5.0 SET UP

5.1 ALIDX-500 Measurement System

The image below shows the laboratory along with the ALIDX-500 Measurement system.

The ALIDX-500 Dosimetric SAR Measurement System was developed jointly with APREL Laboratories and IDX Robotics for use within wireless development and the compliance environment. The system consists of a six axis articulated arm, and controller for precise probe positioning (0.05 mm repeatability). Custom software has been developed to enable communications between the robot controller software and the host operating system.

An amplifier is located on the articulated arm, which is isolated from the custom designed end effector and robot arm. The end effector provides the mechanical touch detection functionality and probe connection interface. The amplifier is functionally validated within the manufacturers site and calibrated at NCL Calibration Laboratories. A Data Acquisition Card (DAC) is used to collect the signal as detected by the isotropic e-field probe. The DAC manufacturer calibrates the DAC to NIST standards. A formal validation is executed using all mechanical and electronic components to prove conformity of the measurement platform as a whole.

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

The ALIDX-500 has been designed to measure devices within the compliance environment to meet all recognized standards. The system also conforms to standards, which are currently being developed by the scientific and manufacturing community.

The course scan resolution is defined by the operator and reflects the requirements of the standard to which the device is being tested. Precise measurements are made within the predefined course scan area and the values are logged.

The user predefines the sample rate for which the measurements are made so as to ensure that the full duty-cycle of a pulse modulation device is covered during the sample. The following algorithm is an example of the function used by the system for linearization of the output for the probe.

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

The APREL E-Field probe is evaluated to establish the diode compression point.

A complex algorithm is then used to calculate the values within the measured points down to a resolution of 1mm. The data from this process is then used to provide the co-ordinates from which the cube scan is created for the determination of the 1 g and 10 g averages.

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

Cube scan averaging consists of a number of complex algorithms, which are used to calculate the one, and ten gram averages. The basis for the cube scan process is centered on the location where the maximum measured SAR value was found. When a secondary peak value is found which is within 60% of the initial peak value, the system will report this back to the operator who can then asses the need for further analysis of both the peak values prior to the one and ten-gram cube scan averaging process. The algorithm consists of 3D cubic Spline, and Lagrange extrapolation to the surface, which form the matrix for calculating the measurement output for the one and ten gram average values. The resolution for the physical scan integral is user defined with a final calculated resolution down to 1mm.

In-depth analysis for the differential of the physical scanning resolution for the cube scan analysis has been carried out, to identify the optimum setting for the probe positioning steps, and this has been determined at 8mm increments on the X, & Y planes. The reduction of the physical step increment increased the time taken for analysis but did not provide a better uncertainty or return on measured values.

Prior to the measurement process the operator can insert the parameters for which the physical measurements are made, defining the X, Y, and Z probe movement integrals. For the FCC compliance process both OET 65 “Supplement C” and the IEEE 1528 were used to define the measurement parameters used during the assessment of the device.

The final output from the system provides data for the area scan measurements, physical and splined (1mm resolution) cube scan with physical and calculated values (1mm resolution).

The overall uncertainty for the methodology and algorithms the ALIDX500 used during the SAR calculation was evaluated using the data from IEEE 1528 f3 algorithm:

$$f_3(x, y, z) = A \frac{a^2}{\frac{a^2}{4} + x'^2 + y'^2} \cdot \left(e^{-\frac{2z}{a}} + \frac{a^2}{2(a + 2z)^2} \right)$$

The probe used during the measurement process has been assessed to provide values for diode compression. These values are calculated during the probe calibration exercise and are used in the mathematical calculations for the assessment of SAR.

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

5.2 Validation

A full system validation was run prior to the SAR testing. The methodology used for the system validation was taken from IEEE 1528 section 7 (where applicable). Further details of the tissue used during the system validation are provided in section 6.3 Simulated Tissue. The results from the system validation are provided in Appendix C Validation Results.

The image below shows the setup used for the system validation.

NOTE:

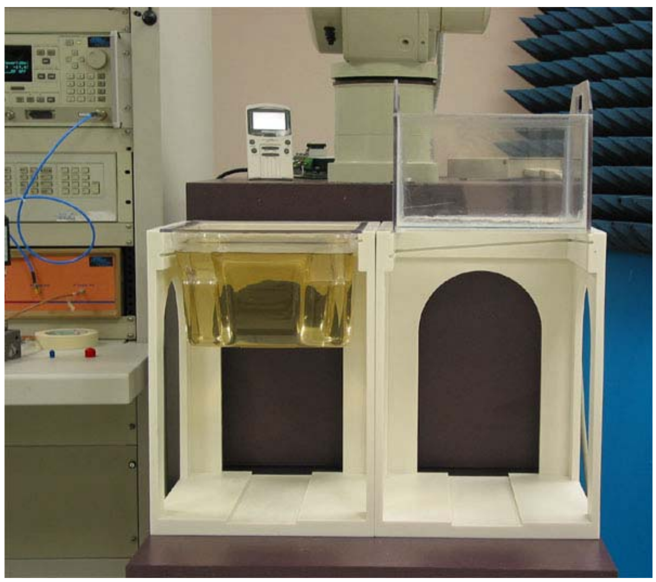
The full analysis of the Device as tested was completed within a 24hr period.

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

5.3 Body & Bystander Analysis

Measurements were made on the DUT while it was operating in all applicable modes and configurations. The device was assessed for both body and direct contact SAR at the low, mid and, high frequency channel settings. A full assessment was made for the device using the laptop configuration, with the top of the LCD, being assessed, along with the DUT being positioned vertically and assessments made on the left and right hand side.

The image below shows part of the setup used for body measurements.



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

5.4 Simulated Tissue

The recipes used to make the simulated tissue were based on those as presented in OET Supplement C for body at 2450MHz and is provided below in table 3.

Table 3: Ingredients used for tissue

INGREDIENT	2450 MHz
DGBE	26.76 %
Water	73.2 %
Salt	0.04
Dielectric Constant	**52.7**
Conductivity (S/m)	**1.95**

The density used to determine SAR from the measurements was the recommended 1.0 kg/m^3 found in Appendix C of “Supplement C OET Bulletin 65, Edition 01-01”.

Dielectric parameters of the simulated tissue material were determined using an Anritsu 37347A Vector Network Analyzer, and the APREL Dielectric Probe.

For the system validation the tissue was calibrated at 2450 MHz.

Table 4: Properties for Tissue used in Validation executed on 11th September 03

BODY Tissue	APREL	Target Value	Δ (%)
Dielectric constant, ε_r	50.6	52.7	-4.0
Conductivity, σ [S/m]	2.01	1.95	+ 3.1

Tissue Conversion Factor,	5.6
Tissue Temperature (ºC)	22.0
Ambient Temperature (°C)	23.5

Table 5: Tissue Calibration Instrumentation

Instrument	Calibration Due	Asset Number/Serial Number
Anritsu VNA	CBT	301382
APREL Dielectric Probe	CBT	-

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

5.5 Methodology

1. The test methodology utilized in the analysis of the Test Case Scenarios 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).

$$SAR = \frac{\sigma |\mathbf{E}|^2}{\rho}$$

3. The probe is moved precisely from one point to the next using the robot (10 mm increments for wide area scanning and 8 mm increments for zoom scanning in the X, Y directions) and (5.0 mm increments for the final depth profile measurement in the Z direction).

4. The probe travels in the homogeneous liquid simulating human tissue (body).

   Section 5.4 contains information about the properties of the simulated tissue used for these measurements.

5. The liquid is contained in a manikin simulating a portion of the human body with an overall shell thickness of 2 mm.

6. The DUT is positioned with the surface under investigation against the phantom with no separation distance for an initial conservative analysis.

7. All tests were performed with the highest power available from the sample DUT under transmit conditions.

More detailed descriptions of the test method are given in Section 6 where appropriate.

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

6.0 TEST RESULTS

6.1 TRANSMITTER CHARACTERISTICS

The Intel Pro/Wireless 2100 WLAN Mini-PCI Type 3A Adapter was integrated by Intel. The Intel Pro/Wireless 2100 WLAN Mini-PCI Type 3A Adapter was then set to transmit, using the software, which was supplied by Intel, with a 100% duty cycle (modulated mode).

The Dell PP10L laptop has been developed to operate with both the AC and, battery cell. The DUT was analyzed and RF conducted power measurements were made on the TX output port for the Mini PCI card using both battery and AC supply. The power measurement exercise showed that **no measurable difference could be made** when comparing battery and AC power modes.

The DUT then had the RF conducted power measured before and after SAR scanning while transmitting using the AC supply. These power measurements were made to assess any measurable drift. Table six contains the results from this exercise.

Note

The power measurements taken were conducted and measured using a power meter with a broadband RF power sensor.

Table 6: Conducted power measurement before and after the scanning

Type of Exposure	Scan Type Equivalent	Power Readings (dBm)		ΔP_{TX} (dB)
		Before scanning	After scanning	
Direct Contact Exposure	Area	16.5	16.5	0.0
	Zoom	16.5	16.5	0.0
Body Exposure	Area	16.5	16.5	0.0
	Zoom	16.5	16.5	0.0

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

6.2 SAR MEASUREMENTS

1) RF exposure is expressed as Specific Absorption Rate (SAR). SAR is defined as time derivative of the incremental energy (*dW*) absorbed by an incremental mass of tissue (*dm*). When testing exposure of humans to RF and microwaves, SAR is calculated from the E-field measured in a grid of test points and expressed as RF power per kilogram of mass, averaged in 10 grams of tissue for the extremities and 1 gram of tissue elsewhere. The equation below is the mathematical definition of SAR:

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dV}\right)$$

2) The DUT was put into test mode for the SAR measurements via test software supplied by the manufacturer running on the host platform. This control software set the DUT channel and operating TX mode/frequency.

3) Table 6, provides the details in tabular form of the full measurement analysis (Test Case Scenarios), which was performed on the DUT. Appendix A provides contour plots of the SAR measurements super imposed on the DUT.

4) Zoom scans were performed for the low, middle and high channels of the DUT. These scans were repeated for all the required positions of the DUT. The DUT was operating with maximum output power and a duty cycle of 100%. The DUT was placed up against the phantom during the test process. The phantom shell thickness is 2 mm overall.

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

6.3 DIRECT CONTACT SAR

All subsequent testing for the direct contact SAR was performed on three channels (low: 2412MHz, middle: 2437MHz, high: 2462MHz) at the normal laptop use position and with the Laptop LCD closed. The results are presented in table 7.

1) The device had an initial area scan executed to establish the location of the maximum peak SAR. A calculated resolution of 1 mm was used to determine the location for the peak SAR.
2) The device was then explored on a refined 32 mm grid (Cube, Zoom Scan) in three dimensions (X, Y & Z) measuring at 8 mm integrals X & Y and 5 mm integrals in the Z plane so as to create a physical measured point matrix. The system then runs a series of complex algorithms, which completes the matrix of calculated and measured values equivalent to a 1 mm resolution in the X, & Y planes.
3) The software uses a series of Lagrange functions to compute the data for the Z plane, which is inserted into the matrix.
4) To complete the calculated matrix (1 mm resolution) a fourth-order polynomial extrapolation is used to obtain the surface values and the 1 and 10-gram averages are then calculated.
5) Where two (or more) peaks with similar values are measured the location of the peaks is recorded. A refined grid is then created to asses each peak location individually, and the maximum value from the assessment is used to record conservative SAR for this report.
6) The highest conservative SAR value averaged over 10 grams for the direct contact exposure analysis (**DUT Front Left Side**) was found to be **0.28 W/kg** at the mid channel (f_{TX} = 2437MHz).

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

6.4 BODY EXPOSURE

All subsequent testing for body exposure SAR was performed on three channels (low: 2412MHz, middle: 2437MHz, high: 2462MHz) at the normal laptop use position and with the Laptop LCD closed.

1) The device had an initial area scan executed to establish the location of the maximum peak SAR. A calculated resolution of 1mm was used to determine the location for the peak SAR.
2) The device was then explored on a refined 32 mm grid (Cube, Fine Scan) in three dimensions (X, Y & Z) measuring at 8 mm integrals X & Y and 5 mm integrals in the Z plane so as to create a physical measured point matrix. The system then runs a series of complex algorithms, which completes the matrix of calculated and measured values equivalent to a 1 mm resolution in the X, & Y planes.
3) The software uses a series of Lagrange functions to compute the data for the Z plane, which is inserted into the matrix.
4) To complete the calculated matrix (1mm resolution) a fourth order polynomial is used to extrapolate the surface values and the 1 and 10-gram averages are then calculated.
5) Where two (or more) peaks with similar values are measured the location of the peaks is recorded. A refined grid is then created to asses each peak location individually, and the maximum value from the assessment is used to record conservative SAR for this report.
6) The highest conservative SAR value averaged over 1 gram for body exposure analysis (**top edge of the LCD**) was found to be **0.97 W/kg** at the mid channel 2437MHz.

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

Table 7:
Test results
1 g and 10 g SAR values for the Dell PP10L laptop

SAR Type	Position Separation 0 mm	Channel	Channel Number	Freq MHz	1g SAR W/kg	10g SAR W/kg
Direct	Laptop Mode LCD Top edge LHS*	Low	1	2412	-	0.17
Direct	Laptop Mode LCD Top edge LHS*	Mid	6	2437	-	0.24
Direct	Laptop Mode LCD Top edge LHS*	High	11	2462	-	0.17
Body	Laptop Mode LCD Top edge LHS*	Low	1	2412	0.70	-
Body	Laptop Mode LCD Top edge LHS*	Mid	6	2437	**0.97**	-
Body	Laptop Mode LCD Top edge LHS*	High	11	2462	0.42	-
Direct	Laptop Mode LCD Top edge RHS**	Mid	6	2437	-	0.02
Body	Laptop Mode LCD Top edge RHS**	Mid	6	2437	0.14	-
Direct	Laptop Mode LCD Front Side	Mid	6	2437	-	0.03
Body	Laptop Mode LCD Front Side	Mid	6	2437	0.17	-
Direct	DUT Left Side	Mid	6	2437	-	0.03
Body	DUT Left Side	Mid	6	2437	0.05	-
Direct	DUT Front Side	Mid	6	2437	-	**0.28**
Body	DUT Front Side	Mid	6	2437	0.67	-
Direct	DUT Back Side	Mid	6	2437	-	0.02
Body	DUT Back Side	Mid	6	2437	0.04	-

* LHS – Left-hand Side
** RHS – Right-hand Side

All Tests Executed 11th September 03

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

7. CONCLUSIONS

The maximum Specific Absorption Rate (SAR) averaged over 10 grams, was found to be **at the Front Left-hand Side of DUT**, where the conservative SAR was measured on the **Mid-channel 2437MHz at 0.28 W/kg** (direct contact SAR for the exposed extremities – hands, wrists, feet and ankles). The overall margin of uncertainty for this measurement is **±17.8 %** (Appendix D).

SAR Limit Direct Contact	Conservative Measured SAR
4.0 W/kg 10 gram Average Maximum	0.28 W/kg 10 gram Average

The maximum Specific Absorption Rate (SAR) averaged over 1 gram, was found to be **the top edge of the LCD**, with the LCD in open position, where the conservative SAR was measured on the **Mid channel 2437MHz at 0.97 W/kg** (Body SAR). The overall margin of uncertainty for this measurement is **±18.0 %** (Appendix D).

SAR Limit Body	Conservative Measured SAR
1.6 W/kg 1 gram Average Maximum	0.97 W/kg 1 gram Average

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 requirements.

Telecommunications Approval Board - Spectrum Sciences Institute - SAR Certified APREL Laboratories

Tested by: ______________________ Date: 11th September, 2003

Roman Kuleba

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