Experimental Analysis SAR Report

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

Product: Asus Notebook

Model: M3000N

Client: AsusTek Computer Inc
No. 150, Li-Te Road.
Peitou, Taipei, Taiwan

Applicant: Intel Corporation
2300 Corporate Center Drive
Thousand Oaks, CA 91320

Manufacturer: AsusTek Computer Inc

Project #: ITLB-ASUS-4019

Prepared by: APREL Laboratories
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Nepean, Ontario
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Approved by ____________ Date: 27 June 2003.
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Submitted by ____________ Date: June 27, 2003
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Released by ____________ Date: June 27/03
Dr. Jacek J. Wojcik, P. Eng.

LICENSED PROFESSIONAL ENGINEER J.J. WOJCIK PROVINCE OF ONTARIO

Applicant:	Intel Corporation
Manufacturer:	AsusTek Computer Inc
FCC ID:	MSQM3000N
Equipment:	Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A inside the AsusTeck notebook
Model:	M3000N
Serial Number:	N/A
Received Status:	Production Unit Pre-release
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 the Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A located inside the Asus M3000N notebook. The analysis was carried out in accordance with the requirements of FCC 96-326, “Guidelines for Evaluating the Environmental Effects of Radio-Frequency Radiation” in accordance with Supplement C and, using methodologies contained within IEEE P-1528. The Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A located inside the Asus M3000N notebook was evaluated for compliance to the RF exposure requirements contained in section 2 “Applicable Documents”. The Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A was operating while located inside the Asus M3000N notebook and was assessed for SAR at the **maximum power level set** at 16.6dBm while operating with the **duty cycle set at 100%**.

The Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A operates while located inside the Asus M3000N notebook and utilizes a Mini PCI type B form factor. The Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A located inside the Asus M3000N notebook has been assessed for body, bystander, and direct contact SAR.

Intel provided APREL laboratories with one pre-production model of the Asus M3000N notebook. The M3000N notebook incorporates a diverse dual band PCB antenna as supplied by YAGO (Phicomp). The Tx (main) antenna is housed internally within the laptop chassis and is located near or around the **Bottom Right Hand Side** of the laptop near the **Palm Rest Area**, below the keyboard on the main body of the laptop.

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For the purpose of the SAR analysis executed and subsequent report the Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A located inside the Asus M3000N notebook will not be labeled as the DUI (Device Under Investigation). For the purpose of this test report the DUI is the Asus notebook model number M3000N.

The Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A located inside the Asus M3000N notebook was evaluated for at the 802.11b standard for both body exposure and direct contact SAR (extremities) at low (ch#1), middle (ch#6) and high (ch#11) for the frequency range of 2412MHz to 2462MHz. Tests were executed at zero mm separation distance, for both direct contact SAR (extremities) and, body analysis.

The conservative 10g average for direct contact SAR for the DUI was found to be **1.21 W/kg for the peak RF output power of the mid channel (ch#6, f=2437MHz)** at the keyboard up position of DUI. For body SAR analysis the conservative 1 g SAR was found to be **0.17 W/kg for the peak RF output power of the Mid channel (ch#06, f=2437MHz)** at Right Hand Side position

Evaluation data and graphs are presented in this report. All analysis conducted and documented in this report were performed while the Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A was located inside the Asus notebook model M3000N.

For the purpose of the SAR assessment the AC power source was used, and the conservative SAR position and frequency for each of the Test Case Scenarios was reassessed using the battery supply. It was found that the conservative SAR presented in this report was measured while using the AC supply.

Based on the measured results and on how the Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A while located inside the Asus notebook model M3000N will be marketed and used, it is certified that the DUI meets the requirements as set forth in the specifications, for the RF exposure environment contained within this report.

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

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1. INTRODUCTION

Tests were conducted to determine the Specific Absorption Rate (SAR) for a sample Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A located inside the Asus M3000N notebook while operating with a YAGO (Phicomp) antenna. These tests were conducted at APREL Laboratories facility located at 51 Spectrum Way, Nepean, Ontario, Canada.

2. APPLICABLE DOCUMENTS

The following documents are applicable to the evaluation 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 (Edition 97-01) Supplement C (Edition 01-01), “Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields”.

5) IEEE P-1528 Draft “Recommended Practice for Determining the Peak Spatial Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communication Devices: Experimental Techniques.”

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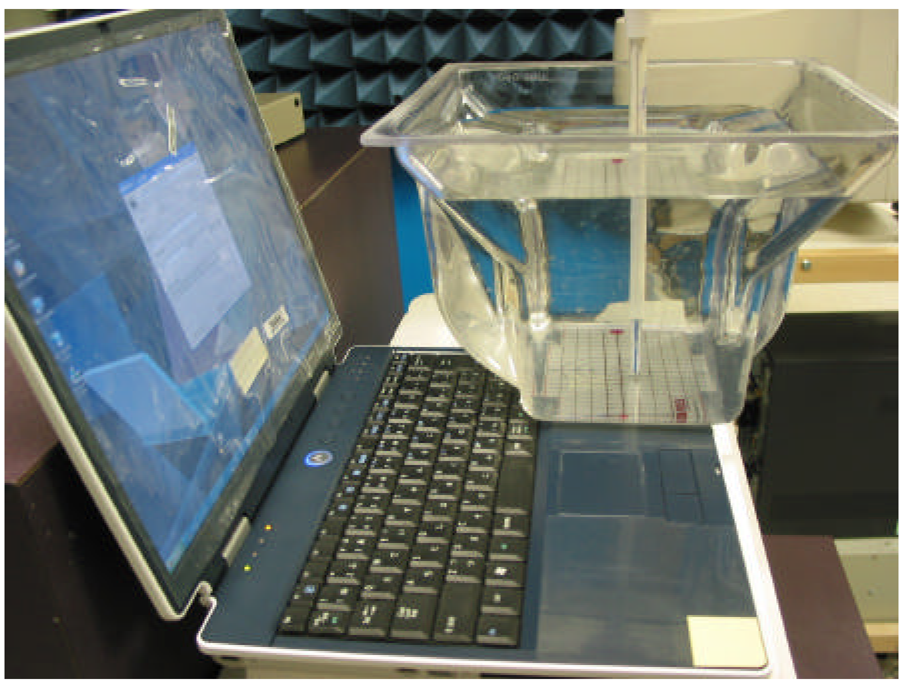
3. Test Case Scenarios

Intel provided APREL Laboratories with a sample Asus M3000N notebook which acts as the host for the Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A for the purpose of the SAR evaluation. The evaluations performed on the Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A while located inside the Asus M3000N notebook were to establish the conservative SAR value for both 1 and 10g averages while the Mini PCI card was transmitting at the set power below the saturation point.

The DUI (device under test) is the Asus M3000N notebook which uses the Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A.

Device Tested Keyboard Up



Asus M3000N notebook with Yageo 2.45/5GHz M3N Dual Band Antenna

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Device Tested Keyboard Down

Asus M3000N notebook with Yageo 2.45/5GHz M3N Dual Band Antenna

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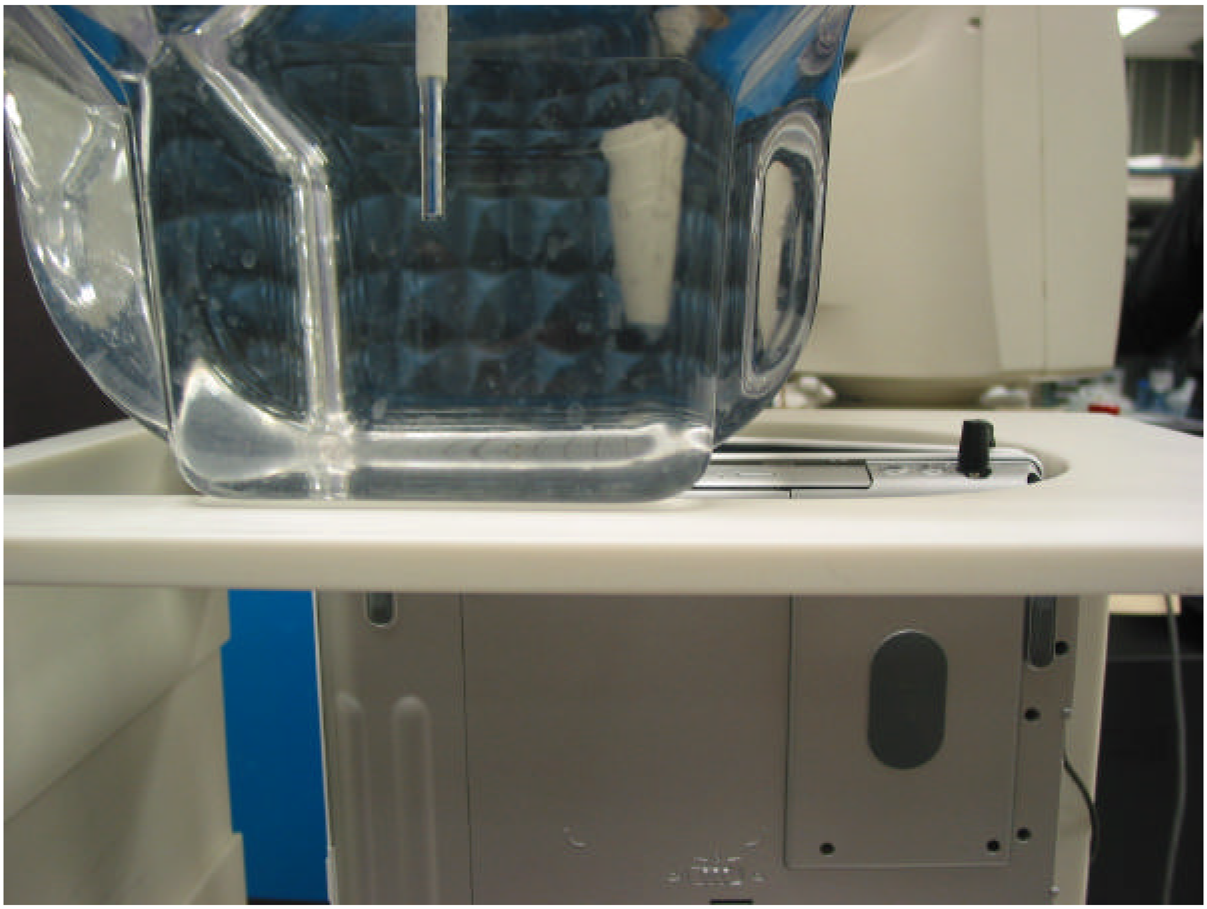
Device Tested Left Hand Side



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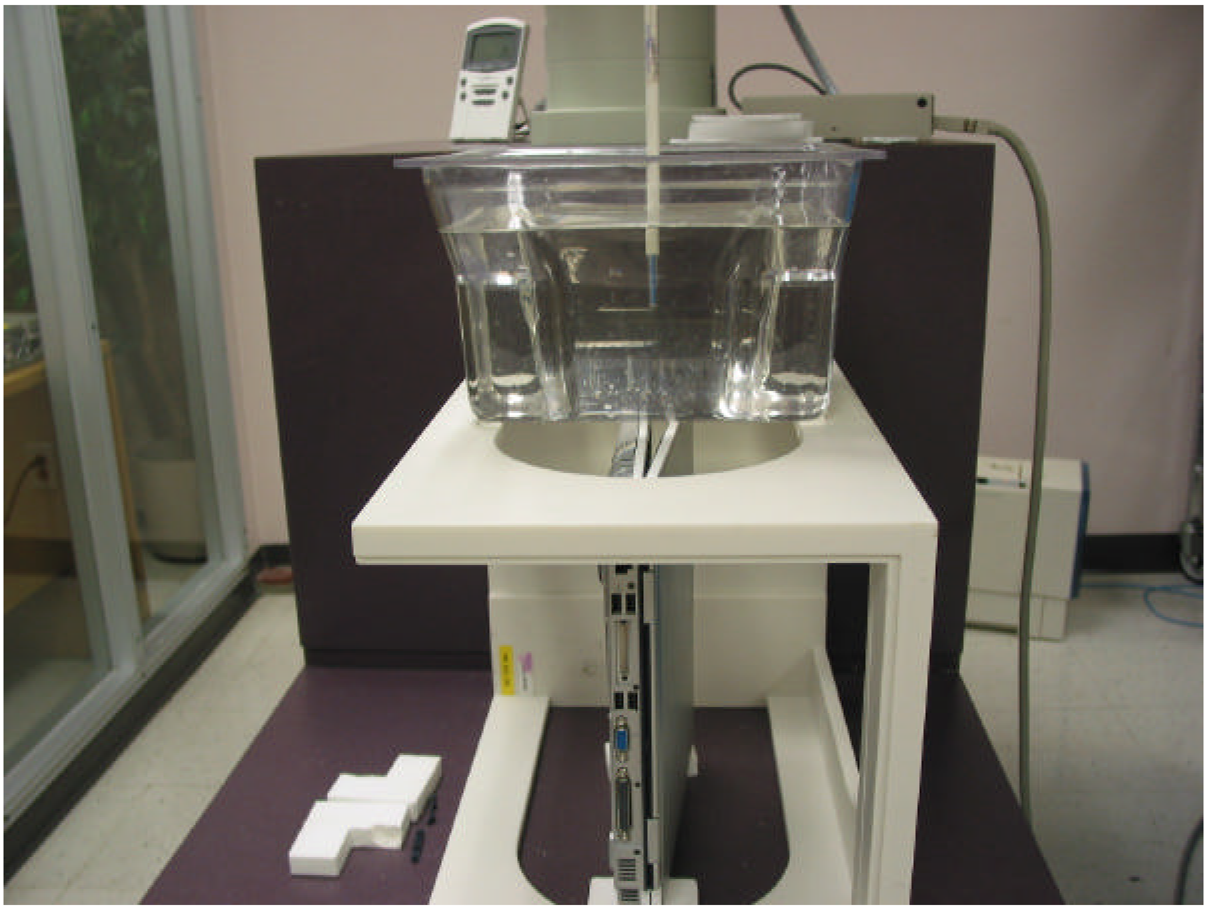
Device Tested Right Hand Side



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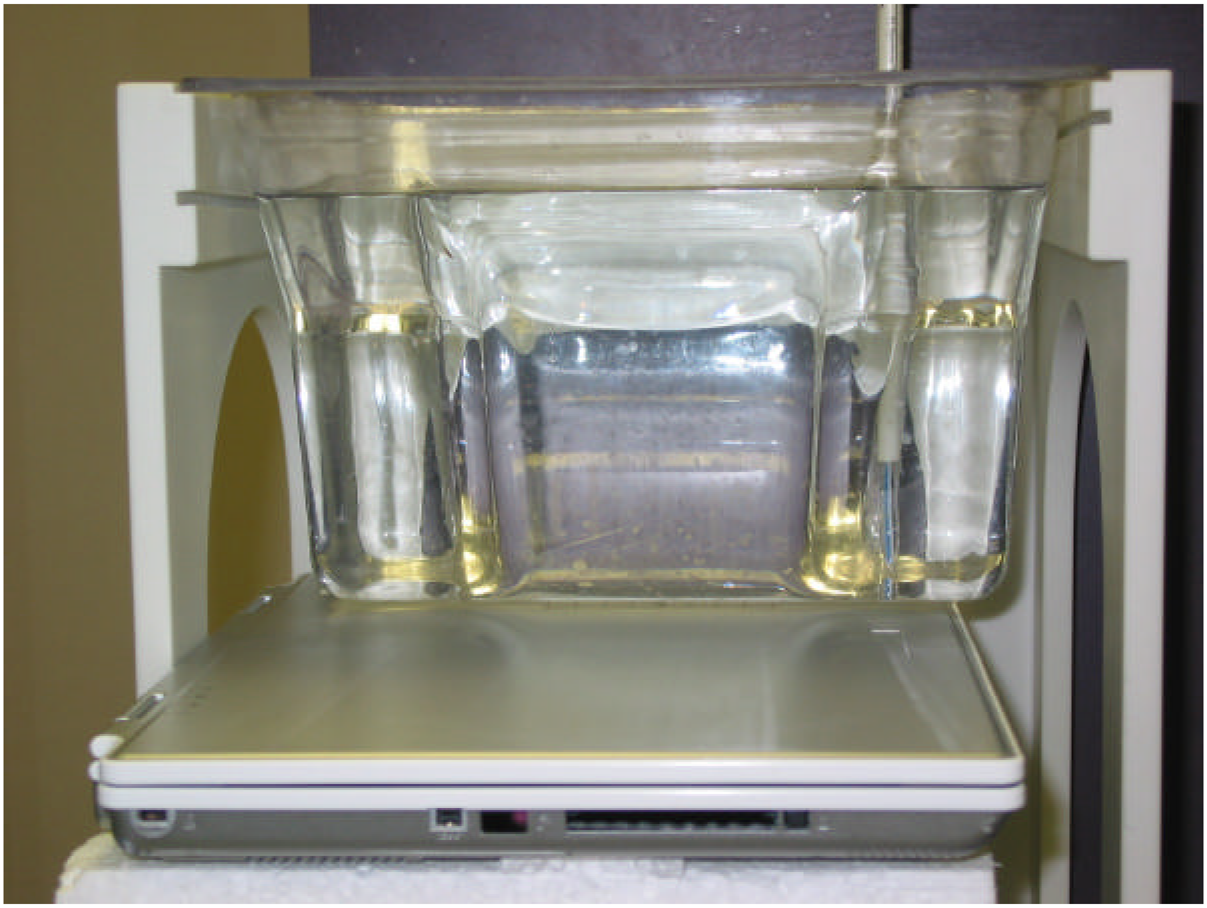
Device Tested LCD Closed



Asus M3000N notebook with Yageo 2.45/5GHz M3N Dual Band Antenna

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4. TEST EQUIPMENT

- APREL Triangular Dosimetric Probe Model E-010, s/n 163
- ALIDX-500 Dosimetric SAR Measurement System
- APREL flat Phantom F1, Part # P-V-G8 (overall shell thickness 2mm)
- APREL 2.45GHz Dipole
- APREL RF Amplifier
- Hewlett Packard Signal Generator Asset
- Gigatronics Power Meter
- Gigatronics Power Sensor (peak detection mode)
- Hewlett Packard Dual Directional Coupler

Table 2: Instrumentation

Instrument	Calibration Due	Asset Number/Serial Number
E-010 Probe	May 2003	163
ALIDX-500	March 2004	N/A
APREL Flat Phantom	N/A	APL-001
APREL UniPhantom	N/A	APL-085
APREL 2450MHz Dipole	CBT	N/A
APREL RF Amplifier	CBT	301467
HP-Signal Generator	September 2003	301468
Gigatronics Power Meter	September 2003	301393
Gigatronics Power Sensor	April 2004	301394
HP Directional Coupler	October 2003	100251

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5. 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.

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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.

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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 draft standard “P-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 P-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.

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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 P-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.

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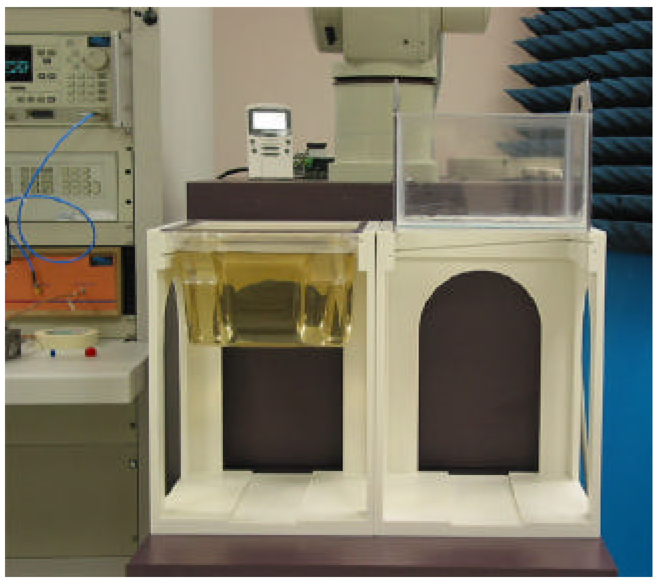
5.3 Body & Bystander Analysis

Measurements were made on each of the Test Case Scenarios using the APREL Universal Phantom, on the low, mid, and high channels. Each Test Case Scenario was assessed for SAR in the keyboard up, keyboard down, left hand side, right hand side with the LCD open and closed. The separation distance used was 0mm for the conservative SAR assessment. The results from this exercise are presented in section 6 test results.

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



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5.4 Simulated Tissue

The recipes used to make the simulated tissue were as presented in OET Supplement C.

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 3: Properties for Tissue used in Validation executed 21st March 03

BODY Tissue	APREL	Target Value	D (%)
Dielectric constant, ε_r	50.4	52.7	4
Conductivity, σ [S/m]	2.03	1.95	4
Tissue Conversion Factor,	5.6	-	-
Tissue Temperature (ºC)	22.0	-	-
Ambient Temperature (°C)	23.5	-	-

Table 4: Tissue Calibration Instrumentation

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

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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 DUI 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 DUI under transmit conditions.

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

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6. TEST RESULTS

6.1. TRANSMITTER CHARACTERISTICS

The Intel Pro/Wireless 2100 WLAN Mini-PCI Type 3B Adapter was integrated by Intel. The Intel Pro/Wireless 2100 WLAN Mini-PCI Type 3B Adapter was then set to transmit, using the software, which was supplied by Intel, with a 100% duty cycle (modulated mode). During the SAR measurement process a spectrum analyzer was setup to measure the radiated power.

The Intel Mini PCI Type 3B 802.11a/b Wireless LAN Adapter model WM3B2100A located inside the Asus M3000N notebook has been developed to operate with both the AC and, battery cell in the laptop. The DUI was analyzed and conducted power measurements were made on the Tx output port for the DUI 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 DUI then had a further assessment executed while transmitting using the AC supply over a period of 40 minutes. During this period conducted 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, and broadband power sensor (peak detection mode).

Table 5: Conducted power measurement before and after the scanning

Type of Exposure	Scan Type Equivalent	Power Readings (dBm)		ΔP_{TX} (dB)
		Initial	After 40 Minutes	
Direct Contact Exposure	Area	16.6	16.6	0
	Fine/Zoom	16.6	16.6	0
Body Exposure	Area	16.6	16.6	0
	Fine/Zoom	16.6	16.6	0

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6.2. SAR MEASUREMENTS

1) RF exposure is expressed as 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. The equation below is a representation of how SAR can theoretically equate.

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

2) The DUI 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 DUI 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 DUI. Appendix A provides contour plots of the SAR measurements super imposed on the DUI.

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

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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 all three positions. The results are presented in table 6.

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 runs a series of Lagrange functions to provide 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 compute 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 was found to be **1.21 W/kg at the mid channel 2437MHz Keyboard UP** (Table 6).

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6.4. BODY EXPOSURE

All subsequent testing for body exposure SAR was performed on three channels (low: 2412MHz, middle: 2437MHz, high: 2462MHz) at all three positions. The results are presented in table 6.

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 runs a series of Lagrange functions to provide 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 was found to be **0.17 W/kg at the mid channel 2437MHz (Table 7) for the DUI located at the keyboard up** position.

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Table 6:
Test results 1 g and 10 g SAR values for the C110

Assessment Type	Position Separation mm	Channel	Channel Number	Frequency MHz	1g SAR W/kg	10g SAR W/kg
Keyboard Up	0	Low	1	2412		1.17
Keyboard Up	**0**	**Mid**	**6**	**2437**		**1.21**
Keyboard Up	0	High	11	2462		1.08
Keyboard Down	0	Low	1	2412	0.03	
Keyboard Down	**0**	**Mid**	**6**	**2437**	**0.06**	
Keyboard Down	0	High	11	2462	0.06	
LCD Closed	0	Low	1	2412	0.06	
LCD Closed	0	Mid	6	2437	0.10	
LCD Closed	**0**	**High**	**11**	**2462**	**0.11**	
Right Side	0	Mid	6	2437	0.17	0.08

NOTE:
Tests were executed on the left side, where no antenna is present. These results were equivalent to the noise level.

All Tests Executed 23rd May 2003

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7. CONCLUSIONS

The maximum Specific Absorption Rate (SAR) averaged over 10 grams, was found to be while the device was in the **Keyboard Up position**, where the conservative SAR was measured on the **mid channel 2437MHz at 1.21 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	1.121W/kg 10 gram Average

The maximum Specific Absorption Rate (SAR) averaged over 1 gram, was found to be while the device was at the **right hand side**, where the conservative SAR was measured on the **Mid channel 2437MHz at 0.17 W/kg** (Body SAR). The overall margin of uncertainty for this measurement is **±18.1% (**Appendix D).

SAR Limit Body	Conservative Measured SAR
1.6 W/kg 1 gram Average	0.17 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: 23rd May, 2003

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