SAR Test Report

No. SAR_573_2003_FCC_5000

for the

The Broadcom Wireless LAN mini-PCI card

WLAN MiniPCI Multiband card incorporating 2.4GHz and 5GHz radios

Model Number: BCM94309MP

FCC ID: QDS-BRCM1007

Date of Report:	**12/03/2003**
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Accredited according to
ISO/IEC 17025 by:

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TTI-P-G 81/94-A0

CTIA
Authorized Testing Laborat

***CETECOM* Inc.**
411 Dixon Landing Road ◆ Milpitas, CA 95035 ◆ U.S.A.
Phone: + 1 (408) 586 6200 ◆ Fax: + 1 (408) 586 6299 ◆ E-mail: info@cetecomusa.com ◆ http://www.cetecom.com
CETECOM Inc. is a Delaware Corporation with Corporation number: 2113686
Board of Directors: Dr. Harald Ansorge, Dr. Klaus Matkey, Hans Peter May

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1. Assessment

The WLAN MiniPCI Multiband card incorporating 2.4GHz and 5GHz radios
The Broadcom Wireless LAN mini-PCI card is in compliance with the exposure criteria specified in Federal Communications Commission (FCC) Guidelines [FCC 2001] for uncontrolled exposure.

12/03/2003
Pete Krebill
Project Leader

12/03/2003
Lothar Schmidt
Test Lab Manager

2. Administrative Data

2.1. Identification of the Testing Laboratory Issuing the SAR Assessment Report

Company Name:	CETECOM Inc.
Department:	SAR
Address:	411 Dixon Landing Road Milpitas, CA 95035 U.S.A.
Telephone:	+1 (408) 586 6200
Fax:	+1 (408) 586 6299
Responsible Test Lab Manager:	Lothar Schmidt

2.2. Identification of the Client

Applicant's Name:	Broadcom Corporation
Address:	190 Mathilda Place Sunnyvale, 94086, USA
Contact Person:	Dan Lawless
Phone No.	408 922 5870
Fax:	408 543 3399
e-mail:	dlawless@broadcom.com

2.3. Identification of the Manufacturer

Manufacturer's Name:	Same as applicant

3. Equipment under Investigation (EUI)

3.1. Identification of the Equipment under Investigation

Product Type	WLAN MiniPCI Multiband card incorporating 2.4GHz and 5GHz radios
Marketing Name:	The Broadcom Wireless LAN mini-PCI card
Model No:	BCM94309MP
FCC-ID:	QDS-BRCM1007
Frequency Range:	5150 MHz – 5350 MHz & 5470 MHz – 5825 MHz
Type(s) of Modulation:	DSSS and OFDM (Orthogonal Frequency Division Multippl exing)
Number of Channels:	8
Antenna Type:	Neweb model CAB-A
Maximum Output Power[1]:	15.8 dBm (38 mW) conducted output power

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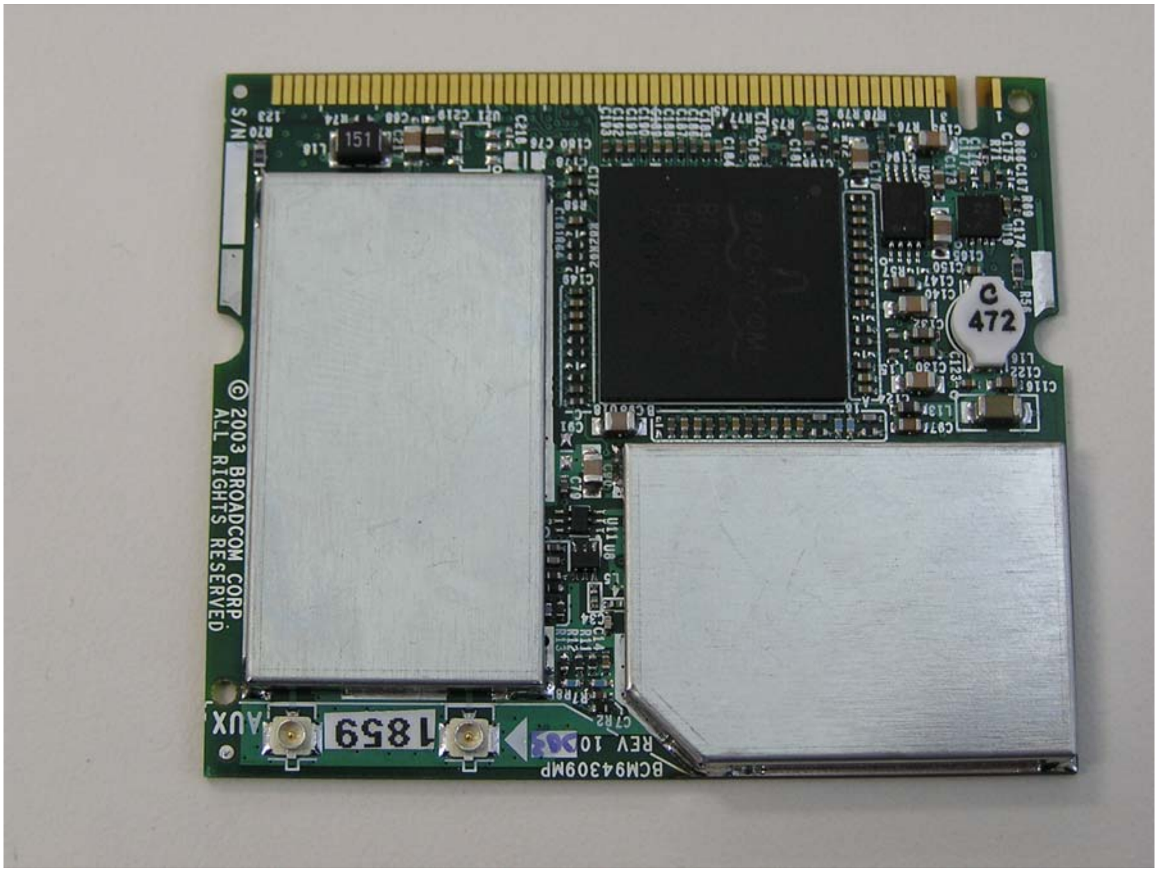
[1] For complete output power measurements see section 8.3 of this report.

3.2. Front View of the Equipment under Investigation



4. Subject of Investigation

The The Broadcom Wireless LAN mini-PCI card is a WLAN MiniPCI Multiband card incorporating 2.4GHz and 5GHz radios from Broadcom Corporation operating in the 5150 MHz – 5350 MHz & 5470 MHz – 5825 MHz frequency ranges. The objective of the measurements done by Cetecom Inc. was the dosimetric assessment of one device. The tests were performed in configurations for devices operated next to a person's body. The examinations were carried out with the dosimetric assessment system SARA2 described below.

4.1. Distinction Between Exposed Population, Duration of Exposure and Frequencies

The American Standard [IEEE 1999] distinguishes between controlled and uncontrolled environment. Controlled environments are locations where there is exposure that may be incurred by persons who are aware of the potential for exposure as a concomitant of employment or by other cognizant persons. Uncontrolled environments are locations where there is the exposure of individuals who have no knowledge or control of their exposure. The exposures may occur in living quarters or workplaces. For exposure in controlled environments higher field strengths are admissible. In addition the duration of exposure is considered. Due to the influence of frequency on important parameters, as the penetration depth of the electromagnetic fields into the human body and the absorption capability of different tissues, the limits in general vary with frequency.

4.2. Distinction between Maximum Permissible Exposure and SAR Limits

The biological relevant parameter describing the effects of electromagnetic fields in the frequency range of interest is the specific absorption rate SAR (dimension: power/mass). It is a measure of the power absorbed per unit mass. The SAR may be spatially averaged over the total mass of an exposed body or its parts. The SAR is calculated from the r.m.s. electric field strength *E* inside the human body, the conductivity σ and the mass density ρ of the biological tissue:

$$SAR = \sigma \frac{E2}{\rho} = c \left.\frac{\partial T}{\partial t}\right|_{t \to 0+}$$

The specific absorption rate describes the initial rate of temperature rise $\partial T / \partial t$ as a function of the specific heat capacity *c* of the tissue. A limitation of the specific absorption rate prevents an excessive heating of the human body by electromagnetic energy.

As it is sometimes difficult to determine the SAR directly by measurement (e.g. whole body averaged SAR), the standard specifies more readily measurable maximum permissible exposures in terms of external electric *E* and magnetic field strength *H* and power density S, derived from the SAR limits. The limits for E, *H* and *S* have been fixed so that even under worst case conditions, the limits for the specific absorption rate SAR are not exceeded.

For the relevant frequency range the maximum permissible exposure may be exceeded if the exposure can be shown by appropriate techniques to produce SAR values below the corresponding limits.

4.3. SAR Limit

In this report the comparison between the American exposure limits and the measured data is made using the spatial peak SAR; the power level of the device under test guarantees that the whole body averaged SAR is not exceeded.

Having in mind a worst case consideration, the SAR limit is valid for uncontrolled environment and mobile respectively portable transmitters. According to Table 1 the SAR values have to be averaged over a mass of 1 g (SAR$_1$g) with the shape of a cube.

Standard	Status	SAR limit (W/kg)
IEEE C95.1	In force	1.6

Table 1: Relevant spatial peak SAR limit averaged over a mass of 1 g

5. The FCC Measurement Procedure

The Federal Communications Commission (FCC) has published a report and order on the 1st of August 1996 [FCC 1996], which requires routine dosimetric assessment of mobile telecom-communications devices, either by laboratory measurement techniques or by computational modeling, prior to equipment authorization or use. In 2001 the Commission's Office of Engineering and Technology has released Edition 01-01 of Supplement C to OET Bulletin 65. This revised edition, which replaces Edition 97-01, provides additional guidance and information for evaluating compliance of mobile and portable devices with FCC limits for human exposure to radiofrequency emissions [FCC 2001].

5.1. General Requirements

The test shall be performed in a laboratory with an environment which avoids influence on SAR measurements by ambient EM sources and any reflection from the environment itself. The ambient temperature shall be in the range of 20°C to 26°C and 30-70% humidity.

5.2. Body-worn and Other Configurations

Phantom Requirements
For body-worn and other configurations a flat phantom shall be used which is comprised of material with electrical properties similar to the corresponding tissues.

Test Positions
The device will be oriented to test exposure to the user of the device and to test exposure to nearby bystanders.

5.3. Procedure for assessing the peak spatial-average SAR

Step 1*:* Power reference measurement:

Prior to the SAR test, a local SAR measurement should be taken at a user-selected spatial reference point to monitor power variations during testing. For example, this power reference point can be spaced 10 mm or less in the normal direction from the liquid-shell interface and within ± 10 mm transverse to the normal line at the ear reference point.

Step 2: Area scan

The measurement procedures for evaluating SAR typically start with a coarse measurement grid in order to determine the approximate location of the local peak SAR values. This is referred to as the "area scan" procedure. The SAR distribution is scanned along the inside surface of the flat phantom in an area at least larger than the areas projected (normal to the phantom's surface) by the devices antenna. The distance between the measured points and phantom surface should be less than 8 mm, and should remain constant (variation less than ± 1 mm) during the entire scan in order to determine the locations of the local peak SAR with sufficient precision. The distance between the measurement points should enable the detection of the location of local maximum with an accuracy of better than half the linear dimension of the tissue cube after interpolation. The resolution can also be tested using the functions in Annex E (see E.5.2). The approximate locations of the peak SARs should be determined from area scan. Since a given amplitude local peak with steep gradients may produce lower spatial-average SAR than slightly lower amplitude peaks with less steep gradients, it is necessary to evaluate the other peaks as well. However, since the spatial gradients of local SAR peaks are a function of wavelength inside the tissue simulating liquid and incident magnetic field strength, it is not necessary to evaluate peaks that are less than – 2dB of the local maximum. Two-dimensional spline algorithms [Press, et al, 1996], [Brishoual, 2001] are typically used to determine the peaks and gradients within the scanned area. If the peak is closer than one-half of the linear dimension of the 1 g or 10 g tissue cube to the scan border, the measurement area should be enlarged if possible, e.g., by tilting the probe or the phantom.

Step 3: Zoom scan

In order to assess the peak spatial SAR values averaged over a 1 g and 10 g cube, fine resolution volume scans, called "zoom scans", are performed at the peak SAR locations determined during the “area scan.” The zoom scan volume should have at least 1.5 times the linear dimension of either a 1 g or a 10 g tissue cube for whichever peak spatial-average SAR is being evaluated. The peak local SAR locations that were determined in the area scan (interpolated value) should be on the centerline of the zoom scans. The centerline is the line that is normal to the surface and in the center of the volume scan. If this is not possible, the zoom scan can be shifted but not by more than half the dimension of the 1 g or a 10 g tissue cube.

The maximum spatial-average SAR is determined by a numerical analysis of the SAR values obtained in the volume of the zoom scan, whereby interpolation (between measured points) and extrapolation (between surface and closest measured points) routines should be applied. A 3-D-spline algorithm [Press, et al, 1996], [Kreyszig, 1983], [Brishoual, 2001] can be used for interpolation and a trapezoidal algorithm for the integration (averaging). Scan resolutions of larger than 2 mm can be used provided the uncertainty is evaluated according to E (see E.5).

In some areas of the phantom, the angle of the probe with respect to the line normal to the surface might become large, e.g., at angles larger than ± 30º, which may increase the boundary effect to an unacceptable level. In these cases, a change in the orientation of the probe and/or the phantom is recommended during the zoom scan so that the angle between the probe housing tube and the line normal to the surface is significantly reduced (<30º).

Step 4: Power reference measurement

The local SAR should be measured at exactly the same location as in Step 1. The absolute value of the measurement drift (the difference between the SAR measured in Step 4 and Step 1) should be recorded in the uncertainty budget. It is recommended that the drift be kept within ± 5%. If this is not possible, even with repeat testing, additional information may be used to demonstrate the power stability during the test. Power reference measurements can be taken after each zoom scan, if more than one zoom scan is needed. However, the drift should always be referred to the initial state with fully charged battery.

5.4. Determination of the largest peak spatial-average SAR

In order to determine the largest value of the peak spatial-average SAR, all device positions, configurations and operational modes should be tested for each frequency band according to steps 1 to 3 below.

Step 1: The tests of 5.3 should be conducted at the channel that is closest to the center of the transmit frequency band (*fc*) for:

a) all device positions.

b) all configurations for each device position in (a), e.g. antenna extended and retracted, and

c) all operational modes for each device position in (a) and configuration in (b) in each frequency band, e.g. analog and digital.

If more than three frequencies need to be tested, (i.e., Nc > 3), then all frequencies, configurations and modes must be tested for all of the above positions.

Step 2: For the condition providing highest spatial peak SAR determined in Step 1 conduct all tests of 5.3 at all other test frequencies, e.g. lowest and highest frequencies. In addition, for all other conditions (device position, configuration and operational mode) where the spatial peak SAR value determined in Step 1 is within 3dB of the applicable SAR limit, it is recommended that all other test frequencies should be tested as well[2].

Step 3: Examine all data to determine the largest value of the peak spatial-average SAR found in Steps 1 to 2.

6. The Measurement System

6.1. Robot system specification

The SAR measurement system being used is the IndexSAR SARA2 system, which consists of a Mitsubishi RV-E2 6-axis robot arm and controller, IndexSAR probe and amplifier and SAM phantom Head Shape. The robot is used to articulate the probe to programmed positions inside the phantom head to obtain the SAR readings from the DUT.

The system is controlled remotely from a PC, which contains the software to control the robot and data acquisition equipment. The software also displays the data obtained from test scans.

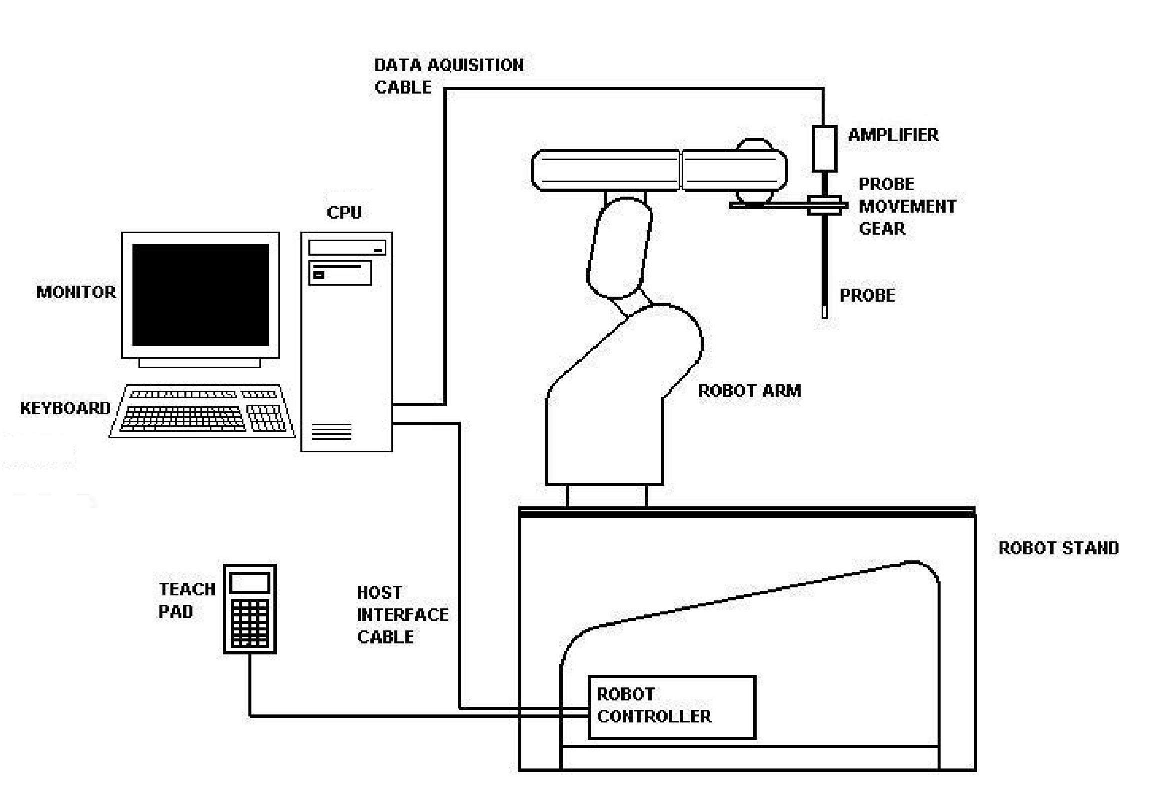


Figure 5: Schematic diagram of the SAR measurement system

The position and digitised shape of the phantom heads are made available to the software for accurate positioning of the probe and reduction of set-up time.
The SAM phantom heads are individually digitised using a Mitutoyo CMM machine to a precision of 0.001mm. The data is then converted into a shape format for the software, providing an accurate description of the phantom shell.

In operation, the system first does an area (2D) scan at a fixed depth within the liquid from the inside wall of the phantom. When the maximum SAR point has been found, the system will then carry out a 3D scan centred at that point to determine volume averaged SAR level.

6.2. Probe and amplifier specification

IXP-050 Indexsar isotropic immersible SAR probe
The probes are constructed using three orthogonal dipole sensors arranged on an interlocking, triangular prism core. The probes have built-in shielding against static charges and are contained within a PEEK cylindrical enclosure material at the tip. Probe calibration is described in the probe's calibration certificate (see appendix C.). The system uses diode compression potential (DCP) to determine SAR values for different types of modulation. Crest factor is not used for determining SAR values. The DCP for different types of modulation is determined during the probe calibration procedure. For a more detailed explanation see *IndexSAR Immesible SAR Probe Calibration Report* included in Appendix C of this report.

IXP-010 Amplifier
The amplifier unit has a multi-pole connector to connect to the probe and a multiplexer selects between the 3-channel single-ended inputs. A 16-bit AtoD converter with programmable gain is used along with an on-board micro-controller with non-volatile firmware. Battery life is around 150 hours and data are transferred to the PC via 3m of duplex optical fibre and a self-powered RS232 to optical converter.

6.3. Phantoms

The box phantom used for body testing and for validation is manufactured from Perspex. The material is 2 mm in thickness on the test surfaces and 4 mm in thickness on the other surfaces. Its dimensions are: X=21 cm., Y=20.5 cm., Z=16 cm. The phantom and robot alignment is assured by both mechanical and laser registration systems.

6.4. SAR measurement procedure

Figure 6: Principal components of the SAR measurement test bench

After an area scan has been done at a fixed distance of 8mm from the surface of the phantom on the source side, a 3D scan is set up around the location of the maximum spot SAR. First, a point within the scan area is visited by the probe and a SAR reading taken at the start of testing. At the end of testing, the probe is returned to the same point and a second reading is taken. Comparison between these start and end readings enables the power drift during measurement to be assessed.

6.5. SARA2 Interpolation and Extrapolation schemes

(see support document IXS-0202)

SARA2 software contains support for both 2D cubic B-spline interpolation as well as 3D cubic B-spline interpolation. In addition, for extrapolation purposes, a general n-th order polynomial fitting routine is implemented following a singular value decomposition algorithm presented in [4]. A 4th order polynomial fit is used by default for data extrapolation, but a linear-logarithmic fitting function can be selected as an option. The polynomial fitting procedures have been tested by comparing the fitting coefficients generated by the SARA2 procedures with those obtained using the polynomial fit functions of Microsoft Excel when applied to the same test input data.

6.6. Interpolation of 2D area scan

The 2D cubic B-spline interpolation is used after the initial area scan at fixed distance from the phantom shell wall. The initial scan data are collected with approx. 10mm spatial resolution and spline interpolation is used to find the location of the local maximum to within a 1mm resolution for positioning the subsequent 3D scanning.

6.7. Extrapolation of 3D scan

For the 3D scan, data are collected on a spatially regular 3D grid having (by default) 6.4 mm steps in the lateral dimensions and 3.5 mm steps in the depth direction (away from the source). SARA2 enables full control over the selection of alternative step sizes in all directions.

The digitised shape of the head is available to the SARA2 software, which decides which points in the 3D array are sufficiently well within the shell wall to be 'visited' by the SAR probe. After the data collection, the data are extrapolated in the depth direction to assign values to points in the 3D array closer to the shell wall. A notional extrapolation value is also assigned to the first point outside the shell wall so that subsequent interpolation schemes will be applicable right up to the shell wall boundary.

6.8. Interpolation of 3D scan and volume averaging

The procedure used for defining the shape of the volumes used for SAR averaging in the SARA2 software follow the method of adapting the surface of the 'cube' to conform with the curved inner surface of the phantom (see Appendix D in FCC Supplement C edition 01-01 to OET Bulletin 65 edition 97-01). This is called, here, the conformal scheme.

For each row of data in the depth direction, the data are extrapolated and interpolated to less than 1mm spacing and average values are calculated from the phantom surface for the row of data over distances corresponding to the requisite depth for 10g and 1g cubes. This results in two 2D arrays of data, which are then cubic B-spline interpolated to sub mm lateral resolution. A search routine then moves an averaging square around through the 2D array and records the maximum value of the corresponding 1g and 10g volume averages. For the definition of the surface in this procedure, the digitised position of the headshell surface is used for measurement in head-shaped phantoms. For measurements in rectangular, box phantoms, the distance between the phantom wall and the closest set of gridded data points is entered into the software. For measurements in box-shaped phantoms, this distance is under the control of the user. The effective distance must be greater than 2.5mm as this is the tip-sensor distance and to avoid interface proximity effects, it should be at least 5mm. A value of 6 or 8mm is recommended. This distance is called **dbe**.

For automated measurements inside the head, the distance cannot be less than 2.5mm, which is the radius of the probe tip and to avoid interface proximity effects, a minimum clearance distance of x mm is retained. The actual value of dbe will vary from point to point depending upon how the spatially-regular 3D grid points fit within the shell. The greatest separation is when a grid point is just not visited due to the probe tip dimensions. In this case the distance could be as large as the step-size plus the minimum clearance distance (i.e with x=5 and a step size of 3.5, **dbe** will be between 3.5 and 8.5mm).

The default step size (**dstep**) used is 3.5mm, but this is under user-control. The compromise is with time of scan, so it is not practical to make it much smaller or scan times become long and power-drop influences become larger.

The robot positioning system specification for the repeatability of the positioning (**dss**) is +/- 0.04mm.

The phantom shell is made by an industrial moulding process from the CAD files of the SAM shape, with both internal and external moulds. For the upright phantoms, the external shape is subsequently digitised on a Mitutoyo CMM machine (Euro an ultrasonic sensor indicate that the shell thickness (**dph**) away from the ear is 2.0 +/- 0.1mm. The ultrasonic measurements were calibrated using additional mechanical measurements on available cut surfaces of the phantom shells. See support document IXS-020x.

For the upright phantom, the alignment is based upon registration of the rotation axis of the phantom on its 253mm diameter baseplate bearing and the position of the probe axis when commanded to go to the axial position. A laser alignment tool is provided (procedure detailed elsewhere). This enables the registration of the phantom tip (**dmis**) to be assured to within approx. 0.2mm. This alignment is done with reference to the actual probe tip after installation and probe alignment. The rotational positioning of the phantom is variable – offering advantages for special studies, but locating pins ensure accurate repositioning at the principal positions (LH and RH ears).

6.9. Probe anisotropy and boundary proximity influence correction software (Virtual Probe Miniaturization VPM software)

Indexsar Report IXS0223 provides a background to the factors affecting measurements at high frequencies when using SAR probes of size 8 – 5mm tip diameter. Although the Indexsar probes are at the smaller end of this range, SAR probes are not isotropic in 5GHz phantom field gradients and additional precautions have to be taken in measurements. The following measures are recommended:

1) At >5GHz, the SAR field decays to 1/e of its value within 3-4mm of the surface of a phantom with a source adjacent. So, measurements are significantly affected by small errors in the separation distances employed between the probe and the phantom surface. The distance between the probe tip and the plane of the sensors should be allowed for using the same value as that declared in the probe calibration document. Distances between the probe tip and phantom surface should be measured accurately to 0.1mm. The best way to assure this is to use the robot to position the probe in light contact with the phantom wall and then to withdraw the probe by the selected amount under robot control.

2) The preferred test geometry at 5GHz is for testing at the bottom of an open phantom. If tests at the side of a phantom are performed, it will be necessary to apply VPM corrections as described below. In either case, careful monitoring of probe spacing from the phantom is required. Probe isotropy is improved for measuring fields polarised either normal to or parallel to the probe axis. If the source polarization is known, this arrangement should be established, if possible.

3) The probe calibration factors including boundary correction terms should be carefully entered from the calibration document. The probe calibration factors require that the probe be oriented in

a known rotational position. The red spot on the Indexsar probe should be aligned facing away from the robot arm.

4) The latest SARA2 software (VPM editions) contain support for correcting for probe anisotropy in strong field gradients and include a procedure for correcting for boundary proximity influences. As noted above, the probe has to be oriented in a given rotational position and some familiarity with the new measurement procedures is necessary. The calculations can be performed either with or without the extended correction schemes applied.

5) If boundary corrections are used, it may be preferable to go rather closer to the phantom surface than is usually recommended and to perform scans using small steps between the measurement planes so that good data on the SAR profiles are collected within the first 10mm of the phantom depth.

7. Uncertainty Assessment

Measurement uncertainty values were evaluated for SAR measurements performed by Cetecom Inc. The uncertainty values for components specified in *FCC Supplement C (01-01) to OET Bulletin 65 (97-01)* were evaluated according to the procedures of *IEEE 1528 April 21, 2003, NIST 1297 1994 edition and ISO Guide to the Expression of Uncertainty in Measurements (GUM)*.

7.1. Table of Measurement Uncertainty Values of SAR Evaluations

a	*b*	*c*	*d*	*e = f(d,k)*	*f*	*g = c x f / e*	*k*
Uncertainty Component	Sec.	**Tol. (± %)**	**Prob. Dist.**	**Div.**	**c_i (1-g)**	**1-g u_i (±%)**	**v_i**
Measurement System							
Probe Calibration	E2.1	3.6	N	1	1	3.6	∞
Axial Isotropy	E2.2	4.23	R	√3	$(1\text{-cp})^{1/2}$	0.00	∞
Hemispherical Isotropy	E2.2	10.7	R	√3	$\sqrt{c_p}$	6.18	∞
Boundary Effect	E2.3	1.7	R	√3	1	0.98	∞
Linearity	E2.4	2.92	R	√3	1	1.69	∞
System Detection Limits	E2.5	0.00	R	√3	1	0.00	∞
Readout Electronics	E2.6	0.00	N	1	1	0.00	∞
Response Time	E2.7	0.00	R	√3	1	0.00	∞
Integration Time	E2.8	0.00	R	√3	1	0.00	∞
RF Ambient Conditions	E6.1	0.00	R	√3	1	0.00	∞
Probe Positioner Mechanical Tolerance	E6.2	1.14	R	√3	1	0.33	∞
Probe Positioning with respect to Phantom Shell	E6.3	2.86	R	√3	1	0.83	∞
Extrapolation, interpolation and Integration Algorithms for Max. SAR Evaluation	E5.2	3.6	R	√3	1	2.08	∞
Test sample Related							
Test Sample Positioning	E4.2	0.00	N	1	1	0.00	*0*
Device Holder Uncertainty	E4.1	0.00	N	1	1	0.00	*0*
Output Power Variation - SAR drift measurement	6.6.2	5.0	R	√3	1	2.89	∞
Phantom and Tissue Parameters							
Phantom Uncertainty (shape and thickness tolerances)	E3.1	1.43	R	√3	1	0.83	∞
Liquid Conductivity Target - tolerance	E3.2	5.0	R	√3	0.7	2.02	∞
Liquid Conductivity - measurement uncertainty	E3.3	2.0	R	√3	0.7	0.81	∞
Liquid Permittivity Target tolerance	E3.2	5.0	R	√3	0.6	1.73	∞
Liquid Permittivity - measurement uncertainty	E3.3	1.0	R	√3	0.6	0.35	∞
Combined Standard Uncertainty			RSS			**± 8.9%**	
Expanded Uncertainty (95% CONFIDENCE INTERVAL)			*k*= 2.003935			**± 17.9%**	

8. Test results summary

8.1. Probe anisotropy and boundary proximity influence correction software

Virtual Probe Miniaturization VPM software correction was used for all measurements listed in this report.

8.2. Test Positions and Configurations

The device was installed in a Dell PP02X laptop PC. The device was set to transmit without antenna diversity. Measurements were conducted with the device transmitting on either the left or right antenna (see: *Antenna Locations* in Appendix B of this report). The area scan of each measurement was centered near the transmitting antenna.

8.3. Conducted Output Power

Prior to testing the conducted output power was measured. The results are shown below.

5180 MHz	15.3 dBm
5500 MHz	15.6 dBm
5700 MHz	15.7 dBm
5800 MHz	15.8 dBm

8.4. Results for BCM94309MP 5150 MHz to 5350 MHz

Position	Antenna	Device Frequency (MHz)	Max. 1g SAR (W/kg)	Area scan (See Appendix A)	Positioning photo (See Appendix B)
Bystander	Main	5180	1.144	Plot 1	Photo 10

8.5. Results for BCM94309MP 5470 MHz to 5825 MHz

Position	Antenna	Device Frequency (MHz)	Max. 1g SAR (W/kg)	Area scan (See Appendix A)	Positioning photo (See Appendix B)
Bystander	Main	5700	1.304	Plot 2	Photo 10
Lap	Main	5700	0.734	Plot 3	Photo 9
Bystander	Aux	5700	0.663	Plot 4	Photo 8
Lap	Aux	5700	0.525	Plot 5	Photo 7
Lap	Main	5500	1.091	Plot 6	Photo 10
Lap	Main	5800	1.275	Plot 7	Photo 10

9. System Verification Check Results

Prior to formal testing at each frequency band a system verification was performed. Two methods of checking the SAR measurement system were used during the verification.

9.1. Dipole Verification

During the first method a balanced dipole source was placed at a distance of 8 mm from the phantom in horizontal orientation. The verification procedure setup described in IEEE 1528 was then followed. The same scan settings (scan dimensions, step size, boundary corrections, etc.) that will be used for compliance testing were used for the verification scan. All of the testing described in this report was performed within 24 hours of the system verification. The following results were obtained:

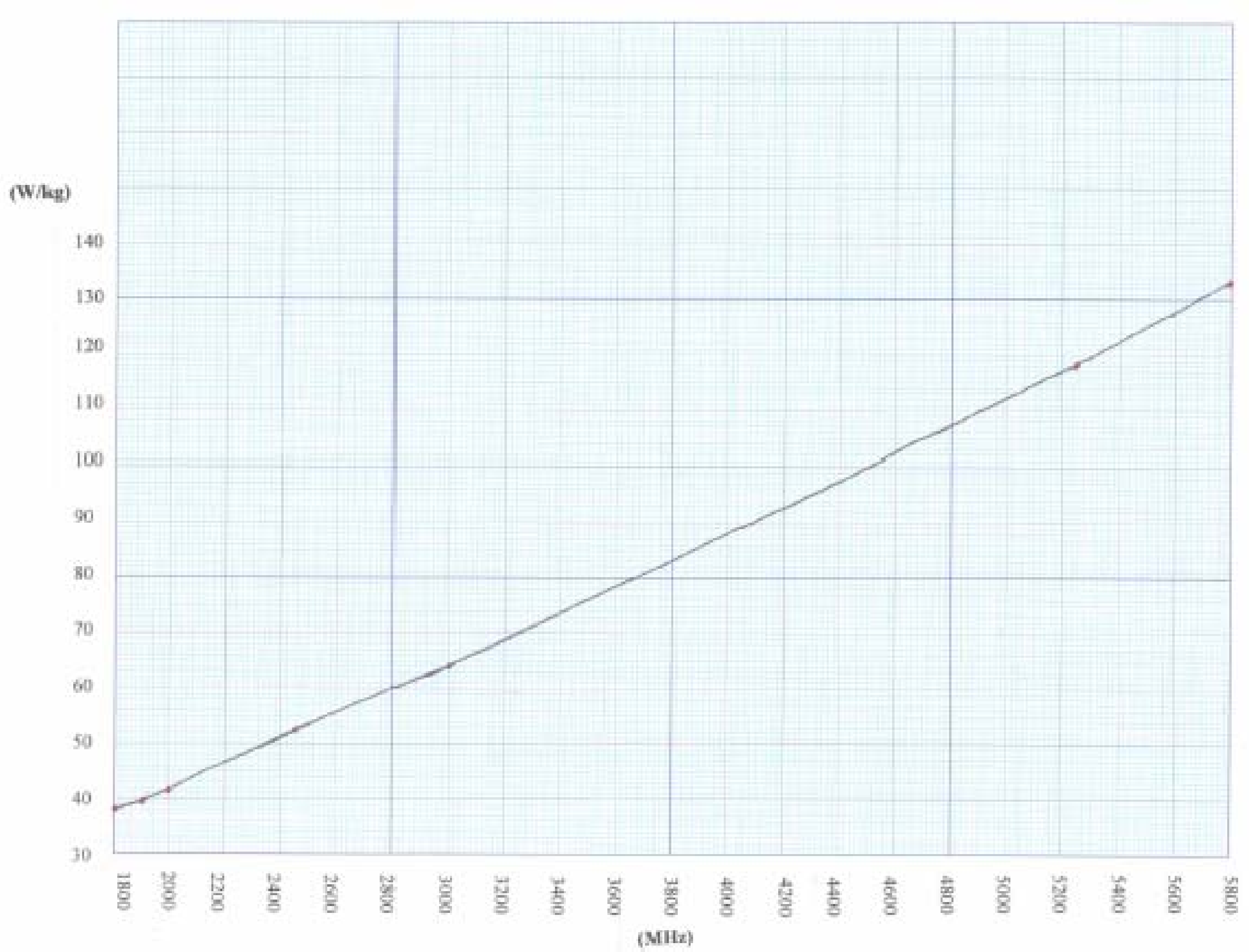
Date	Frequency (MHz)	CW input at dipole feed (Watts)	Max measured1g SAR (W/kg)	Max measured1g SAR normalized to 1 Watt (W/kg)	1 Watt reference SAR (W/kg)	Difference reference SAR value to normalized SAR
11/12/2003	5250	1	118.61	118.61	118.00	+0.52%
11/19/2003	5775	1	124.023	124.023	132.00	-6.043%

Reference Values

The 1 Watt reference values were determined from the values listed in IEEE 1528 for lower frequencies. The steps used to determine the reference values are described below.

First the values listed for frequencies from 1800 MHz to 3000 MHz were entered to a graph. It was noted that the reference values were non-linear. A curve was drawn to 6 GHz, the values on the curve at 5250 MHz and 5775 MHz are noted below:

5250 MHz: 118 W/kg
5775 MHz: 132 W/kg



Values listed for frequencies 1800 MHz and 3000 MHz were then entered into a linear interpolation formula. The formulas and results are shown below. These values are slightly lower than the graphed values due to the nonlinearity of the reference values.

5250 MHz: {(63.8 – 38.1) / (3000 – 1800)} * (5250 – 1800) + 38.1 = 111.99 W/kg

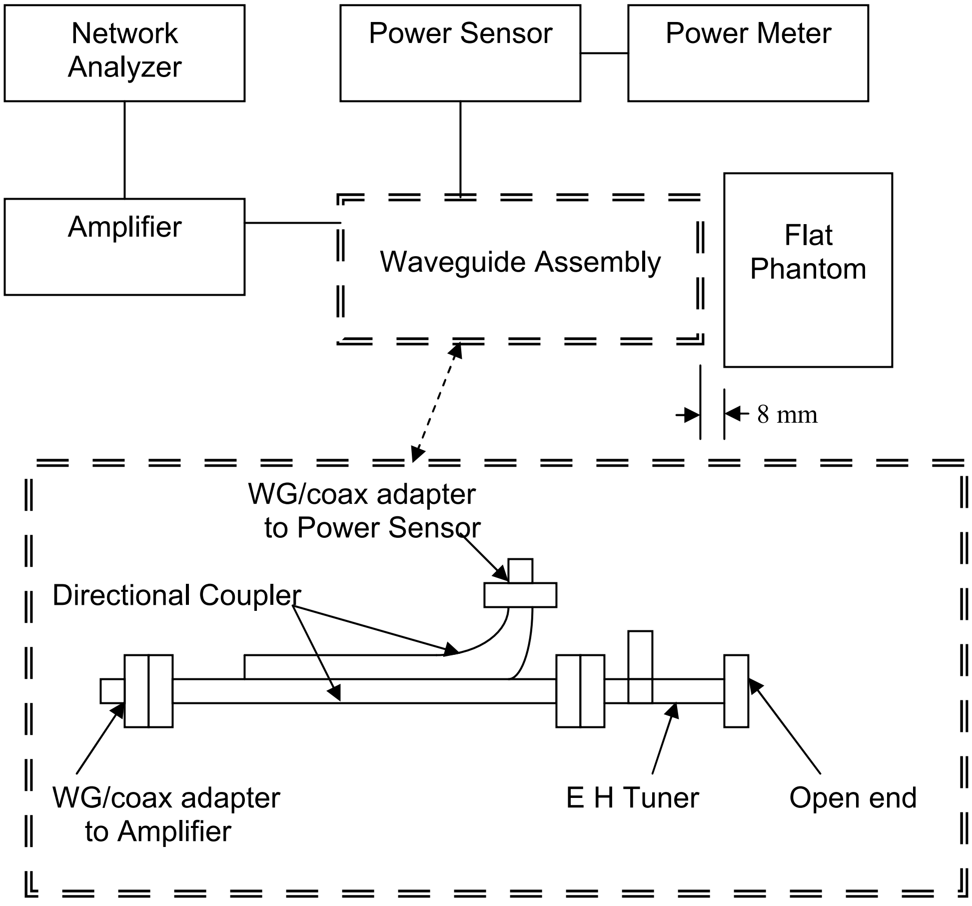
5775 MHz: {(63.8 – 38.1) / (3000 – 1800)} * (5775 – 1800) + 38.1 = 123.23 W/kg

Due to the non-linearity of the reference values, the values determined by graphing were used for system verification reference values.

9.2. Waveguide Verification

The second verification method uses an open-ended waveguide as the radiating source. A waveguide assembly using WR187 (3.95GHz - 5.85 GHz) components was assembled. The waveguide assembly was placed with its open end 8 mm from the liquid filled flat phantom. A micrometer was used to verify the distance and to verify that the waveguide surface was perpendicular to the phantom surface. The input cable to the waveguide assembly was connected to a network analyzer to measure the return loss. The EH tuner in the waveguide assembly was adjusted until a return loss of 40 dB or better was achieved. The input cable was then connected as shown in the setup diagram below. A complete SAR scan is then performed using the same scan settings (scan dimensions, step size, boundary corrections, etc.) that will be used for compliance testing. The results are compared to FDTD calculations of the SAR distributions for a nearly identical setup that was published by Om P. Gandhi at the University of Utah.

Setup Diagram:



Waveguide Assembly

All of the testing described in this report was performed within 24 hours of the system verification. The following results were obtained:

Date	Frequency (MHz)	CW radiated power (Watts)	Max measured1g SAR (W/kg)	Reference SAR (W/kg)	Difference reference SAR value to measured SAR
11/12/2003	5250	0.1	3.535	3.580	-1.26%
11/19/2003	5800	0.1	3.726	3.946	-5.58%

Thermal Calorimetric Measurement

The measurement described below was performed to verify the RF output of the waveguide assembly. A small thin walled rectangular plastic container was placed 8 mm from the open end of the frequency tuned waveguide assemble that is used for system verification. The container's height is approximately 10 cm, the length and width are approximately 6 cm each. It was filled with exactly 200 ml of 5250 MHz SAR liquid, forming a cube with approximately 6 cm sides. The temperature of the liquid was measured and recorded. RF power for 4.57 Watts radiated power was then applied to the waveguide assembly for 120 seconds. The SAR liquid was then shaken and the temperature was measured. This was repeated three time with nearly identical results. Using the calorimetric formula the RF power was calculated as shown below.

$$\text{RF Power (Watts)} = \frac{(4.186\ \text{Joules/Calorie}) * (\text{Volume ml}) * (\text{ending }^\circ\text{C - starting }^\circ\text{C})}{(\text{time seconds})}$$

$$4.186\text{Watts} = \frac{(4.186\ \text{Joules/Calorie}) * (200\ \text{ml}) * (21.0\ ^\circ\text{C} - 20.4^\circ\text{C})}{(120\ \text{seconds})}$$

10. References

[FCC 2001] Federal Communications Commission: Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01), FCC, 2001.
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