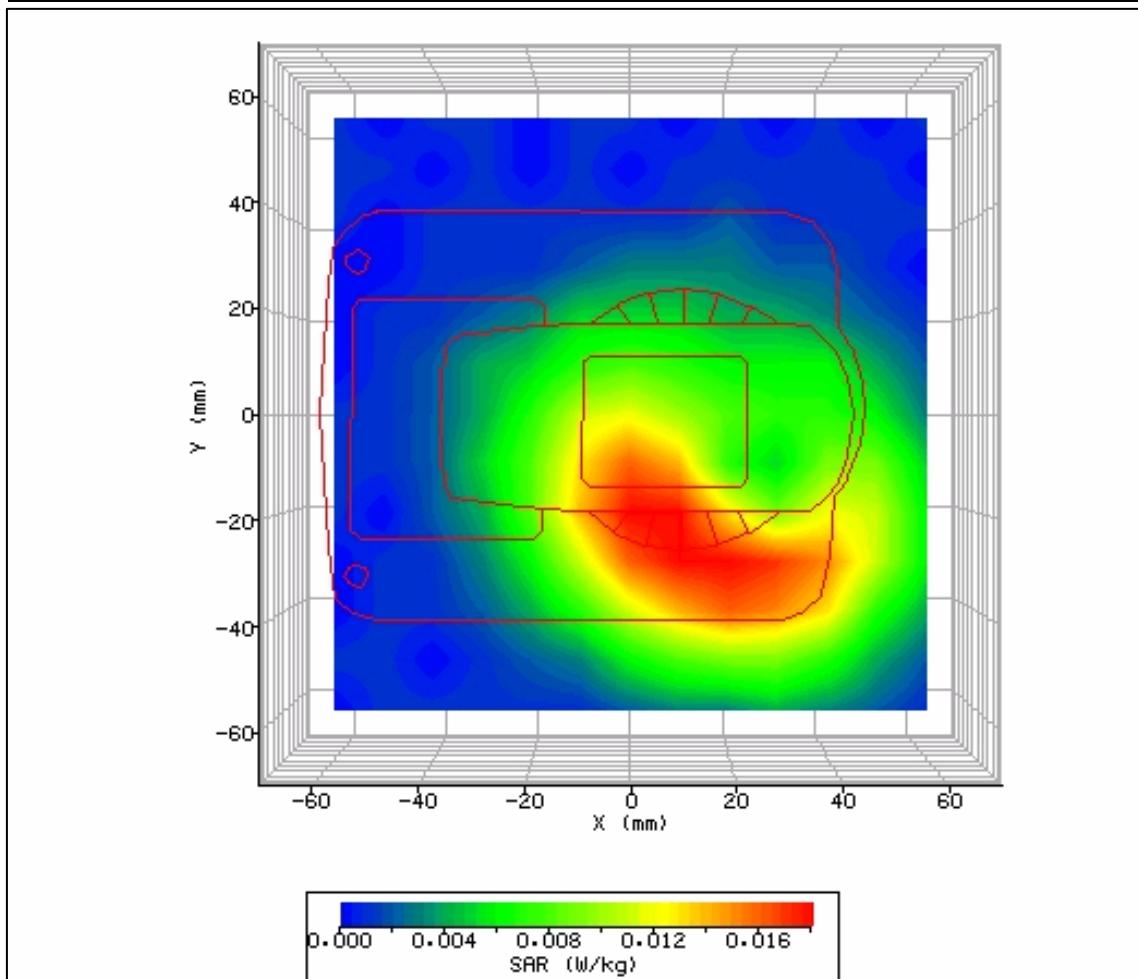


Figure 5: SAR Body Testing Results for the SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter) in Belt Clip Facing Phantom Position; Tested at 824.2MHz (850MHz GSM Low Channel) with 0.0mm Separation.

## 2.2 850MHz GPRS BODY SAR TEST RESULT INCLUDING COURSE AREA SCAN – 2D

SYSTEM / SOFTWARE:	SARA2 / 2.39 VPM	INPUT POWER DRIFT:	0.0dB
DATE / TIME:	19/02/2007 17:00:27	DUT BATTERY MODEL/NO:	AE683466P6H
FILENAME:	75900645_03.txt	PROBE SERIAL NUMBER:	0171
AMBIENT TEMPERATURE:	22.5°C	LIQUID SIMULANT:	835 Body
DEVICE UNDER TEST:	River	RELATIVE PERMITTIVITY:	57.28
RELATIVE HUMIDITY:	39.0%	CONDUCTIVITY:	0.98
PHANTOM S/NO:	HeadBox170.csv	LIQUID TEMPERATURE:	21.2°C
PHANTOM ROTATION:	0°	MAX SAR X-AXIS LOCATION:	7.00 mm
DUT POSITION:	Belt Clip Facing 0mm	MAX SAR Y-AXIS LOCATION:	-25.00 mm
ANTENNA CONFIGURATION:	Fixed (Integral)	MAX E FIELD:	5.31 V/m
TEST FREQUENCY:	848.8MHz	SAR 1g:	0.031 W/kg
AIR FACTORS:	344 / 473 / 382	SAR 10g:	0.020 W/kg
CONVERSION FACTORS:	0.267 / 0.267 / 0.267	SAR START:	0.008 W/kg
TYPE OF MODULATION:	GMSK	SAR END:	0.008 W/kg
MODN. DUTY CYCLE:	25%	SAR DRIFT DURING SCAN:	1.75 %
DIODE COMPRESSION FACTORS (V*200):	20 / 20 / 20	PROBE BATTERY LAST CHANGED:	16/02/2007
INPUT POWER LEVEL:	33dBm X 2	EXTRAPOLATION:	poly4

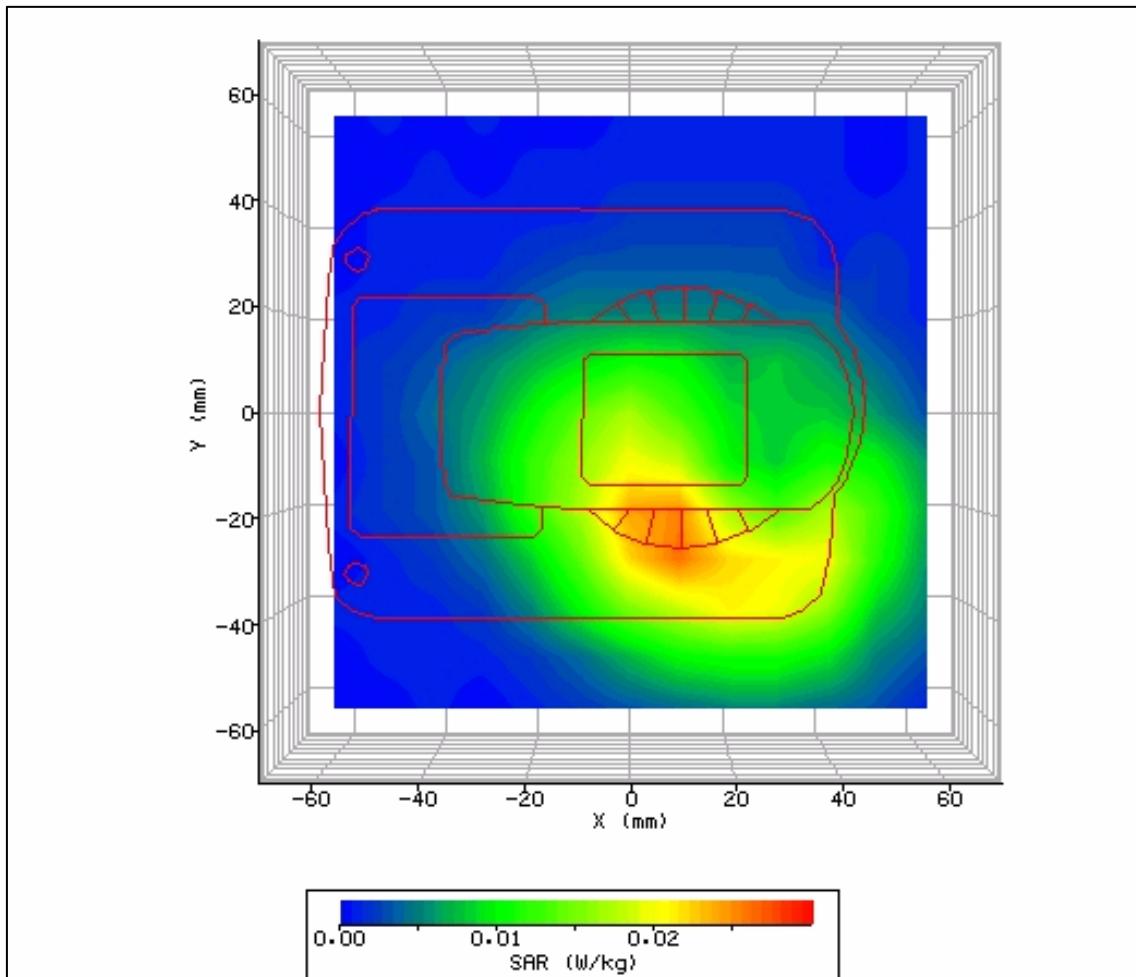


Figure 6: SAR Body Testing Results for the SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter) in Belt Clip Facing Phantom Position; Tested at 848.8MHz (850MHz GSM High Channel) with 0.0mm Separation.

### 2.3 1900MHz GPRS BODY SAR TEST RESULT INCLUDING COURSE AREA SCAN – 2D

SYSTEM / SOFTWARE:	SARA2 / 2.39 VPM	INPUT POWER DRIFT:	0.0dB
DATE / TIME:	20/02/2007 09:11:02	DUT BATTERY MODEL/NO:	AE683466P6H
FILENAME:	75900645_04.txt	PROBE SERIAL NUMBER:	0171
AMBIENT TEMPERATURE:	22.7°C	LIQUID SIMULANT:	1900 Body
DEVICE UNDER TEST:	River	RELATIVE PERMITTIVITY:	52.86
RELATIVE HUMIDITY:	44.1%	CONDUCTIVITY:	1.516
PHANTOM S/NO:	HeadBox170.csv	LIQUID TEMPERATURE:	20.9°C
PHANTOM ROTATION:	0°	MAX SAR X-AXIS LOCATION:	16.00 mm
DUT POSITION:	Belt Clip Facing 0mm	MAX SAR Y-AXIS LOCATION:	-21.00 mm
ANTENNA CONFIGURATION:	Fixed (Integral)	MAX E FIELD:	10.31 V/m
TEST FREQUENCY:	1880.0MHz	SAR 1g:	0.199 W/kg
AIR FACTORS:	344 / 473 / 382	SAR 10g:	0.123 W/kg
CONVERSION FACTORS:	0.368 / 0.368 / 0.368	SAR START:	0.034 W/kg
TYPE OF MODULATION:	GMSK	SAR END:	0.035 W/kg
MODN. DUTY CYCLE:	25%	SAR DRIFT DURING SCAN:	0.72 %
DIODE COMPRESSION FACTORS (V*200):	20 / 20 / 20	PROBE BATTERY LAST CHANGED:	16/02/2007
INPUT POWER LEVEL:	30dBm X 2	EXTRAPOLATION:	poly4

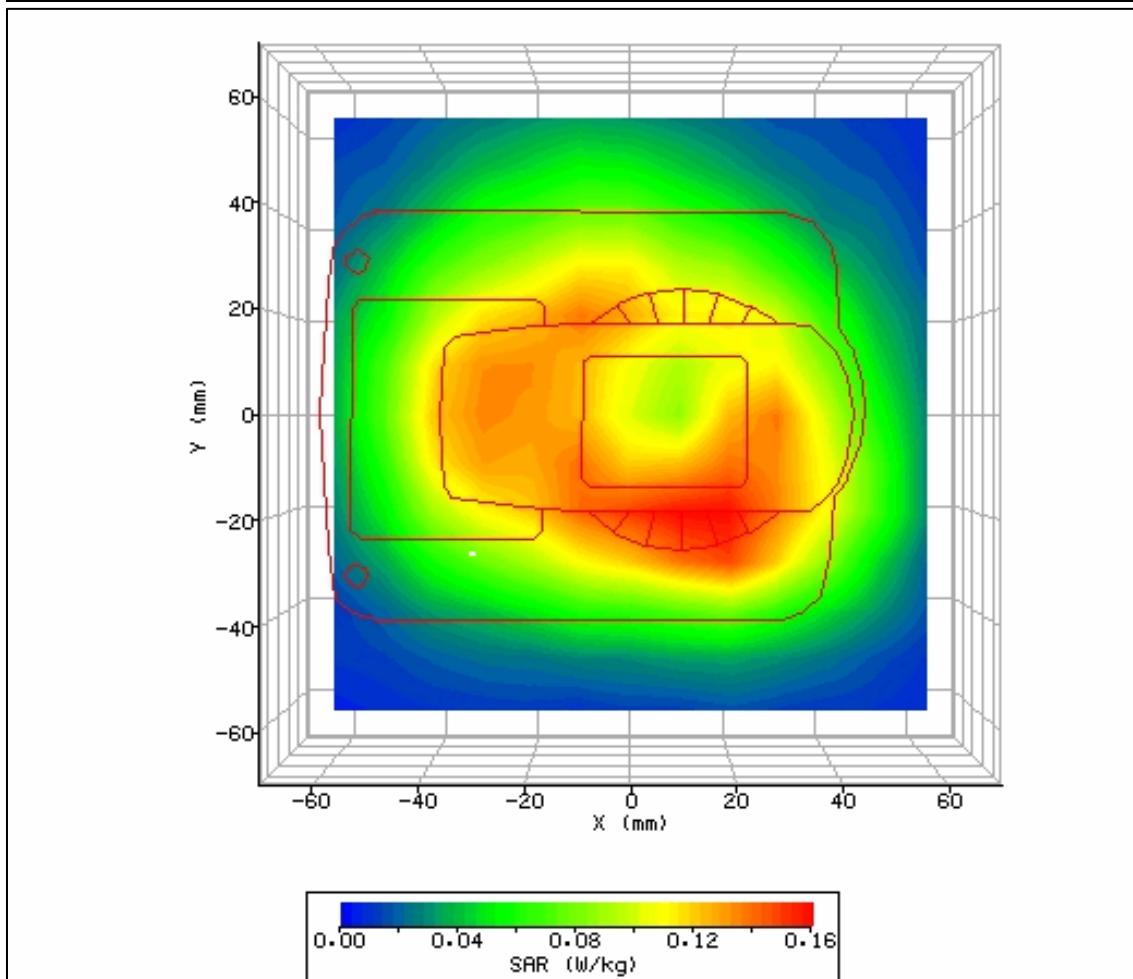


Figure 7: SAR Body Testing Results for the SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter) in Belt Clip Facing Phantom Position; Tested at 1880.0MHz (1900MHz GSM Middle Channel) with 0.0mm Separation.

### 2.3 1900MHz GPRS BODY SAR TEST RESULT INCLUDING COURSE AREA SCAN – 2D

SYSTEM / SOFTWARE:	SARA2 / 2.39 VPM	INPUT POWER DRIFT:	0.0dB
DATE / TIME:	20/02/2007 09:32:36	DUT BATTERY MODEL/NO:	AE683466P6H
FILENAME:	75900645_05.txt	PROBE SERIAL NUMBER:	0171
AMBIENT TEMPERATURE:	22.3°C	LIQUID SIMULANT:	1900 Body
DEVICE UNDER TEST:	River	RELATIVE PERMITTIVITY:	52.86
RELATIVE HUMIDITY:	42.1%	CONDUCTIVITY:	1.516
PHANTOM S/NO:	HeadBox170.csv	LIQUID TEMPERATURE:	20.9°C
PHANTOM ROTATION:	0°	MAX SAR X-AXIS LOCATION:	-8.00 mm
DUT POSITION:	Belt Clip Facing 0mm	MAX SAR Y-AXIS LOCATION:	13.00 mm
ANTENNA CONFIGURATION:	Fixed (Integral)	MAX E FIELD:	11.89 V/m
TEST FREQUENCY:	1850.2MHz	SAR 1g:	0.258 W/kg
AIR FACTORS:	344 / 473 / 382	SAR 10g:	0.168 W/kg
CONVERSION FACTORS:	0.368 / 0.368 / 0.368	SAR START:	0.055 W/kg
TYPE OF MODULATION:	GMSK	SAR END:	0.053 W/kg
MODN. DUTY CYCLE:	25%	SAR DRIFT DURING SCAN:	-3.48 %
DIODE COMPRESSION FACTORS (V*200):	20 / 20 / 20	PROBE BATTERY LAST CHANGED:	16/02/2007
INPUT POWER LEVEL:	30dBm X 2	EXTRAPOLATION:	poly4

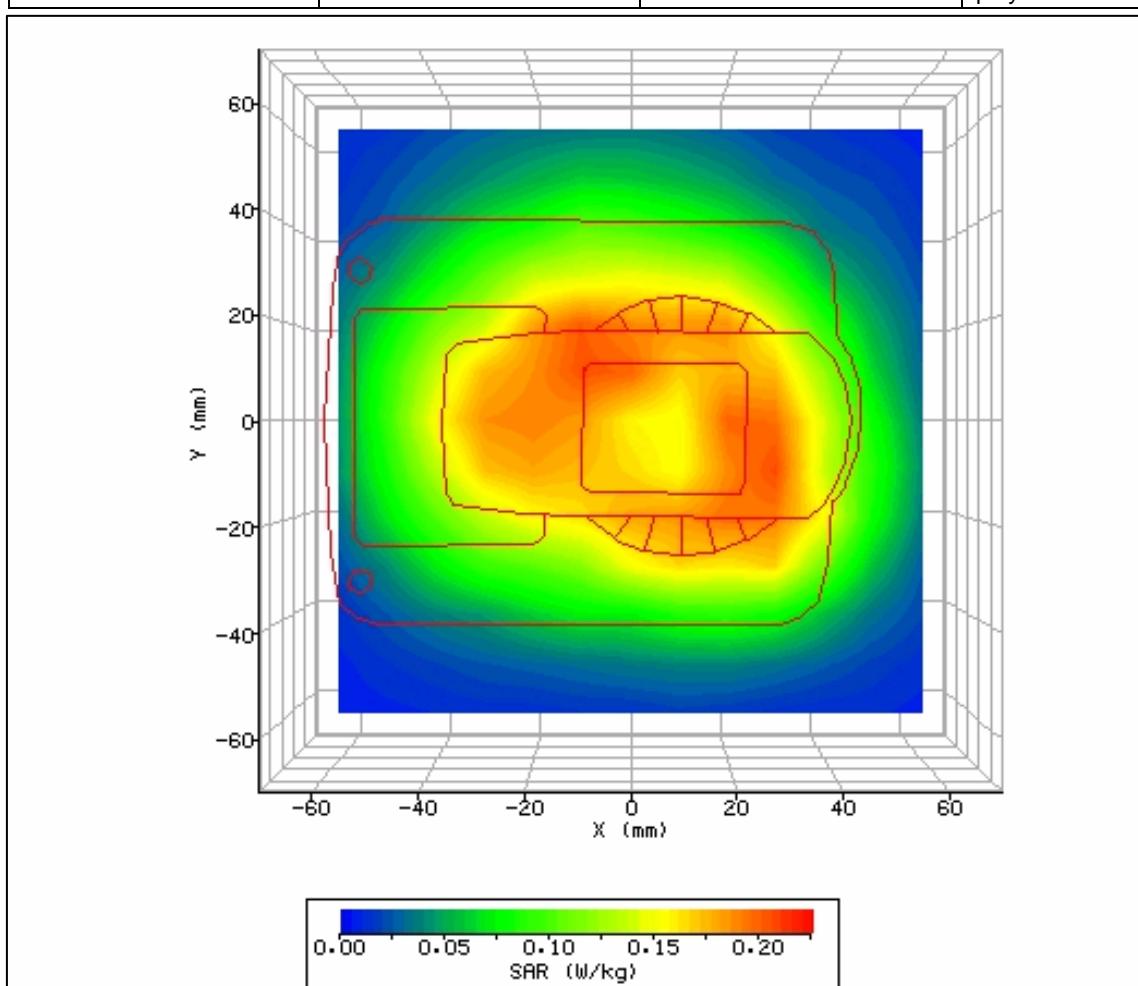


Figure 8: SAR Body Testing Results for the SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter) in Front Facing Phantom Position; Tested at 1850.2MHz (1900MHz GSM Low Channel) with 0.0mm Separation.

### 2.3 1900MHz GPRS BODY SAR TEST RESULT INCLUDING COURSE AREA SCAN – 2D

SYSTEM / SOFTWARE:	SARA2 / 2.39 VPM	INPUT POWER DRIFT:	0.0dB
DATE / TIME:	20/02/2007 09:54:10	DUT BATTERY MODEL/NO:	AE683466P6H
FILENAME:	75900645_06.txt	PROBE SERIAL NUMBER:	0171
AMBIENT TEMPERATURE:	22.4°C	LIQUID SIMULANT:	1900 Body
DEVICE UNDER TEST:	River	RELATIVE PERMITTIVITY:	52.86
RELATIVE HUMIDITY:	38.6%	CONDUCTIVITY:	1.516
PHANTOM S/NO:	HeadBox170.csv	LIQUID TEMPERATURE:	20.9°C
PHANTOM ROTATION:	0°	MAX SAR X-AXIS LOCATION:	5.00 mm
DUT POSITION:	Belt Clip Facing 0mm	MAX SAR Y-AXIS LOCATION:	-20.00 mm
ANTENNA CONFIGURATION:	Fixed (Integral)	MAX E FIELD:	10.38 V/m
TEST FREQUENCY:	1909.8MHz	SAR 1g:	0.192 W/kg
AIR FACTORS:	344 / 473 / 382	SAR 10g:	0.118 W/kg
CONVERSION FACTORS:	0.368 / 0.368 / 0.368	SAR START:	0.033 W/kg
TYPE OF MODULATION:	GMSK	SAR END:	0.033 W/kg
MODN. DUTY CYCLE:	25%	SAR DRIFT DURING SCAN:	0.27 %
DIODE COMPRESSION FACTORS (V*200):	20 / 20 / 20	PROBE BATTERY LAST CHANGED:	16/02/2007
INPUT POWER LEVEL:	30dBm X 2	EXTRAPOLATION:	poly4

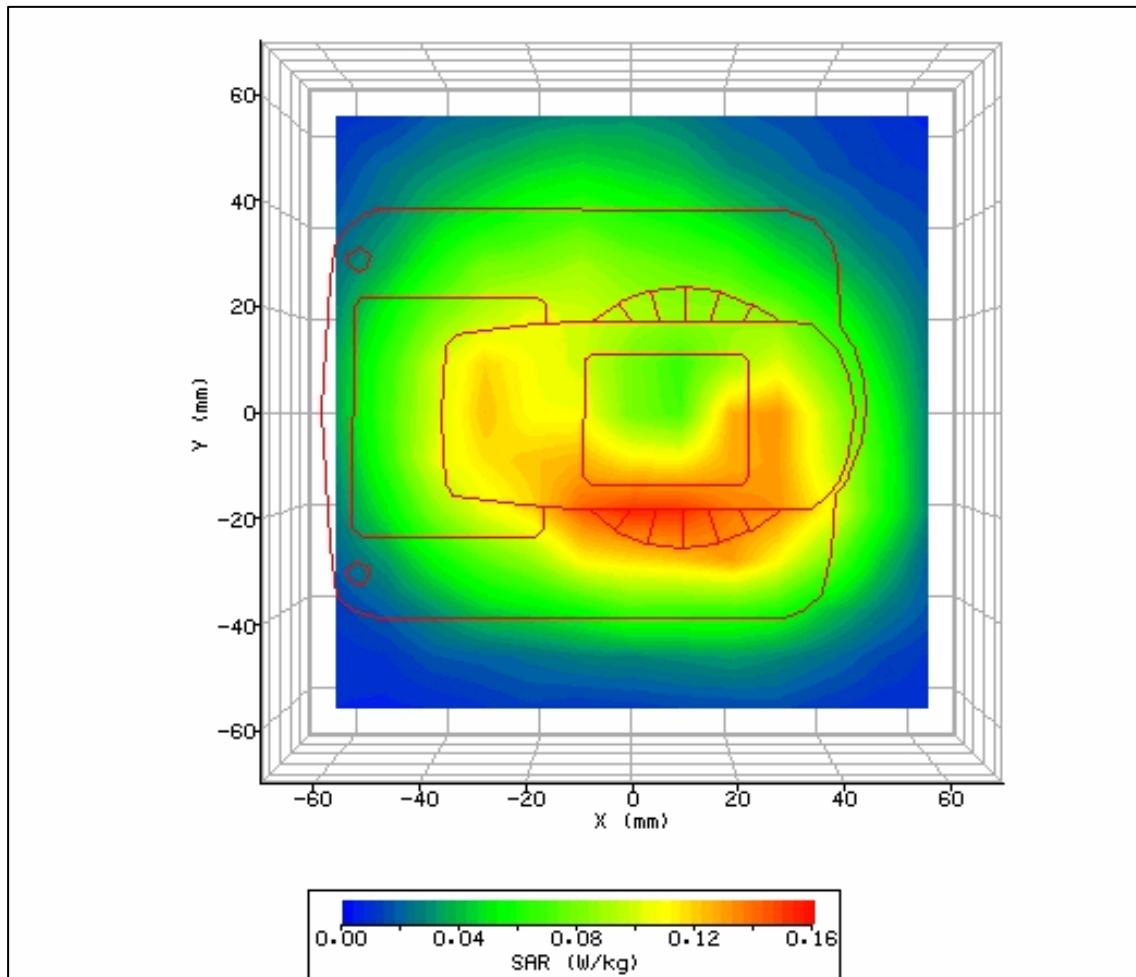


Figure 9: SAR Body Testing Results for the SHL Telemedicine International Ltd River ECG Cardiograph (Recorder/Transmitter) in Belt Clip Facing Phantom Position; Tested at 1909.8MHz (1900MHz GSM High Channel) with 0.0mm Separation.

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Product Service

## **SECTION 3**

### **TEST EQUIPMENT**

### 3.1 TEST EQUIPMENT

The following test equipment was used at TUV Product Service Ltd:

INSTRUMENT DESCRIPTION	MANUFACTURER	MODEL TYPE	TEST EQUIPMENT NO.	CALIBRATION DATES	
Bench-top Robot	Mitsubishi	RV-E2	156	N/A	N/A
Fast Probe Amplifier	IndexSAR Ltd.	IFA-010	1557	N/A	N/A
Side Bench 2	IndexSAR Ltd.	IXM-030	1571	N/A	N/A
Upright Bench 1	IndexSAR Ltd.	SARA2 system	1568	N/A	N/A
SAR Probe	IndexSAR Ltd.	IXP-050	171	19/05/2006	19/05/2007
Radio Communication Tester	Rohde & Schwarz	CMU 200	3035	11/03/2006	11/03/2007
Signal Generator	Hewlett Packard	E4422A	61	02/03/2006	02/03/2007
Power Meter	Rohde & Schwarz	NRVD	3259	06/11/2006	06/11/2007
RF Pre-Amplifier	IndexSAR Ltd.	0.8-3G	2415	N/A	N/A
Bi-Directional Coupler	Indexsar	1850	2414	29/01/2007	29/01/2008
20dB Attenuator	Narda	766F-10	483	01/06/2006	01/06/2007
Hygrometer	Rotronic	I-1000	2783	15/06/2006	15/06/2007
Digital Thermometer	Digitron	T208	64	19/10/2006	19/10/2007
Thermocouple	Rohde & Schwarz	K	65	19/10/2006	19/10/2007
835MHz Body TEM	TUV	Batch 5	N/A	16/02/2007	28/02/2007
835MHz Head TEM	TUV	Batch 11	N/A	16/02/2007	28/02/2007
1900MHz Head TEM	TUV	Batch 2	N/A	16/02/2007	28/02/2007
1900MHz Body TEM	TUV	Batch 3	N/A	16/02/2007	28/02/2007
844.4 MHz Dipole	IndexSAR Ltd.	IEEE1528	N/A	19/02/2007	20/02/2007
1929 MHz Dipole	IndexSAR Ltd.	IEEE1528	N/A	20/02/2007	21/02/2007
Flat Phantom 2mm Side	IndexSAR Ltd.	HeadBox01	1563	N/A	N/A
200mm Cube Box Phantom	IndexSAR Ltd.	IXB-070	1565	N/A	N/A

### 3.2 TEST SOFTWARE

The following software was used to control the TUV SARA2 System:

INSTRUMENT	VERSION NO.	DATE
SARA2 system	v.2.39 VPM	06/07/2005
Mitsubishi robot controller firmware revision	RV-E2 Version C9a	-
IFA-10 Probe amplifier	Version 2.5	-

### 3.3 DIELECTRIC PROPERTIES OF SIMULANT LIQUIDS

The fluid properties of the simulant fluids used during routine SAR evaluation meet the dielectric properties required by EN50361:2001 & OET Bulletin 65 (Edition 97-01).

The fluids were calibrated in our Laboratory and re-checked prior to any measurements being made against reference fluids stated in IEEE 1528-2003 of 0.9% NaCl (Salt Solution) at 23°C and also for Dimethylsulphoxide (DMS) at 21°C.

The fluids were made at TUV Product Service Ltd under controlled conditions from the following OET(65)c formulae and IEEE1528-2003. The composition of ingredients may have been modified accordingly to achieve the desired target tissue parameters required for routine SAR evaluation:

#### OET 65(c) Recipes

Ingredients (% by weight)	Frequency (MHz)									
	450		835		915		1900		2450	
Tissue Type	Head	Body	Head	Body	Head	Body	Head	Body	Head	Body
Water	38.56	51.16	41.45	52.4	41.05	56.0	54.9	40.4	62.7	73.2
Salt (NaCl)	3.95	1.49	1.45	1.4	1.35	0.76	0.18	0.5	0.5	0.04
Sugar	56.32	46.78	56.0	45.0	56.5	41.76	0.0	58.0	0.0	0.0
HEC	0.98	0.52	1.0	1.0	1.0	1.21	0.0	1.0	0.0	0.0
Bactericide	0.19	0.05	0.1	0.1	0.1	0.27	0.0	0.1	0.0	0.0
Triton X-100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.8	0.0
DGBE	0.0	0.0	0.0	0.0	0.0	0.0	44.92	0.0	0.0	26.7
Dielectric Constant	43.42	58.0	42.54	56.1	42.0	56.8	39.9	54.0	39.8	52.5
Conductivity (S/m)	0.85	0.83	0.91	0.95	1.0	1.07	1.42	1.45	1.88	1.78

#### IEEE 1528 Recipes

Frequency (MHz)	300	450	835	900	1450	1800	1900	1950	2000	2100	2450	3000					
Recipe #	1	1	3	1	1	2	3	1	1	2	4	1	1	2	2	3	1
Ingredients (% by weight)																	
1,2-Propanediol					64.81												
Bactericide	0.19	0.19	0.5	0.1	0.1		0.5				0.5						0.5
Diacetin			48.9			49.2				49.43							49.75
DGBE						45.41	47	13.84	44.92		44.92	13.84	45	50	50	7.99	7.99
HEC	0.98	0.98		1	1												
NaCl	5.95	3.95	1.7	1.45	1.48	0.79	1.1	0.67	0.36	0.35	0.18	0.64	0.18	0.35		0.16	0.16
Sucrose	55.32	56.32		57	56.5												0.16
Triton X-100								30.45				30.45				19.97	19.97
Water	37.56	38.56	48.9	40.45	40.92	34.4	49.2	53.82	52.64	55.36	54.9	49.43	54.9	55.36	55	50	71.88
Measured dielectric parameters																	
$\epsilon'_r$	46	43.4	44.3	41.6	41.2	41.8	42.7	40.9	39.3	41	40.4	39.2	39.9	41	40.1	37	36.8
$\sigma(\text{S/m})$	0.86	0.85	0.9	0.9	0.98	0.97	0.99	1.21	1.39	1.38	1.4	1.4	1.42	1.38	1.41	1.4	1.51
Temp. (°C)	22	22	20	22	22	22	20	22	22	21	22	20	21	21	20	22	20
Target dielectric parameters (Table 5-1)																	
$\epsilon'_r$	45.3	43.5	41.5	41.5	40.5						40				39.8	39.2	38.5
$\sigma(\text{S/m})$	0.87	0.87	0.9		0.97	1.2					1.4				1.49	1.8	2.4

### 3.3 DIELECTRIC PROPERTIES OF SIMULANT LIQUIDS

The dielectric properties of the tissue simulant liquids used for the SAR testing at TUV Product Service Ltd are as follows:-

FLUID TYPE	FREQUENCY	RELATIVE PERMITTIVITY $\epsilon_r$ ( $\epsilon'$ ) TARGET	RELATIVE PERMITTIVITY $\epsilon_r$ ( $\epsilon'$ ) MEASURED	CONDUCTIVITY $\sigma$ TARGET	CONDUCTIVITY $\sigma$ MEASURED
HEAD	835 MHz	<b>41.5</b>	42.01	<b>0.90</b>	0.919
BODY	835 MHz	<b>55.0</b>	57.28	<b>1.05</b>	0.980
HEAD	1900 MHz	<b>40.0</b>	38.83	<b>1.40</b>	1.415
BODY	1900 MHz	<b>53.3</b>	52.86	<b>1.52</b>	1.516

### 3.4 TEST CONDITIONS

#### TEST LABORATORY CONDITIONS

Ambient Temperature: Within +15°C to +35°C at 20% RH to 75% RH.

The actual Temperature during the testing ranged from 21.0°C to 22.8 °C.

The actual Humidity during the testing ranged from 36.2% to 44.10% RH.

#### TEST FLUID TEMPERATURE RANGE

FREQUENCY (MHZ)	850	835/900	1900	1900
BODY / HEAD FLUID	HEAD	BODY	HEAD	BODY
MIN TEMPERATURE (°C)	22.3	20.9	22.6	20.9
MAX TEMPERATURE (°C)	22.3	21.2	22.6	20.9

#### SAR DRIFT

The SAR Drift was within acceptable limits during scans. The maximum SAR Drift, drift due to the handset electronics, was recorded as -5.04% (-0.220dB) for all of the testing. The value of 5.04% has been included in the measurement uncertainty budget.

### 3.5 MEASUREMENT UNCERTAINTY

ERROR SOURCES	EN 50361 Description (Subclause)	Uncertainty (%)	Probability Distribution	Divisor	ci	ci^2	Standard Uncertainty (%)	Stand Uncert^2	(Stand Uncert^2) X (ci^2)
<b>Measurement Equipment</b>									
Calibration	7.2.1.1	10	Normal	2.00	1	1	5.00	25.00	25.00
Isotropy	7.2.1.2	10.6	Rectangular	1.73	1	1	6.12	37.45	37.45
Linearity	7.2.1.3	2.92	Rectangular	1.73	1	1	1.69	2.84	2.84
Probe Stability	-	2.46	Rectangular	1.73	1	1	1.42	2.02	2.02
Detection limits	7.2.1.4	0	Rectangular	1.73	1	1	0.00	0.00	0.00
Boundary effect	7.2.1.5	1.7	Rectangular	1.73	1	1	0.98	0.96	0.96
Measurement device	7.2.1.6	0	Normal	1.00	1	1	0.00	0.00	0.00
Response time	7.2.1.7	0	Normal	1.00	1	1	0.00	0.00	0.00
Noise	7.2.1.8	0	Normal	1.00	1	1	0.00	0.00	0.00
Integration time	7.2.1.9	2.3	Normal	1.00	1	1	2.30	5.29	5.29
<b>Mechanical constraints</b>									
Scanning system	7.2.2.1	0.57	Rectangular	1.73	1	1	0.33	0.11	0.11
Phantom shell	7.2.2.2	1.43	Rectangular	1.73	1	1	0.83	0.68	0.68
Matching between probe and phantom	7.2.2.3	2.86	Rectangular	1.73	1	1	1.65	2.73	2.73
Positioning of the phone 'Y' Co-ordinate	7.2.2.4	1.5	Normal	1.00	1	1	1.50	2.25	2.25
Positioning of the phone 'Z' Co-ordinate	7.2.2.4	1.73	Normal	1.00	1	1	1.73	2.99	2.99
<b>Physical Parameters</b>									
Liquid conductivity (deviation from target)	7.2.3.2	5	Rectangular	1.73	0.5	0.25	2.89	8.33	2.08
Liquid conductivity (measurement error)	7.2.3.2	15.3	Rectangular	1.73	0.5	0.25	8.83	78.03	19.51
Liquid permittivity (deviation from target)	7.2.3.3	5	Rectangular	1.73	0.5	0.25	2.89	8.33	2.08
Liquid permittivity (measurement error)	7.2.3.3	5	Rectangular	1.73	0.5	0.25	2.89	8.33	2.08
Drifts in output power of the phone, probe, temperature and humidity	7.2.3.4	5.04	Rectangular	1.73	1	1	2.91	8.47	8.47
Perturbation by the environment	7.2.3.5	3	Rectangular	1.73	1	1	1.73	3.00	3.00
<b>Post-Processing</b>									
SAR interpolation and extrapolation	7.2.4.1	2.4	Rectangular	1.73	1	1	1.39	1.92	1.92
Maximum SAR evaluation	7.2.4.2	2.4	Rectangular	1.73	1	1	1.39	1.92	1.92
<b>Combined standard uncertainty</b>	11.11						<b>Total</b>		<b>123.39</b>
<b>Expanded uncertainty = 22.22 % (Using a Coverage Factor of K=2) (confidence interval of 95 %)</b>									

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## **SECTION 4**

### **PHOTOGRAPHS**

#### 4.1 TEST POSITIONAL PHOTOGRAPHS

##### OET65(c) FLAT PHANTOM TEST POSITIONS



Figure 10. Positional photograph of the River ECG Cardiograph in normal user position, Belt Clip facing 0.0mm spacing from Phantom

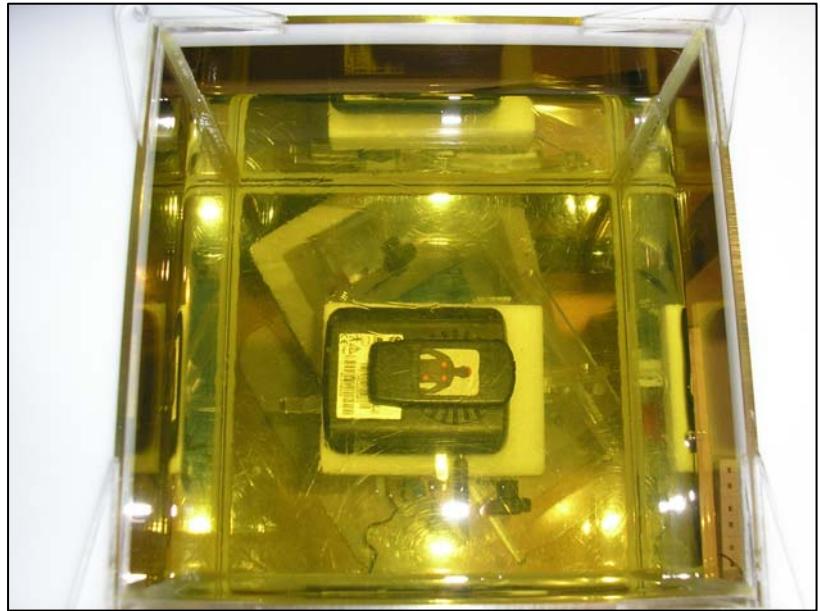


Figure 11. Positional photograph of the River ECG Cardiograph in Normal user position, Belt Clip facing 0.0mm spacing from Phantom

#### 4.2 PHOTOGRAPHS OF EQUIPMENT UNDER TEST (EUT)



Figure 12: Front View of the River ECG Cardiograph



Figure 13: Rear View of the River ECG Cardiograph

#### 4.2 PHOTOGRAPHS OF EQUIPMENT UNDER TEST (EUT)



Figure 14: Rear (Label) View of the River ECG Cardiograph

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## **SECTION 5**

### **ACCREDITATION, DISCLAIMERS AND COPYRIGHT**

## 5.1 ACCREDITATION, DISCLAIMERS AND COPYRIGHT

This report relates only to the actual item/items tested.

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Product Service

## ANNEX A

### PROBE 171 (TYPE IXP-050) CALIBRATION INFORMATION



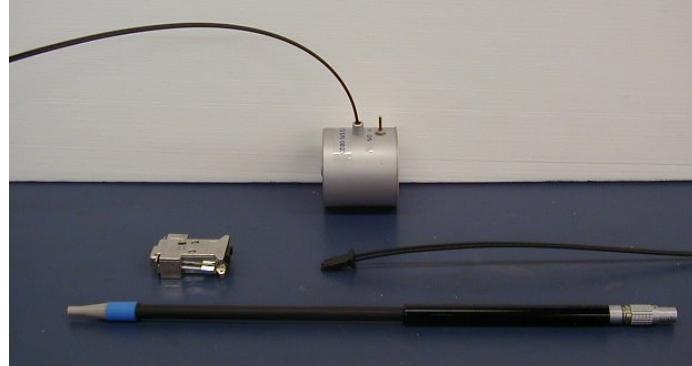
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 050

S/N 0171

May 2006



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## INTRODUCTION

This Report presents measured calibration data for a particular IndexSAR SAR probe (S/N 0171) and describes the procedures used for characterisation and calibration.

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

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

## CALIBRATION PROCEDURE

### 1. Objectives

The calibration process comprises three 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 waveguide fluid cell, and hence derive the liquid conversion factors 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

### 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:

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

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):

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

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.

## CALIBRATION PROCEDURE - Continued

### 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 minimise 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.

## CALIBRATION PROCEDURE - Continued

### 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:

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

Here, the density  $\rho$  is conventionally assumed to be 1000 kg/m<sup>3</sup>,  $ab$  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  $\delta$  (which is the reciprocal of the waveguide-mode attenuation coefficient) is a property of the lossy liquid and is given by Equation (5).

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

where  $\sigma$  is the conductivity of the tissue-simulant liquid in S/m,  $\epsilon_r$  is its relative permittivity, and  $\omega$  is the radial frequency (rad/s). Values for  $\sigma$  and  $\epsilon_r$  are obtained prior to each waveguide test using an IndexSAR DiLine measurement kit, which uses the TEM method as recommended in [2].  $\sigma$  and  $\epsilon_r$  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  $\pm$  2.0°C; if this is not possible, the values of  $\sigma$  and  $\epsilon_r$  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

## CALIBRATION PROCEDURE - Continued

### 4. Determination Of Conversion (“Liquid”) Factors At Each Frequency Of Interest - Continued

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 optimises 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.

#### 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

**CALIBRATION PROCEDURE – Continued****5. Measurement of Spherical Isotropy - Continued**

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.

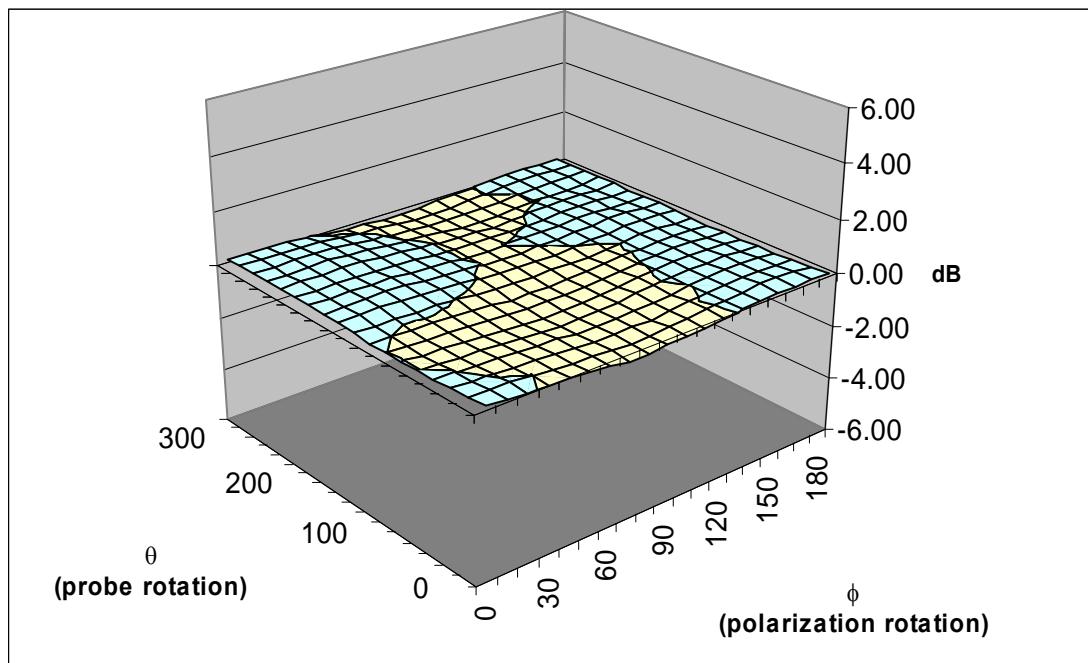
Given the typical dimensions of 3-channel SAR probes presently available, use of the VPM technique extends the satisfactory measurement range to higher frequencies.

## CALIBRATION FACTORS MEASURED FOR PROBE S/N 0170

The probe was calibrated at 450, 835, 900, 1800, 1900 and 2450 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 0171 at 900MHz after VPM**  
(rotational isotropy at side +/-0.05dB, spherical isotropy +/-0.24dB)

Probe tip radius	1.25
X Ch. Angle to red dot	-15

## CALIBRATION FACTORS MEASURED FOR PROBE S/N 0170 - Continued

Frequency	Head		Body	
	Bdy. Corrn. - f(0)	Bdy. Corrn. - d(mm)	Bdy. Corrn. - f(0)	Bdy. Corrn. - d(mm)
450	-	-	-	-
835	1.21	1.2	1.14	1.3
900	0.96	1.4	1.22	1.2
1800	0.91	1.4	0.83	1.5
1900	0.88	1.4	0.79	1.6
2100	0.81	1.4	0.70	1.7
2450	0.83	1.4	0.62	1.7

## SUMMARY OF CALIBRATION FACTORS FOR PROBE IXP-050 S/N 0171

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

	X	Y	Z	
Air Factors	344	473	382	(V*200)
CW DCPs	20	20	20	(V*200)

Freq (MHz)	Axial Isotropy		SAR ConvF		Notes	
	(+/- dB)		(liq/air)			
	Head	Body	Head	Body		
450	-	-	0.291	0.297		
835	-	-	0.271	0.267	1,2	
900	0.05	-	0.278	0.269	1,2	
1800	-	-	0.335	0.356	1,2	
1900	-	-	0.342	0.368	1,2	
2000	-	-	0.354	0.407	1,2	
2450	-	-	0.357	0.404	1,2	

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

## PROBE SPECIFICATIONS

IndexSAR probe 0171, 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 0171	CENELEC [1]	IEEE [2]
Overall length (mm)	350		
Tip length (mm)	10		
Body diameter (mm)	12		
Tip diameter (mm)	5.2	8	8
Distance from probe tip to dipole centers (mm)	2.7		

Dynamic range	S/N 0171	CENELEC [1]	IEEE [2]
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg)	>100	>100	100
N.B. only measured to > 100 W/kg on representative probes			

Isotropy (measured at 900MHz)	S/N 0171	CENELEC [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB)	0.05 Max (See table above)	0.5	0.25
Spherical isotropy covering all orientations to source (+/- dB)	0.24	1.0	0.50

<b>Construction</b>	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.
<b>Chemical resistance</b>	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.

## FIGURES

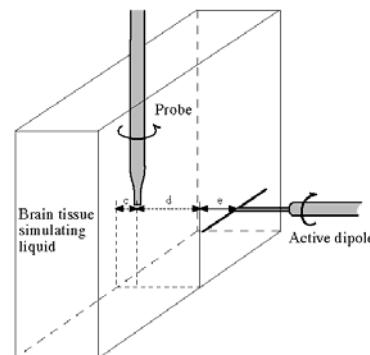


Figure 1. Spherical isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

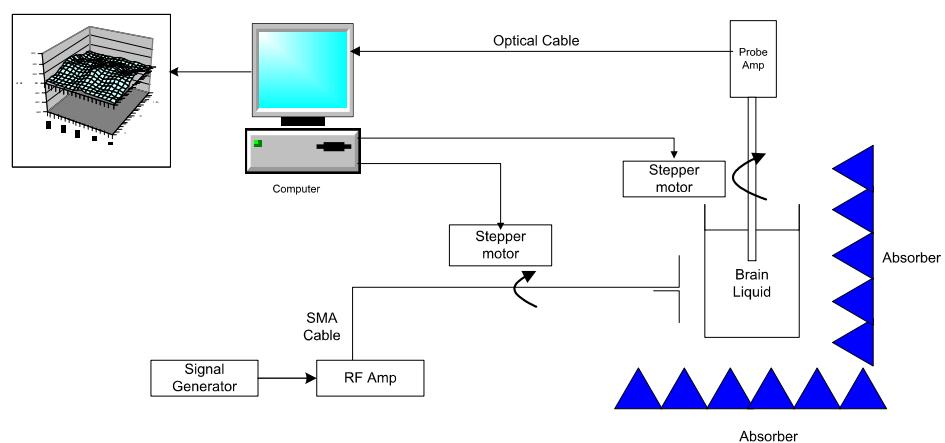


Figure 2. Schematic diagram of the test geometry used for isotropy determination

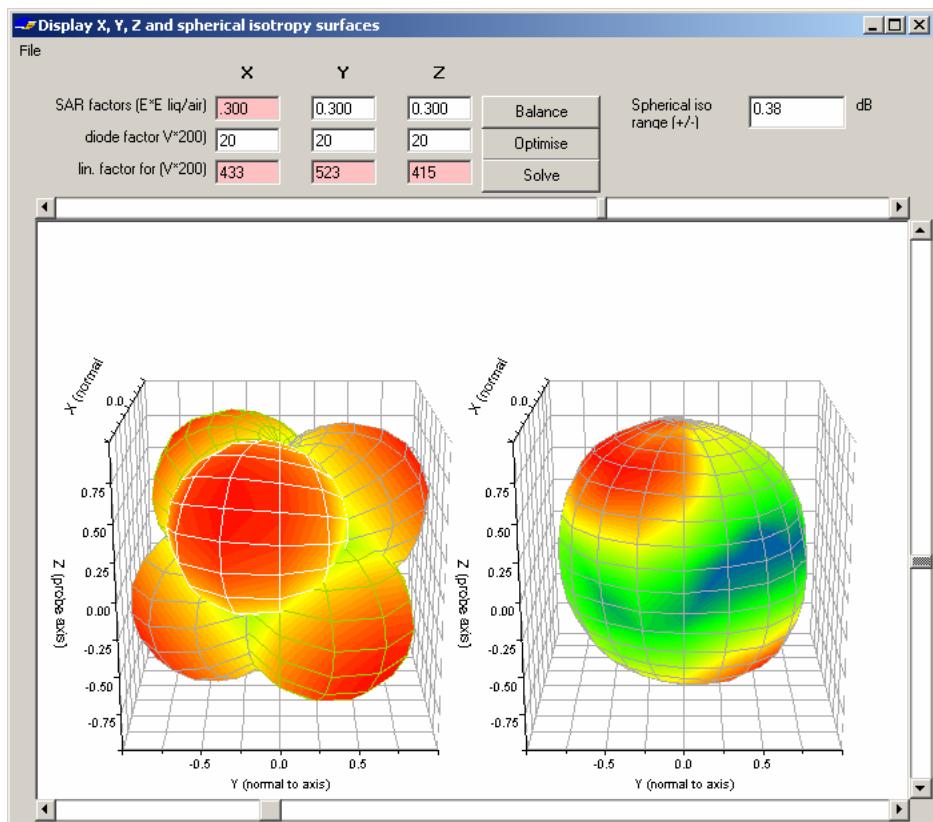


Figure 3. Graphical representation of a probe's response to fields applied from each direction. The diagram on the left shows the individual response characteristics of each of the three channels and the diagram on the right shows the resulting probe sensitivity in each direction. The colour range in the figure images the lowest values as blue and the maximum values as red. For the probe S/N 0171, this range is (+/-) 0.24 dB.

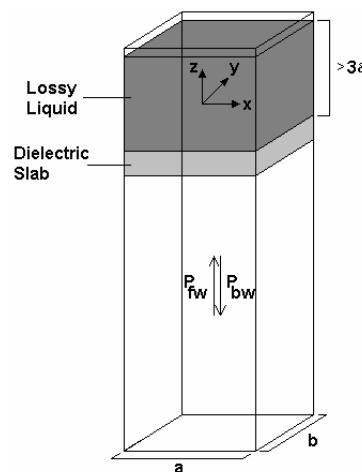


Figure 4. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

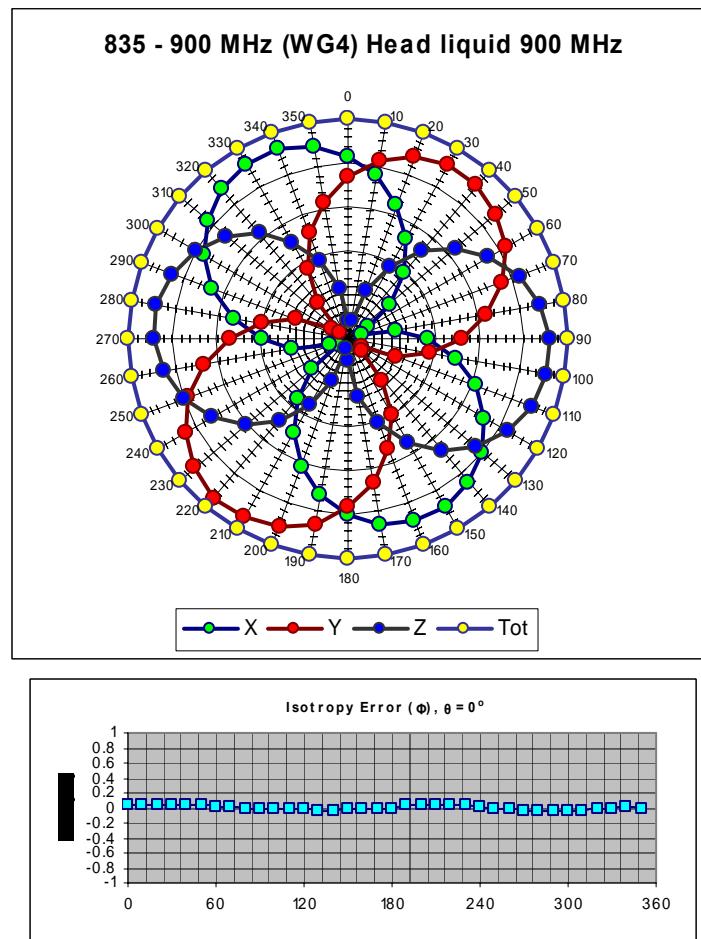


Figure 5. The rotational isotropy of probe S/N 0171 obtained by rotating the probe in a liquid-filled waveguide at 1800 MHz.

### SAR DECAY FUNCTION – Analytical and Measurements

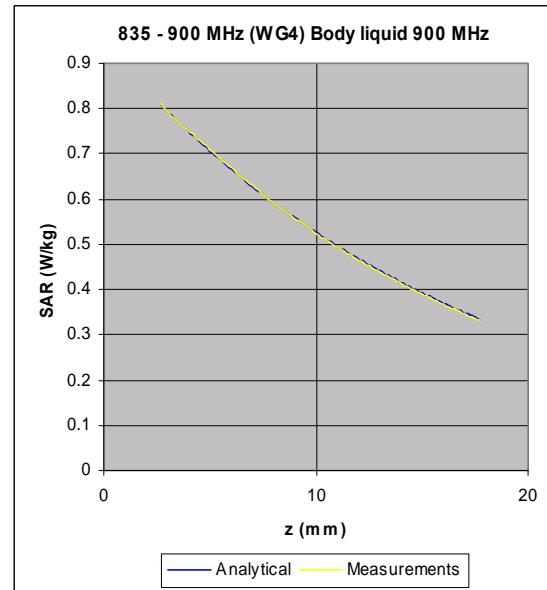
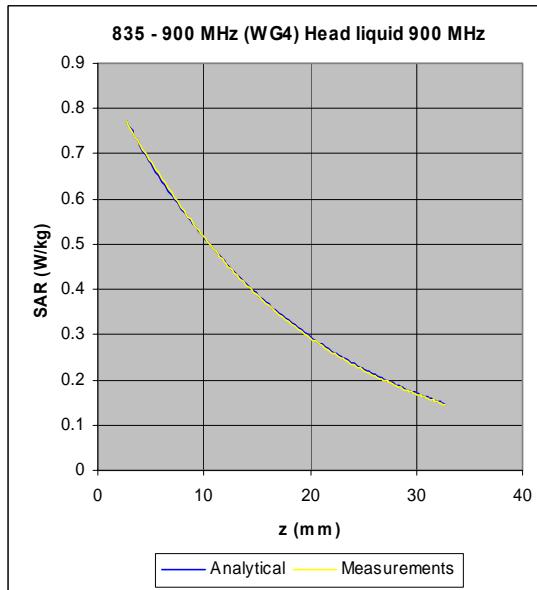
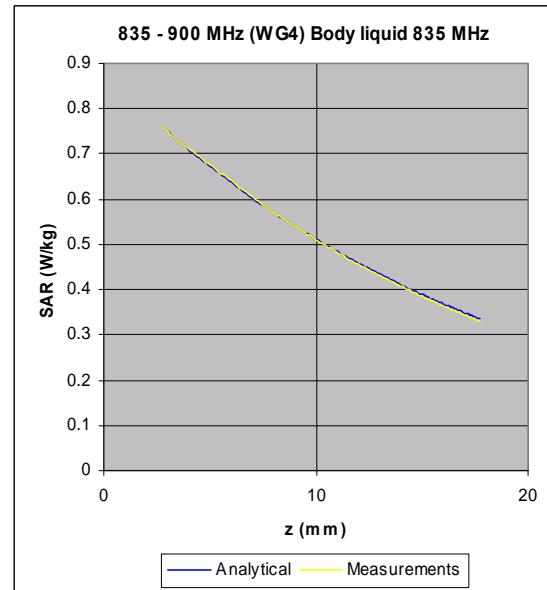
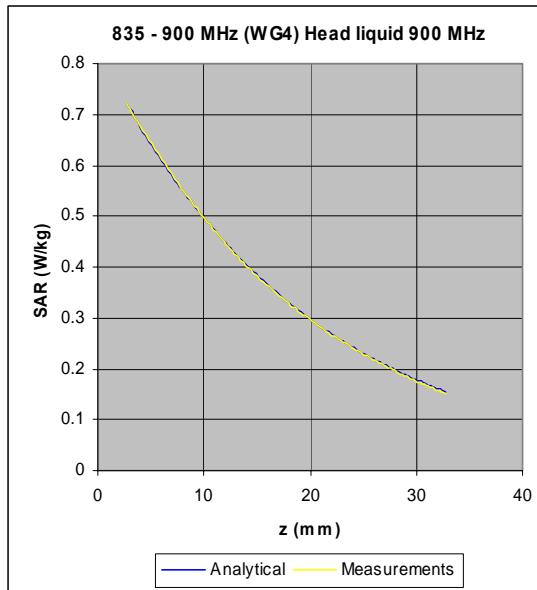


Figure 6a. The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

## SAR DECAY FUNCTION – Analytical and Measurements - Continued

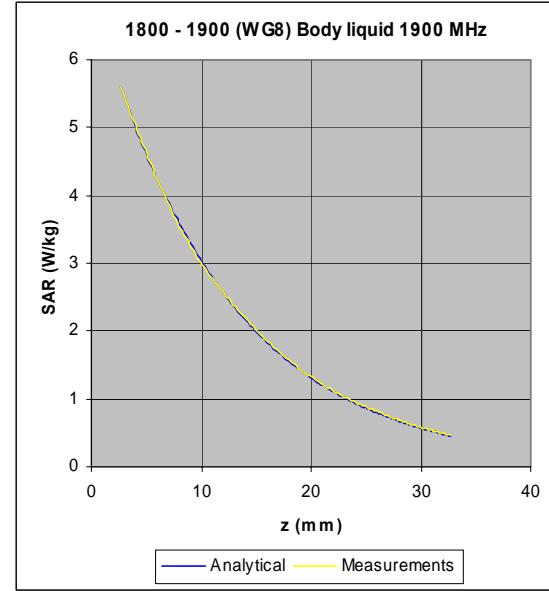
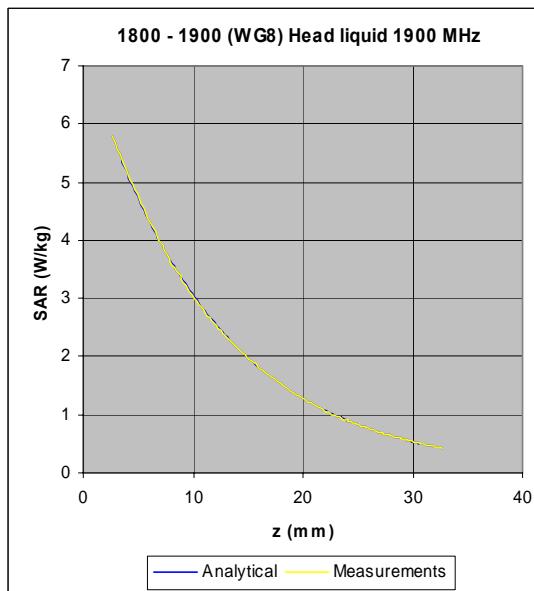
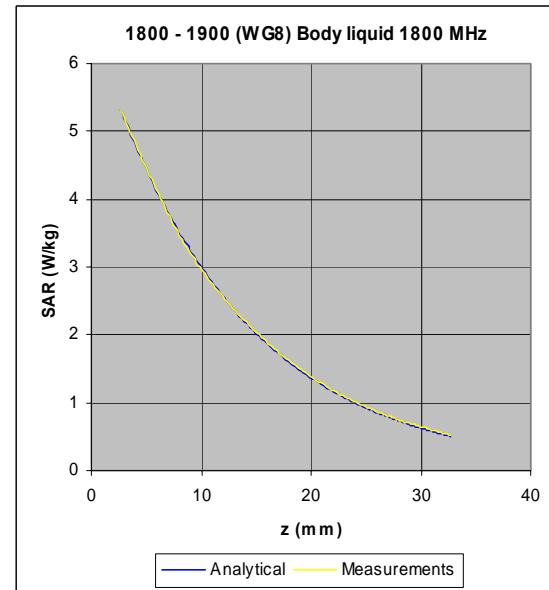
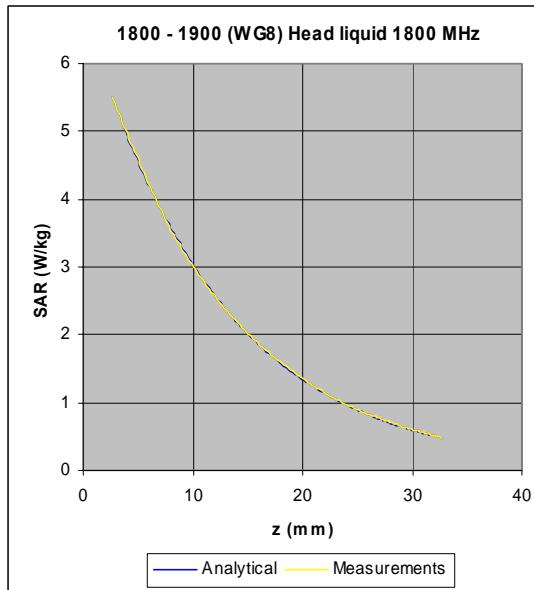


Figure 6b The measured SAR decay function along the centreline of the WG8 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

### SAR DECAY FUNCTION – Analytical and Measurements - Continued

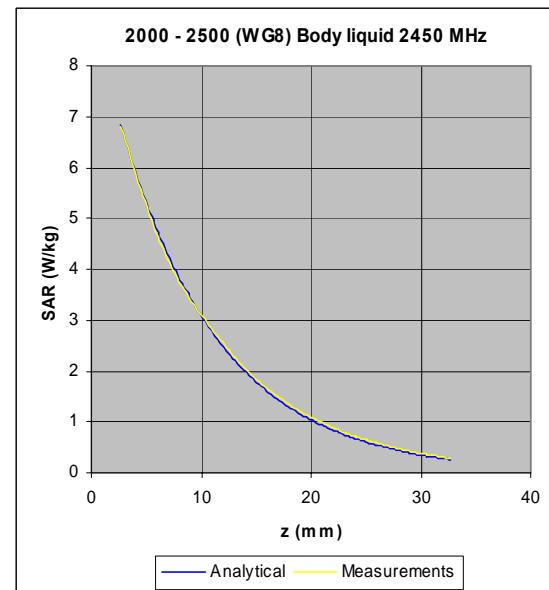
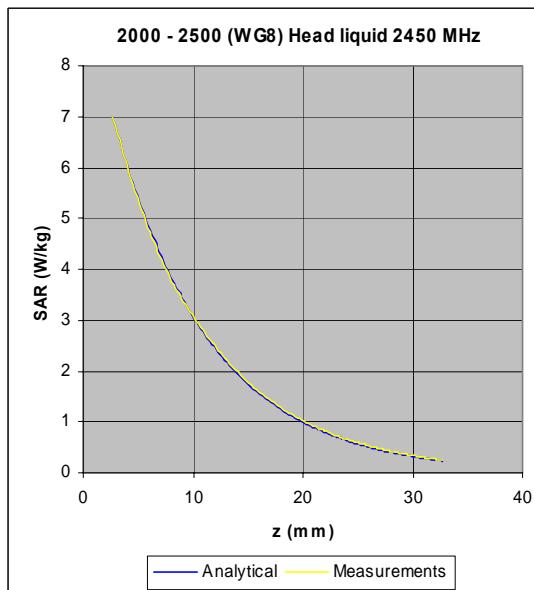
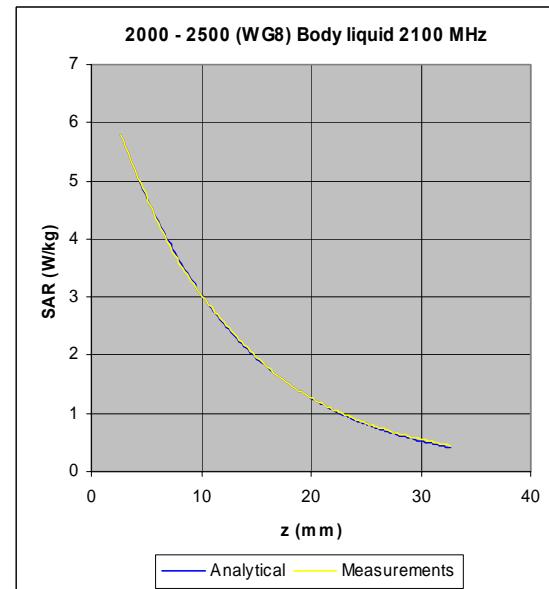
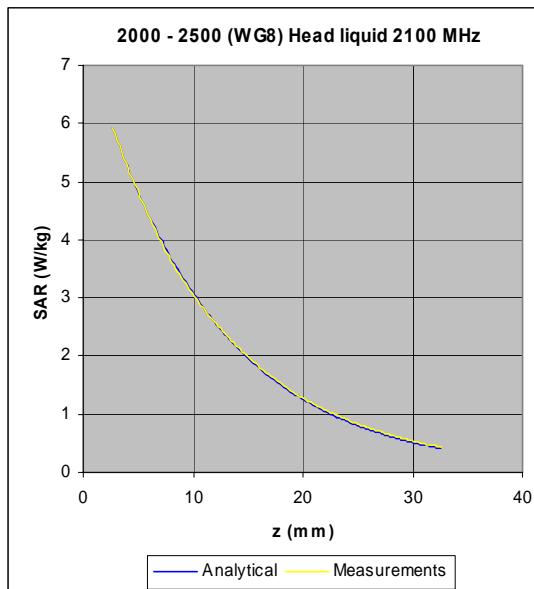


Figure 6c The measured SAR decay function along the centreline of the WG8 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

## SAR DECAY FUNCTION – Analytical And Measurements - Continued

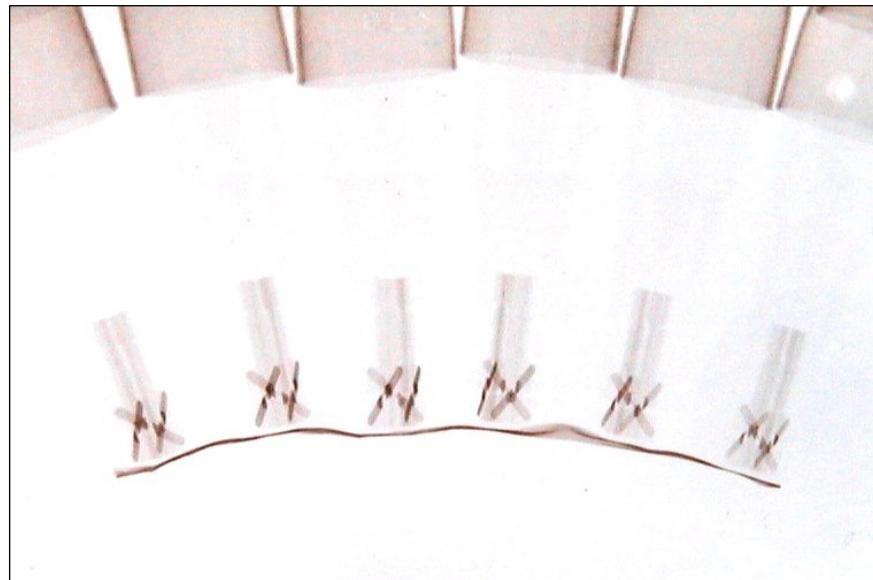


Figure 8: X-ray positive image of 5mm probes

**TABLE INDICATING THE DIELECTRIC PARAMETERS OF THE LIQUIDS USED FOR CALIBRATIONS AT EACH FREQUENCY**

<i>Liquid used</i>	<i>Relative permittivity (measured)</i>	<i>Conductivity (S/m) (measured)</i>
835 MHz BRAIN	42.05	0.91
835 MHz BODY	49.30	1.05
900 MHz BRAIN	40.97	0.97
900 MHz BODY	48.55	1.12
1800 MHz BRAIN	38.93	1.38
1800 MHz BODY	54.32	1.56
1900 MHz BRAIN	38.50	1.47
1900 MHz BODY	54.00	1.66
2100 MHz BRAIN	40.39	1.54
2100 MHz BODY	53.88	1.74
2450 MHz BRAIN	39.04	1.91
2450 MHz BODY	52.83	2.13