Certification Report on

Specific Absorption Rate (SAR)
Experimental Analysis

Com-Net Ericsson

Jaguar 700P

Test Date: 18 May, 2000

CNEB-Jaguar 700P-3446

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CERTIFICATION REPORT

Subject:	**Specific Absorption Rate (SAR) Experimental Analysis**
Product:	800 MHz EDACS trunking radio
Model:	Jaguar 700P
Client:	Com-Net Ericsson Critical Radio Systems
Address:	Mountain View Road Lynchburg, VA 24501 USA
Project #:	CNEB-Jaguar 700P at Face-3446
Prepared by:	APREL Laboratories 51 Spectrum Way Nepean, Ontario K2R 1E6

Tested by Paul G Cardinal Date: 22 June 00
Paul G. Cardinal, Ph.D.

Submitted by Paul G Cardinal Date: 22 June 00
Dr. Paul G. Cardinal
Director, Laboratories

Approved by J. J. Wojcik Date: June 22/2000
Dr. Jacek J. Wojcik, P. Eng.

REGISTERED PROFESSIONAL ENGINEER PROVINCE OF ONTARIO

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

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Model: Jaguar 700P

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Address: Mountain View Road
Lynchburg, VA
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FCC ID: OWDTR0006-E
Applicant: Com-Net Ericsson Critical Radio Systems
Equipment: 800 MHz EDACS trunking radio
Model: Jaguar 700P
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 Com-Net Ericsson Critical Radio Systems 800 MHz EDACS trunking radio. The measurements were carried out in accordance with FCC 96-326. The 800 MHz EDACS trunking radio was evaluated at its maximum nominal power level, 3 W (34.8 dBm).

The 800 MHz EDACS trunking radio was tested at high, middle, and low frequencies in both of the 806-824 MHz EDACS transmit band and the 851-870 MHz talk-around transmit band with both types of antennas offered while held in front of a face phantom. The maximum SAR was found to coincide with the peak performance RF output power of the high channel in the EDACS transmit band (H1, 5, 824.9875 MHz) with the quarter-wavelength antenna. Test data and graphs are presented in this report.

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

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

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TABLE OF CONTENTS

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1. INTRODUCTION

Tests were conducted to determine the Specific Absorption Rate (SAR) of a sample of a Com-Net Ericsson Critical Radio Systems Jaguar 700P 800MHz EDACS trunking 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 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 C95.3-1992, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields – RF and Microwave.

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

3. EQUIPMENT UNDER TEST

- Com-Net Ericsson Jaguar 700P 800 MHz EDACS trunking radio, s/n 9587715, received on 17 May 2000

The 800 MHz EDACS trunking radio will be called DUT (device under test) in the following.

This is a PTT device which can operate in the frequency range 806-824 MHz EDACS transmit band and the 851-870 MHz talk-around transmit band with a maximum output power setting of 3W. One of two whip antennas may be attached to the right side of

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the device. One of the antennas is a λ/4 end fed whip, 98 mm long, while the other is a λ/2 centre fed whip, 195mm long. A photograph of the DUT and the antennas can be found in Appendix B. See the manufacturer's submission documentation for drawings and more design details.

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 DUT 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.

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6. The DUT is positioned in such a way that its front surface is 30mm from the bottom of the phantom with its top, its bottom, or its side.

7. All tests were performed with the highest power available from the sample DUT, 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 DUT will consume energy from its batteries, which may affect the DUT's 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 this DUT, the conducted power was sampled. A power meter was connected to the antenna port. The following table shows the conducted RF power sampled before and after the six sets of data used for the worst case SAR in this report.

Scan		**Conducted Power Readings (dBm)**		**D (dBm)**	**Battery #**
Type	Height (mm)	Before	After		
Area	2.5	12.18	12.13	-0.05	1
Area	12.5	12.16	12.13	-0.03	6
Zoom	2.5	12.14	-	-	2
Zoom	7.5	-	-	-	2
Zoom	12.5	-	12.09	-0.05	2
Depth	2.5 – 22.5	12.15	12.13	-0.02	3

NOTE: These readings do not include the 23.1dB of attenuation, cable and adapter losses.

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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 10 grams of tissue for the extremities and 1 gram of tissue elsewhere.

2) The DUT was put into test mode for the SAR measurements by turning it on at maximum operating power (nominally 3W) and rotating a dial beside the antenna to control the channel (initially 5, 824.9875 MHz, H1).

3) Figure 3 in Appendix A shows a contour plot of the SAR measurements for the DUT (5, 824.9875 MHz, H1 with $\lambda/4$ antenna). The presented values were taken 2.5 mm into the simulated tissue from the Universal Head-Arm's (UH-a) solid inner surface. Figures 1 and 2 in Appendix A show the UH-a used in the measurements. A grid is shown inside of the UH-a indicating the orientation of the x-y grid used, with x = 0 at the top of the channel selector knob and the DUT centred on y = 0 (Figure 2). 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 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. 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 DUT'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.

4) Wide area scans were performed for the low (14, 807.5 MHz), middle (2, 813.25 MHz) and high (5, 824.9875 MHz) channels in the 806-824 MHz EDACS transmit band and low (6, 851.0125 MHz), middle (12, 855.2625 MHz) and high (9, 869.9875 MHz) in the 851-870 MHz talk-around transmit

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band. The DUT was tested with the belt clip against the phantom and with both the λ/2 and λ/4 antennas. The peak single point SAR for the scans were:

Channel			Antenna Type	Highest SAR [W/kg]
	#	Frequency [MHz]		
Low 1	14	807.5000	λ/2	0.74
Middle 1	2	813.2500	λ/2	0.65
High 1	5	824.9875	λ/2	0.65
Low 2	6	851.0125	λ/2	0.82
Middle 2	12	855.2625	λ/2	0.67
High 2	9	869.9875	λ/2	0.64
Low 1	14	807.5000	λ/4	1.41
Middle 1	2	813.2500	λ/4	1.31
High 1	**5**	**824.9875**	**λ/4**	**1.86**
Low 2	6	851.0125	λ/4	1.38
Middle 2	12	855.2625	λ/4	1.32
High 2	9	869.9875	λ/4	1.26

All subsequent testing was performed on the H1 channel (5, 824.9875 MHz) with the λ/4 antenna.

5) The H1 channel (5, 824.9875 MHz) SAR peak was then explored on a refined 0.5 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 cube. The maximum SAR value measured averaged over 1 gram was determined from these measurements to be 1.56 W/kg.

6) To extrapolate the maximum SAR value averaged over 1 gram to the inner surface of the 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 11 in Appendix A shows the data gathered and the exponential curves fit to them. The average exponential coefficient was

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determined to be (-0.0517± 0.0016) / mm.

The distance from the probe tip to the inner surface of the 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 averaged over 1 gram that was determined previously, we obtain **the maximum SAR value at the surface averaged over 1 gram** of 1.999 W/kg.

7. DISCUSSION

The factory tolerance for setting the power level of the 800 MHz EDACS trunking radio is ±5%. The DUT could then have an absolute maximum power of 3.15W. It was determined by proportional scaling of the maximum power to 3.15W that the device would produce an estimated maximum 1g SAR of 2.10 W/kg

The most appropriate nose protrusion to use for SAR measurements is an open question. The DOD Handbook 743A defines Nose Protrusion as "the maximum anterior protrusion of the nose"; it is their dimension 137. In Table 137b they show the percentiles in centimetres for various series of measurements, a portion of which is included in the following table:

No.	Series	Percentiles in Centimeters		
		5th	95th	99th
1	US Army Men (1988)	1.5	2.3	2.4
2	USAF Basic Trainees (1965)	1.8	2.8	3.0
3	US Navy Aviators (1964)	1.9	2.7	3.0
4	USAF Flying Personnel (1950)	1.8	2.7	3.0
5	CWS Face Study (1945)	1.7	2.6	2.8
6	US Army Women (1988)	1.5	2.2	2.4

The SAR measurements reported herein have used a 30mm separation between the face simulating phantom and the DUT. This actually corresponds to 32-33mm between the DUT and the liquid head simulation when the phantom's shell thickness of 2-3mm is included (see Figure 12). This would be equivalent to 1cm in front of the tip of the nose for the average of the most recent 1988 US Army 95th percentile data, series 1 and 6.

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A series of wide area SAR scans were performed on the worst channel (channel H1, #5, 824.9875 MHz) versus the separation between the DUT and the tissue simulation. These will enable the maximum 1g SAR for a separation of 33 mm to be interpolated for other separations between the plane of the face simulation and the surface of the DUT. The peak single point SAR for each of the two peaks, one on the body of the DUT handset and the other on the antenna, for each scan were:

DUT – tissue simulation separation (mm)	Highest local SAR (W/kg)	
	DUT Body DUT	DUT Antenna
8	3.33	5.66
13	3.38	4.35
33	1.88	1.58
53	1.26	1.02

Figure 13 in Appendix A shows the data plotted as a function of separation and the curves fit to them. Note that the data obtained from the area (both peaks), zoom and depth scans (DUT body peak only) for the worst channel, reported elsewhere in this report, are also included in the figure. The 5^{th} and 95^{th} percentile nose protrusions from the DOD-Handbook data for the 1988 US Army (average of men and women) are indicated of the figure.

If the data for Figure 12 is fitted to an exponential equation we get for the DUT body data:

$$\text{Peak Local SAR (DUT body)} = 4.2166\, e^{-0.0231 * (\text{separation})}$$

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

$$\text{Maximum 1g SAR (DUT body)} = k\, e^{-0.0231 * (\text{separation})}$$

Using this equation with:

Maximum 1g SAR determined above = 2.10 W/kg
Tissue simulation – DUT separation = 33 mm

results in a k = 4.49 W/kg, which corresponds to the maximum 1g SAR when the separation is 0mm. The estimated maximum 1g SAR at a separation corresponding to the DUT touching a 5^{th} percentile nose from the 1988 US Army data would be 3.18

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W/kg, which is well below the FCC partial body limit of 8.0 W/kg for occupational or controlled exposure.

8. CONCLUSIONS

The maximum Specific Absorption Rate (SAR) averaged over 1 g, determined at 824.9875 MHz (**H1,** channel 5), for the Com-Net Ericsson Critical Radio Systems Jaguar 700P 800 MHz EDACS trunking radio, is 2.10 W/kg. Since this is a PTT device, its maximum effective duty factor is 50%, resulting in an effective maximum 1g SAR of 1.05 W/kg. The overall margin of uncertainty for this measurement is ± 12.2 % (Appendix C). The SAR limit given in the FCC 96-326 safety guideline is 8 W/kg for occupational/controlled exposure. The product under investigation will be used in an occupational/controlled environment with user training which will be indicated in the manufacturer's documentation.

Considering the above, this unit as tested, and as it will be marketed and used (with user training), is found to be compliant with this requirement.

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APPENDIX A

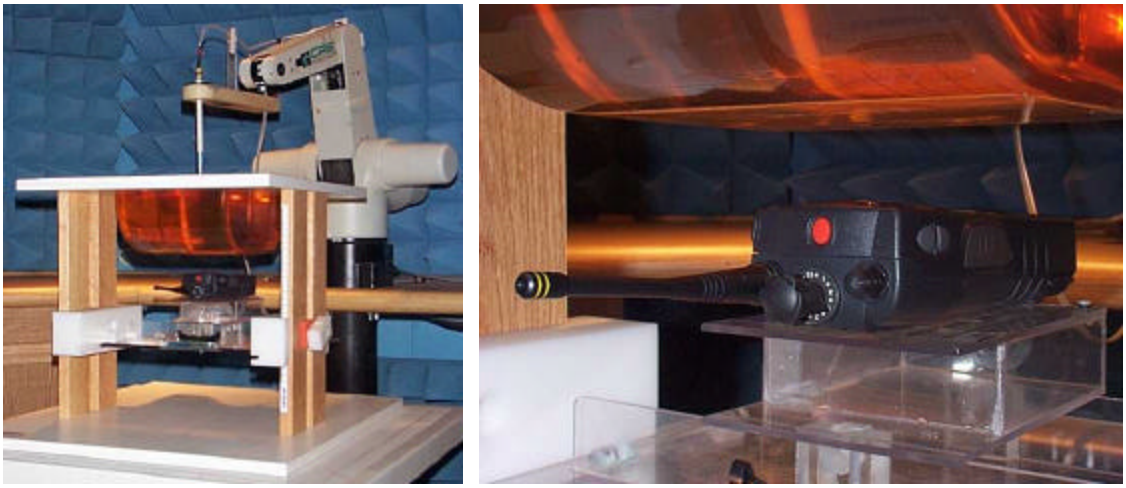

Figure 1

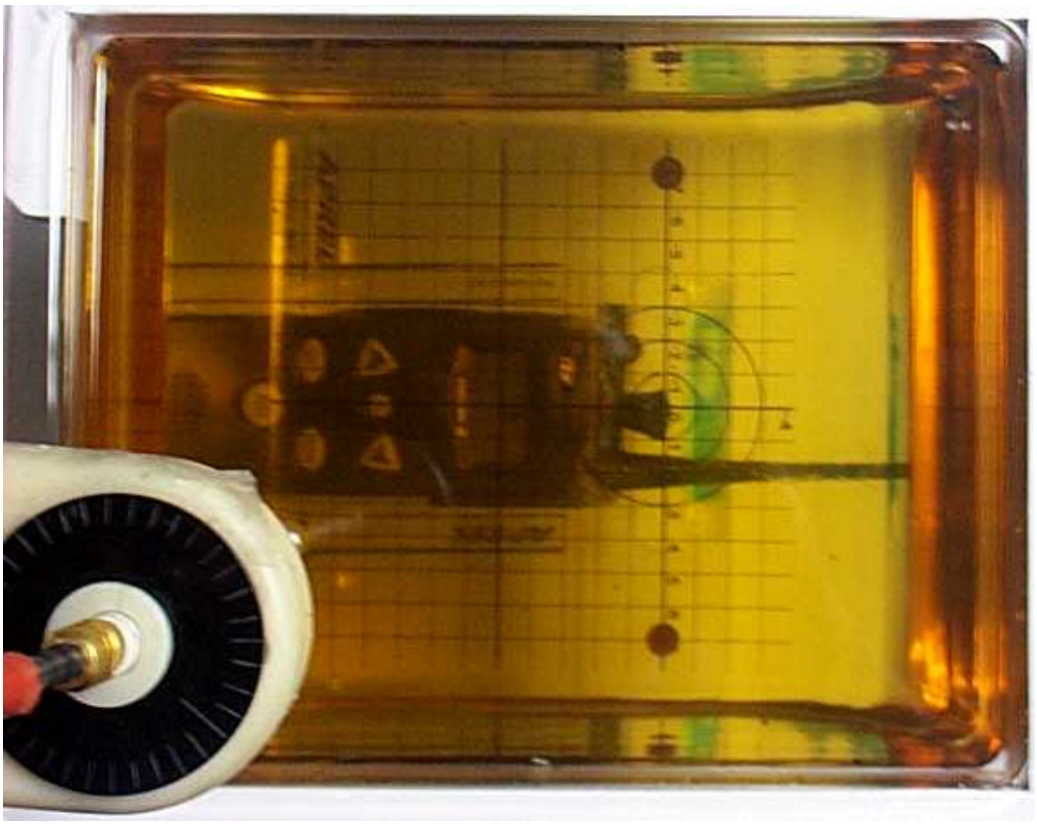

Figure 2

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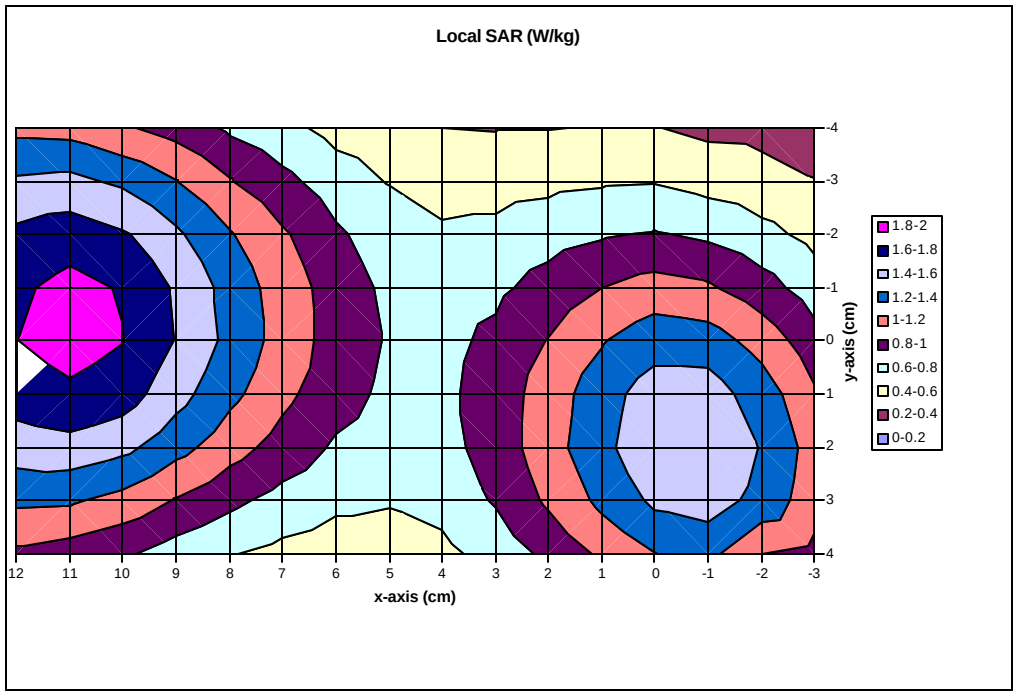

Figure 3. Area Scan 2.5mm Above Surface

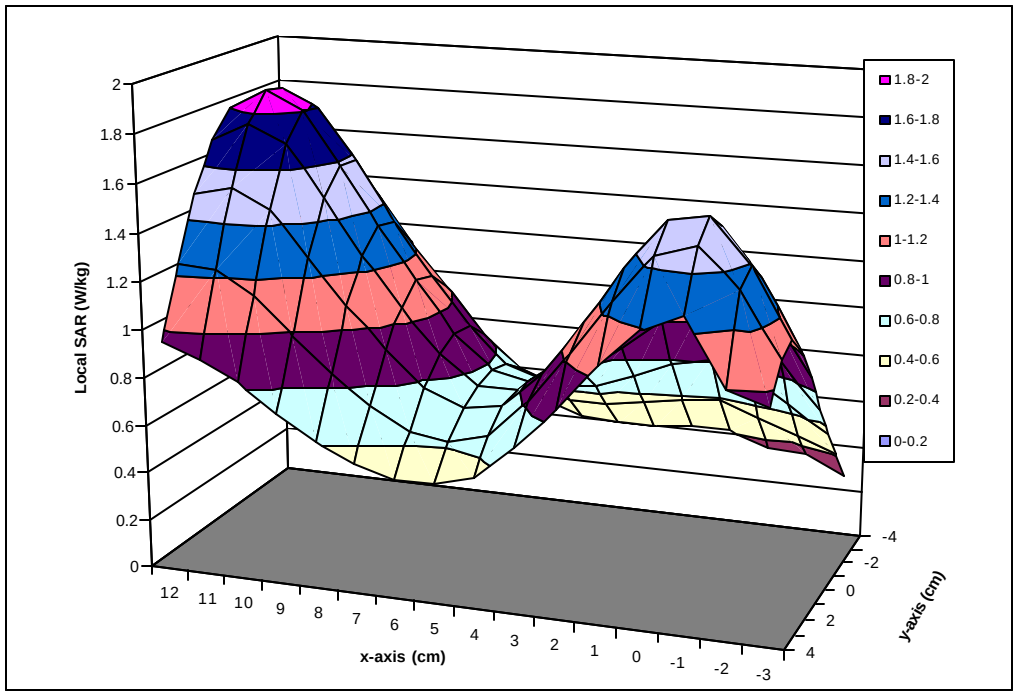

Figure 4. Area Scan 2.5mm Above Surface

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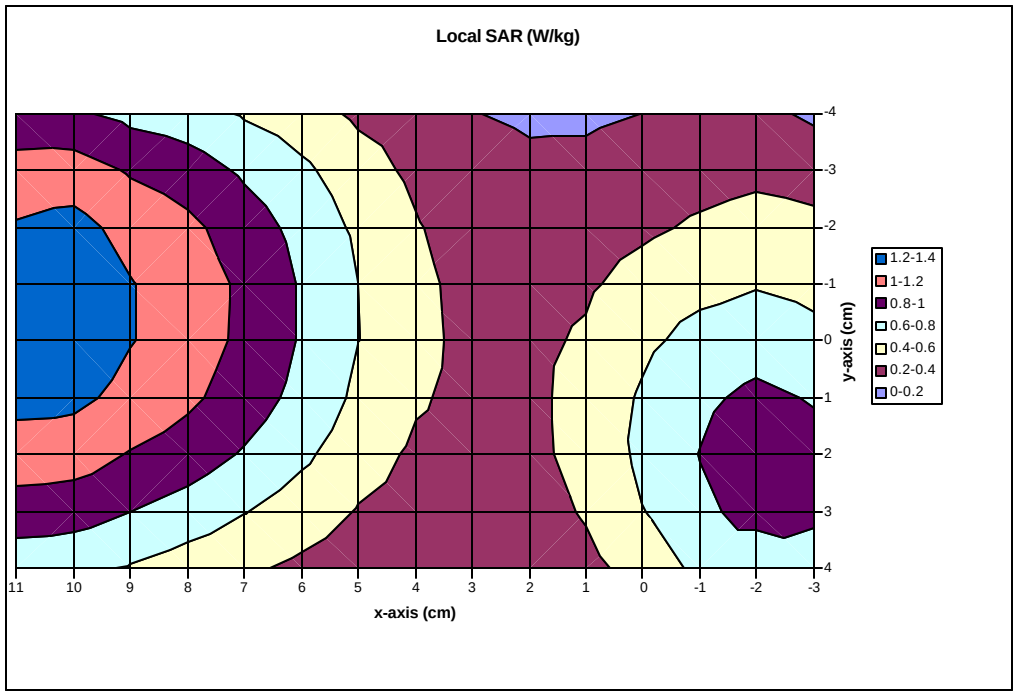

Figure 5. Area Scan 12.5mm Above Surface

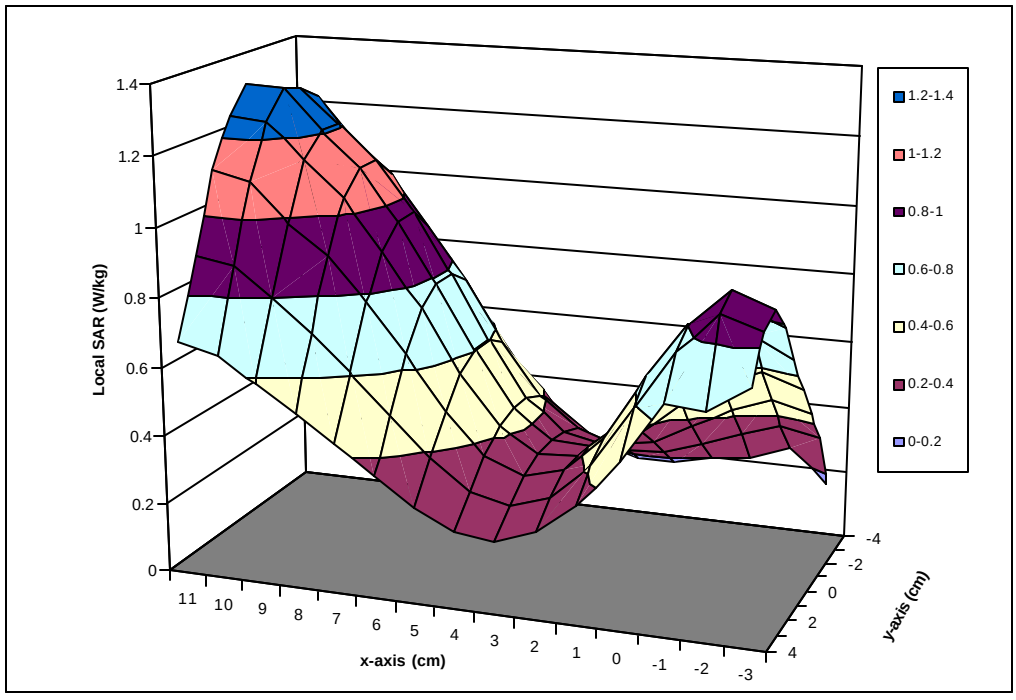

Figure 6. Area Scan 12.5mm Above Surface

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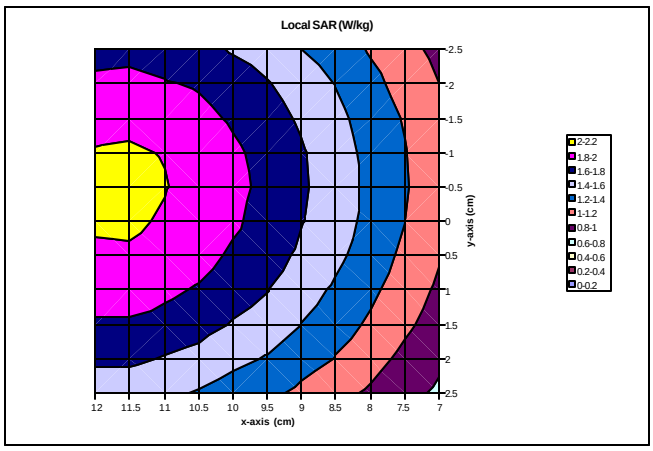

Figure 7. Zoom Scan 2.5mm Above Surface

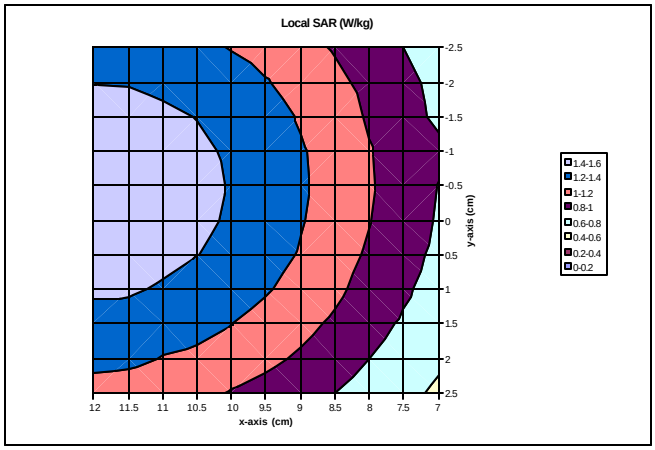

Figure 8. Zoom Scan 7.5mm Above Surface

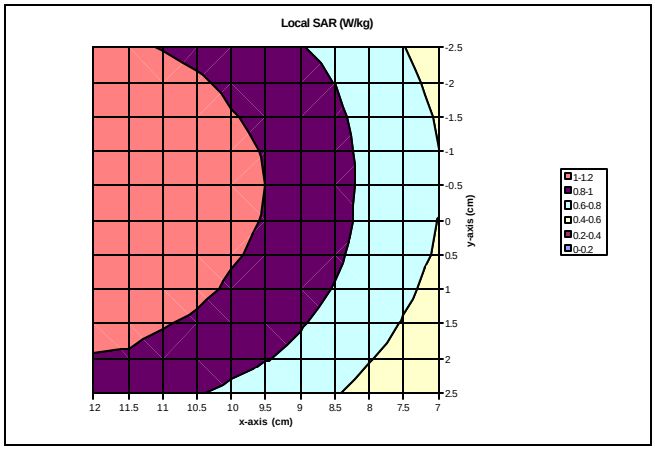

Figure 9. Zoom Scan 12.5mm Above Surface

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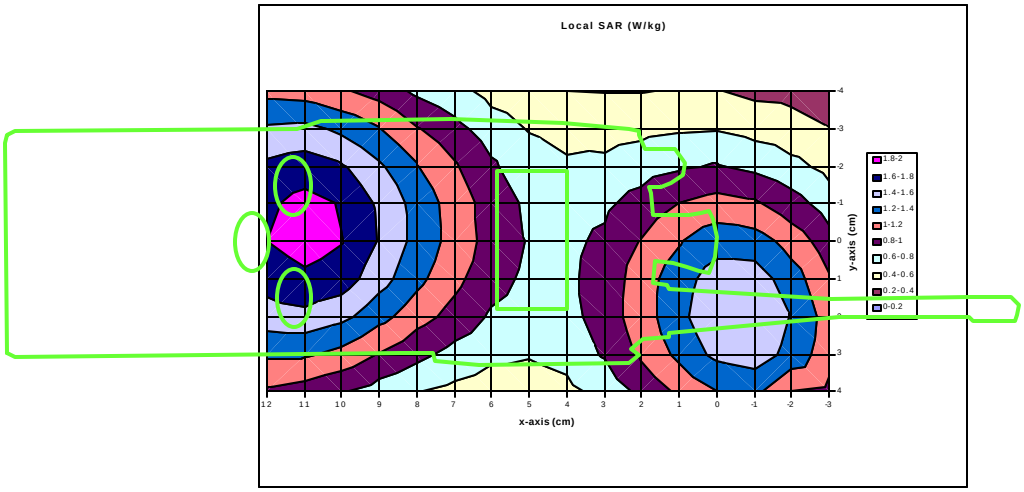

Figure 10

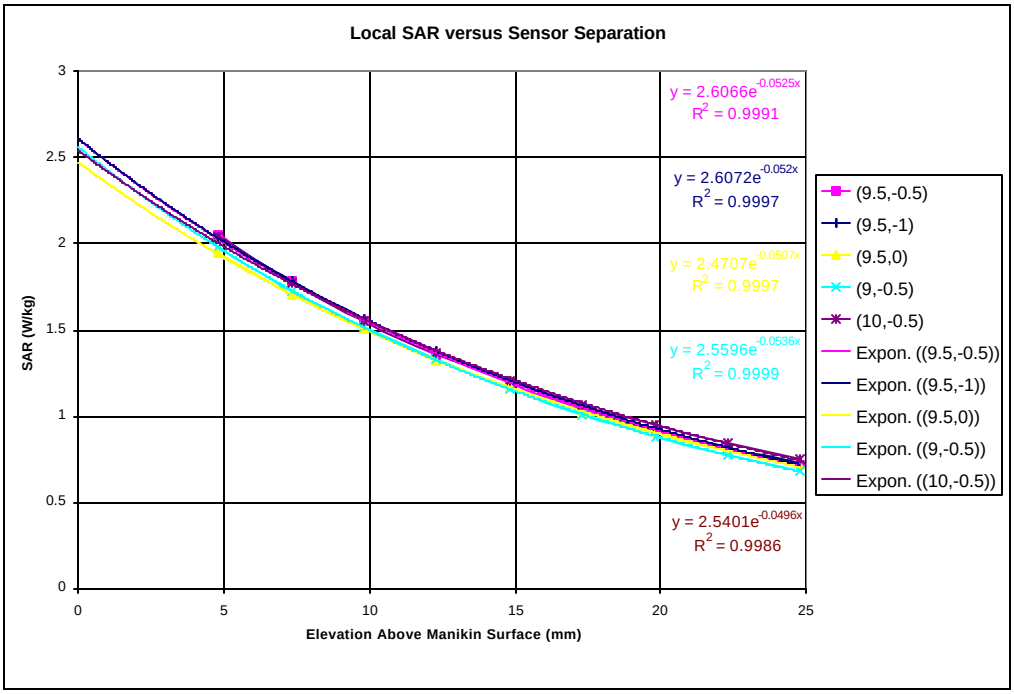

Figure 11

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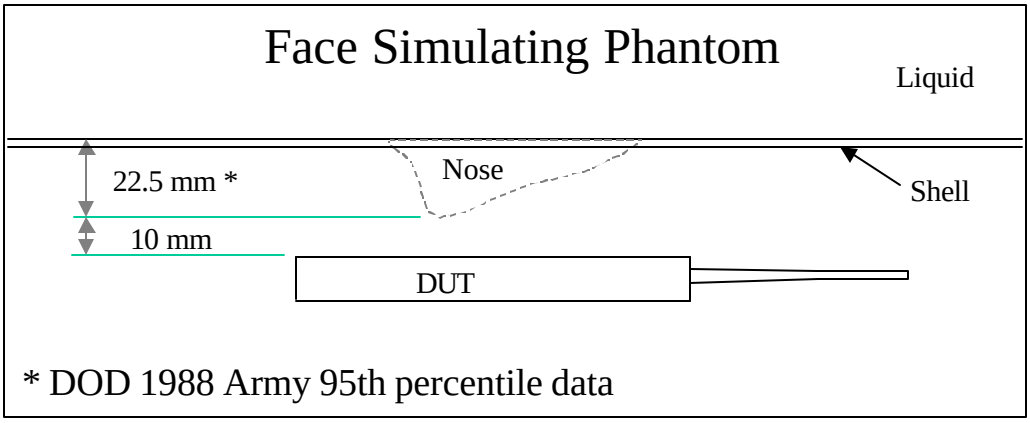

Figure 12

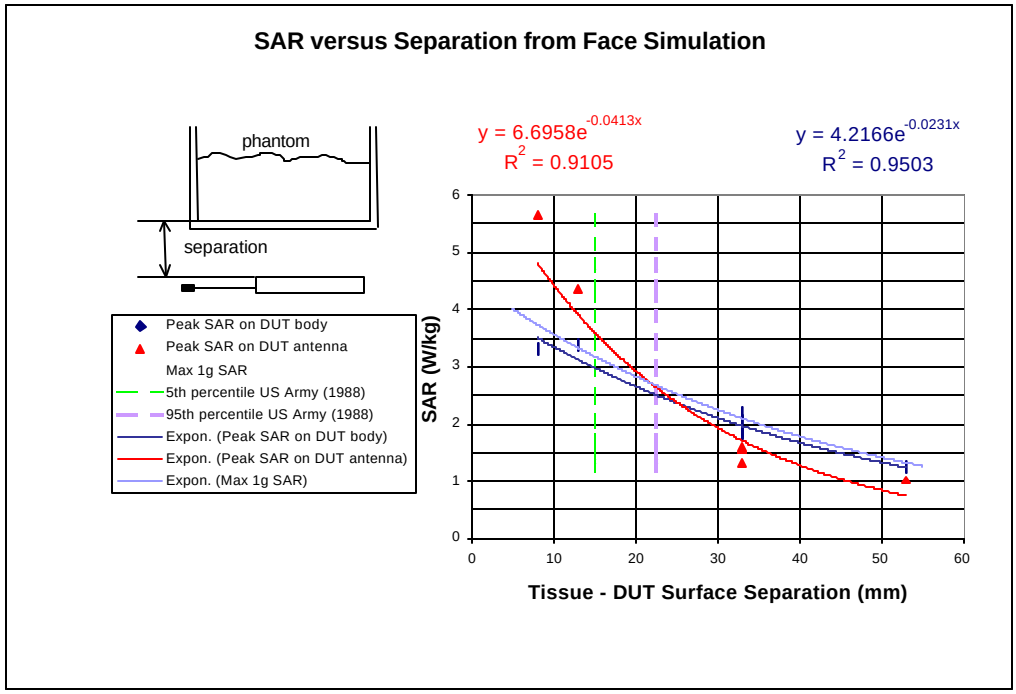

Figure 13

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APPENDIX B

Manufacturer's Antenna Specifications

Type	1/4 antenna	1/2 antenna
Type number	KRE 101 1223/01	KRE 101 1216/01
Location	right side	right side
Dimensions	length=98, ϕ=5	length=195, ϕ=10&5
Configuration	whip	whip

(See manufacturer's submission documentation for drawings and more design details)

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APPENDIX C

Uncertainty Budget

Uncertainties Contributing to the Overall Uncertainty			
Type of Uncertainty	**Specific to**	**Uncertainty**	
Power variation due to battery condition	phone	0.6%	
Extrapolation due to curve fit of SAR vs depth	phone	6.1%	
Extrapolation due to depth measurement	setup	2.5%	
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%	
		12.2%	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	40.6 %
Sugar	58.0 %
Salt	1.0 %
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 1030 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:

835MHz	APREL	OET 65 Supplement	Δ / % (OET)
Dielectric constant, ε_r	44.9	46.1	-2.5%
Conductivity, σ/ [S/m]	0.87	0.74	17.5%
Tissue Conversion Factor, γ	8.0	-	-

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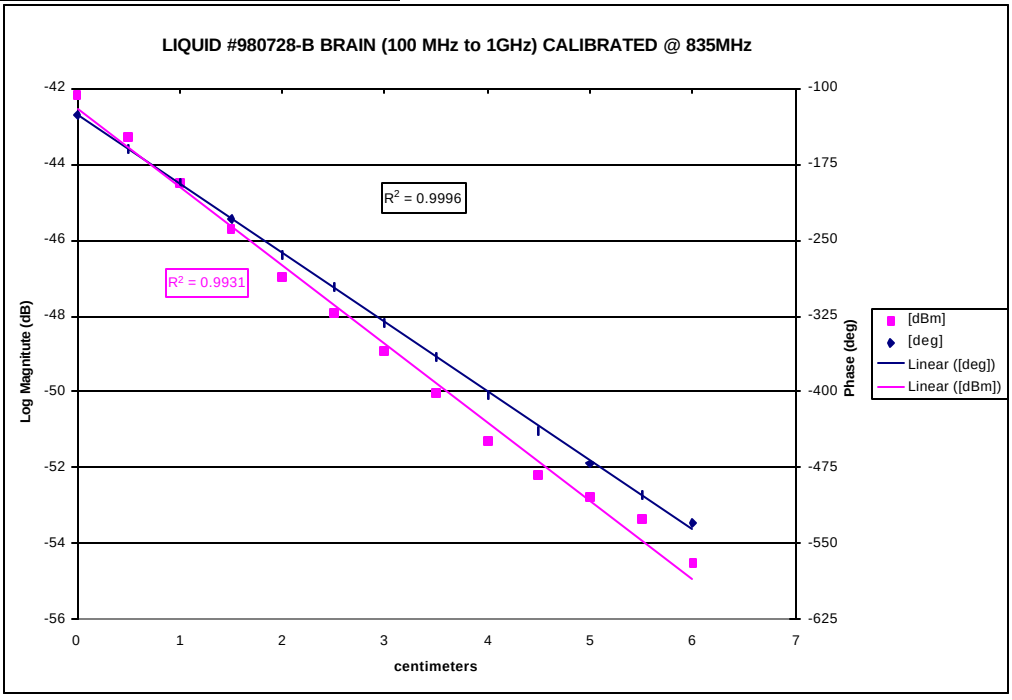
SIMULATION FLUID#	980728-B
CALIBRATION DATE	17-May-00
CALIBRATED BY	Delia Zapata
Frequency Range	100MHz-1GHz
Frequency Calibrated	835MHz
Tissue Type	BRAIN

Position [cm]	Amplitude [dBm]	Phase [deg]	[deg]
0	-42.48	-126.52	-126.52
0.5	-43.62	-160.16	-160.16
1	-44.73	165.82	-194.18
1.5	-45.07	130.91	-229.09
2	-46.53	96.121	-263.879
2.5	-47.94	63.424	-296.576
3	-48.96	28.277	-331.723
3.5	-50.81	-6.206	-366.206
4	-51.27	-43.525	-403.525
4.5	-52.84	-78.152	-438.152
5	-52.71	-111.38	-471.38
5.5	-53.65	-141.63	-501.63
6	-54.94	-170.21	-531.21
ΔdB_1	-6.778	Δdeg_1	-205.203
ΔdB_2	-6.769	Δdeg_2	-206.046
ΔdB_3	-6.804	Δdeg_3	-209.345
ΔdB_4	-6.477	Δdeg_4	-209.062
ΔdB_5	-5.818	Δdeg_5	-207.501
ΔdB_6	-5.431	Δdeg_6	-205.054
ΔdB_7	-5.568	Δdeg_7	-198.487
ΔdB_{AVG} [dB]	-6.24	$D deg_{AVG}$ [deg]	-205.814
$dB_{AVG}(\alpha_{AVG})$ [dBm]	-2.08	$deg_{AVG}(\beta_{AVG})$ [deg/m]	-686.046667
(α_{AVG}) [NP/m]	-0.239276988	(β_{AVG}) [rad/m]	-1.197377316
f [Hz]	835E+08		
μ_0 [H/m]	1.25664E-08		
ε_0 [F/m]	8.854E-14		
			ID
ε_r	44.9		-2.5%
$\sigma_{effective}$	0.87	S/m	17.5%



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835 MHz Data (Heike & Tony) Brain with E=115

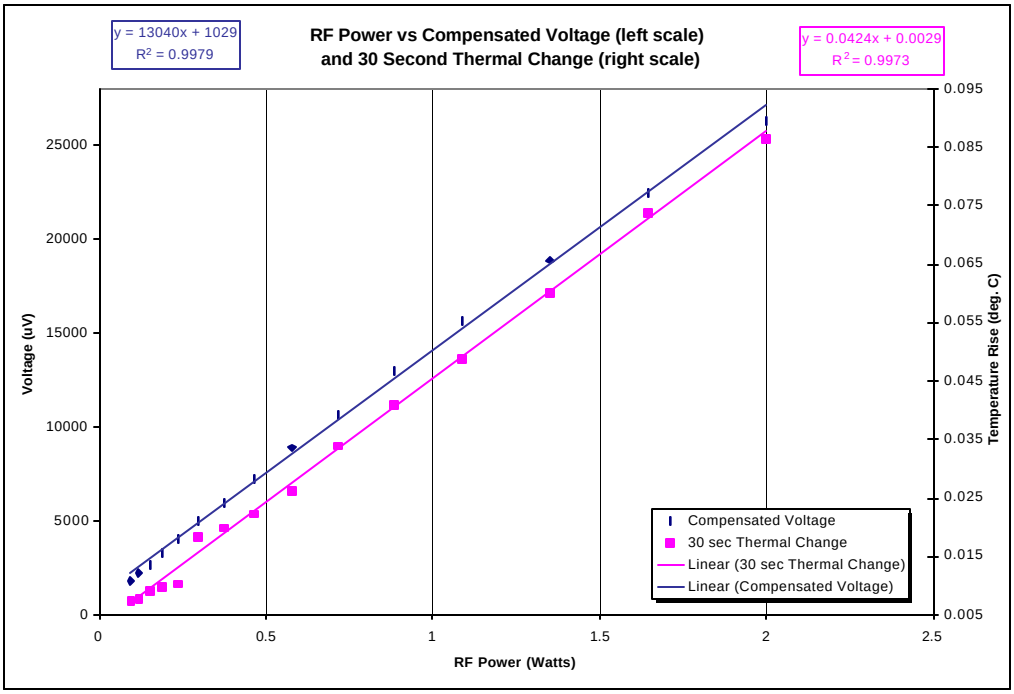
RF Power W	dBm	R&S	Ch0 uV	Ch1 uV	Ch2 uV	delta T (30 sec) deg. C	Sum V^2	Thermal SAR W/kg
0.095719	19.81	-26.08	757	1221	2588	0.0073	1804.35	0.68
0.11995	20.79	-25.1	918	1489	3174	0.0079	2199.41	0.73
0.151706	21.81	-24.08	1099	1831	3965	0.009	2720.62	0.83
0.189567	22.78	-23.11	1343	2246	4883	0.0098	3347.74	0.91
0.237132	23.75	-22.14	1611	2759	6006	0.0103	4099.86	0.95
0.296483	24.72	-21.17	1978	3394	7373	0.0185	5035.62	1.71
0.37325	25.72	-20.17	2437	3516	8911	0.0199	5958.42	1.84
0.463447	26.66	-19.23	3198	4272	10815	0.0223	7232.41	2.06
0.578096	27.62	-18.27	3955	5273	13281	0.0262	8803.12	2.42
0.716143	28.55	-17.34	4517	6239	16016	0.0339	10611.9	3.14
0.88309	29.46	-16.43	5335	7313	19263	0.0408	13016.8	3.77
1.086428	30.36	-15.53	7080	9473	23022	0.0487	15652.1	4.50
1.348963	31.3	-14.59	8643	11548	27588	0.0601	18996.3	5.56
1.644372	32.16	-13.73	10400	13818	32495	0.0739	22429.3	6.84
1.993863	33.01	-12.88	12354	16357	37866	0.0866	26329.5	8.01

Directional Coupler factor 25.89 dB (Asset 100251 cable data (Janusz, 21 JUL 96))
Additional inline attenuation 20 dB

Sensitivity (e) 1.668 1.721 1.68 - Sensor Sensitivity in mV/(mW/cm²)
η=1/2*e 2.487 2.5815 2.52

Density	1.3	g/cm³	1300	kg/m³	- Tony, summer 99
Conductivity	0.9	mS/cm	0.89	S/m	- Heike & JUL 99
Heat Capacity (c)	2.75	J/C/g	2.75	J/C/kg	
Exposure Time	30	seconds	30	seconds	
Slope of Measure Voltage (m)	13.040	uV/W	0.01304	V/W	
- standard error of m)	1.67424	uV/W	0.00017	V/W	1.3%
Slope of Measure Temp Change (m)	0.04244	C/W	0.04244	C/W	
- standard error of m)	0.00061	C/W	0.00061	C/W	1.4%

Tissue Conversion Factor (F)	8.0



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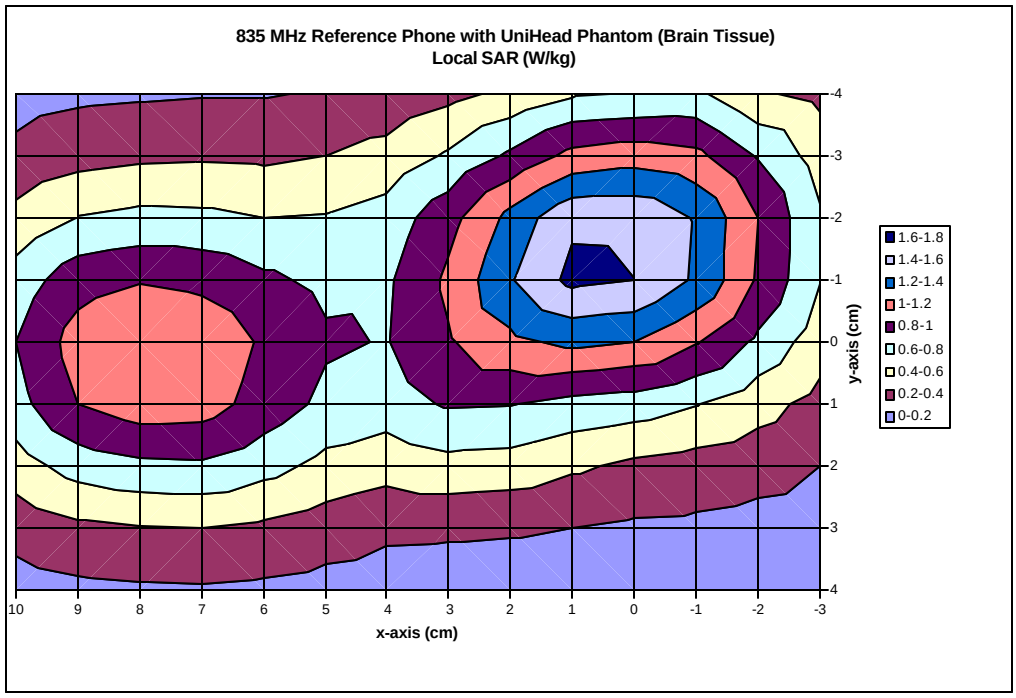
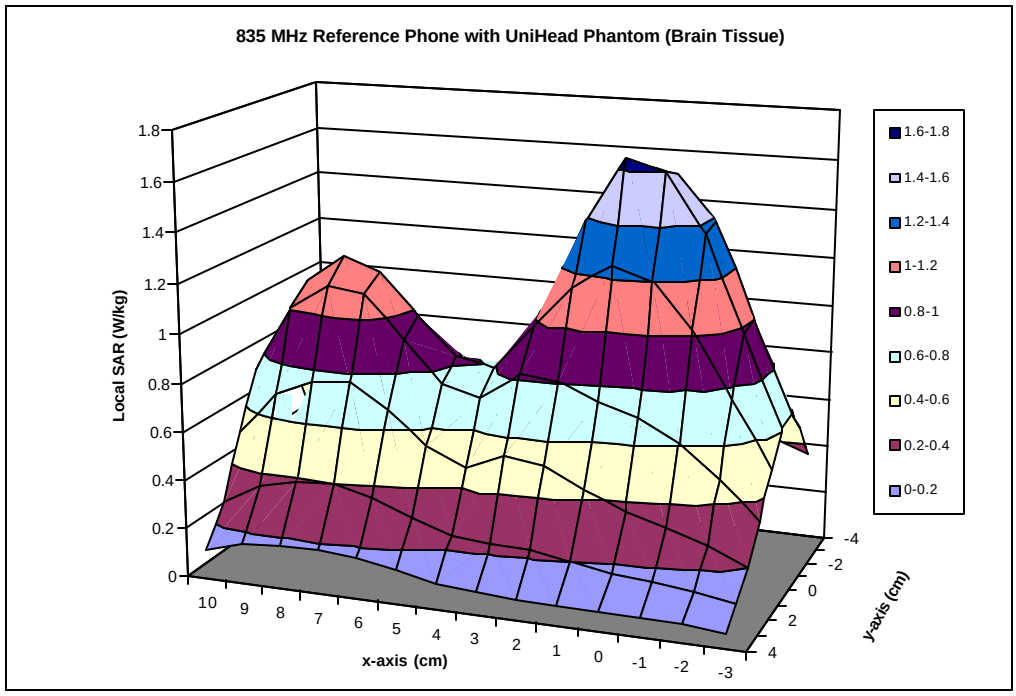
APPENDIX E

Validation Scans





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