Certification Report on

Specific Absorption Rate (SAR)
Experimental Analysis

Novatel Wireless Technologies Ltd.

Minstrel V
(for Body Exposure)

Date: 9 September, 1999

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CERTIFICATION REPORT

Subject:	**Specific Absorption Rate (SAR) Experimental Analysis for Body Exposure**
Product:	Wireless CDPD Modem
Model:	Minstrel V
Client:	Novatel Wireless Technologies Ltd.
Address:	Suite 200 6715 – 8th Street N. E. Calgary, Alberta Canada, T2E 7H7
Project #:	NVWB-MINSTRELV-3284M
Prepared by:	APREL Laboratories 51 Spectrum Way Nepean, Ontario K2R 1E6

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.

CERTIFICATION REPORT

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6715 – 8th Street N. E.
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Telecommunications Approval Board - Spectrum Sciences Institute - SAR Certified APREL Laboratories A997-Minstrel V

Project #: NVWB-MINSTRELV-3284M

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

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FCC ID:	NBZNRM-6832
Applicant:	Novatel Wireless Technologies Ltd.
Equipment:	Wireless CDPD modem
Model:	Minstrel V
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 V wireless CDPD modem for body exposure (see report NVWB-Minstrel V 3284H for hand exposure). The measurements were carried out in accordance with FCC 96-326. The Minstrel V was evaluated for its maximum power level of 478 mW (26.8 dBm).

The Minstrel V 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 991 (high, 824 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 16 mm distance from the antenna), is found to be compliant with the FCC 96-326 requirement, for an 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 Novatel Wireless Minstrel V 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 V wireless CDPD modem, pre-production sample, s/n 00.60.D6.03.09.IC
- 3-Com Palm Pilot V, s/n 10.A8.14.R9.64.R0

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 manufacturers supplied antenna information.
The device under test (DUT) consists of a Palm Pilot V installed into the Minstrel V cradle.

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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 V 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.

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7. All tests were performed with the highest power available from the sample Minstrel V 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 V 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	-21.8	-22.2	-0.4	4
Area	12.5	-22.2	-22.4	-0.2	2
Zoom	2.5	-21.9	-22.0	-0.1	4
Zoom	7.5	-27.6	-28.2	-0.6	1
Zoom	12.5	-22.0	-22.4	-0.4	6
Depth	2.5 – 17.5	-21.9	-21.9	0	2

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

2) The Novatel Wireless Minstrel V wireless CDPD modem was put into test mode for the SAR measurements using manufacturer supplied touch screen commands entered on the Palm Pilot V to control the channel (initially 991) 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 V 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 an 18.5 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 palm top's outline, 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.

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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	6.29
Middle	in	383	down	836.49	5.38
High	in	799	down	848.97	4.62
Low	out	991	down	824.04	7.21
Middle	out	383	down	836.49	6.83
High	out	799	down	848.97	7.12
Low	in	991	up	824.04	0.67
Middle	in	383	up	836.49	0.65
High	in	799	up	848.97	0.85
Low	out	991	up	824.04	1.89
Middle	out	383	up	836.49	1.75
High	out	799	up	848.97	1.77

All subsequent testing was performed on the high channel (991, 824 MHz) with the antenna out and the LCD down.

5) Wide area scans were also performed for the high (991, 824 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	824	0	7.21
			8	3.00
			15.5	1.45
			18.5	1.29

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Considering the anticipated scaling to the inner surface of the phantom, subsequent testing was performed with a DUT surface to phantom bottom separation of 18.5 mm.

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

6) The low channel (991) 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 0.92 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 (-0.053 ± 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 1 g** of 1.19 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 18.5 mm (previous section) to be extrapolated/interpolated for other separations.

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

$$\text{Peak Local SAR} = 6.8636\ e^{-0.0953\ \text{separation}}$$

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

$$\text{Peak 1g SAR} = k\,e^{-0.0953\ \text{separation}}$$

Using this equation with the previous section's data:

Peak 1g SAR = 1.19 W/kg
separation =18.5 mm

results in a k = 6.92 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 16mm.

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8. CONCLUSIONS

The Novatel Wireless Minstrel V 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 824 MHz (low channel - 991) and for a separation between the bottom housing of the DUT and the phantom of 18.5 mm, was determined to be 1.19 W/kg. The overall margin of uncertainty for this measurement is ±26.9 % (Appendix C). The analysis of the previous section shows that a more conservative 1.5W/kg will not be exceeded for a separation exceeding 16 mm.

This unit as tested, and as it will be marketed and used (with a warning in the manual to keep bystanders at least 16 mm from the antenna), is found to be compliant with the FCC 96-326 requirement.

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APPENDIX A

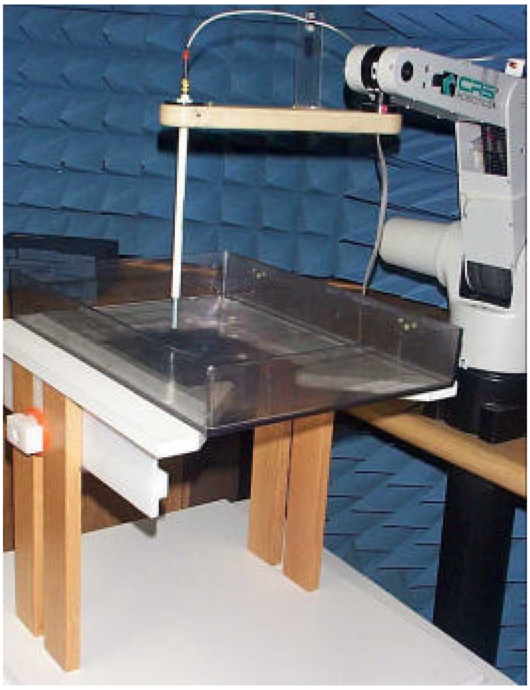

Figure 1

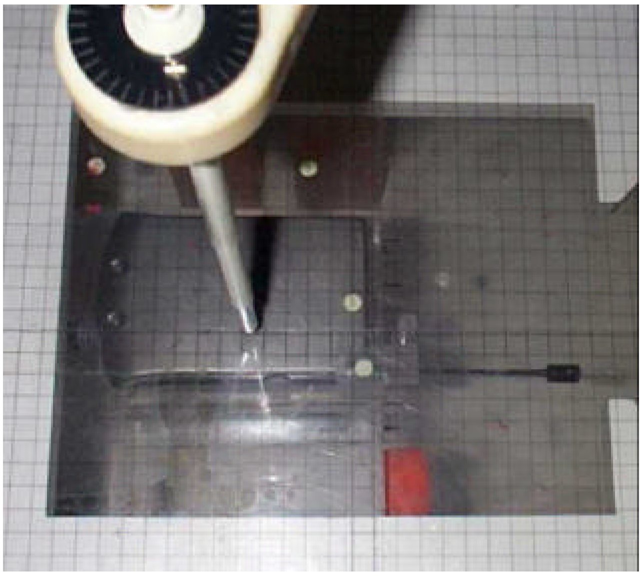

Figure 2

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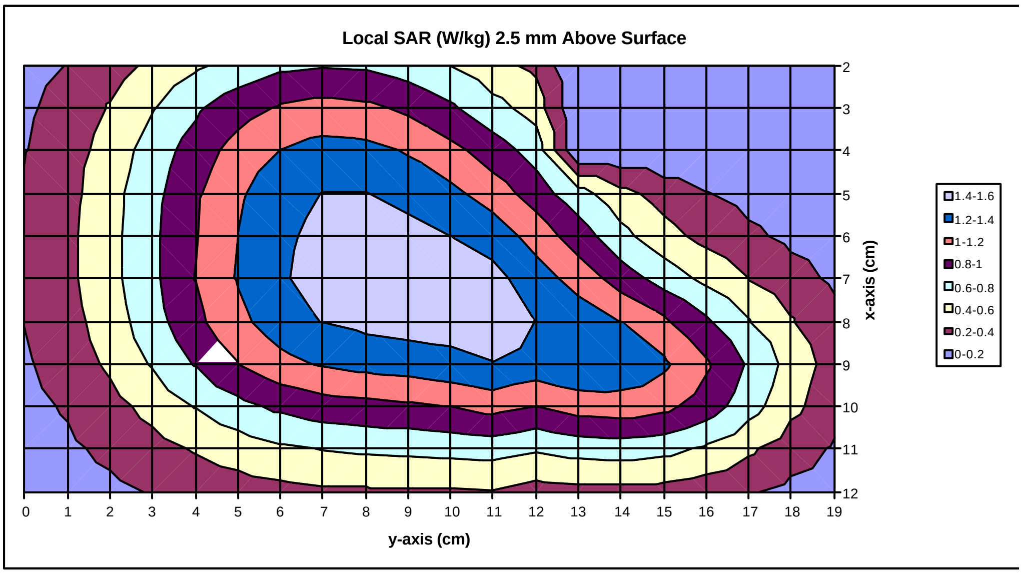

Figure 3

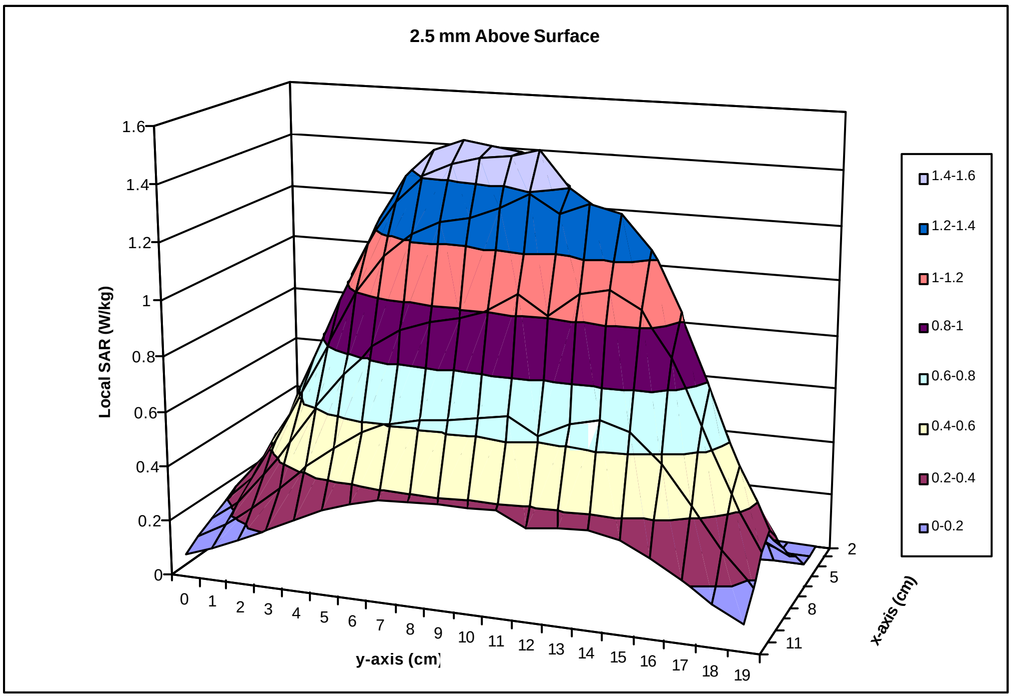

Figure 4

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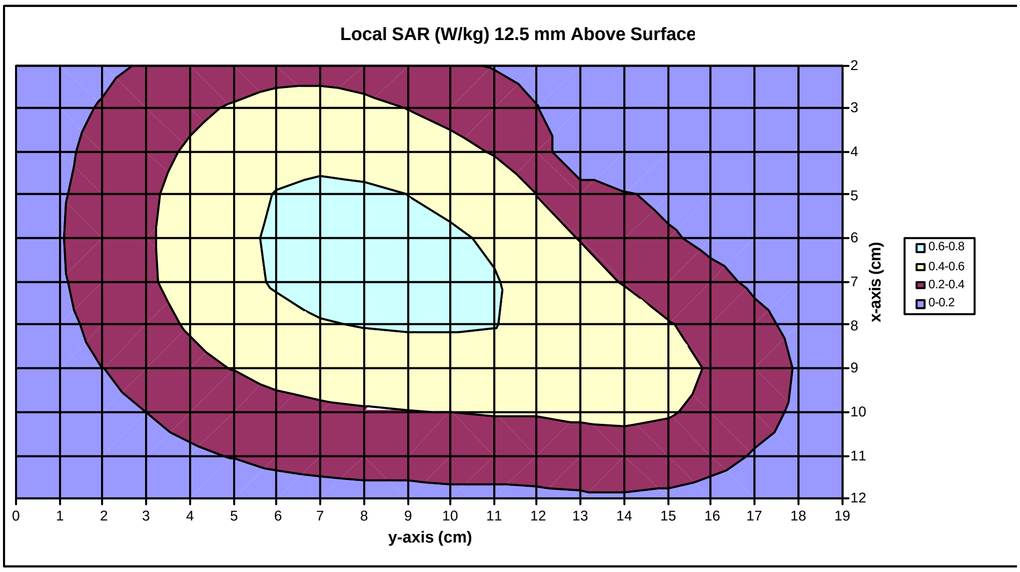

Figure 5

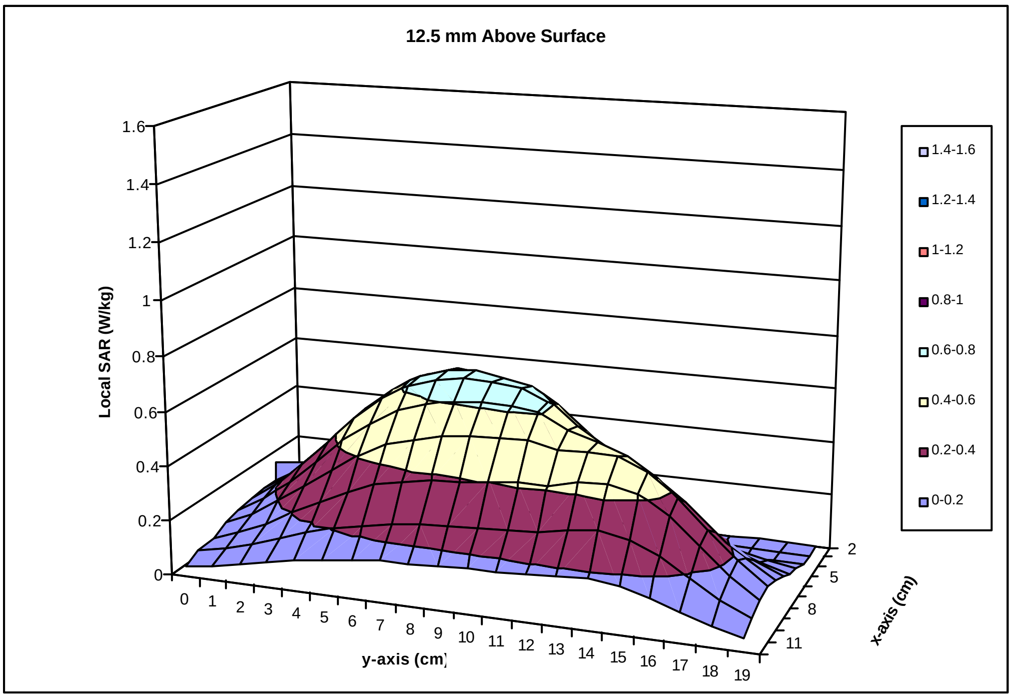

Figure 6

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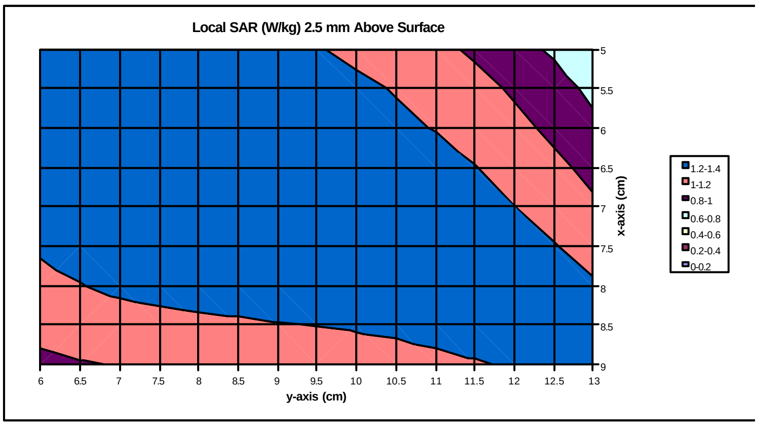

Figure 7

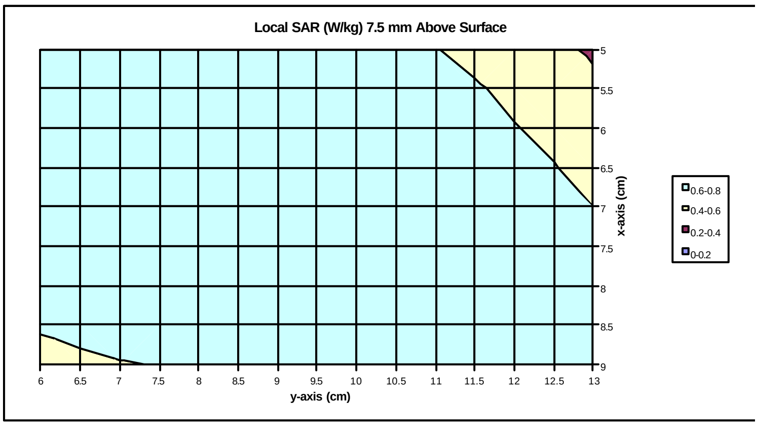

Figure 8

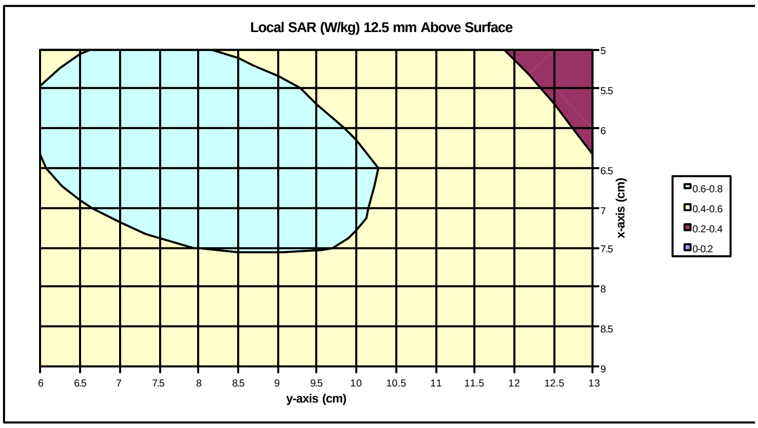

Figure 9

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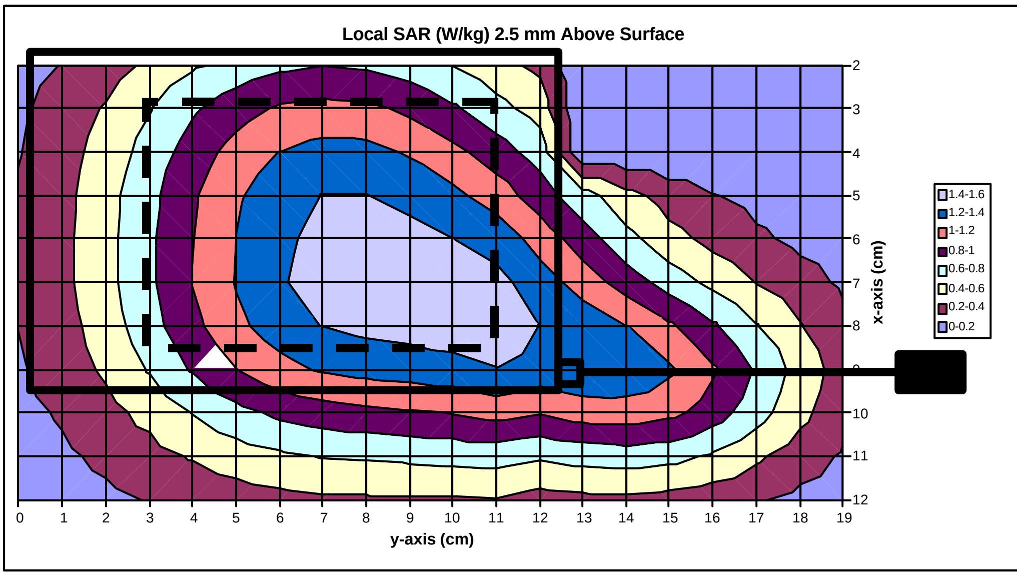

Figure 10

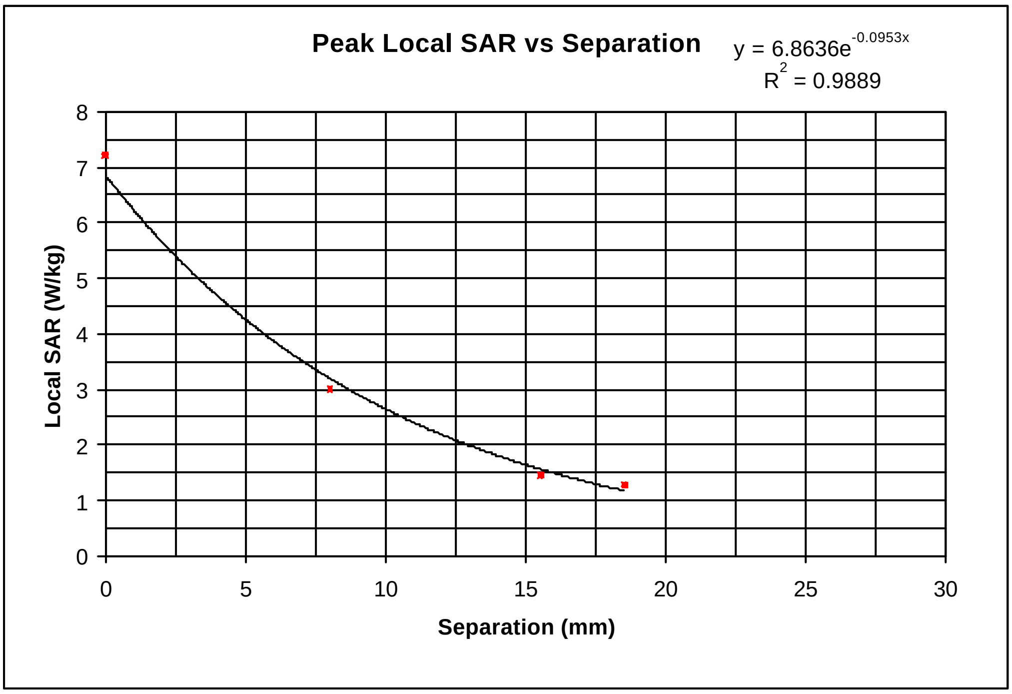

Figure 11

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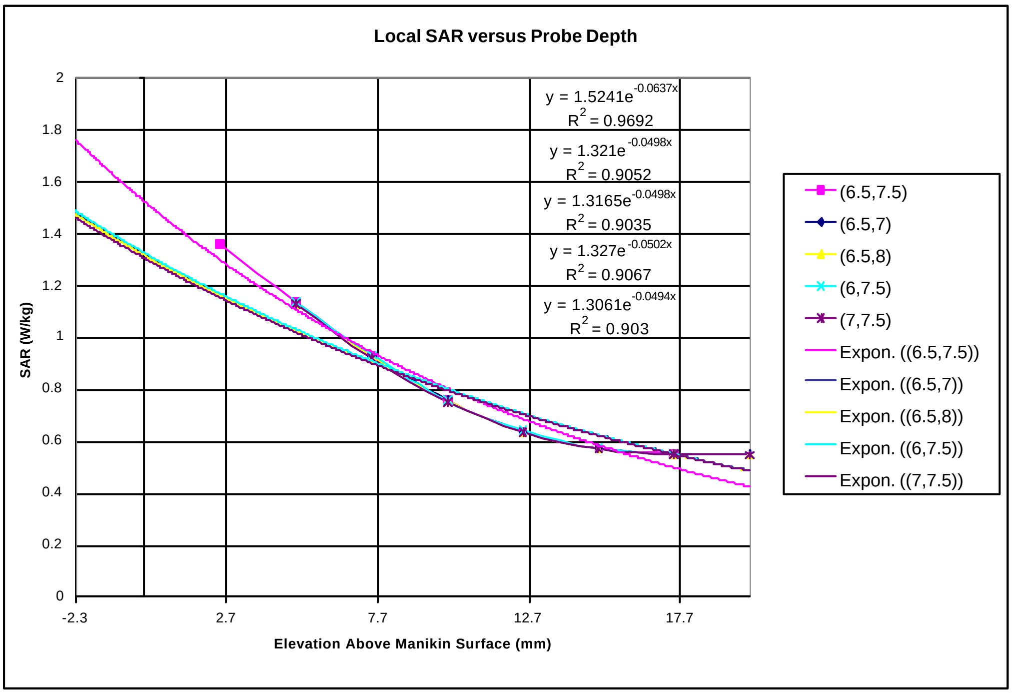

Figure 12

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APPENDIX B

Manufacturer's Antenna Specifications

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ACE ANTENNA COMPANY

Inductive Coupled Extendable Antenna

MODEL : HR-800 / HR-900

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ACE ANTENNA

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1. Comparison of functional characteristics with other designs.

The HR-800 / HR-900 extendable antenna can be operated in either extended or retracted position as deemed appropriate by the user. However, for greater efficiency the extended position is recommended. The antenna should be retracted when not in use to prevent accidental damage.

Many suppliers including, GALTRONICS and ALLGON manufacture their antennas in two parts or sections. One for the helical section and the other for the whip section. The separation of these critical antenna parts can produce problems in antenna function and operation.

For example: In the extended mode, only the whip section is functioning. Conversely, when the antenna is in the retracted mode only the helical section is functiong. This design feature creates narrow bandwidth efficiency and low radiation characteristics. Additionally, the connecting point or junction of the two sections is very susceptible to breakage, thus causing antenna failure and early replacement.

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To eliminate these design flaws Ace Antenna Company opted for a more efficient, albeit more costly design concept, by incorporating an "inductive coupling" design feature which produces greater radiation efficiency and strengthens mechanically the entire extendable antenna assembly.

Operating principle of Inductive Coupled Extendable Antenna.

1. The benefits of the inductive coupling design become apparent when the antenna is operated in the extended position By connecting the 1/4 wavelength helical and the 1/4 wavelength whip, the unit operates equivalent to a 1/2 wavelength dipole antenna.

2. When the antenna is in the retracted position, the helical section is connected by the inductive coupling at the sleeve and compensates for the capacitive component. As a result, wider bandwidth is accomplished by forming 1/4 wavelength balun or (balance to unbalance) thus stabilizing the helical antenna operation.

3. Increased mechanical strength and reliability are achieved when the whip section is inserted into the tube end and at the point the tube joins with the sleeve. Also, the whip element is constructed of super elastic nickel titanium alloy which provides excellent antenna resilience.

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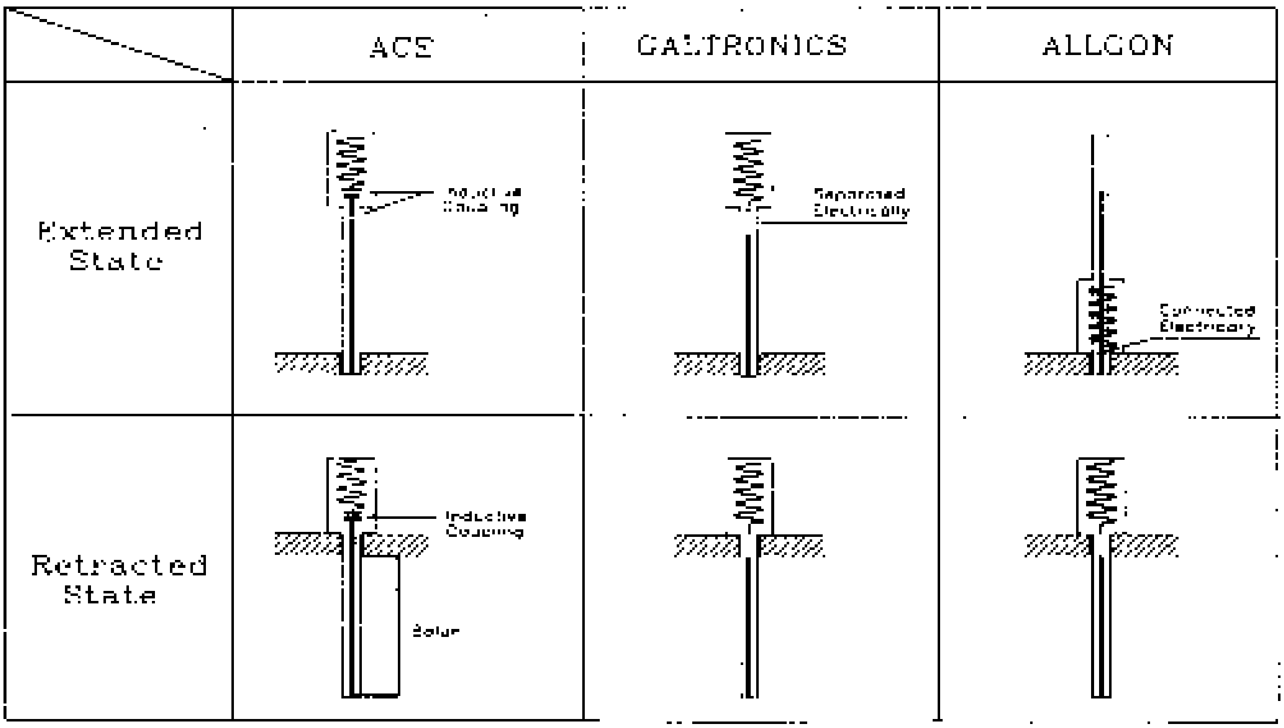
<Figure 1>



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2. Comparative Analysis

	ACE	GALTRONICS	ALLGON
Note (1) Extended Position	Equivalent to 1/2 λ Dipole	1/4 λ Whip	1/4 λ Whip connected with Helical at the bottom
Retracted Position	1/4 λ Helical with balun	1/4 λ Helical	1/4 λ Helical
RX Level			
for the Whip	0.4 dB higher than GALTRONICS	0.4 dB lower than ACE	Not tested
for the Helical	0.8 dB higher than GALTRONICS	0.8 dB lower than ACE	Not tested
Overall Length	Shorter than GALTRONICS & ALLGON	Longer than ACE relatively	Longer than ACE relatively
Mechanical Strength	Strong (used NT-Wire)	Connection part between sleeve & whip is weak	Connected part between sleeve & whip is weak.
Resilience	Superelastic	Lower than ACE	Lower than ACE

* Note (1) : See figure 1 shown in attached drawings.

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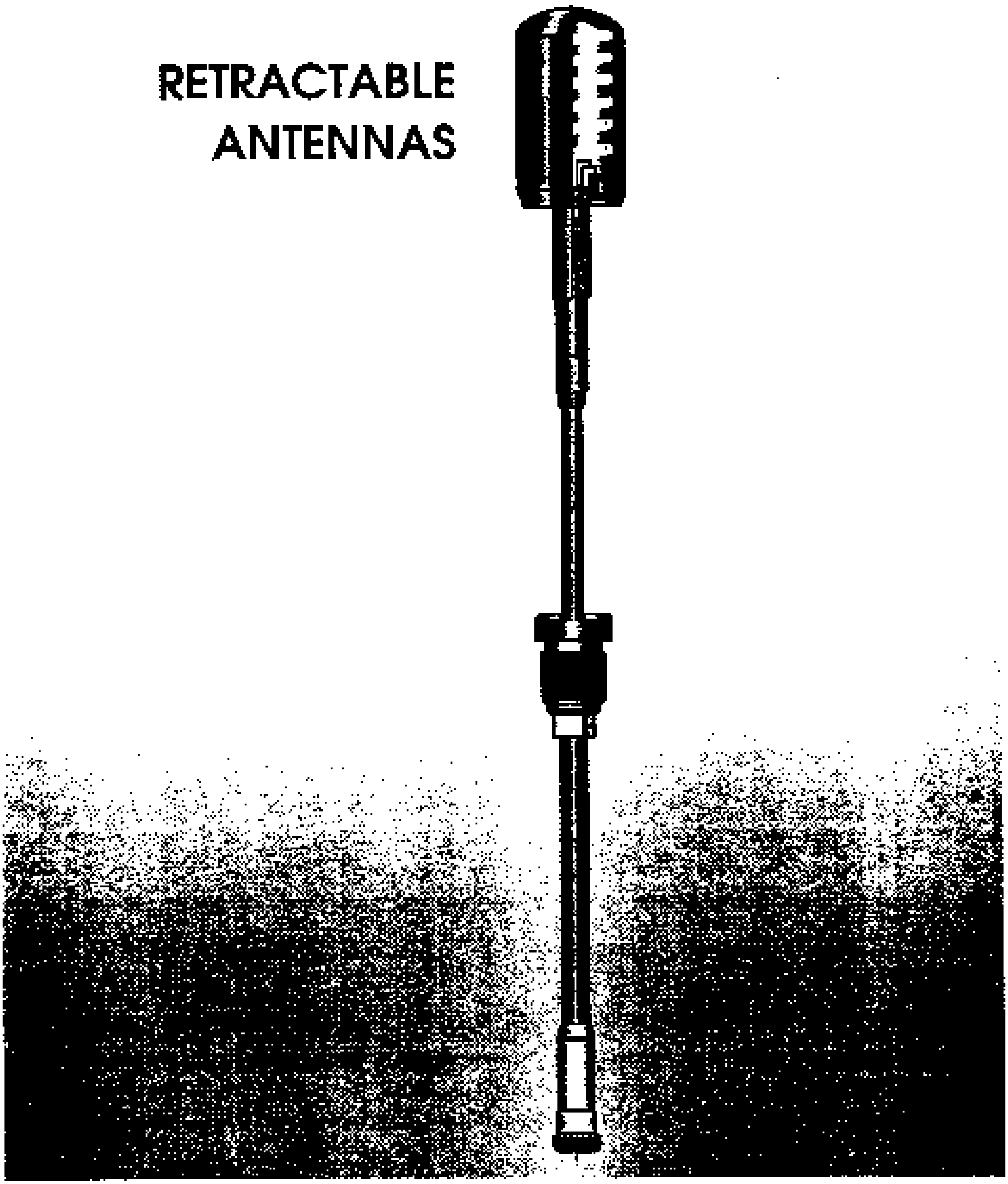
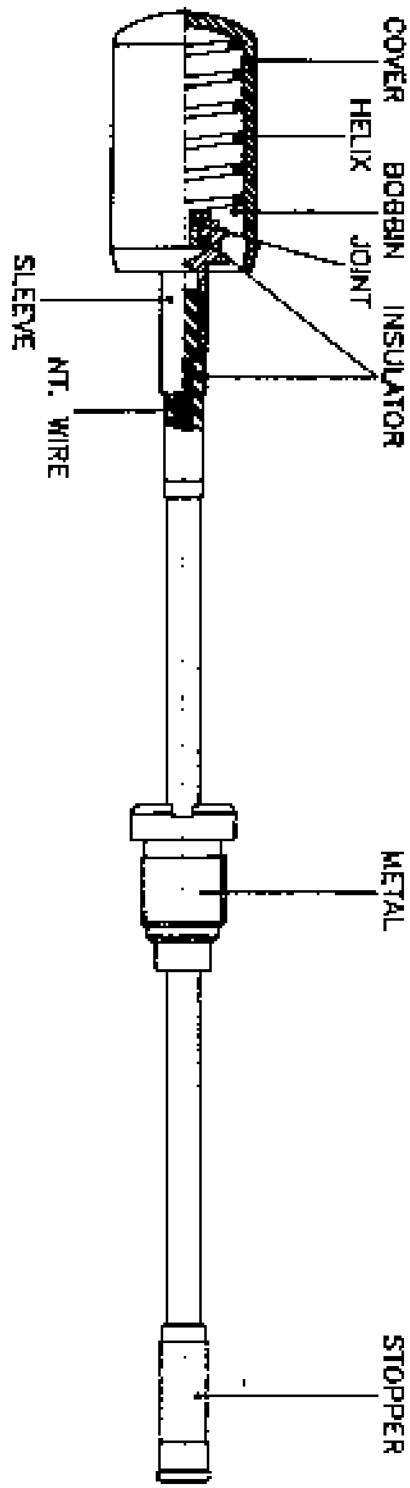
RETRACTABLE ANTENNAS




COVER
HELIX
BOBBIN
JOINT
INSULATOR
SLEEVE
NT. WIRE
METAL
STOPPER

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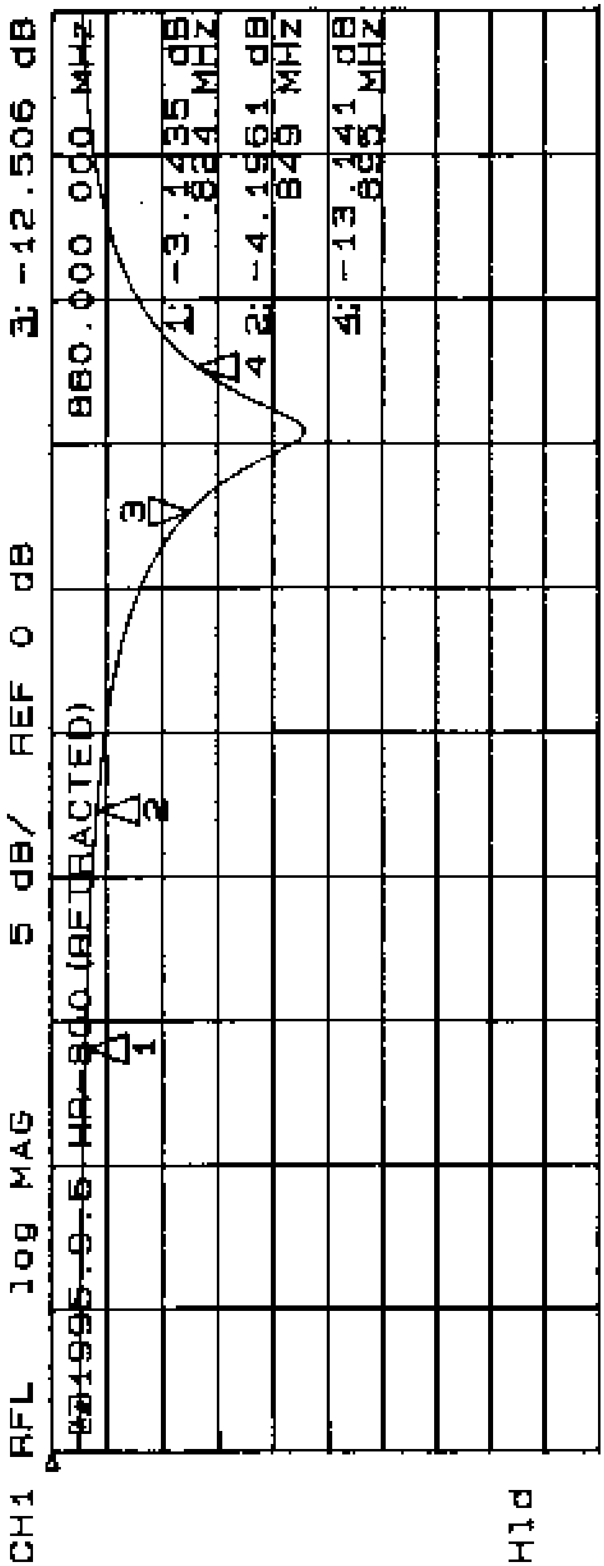

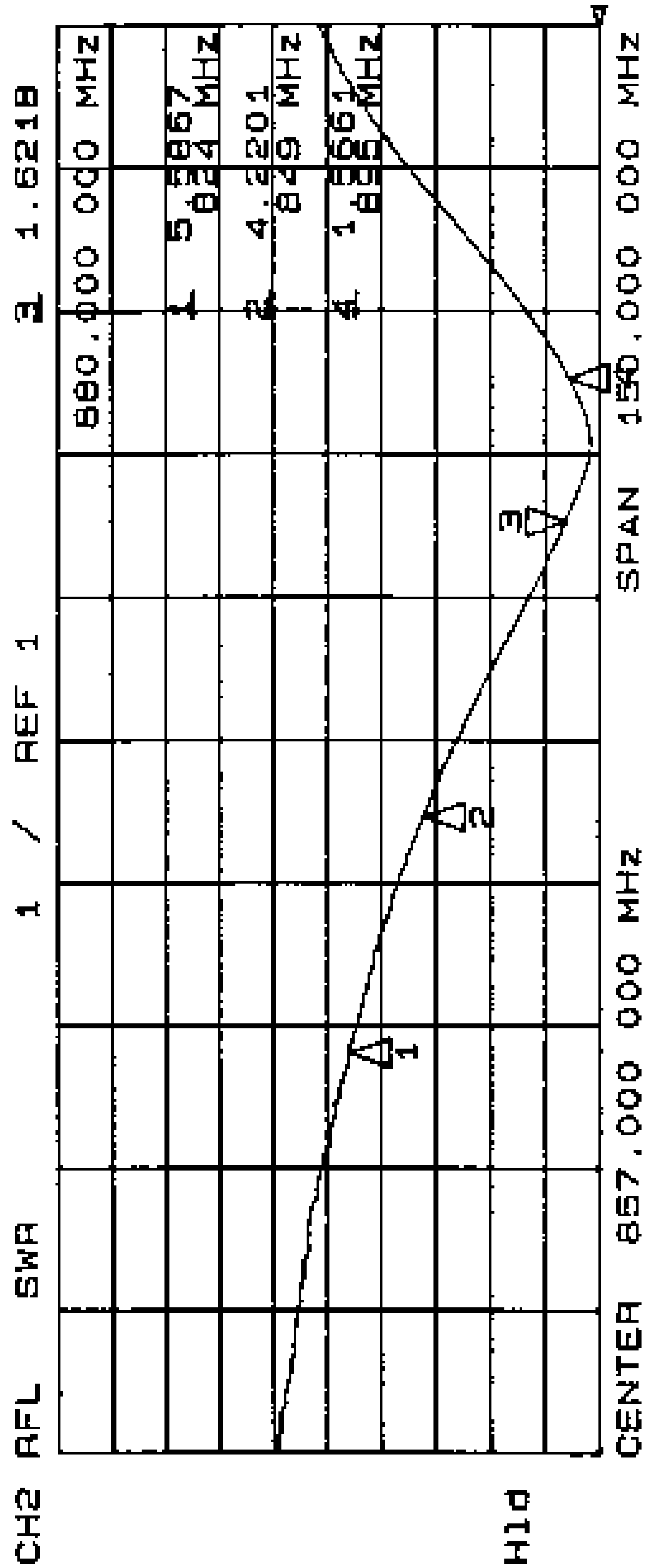

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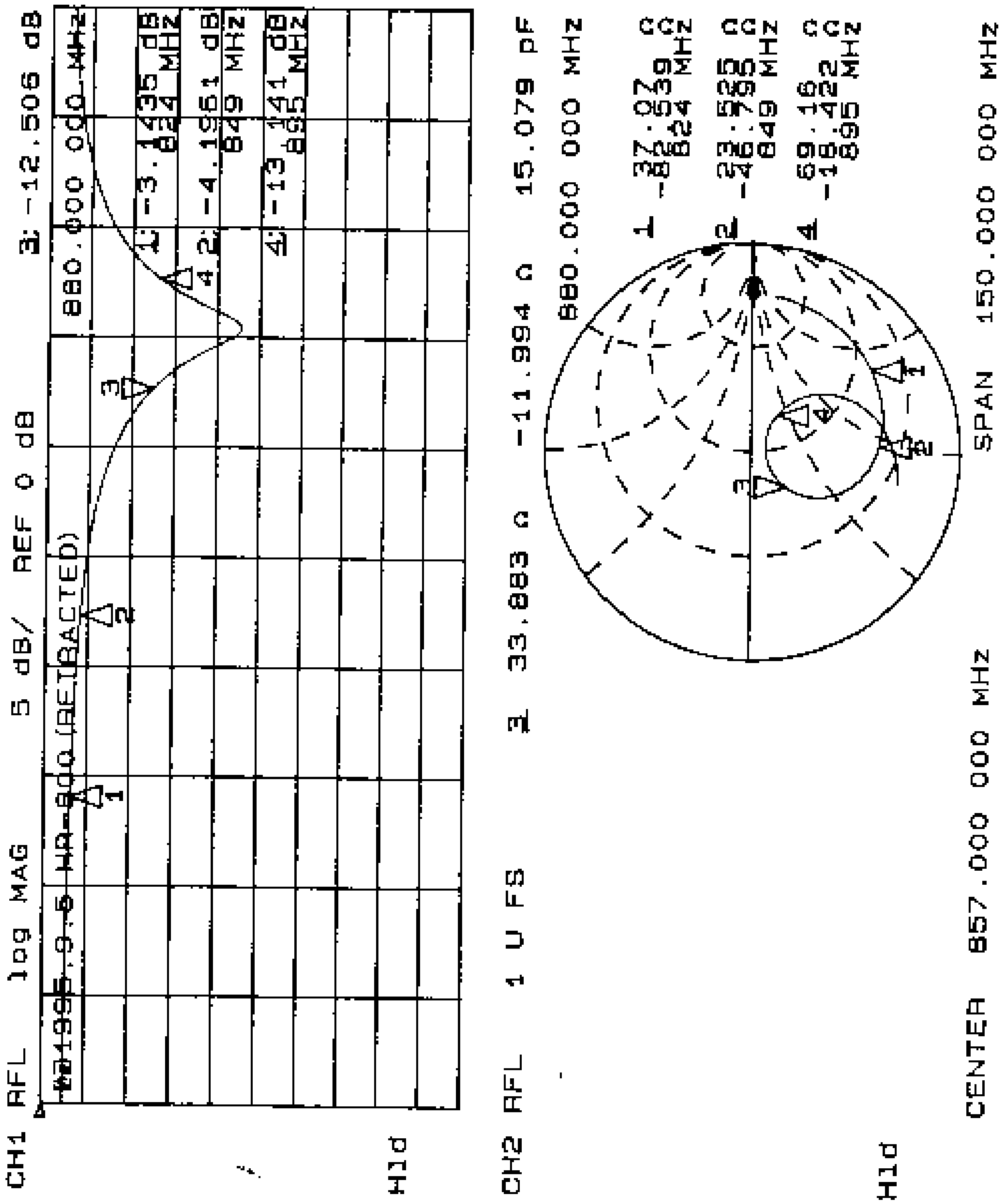

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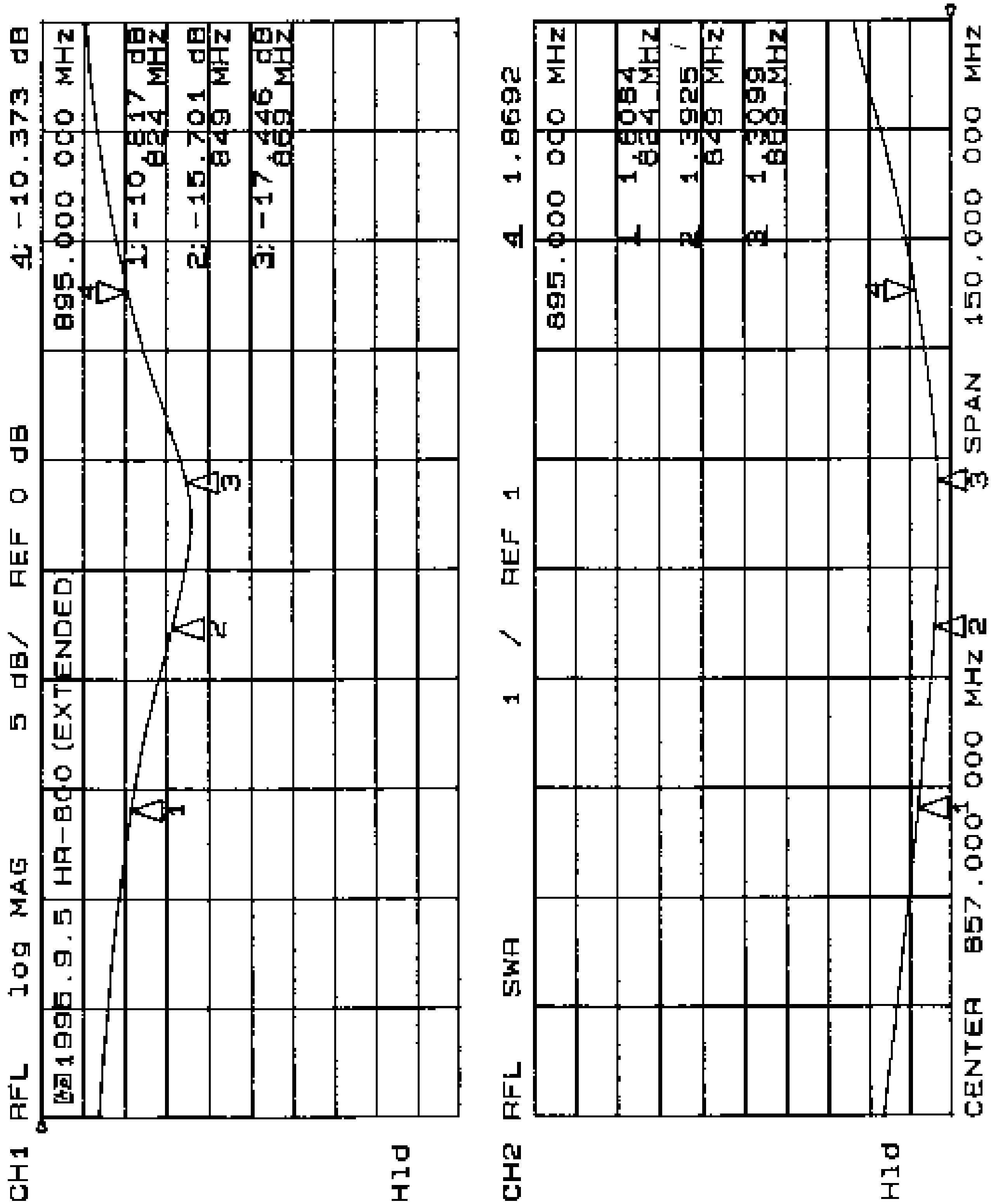

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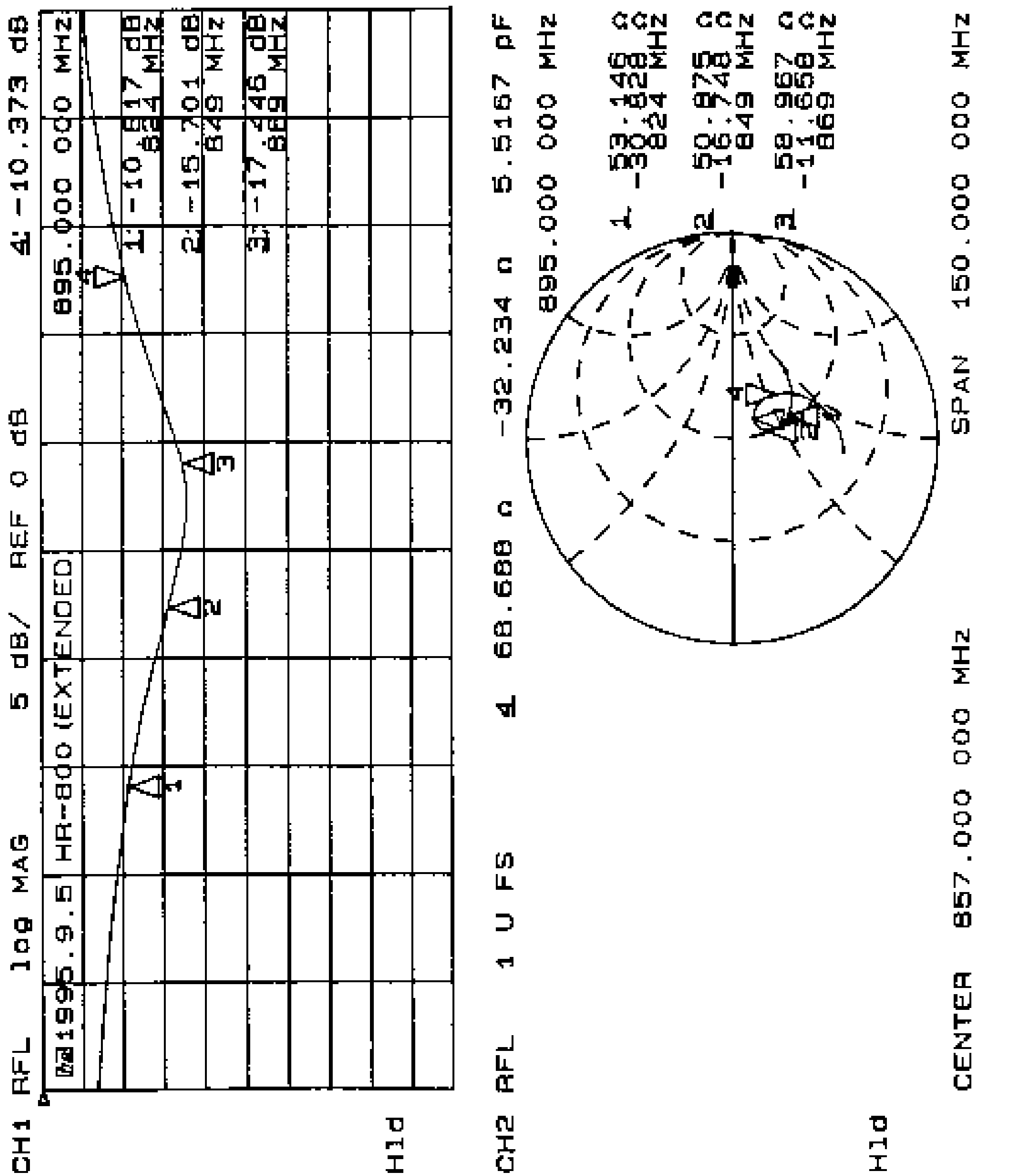

ANTENNA SPECIFICATIONS

GENERAL SPECIFICATIONS

MODEL	MAX-1000
ANTENNA TYPE	EXTENDABLE WITH 1/4 λ HELICAL OVER 1/4 λ WHIP
APPLICATIONS	CELLULAR PHONE

ELECTRICAL SPECIFICATIONS

FREQUENCY RANGE	824 ~ 894MHz
IMPEDANCE (NOMINAL)	50Ω
V. S. W. R.	LESS THAN 1.9:1 (EXTENDED) LESS THAN 3.5:1 (RETRACTED)
GAIN (dBi)	2.0 ± 1 (EXTENDED) -1 ± 1 (RETRACTED)
RADIATION PATTERN	OMNI DIRECTIONAL
POLARIZATION	VERTICAL

MECHANICAL SPECIFICATIONS

LENGTH	104.0mm ± 1.0mm
TEMPERATURE	-30℃ ~ +60℃
CONNECTOR TYPE	THREAD

APPENDIX C

Uncertainty Budget

Uncertainties Contributing to the Overall Uncertainty

Type of Uncertainty	Specific to	Uncertainty
Power variation due to battery condition	DUT	7.2%
Extrapolation due to curve fit of SAR vs depth	DUT	23.7%
Extrapolation due to depth measurement	setup	2.6%
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%
		26.9% RSS

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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]	1.1	0.95	+15.8
Tissue Conversion Factor, γ	7.8		

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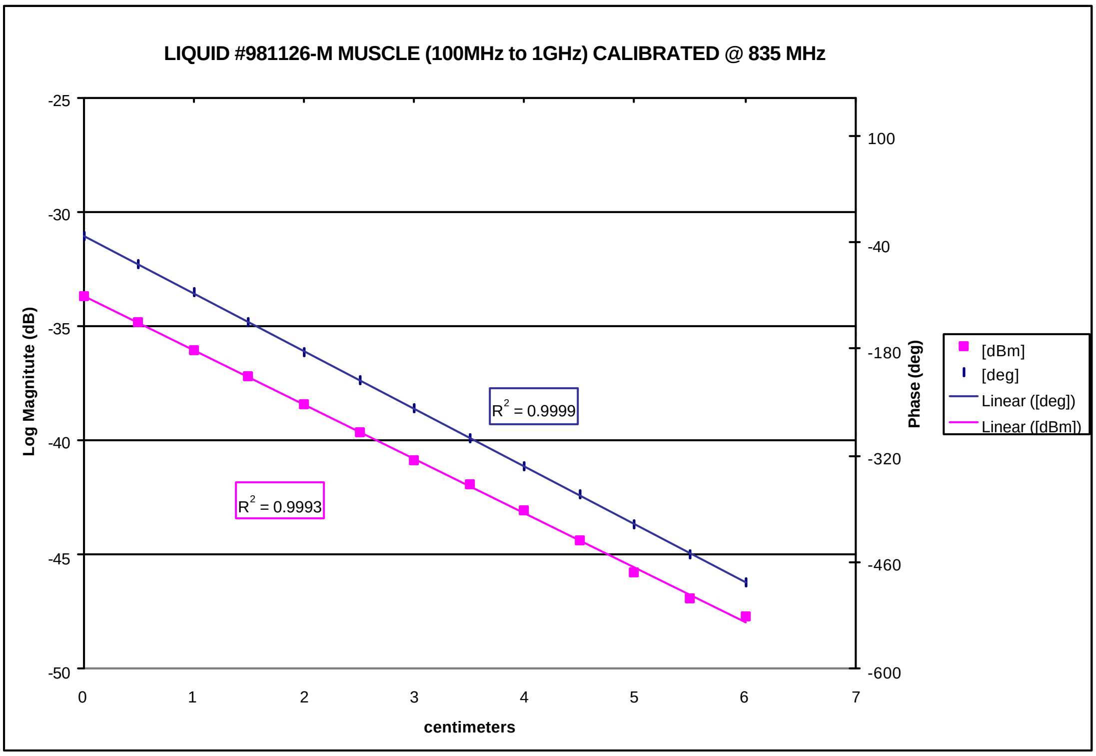
SIMULATION FLUID #	981126-M
CALIBRATION DATE	07-Sep-99
CALIBRATED BY	Heike
Frequency Range	100MHz-1GHz
Frequency Calibrated	835 MHz
Tissue Type	Muscle

Position [cm]	Amplitude [dBm]	Phase [deg]	[deg]
0	-33.7	-31.69	-31.69
0.5	-34.85	-68.71	-68.71
1	-36.06	-106.36	-106.36
1.5	-37.18	-144.61	-144.61
2	-38.41	177.03	-182.97
2.5	-39.68	139.11	-220.89
3	-40.89	101.36	-258.64
3.5	-41.96	63.44	-296.56
4	-43.09	25.77	-334.23
4.5	-44.34	-11.13	-371.13
5	-45.81	-49.25	-409.25
5.5	-46.93	-89.09	-449.09
6	-47.68	-127.67	-487.67
ΔdB_1	-7.19	Δdeg_1	-226.95
ΔdB_2	-7.11	Δdeg_2	-227.85
ΔdB_3	-7.03	Δdeg_3	-227.87
ΔdB_4	-7.16	Δdeg_4	-226.52
ΔdB_5	-7.4	Δdeg_5	-226.28
ΔdB_6	-7.25	Δdeg_6	-228.2
ΔdB_7	-6.79	Δdeg_7	-229.03
ΔdB_{AVG} [dB]	-7.13	$Ddeg_{AVG}$ [deg]	-227.5285714
$dB_{AVG}(\alpha_{AVG})$ [dB/cm]	-2.38	$deg_{AVG}(\beta_{AVG})$ [deg/cm	-75.84285714
(α_{AVG}) [NP/cm]	-0.273733509	(β_{AVG}) [rad/cm]	-1.323707571
f [Hz]	8.35E+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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835 MHz Data (Heike & Tony) Muscle with E-115

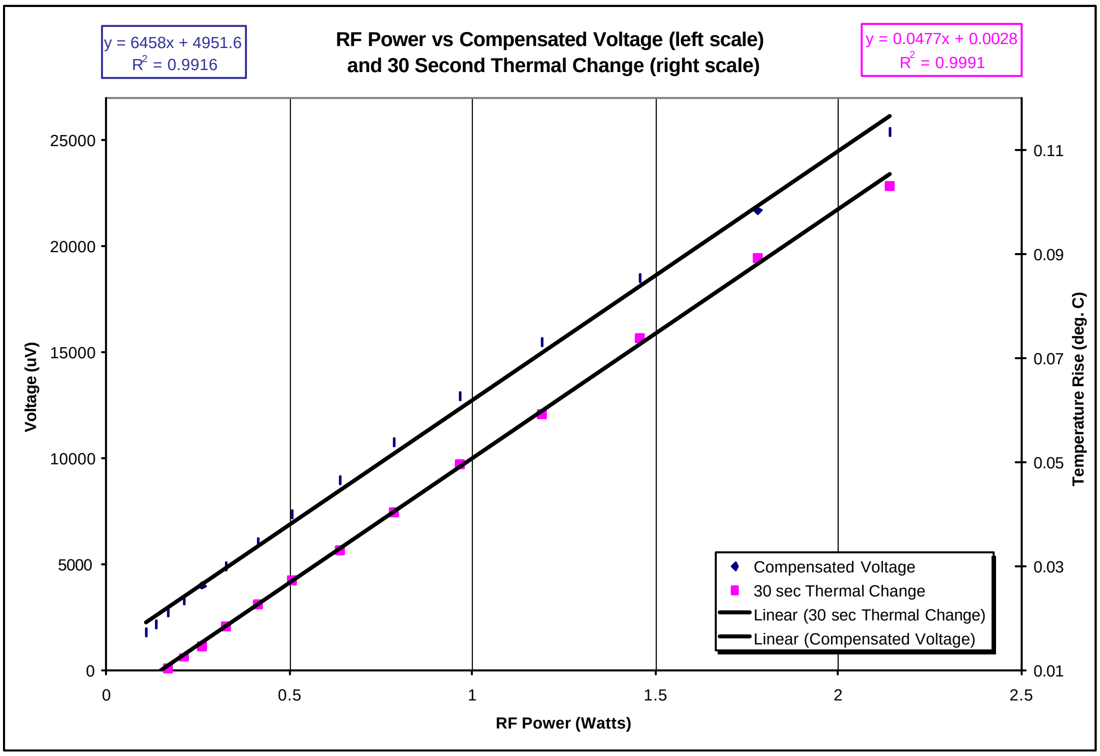
RF Power			Ch0	Ch1	Ch2	delta T (30 sec)	Sum Vi/Ei		Thermal SAR
W	dBm	R&S	uV	uV	uV	deg. C			W/kg
0.10666	20.28	-25.61	391	1196	2954	0.0093	1792.7		0.86
0.133352	21.25	-24.64	439	1440	3638	0.0086	2178		0.80
0.169044	22.28	-23.61	513	1782	4517	0.0102	2689		0.94
0.210863	23.24	-22.65	586	2173	5542	0.0125	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 (ε) 7.8



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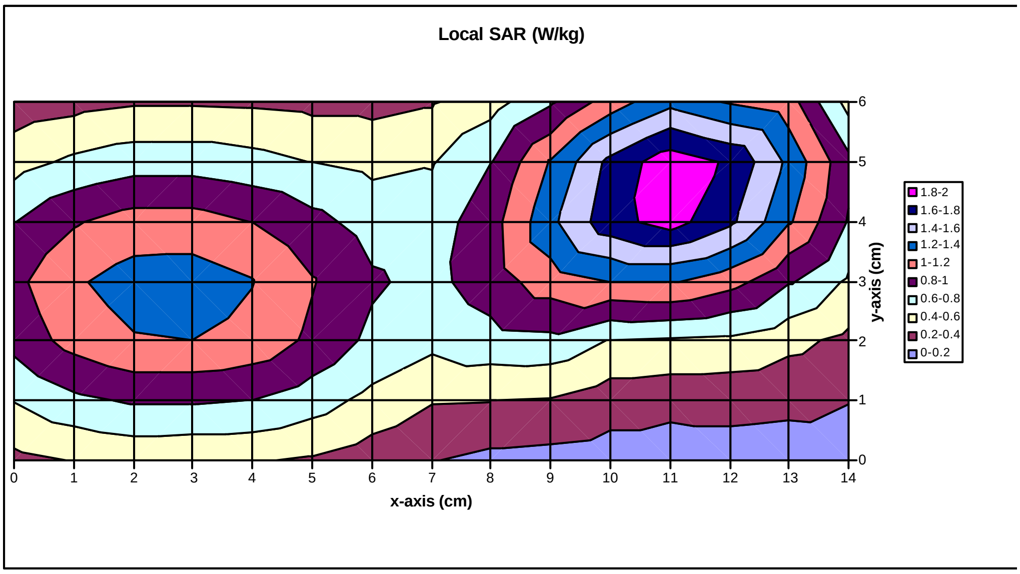
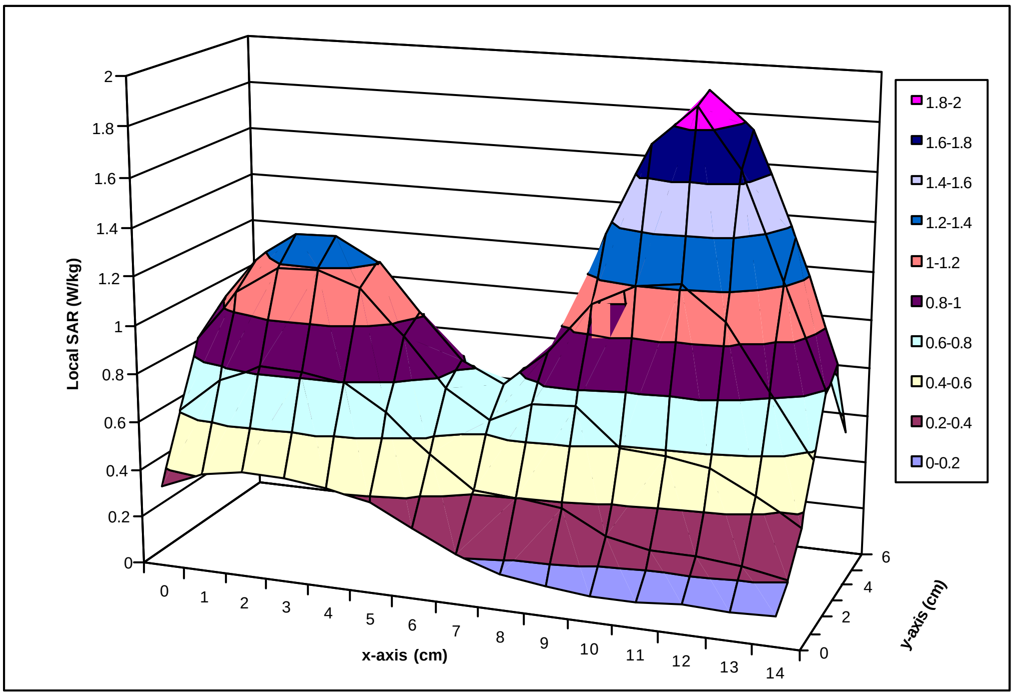
APPENDIX E

Validation Scans





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