Certification Report on

Specific Absorption Rate (SAR)
Experimental Analysis

Sharewave, Inc.

Power Wave 2.4G Radio

Date: 07 April, 1999

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CERTIFICATION REPORT

Subject: **Specific Absorption Rate (SAR) Experimental Analysis**

Product: **ShareWave Power Wave 2.4G Radio**

Client: ShareWave, Inc.

Address: 5175 Hillsdale Circle
El Dorado Hills
CA 95762

Telecommunications Approval Board - Spectrum Sciences Institute
SAR Certified
APREL
A932-PowerWaveRev.2

Project #: SHWB-PowerWave Rev.2-3174

Prepared by: APREL Laboratories
51 Spectrum Way
Nepean, Ontario
K2R 1E6

Submitted by Paul G Cardinal Date: 07 Apr 99
Dr. Paul G. Cardinal
Director, Laboratories

Approved by [signature] Date: April 7/99.
Dr. Jacek J. Wojcik, P. Eng.

Registered Professional Engineer J. J. Wojcik Province of Ontario

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Submitted by ______________________________ Date: __________________
Dr. Paul G. Cardinal
Director, Laboratories

Approved by ________________________________ Date: __________________
Dr. Jacek J. Wojcik, P. Eng.

FCC ID: N9PSW1-2450
Applicant: ShareWave, Inc.
Equipment: Digital Radio
Model: Power Wave 2.4G Radio
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 a ShareWave Power Wave 2.4G Radio. The measurements were carried out in accordance with FCC 96-326. The Power Wave 2.4G Radio was evaluated for its maximum power level of Power Level of 20.4 dBm (110 mW).

The digital radio was tested at high, middle, and low frequencies, on both sides of the transmitting structure ("paddle") with the maximum SAR coinciding with the peak performance RF output power of channel 1 (low, 2425 MHz) on the inside surface of the paddle. Test data and graphs are presented in this report.

Based on the test results, it is certified that the product meets the requirements as set forth in the above specifications, for uncontrolled RF exposure environment.

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1. INTRODUCTION

Tests were conducted to determine the Specific Absorption Rate (SAR) of a sample of a ShareWave Power Wave 2.4G Radio. 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 2. 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 C95.1-1992, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

3) ANSI/IEEE 95.3-1992, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields – RF and Microwave.

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

3. EQUIPMENT UNDER TEST

- ShareWave Model Power Wave 2.4G Radio, (sample 1)

The transmission antenna consists of a patch centred on a printed circuit board, and is positioned inside the movable plastic housing. The antenna specifications supplied by the manufacturer can be found in Appendix B.

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4. TEST EQUIPMENT

- Narda 8021B miniature E-field probe, s/n 04007, Asset # 301339
- CRS Robotics A255 articulated robot arm, s/n RA2750, Asset # 301355
- CRS Robotics C500 robotic system controller, s/n RC584, Asset # 201354
- R&S NRVS power meter, s/n 864268/017, Asset # 100851
- APREL F–2 flat manikin, s/n 001
- Tissue Recipe and Calibration Requirements, APREL procedure SSI/DRB-TP-D01-033

5. TEST METHODOLOGY

1. The test methodology utilised in the certification of the Power Wave 2.4G Radio 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).
3. The probe is moved precisely form one point to the next using the robot (10 mm increments for wide area scanning and 5 mm increments for zoom scanning, and 2.5 mm increments for the final depth profile measurements).
4. The probe travels in the homogeneous liquid simulating human tissue. Appendix D contains information about the recipe and properties of the simulated tissue used for these measurements.
5. The liquid is contained in a manikin simulating a portion of the human body.
6. The Power Wave 2.4G Radio is positioned in such a way that it either touches the bottom of the phantom with either the outside or the inner side of the transmitting paddle, or is separated by a few millimetres.
7. All tests were performed with the highest power available from the sample Power Wave 2.4G Radio, under transmit conditions.

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More detailed descriptions of the test method is given in Section 6 when appropriate.

6. TEST RESULTS

6.1. TRANSMITTER CHARACTERISTICS

The Power Wave 2.4G digital radio receives its power from the power supply to which it is connected. The radio, computer board, and power supply used in the setup are shown in Appendix A Figure 1. Consequently, the digital radio's output power will not be dependent on the power usage under test conditions. The following table shows the conducted RF power measured for each of the three transmitting channels before starting the SAR measurements:

Channel		**HP Power Meter**	**Adapter Cable Loss**	**Power at Antenna Feedpoint**
#	**Frequency**			
	(MHz)	(dBm)	(dB)	(dBm)
1	2425	19.8	0.6	20.4
2	2440	18.3	0.6	18.9
3	2455	18.7	0.6	19.3

6.2. 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 as shown in Appendix A Figure 3. SAR is expressed as RF power per kilogram of mass, averaged in 1 cubic centimetre of tissue.

2) The ShareWave Power Wave 2.4G Radio was put into test mode for the SAR measurements by application software running from an EPROM, supplied by ShareWave, to control the channel (H, M, L) and maximum operating power (nominally 19.5 dBm).

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3) Figure 4 in Appendix A shows a contour plot of the SAR measurements for the ShareWave Power Wave 2.4G Radio sample operating on the low channel. The presented values were taken 2.5 mm into the simulated tissue from the Flat Phantom's solid inner surface. Figure 2 in Appendix A shows the phantom used in the measurements. The separation was 1.88 mm for the data presented in Figure 4. The axis of the antenna-housing is aligned with the y = 0 cm gridline, with the radio housing butting up against the phantom wall. A grid is shown inside the phantom indicating the orientation of the x-y grid used, with the origin (0,0) half way up the right hand side. The x-axis is positive towards the left and the y-axis is positive towards the bottom.

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

4) Wide area scans were also performed on the low channel versus separation between the antenna-housing and the lower surface of the phantom. The peak single point SAR for the scans were:

Channel		**Separation**	**Highest Local SAR**
	(MHz)	(mm)	(W/kg)
Low (1)	2425	0	1.55
Low (1)	2425	1.88	1.03
Low (1)	2425	1.88	1.16
Low (1)	2425	3.8	0.80

Appendix A Figure 6 shows the data plotted as a function of separation and the exponential curves fit to them (Microsoft Excel 97).

5) Wide area scans were also performed for the middle (2) and high (3) channels, when the unit was in contact with the phantom and with an antenna-housing separation of 1.88 mm from the lower surface of the phantom for the low (1) channel. The peak single point SAR for these scans were:

Channel		**Highest Local SAR (W/kg)**	
	(MHz)	@ 0.0 mm	@ 1.88 mm
Low (1)	2425	1.55	1.16
Middle (2)	2440	1.08	-
High (3)	2455	1.31	-

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6) Subsequent testing was performed with the digital radio operating on its low channel, and considering the anticipated scaling to the surface of the phantom, with an antenna-housing to phantom separation of 1.88 mm.

7) Area scan data was then obtained at 12.5 mm into the simulated brain tissue on the low channel. These measurements are presented as a contour plot in Appendix A Figure 7 and surface plot in Figure 8.
Figure 9 shows an overlay of the antenna-housing's outline, superimposed onto the contour plot previously shown as Figure 4.
Figures 5 and 8 show that there is a dominant peak, in the contour plots, that diminishes in magnitude with depth into the tissue simulation.

8) The low channel (1) SAR peak was then explored on a refined 0.5 cm grid in three dimensions. Appendix A Figures 10, 11, and 12 show the measurements made at 2.5, 7.5 and 12.5 mm respectively. The SAR value averaged over 1 cm^3 was determined from these measurements by averaging the 27 points (3x3x3) comprising a 1 cm cube. The maximum SAR value measured averaged over 1 cm^3 was determined from these measurements to be 0.478 W/kg.

9) To extrapolate the maximum SAR value averaged over 1 cm^3 to the inner surface of the head phantom a series of measurements were made at a few (x,y) co-ordinates within the refined grid as a function of depth, with 2.5 mm spacing. Appendix A Figure 12 shows the data gathered and the exponential curves fit to them (Microsoft Excel 97). The average exponential coefficient was determined to be (-0.168 ± 0.004) /mm.

   The distance from the probe tip to the inner surface of the head phantom for the lowest point is 2.5 mm. The distance from the probe tip to the tip of the measuring dipole within the Narda 8021B miniature RF probe is 7 mm. The total extrapolation distance is 9.5 mm, the sum of these two.

   Applying the exponential coefficient over the 9.5 mm to the maximum SAR value average over 1 cm^3 that was determined previously, we obtain **the maximum SAR value at the surface averaged over 1 cm^3** of 2.359 W/kg.

7. ANALYSIS

The measurements of highest local SAR versus separation of the antenna housing from the bottom of the phantom (Section 6.2.4) will enable the peak 1g SAR for a separation of 1.88mm (previous section) to be extrapolated/interpolated for smaller separations.

If the data for Figure 5 is fitted to an exponential equation we get:

$$\text{Peak Local SAR} = 1.5328\, e^{-0.174\ \text{separation}}$$

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A similar equation will exist for the peak 1g SAR versus separation:

$$\text{Peak 1g SAR} = k\ e^{-0.174\ \text{separation}}$$

Using this equation with the previous section's data:

Peak 1g SAR = 2.359 W/kg
separation =1.88mm

results in a k = 3.27 W/kg, which corresponds to the peak 1g SAR when the separation is zero. A conservative peak 1g SAR of 1.5 W/kg would occur for a separation of 4.5mm.

8. CONCLUSION

The maximum Specific Absorption Rate (SAR) averaged over 1g, determined at 2425 MHz (low channel - 1) and for a separation between the inside surface of the antenna housing and the phantom of 4.5 mm, of the ShareWave, Inc. Model Power Wave 2.4G Radio, is 1.5 W/kg. The overall margin of uncertainty for this measurement is ±15.5%.

A user would not casually rest his/her arm in a position across the Power Wave digital radio housing and against the surface of the antenna housing for any period of time. This is due to possible damage to the unit by blocking the ventilation. Resting an arm in such a position would expose the user to the heat given off by the digital radio; block the cooling holes thereby potentially damaging the device; or potentially damage the paddle if too much force is applied against it.

Consequently, the analysis of Section 7 which showed that theoretically the FCC 96-326 SAR safety guideline limit of 1.6W/kg applicable to the exposure of the arm to this device could only be exceeded if the separation between the antenna housing and the arm was 4.5 mm or less for 6 minutes or more, should not be an issue.

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

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APPENDIX A

Figure 1

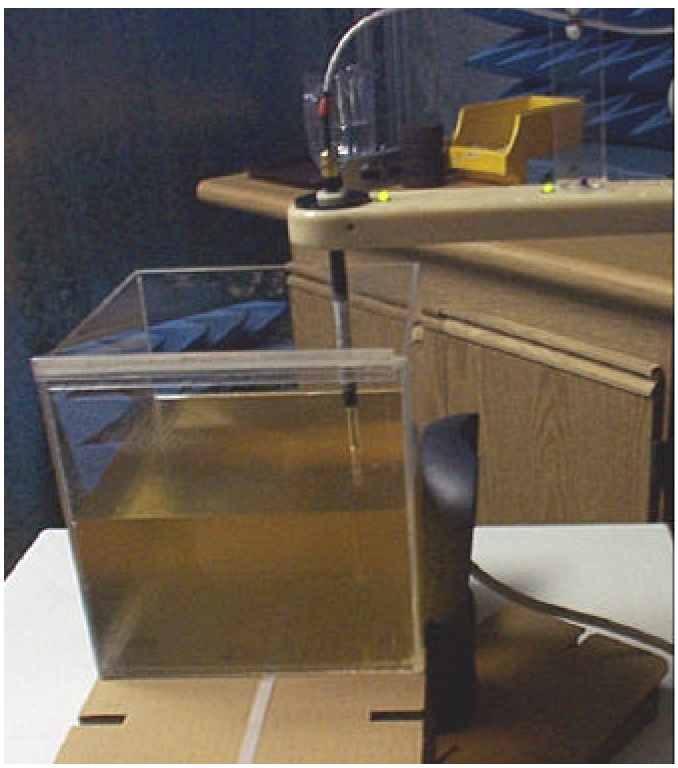

Figure 2

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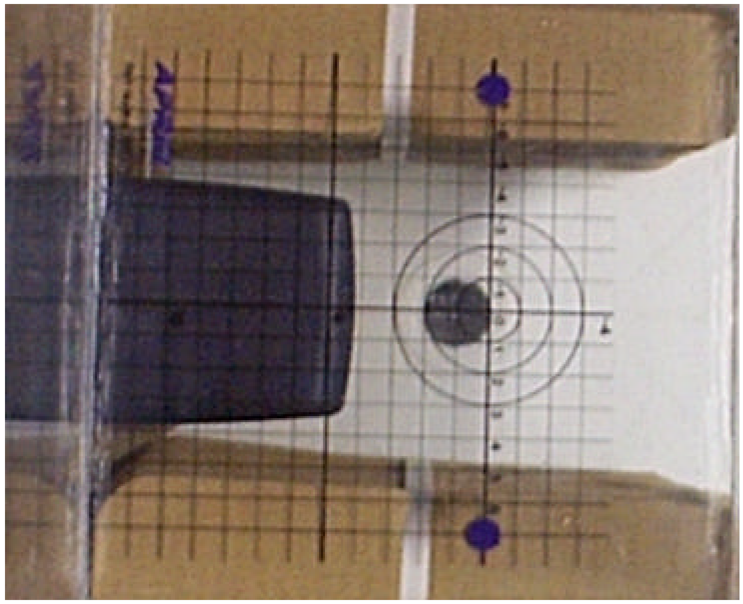

Figure 3

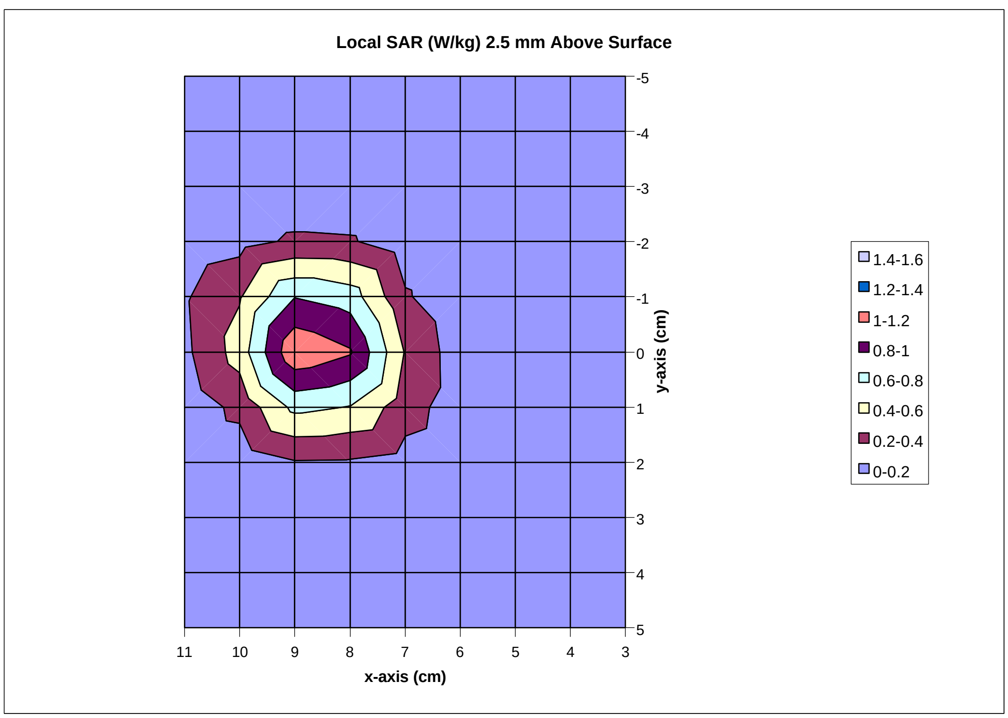

Figure 4

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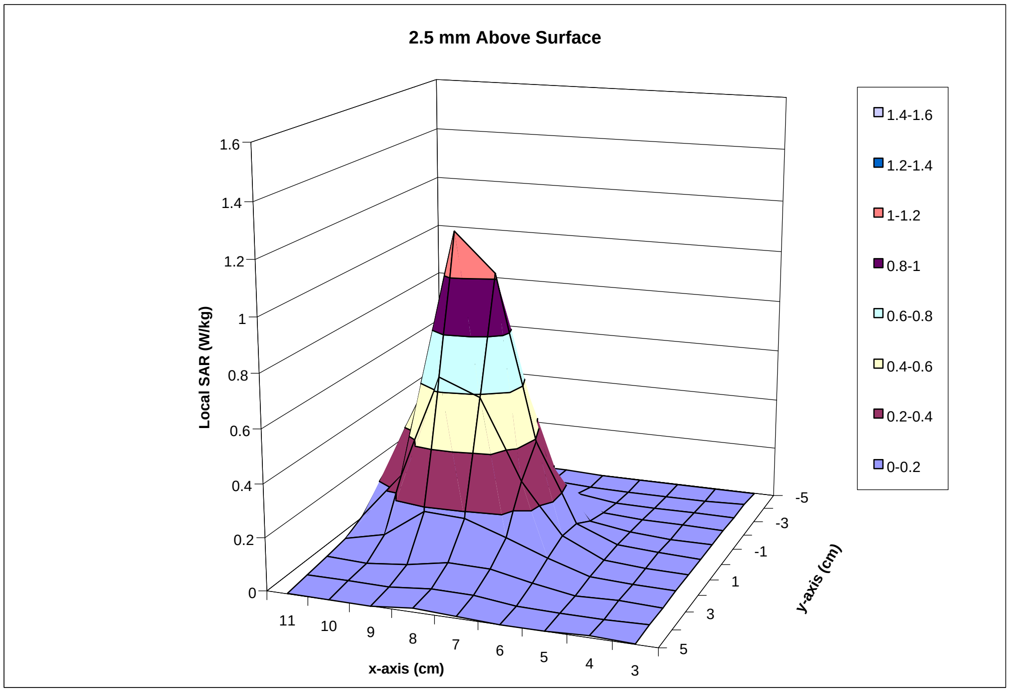

Figure 5

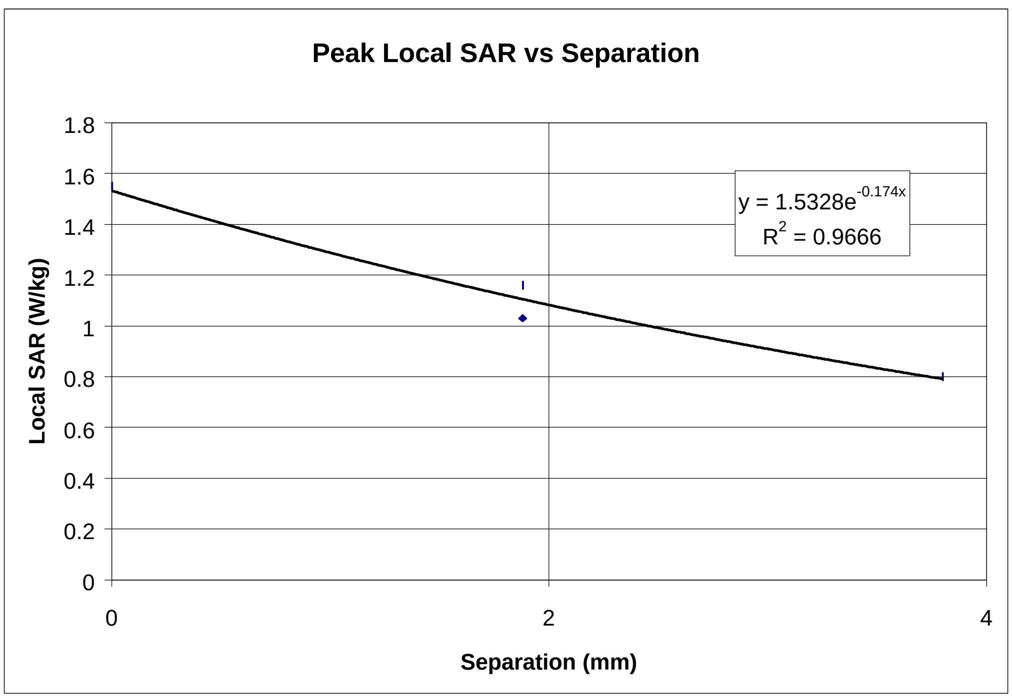

Figure 6

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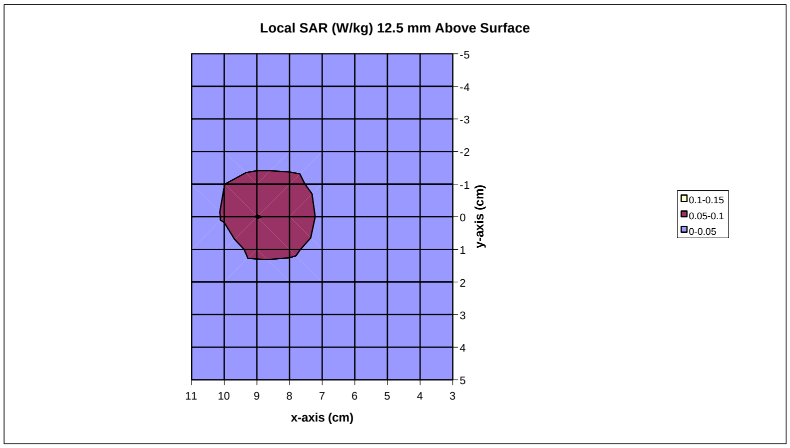

Figure 7

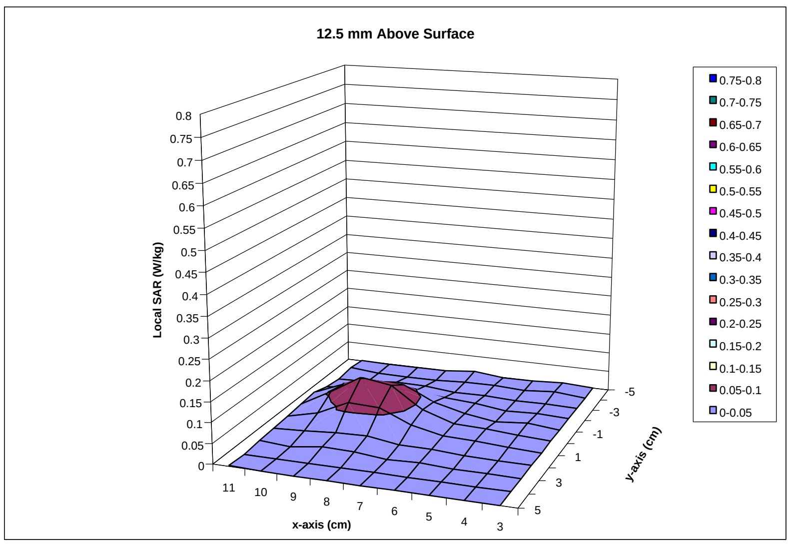

Figure 8

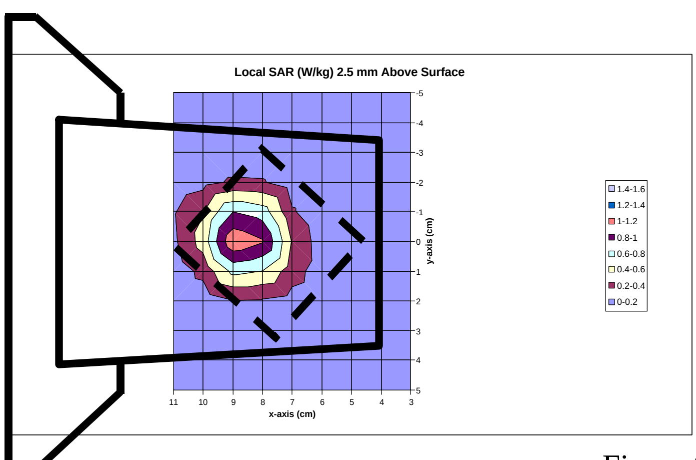

Figure 9

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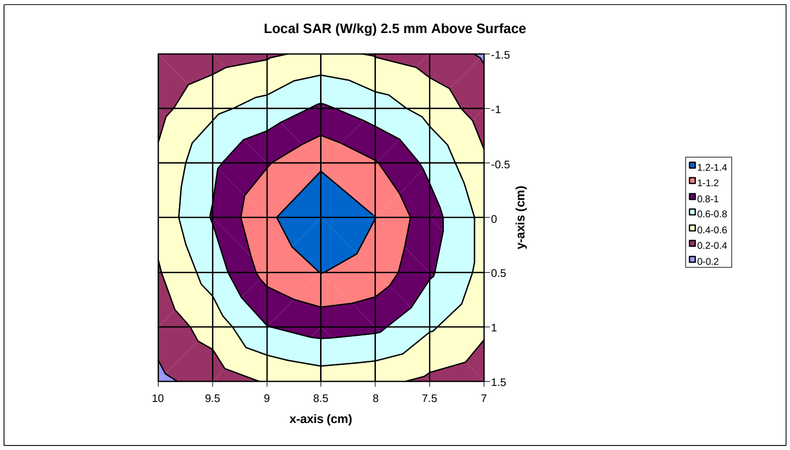

Figure 10

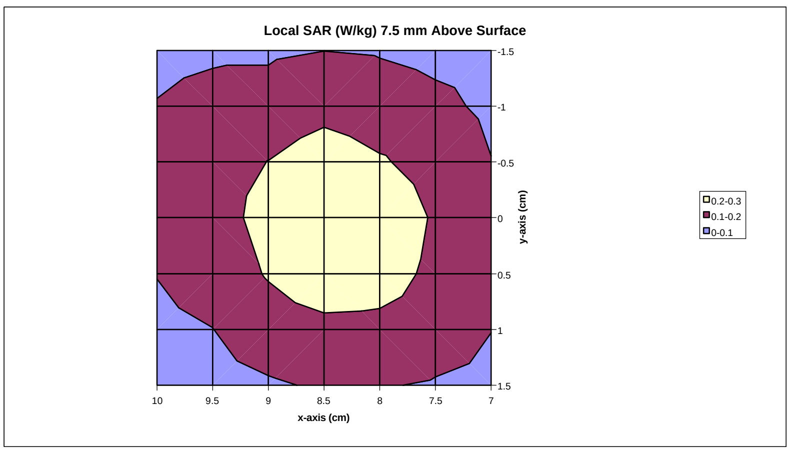

Figure 11

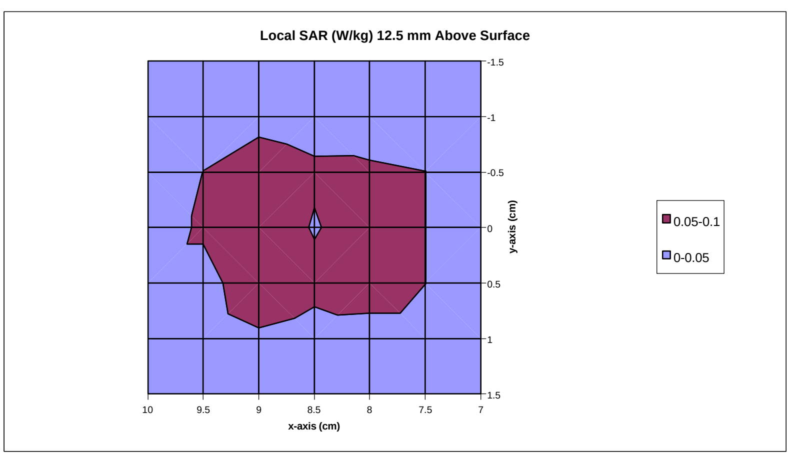

Figure 12

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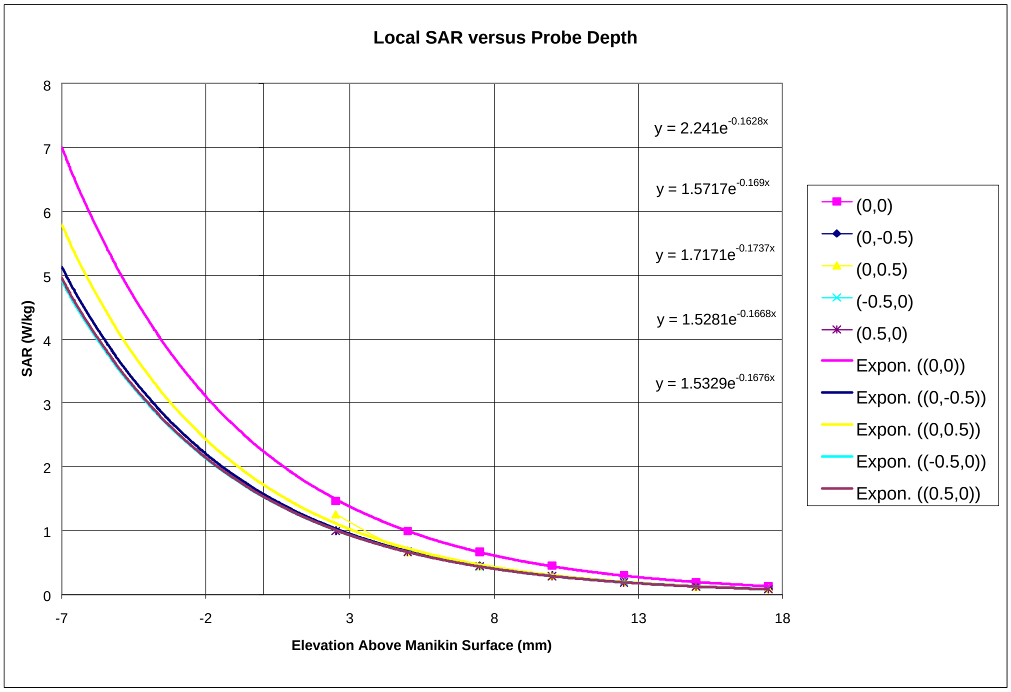
Local SAR versus Probe Depth
y = 2.241e^-0.1628x
y = 1.5717e^-0.169x
y = 1.7171e^-0.1737x
y = 1.5281e^-0.1668x
y = 1.5329e^-0.1676x
SAR (W/kg)
Elevation Above Manikin Surface (mm)
(0,0)
(0,-0.5)
(0,0.5)
(-0.5,0)
(0.5,0)
Expon. ((0,0))
Expon. ((0,-0.5))
Expon. ((0,0.5))
Expon. ((-0.5,0))
Expon. ((0.5,0))

Figure 13

APPENDIX B

Manufacturer's Antenna Specifications

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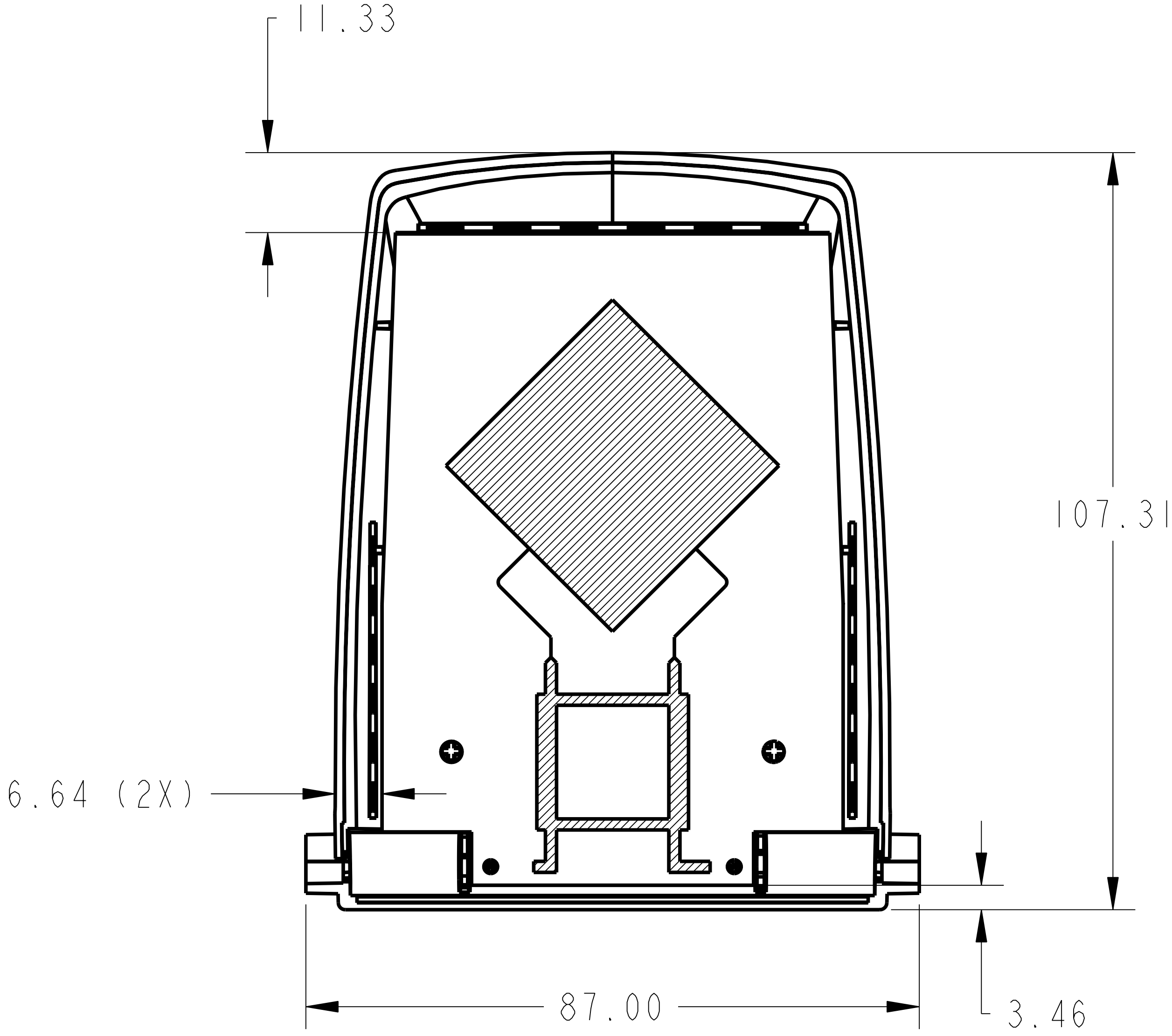
SHAREWAVE, INC
P/N: 200-0115-001
"ASSY, ANTENNA"



ALL DIMENSIONS IN MILLIMETERS

APPENDIX C

Uncertainty Budget

Uncertainties Contributing to the Overall Uncertainty

Type of Uncertainty	Specific to	Uncertainty	
Power variation due to battery condition	phone	0.0%	
Extrapolation due to curve fit of SAR vs depth	phone	9.8%	
Extrapolation due to depth measurement	setup	5.5%	
Conductivity	setup	6.0%	
Density	setup	2.6%	
Tissue enhancement factor	setup	7.0%	
Voltage measurement	setup	3.0%	
Probe sensitivity factor	setup	3.5%	
		15.5%	**RSS**

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APPENDIX D

Simulated Tissue Material Properties

The tissue mixture used was based on that presented SSI/DRB-TP-D01-033, "Tissue Recipe and Calibration Requirements".

Deionized water	45.3%
Sugar	54.3%
Salt	0.0%
HEC	0.3%
Bactericide	0.1%

Mass density, ρ	1.30g/ml. (The density used to determine SAR from the measurements was the recommended 1040 kg/m^{3}, found in Appendix C of Supplement C to OET Bulletin 65, Edition 97-01.)

Dielectric parameters of the 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. The dielectric properties are :

Dielectric constant, ε_r	34.6
Conductivity, σ	2.39 S/m
Tissue conversion factor, γ	11.9

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SIMULATION FLUID #	**981125-MB**
CALIBRATION DATE	**26-Mar-99**
CALIBRATED BY	**Heike**
Frequency Range	**1GHz-2.5GHz**
Frequency Calibrated	**2450 MHz**
Tissue Type	**MIXED BRAIN**

Position [cm]	Amplitude [dBm]	Phase [deg]
0	-37.52	3.6
0.5	-40.71	-86.27
1	-44.19	-174.88
1.5	-47.24	97.57
2	-50.45	6.5
2.5	-53.06	-82.34
3	-56.76	-165.56
3.5	-60.95	96.34
ΔdB_1	-12.93	Δdeg_1
ΔdB_2	-12.35	Δdeg_2
ΔdB_3	-12.57	Δdeg_3
ΔdB_4	-13.71	Δdeg_4
ΔdB_{AVG} [dB]	-12.89	Δdeg_{AVG} [deg]
dB_{AVG} (α_{AVG}) [dB/cm]	-6.45	deg_{AVG} (β_{AVG}) [deg/cm]
(α_{AVG}) [NP/cm]	-0.74200805	(β_{AVG}) [rad/cm]
f [Hz]	2.45E+09	
μ [H/cm]	1.25664E-08	
ε_o [F/cm]	8.854E-14	
ε_r	34.57	
$\sigma_{effective}$ [S/m]	2.39	

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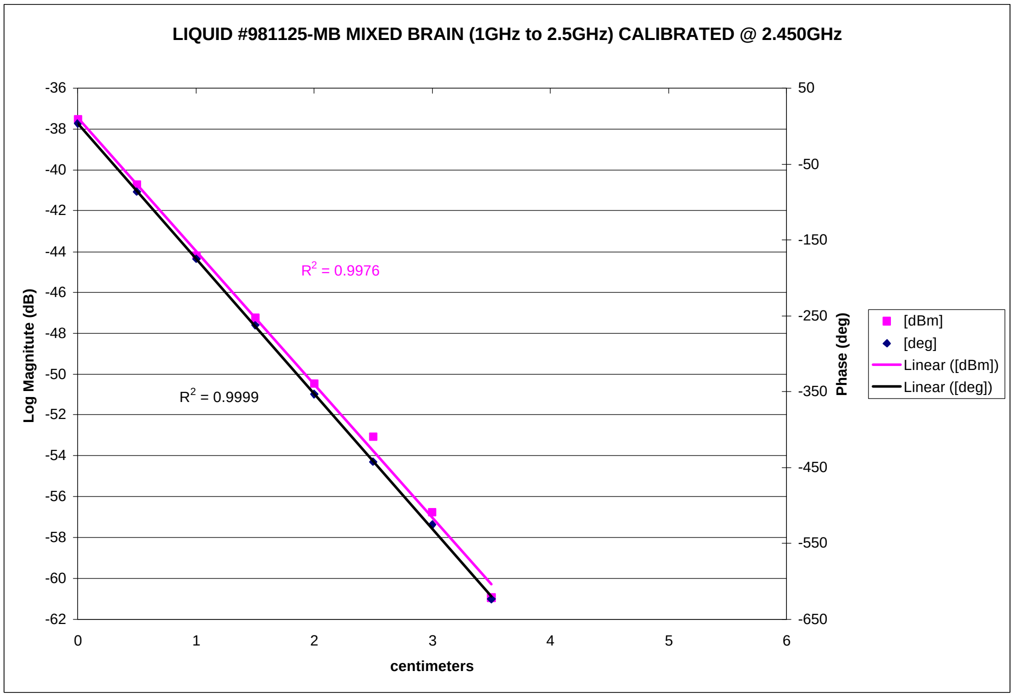

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2450 MHz Data (Paul & Antonio)

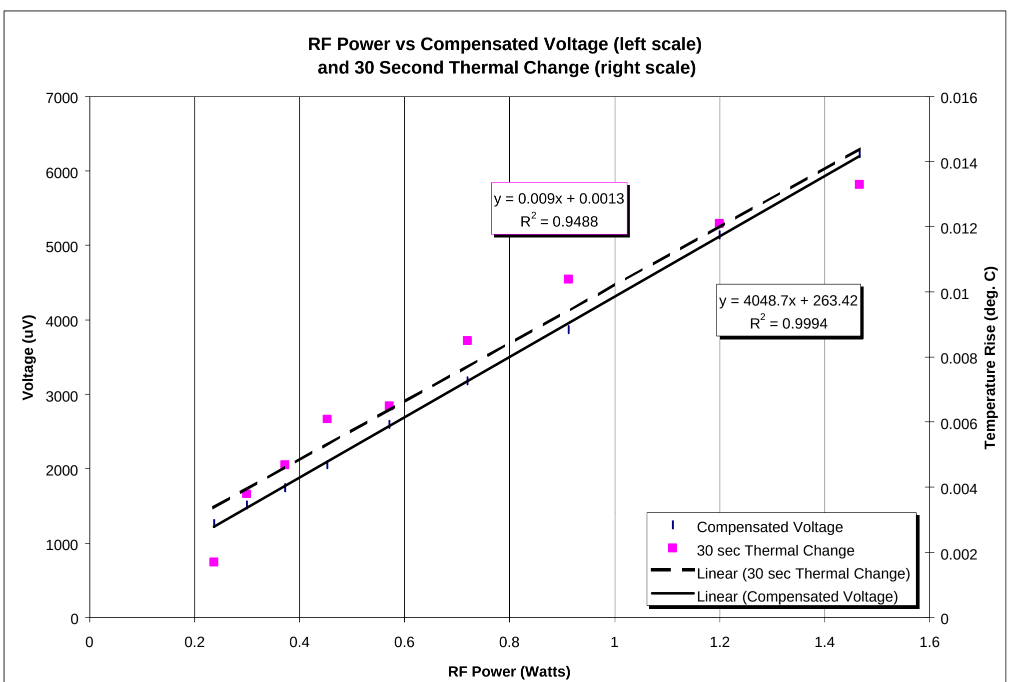
RF Power			Ch0	Ch1	Ch2	delta T (30 sec)	Sum Vi/Ei	Thermal SAR
W	dBm	R&S	uV	uV	uV	deg. C		W/kg
0.236592	23.74	-5.46	200	579	232	0.0017	1260.51	0.16
0.298538	24.75	-4.45	216	690	302.5	0.0038	1509.09	0.35
0.371535	25.7	-3.5	244	802	350.5	0.0047	1744.05	0.43
0.451856	26.55	-2.65	287	947	409	0.0061	2051.66	0.56
0.570164	27.56	-1.64	361	1206	510.5	0.0065	2593.78	0.60
0.719449	28.57	-0.63	444.5	1486.5	615	0.0085	3177.89	0.79
0.912011	29.6	0.4	548	1809	741	0.0104	3866.2	0.96
1.199499	30.79	1.59	722.5	2408.5	986.5	0.0121	5138.76	1.12
1.465548	31.66	2.46	869	2910.5	1213.5	0.0133	6232.82	1.23

Directional Coupler factor 19.2 dB (Asset 100251 cal file data (Janusz, 21 Jul 96))
Additional inline attenuation 10 dB

	Ch0	Ch1	Ch2	
Sensitivity (e)	0.55	0.54	0.51	- Sensor Sensitivity in mV/ (mW/cm^2): 2450 MH
η = 1.50 e	0.825	0.81	0.765	

Density	1.3	g/cm^3	1300	kg/m^3	- Marcin, summer 97	
Conductivity	23.65	mS/cm	2.365	S/m	- Antonio Utano, 10 Jun 98	
Heat Capacity (c)	2.775	J/C/g	2775	J/C/kg	- average of Balzano (2.7) a	
Exposure Time	30	seconds	30	seconds		
Slope of Measure Voltage (m_V)	4048.71	uV/W	0.00405	V/W		
- standard error or m_V	38.9591	uV/W	3.9E-05	V/W		1.0%
Slope of Measure Temp Change (m_T)	0.00897	C/W	0.00897	C/W		
- standard error or m_T	0.00079	C/W	0.00079	C/W		8.8%

Tissue Conversion Factor (γ) 11.9



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APPENDIX E

Validation Scan

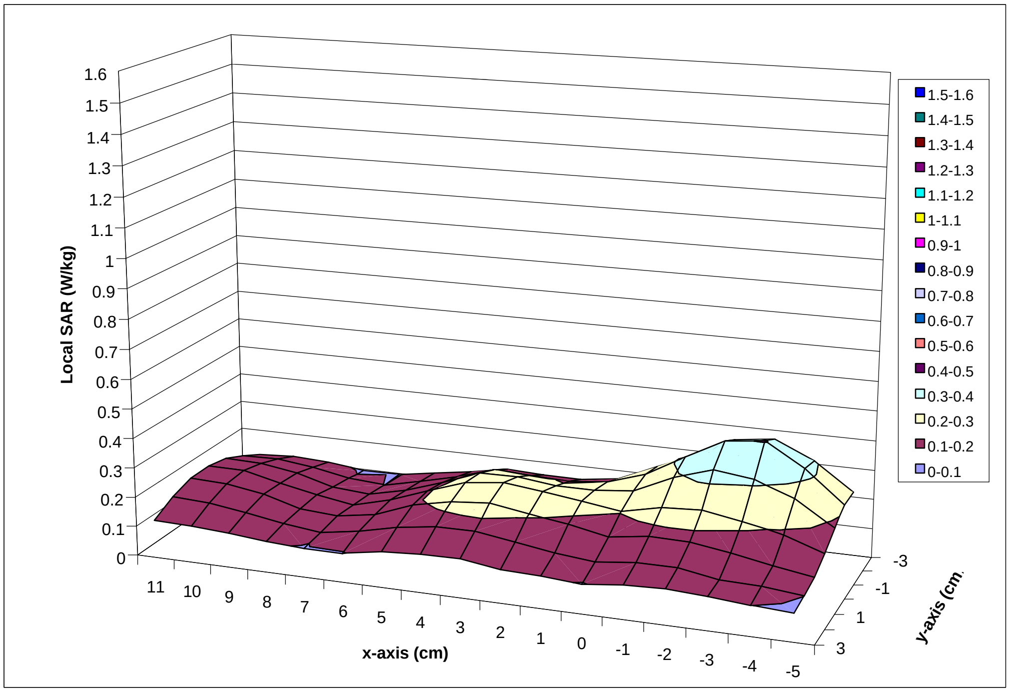

Figure 14

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