APREL Laboratories

Certification Report on

Specific Absorption Rate (SAR)
Experimental Analysis

Novatel Wireless Technologies Ltd.

Minstrel III

(for Body Exposure)

Date: 3 September, 1999

Telecommunications Approval Board - Spectrum Sciences Institute -
SAR Certified
APREL Laboratories
A994-Minstrel III

51 Spectrum Way Nepean ON K2R 1E6
Tel: (613) 820-2730 Fax: (613) 820-4161
email: info@aprel.com

CERTIFICATION REPORT

Subject:	**Specific Absorption Rate (SAR) Experimental Analysis for Body Exposure**
Product:	Wireless CDPD Modem
Model:	Minstrel III
Client:	Novatel Wireless Technologies Ltd.
Address:	Suite 200 6715 – 8th Street N. E. Calgary, Alberta Canada, T2E 7H7
Project #:	NVWB-MINSTRELIII-3282M
Prepared by:	APREL Laboratories 51 Spectrum Way Nepean, Ontario K2R 1E6

Telecommunications Approval Board - Spectrum Sciences Institute - SAR Certified APREL Laboratories A994-Minstrel III

Tested by ______________________ Date: 13 Oct 99
Heike Wünschmann, C.E.T.

Submitted by ______________________ Date: 25 Oct 99
Dr. Paul G. Cardinal
Director, Laboratories

Approved by ______________________ Date: Oct 25/99
Dr. Jacek J. Wojcik, P. Eng.

Registered Professional Engineer J. J. Wojcik Province of Ontario

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
E-mail: info@aprel.com

CERTIFICATION REPORT

Subject: **Specific Absorption Rate (SAR) Experimental Analysis for Body Exposure**

Product: Wireless CDPD Modem

Model: Minstrel III

Client: Novatel Wireless Technologies Ltd.

Address: Suite 200
6715 – 8th Street N. E.
Calgary, Alberta
Canada, T2E 7H7

Project #: NVWB-MINSTRELIII-3282M

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

Tested by ______________________________ Date: _________________
Heike Wünschmann, C.E.T.

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

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

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

FCC ID: NBZNRM-6832
Applicant: Novatel Wireless Technologies Ltd.
Equipment: Wireless CDPD Modem
Model: Minstrel III
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 Novatel Wireless Minstrel III wireless CDPD modem for body exposure (see Report NVWB – MINSTREL III – 3282 H for hand exposure). The measurements were carried out in accordance with FCC 96-326. The Minstrel III was evaluated for its maximum power level of 478 mW (26.8 dBm).

The Minstrel III was tested at high, middle, and low frequencies with the antenna extended and retracted as well as the top and the bottom sides. The maximum SAR coinciding with the peak performance RF output power of channel 799 (high, 849 MHz) for the bottom side with the antenna out. Test data and graphs are presented in this report.

This unit as tested, and as it will be marketed and used (with a warning in the manual to keep at least 18 mm distance from the antenna), is found to be compliant with the FCC 96-326 requirement, for an uncontrolled RF exposure environment.

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

TABLE OF CONTENTS

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

1. INTRODUCTION

Tests were conducted to determine the Specific Absorption Rate (SAR) of a sample of a Novatel Wireless Minstrel III wireless CDPD modem. 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

- Novatel Wireless Minstrel III wireless CDPD modem, pre-production sample, s/n 00.60.D6.03.02.3C
- 3-Com Palm Pilot III, s/n 10.80.12.H8.79.DY

The antenna is a ¼ λ helical antenna when retracted and becomes the equivalent to a ½ λ dipole antenna when extracted. See Appendix B for manufacturer supplied antenna information.
The device under test (DUT) consists of a Palm Pilot III installed into the Minstrel III cradle.

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

4. TEST EQUIPMENT

- APREL Triangular Dosimetric Probe Model E-009, s/n 115, Asset # 301420
- CRS Robotics A255 articulated robot arm, s/n RA2750, Asset # 301335
- CRS Robotics C500 robotic system controller, s/n RC584, Asset # 301334
- R&S NRVS power meter, s/n 864268/017, Asset # 100851
- R&S NRV-Z7 power sensor, s/n 862 509/006, Asset # 100852
- APREL F-1, 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 Minstrel III wireless CDPD modem 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 from one point to the next using the robot (10 mm increments for wide area scanning, 5 mm increments for zoom scanning, and 2.5 mm increments for the final depth profile measurement).
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 DUT is positioned in such a way that it touches the bottom of the phantom with either its top or its bottom side.

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

7. All tests were performed with the highest power available from the sample Minstrel III wireless CDPD modem, 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 Minstrel III wireless CDPD modem which does not have an externally accessible feedpoint the radiated power was sampled. 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 conducted RF power sampled before and after each of the six sets of data used for the worst case SAR in this report.

Scan		**Relative Power Reading (dBm)**		**D**	**Battery #**
Type	Height (mm)	Before	After		
Area	2.5	-24.6	-24.5	+0.1	4
Area	12.5	-23.7	-24.5	-0.8	3
Zoom	2.5	-23.7	-24.0	-0.3	2
Zoom	7.5	-24.0	-23.9	+0.1	1
Zoom	12.5	-23.7	-24.3	-0.6	3
Depth	2.5 – 17.5	-23.6	-24.1	-0.5	2

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

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. SAR is expressed as RF power per kilogram of mass, averaged in 1 gram of tissue.

2) The Novatel Wireless Minstrel III wireless CDPD modem was put into test mode for the SAR measurements using manufacturer supplied touch screen commands entered on the Palm Pilot III to control the channel (initially 799) and maximum operating power (nominally 26.8 dBm).

3) Figure 3 in Appendix A shows a contour plot of the SAR measurements for the Novatel Wireless Minstrel III wireless CDPD modem sample. The presented values were taken 2.5 mm into the simulated tissue from the flat phantom's solid inner surface with a 20.5 mm separation between the DUT and the bottom of the phantom. Figures 1 and 2 in Appendix A show the flat phantom used in the measurements, with the DUT sample against or near the simulated bystander body (the most likely body part to be in the vicinity of the transmitting antenna). A grid is shown inside of the phantom indicating the orientation of the x-y grid used, with the co-ordinates 0,0 at the top left corner. The x-axis is positive towards the bottom and the y-axis is positive towards the right.

   A different presentation of the same data is shown in Appendix A Figure 4. 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 tissue. These measurements are presented as a contour plot in Appendix A Figure 5 and surface plot in Figure 6.

   Figure 10 in Appendix A shows an overlay of the pager's outlines, superimposed onto the contour plot previously shown as Figure 3.

   Figures 3 through 6 in Appendix A show that there is a dominant peak, in the contour plots, that diminishes in magnitude with depth into the tissue simulation.

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

4) Wide area scans were performed for the low (991), middle (383) and high (799) channels with the DUT in contact (0 mm separation) with the phantom. The peak single point SAR for the scans were:

Channel	Antenna Position	Channel #	LCD position	Frequency (MHz)	Peak Single Point SAR (W/kg)
Low	in	991	down	824.04	6.67
Middle	in	383	down	836.49	6.17
High	in	799	down	848.97	6.16
Low	out	991	down	824.04	6.98
Middle	out	383	down	836.49	7.59
High	out	799	down	848.97	7.80
Low	in	991	up	824.04	0.96
Middle	in	383	up	836.49	0.95
High	in	799	up	848.97	1.14
Low	out	991	up	824.04	2.03
Middle	out	383	up	836.49	2.27
High	out	799	up	848.97	1.95

All subsequent testing was performed on the high channel (799, 849 MHz) with the antenna out and the LCD down.

5) Wide area scans were also performed for the high (799, 849 MHz) channel versus separation. The peak single point SAR for the scans were:

Channel			Palm Top's surface to phantom's outer surface separation	Highest local SAR
	#	MHz	mm	W/kg
Low	799	849	0.0	7.80
			14.5	2.14
			20.5	1.28
			23.5	0.98

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

Considering the anticipated scaling to the inner surface of the phantom, subsequent testing was performed with a DUT surface to phantom bottom separation of 20.5 mm.

Figure 11 in Appendix A shows the data plotted as a function of separation and the exponential curves fit to them.

6) The high channel (799) SAR peak was then explored on a refined 5 mm grid in three dimensions. Figures 7, 8, and 9 show the measurements made at 2.5, 7.5, and 12.5 mm respectively. The SAR value averaged over 1 gram was determined from these measurements by averaging the 27 points (3x3x3) comprising a 1 cm x 1 cm x 1 cm cube. The maximum SAR value measured averaged over 1 gram was determined from these measurements to be 0.87 W/kg.

7) To extrapolate the maximum SAR value averaged over 1 gram to the inner surface of the head phantom a series of measurements were made at a few (x,y) coordinates within the refined grid as a function of depth, with 2.5 mm spacing. Figure 12 in Appendix A shows the data gathered and the exponential curves fit to them. The average exponential coefficient was determined to be (-0.056 ± 0.006) / 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 APREL Triangular Dosimetric Probe Model E-009 is 2.3 mm. The total extrapolation distance is 4.8 mm, the sum of these two.

   Applying the exponential coefficient over the 4.8 mm to the maximum SAR value average over 1 gram that was determined previously, we obtain **the maximum SAR value at the surface averaged over 1g** of 1.13 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 20.5 mm (previous section) to be extrapolated/interpolated for other separations.

If the data for Figure 11 is fitted to an exponential equation we get:

$$\text{Peak Local SAR} = 7.7731\ e^{-0.0882\ \text{separation}}$$

© APREL Project #: NVWB-MINSTRELIII-3282M
51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

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

$$\text{Peak 1g SAR} = k\, e^{-0.0882\ \text{separation}}$$

Using this equation with the previous section's data:

Peak 1g SAR = 1.13 W/kg
separation =20.5 mm

results in a k = 6.90 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 17.3mm.

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

8. CONCLUSIONS

The Novatel Wireless Minstrel III wireless CDPD modem will not expose the user to a maximum Specific Absorption Rate (SAR) exceeding the FCC 96-326 SAR safety guideline limit of 1.6W/kg. However, a person in the near proximity of the transmitting antenna may be exposed to such levels.

The maximum SAR averaged over 1g, determined at 849 MHz (high channel - 799) and for a separation between the bottom housing of the DUT and the phantom of 20.5 mm, was determined to be 1.13 W/kg. The overall margin of uncertainty for this measurement is ±25.7 % (Appendix C). The analysis of the previous section shows that a conservative 1.5W/kg will not be exceeded for a separation exceeding 17.3 mm.

This unit as tested, and as it will be marketed and used (with a warning in the manual to keep bystanders at least 18 mm from the antenna), is found to be compliant with the FCC 96-326 requirement.

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

APPENDIX A

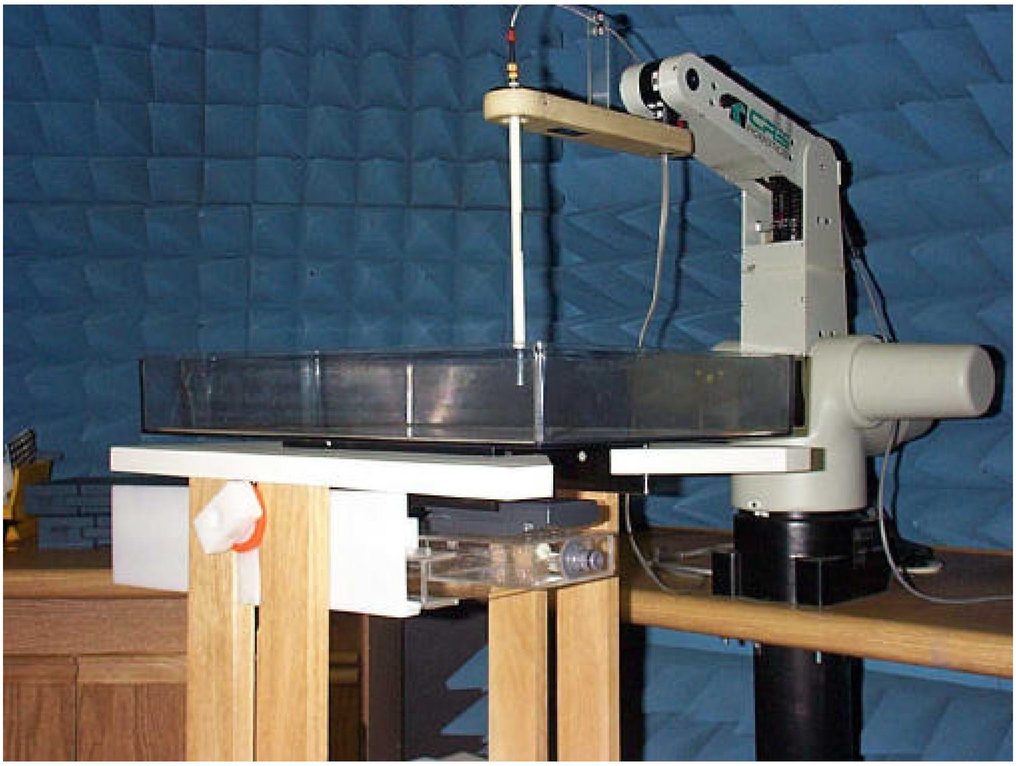


Figure 1

Figure 2

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

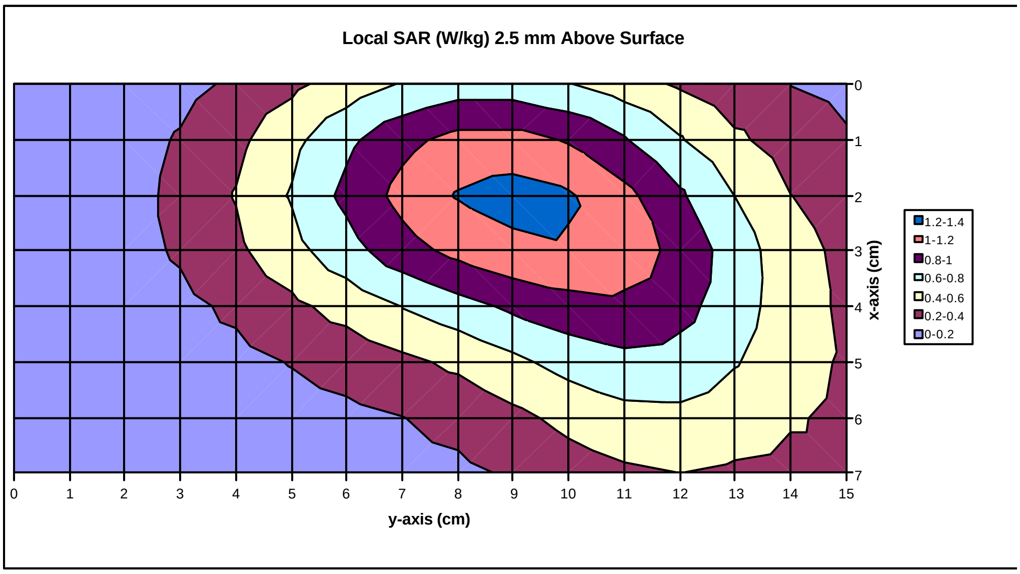


Figure 3

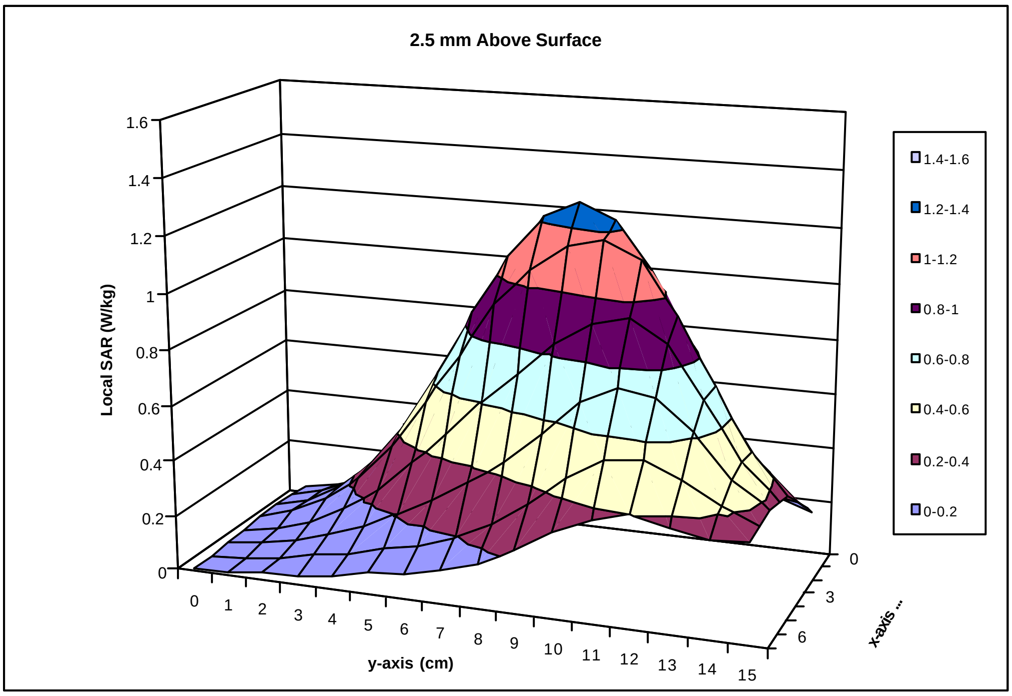


Figure 4

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

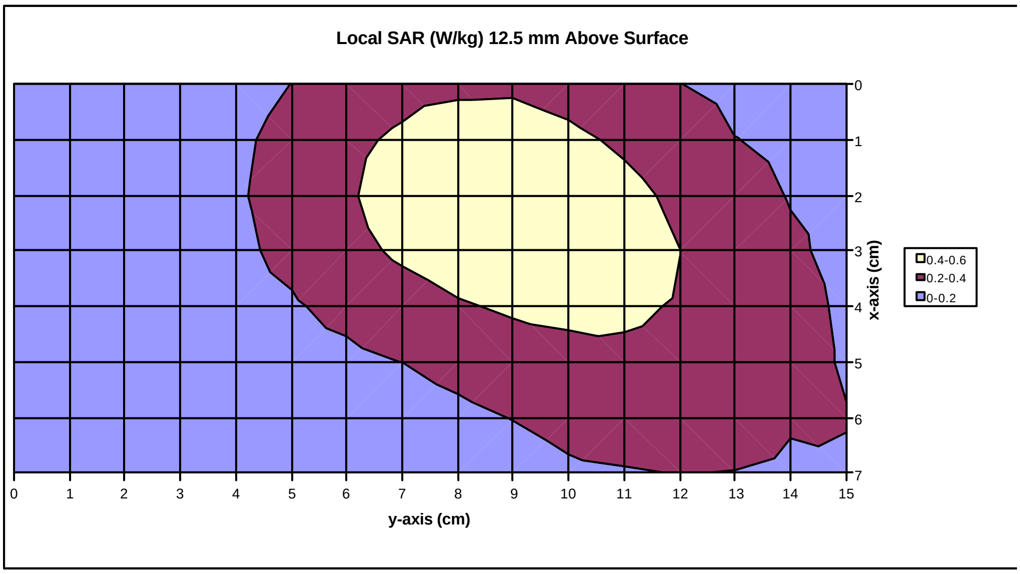


Figure 5

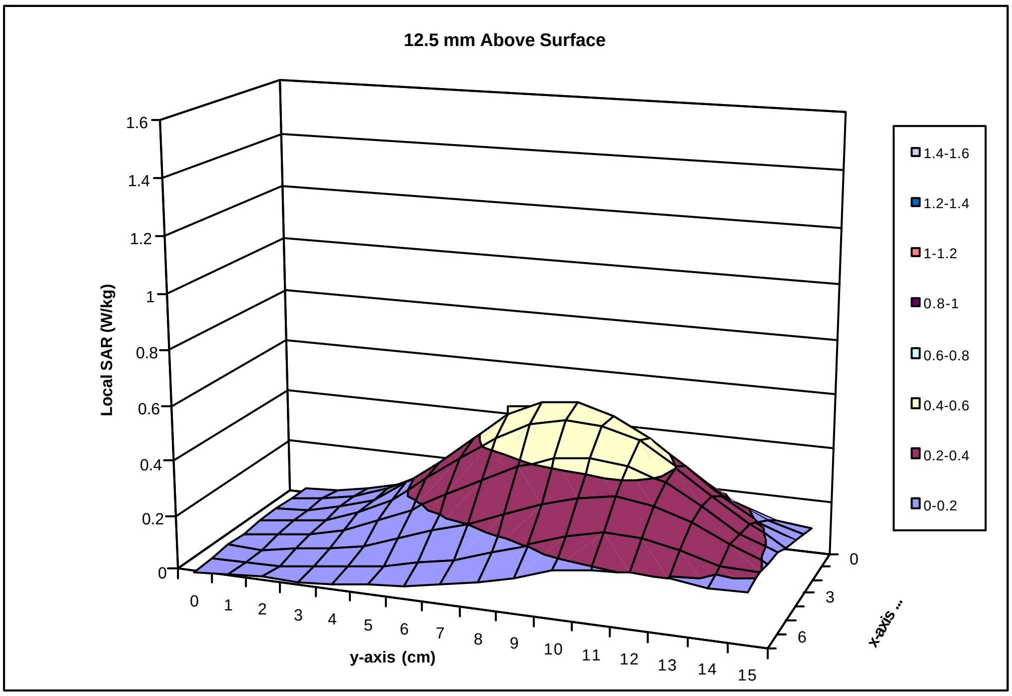


Figure 6

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

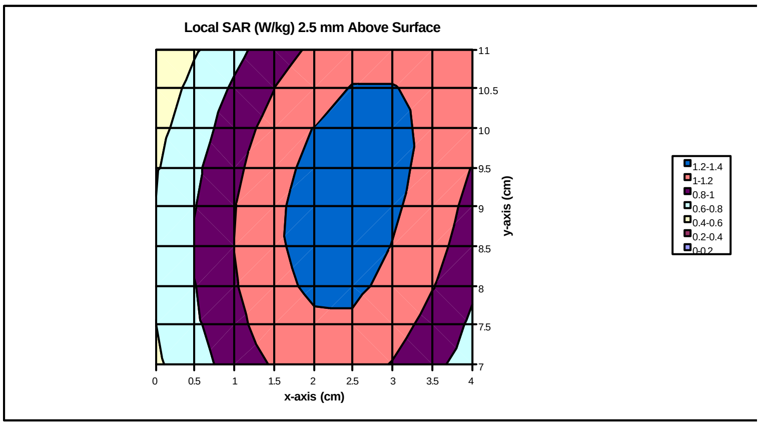


Figure 7

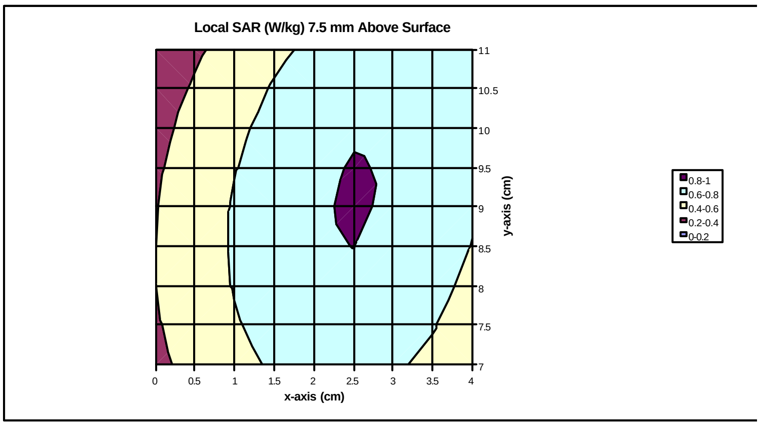


Figure 8

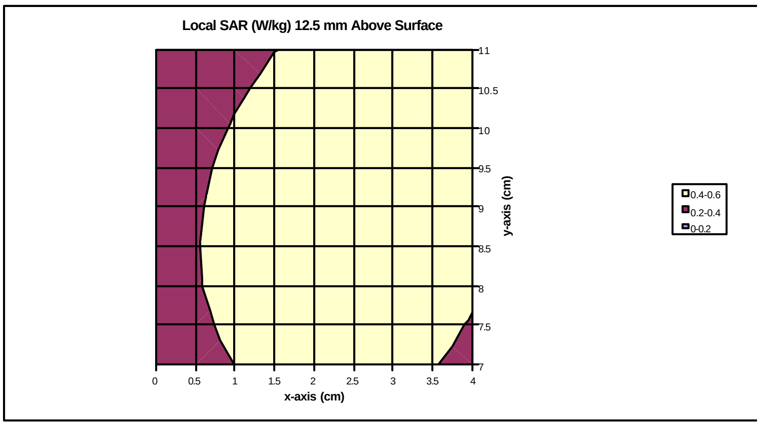


Figure 9

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

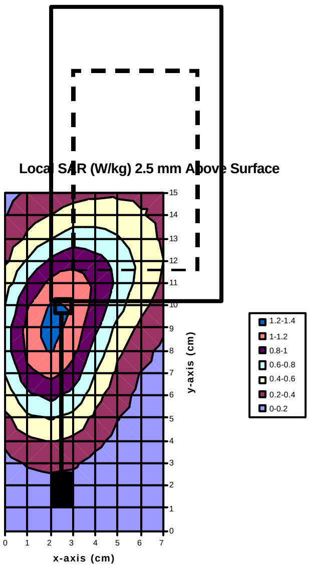


Figure 10

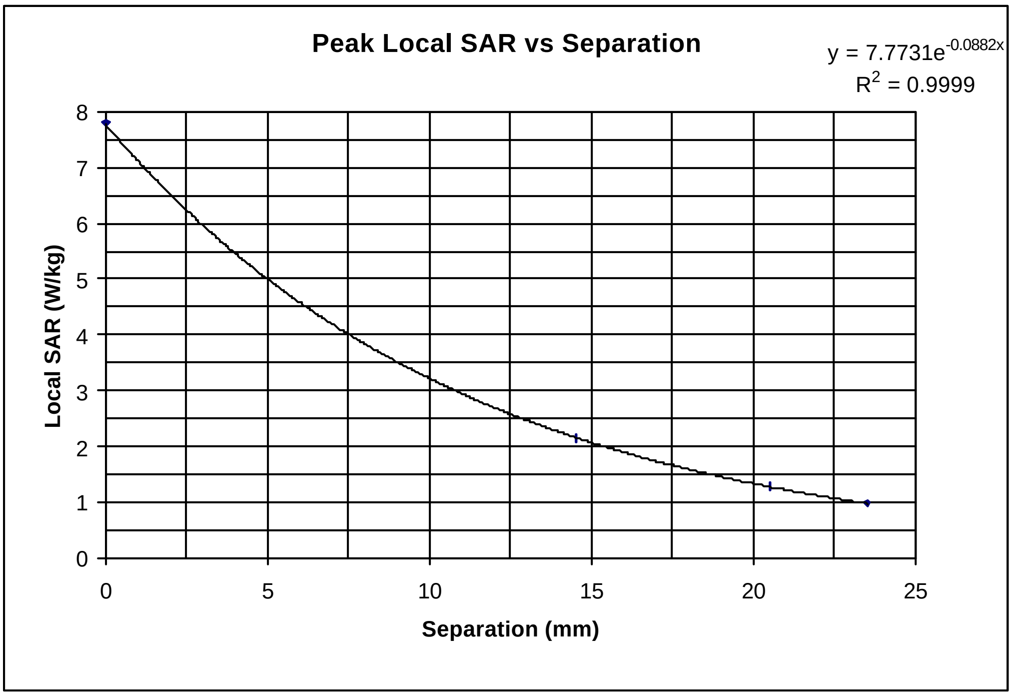


Figure 11

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

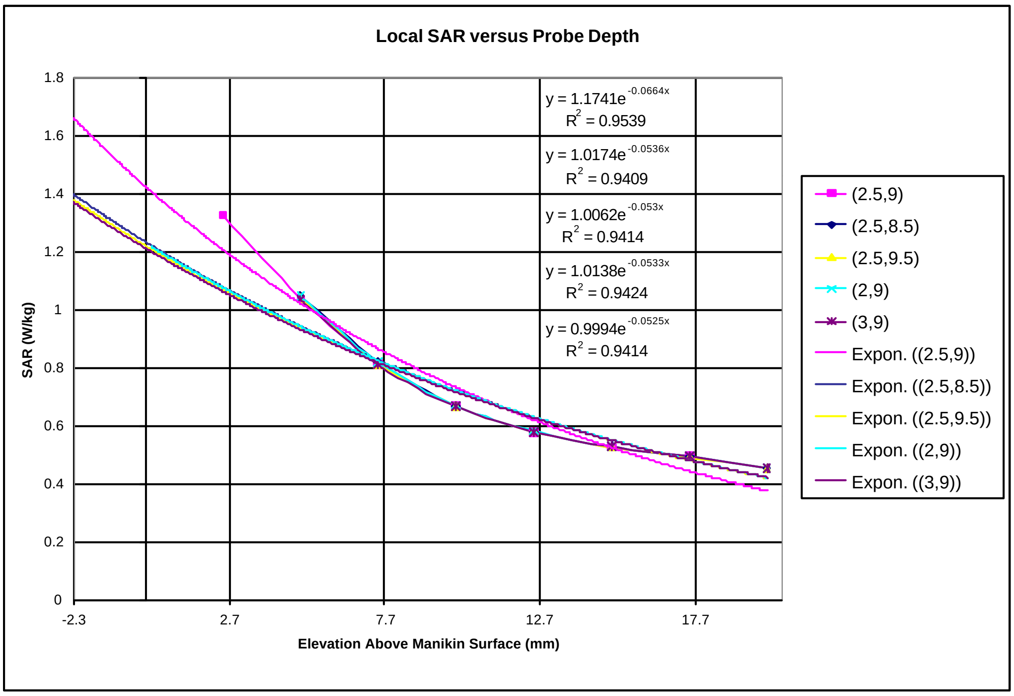


Figure 12

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

APPENDIX B

Manufacturer's Antenna Specifications

51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

APPENDIX C

Uncertainty Budget

Uncertainties Contributing to the Overall Uncertainty

Type of Uncertainty	Specific to	Uncertainty	
Power variation due to battery condition	DUT	9.6%	
Extrapolation due to curve fit of SAR vs depth	DUT	21.3%	
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	0.6%	
Probe sensitivity factor	setup	3.5%	
		25.7%	**RSS**

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

APPENDIX D

Simulated Tissue Material and Calibration Technique

The 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 C 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:

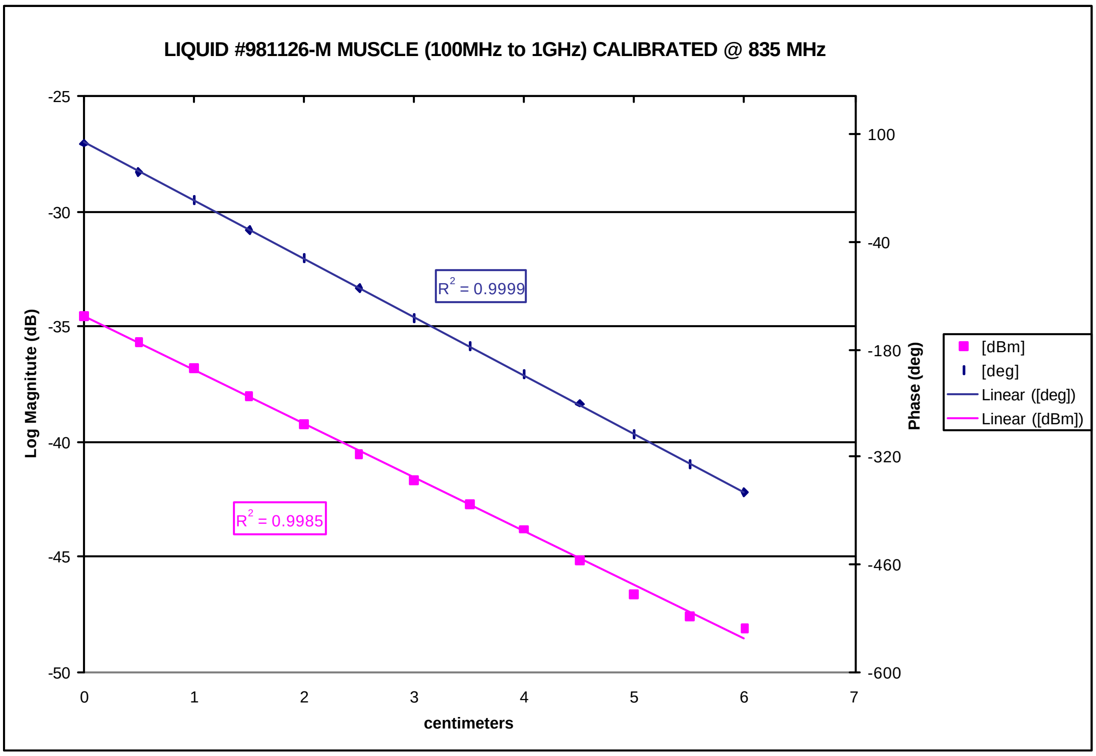
	APREL	OET 65 Supplement	Δ / % (OET)
Dielectric constant, ε_r	54.9	56.1	-2.1
Conductivity, σ/ [S/m]	1.08	0.95	+13.7
Tissue Conversion Factor, γ	7.8		

51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

SIMULATION FLUID #	**981126-M**
CALIBRATION DATE	**08-Jul-99**
CALIBRATED BY	**Heike**
Frequency Range	**100MHz-1GHz**
Frequency Calibrated	**835 MHz**
Tissue Type	**Muscle**

Position [cm]	Amplitude [dBm]	Phase [deg]	[deg]
0	-34.52	89.11	89.11
0.5	-35.71	51.68	51.68
1	-36.85	13.68	13.68
1.5	-38.06	-24.38	-24.38
2	-39.26	-61.29	-61.29
2.5	-40.52	-100.06	-100.06
3	-41.65	-138.16	-138.16
3.5	-42.69	-176.16	-176.16
4	-43.81	146.95	-213.05
4.5	-45.15	110.05	-249.95
5	-46.6	70.73	-289.27
5.5	-47.56	30.56	-329.44
6	-48.14	-6.19	-366.19
ΔdB_1	-7.13	Δdeg_1	-227.27
ΔdB_2	-6.98	Δdeg_2	-227.84
ΔdB_3	-6.96	Δdeg_3	-226.73
ΔdB_4	-7.09	Δdeg_4	-225.57
ΔdB_5	-7.34	Δdeg_5	-227.98
ΔdB_6	-7.04	Δdeg_6	-229.38
ΔdB_7	-6.49	Δdeg_7	-228.03
ΔdB_{AVG} [dB]	-7.00	Ddeg $_{AVG}$ [deg]	-227.5428571
dB$_{AVG}$ (α_{AVG}) [dB/cm]	-2.33	deg$_{AVG}$ (β_{AVG}) [deg/cm	-75.84761905
(α_{AVG}) [NP/cm]	-0.268799398	(β_{AVG}) [rad/cm]	-1.323790682
f [Hz]	8.35E+08		
μ [H/cm]	1.25664E-08		
ε_o [F/cm]	8.854E-14		
ε_r	**54.9**		
$\sigma_{effective}$	**1.08**	**S/m**	



51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

835 MHz Data (Heike & Tony) Muscle with E-115

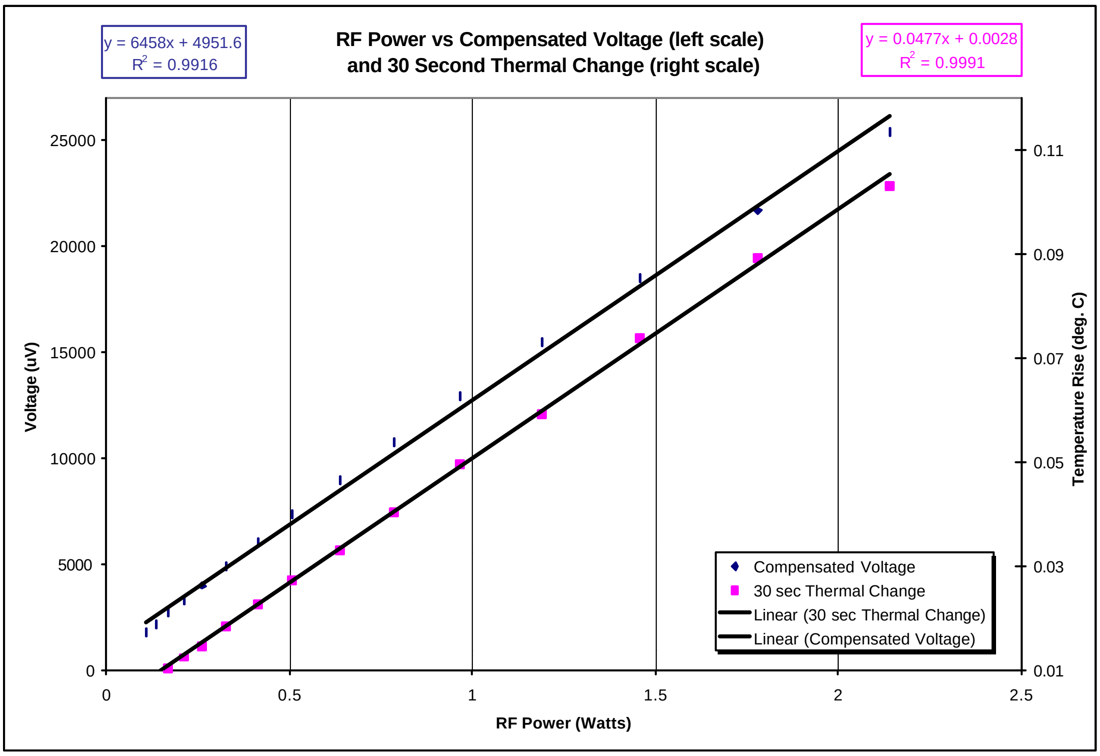
RF Power			Ch0	Ch1	Ch2	delta T (30 sec)	Sum Vi/Ei		Thermal SAR
W	dBm	R&S	uV	uV	uV	deg. C			W/kg
0.10666	20.28	-25.61	391	1196	2954	0.0093	1792.7		0.86
0.133352	21.25	-24.64	439	1440	3638	0.0086	2178		0.80
0.169044	22.28	-23.61	513	1782	4517	0.0102	2689		0.94
0.210863	23.24	-22.65	586	2173	5542	0.0125	3276.6		1.16
0.263027	24.2	-21.69	684	2661	6787	0.0147	3999.1		1.36
0.328095	25.16	-20.73	830	3247	8276	0.0185	4875.7		1.71
0.412098	26.15	-19.74	1001	4028	10205	0.0227	6012.4		2.10
0.509331	27.07	-18.82	1196	4932	12402	0.0273	7312.8		2.53
0.639735	28.06	-17.83	1440	6079	15137	0.0331	8940.6		3.06
0.787046	28.96	-16.93	1733	7397	18188	0.0405	10780		3.75
0.966051	29.85	-16.04	2100	8960	21680	0.0495	12918		4.58
1.188502	30.75	-15.14	2515	10815	25806	0.0592	15441		5.48
1.458814	31.64	-14.25	3052	13086	30640	0.0736	18455		6.81
1.778279	32.5	-13.39	3662	15503	35718	0.0893	21652		8.26
2.142891	33.31	-12.58	4395	18335	41528	0.1031	25349		9.54

Directional Coupler factor 25.89 dB (Asset 100251 cal file data (Janusz, 21 Jul 96))
Additional inline attenuation 20 dB

Sensitivity (e) 1.658 1.721 1.68 - Sensor Sensitivity in mV/ (mW/cm^2): 835 MHz cal (HW, 2 July 99)
η = 1.50 e 2.487 2.5815 2.52

Density	1.3	g/cm^3	1300	kg/m^3	-Tony, summer 99	
Conductivity	10.8	mS/cm	1.08	S/m	- Heike 8-Jul-99	
Heat Capacity (c)	2.775	J/C/g	2775	J/C/kg		
Exposure Time	30	seconds	30	seconds		
Slope of Measure Voltage (m_V)	11722	uV/W	0.0117	V/W		
- standard error or m_V	182.13	uV/W	0.0002	V/W		1.6%
Slope of Measure Temp Change (m_T)	0.0477	C/W	0.0477	C/W		
- standard error or m_T	0.0004	C/W	0.0004	C/W		0.8%

Tissue Conversion Factor (?)	7.8

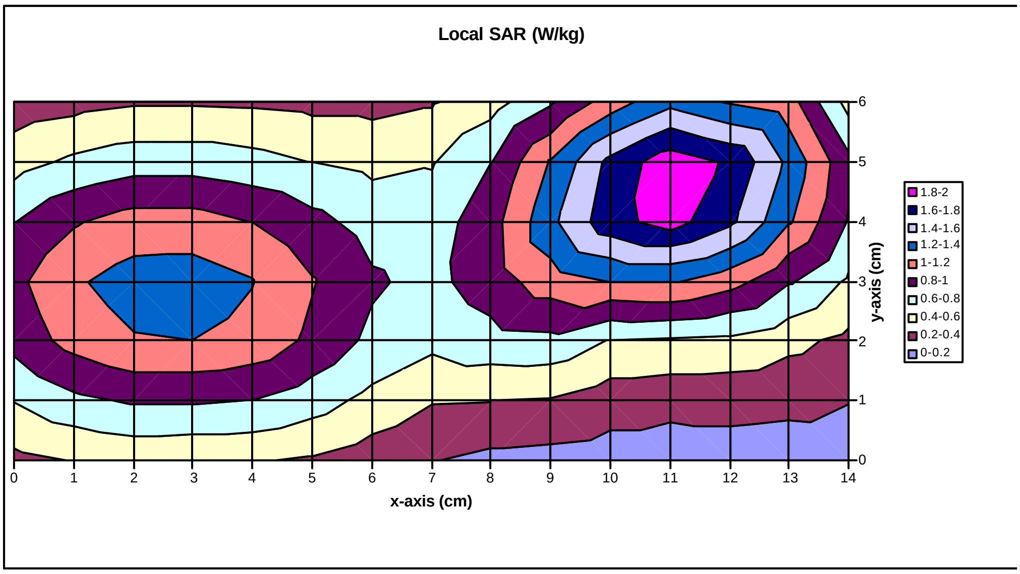


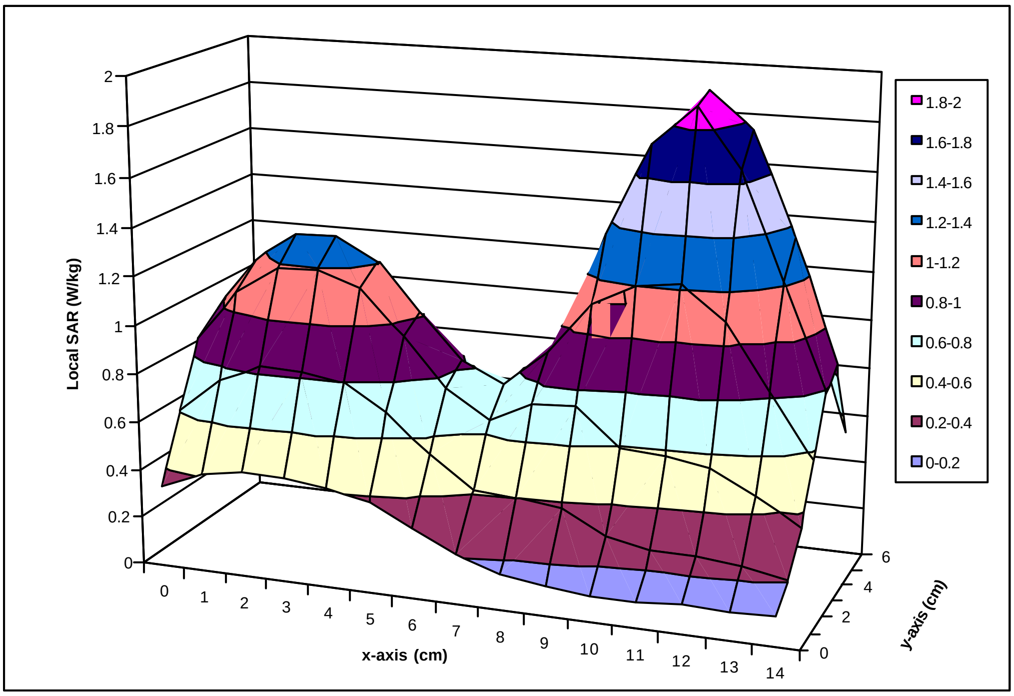
51 Spectrum Way
Nepean, Ontario, K2R 1E6

Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com

APPENDIX E

Validation Scans





51 Spectrum Way
Nepean, Ontario, K2R 1E6
Tel. (613) 820-2730
Fax (613) 820 4161
e-mail: info@aprel.com