Experimental Analysis SAR Report

Subject: **Specific Absorption Rate (SAR) Hand and Body Report**

Product: 32 Bit 802.11a PCMCIA wireless Ethernet Adapter

Model: WCB5000

Client: Intel

Address: 2300 Corporate Center Drive
Thousand Oaks, Ca 91320

Project #: XIRB-WCB5000 Beta-3805

Prepared by APREL Laboratories
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FCC ID: J3OWCB5000
Applicant: Intel
Equipment: 802.11a PCMCIA wireless Ethernet Adapter
Model: WCB5000
Standard: FCC 96 –326, Guidelines for Evaluating the Environmental Effects of Radio-Frequency Radiation

ENGINEERING SUMMARY

This report contains the results of the engineering evaluation performed on the Intel WCB5000 802.11a PCMCIA wireless Ethernet adapter operating within a laptop computer. The measurements were carried out in accordance with FCC 96-326. Scientific and technical details as presented in IEEE P-1528 were also used for the assessment of the device tested. The Device Under Investigation (DUI) was evaluated for its maximum power level 40 mW for the low and middle channels and 90 mW for the high channel (nominally). The duty cycle for the radio is 100 %.

The DUI was tested at low, middle and high channels for the keyboard up, keyboard down, and left side for hand and body exposure. The maximum 10g SAR (0.20 W/kg) was found to coincide with the peak performance RF output power of channel 20, high (5320 MHz) for the left side of the device. The maximum 1g SAR (0.67 W/kg) was found to coincide with the peak performance RF output power of channel 20, high (5320 MHz) for the left side of the device.

The left hand side of the device corresponds to the area where the PCMCIA card would be installed.

Test data and graphs are presented in this report.

Based on the test results and on how the device will be marketed and used, it is certified that the product meets the requirements as set forth in the above specifications, for RF exposure environment.

The results presented in this report relate only to the sample tested.

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TABLES AND FIGURES

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1. INTRODUCTION

Tests were conducted to determine the Specific Absorption Rate (SAR) for a sample WCB5000 802.11a PCMCIA wireless Ethernet adapter located in a laptop computer. These tests were conducted at APREL Laboratories' facility located at 51 Spectrum Way, Nepean, Ontario, Canada. A view of the SAR measurement setup can be seen in Appendix A Figure 1. This report describes the results obtained.

2. APPLICABLE DOCUMENTS

The following documents are applicable to the work performed:

1) FCC 96-326, Guidelines for Evaluating the Environmental Effects of Radio-Frequency Radiation

2) ANSI/IEEE C95.1-1999, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

3) ANSI/IEEE C95.3-1992, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields – RF and Microwave.

4) OET Bulletin 65 (Edition 97-01) Supplement C (Edition 01-01), "Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields".

5) IEEE P-1528 Draft "Recommended Practice for Determining the Peak Spatial Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communication Devices: Experimental Techniques."

3. DEVICE UNDER INVESTIGATION

- WCB5000 802.11a PCMCIA wireless Ethernet adapter , s/n 9009T0008037, received on Oct 15, 2001 .

The 802.11a PCMCIA wireless Ethernet adapter will be called DUI (Device Under Investigation) in the following test report.

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4. TEST EQUIPMENT

- APREL Triangular Dosimetric Probe Model E-009, s/n 154, Asset # 301485
- ALIDX-500 Dosimetric SAR Measurement System
- Anritsu spectrum analyzer, Asset # 301330
- APREL flat Phantom F1, Part # P-V-G8 (overall shell thickness 2mm)
- APREL 5.24 GHz Dipole Asset # 301460
- Anritsu Power Meter ML2438A Asset # 2162
- Hewlett Packard 8349B High Frequency RF Amplifier Asset # 100952
- Agilent 83640B Signal Generator Asset # 9493
- Hewlett Packard 11691D Directional Coupler Asset # 301279

5. ALIDX-500 SPECIFICATION

The ALIDX-500 Dosimetric SAR Measurement System was developed jointly with APREL Laboratories and IDX Robotics for use within wireless development and the compliance environment. The system consists of a six axis articulated arm, and controller for precise probe positioning (0.05mm repeatability). Custom software has been developed to enable communications between the robot controller software and the host operating system.

An amplifier is located on the articulated arm, which is isolated from the custom designed end effector and robot arm. The en effector provides the mechanical touch detection functionality and probe connection interface. The amplifier is functionally validated within the manufacturers site and calibrated at NCL. A Data Acquisition Card (DAC) is used to collect the signal as detected by the isotropic e-field probe. The manufacturer calibrates the DAC to NIST standards. A formal validation is executed using all mechanical and electronic components to prove conformity of the measurement platform as a whole.

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The ALIDX-500 has been designed to measure devices within the compliance environment to meet all recognized standards. The system also conforms to standards, which are currently being developed by the scientific and manufacturing community.

The course scan resolution is defined by the operator and reflects the requirements of the standard to which the device is being tested. Precise measurements are made within the predefined course scan area and the values are logged. The sample rate for which the measurements are made is also predefined and the default is set at 6000 samples per second, which acts as a secondary method for eliminating noise.

A complex algorithm is then used to calculate the values within the measured points down to a resolution of 1mm. The data from this process is then used to provide the co-ordinates from which the cube scan is created for the determination of the one and ten gram averages.

Cube scan averaging consists of a number of complex algorithms, which are used to calculate the one, and ten gram averages. The basis for the cube scan process is centered on the location where the maximum measured SAR value was found. When a secondary peak value is found which is within 60% of the initial peak value, the system will report this back to the operator who can then asses the need for further analysis of both the peak values prior to the one and ten gram cube scan average process. The algorithm consists of 3D cubic Spline, and Lagrange extrapolation to the surface, which form the matrix for calculating the measurement output for the one and ten gram average values. The resolution for the physical scan integral is user defined with a final calculated resolution down to 1mm.

In-depth analysis for the differential of the physical scanning resolution for the cube scan analysis has been carried out, to identify the optimum setting for the probe positioning steps, and this has been determined at 8mm increments on the X, & Y planes. The reduction of the physical step increment increased the time taken for analysis but did not provide a better uncertainty or return on measured values.

Prior to the measurement process the operator can insert the parameters for which the physical measurements are made, defining the X, Y, and Z probe movement integrals. For the FCC compliance process both OET 65 “Supplement C” and the IEEE draft standard “P-1528” were used to define the measurement parameters used during the assessment of the device.

The final output from the system provides data for the area scan measurements, physical and splined (1mm resolution) cube scan with physical and calculated values (1mm resolution).

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The over all uncertainty for the methodology and algorithms the ALIDX500 used during the SAR calculation was evaluated using the data from IEEE P-1528 f3 algorithm.

$$f_3(x,y,z) = A\frac{a^2}{\frac{a^2}{4}+x'^2+y'^2}\cdot\left(e^{-\frac{2z}{a}}+\frac{a^2}{2(a+2z)^2}\right)$$

6. TEST METHODOLOGY

1. The test methodology utilized in the certification of the DUI complies with the requirements of FCC 96-326 and ANSI/IEEE C95.3-1992.

2. The E-field is measured with a small isotropic probe (output voltage proportional to E^2).

$$SAR = \frac{\sigma\,|\mathbf{E}|^2}{\rho}$$

3. The probe is moved precisely from one point to the next using the robot (10 mm increments for wide area scanning and 8 mm increments for zoom scanning in the X, Y directions) and (4.0 mm increments for the final depth profile measurement in the Z direction).

4. The probe travels in the homogeneous liquid simulating human tissue. Not all tissues are electrically the same so the equation below is a clear representation of the methodolo gy used for the SAR assessment when you substitute head for body.

$$SAR_{head} = \frac{\rho_{solution}}{\rho_{head}}\underbrace{c_{solution}\left.\frac{\Delta T}{\Delta t}\right|_{t=0}}_{SAR_{solution}}$$

   Appendix A contains information about the properties of the simulated tissue used for these measurements.

5. The liquid is contained in a manikin simulating a portion of the human body with an overall shell thickness of 2 mm.

6. The DUI is positioned with the surface under investigation against the phantom with no separation distance.

7. All tests were performed with the highest power available from the sample DUI under transmit conditions.

   More detailed descriptions of the test method are given in Section 6 where appropriate.

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7. TEST RESULTS

7.1. TRANSMITTER CHARACTERISTICS

The battery-powered DUI will consume energy from its batteries, which may affect the DUI's transmission power characteristics. In order to gage this effect the output of the transmitter is sampled before and after each SAR test. In the case of this DUI, the Tx power was sampled through out the test process. The following table shows the RF power sampled before and after each of the two sets of data used for the worst case SAR in this report.

<u>Note</u>

The power measurement is not conducted and only relative to a true pin on pin conducted measurement. The spectrum analyzer provides the technician with the functionality of viewing the expected power and the actual received power from the DUI. This allows the technician to monitor the possible drift in power during the test process, and as a result assess the delta if any.

Scan	Power Readings (dBm)		D	Battery #
Type	Before	After	(dB)	
Coarse	-20.07	-20.47	0.4	1
Fine	-20.07	-20.47	0.4	1

Table 1. Sampled RF Power

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7.2. SAR MEASUREMENTS

1) RF exposure is expressed as a Specific Absorption Rate (SAR). SAR is calculated from the E-field, measured in a grid of test points. SAR is expressed as RF power per kilogram of mass, averaged in 10 grams of tissue for the extremities and 1 gram of tissue elsewhere. The equation below is a representation of how SAR theoretically equates.

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dV}\right)$$

2) The DUI was put into test mode for the SAR measurements by using software installed in the DUI which was used to control the channel and maximum operating power via the host computers keyboard.

3) Figures 2 & 4 in Appendix A show a contour plot of the SAR measurements for the DUI (channel 20, 5320 MHz) it also shows an overlay of the DUI's outlines, superimposed onto the contour plots.

   A different presentation of the same data is shown in Appendix A Figures 3 & 5. This is a surface plot, where the measured SAR values provide the vertical dimension, which is useful as a visualization aid.

4) Wide area scans were performed for the low, middle and high channels of the DUI. The DUI was operating at maximum output power (40 mW) for the low and middle channels and (90mW) for the high channel with the duty cycle set at 100%. The DUI was placed in close proximity to the phantom for the keyboard up, keyboard down and left side permutations. The phantom shell thickness is 2 mm overall.

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TYPE OF EXPOSURE	DUI side	Antenna distance from phantom (mm)	Channel			Peak Local SAR (W/kg)
			L/M/H	#	Freq (MHz)	
Hand &Body Exposure	keyboard down side	9	Low	6	5180	0.06
	Keyboard down side	9	Middle	12	5240	0.06
	Keyboard down side	9	High	20	5320	0.09
	Keyboard up side	6	Low	6	5180	0.07
	Keybo ard up side	6	Middle	12	5240	0.08
	Keyboard up side	6	High	20	5320	0.16
	Left side	0	Low	6	5180	0.25
	Left side	0	Middle	12	5240	0.19
	Left side	0	High	20	5320	0.50

Table 2. SAR Measurements

8. USER'S HAND EXPOSURE

All subsequent testing for user's hand exposure was performed on channel 20 (5320 MHz) with the left side of the DUI facing up against the bottom of the phantom. This relates to the position and frequency found to provide the maximum measured SAR value.

1) Channel 20 (5320 MHz) was then explored on a refined 32 mm grid in three dimensions (X, Y & Z) measuring at 8 mm integrals X & Y and 4 mm integrals in the Z plain so as to create a physical measured point matrix. The system then runs the algorithms, which completes the matrix of calculated and measured values equivalent to a 1 mm resolution.

2) To establish the maximum SAR values averaged over 1 and 10 grams the software runs a series of Lagrange functions to provide the data for the Z plain.

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From the calculated matrix which has a 1 mm resolution a fourth order polynomial is used to extrapolate the surface values. The maximum SAR value averaged over 10 grams was found to be 0.20 W/kg.

9. BODY EXPOSURE

All subsequent testing for user's body exposure was performed on channel 20 (5320 MHz) with the left side of the DUI facing up against the bottom of the phantom. This relates to the position and frequency found to provide the maximum measured SAR value.

1) Channel 20 (5320 MHz) was then explored on a refined 32 mm grid in three dimensions (X, Y & Z) measuring at 8 mm integrals X & Y and 4 mm integrals in the Z axis so as to create a physical measured point matrix. The system then runs the algorithm, which creates a matrix of values equivalent to a 1 mm resolution.
2) To establish the maximum SAR values averaged over 1 and 10 grams the software runs a series of Lagrange functions to provide the data for the Z plain.

From the calculated matrix which has a 1 mm resolution a fourth order polynomial is used to extrapolate the surface values. The maximum SAR value averaged over 1 gram was found to be 0.67 W/kg.

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10. CONCLUSIONS

The maximum Specific Absorption Rate (SAR) averaged over 10 grams, determined at 5320 MHz (channel 20) of the WCB5000 802.11a PCMCIA wireless Ethernet adapter, is 0.20 W/kg. The overall margin of uncertainty for this measurement is ±16% (Appendix B). The SAR limit given in the FCC 96-326 Safety Guideline is 4 W/kg for hand exposure for the general population.

The maximum Specific Absorption Rate (SAR) averaged over 1 gram, determined at 5320 MHz (channel 20) of the WCB5000 802.11a PCMCIA wireless Ethernet adapter is 0.67 W/kg. The overall margin of uncertainty for this measurement is ±16% (Appendix B). The SAR limit given in the FCC 96-326 Safety Guideline is 1.6 W/kg for body exposure for the general population.

Considering the above, this unit as tested, and as it will be marketed and used, is found to be compliant with the FCC 96-326 requirement.

Tested by ____________________________ Date _________________

Telecommunications Approval Board - Spectrum Sciences Institute - SAR Certified APREL Laboratories

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APPENDIX A. Measurement Setup, Tissue Properties and SAR Graphs


Figure 1. Setup

Simulated Tissue Material and Calibration Technique

The mixture used was based on that presented SSI/DRB-TP-D01-033, “Tissue Recipe and Calibration Requirements”. The density used to determine SAR from the measurements was the recommended 1000 kg/m^3 found in Appendix C of Supplement C to OET Bulletin 65, Edition 01-01).

Dielectric parameters of the simulated tissue material were determined using a Hewlett Packard 8510 Network Analyzer, a Hewlett Packard 809B Slotted Line Carriage, and an APREL SLP-001 Slotted Line Probe.

	APREL	Target Value	Δ (%)
Dielectric constant, ε_r	45.02	48.64	-7.44 %
Conductivity, σ [S/m]	5.85	5.35	8.55 %
Tissue Conversion Factor, γ	10.7	-	-

Table 3. Dielectric Properties of the Simulated Muscle Tissue at 5240 MHz

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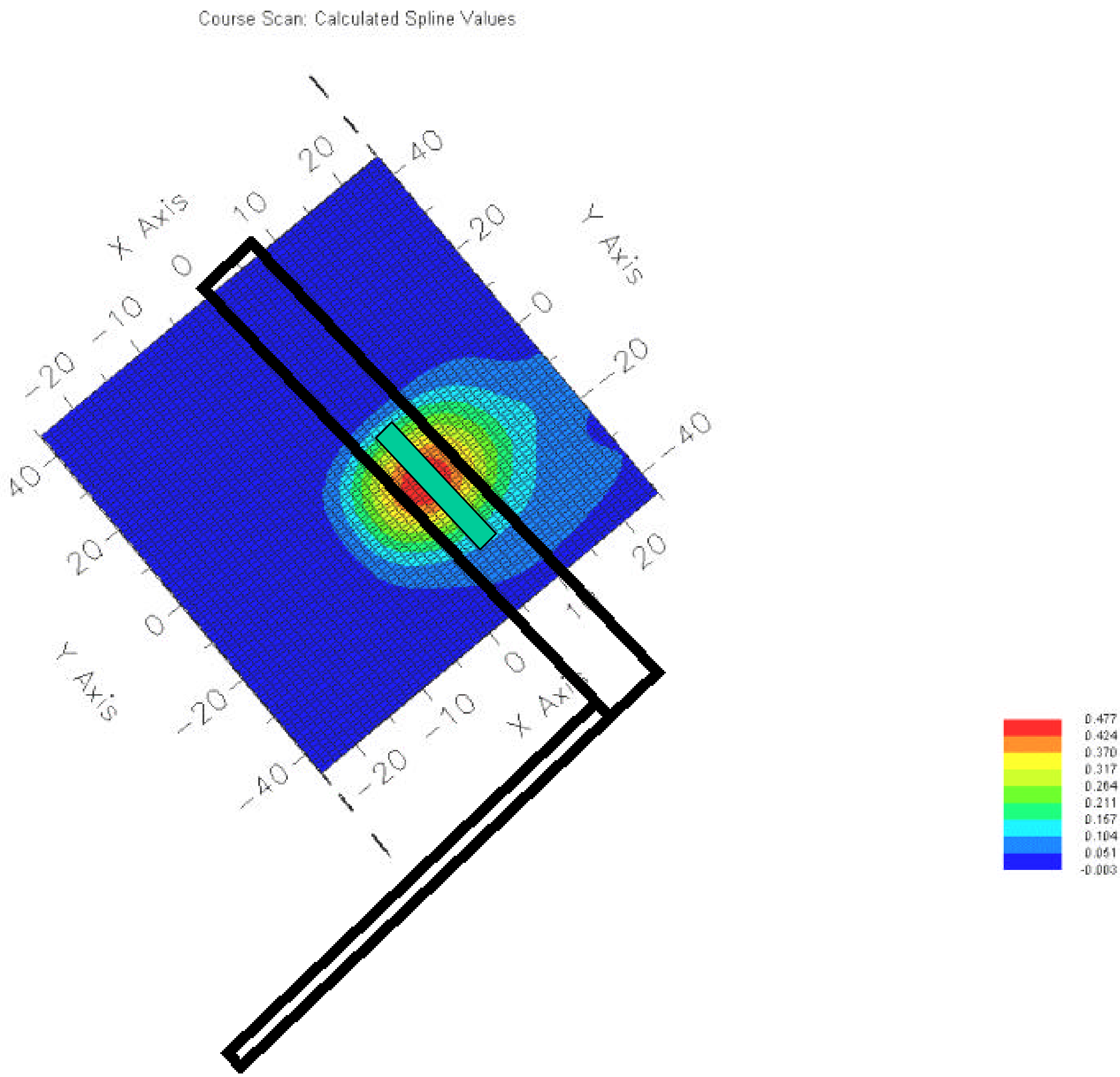

Figure 2. Contour Plot of Area Scan

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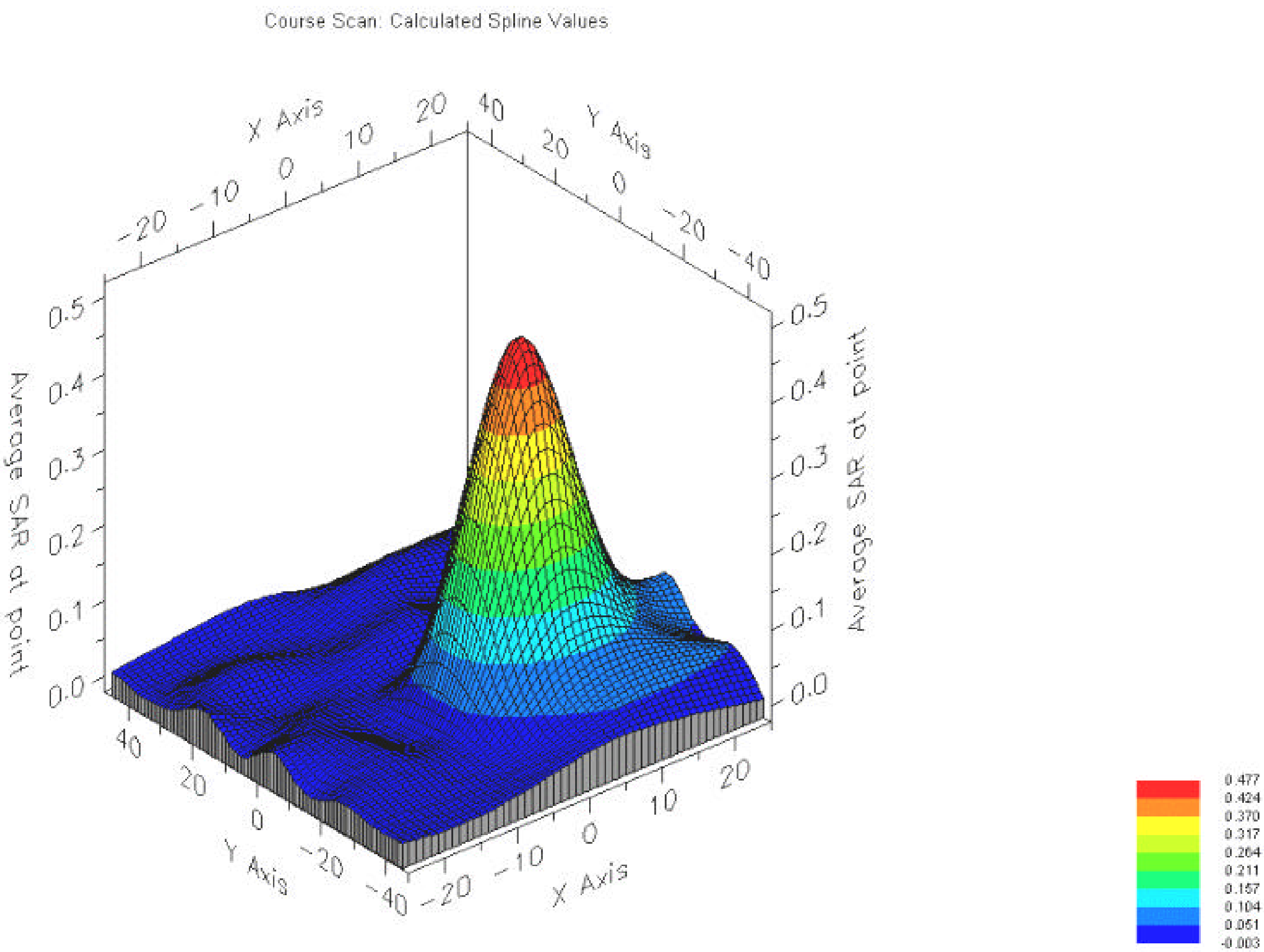

Figure 3. Surface Plot of Area Scan

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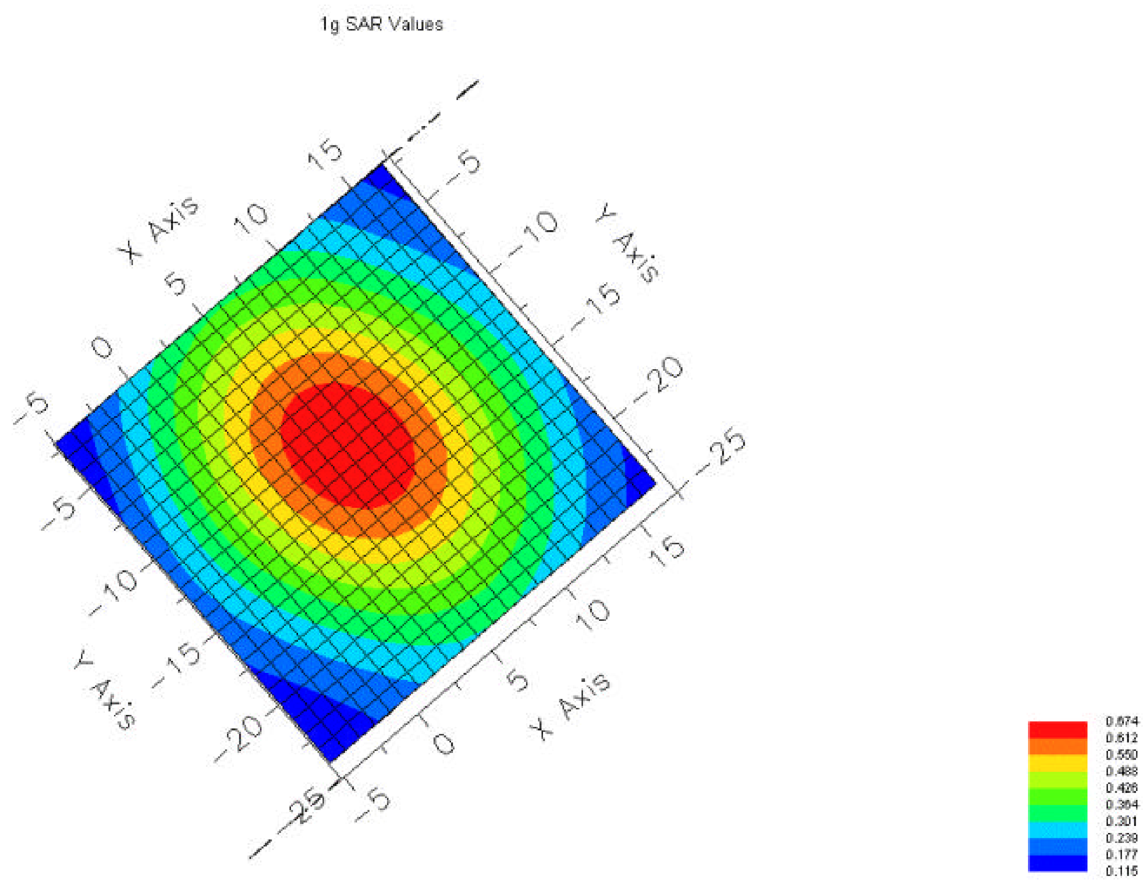

Figure 4. Contour Plot of 1 gram Scan

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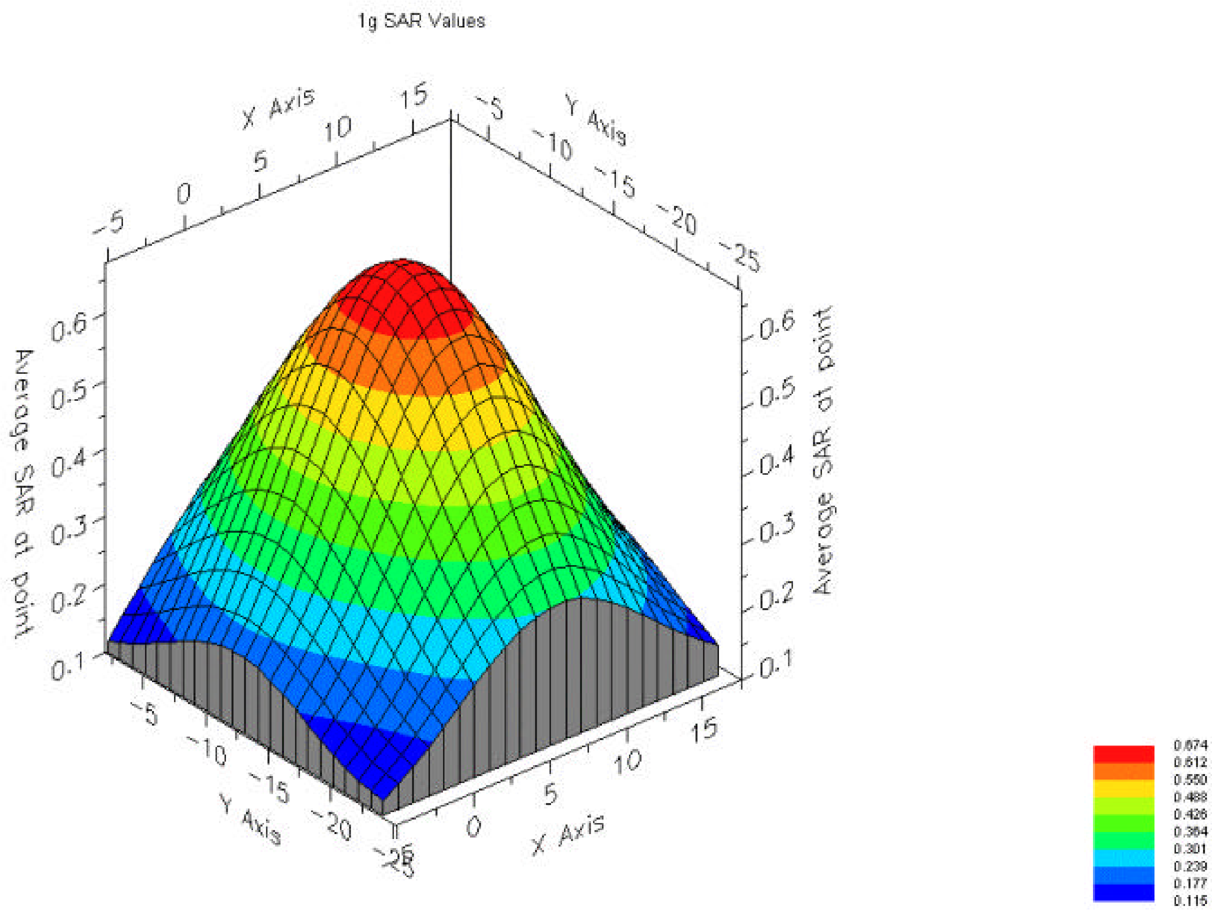

Figure 5. Surface Plot of 1 gram Scan

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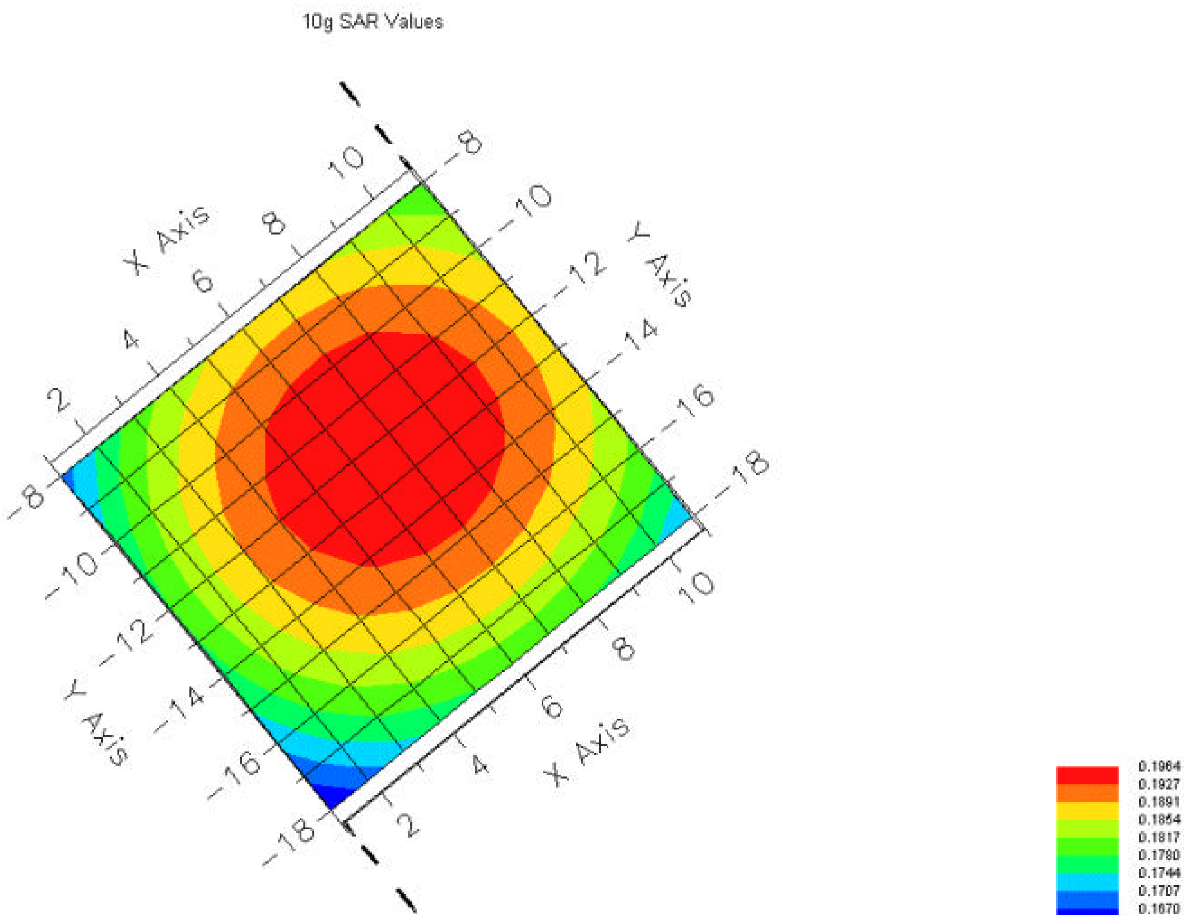

Figure 6. Contour Plot of 10 gram Scan

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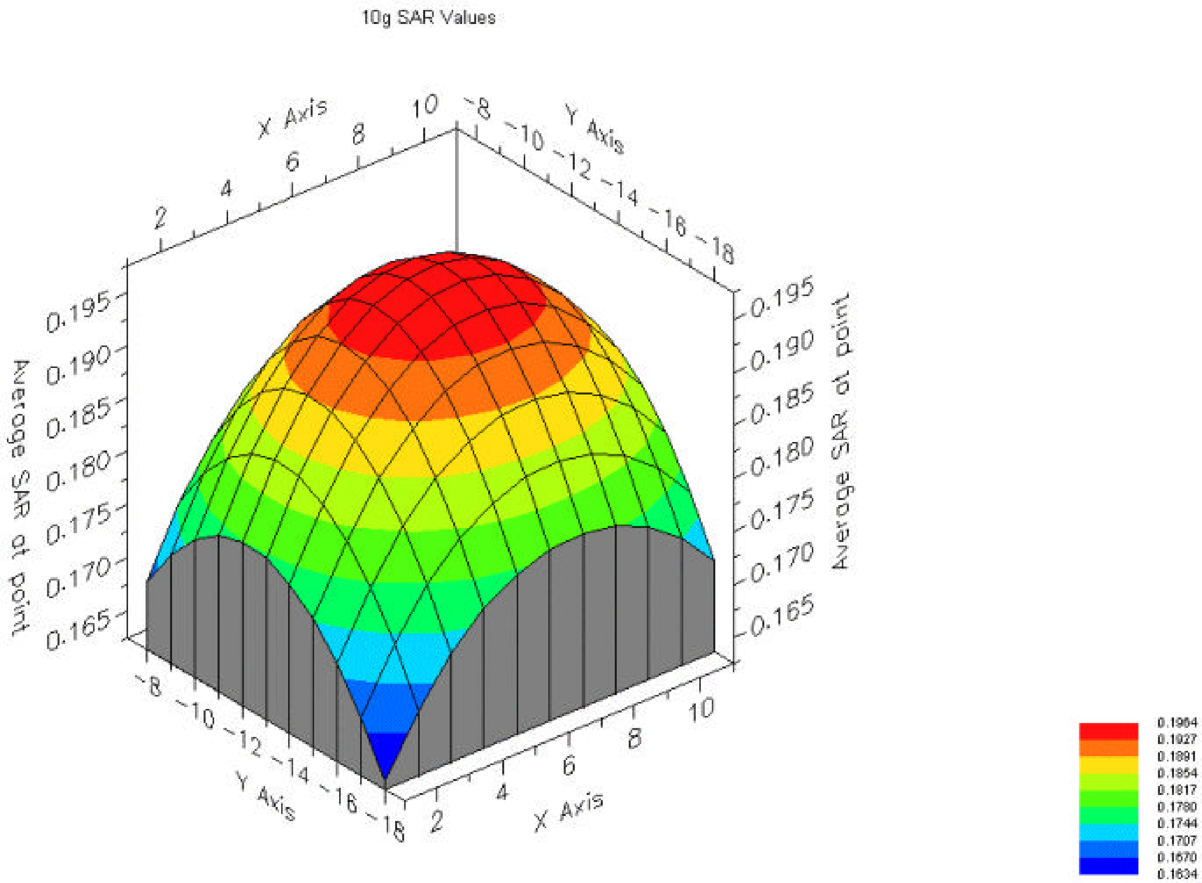

Figure 7. Surface Plot of 10 gram Scan

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APPENDIX B. Uncertainty Budget

Calculated Uncertainties		
Type of Uncertainty	**Specific to**	**Uncertainty**
Power variation due to battery condition	DUI	8.0%
Extrapolation due to depth measurement	Setup	3.8%
Conductivity	Setup	8.5%
Permitivity	Setup	7.4%
Probe Calibration	Setup	6.0%
Probe Positioning	Setup	1.0%
Probe Isotropicity	Setup	1.5%
Other Setup Uncertainty (Ambient,,,)	Setup	3.0%
	31.9%	**Expanded Uncertainty K^2**

Table 4. Uncertainty Budget

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APPENDIX B. Validation Scan

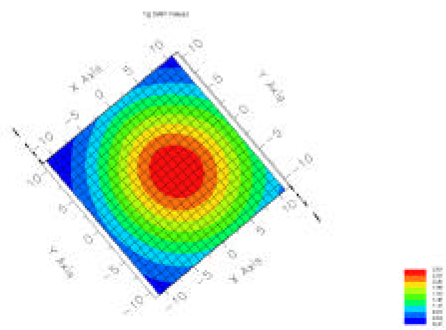

Figure 8. Contour Plot of 1 gram Validation Scan

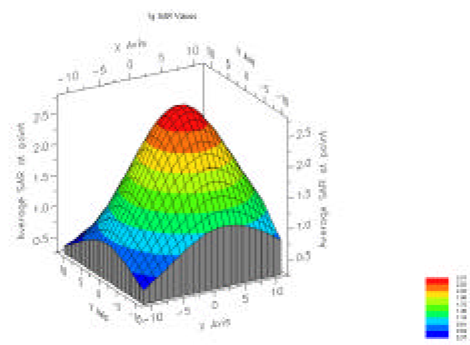

Figure 9. Surface Plot of 1 gram Validation Scan

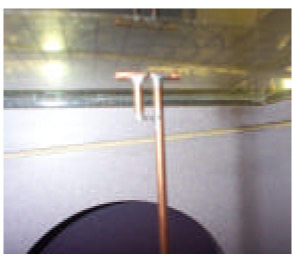

Figure 10. Dipole Under Phantom

Figure 11. Dipole Under Phantom

Frequency (MHz)	1 Gram SAR (W/Kg)	Target Value (W/Kg)	Delta (%)	Input Power to Dipole (mW)	Distance from Dipole to Tissue (mm)
5240	2.81	2.81	0	85	10

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APPENDIX C. Probe Calibration

NCL CALIBRATION LABORATORIES

Calibration File No.: 301485

CERTIFICATE OF CALIBRATION

It is certified that the equipment identified below has been calibrated in the **NCL CALIBRATION LABORATORIES** by qualified personnel following recognized procedures and using transfer standards traceable to NRC/NIST.

Equipment: Miniature Isotropic RF Probe

Manufacturer: APREL Laboratories/IDX Robotics Inc
Model No.: E-009
Serial No.: 154

Customer: APREL
Asset No.:301485

Calibration Procedure: SSI/DRB-TP-D01-032

Cal. Date: 15 October, 2001 Cal. Due Date: 14 October, 2001
Remarks: None

Calibrated By: ____

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