Certification Report on

Specific Absorption Rate (SAR)
Experimental Analysis

Research in Motion Ltd.

R800D-2-PW Two-Way Pager

Date: 17 March, 1999

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CERTIFICATION REPORT

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

Product: **Two-Way-Pager, R800D-2-PW**

Client: Research in Motion Limited

Address: 295 Phillip Street
Waterloo, Ontario
Canada, N2L 3W8

Telecommunications Approval Board - Spectrum Sciences Institute
SAR Certified
APREL
A931-R800D2PW

Project #: RIMB-R800D2PW-3153

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

Submitted by Paul G Cardinal Date: 17 Mar 99
Dr. Paul G. Cardinal
Director, Laboratories

Approved by Date: March 17/99
Dr. Jacek J. Wojcik, P. Eng.

PROFESSIONAL ENGINEER
J. J. Wojcik
PROVINCE OF ONTARIO
REGISTERED

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FCC ID: L6AR800D-2-PW
Applicant: Research in Motion Limited
Equipment: Two-Way-Pager
Model: R800D-2-PW
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 Research in Motion two-way-pager, R800D-2-PW. The measurements were carried out in accordance with FCC 96-326. The two-way-pager was evaluated for its maximum power level of 2 W(33 dBm).

The R800D-2-PW was tested at high, middle, and low frequencies, with the maximum SAR coinciding with the peak performance RF output power of channel 2000_h (low, 806 MHz). 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 Research in Motion R800D-2-PW two-way-pager. 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 C95.1-1992, 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

- Research in Motion R800D-2-PW

The two-way-pager is intended to be held in a belt-mounted plastic holster. The device is held in the plastic holster with the keypad and LCD display facing the user's body. The separation of the device from the body provided by the plastic holster and belt clip is 1.1 cm (no clothing allowance is included).

The actual test was conducted with the sample pager simulating the shirt pocket location, i.e. at a distance of 0 mm from the phantom surface. The sample transmitted at 2 Watts in the band of 806 – 821 MHz.

The pager's antenna is a top loaded monopole type antenna with meander type of structure at the top and the bottom. Two antennas are used, one for transmit and the other for receive, with the receiving antenna closer to the LCD and the transmit antenna

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closer to the back of the pager case. The antenna specifications supplied by the manufacturer can be found in Appendix B. A picture of the inside of the device, indicating the antenna, is included.

The device intrinsically restricts the transmit duty factor to less than 9% (32 seconds) in any 6 minute time window.

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
- HP EPM –441A power meter, s/n GB37481303
- APREL UH-1, Universal Head-Arm, s/n 001, Asset # 301376
- 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 two-way-pager 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 (1 cm increments for wide area scanning, 0.5 cm for zoom scanning, and 0.25 cm for depth profile).
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.

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6. The two-way-pager is positioned in such a way that it touches the bottom of the phantom with either its top or its bottom side which simulates having the device in a pocket.

7. All tests were performed with the highest power available from the sample two-way-pager, under transmit conditions.

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

6. TEST RESULTS

6.1. TRANSMITTER CHARACTERISTICS

The battery-powered transmitter will consume energy from its batteries, which may affect its transmission characteristics. In order to gage this effect the output of the transmitter is sampled before and after each SAR run. In the case of the two-way-pager which does not have an externally accessible feedpoint the radiated relative power was measured. A power meter was connected to an antenna adjacent to a fixture to hold the transmitter in a reproducible position. The following table shows the results for the five sets of data used for this report.

<table>
<tr><th colspan="2">Scan</th><th>Δ Relative Power Reading (dB)</th><th colspan="2">Battery #</th></tr>
<tr><th>Type</th><th>Height [mm]</th><th></th><th>3</th><th>4</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Area</td><td>2.5</td><td>0</td><td rowspan="2"></td><td rowspan="2">x</td></tr>
<tr><td>Area</td><td>12.5</td><td>-0.5</td></tr>
<tr><td>Zoom</td><td>2.5</td><td>0</td><td rowspan="3">x</td><td rowspan="3"></td></tr>
<tr><td>Zoom</td><td>7.5</td><td>-</td></tr>
<tr><td>Zoom</td><td>12.5</td><td>-1</td></tr>
</table>

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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 2 and 3. SAR is expressed as RF power per kilogram of mass, averaged in 1 cubic centimetre of tissue.

2) The Research in Motion R800D-2-PW two-way-pager was put into test mode for the SAR measurements using manufacturer supplied keypad commands to control the channel (2000_h) and maximum operating power (nominally 33 dBm) with an 18 % duty factor for zoom and depth profile measurements and either 18 % or 31 % for wide area scan measurements.

3) Appendix A, Figure 4 shows a contour plot of the SAR measurements for the Research in Motion R800D-2-PW two-way-pager sample. The presented values were taken 2.5 mm into the simulated tissue from the Universal Head-Arm's (UH-a) solid inner surface with the bottom of the pager against the phantom and an 18 % duty factor. Figures 2 and 3 show the UH-a used in the measurements with its arm (empty) in position to hold the pager against the simulated body, top and bottom of pager, respectively. A grid is shown inside the UH-a indicating the orientation of the x-y grid used, with the co-ordinates (1,0) at the bottom right corner of the pager's LCD display for the top position. The bottom of the LCD display was aligned with the x-axis at y = 0 cm and the right edge of the LCD display was aligned with the y-axis at x = 1. For the bottom position the screw close to the antenna was aligned on the co-ordinates (8,1). The x-axis is positive towards the left and the y-axis is positive towards the bottom. The antenna inside the two-way-pager is located at the left end of the device (top view), wrapped around the top part of the LCD display and the bottom of the keypad (see specifications and picture in Appendix B).

   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.

   Similar data was obtained 12.5 mm into the simulated muscle tissue. These measurements are presented as a contour plot in Appendix A, Figure 6 and surface plot in Appendix A, Figure 7.

   Figure 8, Appendix A shows an overlay of the pager's outline (bottom side), superimposed onto the contour plot previously shown as Figure 4 in Appendix A.

   Figures 4 through 7 show that there is a dominant peak, in the contour plots, that diminishes in magnitude with depth into the tissue simulation.

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4) Wide area scans were performed for the low (2000_h, 806 MHz), middle ($22D0_h$, 815 MHz) and high ($24B0_h$, 821 MHz) channels with a 31 % duty factor. The peak single point SAR for the scans were:

Channel	Channel # [hexadecimal]	Frequency [MHz]	Pager Keyboard	Highest Peak SAR [W/kg]
Low	2000	806	down	4.31
Middle	22D0	815	down	3.38
High	24B0	821	down	2.18
Low	2000	806	up	0.64
Middle	22D0	815	up	1.23
High	24B0	821	up	0.88

5) The low channel (2000_h) SAR peak was then explored on a refined 0.5 cm grid in three dimensions. Figures 9, 10, and 11 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 1cm^3, was determined from these measurements to be 1.442 W/kg.

6) 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 (-0.068 ± 0.002) / 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 <u>2.739 W/kg</u>.

These measurements were performed with an 18 % duty cycle and a maximum power of 2 W (33dBm). RIM has found that due to the 0.5 dB tolerance in the calibration software tool the pager could have an absolute maximum power of 2.25 W (33.5 dBm). It was determined by proportional scaling of the duty factor and the maximum power of 2.25 W that the device could be operated with a duty cycle of 9 %, producing an estimated SAR of 1.541 W/kg.

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7. CONCLUSIONS

The maximum Specific Absorption Rate (SAR) averaged over 1 g, determined at 806 MHz (low channel, 2000_h), of the Research in Motion Limited R800D-2-PW two-way-pager, is 2.739 W/kg when operating with an 18 % duty cycle. The overall margin of uncertainty for this measurement is ± 18.2 % (Appendix C). Based on these measurements, the device will be marketed with a maximum operating duty cycle of 9%. This would result in a scaled SAR averaged over 1 g of 1.541 W/kg. The SAR limit given in the FCC 96-326 safety guideline is 1.6 W/kg. This unit as tested, and as it will be marketed, is found to be compliant with this requirement.

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8. APPENDIX A

Figure 1

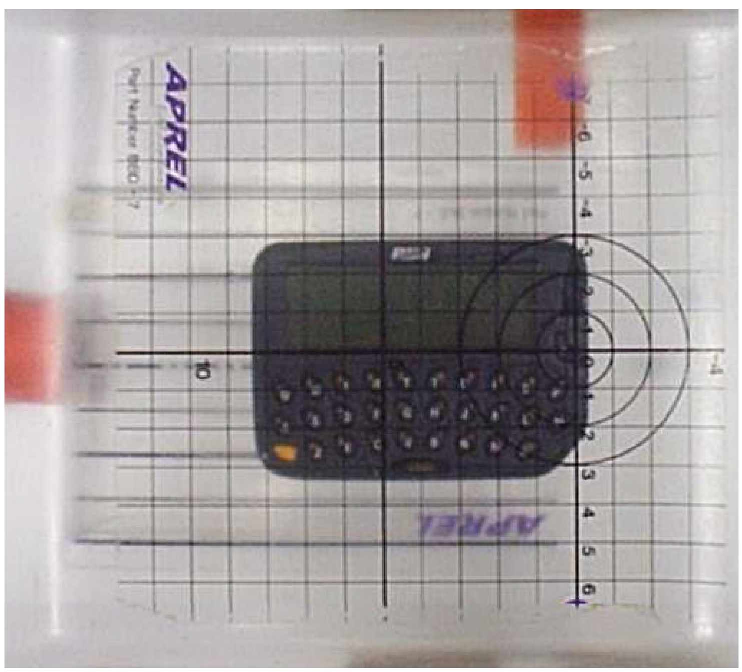

Figure 2

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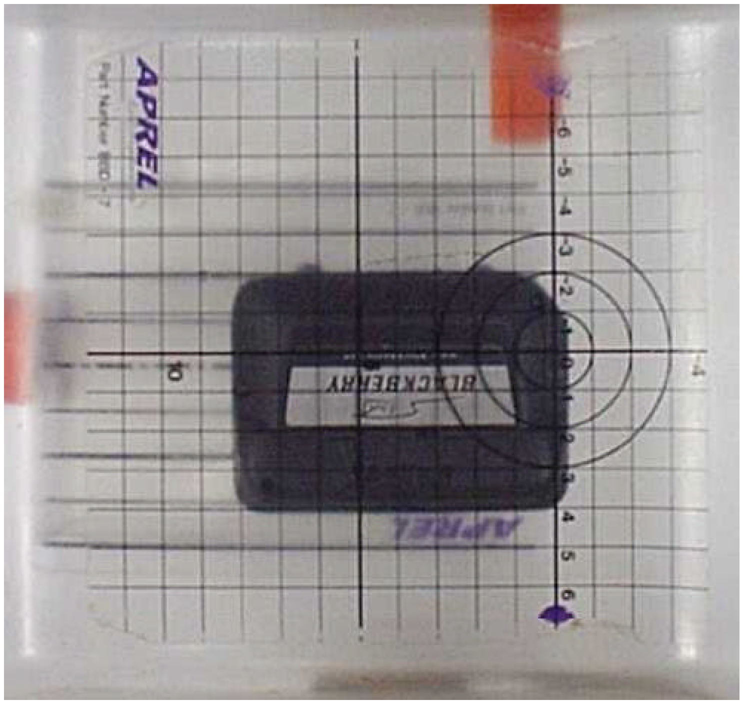

Figure 3

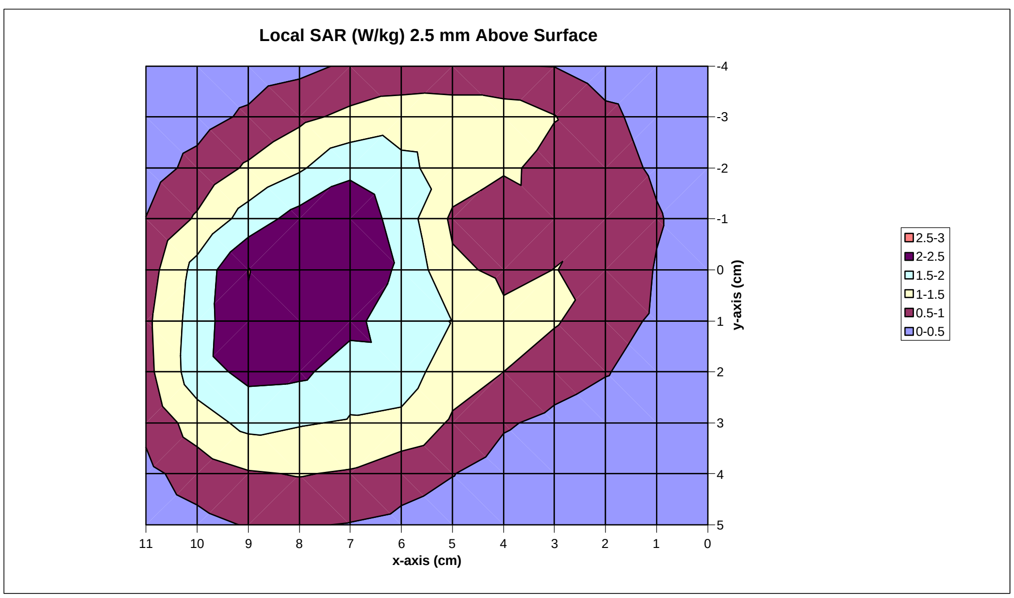

Figure 4

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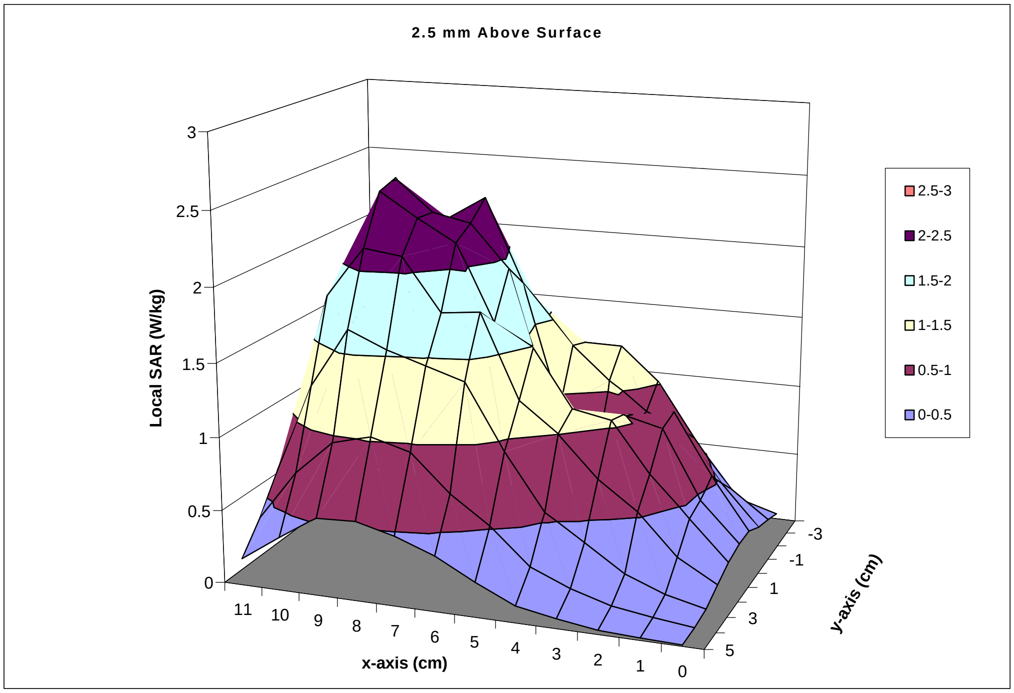

Figure 5

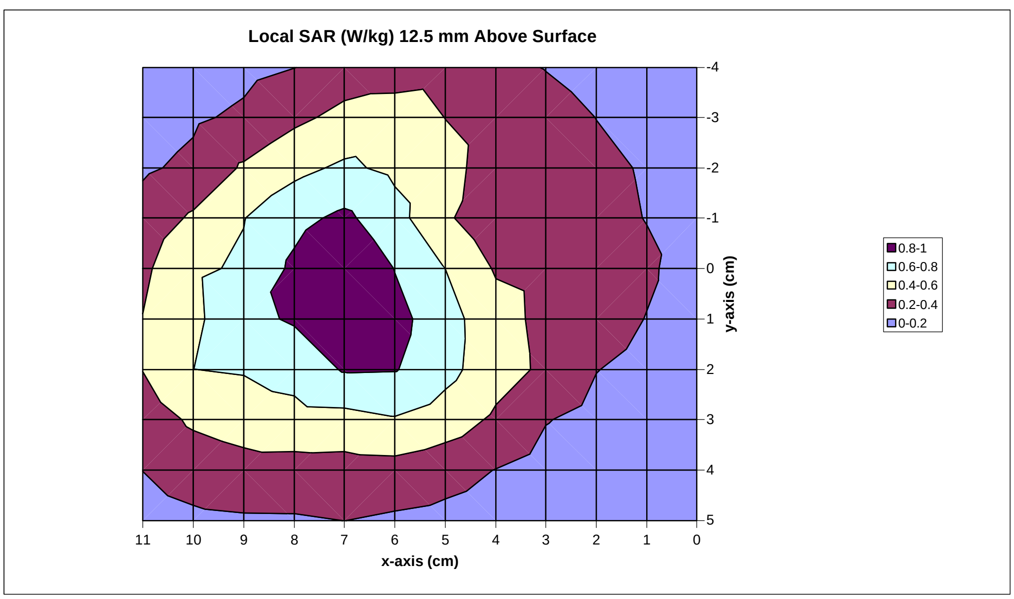

Figure 6

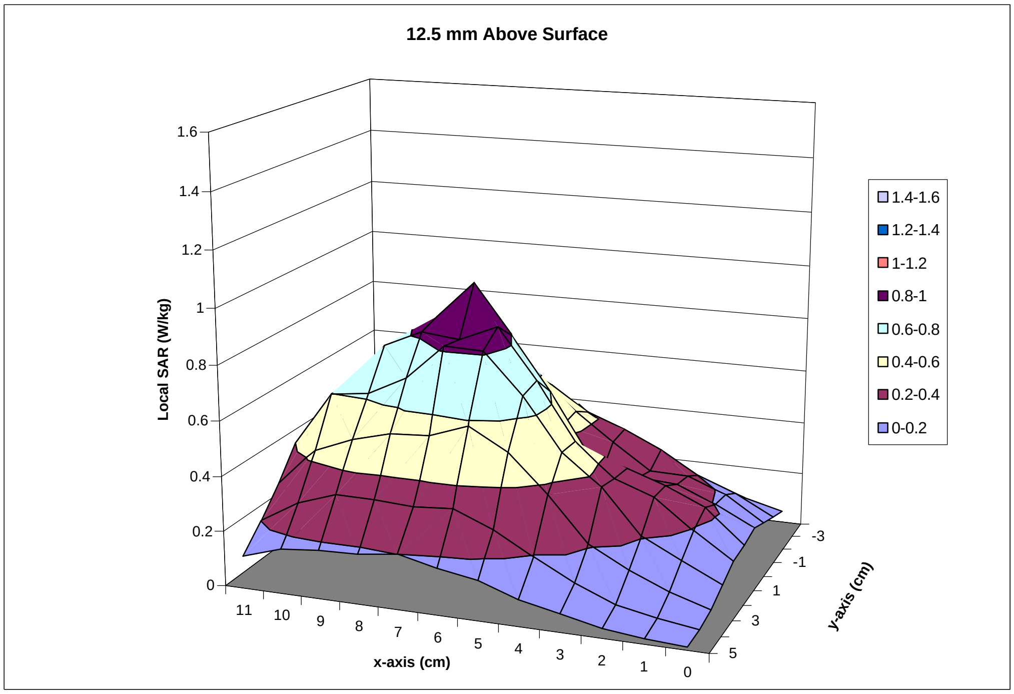

Figure 7

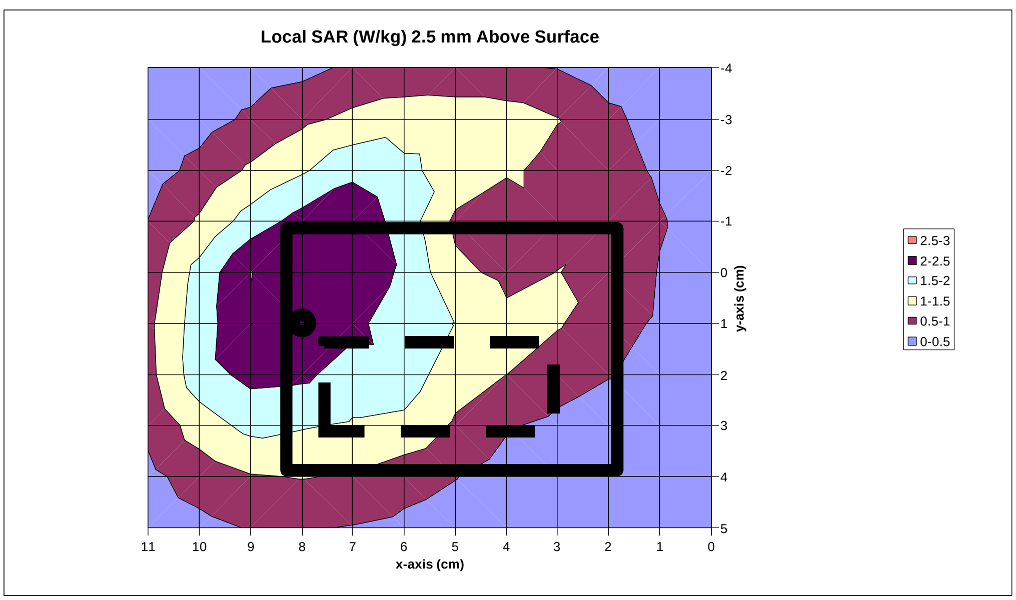

Figure 8

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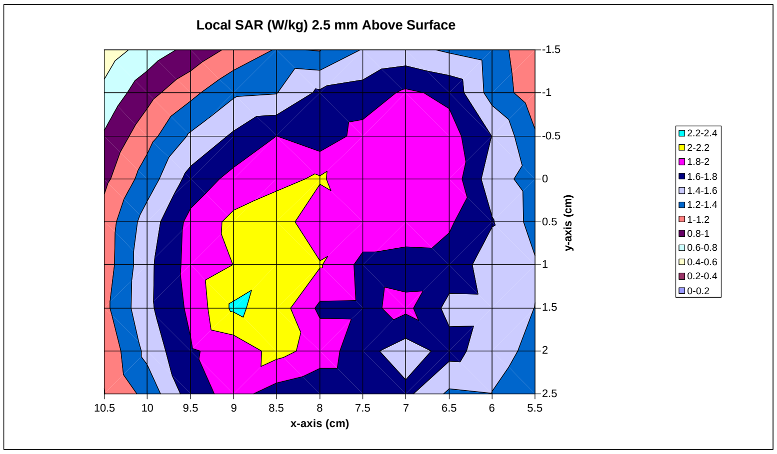

Figure 9

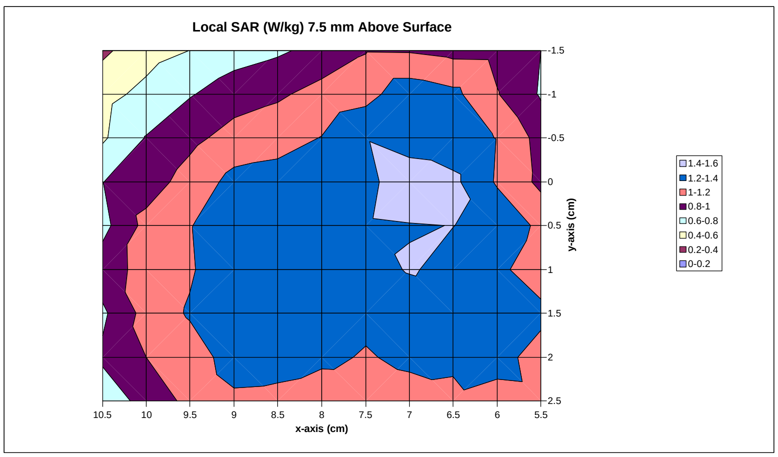

Figure 10

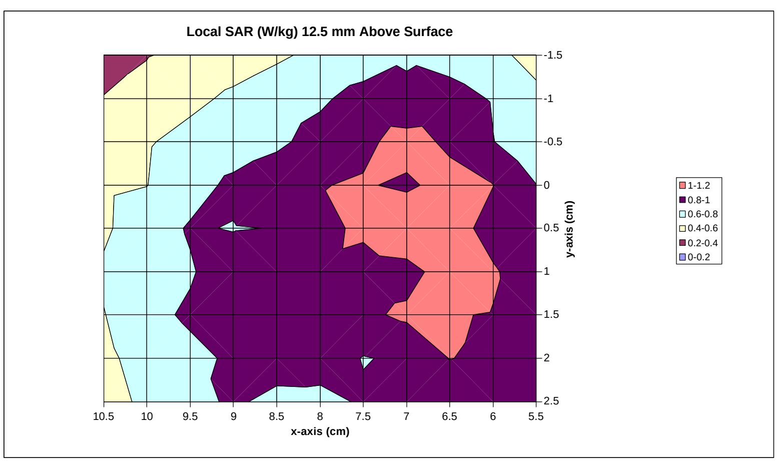

Figure 11

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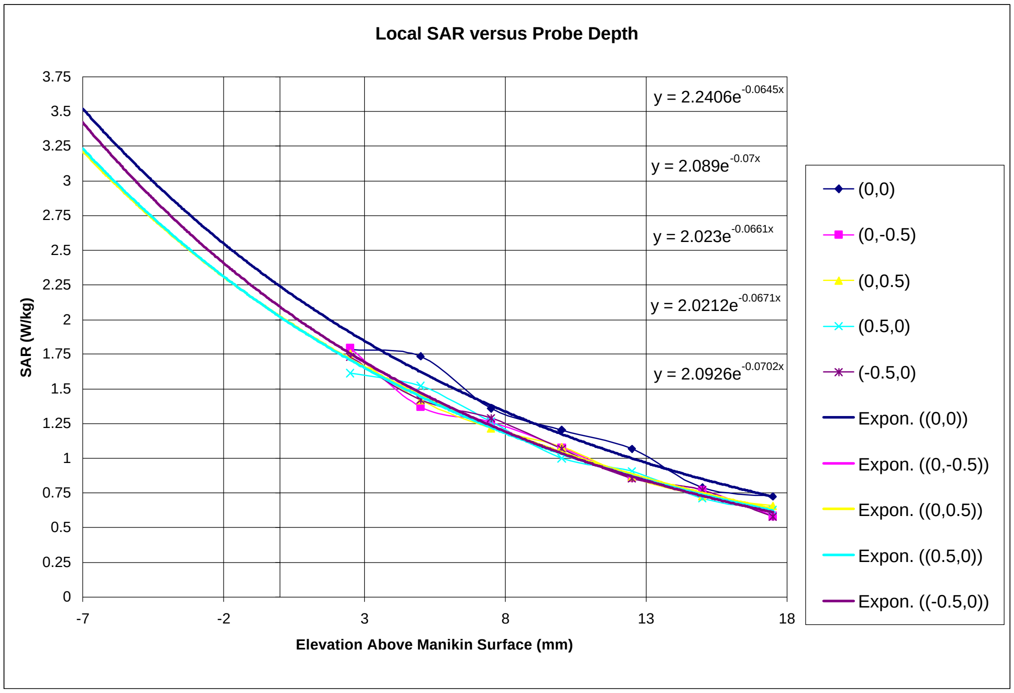

Figure 12

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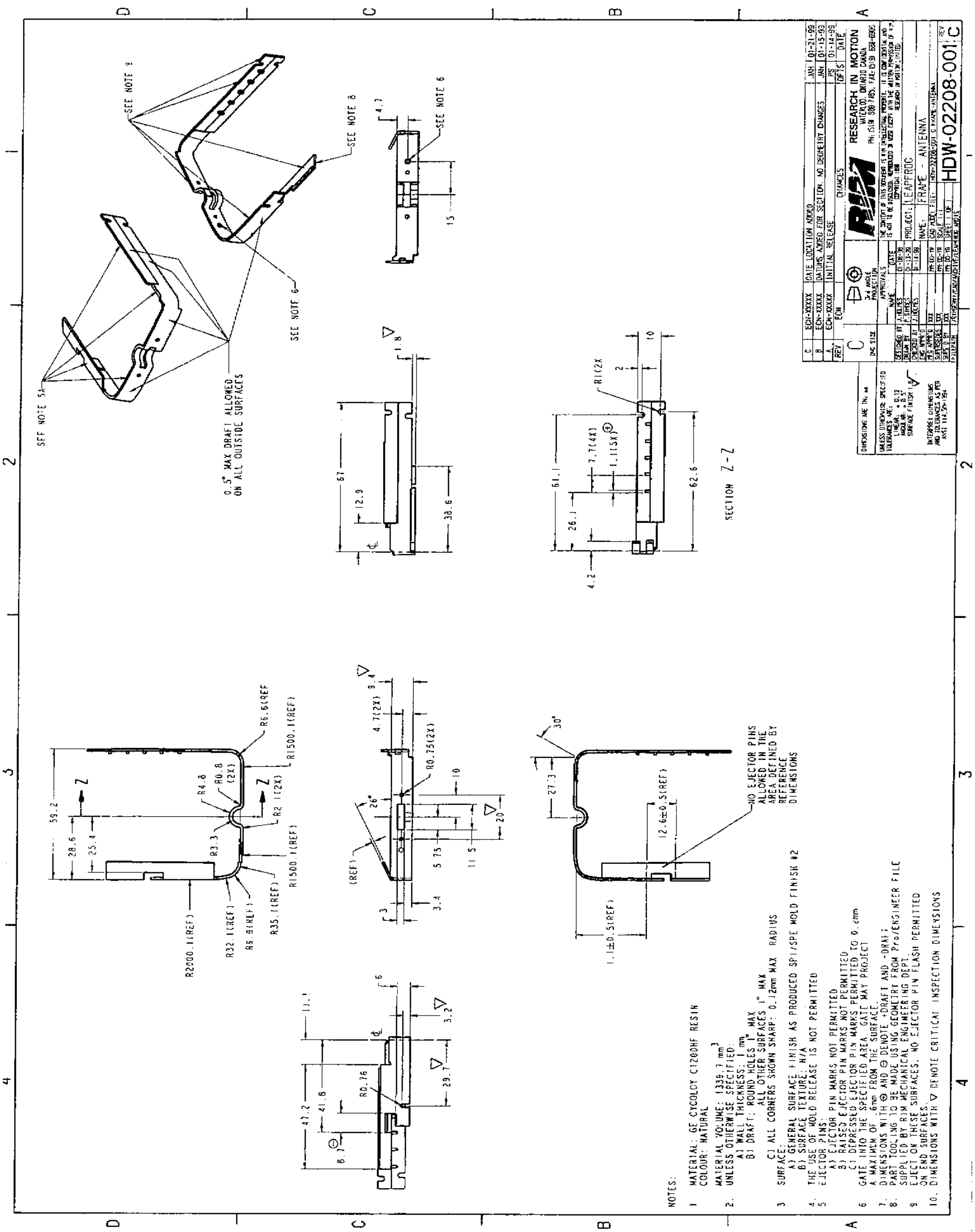
9. APPENDIX B

Manufacturer's Antenna Specifications



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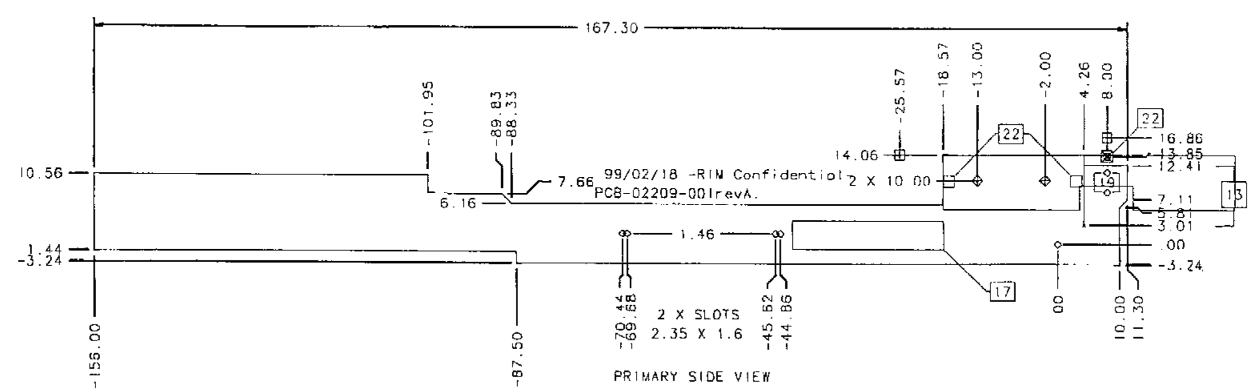

PANEL's DRILL SCHEDULE

DRILL SYMBOL	DRILL SIZE	COUNT	Min/Max	TOOL
×	.5	1	+/-.0762	T1
◇	1.6	7	+/-.0762	T2
⊞	3.175	2	+.0508	T3
⊠	3.176	1	---	T4
⊕	2.38	2	+/-.0508	T5

NOTES:

1. FABRICATE BOARDS IN ACCORDANCE WITH IPC-FC-250, CLASS 2, USING IPC-A-600 (LATEST ISSUE) FOR VISUAL EVALUATIONS AND INTERPRETATIONS.
2. FLEX MATERIAL IS DUPONT FR9120.
3. SMOBC USING DUPONT PC2025 PHOTO-IMAGEABLE COVERLAY APPLIED TO PRIMARY SIDE ONLY IN ACCORDANCE WITH IPC-SM-840B (TYPE A, CLASS 3), AND DUPONT GENERAL PROCESSING GUIDELINES #244238A.
4. COVERLAY MIS-REGISTRATION SHALL NOT EXCEED +/-0.2. HOLES TO BE CLEAR. NO OVERLAP PERMITTED ON SMD RECTANGULAR PADS.
5. COVERLAY THICKNESS MIN 0.05 - MAX 0.1. COVERLAY MAT'L TO BE HIGHLY TRANSPARENT.
6. HASL, SOLDER COATING THICKNESS ON SURFACE PADS AND EXPOSED COPPER SHALL BE 0.008 MIN - 0.05 MAX.
7. MINIMUM DESIGN SPACING IS 0.2, TRACE IS 0.6
8. ALL DIMENSIONS SHOWN ARE FINISHED.
9. PCB REPAIRS OF DAMAGED COPPER OR COVERLAY IS NOT PERMISSIBLE.
10. COVERLAY OPENINGS ARE 1:1 WITH COPPER PADS IN CAD FILES. OPENINGS MUST BE ENLARGED <0.23 TO SUIT PROCESS.
11. ADHESIVE 3M 950 APPLIED TO PRIMARY COPPER/COVERLAY SIDE BEFORE DIECUTTING.
12. COVERLAY TEXT APPEARS MIRRORED FOR VIEWING THRU KAPTON.
13. DO NOT APPLY ADHESIVE ON CONNECTOR TAB ABOVE BOTTOM OF SLOT OR SOLDER PADS.
14. DRILL SIZE TOLERANCE IS +/-0.0762
15. OVERALL THICKNESS TO BE 0.26 +/-10%
16. HOLES AND SLOTS TO BE CLEAR OF ADHESIVE.
17. VENDOR IDENTIFICATION AND DATE CODE TO BE INSERTED IN COVERLAY WHERE SHOWN.
18. ASSEMBLY TO CONFORM TO J-STD-001B CLASS 2 USING IPC-A-610 (LATEST ISSUE) FOR VISUAL EVALUATIONS AND INTERPRETATIONS.
19. PICK AND PLACE LOCATION OF RIM PART NUMBER CON-06S33-002 IS X 8.0, Y 9.76.
20. FINISHED COPPER LINE WIDTH TOLERANCE IS +/-0.0254.
21. NO X-OUTS ALLOWED IN PANEL.
22. SOLDER PADS AND FIDUCIAL AREAS TO BE CLEAR OF ADHESIVE.

REVISIONS

REV	ECN	DESCRIPTION	DFTS	DATE
A1	-	ADDED 2 X 2.38 HOLES	GCF	99.03.05
A	-	PROTO-TYPE RELEASE	GCF	99.02.16

DIMENSIONS ARE IN MM. UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:
DECIMALS .X +/-0.3
.XX +/-0.2

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APPROVALS		DATE
DRAWN	GCF	99.02.16
R&D CHECK		
MFG CHECK		
RELEASED		

TITLE PRINTED WIRING FLEX
IP850 ANTENNA (1of2)

RIM CONFIDENTIAL — REV A1
SIZE A — DWG NO. PCB-02209-001
SCALE 1:1 — SHEET 1 OF 1
MENTOR CADFILE

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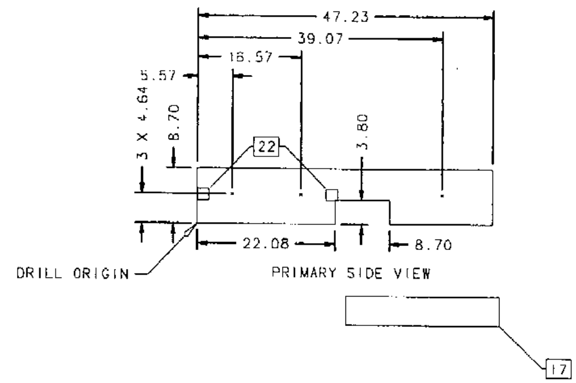

PANEL's DRILL SCHEDULE

DRILL SYMBOL	DRILL SIZE	COUNT	Min/Max	TOOL
x	2.38	3	+/-.0508	T1

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5. COVERLAY THICKNESS MIN 0.05 - MAX 0.1 . COVERLAY MAT'L TO BE HIGHLY TRANSPARENT.
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18. ASSEMBLY TO CONFORM TO J-STD-001B CLASS 2 USING IPC-A- 610 (LATEST ISSUE). FOR VISUAL EVALUATIONS AND INTERPRETATIONS.
20. FINISHED COPPER LINE WIDTH TOLERANCE IS +/-0.0254 .
21. NO X-OUTS ALLOWED IN PANEL
22. SOLDER PADS AND FIDUCIAL AREAS TO BE CLEAR OF ADHESIVE ON BOTH SIDES.

REVISIONS

REV	ECN	DESCRIPTION	DFTS	DATE
A1	-	3 X 2.38 HOLES ADDED	GCF	99.03.05
A	-	PROTO-TYPE RELEASE	GCF	99.02.18

DIMENSIONS ARE IN MM. UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:
DECIMALS .X +/-0.3
.XX +/-0.2

APPROVALS		DATE
DRAWN	GCF	99.02.18
R&D CHECK		
MFG CHECK		
RELEASED		

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TITLE PRINTED WIRING FLEX
IP850 ANTENNA (2of2)

RIM CONFIDENTIAL | REV A1
SIZE A | DWG.NO. PCB-02209-002
SCALE 1 : 1 | SHEET 1 OF 1
1 MENTOR CADFILE

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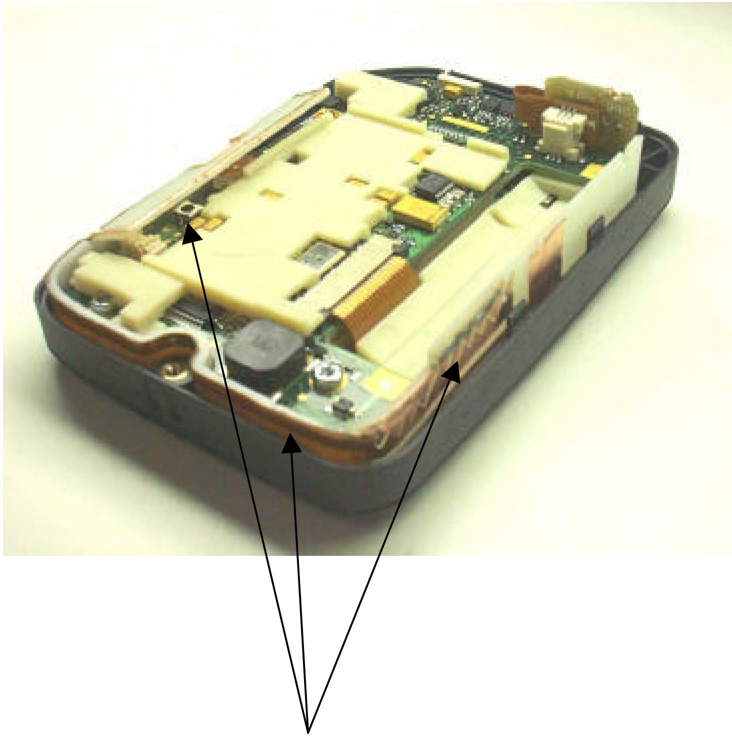

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10. APPENDIX C

Uncertainties Contributing to the Overall Uncertainty

Type of Uncertainty	Specific to	Uncertainty	
Power variation due to battery condition	pager	12.2%	
Extrapolation due to curve fit of SAR vs depth	pager	5.9%	
Extrapolation due to depth measurement	setup	2.7%	
Conductivity	setup	6.0%	
Density	setup	2.6%	
Tissue enhancement factor	setup	7.0%	
Voltage measurement	setup	1.1%	
Probe sensitivity factor	setup	3.5%	
		18.2%	**RSS**

Note that the overall uncertainty is determined using the root sum square method (RSS).

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11. APPENDIX D

Simulated Muscle Material and Calibration Technique

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

De-ionised water	52.8 %
Sugar	45.3 %
Salt	1.5 %
HEC	0.3 %
Bactericide	0.1 %

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

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

The dielectric properties are:

Dielectric constant, ε_r	54.8
Conductivity, σ	1.10 S/m
Tissue Conversion Factor, γ	5.4

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SIMULATION FLUID #	**981126-M**
CALIBRATION DATE	**01-Mar-99**
CALIBRATED BY	**Heike**
Frequency Range	**100MHz-1GHz**
Frequency Calibrated	**808MHz**
Tissue Type	**Muscle**

Position [cm]	**Amplitude [dBm]**	**Phase [deg]**	**[deg]**
0	-32.44	44.49	44.49
0.5	-33.61	7.37	7.37
1	-34.76	-28.68	-28.68
1.5	-35.99	-65.21	-65.21
2	-37.25	-101.14	-101.14
2.5	-38.54	-138.46	-138.46
3	-39.7	-175.7	-175.7
3.5	-40.83	147.85	-212.15
4	-42.05	111.8	-248.2
4.5	-43.38	75.12	-284.88
5	-44.68	36.59	-323.41
5.5	-45.5	-1.39	-361.39
6	-46.2	-35.68	-395.68

ΔdB_1	-7.26	Δdeg_1	-220.19
ΔdB_2	-7.22	Δdeg_2	-219.52
ΔdB_3	-7.29	Δdeg_3	-219.52
ΔdB_4	-7.39	Δdeg_4	-219.67
ΔdB_5	-7.43	Δdeg_5	-222.27
ΔdB_6	-6.96	Δdeg_6	-222.93
ΔdB_7	-6.5	Δdeg_7	-219.98
ΔdB_{AVG} [dB]	-7.15	$Ddeg_{AVG}$ [deg]	-220.5828571
dB_{AVG} (α_{AVG}) [dB/cm]	-2.38	deg_{AVG} (β_{AVG}) [deg/cm]	-73.52761905
(α_{AVG}) [NP/cm]	-0.27439139	(β_{AVG}) [rad/cm]	-1.283299044

f [Hz]	8.08E+08
μ [H/cm]	1.25664E-08
ε_o [F/cm]	8.854E-14

ε_r	**54.8**	
$\sigma_{effective}$	**1.10**	**S/m**

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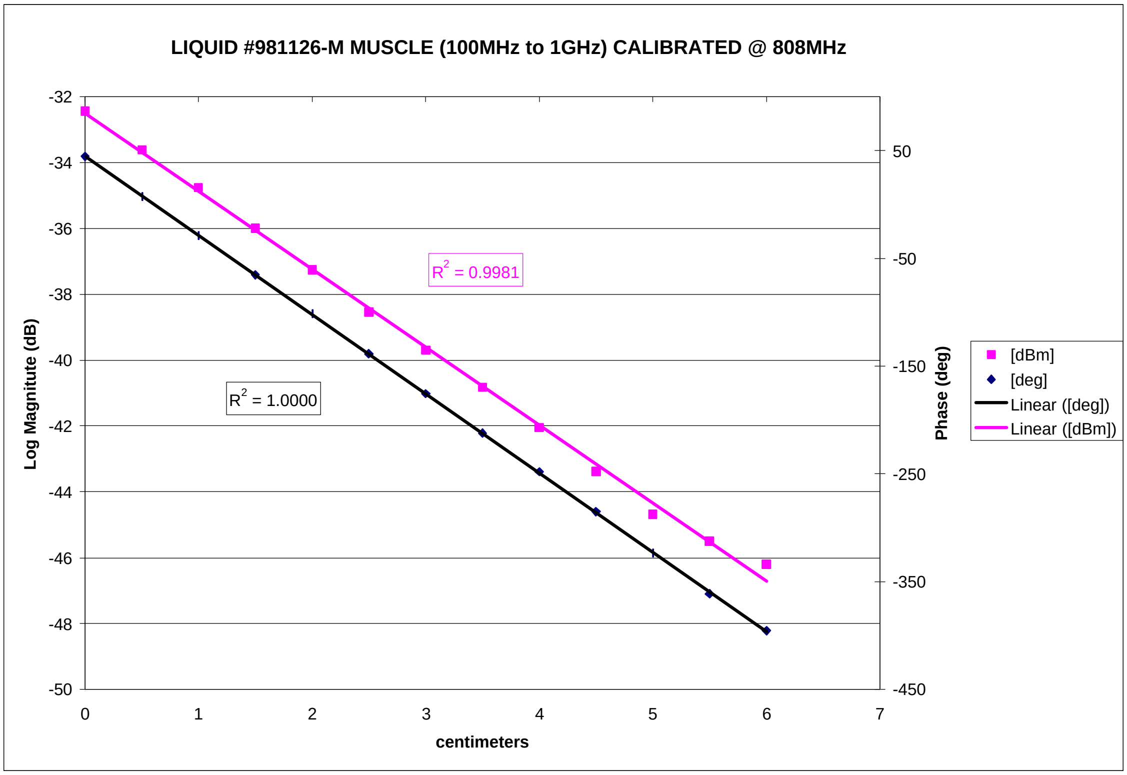

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808 MHz Data (Heike & Sherry) MUSCLE

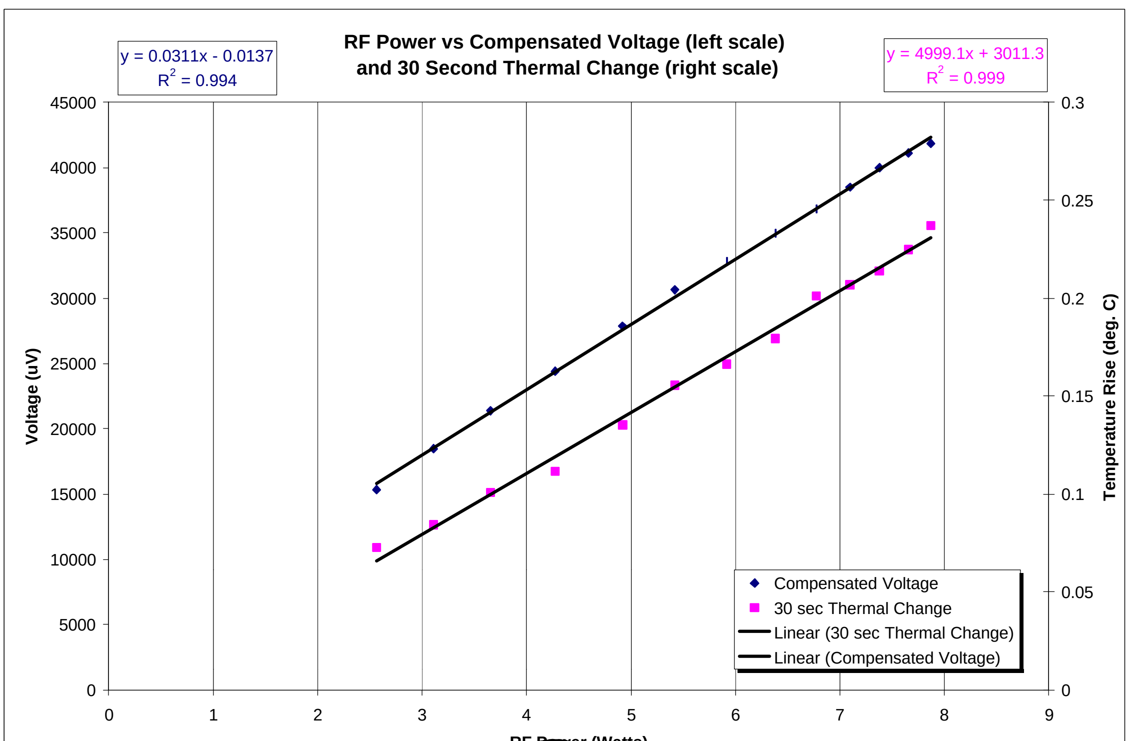
						delta T	Sum		Thermal
RF Power			Ch0	Ch1	Ch2	(30 sec)	Vi/Ei		SAR
W	dBm	R&S	uV	uV	uV	deg. C			W/kg
2.564484	34.09	-12.02	11719	3467	2344	0.0728	15321.9		6.73
3.111716	34.93	-11.18	14087	4199	2856	0.0843	18477.9		7.80
3.655948	35.63	-10.48	16260	4858	3369	0.1008	21398.9		9.32
4.275629	36.31	-9.8	18457	5591	3882	0.1116	24406.4		10.32
4.920395	36.92	-9.19	20996	6445	4443	0.1352	27861.4		12.51
5.420009	37.34	-8.77	23022	7153	4907	0.1555	30655.6		14.38
5.915616	37.72	-8.39	24561	7715	5273	0.1664	32810.8		15.39
6.382635	38.05	-8.06	26099	8252	5688	0.1795	34984		16.60
6.776415	38.31	-7.8	27417	8691	6055	0.2013	36837.2		18.62
7.095778	38.51	-7.6	28589	9131	6323	0.2069	38480.1		19.14
7.379042	38.68	-7.43	29639	9570	6567	0.2138	39994.9		19.78
7.655966	38.84	-7.27	30420	9839	6812	0.2249	41123.9		20.80
7.870458	38.96	-7.15	30933	10034	6934	0.237	41849.1		21.92

Directional Coupler factor 26.11 dB (Asset 100251 cal file data (Janusz, 21 Jul 96))
Additional inline attenuation 20 dB

Sensitivity (e) 0.759 0.754 0.796 - Sensor Sensitivity in mV/ (mW/cm^2): 835 MHz cal (AU + HW, 1 Sep 98)
η = 1.50 e 1.1385 1.131 1.194

Density	1.3	g/cm^3	1300	kg/m^3	- Marcin, summer 97
Conductivity	11	mS/cm	1.1	S/m	- Heike 1-Mar-99
Heat Capacity (c)	2.775	J/C/g	2775	J/C/kg	- average of Balzano (2.7) and Kuster (2.85) values
Exposure Time	30	seconds	30	seconds	
Slope of Measure Voltage (m_V)	4999.11	uV/W	0.005	V/W	
- standard error or m_V	628.416	uV/W	6.3E-05	V/W	1.3%
Slope of Measure Temp Change (m_T)	0.03004	C/W	0.03004	C/W	
- standard error or m_T	0.00114	C/W	0.00114	C/W	3.8%

Tissue Conversion Factor (γ) 5.4



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12. APPENDIX E

Validation Scan

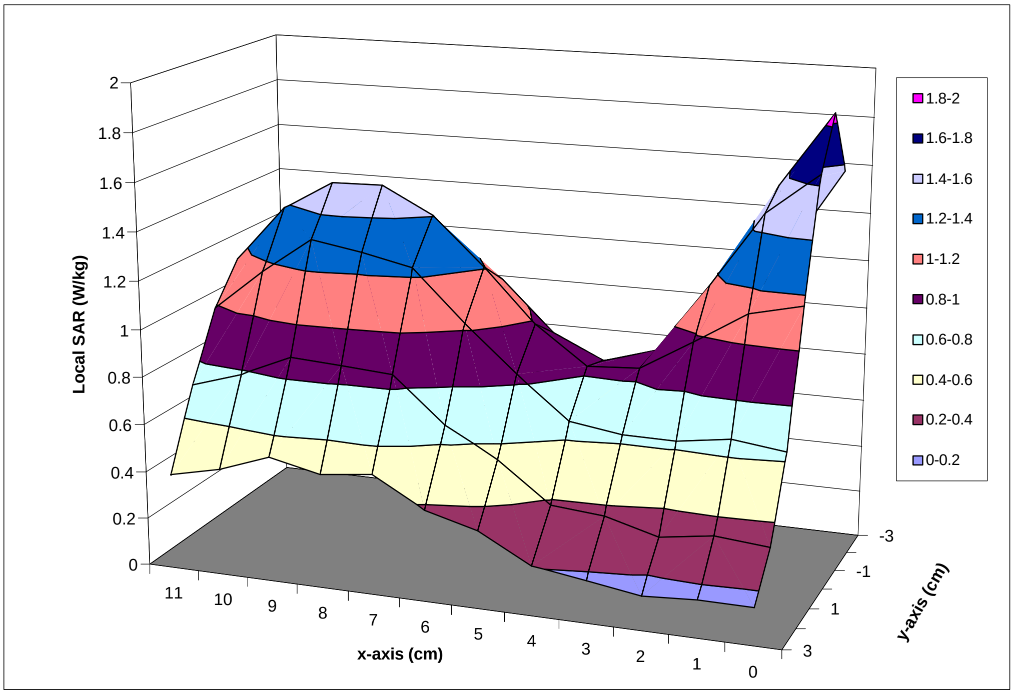

Figure 13

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