MEASUREMENT/TECHNICAL REPORT

Technologies Corporation
EMC Test Laboratory
Cedar Rapids, IA

Intermec Technologies Corporation
700 With Novatel CDPD
Cellular Radio Module

REPORT NO: 20010830-1

DATE: August 30, 2001

APPENDIX H

APREL LABORATORIES, SAR TEST REPORT

Certification Report on

Specific Absorption Rate (SAR)
Experimental Analysis

Intermec Technologies Corporation

Handheld PC
Intermec 700 with Novatel CDPD Modem

Test Date: August 2001

ITCC-Intermec 700 w. Novatel CDPD-3782

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INVESTIGATIVE SAR REPORT

Subject: **Specific Absorption Rate (SAR) Hand and Bystander Report**

Product: Handheld PC

Model: Intermec 700 with Novatel CDPD Modem

Client: Intermec

Address: 550 Second Street S.E.
Cedar Rapids, IA
52401

Project #: ITCC-Intermec 700 w. Novatel CDPD-3782

Prepared by APREL Laboratories
51 Spectrum Way
Nepean, Ontario
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Approved by _____ Date: 19 SEPTEMBER 2001
Stuart Nicol
Director Product Development, Dosimetric R&D

Submitted by _____ Date: Sept. 19, 2001
Jay Sarkar
Technical Director of Standards & Certification

Released by _____ Date: Sept 19/2001
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FCC ID: EHANOVCDPD
Applicant: Intermec
Equipment: Handheld PC
Model: Intermec 700 with CDPD Modem
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 the an Intermec 700 Handheld PC with CDPD Modem in support of a FCC grant application. The measurements were carried out in accordance with FCC 96-326. The Device Under Investigation (DUI) was evaluated for its maximum power level 66.7 mW (ERP). The duty cycle of the device was set at 100%.

The DUI was tested at low, middle and high channels for the CDPD network frequency range 824.04 MHZ to 848.97 MHz . The maximum 10g SAR (1.78 W/kg) was found to coincide with the peak performance RF output power of channel 991 low (824.04 MHz) for the keyboard down side of the device. (The hot spot is located near the base of the antenna).

At a separation distance of 11.2 mm from the backside of the device, the 1g SAR is 1.19 W/Kg. In the operational manual will be a warning stating that bystanders and parts of the user's body other than extremities, must be at least 11.2 mm away from the back side of the device. Test data and graphs are presented in this report.

Based on the test results and on how the device will be marketed and used, it is certified that the product meets the requirements as set forth in the above specifications, for RF exposure environment in relation to SAR and the required limiting values.

Additional Comment

It has been noted that the ERP measured was low and thus does not fulfill the requirements of the FCC, and APREL acknowledge that an increase of ERP will lead to a more conservative measured SAR value for the product tested.

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TABLES AND FIGURES

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1. INTRODUCTION

Tests were conducted to determine the Specific Absorption Rate (SAR) for a sample Intermec 700 with 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 2. This report describes the results obtained.

2. APPLICABLE DOCUMENTS

The following documents are applicable to the work performed:

1) FCC 96-326, Guidelines for Evaluating the Environmental Effects of Radio-Frequency Radiation

2) ANSI/IEEE C95.1-1999, 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 Supplement C (Edition 01-01), "Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields".

3. DEVICE UNDER INVESTIGATION

- Intermec 700, s/n 4734165, received on Aug 21, 2001.

The Intermec 700 will be called DUI (Device Under Investigation) in the following test report.

The manufacturer's original submission documentation contains all the necessary drawings and applicable design details.

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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
- Tissue Recipe and Calibration Requirements, APREL procedure SSI/DRB-TP-D01-033
- APREL flat Phantom F1 (overall shell thickness 3mm)
- Anritsu Spectrum Analyser, Asset # 100479

5. TEST METHODOLOGY

1. The test methodology utilized in the certification of the DUI 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 muscle tissue. Appendix A contains information about the properties of the simulated tissue used during the measurement process.
5. The liquid is contained in a manikin simulating a portion of the human body with an overall shell thickness of 3 mm.
6. The DUI is positioned with the surface under investigation against the phantom.
7. All tests were performed with the highest power available from the sample DUI under transmit conditions.

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

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6. TEST RESULTS

6.1. TRANSMITTER CHARACTERISTICS

The battery-powered DUI will consume energy from its batteries, which may affect the DUI's transmission power characteristics. In order to gage this effect the output of the transmitter is generally sampled before and after each SAR test. In the case of this DUI, the Tx power was sampled through out the test process. The following table shows the RF power sampled before and after each of the seven sets of data used for the worst case SAR in this report.

Note

The power measurement is not conducted and only relative to a true pin on pin conducted measurement. A spectrum analyzer was connected to an antenna and set to measure the frequency for which the device was transmitting. This allows the technician to monitor possible drift in power during the test process, and as a result assess the delta if any.

Scan		**Power Readings (dBm)**		**D**	**Battery #**
Type	**Height (mm)**	**Before**	**After**	**(dB)**	
Area	2.5	-49.51	-49.71	0.2	1
Zoom	2.5	-49.51	-49.71	0.2	2
Zoom	7.5	-49.51	-49.71	0.2	2
Zoom	12.5	-47.31	-47.66	0.35	1
Zoom	17.5	-47.31	-47.66	0.35	1
Zoom	22.5	-47.31	-47.66	0.35	1
Depth	2.5 – 22.5	-49.52	-49.61	0.09	3

Table 1. Sampled RF Power

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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. 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 DUI was put into test mode for the SAR measurements by application software imbedded in the DUI. Manufacturer supplied commands were used to control the channel and transmit power.

3) Figure 3 in Appendix A shows a contour plot of the SAR measurements for the DUI (channel 991, 824.04 MHz). It also shows an overlay of the DUI's outlines, superimposed onto the contour plot

   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 visualization aid.

4) Wide area scans were performed for the low, middle and high channels of the DUI. The DUI was operating at maximum output power 66.7 mW (ERP) with the duty factor set at 100%. The DUI was placed in close proximity of the phantom for the keyboard up, keyboard down, left, and right sides. The phantom shell thickness is 3 mm overall.

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DUI Side	Antenna Distance to Phantom (mm)	L/M/H	Channel #	Freq (MHz)	Peak Local SAR (W/Kg
Keyboard down side	15	Low	991	824.04	2.33
Keyboard down side	15	Middle	367	836.01	2.31
Keyboard down side	15	High	799	848.97	2.18
Right side	25	Low	991	824.04	0.56
Left side	70	Low	991	824.04	0.17
Keyboard up side	35	Low	991	824.04	0.09

Table 2. SAR Measurements

7. USER'S HAND EXPOSURE

All subsequent testing for user's hand exposure was performed on channel 991 (824.04 MHz), with the keyboard down side of the DUI facing up against the bottom of the phantom. This relates to the position and frequency found to provide the maximum measured SAR value.

1) Channel 991 (824.04 MHz) was then explored on a refined 5 mm grid in three dimensions. The SAR value averaged over 10 grams was determined from these measurements by averaging the 125 points (5x5x5) comprising a 2 cm cube. The maximum SAR value measured averaged over 10 grams was determined from these measurements to be 1.27 W/kg.

2) To extrapolate the maximum SAR value averaged over 10 grams to the inner surface of the phantom a series of measurements were made at five (x,y) co-ordinates within the refined grid as a function of depth, with 2.5 mm spacing. The average exponential coefficient was determined to be (-0.070 ± 0.002) mm.

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3) 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 10 grams that was determined previously, we obtain the **maximum SAR value at the surface averaged over 10 grams, 1.78 W/kg.**

8. BYSTANDER EXPOSURE

All subsequent testing for bystander exposure was performed on channel 991 (824.04 MHz), with the keyboard down side of the DUI facing up against the bottom of the phantom. This relates to the position and frequency found to provide the maximum measured SAR value.

1) Channel 991 (824.04 MHz) was also explored on a refined 5 mm grid in three dimensions. 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 1.80 W/kg.

2) 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 five (x,y) co-ordinates within the refined grid as a function of depth, with 2.5 mm spacing. The average exponential coefficient was determined to be (-0.070 ± 0.002) mm.

3) 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, 2.51 W/kg**.

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4) Wide area scans were then performed for channel 991 (824.04 MHz) versus DUI separation from the bottom of the phantom. The peak single point SAR for the scans were:

DUI to phantom separation (mm)	**Highest Local SAR (W/kg)**
10	0.77
20	0.33
30	0.17

Table 3. SAR versus DUI-Phantom Separation

The measurements of highest local SAR versus separation of the DUI from the bottom of the phantom can be used to determine the SAR exposure of the bystander during operation of the DUI.

If the data for Figure 4 is fitted to an exponential equation we get:

$$\text{Peak Local SAR} = 3.1421\, e^{*-0.0928\ (\text{separation})}$$

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

$$\text{Maximum 1g SAR} = k\, e^{*\ -0.0928\ (\text{separation})}$$

Using this equation with the previous data:

Maximum 1g SAR at the surface = 2.51 W/kg
Tissue to DUI separation = 3 mm

Results in k = 3.32 which corresponds to the maximum 1g SAR when the separation is 0 mm. A conservative maximum 1g SAR of 1.19 W/kg (1.6 W/kg reduced by our measurement uncertainty, 13.1 %) would occur for a separation of 11.2 mm from the antenna of the DUI.

At a standard separation distance of 4 cm, the maximum 1g SAR would be 0.08 W/kg.

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9. CONCLUSIONS

The maximum Specific Absorption Rate (SAR) for the hand averaged over 10 grams, determined at 824.04 MHz (channel 991) of the Intermec 700 handheld PC, is **1.78 W/kg**. The overall margin of uncertainty for this measurement is 26.7% K=2 (Appendix B). The SAR limit given in the FCC 96-326 Safety Guideline is 4 W/kg for hand exposure for the general population.

For a user exposing a part of the body other than the extremities, at a separation distance of 4 cm from the device, **the maximum Specific Absorption Rate (SAR) averaged over 1g is 0.08 W/kg**. The SAR limit given in the FCC 96-326 Safety Guideline is 1.6 W/kg for uncontrolled partial body exposure of the general population. The minimum separation distance that will ensure that the limit is not exceeded is 11.2 mm.

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

Tested by _____ Date Aug. 21, 2001

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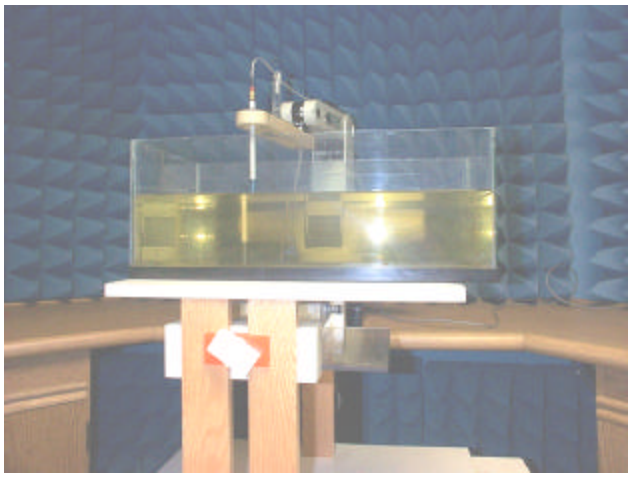
APPENDIX A. Measurement Setup, Tissue Properties and SAR Graphs



Figures 1 & 2. Setup

Simulated Tissue Material and Calibration Technique

The mixture used was based on that presented SSI/DRB-TP-D01-033, "Tissue Recipe and Calibration Requirements". The density used to determine SAR from the measurements was the recommended 1000 kg/m^3 found in Appendix C of Supplement C to OET Bulletin 65, Edition 01-01).

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

	APREL	Target values	Δ (%)
Dielectric constant, ε_r	52.2	52	0.3 %
Conductivity, σ [S/m]	1.04	1.1	-5.4%
Tissue Conversion Factor, γ	6.7	-	-

Table 4. Dielectric Properties of the Simulated Muscle Tissue at 835 MHz

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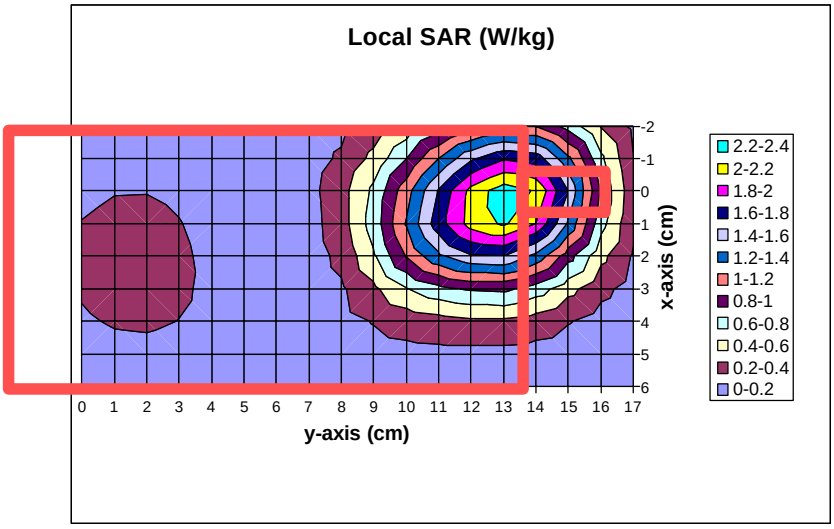

Figure 3. Contour Plot of Area Scan 2.5mm Above Phantom Surface

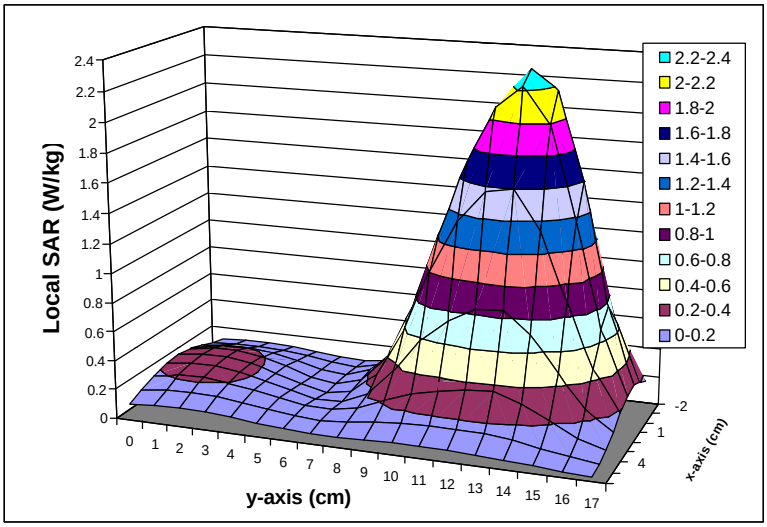

Figure 4. Surface Plot of Area Scan 2.5mm Above Phantom Surface

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APPENDIX B. Uncertainty Budget

Calculated Uncertainties Type of Uncertainty	Specific to	Uncertainty
Power variation due to battery condition	DUI	6.5%
Extrapolation due to curve fit of SAR vs depth	Setup	3.0%
Extrapolation due to depth measurement	Setup	4.8%
Conductivity	Setup	5.4%
Permitivity	Setup	0.3%
Probe Calibration	Setup	6.5%
Probe Positioning	Setup	2.0%
Probe Isotropicity	Setup	3.5%
Other Setup Uncertainty (Ambient,,,)	Setup	3.0%
	Expanded Uncertainty	
	26.2% K=2	

Table 5. Uncertainty Budget (Hand & Bystander)

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APPENDIX C. Dipole Validation Scan on a Flat Phantom

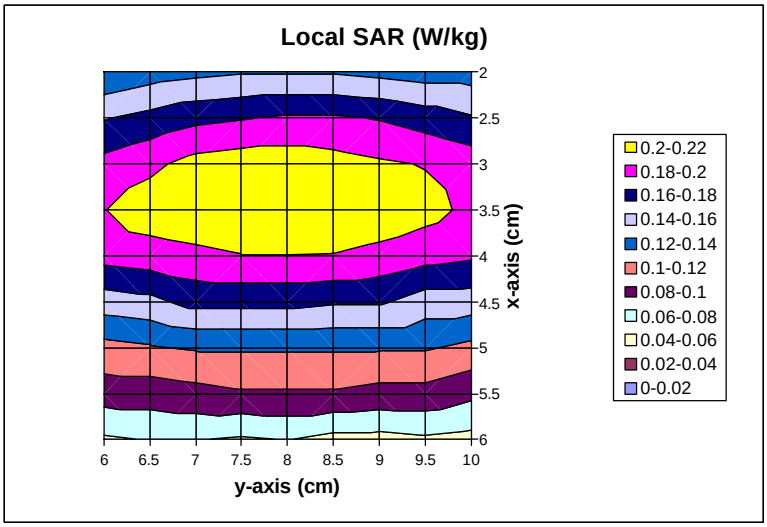

Figure 5. Surface Plot for Validation Dipole (Area Scan 2.5mm Above Phantom)

Frequency (MHz)	1 Gram SAR (W/Kg)	Target Value (W/Kg)	Delta (%)	Input Power to Dipole (mW)	Distance from Dipole to Tissue (mm)
835	0.21	0.19	+9.52%	20.33	15

Figure 6. Validation Dipole Under Phantom

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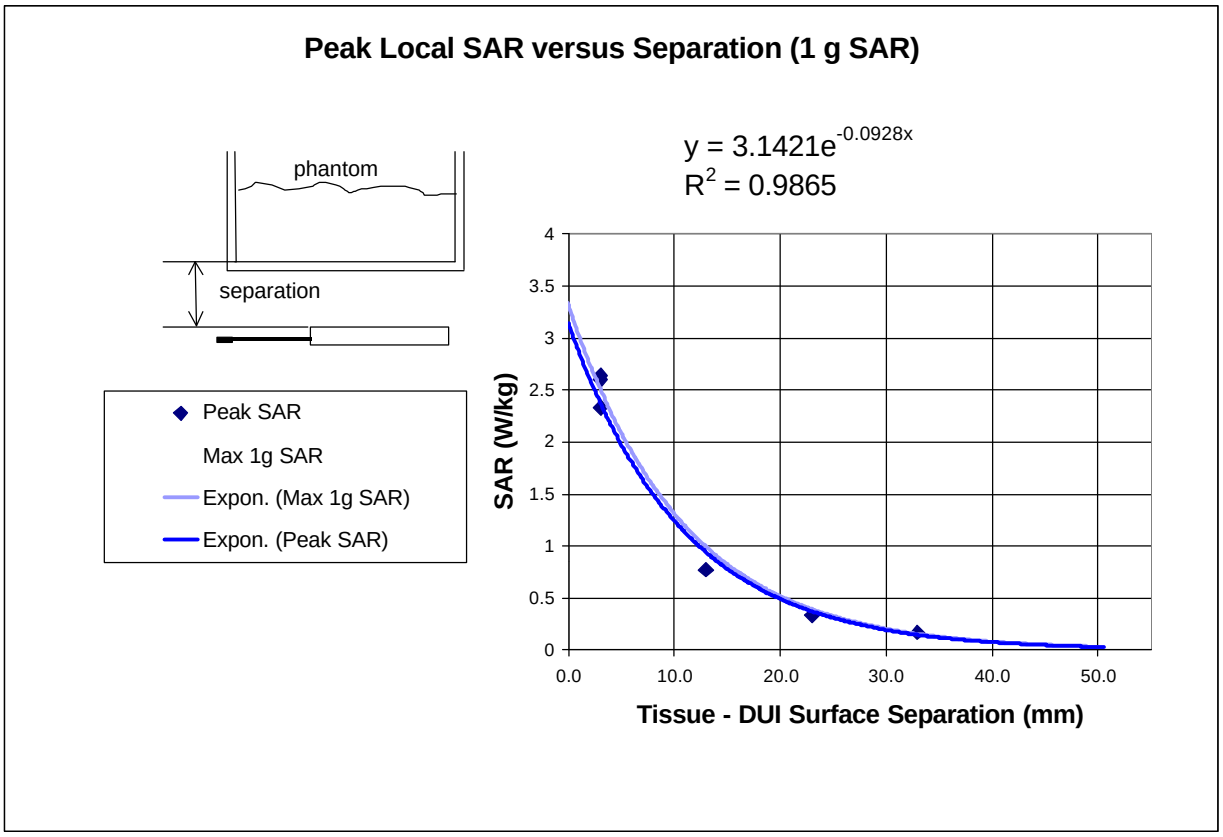

Figure 7. Peak Local SAR versus DUI Separation

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APPENDIX D. Probe Calibration

NCL CALIBRATION LABORATORIES

Calibration File No.: 301420

CERTIFICATE OF CALIBRATION

It is certified that the equipment identified below has been calibrated in the **NCL CALIBRATION LABORATORIES** by qualified personnel following recognized procedures and using transfer standards traceable to NRC/NIST.

Equipment: Miniature Isotropic RF Probe

Manufacturer: APREL Laboratories/IDX Robotics Inc
Model No.: E-009
Serial No.: 115

Customer: APREL
Asset No.:301420

Calibration Procedure: SSI/DRB-TP-D01-032

Cal. Date: 9 November, 2000 Cal. Due Date: 8 November, 2001
Remarks: None

Calibrated By: _____

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