# *Specific Absorption Rate (SAR) Test Report*

for

ZyXEL Communications Corporation

on the

802.11g Wireless USB Adapter

**Model Number: G-210H**

Test Report: EME-070048
Issue date: Jan. 29, 2007

Total No of Pages Contained in this Report: 75

**Testing Laboratory
0597**

Accredited for testing to FCC Part 15

| | |
|---|---|
| Tested by: Marx Yan | |
| Reviewed by: Kevin Chen | |

Review Date: Jan. 29, 2007

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## 1.0 General information

The device was tested at the Intertek Testing Services facility in Hsinchu, Taiwan. The maximum output power declared by the Hawking Technologies, Inc..

EUT model # G-210H was evaluated accordance with the requirements for compliance testing defined in FCC OET Bulletin 65, Supplement C (Edition 01-01) and meet the SAR requirement, the phantom employed was the box phantom of 2mm thick in one wall. The total uncertainty for the evaluation of the spatial peak SAR values averaged over a cube of 1g tissue mass had been assessed for this system to be ±20.6%, the dosimeter assessment system INDEXSAR SARA2 was used.

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** |
|---|---|---|
| 2mm thick box phantom wall | 802.11b middle channel<br>EUT stand perpendicular<br>0mm to phantom | 0.562 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 G-210H has been tested at the request of:

**Applicant: ZyXEL Communications Corporation**
**6, Innovation Rd II, Science-Based Industrial Park, Hsin-Chu, Taiwan**

## 1.2 Equipment under test (EUT)

**Product Descriptions:**

| | | | |
|---|---|---|---|
| **Equipment** | 802.11g Wireless USB Adapter | | |
| **Trade Name** | ZyXEL | **Model No:** | G-210H |
| **FCC ID** | I88G210H | **S/N No.** | Not Labeled |
| **Category** | Portable | **RF Exposure** | Uncontrolled Environment |
| **EUT Type** | Production Unit | | |
| **Frequency Band** | 2412 – 2462 MHz | **System** | DSSS, OFDM |

| **EUT Antenna Description** | | | |
|---|---|---|---|
| **Type** | Patch antenna | **Configuration** | Fixed |
| **Dimensions** | 29 x 53 mm | **Gain** | 5 dBi |
| **Location** | Embedded | | |

**Use of Product :** 802.11g Wireless USB Adapter
**Manufacturer:** ZyXEL Communications Corporation (or Same as applicant)

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

**EUT receive date:** Oct. 24, 2005

**EUT status:** Normal operating condition

**Test start date:** Nov. 2, 2005

**Test end date:** Nov. 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 ~ 13

### 1.4.1 Support equipment & EUT antenna position

| Support Equipment | | | | |
|---|---|---|---|---|
| **Item #** | **Equipment** | **Brand** | **Model No.** | **S/N** |
| 1 | Note PC | IBM | 2887 | 99XML12 |

### 1.4.2 Test Condition

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

| | | | | |
|---|---|---|---|---|
| **Usage** | Operates with a portable computer | **Distance between antenna axis at the joint and the liquid surface:** | Laptop is touching the Phantom in bottom position, separating 0mm in front position, separating 0mm and 15mm in rear position. | |
| **Simulating human Head/ Body/Hand** | Body | **EUT Battery** | Device is powered from host computer through battery. | |
| **802.11b Conducted output Power** | **Channel** | **Frequency MHz** | **Before SAR Test (dBm)** | **After SAR Test (dBm)** |
| | Low Channel - 1 | 2412 | 11.36 | - |
| | Mid Channel - 6 | 2437 | 11.03 | 11.02 |
| | High Channel- 11 | 2462 | 11.28 | - |
| **802.11g Conducted output Power** | **Channel** | **Frequency MHz** | **Before SAR Test (dBm)** | **After SAR Test (dBm)** |
| | Low Channel – 1 | 2412 | 14.95 | - |
| | Mid Channel – 6 | 2437 | 14.48 | 14.47 |
| | High Channel- 11 | 2462 | 14.79 | - |

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

The conducted output power was measured before and after the test using a wideband peak power meter.

The EUT was run the test program “QAU2751W.exe” under windows OS, which provide by manufacturer.

The EUT was transmitted continuously during the test.

With individual verifying, the maximum output power was found at 1Mbps data rate for 802.11b mode and 6Mbps data rate for 802.11g mode. The final tests were executed under these conditions recorded in this report individually.

### 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

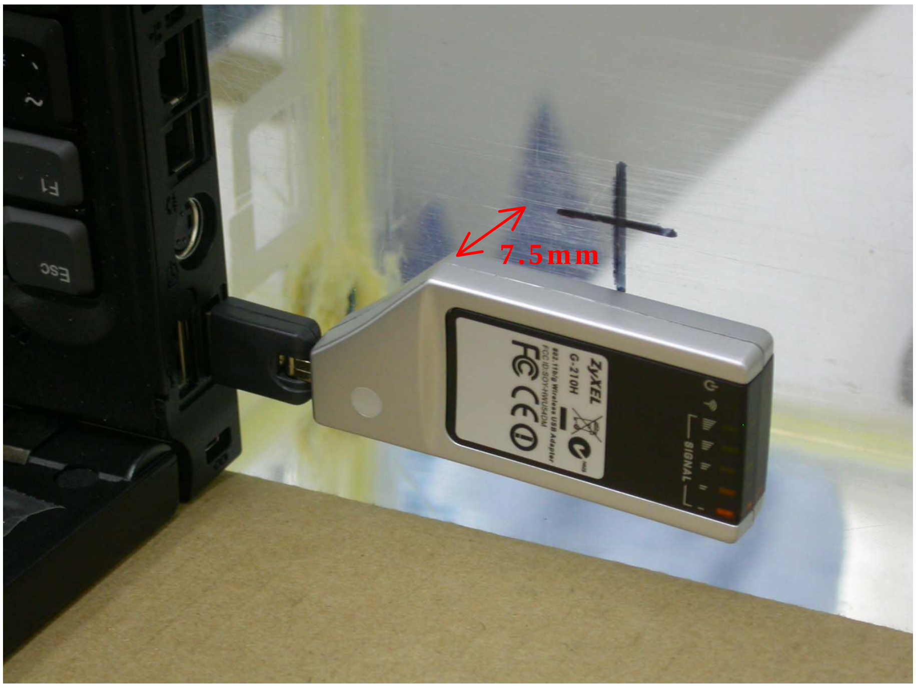
**SAR Measurement Test Setup**

**Figure 1: Test System**

**SAR Measurement Test Setup**

**Figure 2: Bottom side of Laptop facing phantom touching with EUT lie down**

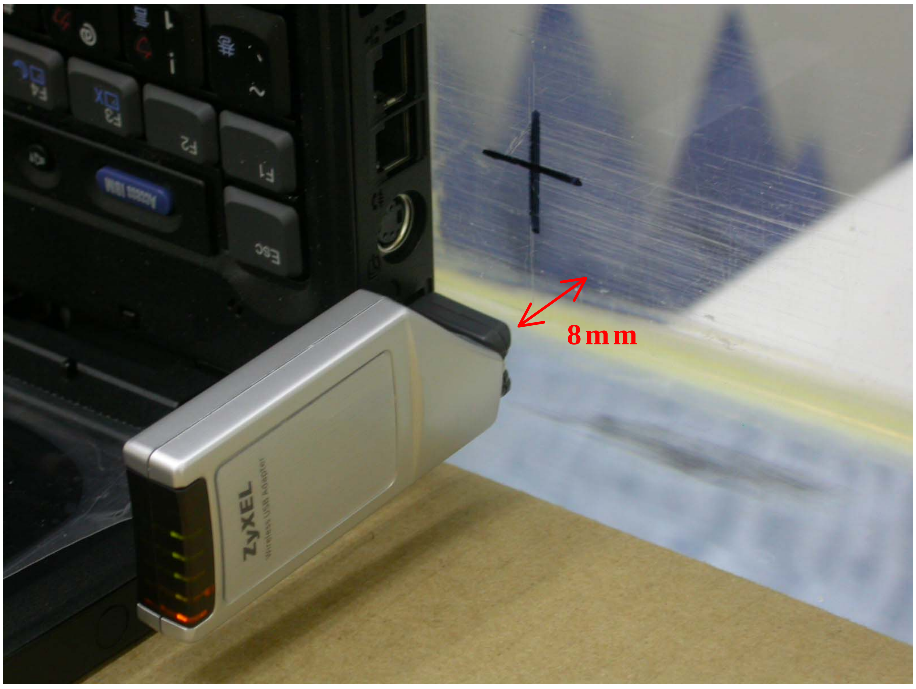
**Figure 3: Bottom side of Laptop facing phantom touching with EUT lie down - Zoom In**



**SAR Measurement Test Setup**

**Figure 4: Bottom side of Laptop facing phantom touching with EUT stand**

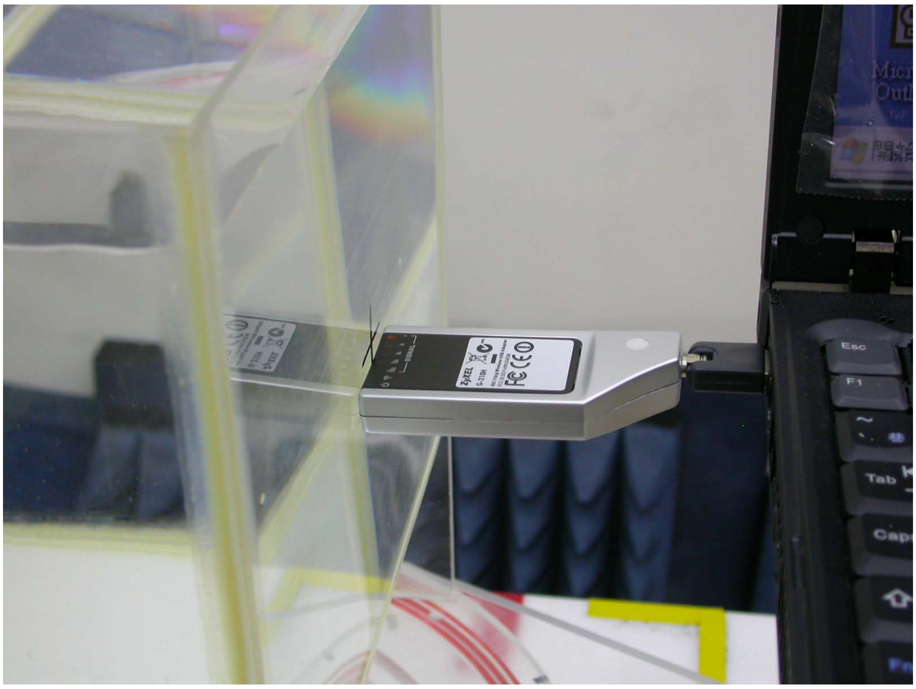
**Figure 5: Bottom side of Laptop facing phantom touching with EUT stand - Zoom In**



**SAR Measurement Test Setup**

**Figure 6: EUT perpendicular to phantom, 0 mm separation (with EUT lie down)**

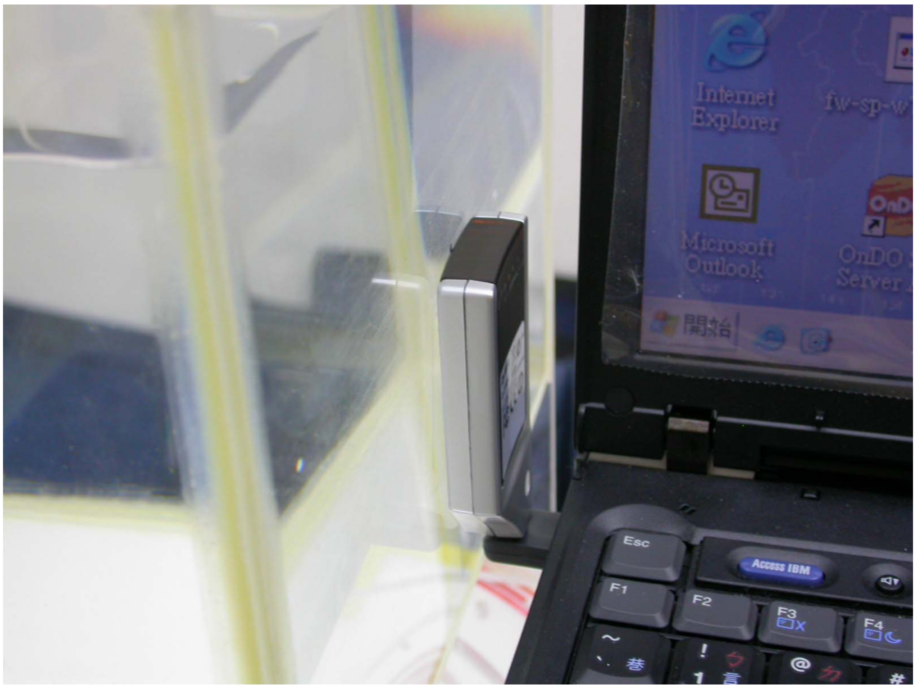
**Figure 7: EUT perpendicular to phantom, 0 mm separation (with EUT lie down) - Zoom In**



**SAR Measurement Test Setup**

**Figure 8: EUT perpendicular to phantom, 0 mm separation (with EUT stand)**

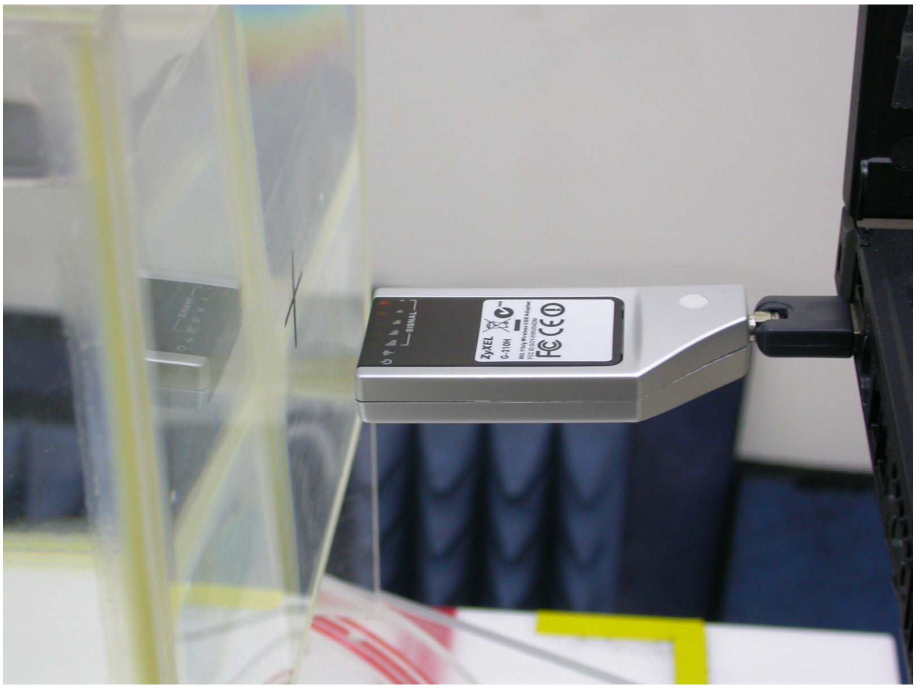
**Figure 9: EUT perpendicular to phantom, 0 mm separation (with EUT stand) - Zoom In**



**SAR Measurement Test Setup**

**Figure 10: EUT perpendicular to phantom, 15 mm separation (with EUT lie down)**

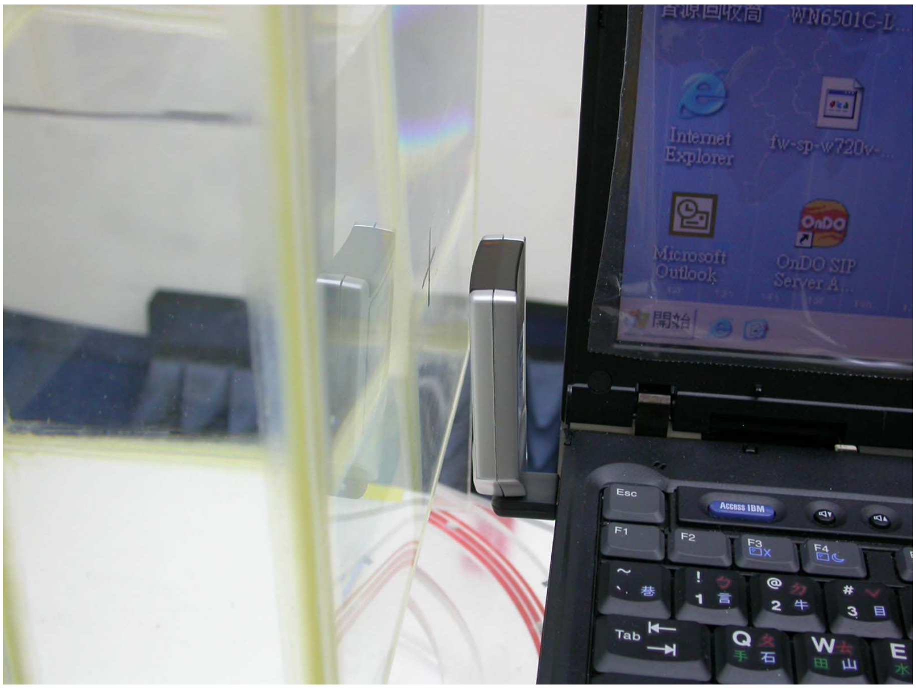
**Figure 11: EUT perpendicular to phantom, 15 mm separation (with EUT lie down) - Zoom In**



**SAR Measurement Test Setup**

**Figure 12: EUT perpendicular to phantom, 15 mm separation (with EUT stand)**

**Figure 13: EUT perpendicular to phantom, 15 mm separation (with EUT stand) - Zoom 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.

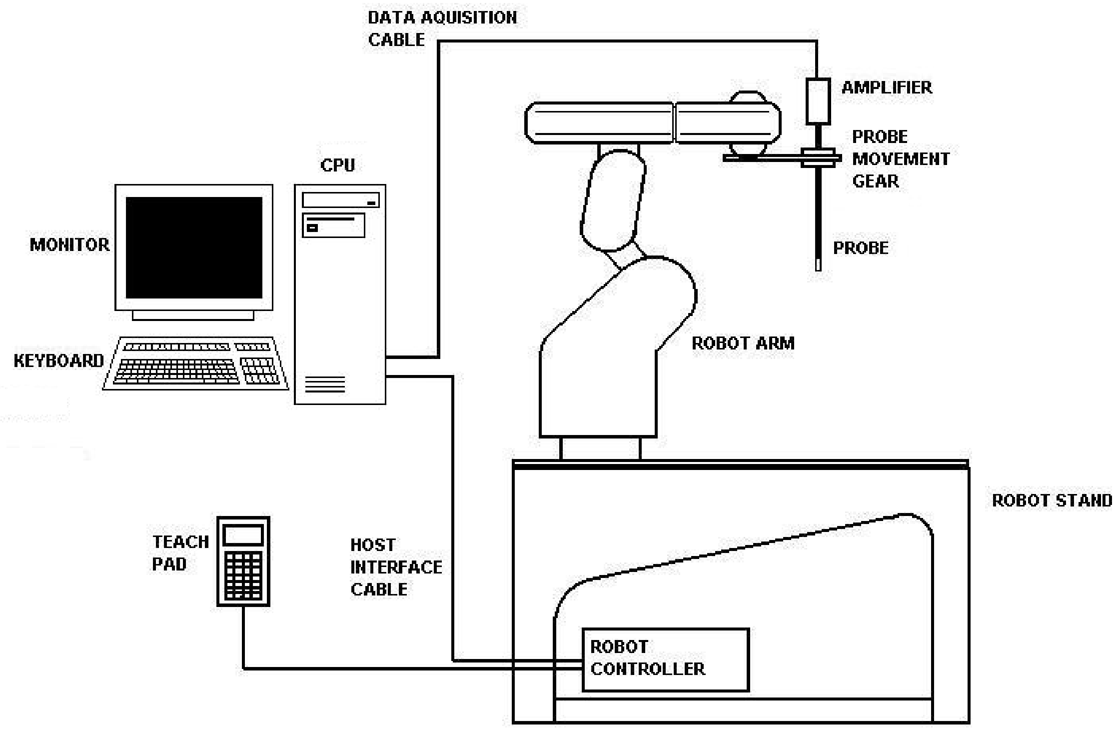



*Figure 1: Schematic diagram of the SAR measurement system*

The position and digitized 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 digitized 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 central 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 2450 MHz on then 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 scans procedure for system validation also applies 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 standard dipole antenna was placed at the bottom of phantom

## 2.4.1 System Validation result

| System Validation (2450 MHz Head) | | | | |
|---|---|---|---|---|
| **Frequency MHz** | **Operating Mode** | **Target $SAR_{1g}$ (W/kg)** | **Measured $SAR_{1g}$ (W/kg)** | **Deviation (±10%)** |
| 2450 | CW | 52.4 | 52.8 | 0.76% |

Please see the plot below:

| | | | |
|---|---|---|---|
| **Date:** | 2005/6/1 | **Position:** | Bottom of the Phantom |
| **Filename:** | 2450 system validation.txt | **Phantom:** | HeadBox2-val..csv |
| **Device Tested:** | SARA2 system validation | **Head Rotation:** | 0 |
| **Antenna:** | 2450 STD Dipole Antenna | **Test Frequency:** | 2450MHz |
| **Shape File:** | none.csv | **Power Level:** | 23dBm /CW |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_HEAD

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .508 | .508 | .508 |

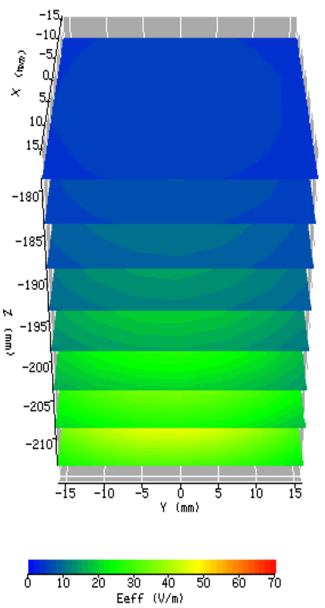
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450MHz Head |
| **Conductivity:** | 1.8441 |
| **Relative Permittivity:** | 38.562 |
| **Liquid Temp (deg C):** | 23 |
| **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):** | 0.663 | 0.663 |

**Change during Scan (%)** 0.02

**Max E-field (V/m):** 64.91

| | 1g | 10g |
|---|---|---|
| **Max SAR (W/kg)** | 10.560 | 4.938 |

| | X | Y | Z |
|---|---|---|---|
| **Location of Max (mm):** | -1.3 | -1.3 | -221.7 |

**Normalized to an input power of 1W**
**Averaged over 1 $cm^3$ (1g) of tissue**
**52.8W/kg**

## 2.4.2 System Performance Check result

| System performance check (2450 MHz Head) | | | | |
|---|---|---|---|---|
| **Frequency MHz** | **Operating Mode** | **Target $SAR_{1g}$ (W/kg)** | **Measured $SAR_{1g}$ (W/kg)** | **Deviation (±10%)** |
| 2450 | CW | 52.4 | 51.405 | -1.899% |

Please see the plot below:

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/01 | **Position:** | bottom of the phantom |
| **Filename:** | 2450per. check.txt | **Phantom:** | HeadBox2-val..csv |
| **Device Tested:** | 2450per. check | **Head Rotation:** | 0 |
| **Antenna:** | 2450 Dipole Ant. | **Test Frequency:** | 2450MHz |
| **Shape File:** | none.csv | **Power Level:** | 23 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_HEAD

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .508 | .508 | .508 |

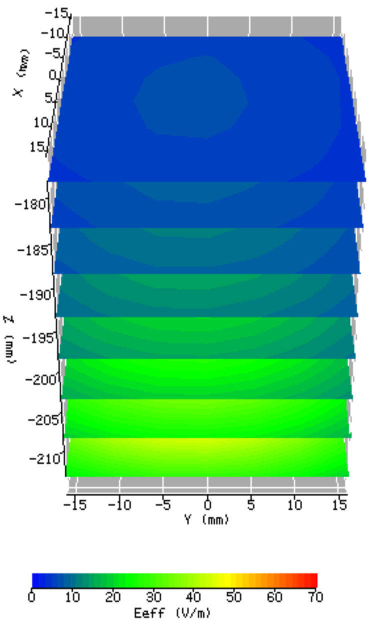
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Head |
| **Conductivity:** | 1.846 |
| **Relative Permittivity:** | 38.501 |
| **Liquid Temp (deg C):** | 23 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 58 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




ZOOM SCAN RESULTS:

| | Start Scan | End Scan |
|---|---|---|
| **Spot SAR (W/kg):** | 0.718 | 0.717 |

**Change during Scan (%)** 0.12

**Max E-field (V/m):** 64.90

| **Max SAR (W/kg)** | 1g | 10g |
|---|---|---|
| | 10.281 | 4.897 |

| **Location of Max (mm):** | X | Y | Z |
|---|---|---|---|
| | -1.3 | -1.3 | -221.5 |

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

**51.405W/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:** | ZyXEL | **Model No.:** | G-210H |
| **Serial No.:** | Not Labled | **Test Engineer:** | Kevin Chen |
| **TEST CONDITIONS** | | | |
| **Ambient Temperature** | 23 °C | **Relative Humidity** | 55 % |
| **Test Signal Source** | Tx Mode | **Signal Modulation** | DSSS, OFDM |
| **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** | 1 |

| **EUT Position** | | | | | | |
|---|---|---|---|---|---|---|
| **Channel (MHz)** | **Operating Mode** | **Crest Factor** | **Description** | **Distance (mm)** | **Measured $SAR_{1g}$ (W/kg)** | **Plot Number** |
| CH6_2437 | DSSS | 1 | Bottom to Phantom (EUT lie down) | 0 | 0.253 | 1 |
| CH6_2437 | DSSS | 1 | Bottom to Phantom (EUT stand) | 0 | Note 3 | 2 |
| CH6_2437 | DSSS | 1 | Perpendicular to Phantom (EUT lie down) | 0 | 0.029 | 3 |
| CH6_2437 | DSSS | 1 | Perpendicular to Phantom (EUT stand) | 0 | 0.562 | 4 |
| CH6_2437 | DSSS | 1 | Perpendicular to Phantom (EUT lie down) | 15 | Note 3 | 5 |
| CH6_2437 | DSSS | 1 | Perpendicular to Phantom (EUT stand) | 15 | 0.099 | 6 |

Note:
1. The distance from bottom of EUT (lie) to flat phantom is 7.5 mm.
2. The distance from bottom of EUT (stand) to flat phantom is 7.5 mm.
3. The measurement was only performed in Area Scan due to scanning system couldn't continue performing Zoom Scan with such a low SAR distribution.
4. Configuration at middle channel with more than –3dB of applicable limit.

| EUT Position | | | | | | |
|---|---|---|---|---|---|---|
| **Channel (MHz)** | **Operating Mode** | **Crest Factor** | **Description** | **Distance (mm)** | **Measured $SAR_{1g}$ (W/kg)** | **Plot Number** |
| CH6_2437 | OFDM | 1 | Bottom to Phantom (EUT lie down) | 0 | 0.100 | 7 |
| CH6_2437 | OFDM | 1 | Bottom to Phantom (EUT stand) | 0 | Note 3 | 8 |
| CH6_2437 | OFDM | 1 | Perpendicular to Phantom (EUT lie down) | 0 | Note 3 | 9 |
| CH6_2437 | OFDM | 1 | Perpendicular to Phantom (EUT stand) | 0 | 0.118 | 10 |
| CH6_2437 | OFDM | 1 | Perpendicular to Phantom (EUT lie down) | 15 | Note 3 | 11 |
| CH6_2437 | OFDM | 1 | Perpendicular to Phantom (EUT stand) | 15 | 0.023 | 12 |

Note: 1. The distance from bottom of EUT lie down to flat phantom is 7.5 mm.
2. The distance from bottom of EUT stand to flat phantom is 8 mm.
3. The measurement was only performed in Area Scan due to scanning system couldn’t continue performing Zoom Scan with such a low SAR distribution.
4. Configuration at middle channel with more than –3dB of applicable limit.

## 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** | **2450MHz** | EC381-4 | 05/2005 |
| **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<br>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;<br>Software: SARA2 Ver. 2.33VPM (**V**irtual **P**robe **M**inaturisation) | | |
| **Phantom** | **2mm wall thickness box phantom** | N/A | N/A |
| | Shell Material: clear Perspex; Thickness: 2 ± 0.1 mm; Capacity: 152.5 x 225.5 x 200 (W x L x D) $mm^3$; Dielectric constant: less than 2.85 above 500MHz; | | |
| **Device holder** | Material: clear Perspex; Dielectric constant: less than 2.85 above 500MHz | N/A | N/A |
| **Simulated Tissue** | **Mixture** | N/A | 11/01/2005 |
| | Please see section 3.2 for details | | |
| **Wideband Peak Power Meter/ Sensor** | **Anritsu ML2487A with MA2491A power sensor** | EC396 | 10/19/2005 |
| | Frequency Range: 100MHz~18GHz | | |
| **Vector Network Analyzer** | **HP 8753B**<br>**HP 85046A** | EC375 | 08/19/2005 |
| | Frequency Range: 300k to 3GHz | | |
| **Signal Generator** | **R&S SMR27** | EC354 | 08/16/2005 |
| | Frequency Range: 10M to 27GHz, <120dBuV | | |

## 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<br>Frequency (2.45 GHz)** | |
|---|---|
| DGBE (Dilethylene Glycol Butyl Ether) | 26.7% |
| Salt | 0.04% |
| Water | 73.2% |

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

| **Frequency (MHz)** | **Temp. (℃)** | **$\varepsilon_r$ / Relative Permittivity** | | | **σ / Conductivity (mho/m)** | | | **ρ *(kg/m$^3$)** |
|---|---|---|---|---|---|---|---|---|
| | | measured | target | △(±5%) | measured | target | △(±5%) | |
| 2450 | 22.5 | 51.115 | 52.7 | -3.00% | 1.962 | 1.95 | 0.62% | 1000 |

* *Worst-case assumption*

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

| **Head Ingredients<br>Frequency (2.45 GHz)** | |
|---|---|
| DGBE (Dilethylene Glycol Butyl Ether) | 53.3% |
| Water | 46.7% |

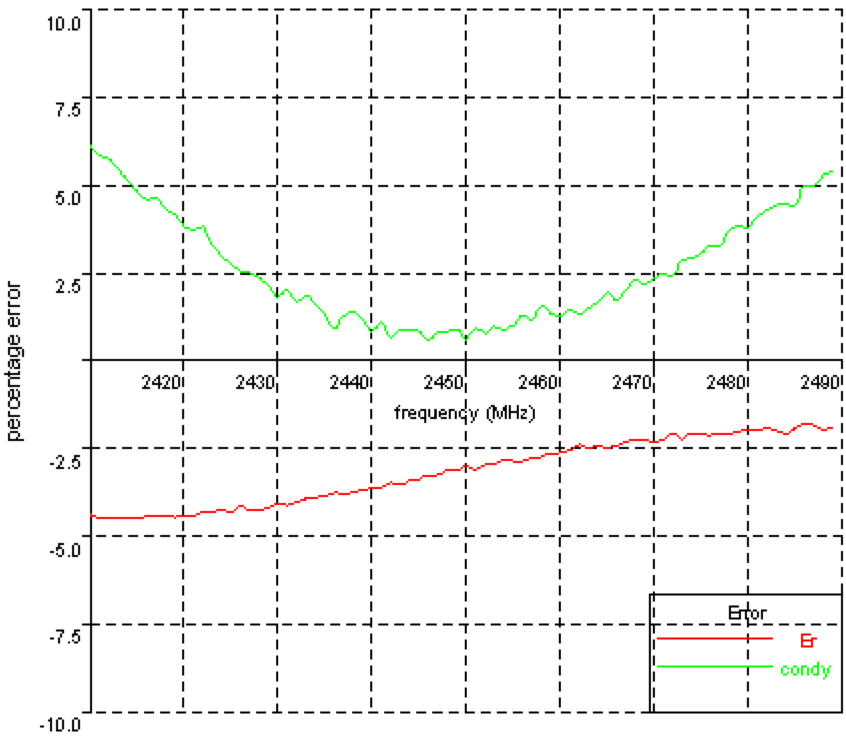
The dielectric parameters were verified prior to assessment using the HP 85046A dielectric probe kit and the HP 8753B network Analyzer. The dielectric parameters were:

| **Frequency (MHz)** | **Temp. (℃)** | **$\varepsilon_r$ / Relative Permittivity** | | | **σ / Conductivity (mho/m)** | | | **ρ *(kg/m$^3$)** |
|---|---|---|---|---|---|---|---|---|
| | | measured | target | △(±5%) | measured | target | △(±5%) | |
| 2450 | 23.5 | 38.501 | 39.2 | -1.78% | 1.846 | 1.80 | 2.56% | 1000 |

* *Worst-case assumption*

### 3.2.3 Body Liquid results

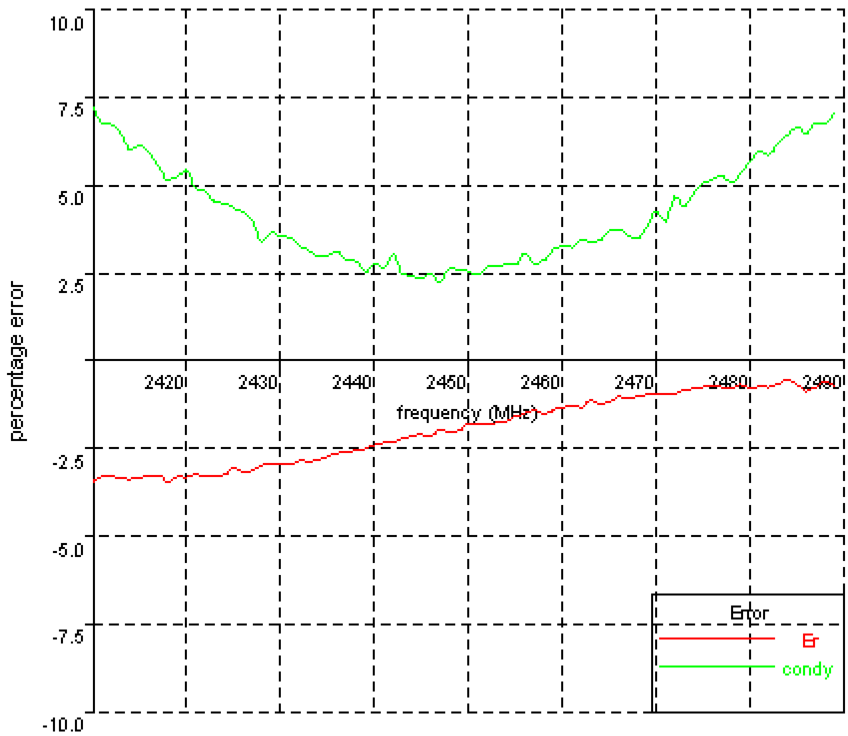
<table>
<tr><td>Date: 01 Nov. 2005</td><td>Temperature: 22.5 ℃</td><td>Type: 2450 MHz/ body</td><td>Tested by: Kevin</td></tr>
<tr><td colspan="2">2410, 50.4340413118, -2.0291192382<br>2411, 50.373360043, -2.0245683286<br>2412, 50.3980470201, -2.0236650211<br>2413, 50.3832057474, -2.0188803559<br>2414, 50.3930006889, -2.0140846334<br>2415, 50.3792626847, -2.009424468<br>2416, 50.3996662861, -2.0058113618<br>2417, 50.4026664106, -2.0077201314<br>2418, 50.4087903345, -2.0027061878<br>2419, 50.3907624477, -2.000608441<br>2420, 50.3992730018, -1.9953830262<br>2421, 50.4098213003, -1.9940268675<br>2422, 50.4608393262, -1.9967563825<br>2423, 50.4664184618, -1.9878587686<br>2424, 50.4918688037, -1.9829646738<br>2425, 50.4589393442, -1.979562052<br>2426, 50.5542166994, -1.9762444394<br>2427, 50.4861341261, -1.9763152474<br>2428, 50.4747623795, -1.9749480992<br>2429, 50.5237224926, -1.9709906682<br>2430, 50.5808658004, -1.9658829768<br>2431, 50.5566329962, -1.9708200564<br>2432, 50.6006305576, -1.9654797844<br>2433, 50.6484204876, -1.9693545366<br>2434, 50.6670862153, -1.9663967779<br>2435, 50.6890659442, -1.9613731635<br>2436, 50.7345352477, -1.9543275192<br>2437, 50.7214436148, -1.962092342<br>2438, 50.7294552914, -1.965351547<br>2439, 50.7671004262, -1.9620773163<br>2440, 50.7956832378, -1.956686774<br>2441, 50.804817718, -1.9626305922<br>2442, 50.8771744317, -1.9554620503<br>2443, 50.8426885215, -1.9601133867<br>2444, 50.9051404249, -1.9614715485<br>2445, 50.9190127218, -1.961717133<br>2446, 50.9808150251, -1.9574490435<br>2447, 50.9870091942, -1.9628548664<br>2448, 51.0552833609, -1.9642852096<br>2449, 51.0531990845, -1.9664102786</td><td colspan="2">2450, 51.1146053228, -1.9617701526<br>2451, 51.0657156642, -1.9692990919<br>2452, 51.1384439512, -1.9680938488<br>2453, 51.1494825438, -1.9732976962<br>2454, 51.2064376929, -1.9729621826<br>2455, 51.1832736716, -1.9767645467<br>2456, 51.1808483726, -1.9836689557<br>2457, 51.2238581457, -1.982403413<br>2458, 51.245164168, -1.9923259062<br>2459, 51.2903217799, -1.9894486065<br>2460, 51.3035509983, -1.9888230601<br>2461, 51.3433325366, -1.9945851125<br>2462, 51.4207668907, -1.9932666389<br>2463, 51.3683384297, -1.9979947005<br>2464, 51.4035772861, -2.0026530746<br>2465, 51.3752049398, -2.0094471526<br>2466, 51.3986721253, -2.0066403445<br>2467, 51.4667471046, -2.01419416<br>2468, 51.4832118895, -2.021271979<br>2469, 51.4800216913, -2.0206183347<br>2470, 51.4572965957, -2.0246656193<br>2471, 51.4945348335, -2.0287724428<br>2472, 51.5664958387, -2.0288676245<br>2473, 51.4955671059, -2.0398731953<br>2474, 51.5713512795, -2.0420206262<br>2475, 51.5572920365, -2.0464323303<br>2476, 51.5510278255, -2.0524310407<br>2477, 51.5749137064, -2.0535094419<br>2478, 51.5654518621, -2.0639315168<br>2479, 51.6008259389, -2.0673986032<br>2480, 51.6173336172, -2.0682778002<br>2481, 51.6241696273, -2.0762809284<br>2482, 51.6420022964, -2.0809639933<br>2483, 51.6102654686, -2.0853025422<br>2484, 51.5614655499, -2.08773717<br>2485, 51.6418796361, -2.0875009372<br>2486, 51.7083287097, -2.1012654321<br>2487, 51.686821635, -2.102527641<br>2488, 51.6189258671, -2.1098064317<br>2489, 51.6531424333, -2.1134498812<br>2490, 51.6371786489, -2.1110573316</td></tr>
</table>



### 3.2.4 Head Liquid results

| Date: 02 Nov. 2005 | Temperature: 23.5 ℃ | Type: 2450 MHz/ head | Tested by: Kevin |
|---|---|---|---|

| | |
|---|---|
| 2410, 37.9234251904, -1.8919650244 | **2450, 38.5007583908, -1.8458899377** |
| 2411, 37.9705614703, -1.8847461742 | 2451, 38.4888594476, -1.8452984999 |
| 2412, 37.9709766784, -1.8850207439 | 2452, 38.4850247002, -1.8506744703 |
| 2413, 37.9470428968, -1.880680416 | 2453, 38.5066924773, -1.8516541801 |
| 2414, 37.9386337344, -1.8740477716 | 2454, 38.5109499186, -1.8545469164 |
| 2415, 37.9539988811, -1.8775832075 | 2455, 38.5703562313, -1.8548705452 |
| 2416, 37.9725993774, -1.8746015244 | 2456, 38.6016712914, -1.8620759059 |
| 2417, 37.9666017735, -1.8687014731 | 2457, 38.6452177697, -1.857618876 |
| 2418, 37.9041815078, -1.8628672016 | 2458, 38.5907487674, -1.860308614 |
| 2419, 37.9561822364, -1.8658111676 | 2459, 38.6371653046, -1.8671433329 |
| 2420, 37.9501872255, -1.8695163143 | 2460, 38.6622059901, -1.8704447645 |
| 2421, 37.9878293863, -1.8616666815 | 2461, 38.6859529135, -1.8706063431 |
| 2422, 37.9519101177, -1.8607921733 | 2462, 38.6680298824, -1.87611448 |
| 2423, 37.9589185689, -1.8563894211 | 2463, 38.7397725727, -1.8757995373 |
| 2424, 37.9653294945, -1.8566966535 | 2464, 38.7060105826, -1.8774397333 |
| 2425, 38.0487629481, -1.8547972708 | 2465, 38.7259677287, -1.8839257539 |
| 2426, 37.9890221816, -1.8539855462 | 2466, 38.777823745, -1.8852036259 |
| 2427, 38.0184794357, -1.8510176222 | 2467, 38.7621187264, -1.8834220473 |
| 2428, 38.0688330167, -1.841202444 | 2468, 38.7796548868, -1.8835322412 |
| 2429, 38.0828627232, -1.8465466964 | 2469, 38.7935223444, -1.8901000704 |
| 2430, 38.0897110838, -1.8454929193 | 2470, 38.8067815095, -1.8994921915 |
| 2431, 38.0682710861, -1.8457961548 | 2471, 38.8137600508, -1.8955122463 |
| 2432, 38.1140591928, -1.8423625713 | 2472, 38.792478106, -1.9098349177 |
| 2433, 38.1066030874, -1.8408354165 | 2473, 38.8535443737, -1.9055108794 |
| 2434, 38.1182380619, -1.838991917 | 2474, 38.8553854644, -1.9134442058 |
| 2435, 38.1564641413, -1.8405596437 | 2475, 38.8748528041, -1.9199534854 |
| 2436, 38.189670296, -1.8434899173 | 2476, 38.8862971289, -1.9229459566 |
| 2437, 38.2051371125, -1.8399152309 | 2477, 38.8695563811, -1.9258225451 |
| 2438, 38.2179164887, -1.8404667066 | 2478, 38.8619524807, -1.9236952298 |
| 2439, 38.2362282081, -1.8356135112 | 2479, 38.8961979164, -1.9295970392 |
| 2440, 38.27192203, -1.8404689783 | 2480, 38.8512860254, -1.9367949054 |
| 2441, 38.2977579047, -1.8392118797 | 2481, 38.8713180768, -1.9434808946 |
| 2442, 38.3028299191, -1.8472250463 | 2482, 38.8665952116, -1.9424966491 |
| 2443, 38.3446416637, -1.838580868 | 2483, 38.8936831317, -1.9496256578 |
| 2444, 38.3694927652, -1.837958483 | 2484, 38.9385707121, -1.9553118779 |
| 2445, 38.382607002, -1.8380730257 | 2485, 38.8850114498, -1.9606566604 |
| 2446, 38.3566112358, -1.8410365125 | 2486, 38.8172139767, -1.9581494993 |
| 2447, 38.4338523793, -1.8376696485 | 2487, 38.8600121622, -1.9649287815 |
| 2448, 38.4059614346, -1.8455586363 | 2488, 38.9149314239, -1.9661589384 |
| 2449, 38.4242231138, -1.8460209241 | 2489, 38.8757264224, -1.9720440597 |
| | 2490, 38.9244719927, -1.9820800835 |



### 3.3 E-Field Probe and 2450 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**

| 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**

| 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 Revision Record

| Revision/ Job Number | Writer Initials | Date | Change |
|---|---|---|---|
| TC0700082 | SL | Jan. 29, 2007 | Original document |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

## APPENDIX A - SAR Evaluation Data

**Power drift:** 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:** | 2005/11/2 | **Position:** | EUT lie bot. 0mm to phantom |
| **Filename:** | 11b_CH6-bot0_lie.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11b_2437MHz |
| **Shape File:** | G-210H-bot_lie.csv | **Power Level:** | 11.03 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_BODY

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

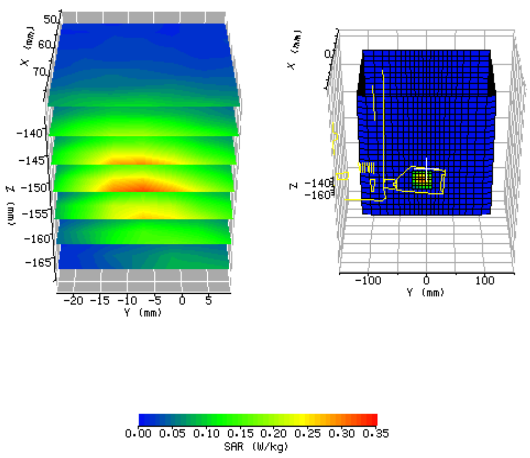
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 55 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




ZOOM SCAN RESULTS:

**Spot SAR (W/kg):**

| Start Scan | End Scan |
|---|---|
| 0.089 | 0.096 |

**Change during Scan (%)** 3.75

**Max E-field (V/m):** 12.90

**Max SAR (W/kg)**

| 1g | 10g |
|---|---|
| 0.253 | 0.135 |

**Location of Max (mm):**

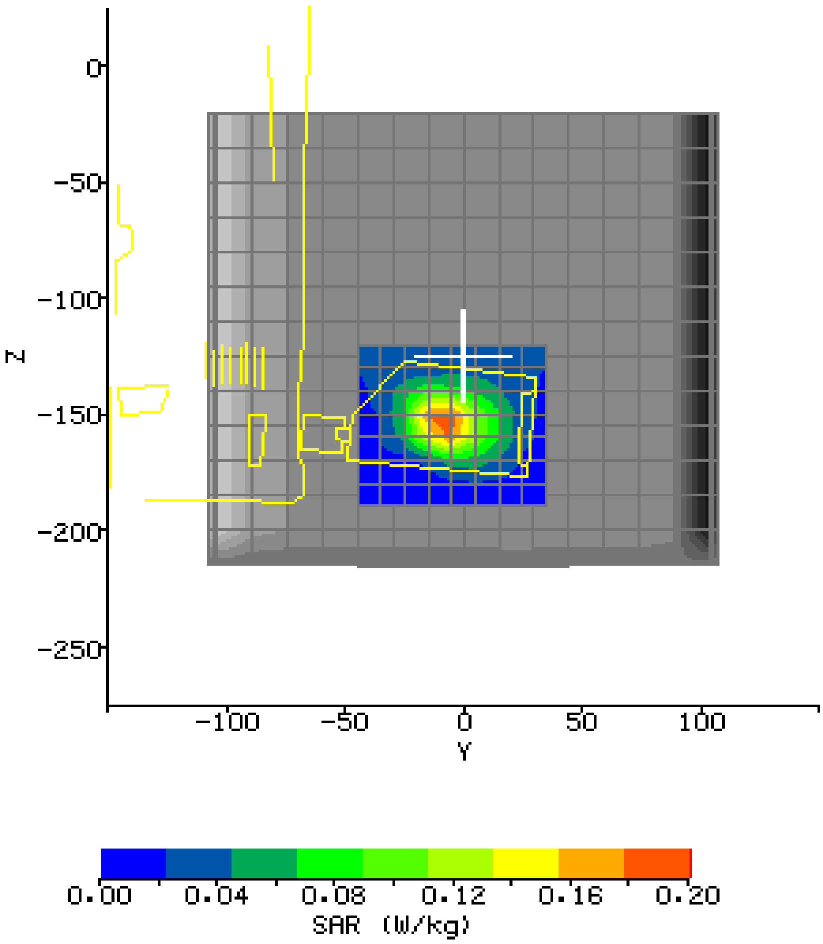
| X | Y | Z |
|---|---|---|
| 78.1 | -23.0 | -153.1 |

Plot #1 (2/2)

AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -45.0 | 35.0 | 8.0 |
| **Z** | -190.0 | -120.0 | 7.0 |



Plot #2

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT stand bot. 0mm to phantom |
| **Filename:** | 11b_CH6-bot0_standa.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11b_2437MHz |
| **Shape File:** | G-210H -bot_stand.csv | **Power Level:** | 11.03 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_BODY

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

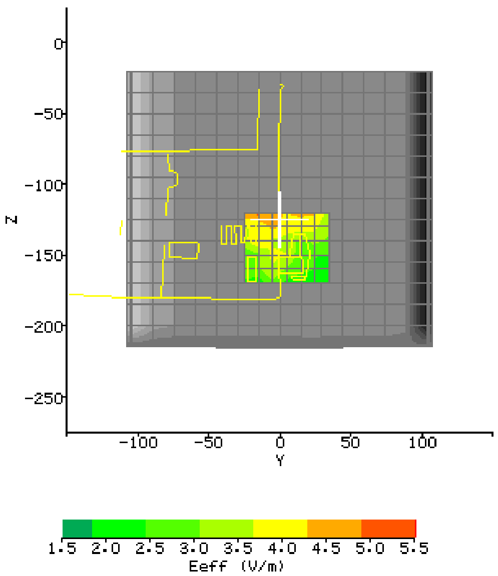
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 55 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -25.0 | 35.0 | 6.0 |
| **Z** | -170.0 | -120.0 | 5.0 |

Plot #3 (1/2)

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT lie per. 0mm to phantom |
| **Filename:** | 11b_CH6-per0_lie.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11b_2437MHz |
| **Shape File:** | G-210H -per_lie.csv | **Power Level:** | 11.03 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_BODY

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

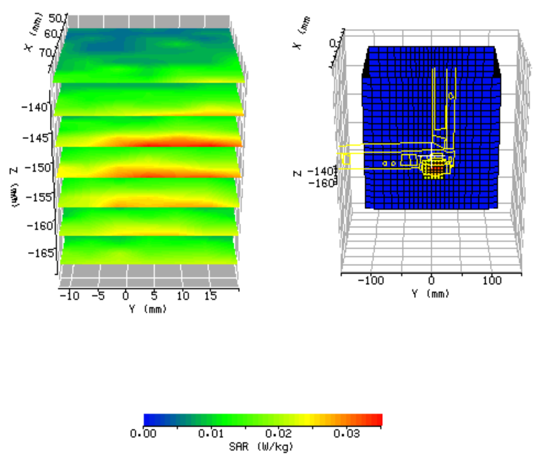
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **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):** | 0.010 | 0.012 |

**Change during Scan (%)** 2.05

**Max E-field (V/m):** 4.25

| | 1g | 10g |
|---|---|---|
| **Max SAR (W/kg)** | 0.029 | 0.018 |

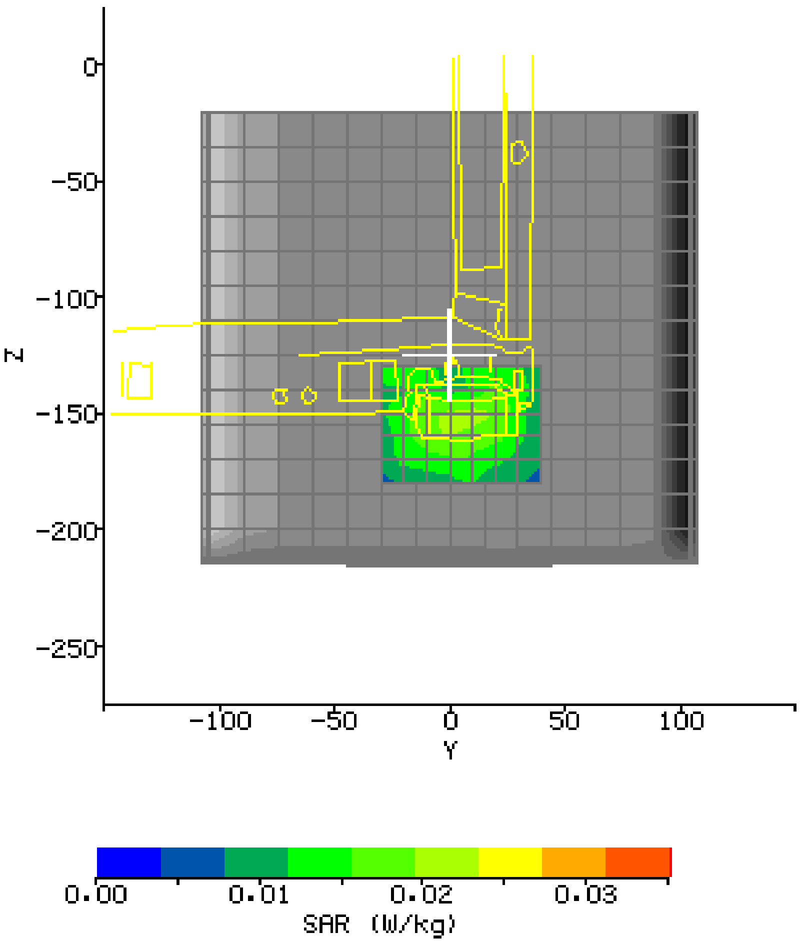
| | X | Y | Z |
|---|---|---|---|
| **Location of Max (mm):** | 78.1 | -12.0 | -151.3 |

Plot #3 (2/2)

AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -30.0 | 40.0 | 7.0 |
| **Z** | -180.0 | -130.0 | 5.0 |



Plot #4 (1/2)

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT stand per. 0mm to phantom |
| **Filename:** | 11b_CH6-per0_stand.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11b_2437MHz |
| **Shape File:** | G-210H -per_stand.csv | **Power Level:** | 11.03 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_BODY

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

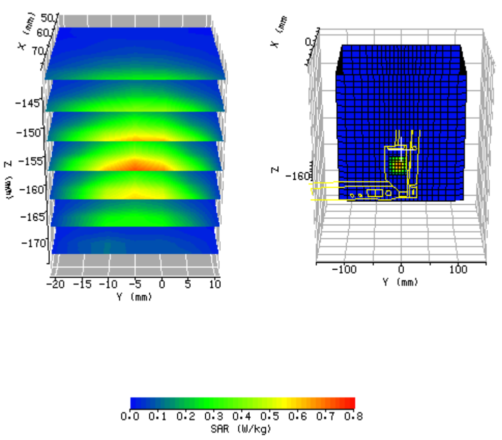
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **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):** | 0.249 | 0.241 |

**Change during Scan (%)** -3.02

**Max E-field (V/m):** 19.30

| | 1g | 10g |
|---|---|---|
| **Max SAR (W/kg)** | 0.562 | 0.275 |

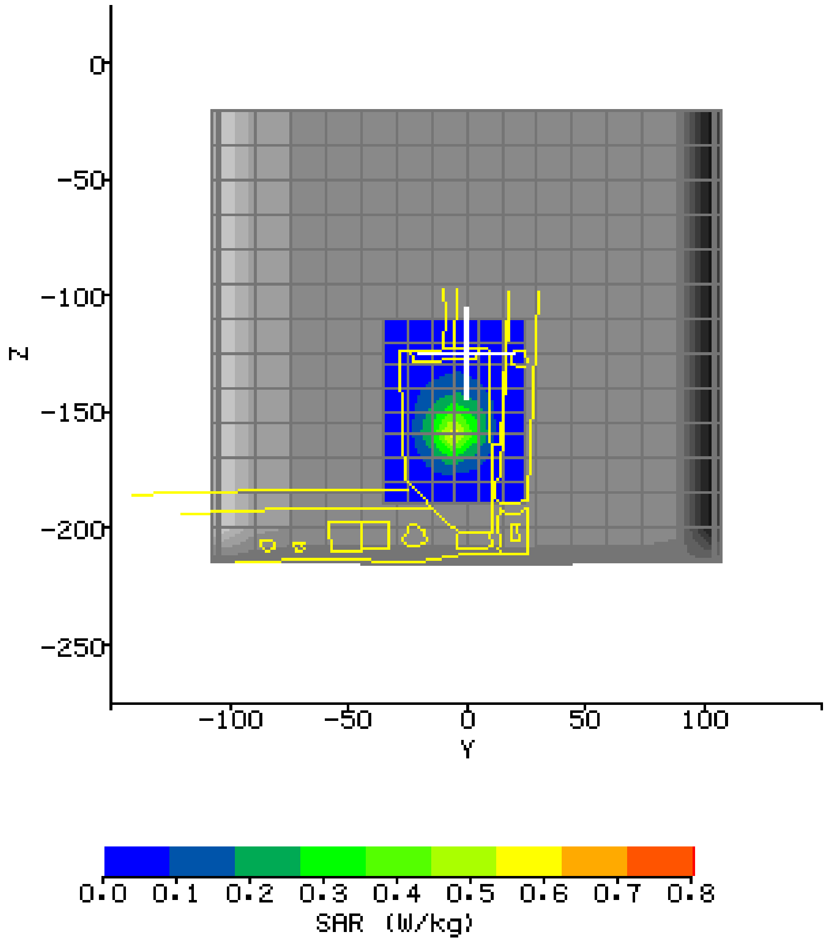
| | X | Y | Z |
|---|---|---|---|
| **Location of Max (mm):** | 78.0 | -21.0 | -158.1 |

Plot #4 (2/2)

AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -35.0 | 25.0 | 6.0 |
| **Z** | -190.0 | -110.0 | 8.0 |



Plot #5

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT lie per. 15mm to phantom |
| **Filename:** | 11b_CH6-per15_liea.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11b_2437MHz |
| **Shape File:** | G-210H -per_lie.csv | **Power Level:** | 11.03 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_BODY

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

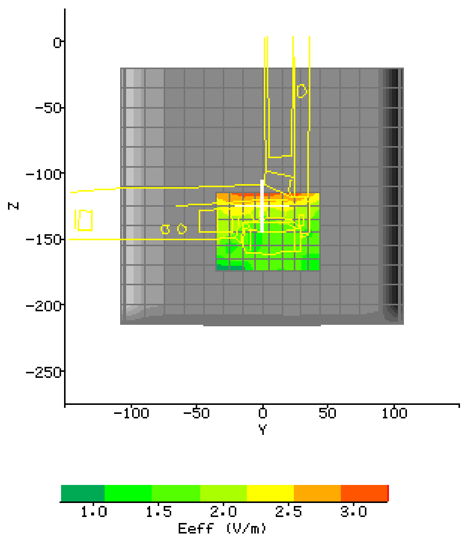
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 55 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -35.0 | 45.0 | 8.0 |
| **Z** | -175.0 | -115.0 | 6.0 |

Plot #6 (1/2)

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT stand per. 15mm to phantom |
| **Filename:** | 11b_CH6-per15_stand.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11b_2437MHz |
| **Shape File:** | G-210H -per_stand.csv | **Power Level:** | 11.03 dBm |

**Probe:** 0114
**Cal File:** SN0114_2450_CW_BODY

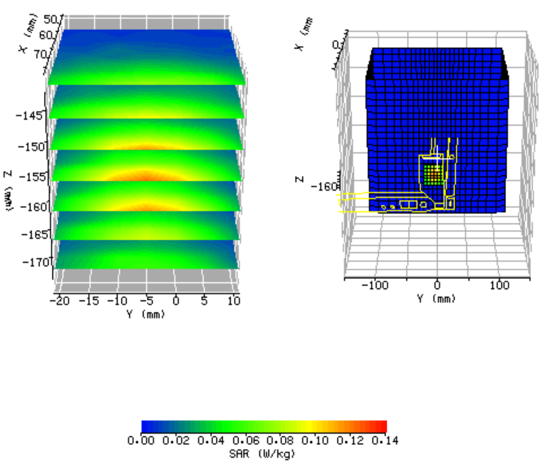
**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

**Amp Gain:** 2
**Averaging:** 1
**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **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):** | 0.034 | 0.034 |

**Change during Scan (%)** 0

**Max E-field (V/m):** 7.88

| | 1g | 10g |
|---|---|---|
| **Max SAR (W/kg)** | 0.099 | 0.056 |

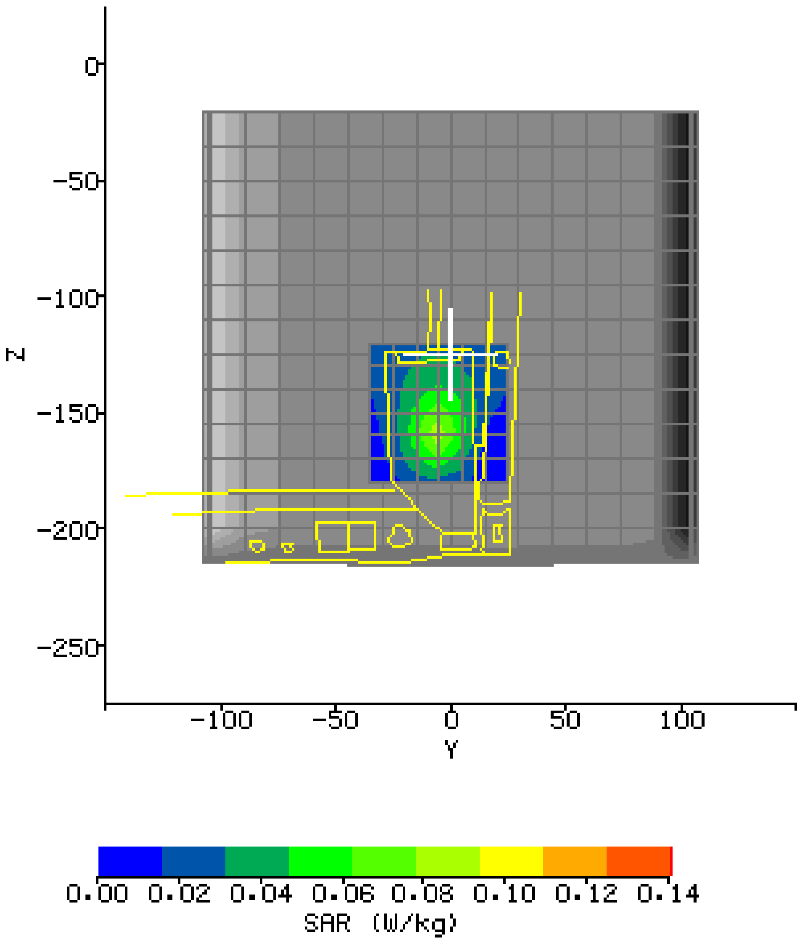
| | X | Y | Z |
|---|---|---|---|
| **Location of Max (mm):** | 78.0 | -21.0 | -158.0 |

Plot #6 (2/2)

AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -35.0 | 25.0 | 6.0 |
| **Z** | -180.0 | -120.0 | 6.0 |



Plot #7 (1/2)

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT lie bot. 0mm to phantom |
| **Filename:** | 11g_CH6-bot0_lie.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11g_2437MHz |
| **Shape File:** | G-210H -bot_lie.csv | **Power Level:** | 14.48 dBm |

| | |
|---|---|
| **Probe:** | 0114 |
| **Cal File:** | SN0114_2450_CW_BODY |

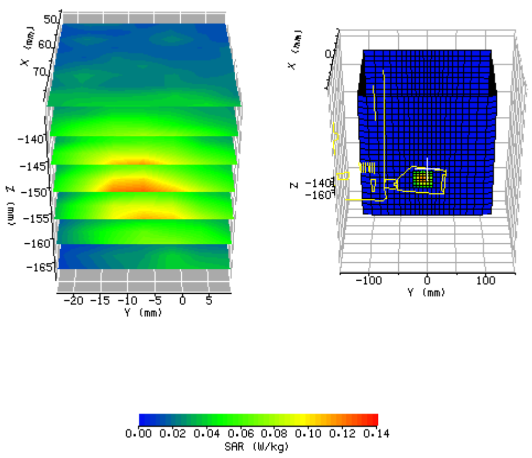
**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

| | |
|---|---|
| **Amp Gain:** | 2 |
| **Averaging:** | 1 |
| **Batteries Replaced:** | - |

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 55 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




ZOOM SCAN RESULTS:

**Spot SAR (W/kg):**

| Start Scan | End Scan |
|---|---|
| 0.038 | 0.040 |

**Change during Scan (%)** 3.48

**Max E-field (V/m):** 7.94

**Max SAR (W/kg)**

| 1g | 10g |
|---|---|
| 0.100 | 0.056 |

**Location of Max (mm):**

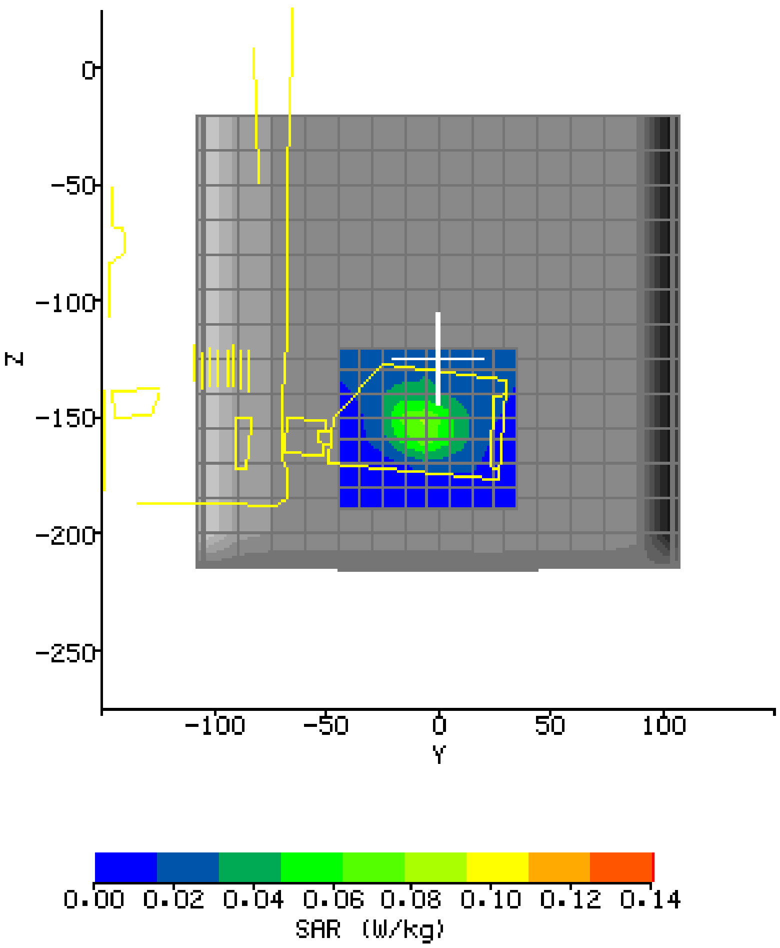
| X | Y | Z |
|---|---|---|
| 78.1 | -23.0 | -153.0 |

Plot #7 (2/2)

AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -45.0 | 35.0 | 8.0 |
| **Z** | -190.0 | -120.0 | 7.0 |



Plot #8

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT stand bot. 0mm to phantom |
| **Filename:** | 11g_CH6-bot0_standa.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11g_2437MHz |
| **Shape File:** | G-210H -bot_stand.csv | **Power Level:** | 14.48 dBm |

**Probe:** 0114
**Cal File:** SN0114_2450_CW_BODY

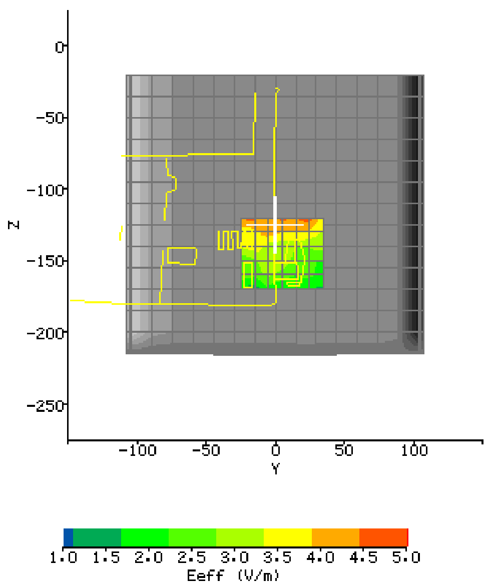
**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

**Amp Gain:** 2
**Averaging:** 1
**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 55 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -25.0 | 35.0 | 6.0 |
| **Z** | -170.0 | -120.0 | 5.0 |

Plot #9

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT lie per. 0mm to phantom |
| **Filename:** | 11g_CH6-per0_liea.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11g_2437MHz |
| **Shape File:** | G-210H -per_lie.csv | **Power Level:** | 14.48 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_BODY

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

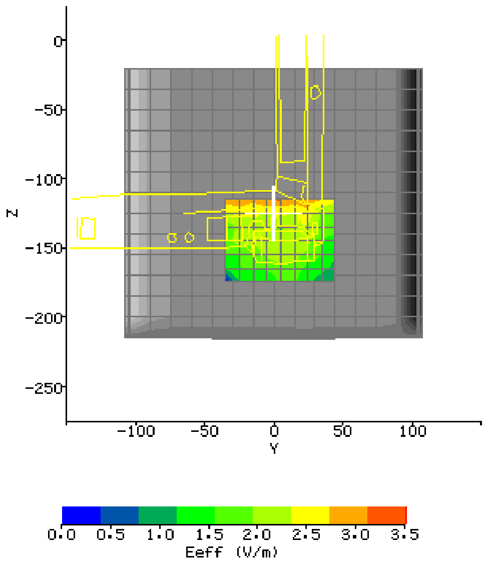
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 55 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




AREA SCAN:

**Scan Extent:**

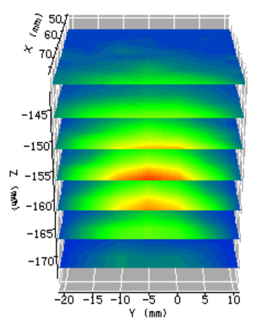
| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -35.0 | 45.0 | 8.0 |
| **Z** | -175.0 | -115.0 | 6.0 |

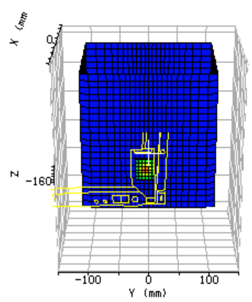
Plot #10 (1/2)

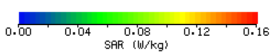
| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT stand per. 0mm to phantom |
| **Filename:** | 11g_CH6-per0_stand.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11g_2437MHz |
| **Shape File:** | G-210H -per_stand.csv | **Power Level:** | 14.48 dBm |

| | | | | |
|---|---|---|---|---|
| **Probe:** | 0114 | | | |
| **Cal File:** | SN0114_2450_CW_BODY | | | |
| **Cal Factors:** | | X | Y | Z |
| | Air | 438 | 359 | 403 |
| | DCP | 20 | 20 | 20 |
| | Lin | .585 | .585 | .585 |
| **Amp Gain:** | 2 | | | |
| **Averaging:** | 1 | | | |
| **Batteries Replaced:** | - | | | |

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **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):** | 0.049 | 0.051 |

**Change during Scan (%)** 3.45

**Max E-field (V/m):** 8.79

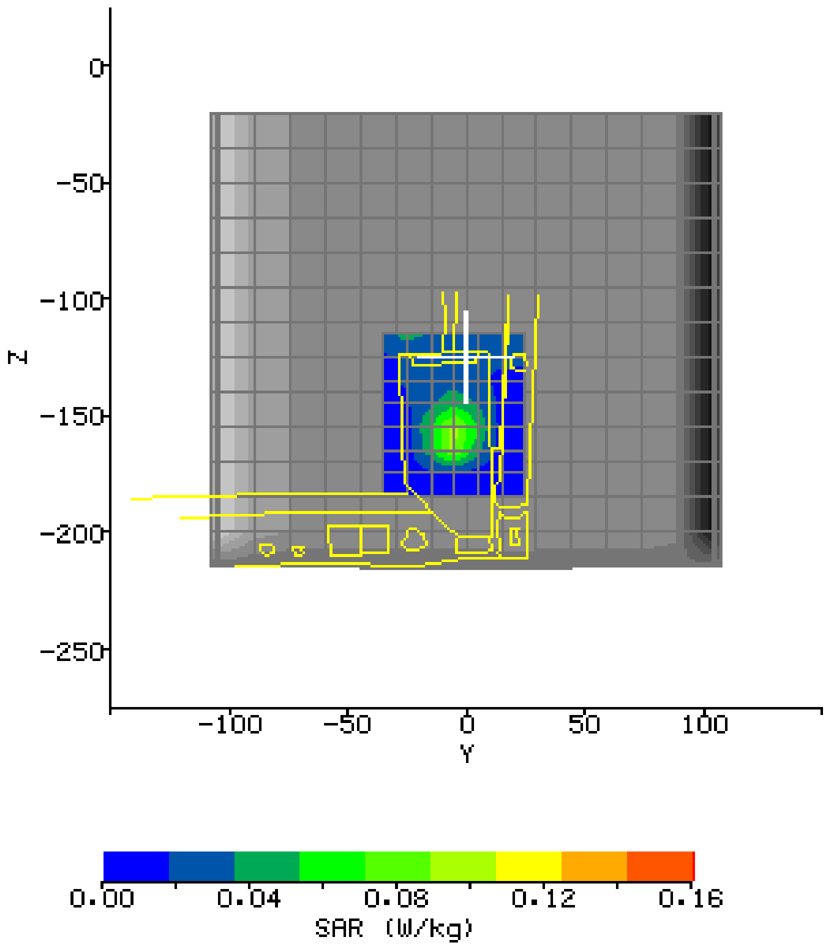
| | 1g | 10g |
|---|---|---|
| **Max SAR (W/kg)** | 0.118 | 0.060 |

| | X | Y | Z |
|---|---|---|---|
| **Location of Max (mm):** | 78.0 | -21.0 | -158.0 |

Plot #10 (2/2)

AREA SCAN:

| | | Min | Max | Steps |
|---|---|---|---|---|
| **Scan Extent:** | **Y** | -35.0 | 25.0 | 6.0 |
| | **Z** | -185.0 | -115.0 | 7.0 |



Plot #11

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT lie per. 15mm to phantom |
| **Filename:** | 11g_CH6-per15_liea.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11g_2437MHz |
| **Shape File:** | G-210H -per_lie.csv | **Power Level:** | 14.48 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_BODY

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

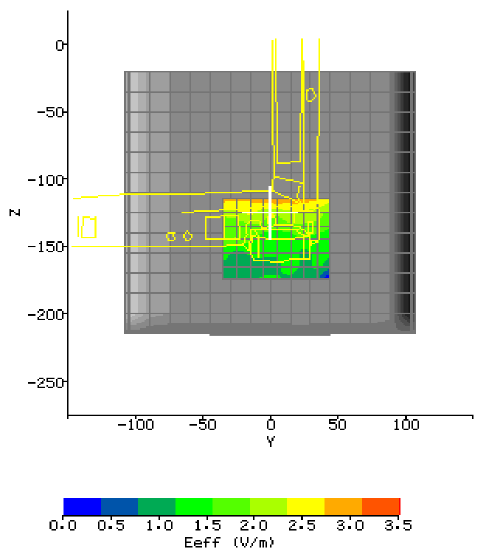
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 55 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -35.0 | 45.0 | 8.0 |
| **Z** | -175.0 | -115.0 | 6.0 |

Plot #12 (1/2)

| | | | |
|---|---|---|---|
| **Date:** | 2005/11/2 | **Position:** | EUT stand per. 15mm to phantom |
| **Filename:** | 11g_CH6-per15_stand.txt | **Phantom:** | HeadBox2-test.csv |
| **Device Tested:** | G-210H | **Head Rotation:** | 0 |
| **Antenna:** | Integral Antenna | **Test Frequency:** | 11g_2437MHz |
| **Shape File:** | G-210H -per_stand.csv | **Power Level:** | 14.48 dBm |

**Probe:** 0114

**Cal File:** SN0114_2450_CW_BODY

**Cal Factors:**

| | X | Y | Z |
|---|---|---|---|
| **Air** | 438 | 359 | 403 |
| **DCP** | 20 | 20 | 20 |
| **Lin** | .585 | .585 | .585 |

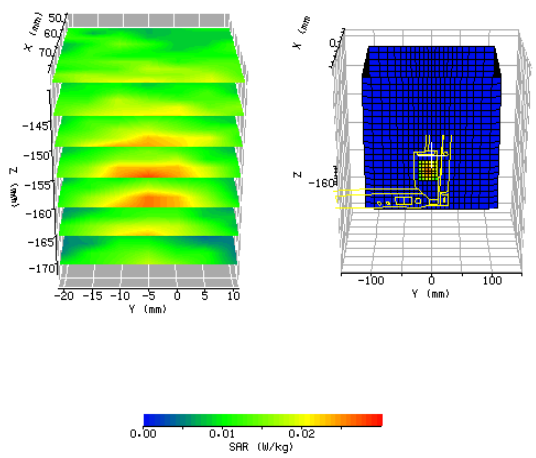
**Amp Gain:** 2

**Averaging:** 1

**Batteries Replaced:** -

| | |
|---|---|
| **Liquid:** | 15.5cm |
| **Type:** | 2450 MHz Body |
| **Conductivity:** | 1.962 |
| **Relative Permittivity:** | 51.115 |
| **Liquid Temp (deg C):** | 22 |
| **Ambient Temp (deg C):** | 23 |
| **Ambient RH (%):** | 55 |
| **Density (kg/m3):** | 1000 |
| **Software Version:** | 2.33VPM |

**Crest Factor = 1**




## ZOOM SCAN RESULTS:

| **Spot SAR (W/kg):** | **Start Scan** | **End Scan** |
|---|---|---|
| | 0.010 | 0.013 |

**Change during Scan (%)** 3.75

**Max E-field (V/m):** 3.74

| **Max SAR (W/kg)** | **1g** | **10g** |
|---|---|---|
| | 0.023 | 0.015 |

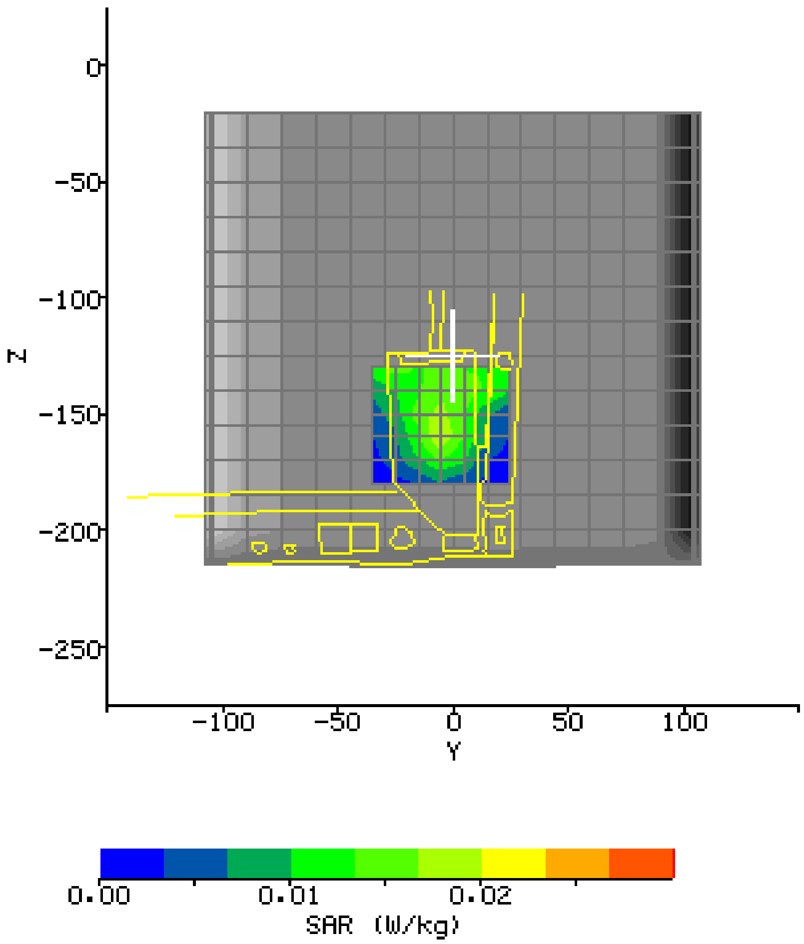
| **Location of Max (mm):** | **X** | **Y** | **Z** |
|---|---|---|---|
| | 78.0 | -21.0 | -156.9 |

Plot #12 (2/2)

AREA SCAN:

**Scan Extent:**

| | Min | Max | Steps |
|---|---|---|---|
| **Y** | -35.0 | 25.0 | 6.0 |
| **Z** | -180.0 | -130.0 | 5.0 |



**APPENDIX B - Photographs**


**APPENDIX C - E-Field Probe and 2450MHz Balanced Dipole Antenna Calibration Data**

INDEXSAR

# *IMMERSIBLE SAR PROBE*

## CALIBRATION REPORT

## Part Number: IXP – 050

## S/N 0114

***March 2005***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**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):

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

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 $\rho$ 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 $\delta$ (which is the reciprocal of the waveguide-mode attenuation coefficient) is a property of the lossy liquid and is given by Equation (5).

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

where $\sigma$ is the conductivity of the tissue-simulant liquid in S/m, $\varepsilon_r$ is its relative permittivity, and $\omega$ is the radial frequency (rad/s). Values for $\sigma$ and $\varepsilon_r$ are obtained prior to each waveguide test using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2]. $\sigma$ and $\varepsilon_r$ 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 $\sigma$ and $\varepsilon_r$ 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 $\sigma$ 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.

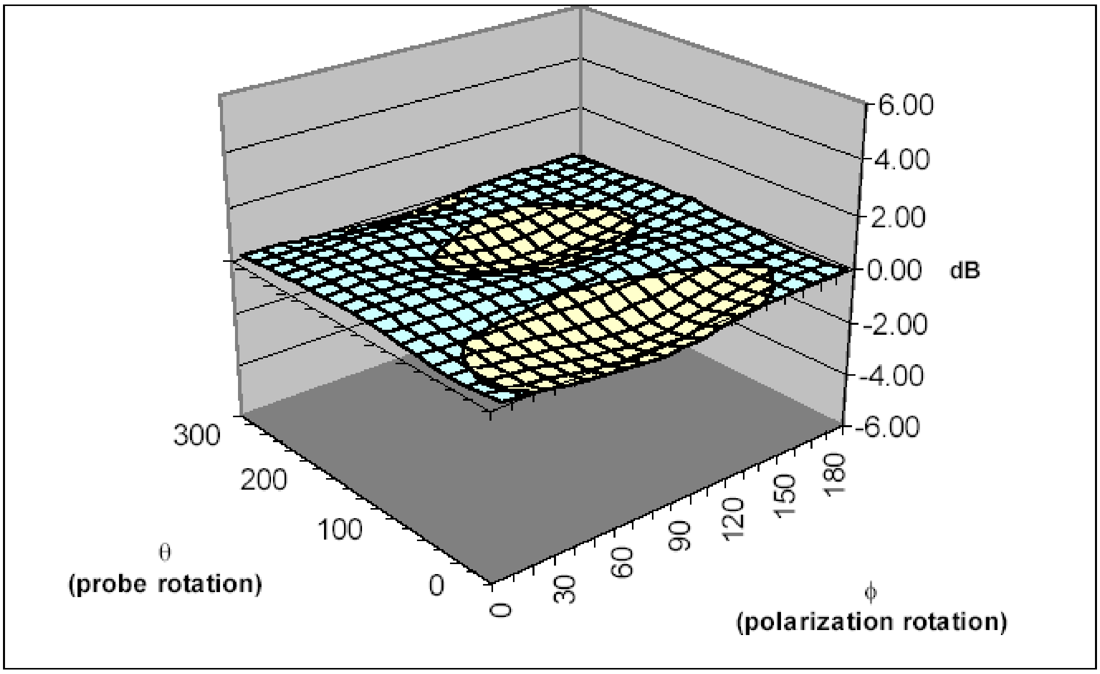
Given the typical dimensions of 3-channel SAR probes presently available, use of the VPM technique extends the satisfactory measurement range to higher frequencies.

**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 +/-0.56dB)

| | |
|---|---|
| Probe tip radius | 1.24 |
| X Ch. Angle to red dot | -5 |

| | 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 | 0.56 | (+/-) 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)<br>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) | 0.56 | 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.

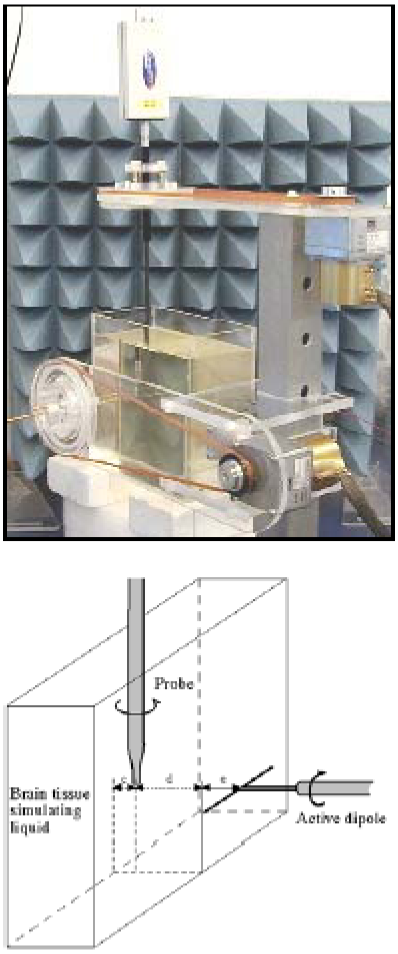



Figure 1. Spherical isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

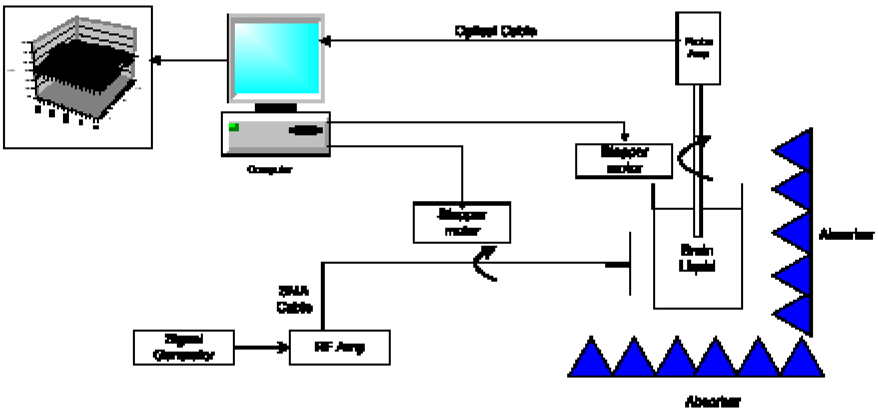



Figure 2. Schematic diagram of the test geometry used for isotropy determination

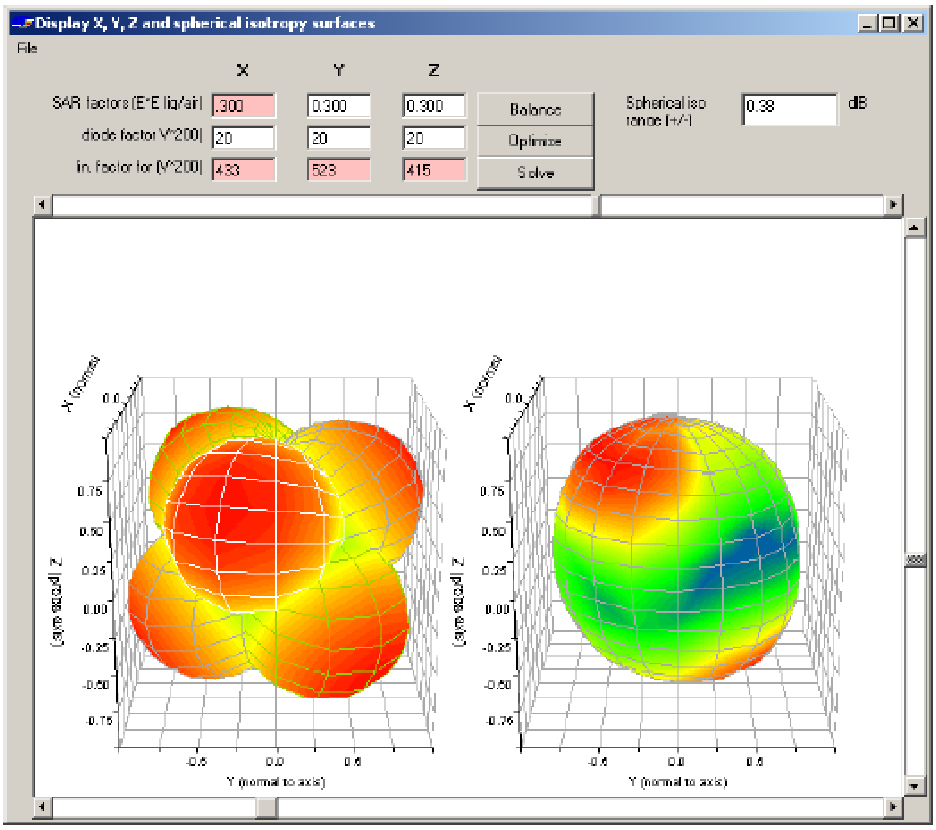



Figure 3. Graphical representation of a probe ' s response to fields applied from each direction. The diagram on the left shows the individual response characteristics of each of the three channels and the diagram on the right shows the resulting probe sensitivity in each direction. The colour range in the figure images the lowest values as blue and the maximum values as red. For the probe S/N 0114, this range is (+/-) 0.56 dB.

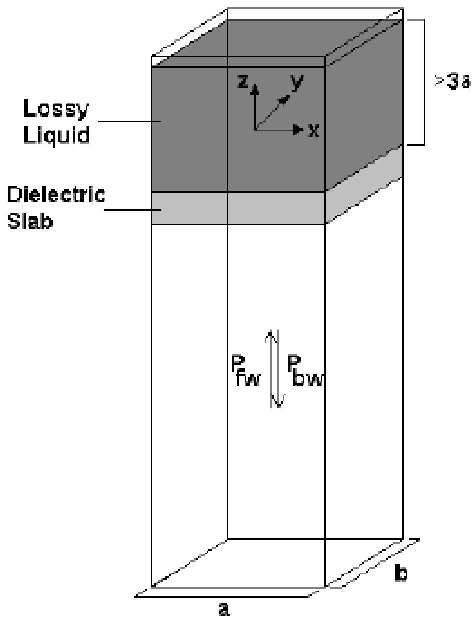



Figure 4. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

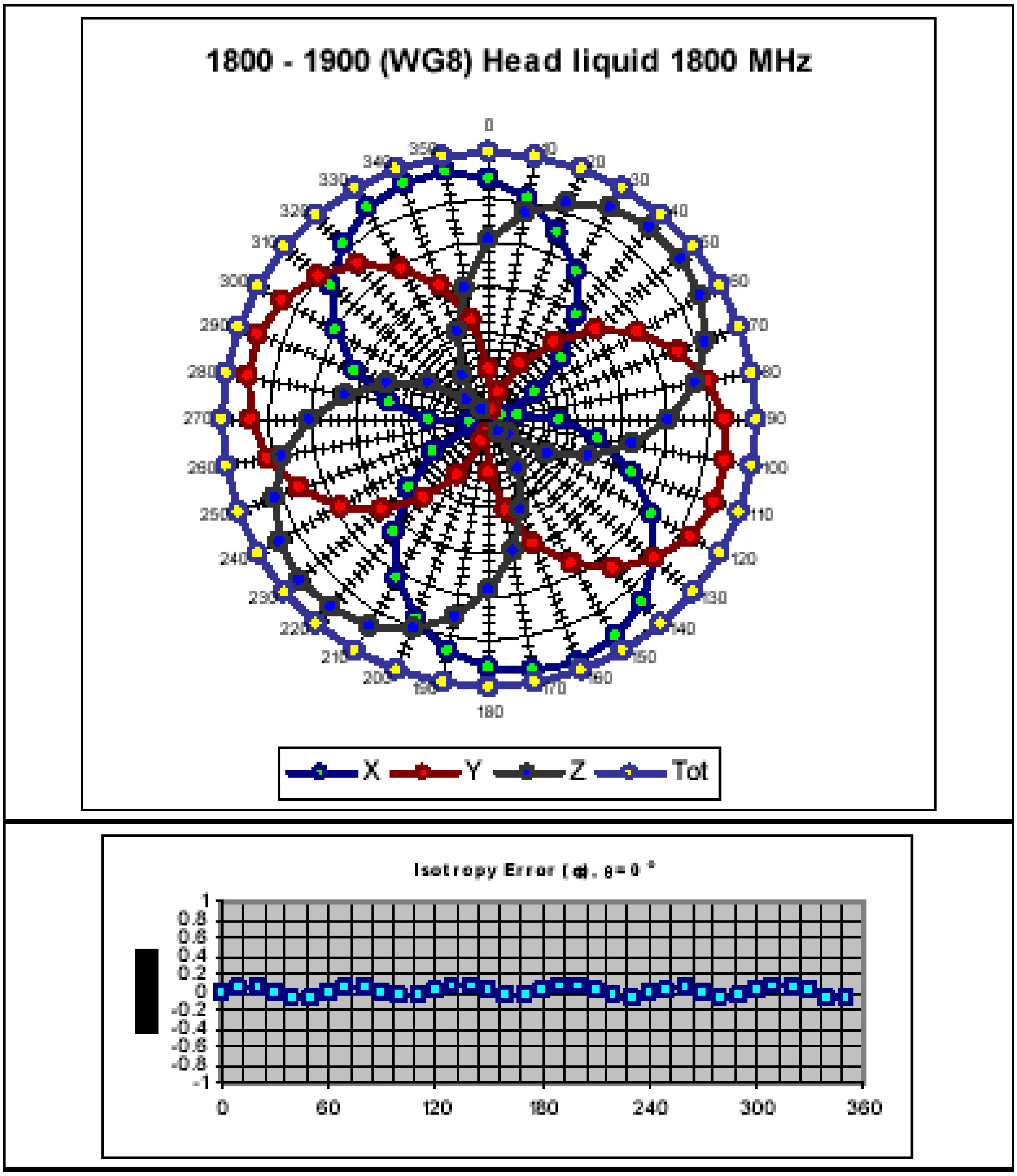
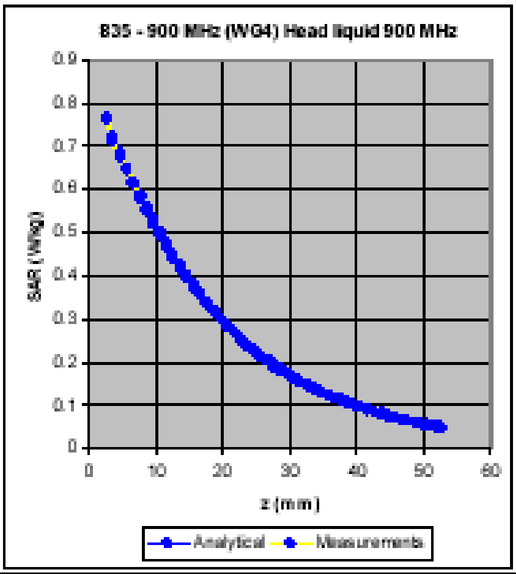
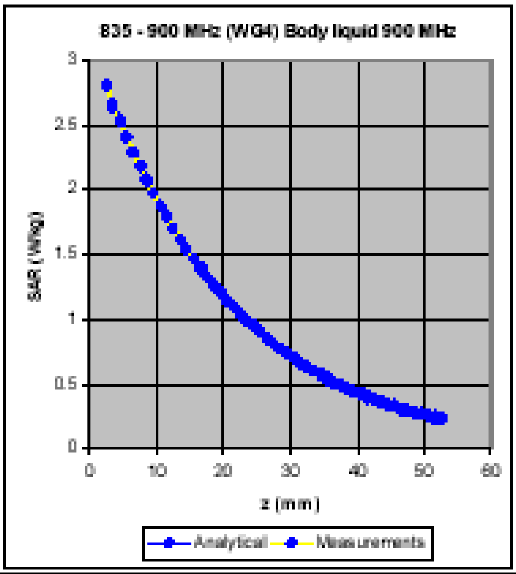
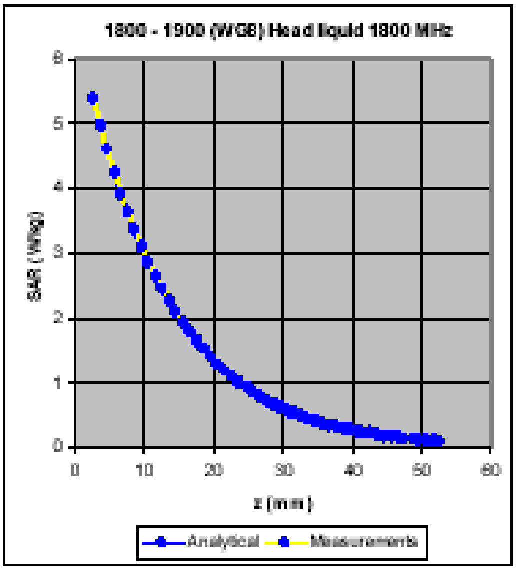
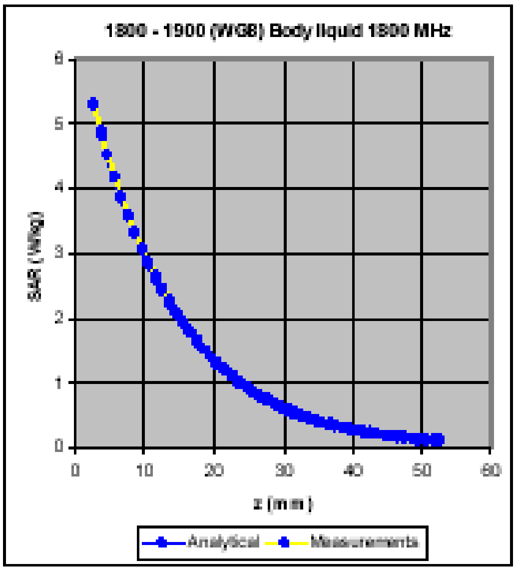



Figure 5. The rotational isotropy of probe S/N 0114 obtained by rotating the probe in a liquid-filled waveguide at 1800 MHz.


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

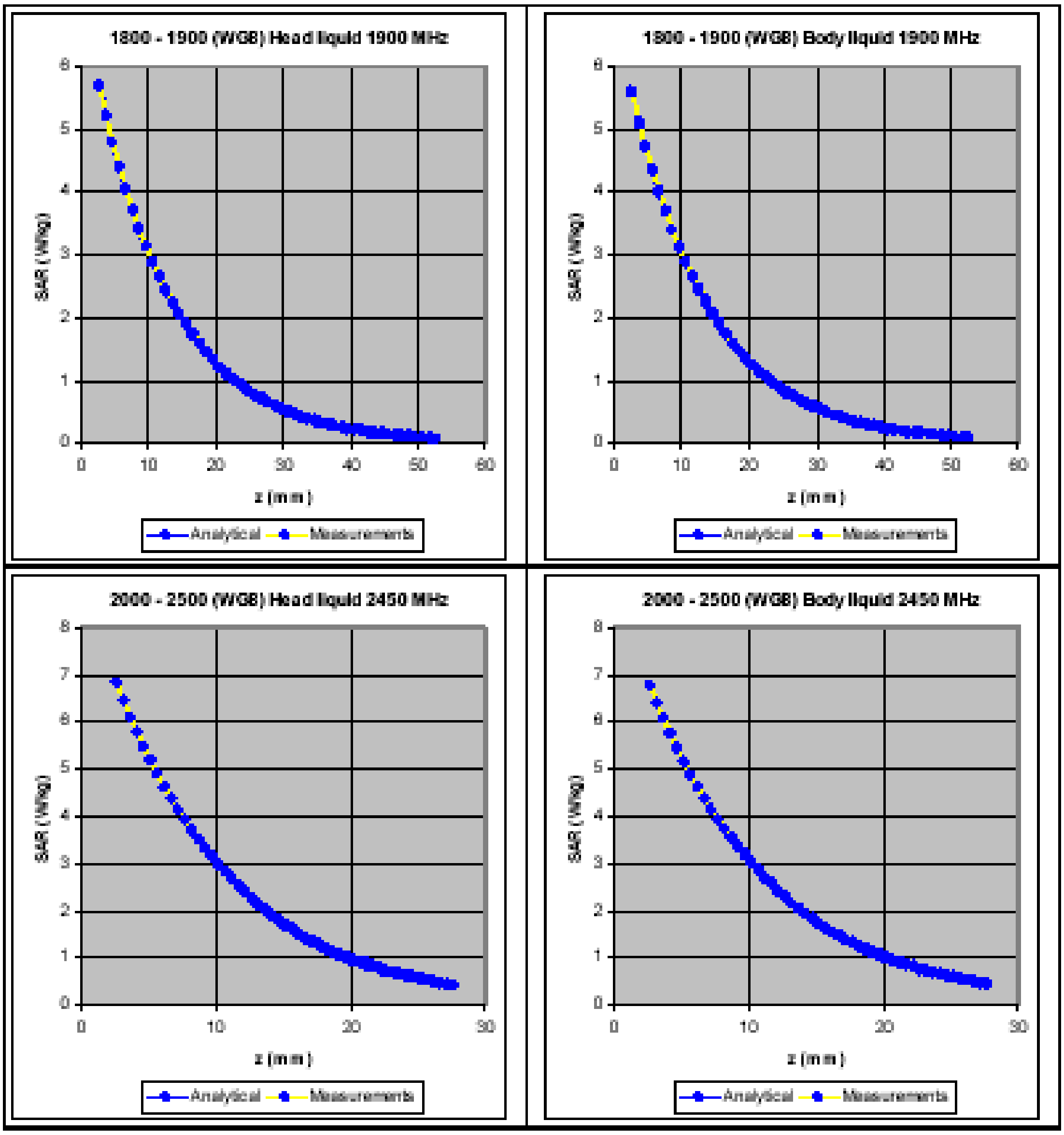



Figure 6. The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

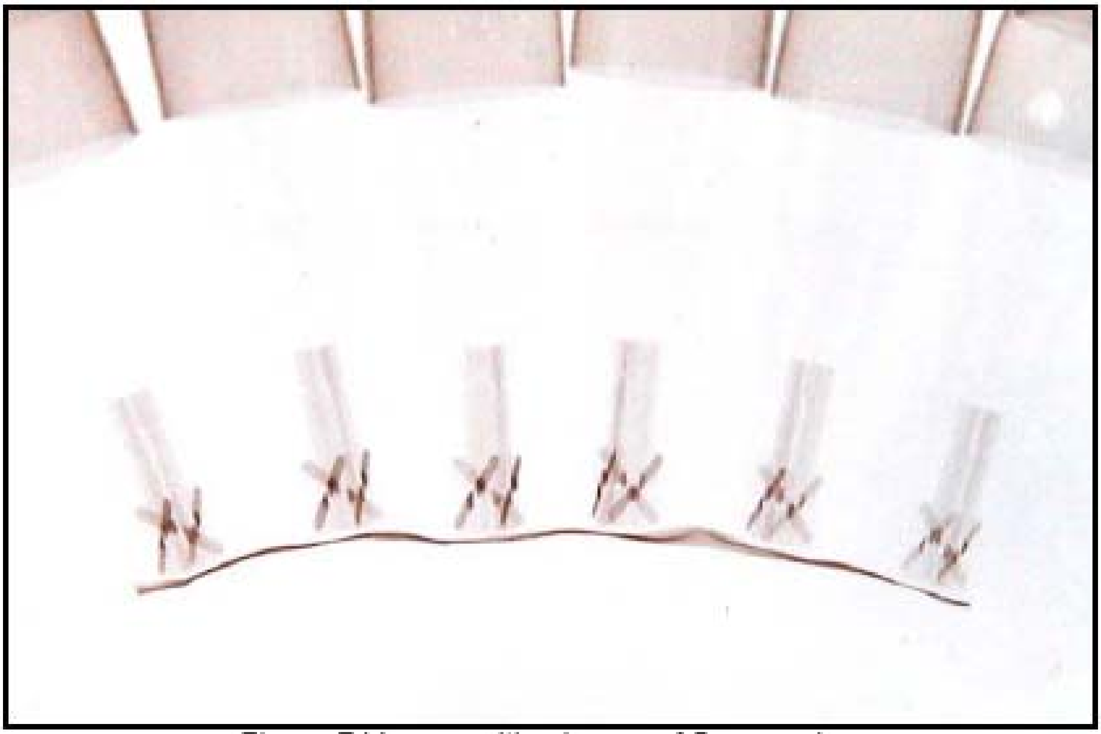


Figure 7 X-ray positive image of 5mm probes

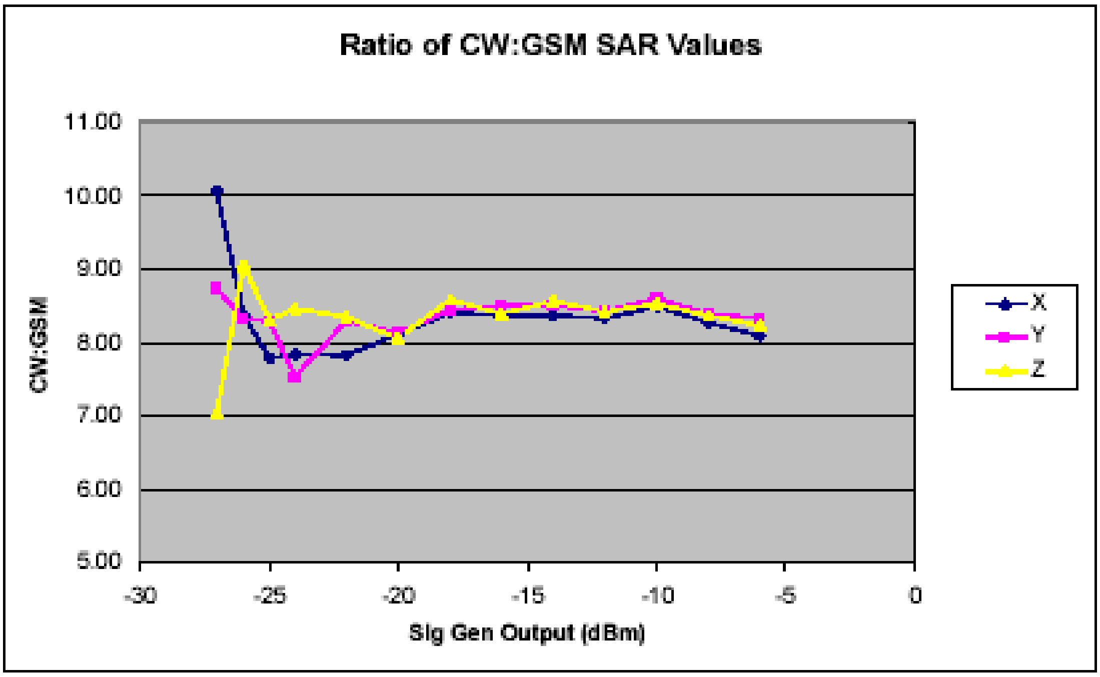



Figure 8 Response of probe to GSM-modulated signals over a range of powers

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

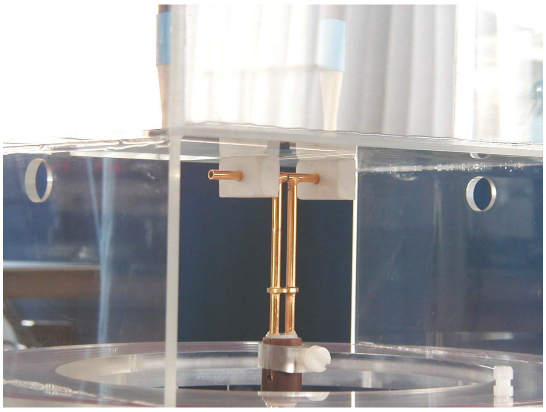
| Liquid used | Relative permittivity (measured) | Conductivity (S/m) (measured) |
|---|---|---|
| 900 MHz BRAIN | 39.40 | 0.93 |
| 900 MHz BODY | 56.33 | 1.01 |
| 1800 MHz BRAIN | 40.10 | 1.36 |
| 1800 MHz BODY | 54.39 | 1.55 |
| 1900 MHz BRAIN | 39.70 | 1.46 |
| 1900 MHz BODY | 54.07 | 1.65 |
| 2450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

**Report No. SN0048_2450**
**12th May 2005**

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

**Performance measurements**

*Ian Bridger*



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e-mail: enquiries@indexsar.com

## 1. Measurement Conditions

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

An Anritsu MS4623B 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 900 MHz 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. SAR Measurement**

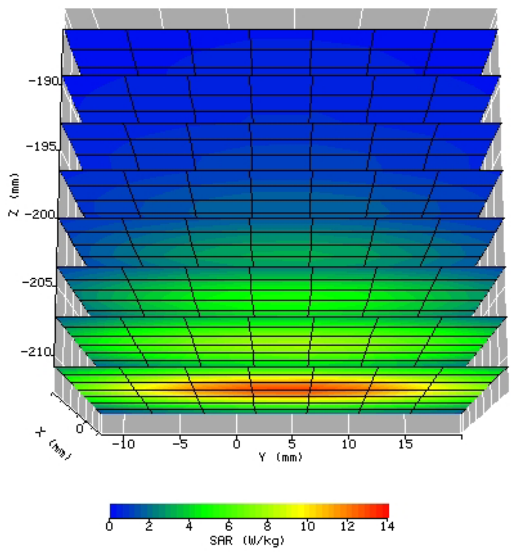
A SAR validation check is performed with the box-phantom located on the SARA2 phantom support base on the SARA2 robot system. Tests are then conducted at a feed power level of approx. 0.25W. The actual power level is recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature is 22$^{o}$C +/- 1$^{o}$C and the relative humidity is around 32% during the measurements.

The phantom is filled with a 2450MHz brain liquid using a recipe from [1], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 2450MHz:

| | |
|---|---|
| Relative Permittivity | **39.54** |
| Conductivity | **1.95 S/m** |

The SARA2 software version 2.36 VPM is used with Indexsar IXP_050 probe Serial Number 0171 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 | **49.132 W/kg** |
| Averaged over 10cm3 (10g) of tissue | **23.992 W/kg** |

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

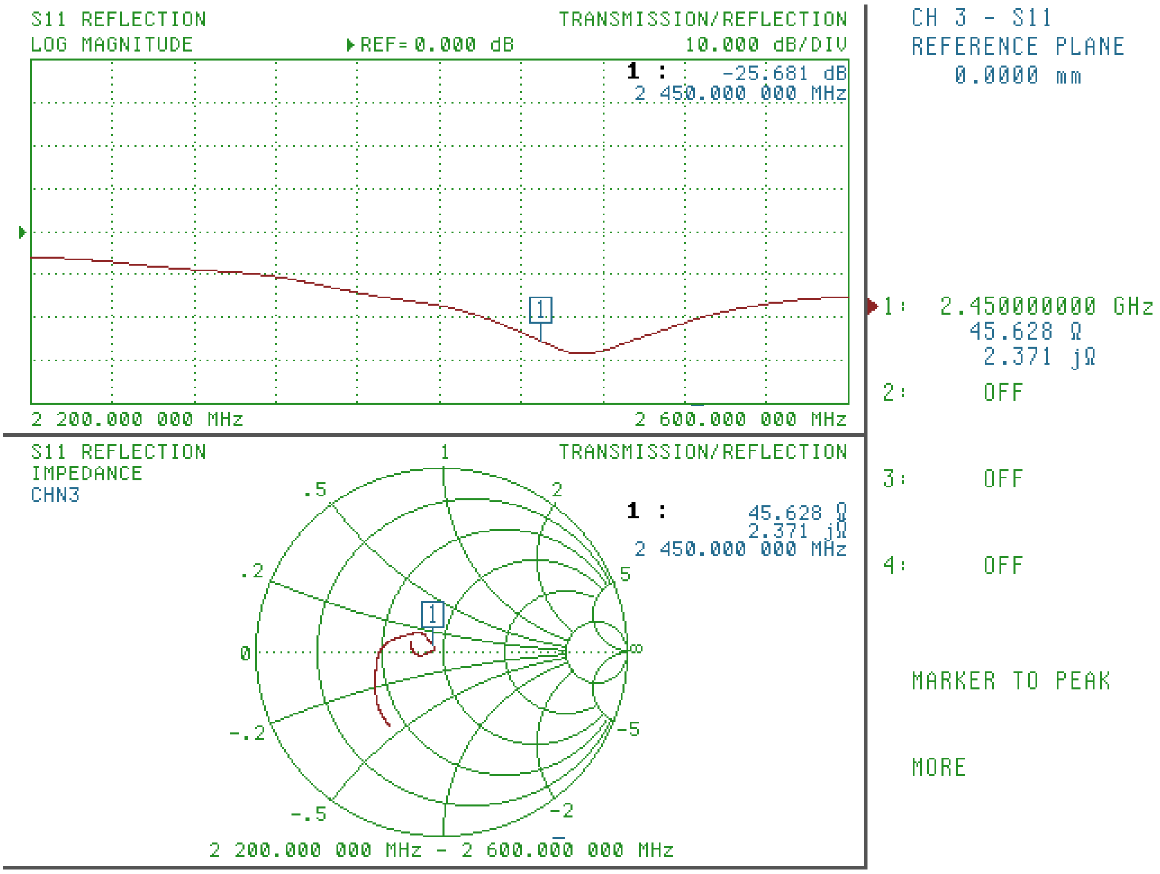
### 3. Dipole impedance and return loss

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. 15mm from the liquid (for 2450MHz). The Indexsar foam spacers (described above) were used to ensure this condition during measurement.

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

Dipole impedance at 2450 MHz Re{Z} = **45.628 Ω**
Im{Z} = **2.371 mΩ**

Return loss at 2450MHz **-25.681 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

IEEE Std 1528-2003. IEEE recommended practice for determining the peak spatial-average specific absorption rate (SAR) in the human body due to wireless communications devices: Measurement Techniques - Description