SAR COMPLIANCE TESTING OF 3COM 802.11 a/b/g CARDBUS CARD MODEL SL-3040 (FCC ID# O9C-SL3040) WITH THREE HOST COMPUTERS

Host Computers:

1. Toshiba Tecra 750 DVD s/n: 38638812-3
2. Hewlett Packard (HP) Pavillion s/n: TW00311692
3. Dell Inspiron 4000 s/n: C7TKD01

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Prepared for: 3Com Corporation
3930 West Parkway Blvd.
West Valley City, UT 84120-6300
Attention: Mr. Greg Hansen, Regulatory Engineer

Prepared by: Om P. Gandhi
Professor of Electrical and Computer Engineering
University of Utah
50 S Central Campus Dr., Rm. 3280
Salt Lake City, UT 84112-9206

TABLE OF CONTENTS

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I. Introduction

We have used the measurement procedures outlined in FCC Supplement C (Edition 97-01) to OET Bulletin 65 [1] and an updated version of the same [2] for evaluating compliance of the 3Com 802.11 a/b/g Cardbus Card Model SL-3040 with three host computers. Photographs of the 3Com Cardbus Card inserted in the three host computers are given in Figs. 1a, b, c, respectively. The salient features of the 802.11 a/b/g antennas are as follows:

802.11a	5.15 to 5.35, 5.725 to 5.805 GHz (base and turbo modes)
802.11b	2.412 to 2.462 GHz (base mode)
802.11g	2.412 to 2.462 GHz (base and turbo modes)

For SAR measurements, two configurations of each of the wireless PCs relative to the planar phantom have been used. These are as follows:

a. **Configuration 1** is for the wireless PC placed on a user's lap. For this configuration, a planar phantom model with inside dimensions 12" x 16.5" (30.5 x 41.9 cm) and a base thickness of 2.0 ± 0.2 mm (recommended in [2]) was used for SAR measurements and the bottom side of each of the laptop computer was pressed against it (see Fig. 2).

b. **Configuration 2** -- Edge-on position. This configuration corresponds to a bystander close to the outer edge of the Cardbus Card. For this configuration, the PC is placed at 90° with the edge of the 3Com Model SL-3040 Cardbus Card pressed against the bottom of the planar phantom. A photograph for this edge-on position for SAR testing is given in Fig. 3. Similarly, pressed additional host PCs i.e. HP Pavillion and Dell Inspiron 4000 are also used for SAR measurements.

II. The SAR Measurement System

The University of Utah SAR Measurement System has been described in peer-reviewed literature [3]. A photograph of the SAR Measurement System is given in Fig. 4. This SAR Measurement System uses a computer-controlled 3-D stepper motor system (Arrick Robotics MD-2A). A triaxial Narda Model 8021 E-field probe is used to determine the internal electric fields. The positioning repeatability of the stepper motor system moving the E-field probe is within ±0.1 mm. Outputs from the three channels of the E-field probe are dc voltages, the sum of which is proportional to the square of the internal electric fields $\left(|E_i|^2\right)$ from which the SAR can be obtained from the equation SAR = $\sigma\left(|E_i|^2\right)/\rho$, where σ and ρ are the conductivity and mass density of the tissue-simulant materials, respectively [4]. The dc voltages for the three channels of the E-field probe are read by three HP 34401A multimeters and sent to the computer via an HPIB interface. The setup is carefully grounded and shielded to reduce the noise due to the electromagnetic interference (EMI). A cutout in a wooden table allows placement of a plastic holder (shown in Fig. 5) on which the laptop computers with the 802.11 a/b/g wireless antennas (see Figs. 1a, b, c) are supported. The plastic holder (see Fig. 5) can be moved up or down so that the base of the PC (for Configuration 1) is pressed against the base of the flat phantom for determination of SAR for Above-lap position (see e.g. Fig. 2). Similarly, for "Edge-On" SAR determination, Configuration 2, the laptop computer is mounted sideways (at 90°) on the plastic holder and moved up so that the edge of the 3Com Model SL-3040 PC Cardbus Card with the 802.11 a/b/g antennas is pressed against the bottom of the flat phantom (see Fig. 3).

The Flat Phantom

As recommended in Supplement C Edition 01-01 to OET Bulletin 65 [2], a planar phantom model with inside dimensions 12" × 16.5" (30.5 × 41.9 cm) and base thickness 2.0 ± 0.2 mm was used for SAR measurements (see Figs. 2-4).

III. Calibration of the E-Field Probe

The IEEE Standard P1528 [5] suggests a recommended procedure for probe calibration (see Section 4.4.1 of [5]) for frequencies above 800 MHz where waveguide size is manageable. Calibration using an appropriate rectangular waveguide is recommended.

Calibration in the 5.2-5.8 GHz Range

As in some previously reported SAR measurements at 6 GHz [4], we have calibrated the Narda Model 8021 Miniature Broadband Electric Field Probe of tip diameter 4 mm (internal dipole dimensions on the order of 2.5 mm) using a rectangular waveguide WR 159 (of internal dimensions 1.59 x 0.795 inches) that was filled with the tissue-simulant fluid of composition given in Section V (see Figs. 6a, b). The triaxial (3 dipole) E-field probe shown in Fig. 7 was originally developed by Howard Bassen and colleagues of FDA and has been manufactured under license by Narda Microwave Corporation, Hauppage, New York. The probe is described in detail in references 6 and 7. It uses three orthogonal pick up dipoles each of length about 2.5 mm offset from the tip by 3 mm, each with its own leadless zero voltage Schottky barrier diode operating in the square law region. The sum of the three diode outputs read by three microvoltmeters [3] gives an output proportional to E^2. By rotating the probe around its axis, the isotropy of the probe was measured to be less than ± 0.23 dB and the deviation of the probe from the square law behavior was less than ± 3%.

As suggested in the IEEE Standard P1528, the waveguide (WR 159) filled with the tissue-simulant fluid was maintained vertically. From microwave field theory [see e.g. ref. 8], the transverse field distribution in the liquid corresponds to the fundamental mode (TE_{10}) with an exponential decay in the vertical direction (z-axis). The liquid level was 15 cm deep which is deep enough to guarantee that reflections from the top liquid surface do not affect the calibration. By comparing the square of the decaying electric fields expected in the tissue from the analytical expressions for the TE_{10} mode of the rectangular waveguide, we obtained a calibration factor of

2.98 (mW/kg)/μV with a variability of less than ± 2% for measurement frequencies of 5.25 and 5.8 GHz, respectively. This is no doubt due to a fairly limited frequency band of only 0.55 GHz out of a recommended bandwidth of 2.2 GHz for the TE_{10} mode for the WR159 waveguide (recommended band of 4.9-7.1 GHz -- see e.g. ref. 8) and the fact that the bandwidth of 550 MHz for the entire set of measurements is on the order of ± 5% of the midband frequencies.

Calibration for the 802.11 b/g Midband 2.45 GHz

The procedure for the calibration of the E-field probe for the 802.11 b/g midband frequency of 2.437 GHz is similar to that used for the 802.11a frequencies of 5.25 and 5.8 GHz given earlier. For the lower frequency of 2.45 GHz, a rectangular waveguide WR284 (of internal dimensions 2.84 × 1.34 inches) was used with a tissue-simulant fluid recommended in IEEE Standard P1528 [5]. The arrangement was similar to that shown in Figs. 7a, b and the depth of the fluid was 15 cm which is deep enough to guarantee that reflections from the top liquid surface do not affect the calibration. By comparing the square of the decaying electric fields expected in the tissue-simulant fluid from the analytical expressions for the TE_{10} mode of the WR284 waveguide, we obtained a calibration factor of 1.18 (mW/kg)/μV with a variability of less than ± 2% for the 802.11 b/g midband measurement frequency of 2.45 GHz.

The date for the calibration of the E-field probe closest to the SAR tests given here was July 1, 2003.

To verify that the probe calibration conducted for each of the bands i.e. the 802.11 b/g and 802.11 bands with CW signals is also valid for modulated signals used for the Cardbus Card, the procedure was as follows:

For the microvoltmeters in our SAR system (HP34401 multimeters), we use an AC signal filter with a passband of 20 Hz to 300 kHz (1 reading/second). This allows faithful readings of the rectified values of voltage outputs from the three pickup antennas (proportional to E^2) of the E-field probe used for SAR measurements. For a variety of modulated signals used for the 802.11 a/b/g bands including the present 3Com Model SL-3040 Cardbus Card, the multimeter passband of 20 Hz to 300 kHz is more than sufficient to read all of the frequency components. We have tested the validity of using this AC signal filter by applying signals from a Hewlett Packard Model 83620A Synthesized Sweeper operating at 2.45, 5.25, and 5.8 GHz in the CW mode as well as the pulse mode with pulse repetition rates for the latter variable from 50 to 500 Hz and pulse duration variable from 0.5 to 1 msec. For a fixed location of the E-field probe, the SAR readings were proportional to the time-averaged radiated power (from 2.5 to 100 mW) from the reference dipole at 2.45 GHz and the WR187 rectangular waveguide at 5.25 and 5.8 GHz, respectively. Thus the probe calibration factors are no different for CW signals or for pulsed signals.

IV. SAR System Verification

System Validation for the 802.11 b/g Midband 2.45 GHz

As recommended in the IEEE Standard P1528 [5], a reference dipole shown in Fig. 8 is used. This dipole of length 51.5 mm and diameter 3.6 mm and h = 30.4 mm was fabricated and tested for excellent matching at the University of Utah (VSWR ≤ 1.4 at 2.45 GHz). As recommended in OET65 Supplement C [2], we used a spacing of 10 mm from the dipole to the tissue-simulant fluid composed of 73.2% water, 0.04% salt (NaCl) and 26.7% DGBE. The microwave circuit arrangement used for system vereification is sketched in Fig. 9. The dielectric properties for this body-simulant fluid were measured using the Hewlett Packard (HP) Model 85070 B Dielectric Probe (rated frequency band 200 MHz to 20 GHz in conjunction with HP Model 8720C Network Analyzer (50 MHz-20 GHz) using a procedure detailed in Section V. The measured dielectric parameters of the body-simulant fluid at 2450 MHz are $\varepsilon_r = 52.3 \pm 0.6$ and $\sigma = 1.92 \pm 0.07$ S/m. The measured properties are close to the values of $\varepsilon_r = 52.7$ and $\sigma = 1.95$ S/m given in OET Supplement C [2].

The measured SAR distribution for the peak 1-g SAR region using this system verification dipole for the day of SAR measurements July 1, 2003 is given in Appendix A. Also given in Appendix A is the dipole SAR plot for this date of device testing. The peak 1-g SAR is

52.15 W/kg. The measured 1-g SAR is in excellent agreement with the FDTD-calculated 1-g SAR of 51.3 W/kg for this dipole. Also as expected, the measured SAR plot is quite symmetric.

System Validation for the 802.11a band 5.2 to 5.8 GHz

It is very difficult to develop half wave dipole antennas for use in the 5.2 to 5.8 GHz band both because of fairly small dimensions and the resulting dimensional tolerances, and relatively narrow bandwidths of the required baluns – balanced-to-unbalanced transformers. On the other hand, waveguides are broadband with simultaneous bandwidths larger than 1-2 GHz and fairly easy to use for frequencies in excess of 3 GHz. As shown in Fig. 10, we have, therefore, developed a system verification system by using an open-ended, air-filled waveguide as an irradiation system placed at a distance of 8 mm below the base of the planar phantom (10 mm from the lossy fluid in the phantom). For this application, we have set up a WR 187 rectangular waveguide of internal dimensions 1.872" × 0.872" that is fed with microwave power from a Hewlett Packard Model 83620A Synthesized Sweeper (10 MHz-20 GHz). The operating (TE_{10} mode) band of this waveguide is from 3.95 to 5.85 GHz. The microwave circuit arrangement used for system verification is sketched in Fig. 11. When placed at a distance of 8 mm from the base of the planar phantom, the reflection coefficient is about 10-20%. As seen in Fig. 10, even this relatively small amount of reflection has been reduced to less than 0.5% by using a movable slide-screw waveguide tuner (Narda Model 22CI). The measured SAR distributions for peak 1-g SAR region using this system at 5.25 and 5.80 GHz for the day of SAR measurements July 1, 2003 are given in Appendix B. Also given in Appendix B are the waveguide SAR plots for this date of SAR measurements. The peak 1-g SARs measured for 100 mW of radiated power for 5.25 and 5.80 GHz are 3.612 and 3.825 W/kg, respectively. The measured 1-g SARs are in excellent agreement with the FDTD-calculated 1-g SARs for this waveguide of 3.580 and 3.946 W/kg at 5.25 and 5.80 GHz, respectively. Also as expected, the measured SAR plots in Appendix B are quite symmetric at both of the irradiation frequencies.

For FDTD-calculations of the SAR distributions for the WR187 rectangular waveguide irradiation system, we have used the dielectric properties for the phantom given in Table 1 that have been taken from [2]. Using a resolution of 0.5 mm for the FDTD cells, the calculated variations of the SAR distributions are given in Figs. 12a, b as a function of height above the bottom surface of the phantom. From Figs. 12a, b, it is obvious that the penetration of electromagnetic fields in the 5.2-5.8 GHz range is extremely shallow. The calculated depths of penetration corresponding to $1/e^2$-reduction of SAR (13.5% of the SAR at the surface) are only 6.85 and 5.95 mm at 5.25 and 5.8 GHz, respectively. Both of these depths of penetration for this near-field exposure system are very similar to those obtained for plane wave irradiation at these frequencies (7.15 mm for 5.25 GHz and 6.25 mm for 5.8 GHz).

Also shown in Figs. 12a, b are the SAR variations measured for this waveguide exposure system at depths of 4, 6, 8, 10, 12, and 14 mm in the tissue-simulant fluid. We tried second-, third-, fourth-, and fifth-order polynomial least-square fits to extrapolate the measured SARs to depths of 1, 3, 5, 7, and 9 mm. As seen in Figs. 12a, b, the fourth-order polynomial provides an excellent agreement with the FDTD-calculated in-depth variation of SAR both at 5.25 and 5.8 GHz. Also as aforementioned, the peak 1-g SARs thus obtained for 100 mW of radiated power for 5.25 and 5.80 GHz of 3.612 and 3.825 W/kg are extremely close to the FDTD-calculated 1-g SARs for this waveguide of 3.580 and 3.946 W/kg at the two frequencies, respectively.

V. Tissue Simulant Fluids for the 802.11 a/b/g Bands

The Tissue-Simulant Fluid for the 802.11a Band 5.2 to 5.8 GHz

In OET 65 Supplement C [2], the dielectric parameters suggested for body phantom are given only for 3000 and 5800 MHz. These are listed in Table 1 here. Using linear interpolation, we can obtain the dielectric parameters to use for the frequency band between 5.25 to 5.8 GHz. The desired dielectric properties thus obtained are also given in Table 1. From Table 1, it can be noticed that the desired dielectric constant ε_r varies from 48.2 to 49.0 which is a variation of less than ± 1% from the average value of 48.6 for this band. Also the conductivity σ varies linearly with frequency from 5.3 to 6.00 S/m. For the SAR measurements given in this report, we have used a tissue-simulant fluid developed at the University of Utah which consists of 68.0% water, 31.0% sugar and 1% HEC. For this composition, we have measured the dielectric properties using a Hewlett Packard (HP) Model 85070B Dielectric Probe in conjunction with HP Model 8720C Network Analyzer (50 MHz-20 GHz). The measured dielectric properties at a mid band frequency of 5.30 GHz are as follows: $\varepsilon_r = 48.5 \pm 1.7$ and $\sigma = 5.40 \pm 0.08$ S/m. From Table 1, we obtain the desired dielectric properties to simulate the body tissue at the midband frequency of 5.30 GHz to be $\varepsilon_r = 48.9$ and $\sigma = 5.42$ S/m. Thus, the measured properties for the body-simulant fluid are close to the desired values. Also as expected, the conductivity of this fluid varies linearly with frequency rising to 6.03 ± 0.09 S/m at 5.8 GHz, while the dielectric constant ε_r is nearly the same as the measured value at 5.3 GHz.

The procedure is as follows: The HP Model 95070B Dielectric Probe (see Fig. 13) is an open-circuited transmission-line (coaxial line) probe similar to that described in Section B.1.2 of the IEEE Standard P1528 [5]. The theory of the open-circuited coaxial line method has been described in scientific literature [9-11]. We have previously used this method in determining the dielectric properties of tissue-simulant materials at 6 GHz [4]. In this method, the complex reflection coefficient Γ^* measured for the open end of the coaxial line can be used to calculate the complex permittivity ε* from the following equation [4]

$$\varepsilon^* = \frac{1-\Gamma^*}{j\omega Z_o C_o\left(1+\Gamma^*\right)} - \frac{C_f}{C_o} \quad (1)$$

where Z_o is the characteristic impedance (50 Ω) for the coaxial line, C_o is the capacitance when the line is in air and C_f is the capacitance that accounts for the fringing fields in the dielectric of the coaxial line.

For the HP85070B Dielectric Probe with diameters of the outer and inner conductors 2b = 3.00 mm and 2a = 0.912 mm, respectively, the following capacitances were obtained using deionized water and methanol as the calibration fluids. The following capacitances were obtained:

$$C_o = 0.022 \text{ pF}$$

$$C_f = 0.005 \text{ pF}$$

Using the network analyzer HP8720C, we measured the reflection coefficient Γ^* for the open end of the coaxial line that was submerged in the tissue-simulant fluid. Using Eq. 1, the complex permittivity of the fluid was measured at various frequencies 5.2-5.4 GHz. From the imaginary part of the complex permittivity Im(ε^*), we can obtain the conductivity σ from the relationship

$$\sigma = \frac{\text{Im}(\varepsilon^*)}{\omega \varepsilon_o} \tag{2}$$

The Tissue-Simulant Fluid for the 802.11 b/g Band 2.412-2.462 GHz

The body tissue-simulant fluid recommended for the 2.45 GHz in FCC OET Bulletin 65 Supplement C [2] is made of the following composition: 73.2% water, 0.04% salt (NaCl), and 26.7% DGBE. The measured dielectric properties for this fluid of $\varepsilon_r = 52.3 \pm 0.6$ and $\sigma = 1.92 \pm 0.07$ S/m are in good agreement with those proposed in [2] i.e. $\varepsilon_r = 52.7$ and $\sigma = 1.95$ S/m.

VI. The Measured SAR Distributions

Using a Hewlett Packard Model 436A Power Meter, the maximum power outputs of the 3Com 802.11 a/b/g Cardbus Card were measured for each of the host computers at a number of frequencies through the coaxial connector provided for this purpose on the Cardbus Card (see Figs. 14, 15). The average conducted RF power outputs measured at various frequencies for the 3 Com Cardbus Card inserted into the three host computers are given in Tables 2-4, respectively. As recommended in Supplement C, Edition 01-01 [2], the conducted power was measured before and after each SAR measurement and found to be within ± 0.1 dB (± 2.5%) of the values given in Tables 2-4, respectively.

The highest SAR region for each of the measurement frequencies was identified in the first instance by using a coarser sampling with a step size of 8.0 mm over three overlapping areas for a total scan area of 11.2 × 19.2 cm. The data thus obtained is resolved into a 4 × 4 times larger grid i.e. a grid involving 56 × 96 points by linear interpolation using a 2 mm step size. After thus identifying the region of the highest SAR, the SAR distribution was then measured with a resolution of 2 mm in order to obtain the peak 1 cm^3 or 1-g SAR. The SAR measurements are performed at 4, 6, 8, 10, 12 mm height from the bottom surface of the body-simulant fluid. The SARs thus measured were extrapolated using a second-order least-square fit to the measured data for the lower frequency 802.11 b/g bands (2.412-2.462 GHz). Because of the more rapid decrease of the in-depth SAR, a fourth-order fit to the measured data was needed to obtain the SAR variation correctly for the 802.11a frequencies of 5.2 to 5.8 GHz [12, attached here as Appendix C]. This allowed us to obtain SAR values at 1, 3, 5, 7, and 9 mm height that were used to obtain 1-g SARs. The uncertainty analysis of the University of Utah SAR measurement system is given in Appendix D. The combined standard uncertainty is ± 8.3%.

As determined by the coarse scans, the highest SAR region was invariably found for the 5.6 × 8.0 cm area immediately below the Cardbus Card for the "Above-lap" Configuration 1 and above the projected area of the antenna for the "Edge-on" Configuration 2. The coarse scans for these highest SAR regions are given in Appendix E Figs. E-1 to E-66. In these figures, the two axes are marked in units of step size of 8 mm. Also shown in these figures are the respective antenna outlines overlaid on the SAR contours. Also given in Appendix E as Tables E-1 to E-66 are the SAR distributions for the peak SAR region of volume 10 × 10 × 10 mm for which the coarse scans are given in Figs. E-1 to E-66, respectively. The SARs are given for xy planes at heights Z of 1, 3, 5, 7, and 9 mm from the bottom of the flat phantom. The individual SAR values for this grid of 5 × 5 × 5 or 125 points are averaged to obtain peak 1-g SAR values (for a volume of 1 cm^3). The temperature variation of the tissue-simulant fluid measured with a Bailey

Instruments Model BAT 8 Temperature Probe for measurements at the various frequencies was $23.3 \pm 0.2^{\circ}C$.

The z-axis scan plots taken at the highest SAR locations for each set of tests are given in Appendix F. As discussed in Section IV, the SARs drop off fairly rapidly with depth in the phantom.

The SAR measurement results for the three host computers are summarized in Tables 5-7, respectively. All of the measured 1-g SARs are less than the FCC 96-326 guideline of 1.6 W/kg.

VII. Comparison of the Data with FCC 96-326 Guidelines

According to the FCC 96-326 Guideline, the peak SAR for any 1-g of tissue should not exceed 1.6 W/kg. For the 3Com 802.11 a/b/g Cardbus Card Model SL-3040 (FCC ID# O9C-SL3040) used with three host computers, the measured peak 1-g SARs vary from 0.145 to 0.810 W/kg which are smaller than 1.6 W/kg.

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Table 1. Dielectric parameters for body phantom for the frequency band 5.2 to 5.8 GHz [2].

Frequency GHz	ε_r	σ S/m	Reference
3.0	52.0	2.73	Ref. 3
5.8	48.2	6.00	Ref. 3
5.25	49.0	5.30	Interpolated
5.3	48.9	5.42	Interpolated
5.4	48.7	5.53	Interpolated
5.6	48.5	5.77	Interpolated
5.7	48.3	5.88	Interpolated

Table 2. Average conducted RF power outputs measured at various frequencies for the 3Com 802.11 a/b/g Cardbus Card Model SL-3040 with Toshiba Tecra 750 DVD Host Computer.

Band	Mode	Frequency (GHz)	Conducted Output Power (dBm)
IEEE 802.11 a	Base	5.24	16.30
	Base	5.32	17.91
	Base	5.765	17.18
	Turbo	5.29	17.02
IEEE 802.11 b	Base	2.412	19.37
	Base	2.437	19.10
	Base	2.462	18.81
IEEE 802. 11 g	Base	2.412	18.24
	Base	2.437	18.02
	Base	2.462	17.92
	Turbo	2.437	18.08

Table 3. Average conducted RF power outputs measured at various frequencies for the 3Com 802.11 a/b/g Cardbus Card Model SL-3040 with Hewlett Packard (HP) Pavillion Host Computer.

Band	Mode	Frequency (GHz)	Conducted Output Power (dBm)
IEEE 802.11 a	Base	5.24	16.33
	Base	5.32	17.88
	Base	5.765	17.21
	Turbo	5.29	17.00
IEEE 802.11 b	Base	2.412	19.40
	Base	2.437	19.12
	Base	2.462	18.80
IEEE 802. 11 g	Base	2.412	18.26
	Base	2.437	18.05
	Base	2.462	17.93
	Turbo	2.437	18.03

Table 4. Average conducted RF power outputs measured at various frequencies for the 3Com 802.11 a/b/g Cardbus Card Model SL-3040 with Dell Inspiron 4000 Host Computer.

Band	Mode	Frequency (GHz)	Conducted Output Power (dBm)
IEEE 802.11 a	Base	5.24	16.29
	Base	5.32	17.93
	Base	5.765	17.21
	Turbo	5.29	17.04
IEEE 802.11 b	Base	2.412	19.32
	Base	2.437	19.13
	Base	2.462	18.85
IEEE 802. 11 g	Base	2.412	18.26
	Base	2.437	18.06
	Base	2.462	17.96
	Turbo	2.437	18.13

Table 5. The SAR measurement results for the 3Com 802.11 a/b/g Cardbus Card Model SL-3040 inserted into Toshiba Tecra 750 DVD Host Computer.

Liquid temperature = 23.3 ± 0.2°C
Measurement date: July 2, 2003

Configu-ration	Separation from Phantom (cm)	Frequency (GHz)	Mode	Average Conducted Output Power (dBm)		1-g SAR (W/kg)	See Appendix E Table	See Appendix E Figure
				Before	After			
IEEE 802.11 a								
1	0	5.24	Base	16.30	16.33	0.150	E-1	E-1
	0	5.32	Base	17.91	17.95	0.157	E-2	E-2
	0	5.765	Base	17.18	17.15	0.288	E-3	E-3
	0	5.29	Turbo	17.02	17.07	0.144	E-4	E-4
2	0	5.24	Base	16.30	16.36	0.511	E-5	E-5
	0	5.32	Base	17.91	17.92	0.650	E-6	E-6
	0	5.765	Base	17.18	17.17	0.364	E-7	E-7
	0	5.29	Turbo	17.02	17.09	0.457	E-8	E-8
IEEE 802.11 b								
1	0	2.412	Base	19.37	19.41	0.240	E-9	E-9
	0	2.437	Base	19.10	19.08	0.294	E-10	E-10
	0	2.462	Base	18.81	18.82	0.337	E-11	E-11
2	0	2.412	Base	19.37	19.43	0.242	E-12	E-12
	0	2.437	Base	19.10	19.11	0.258	E-13	E-13
	0	2.462	Base	18.81	18.79	0.237	E-14	E-14
IEEE 802.11 g								
1	0	2.412	Base	18.24	18.21	0.294	E-15	E-15
	0	2.437	Base	18.02	18.07	0.245	E-16	E-16
	0	2.462	Base	17.92	17.96	0.292	E-17	E-17
	0	2.437	Turbo	18.08	18.12	0.224	E-18	E-18
2	0	2.412	Base	18.24	18.24	0.264	E-19	E-19
	0	2.437	Base	18.92	18.11	0.248	E-20	E-20
	0	2.462	Base	17.92	17.93	0.214	E-21	E-21
	0	2.437	Turbo	18.08	18.14	0.297	E22	E22

Table 6. The SAR measurement results for the 3Com 802.11 a/b/g Cardbus Card Model SL-3040 inserted into HP Pavillion Host Computer.

Liquid temperature = 23.3 ± 0.2°C
Measurement date: July 2, 2003

Configu-ration	Separation from Phantom (cm)	Frequency (GHz)	Mode	Average Conducted Output Power (dBm)		1-g SAR (W/kg)	See Appendix E Table	See Appendix E Figure
				Before	After			
IEEE 802.11 a								
1	0	5.24	Base	16.33	16.37	0.185	E-23	E-23
	0	5.32	Base	17.88	17.82	0.169	E-24	E-24
	0	5.765	Base	17.21	17.20	0.145	E-25	E-25
	0	5.29	Turbo	17.00	17.07	0.342	E-26	E-26
2	0	5.24	Base	16.33	16.32	0.810	E-27	E-27
	0	5.32	Base	17.88	17.84	0.798	E-28	E-28
	0	5.765	Base	17.21	17.26	0.458	E-29	E-29
	0	5.29	Turbo	17.00	17.07	0.550	E-30	E-30
IEEE 802.11 b								
1	0	2.412	Base	19.40	19.38	0.762	E-31	E-31
	0	2.437	Base	19.12	19.20	0.762	E-32	E-32
	0	2.462	Base	18.80	18.77	0.749	E-33	E-33
2	0	2.412	Base	19.40	19.36	0.196	E-34	E-34
	0	2.437	Base	19.12	19.18	0.174	E-35	E-35
	0	2.462	Base	18.80	18.76	0.179	E-36	E-36
IEEE 802.11 g								
1	0	2.412	Base	18.26	18.23	0.763	E-37	E-37
	0	2.437	Base	18.05	18.06	0.719	E-38	E-38
	0	2.462	Base	17.93	17.95	0.690	E-39	E-39
	0	2.437	Turbo	18.03	18.02	0.620	E-40	E-40
2	0	2.412	Base	18.26	18.26	0.200	E-41	E-41
	0	2.437	Base	18.05	18.02	0.185	E-42	E-42
	0	2.462	Base	17.93	17.96	0.173	E-43	E-43
	0	2.437	Turbo	18.03	18.04	0.165	E-44	E-44

Table 7. The SAR measurement results for the 3Com 802.11 a/b/g Cardbus Card Model SL-3040 inserted into Dell Inspiron 4000 Host Computer.

Liquid temperature = 23.3 ± 0.2°C
Measurement date: July 2, 2003

Configu-ration	Separation from Phantom (cm)	Frequency (GHz)	Mode	Average Conducted Output Power (dBm)		1-g SAR (W/kg)	See Appendix E Table	See Appendix E Figure
				Before	After			
IEEE 802.11 a								
1	0	5.24	Base	16.29	16.26	0.187	E-45	E-45
	0	5.32	Base	17.93	17.91	0.138	E-46	E-46
	0	5.765	Base	17.21	17.26	0.177	E-47	E-47
	0	5.29	Turbo	17.04	17.06	0.120	E-48	E-48
2	0	5.24	Base	16.29	16.28	0.380	E-49	E-49
	0	5.32	Base	17.93	17.89	0.426	E-50	E-50
	0	5.765	Base	17.21	17.31	0.315	E-51	E-51
	0	5.29	Turbo	17.04	17.08	0.297	E-52	E-52
IEEE 802.11 b								
1	0	2.412	Base	19.32	19.31	0.475	E-53	E-53
	0	2.437	Base	19.13	19.16	0.447	E-54	E-54
	0	2.462	Base	18.85	18.89	0.425	E-55	E-55
2	0	2.412	Base	19.32	19.33	0.243	E-56	E-56
	0	2.437	Base	19.13	19.22	0.219	E-57	E-57
	0	2.462	Base	18.85	18.87	0.183	E-58	E-58
IEEE 802.11 g								
1	0	2.412	Base	18.26	18.29	0.397	E-59	E-59
	0	2.437	Base	18.06	18.11	0.382	E-60	E-60
	0	2.462	Base	17.96	18.01	0.377	E-61	E-61
	0	2.437	Turbo	18.13	18.10	0.313	E-62	E-62
2	0	2.412	Base	18.26	18.31	0.143	E-63	E-63
	0	2.437	Base	18.06	18.19	0.130	E-46	E-46
	0	2.462	Base	17.96	17.98	0.123	E-65	E-65
	0	2.437	Turbo	18.10	18.11	0.120	E-66	E-66

a. Inserted in Toshiba Tecra 750 DVD Notebook Computer.

Fig. 1. Photographs of the 3Com Cardbus Card Model SL-3040.

b. Inserted in HP Pavillion Notebook Computer.

Fig. 1. Photographs of the 3Com Cardbus Card Model SL-3040.

c. Inserted in Dell Inspiron 4000 Notebook Computer.

Fig. 1. Photographs of the 3Com Cardbus Card Model SL-3040.

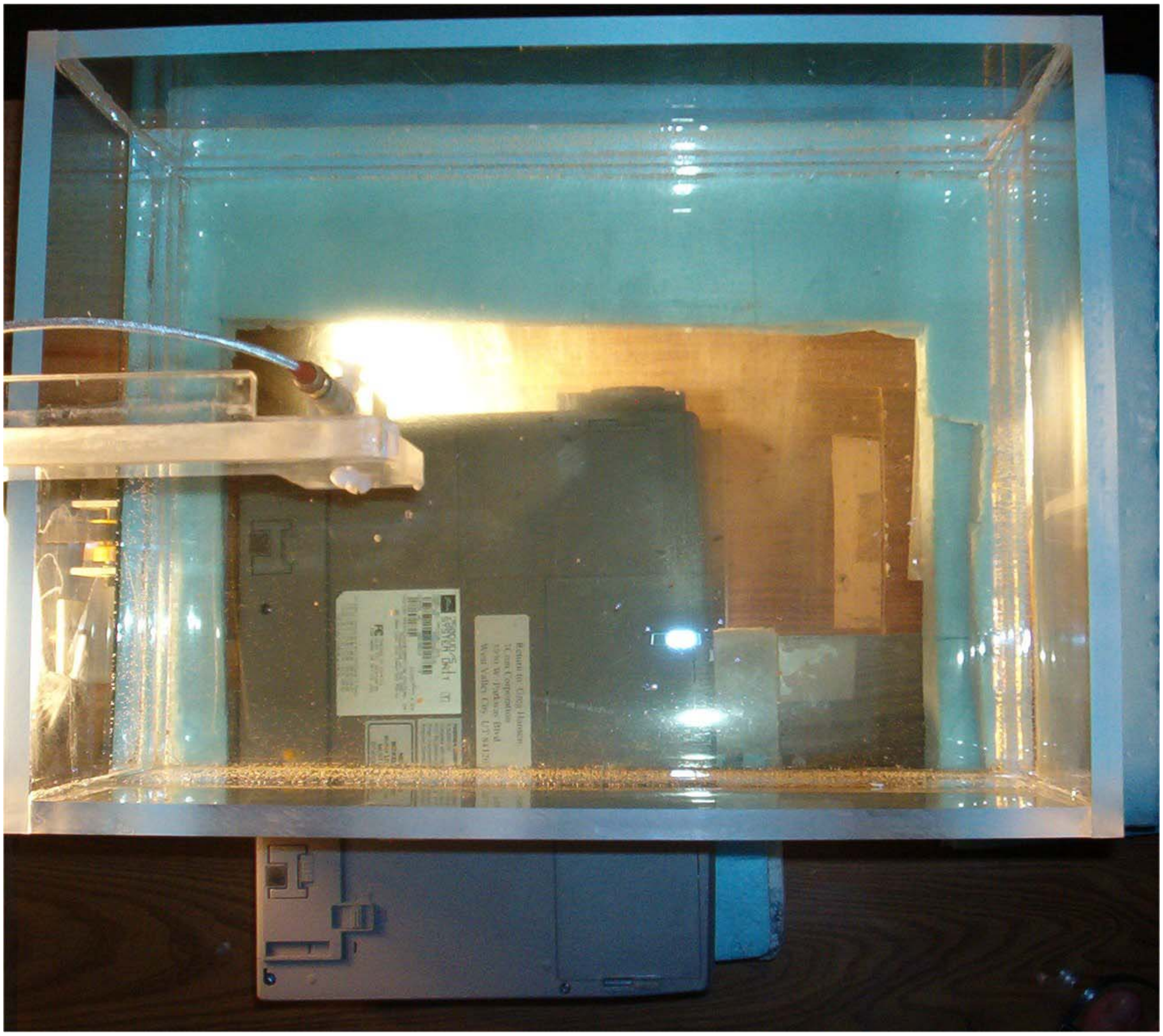


Fig. 2. Photograph of the base of Toshiba Tecra Model 750 DVD (with 3Com Model SL-3040 Cardbus Card) pressed against the bottom of the planar phantom (similarly pressed bases for the other two PCs i.e. HP Pavillion and Dell Inspiron 4000 are also used for SAR measurements). This is **Configuration 1 – Laptop position** for SAR testing.

Fig. 3. Photograph of the Toshiba Tecra Model 750 DVD at 90° with the edge of the 3Com Model SL-3040 Cardbus Card pressed against the bottom of the planar phantom (similarly pressed PCs i.e. HP Pavillion and Dell Inspiron 4000 are also used for SAR measurements). This is **Configuration 2** for SAR testing and represents the case of a bystander at a distance of 0 cm from the edge of the Cardbus Card.

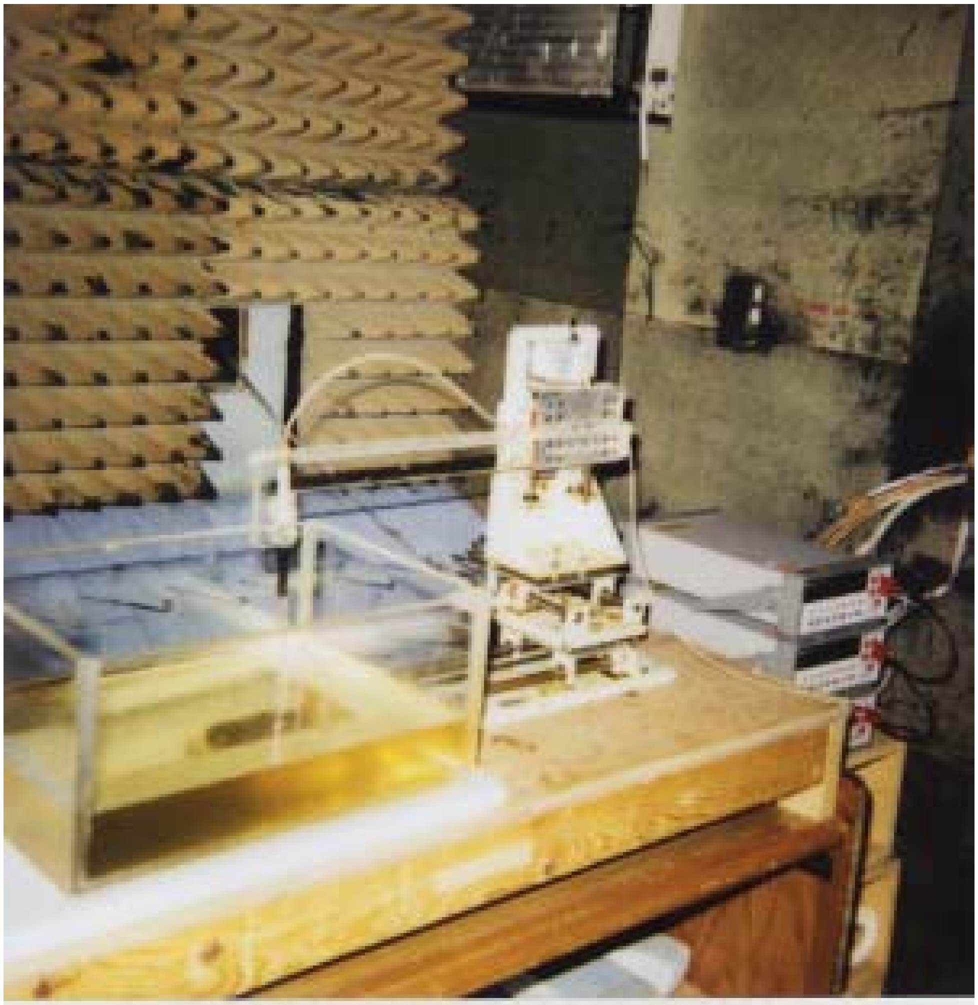


Fig. 4. Photograph of the three-dimensional stepper-motor-controlled SAR measurement system using a planar phantom (see Figs. 2 and 3 for the placement of the PCs for Configurations 1 and 2, respectively).

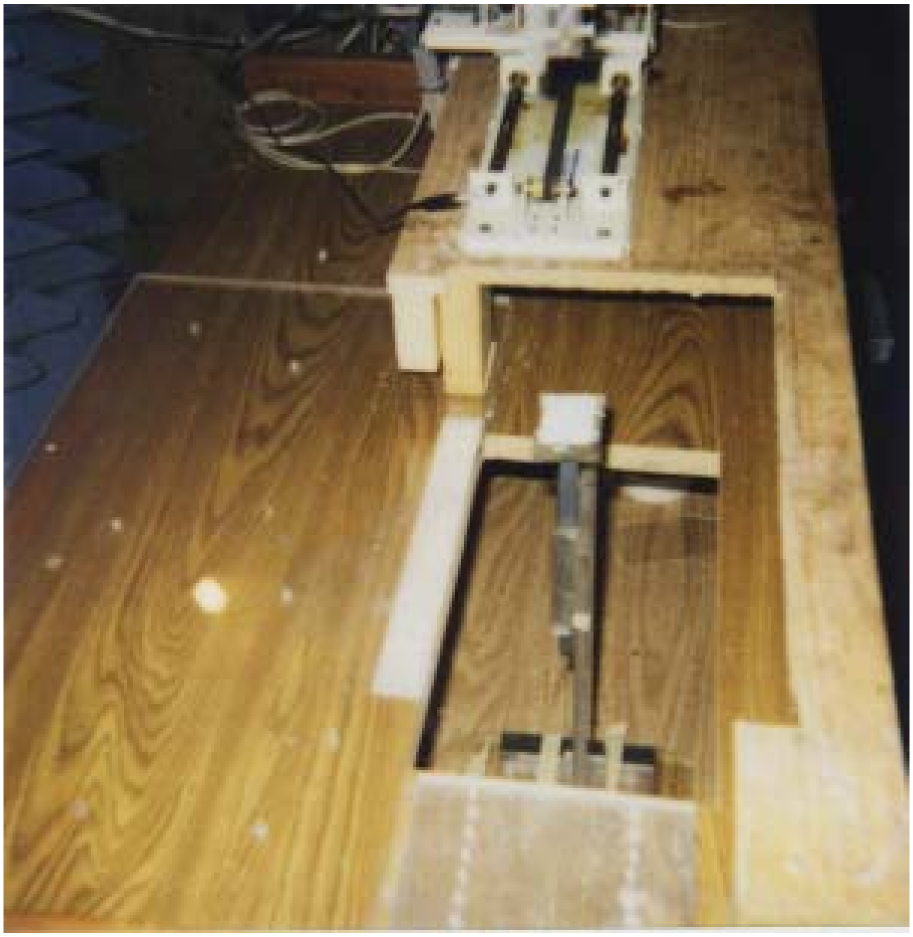


Fig. 5. The plastic holder used to support the PCs with the Cardbus Card inserted in it. (See Figs. 1a, b, c.)

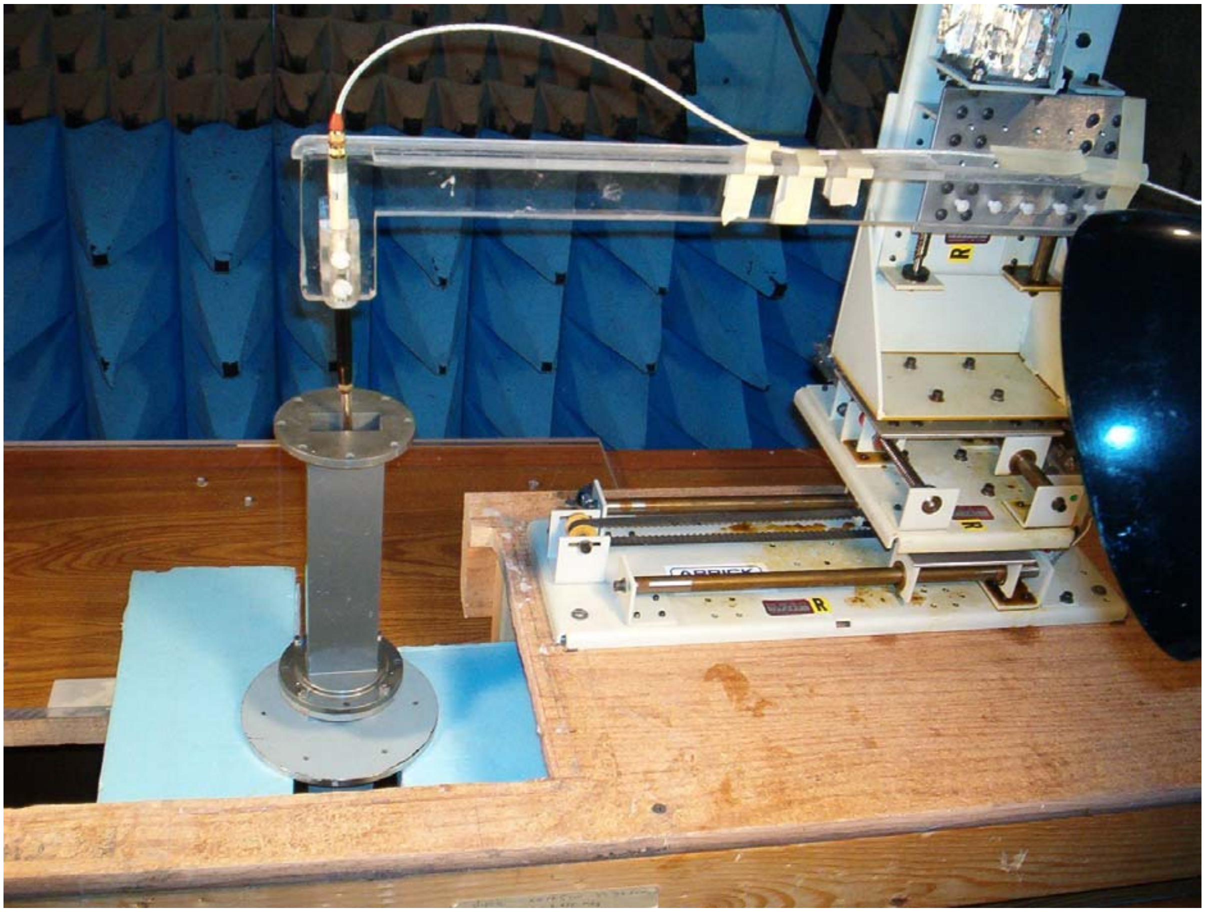


Fig. 6a. A photograph of the waveguide setup used for calibration of the Narda Model 8021 E-field probe in the frequency band 5.2-5.8 GHz.

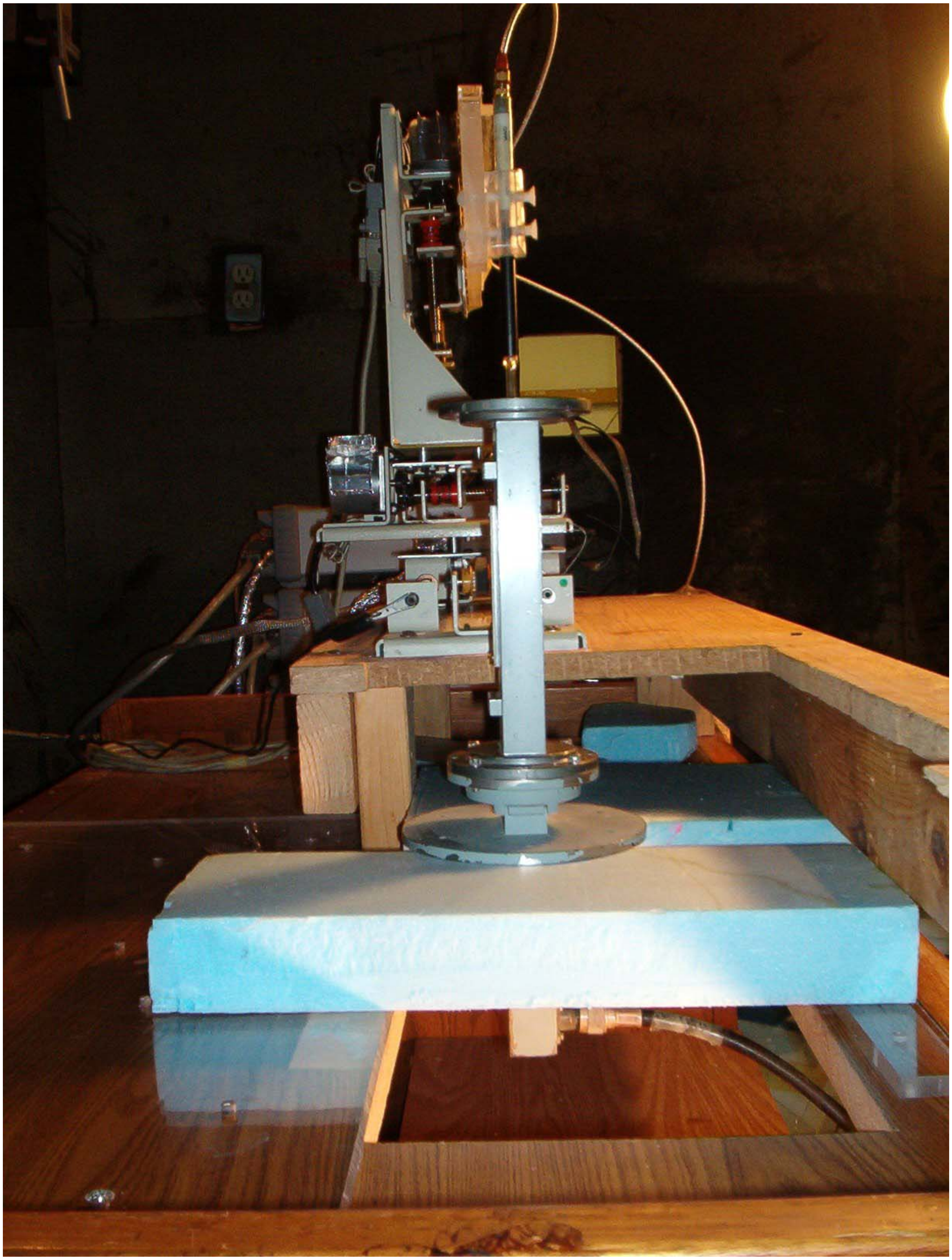
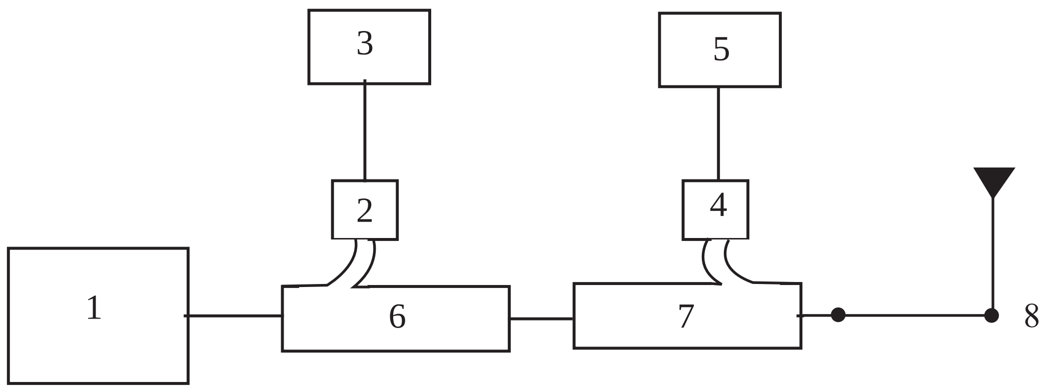


Fig. 6b. Photograph of the waveguide setup showing also the coax to waveguide coupler at the bottom used to feed power to the vertical waveguide containing the tissue-simulant fluid.

Fig. 7. Photograph of the Narda Model 8021 Broadband Electric Field Probe used for SAR measurements.

Fig. 8. Photograph of the reference dipole at 2450 MHz used for system verification for 802.11 b/g band.



1. Hewlett Packard (HP) Model 83620 A Synthesized Sweeper (10 MHz-20 GHz).
2. HP Model 8481A power sensor.
3. HP Model 436A power meter.
4. HP Model 8482A power sensor.
5. HP Model 436A power meter.
6. Narda Model 3042B-30, 30 dB coaxial directional coupler.
7. Narda Model 3042-10, 10 dB coaxial directional coupler.
8. Reference dipole antenna.

Fig. 9. The microwave circuit arrangement used for SAR system verification for the 802.11 b/g bands.

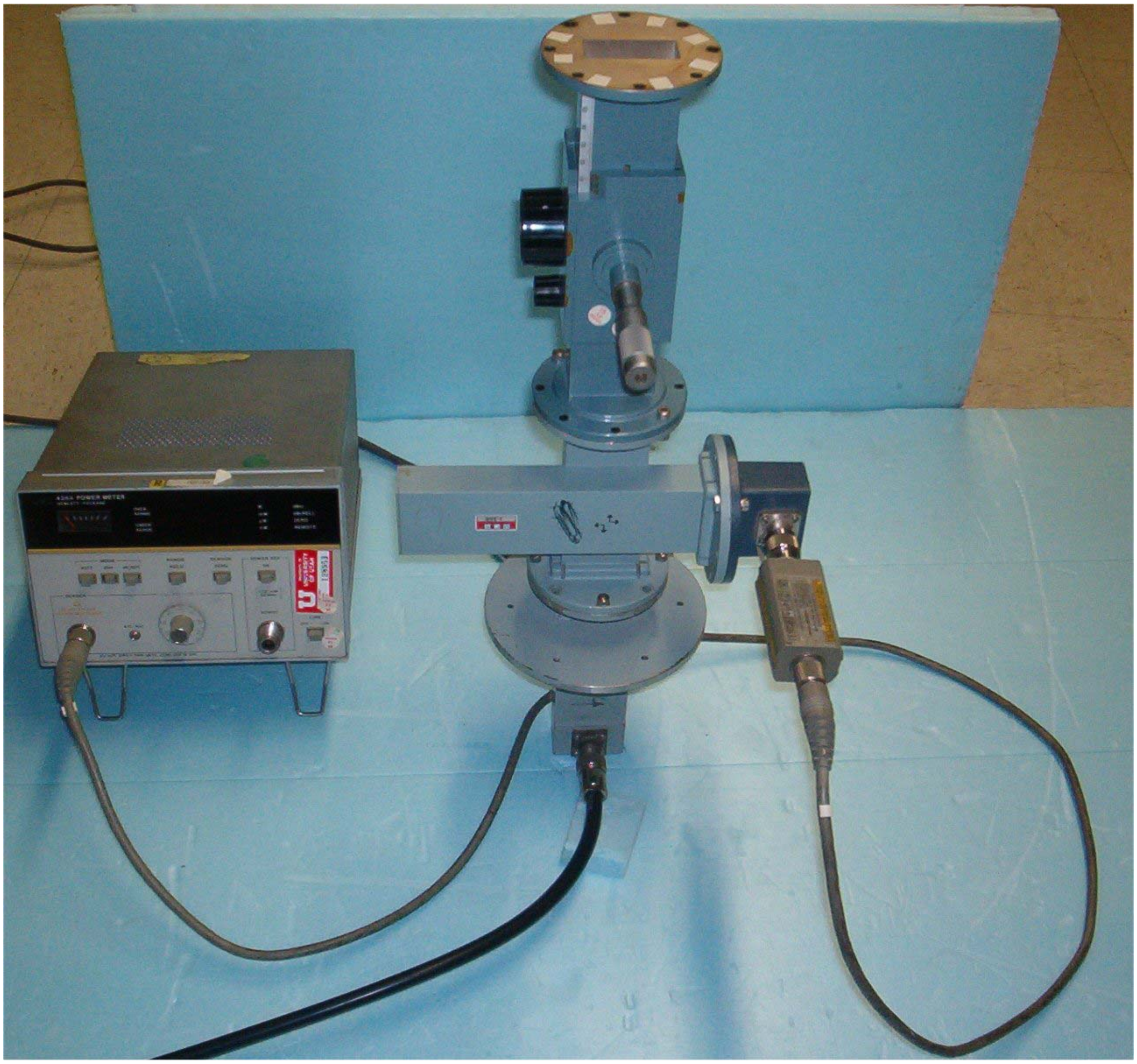
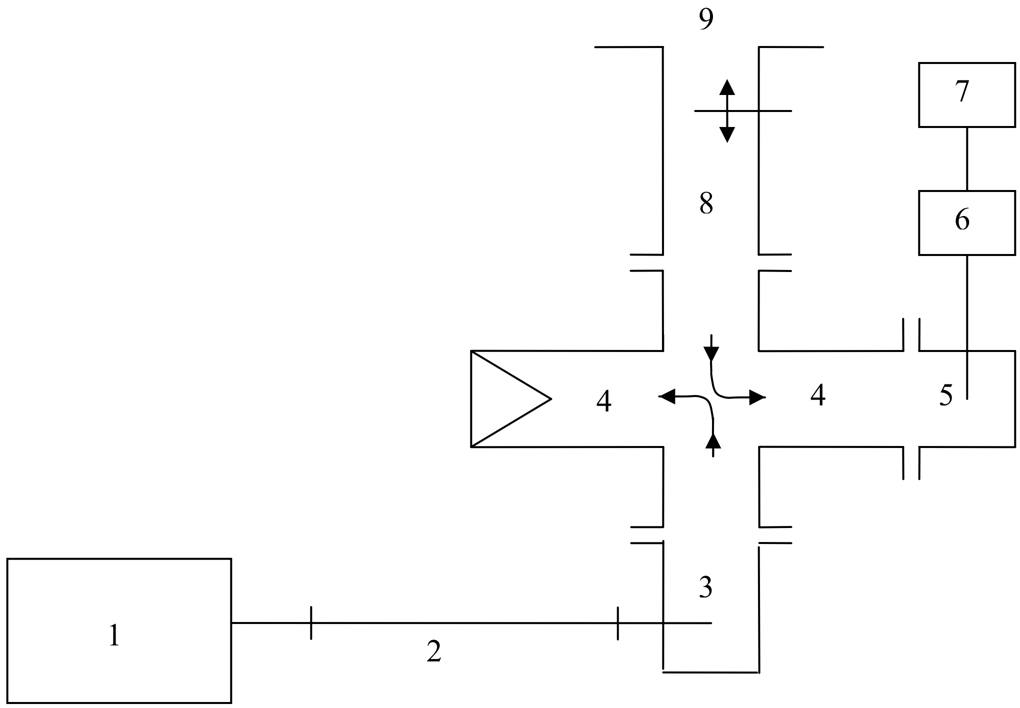
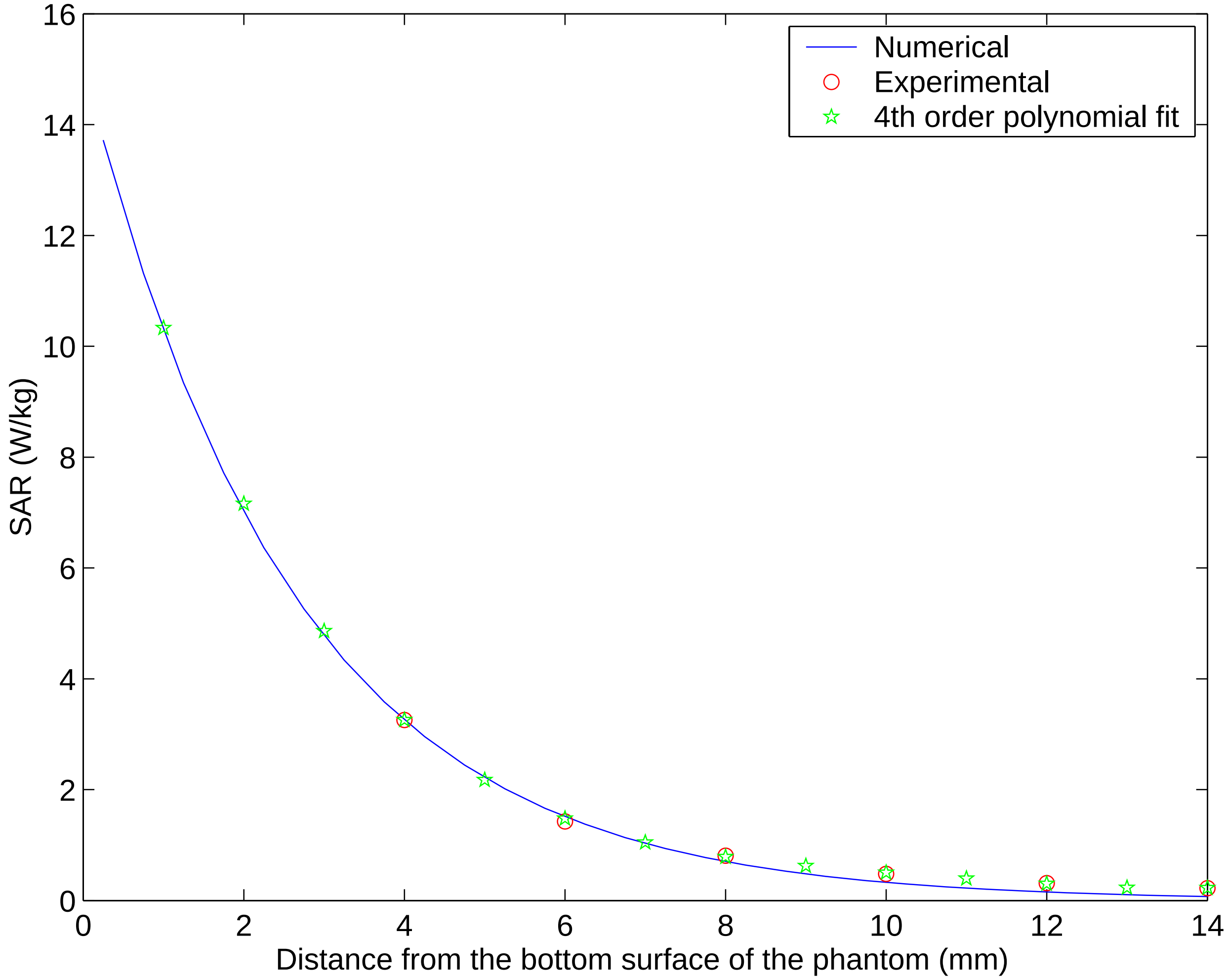


Fig. 10. Photograph of the rectangular waveguide radiator used for system verification for the 802.11a band. Also seen is the Narda Model 22CI movable slide screw tuner used to match the input power at 5.25 or 5.8 GHz to the planar phantom.



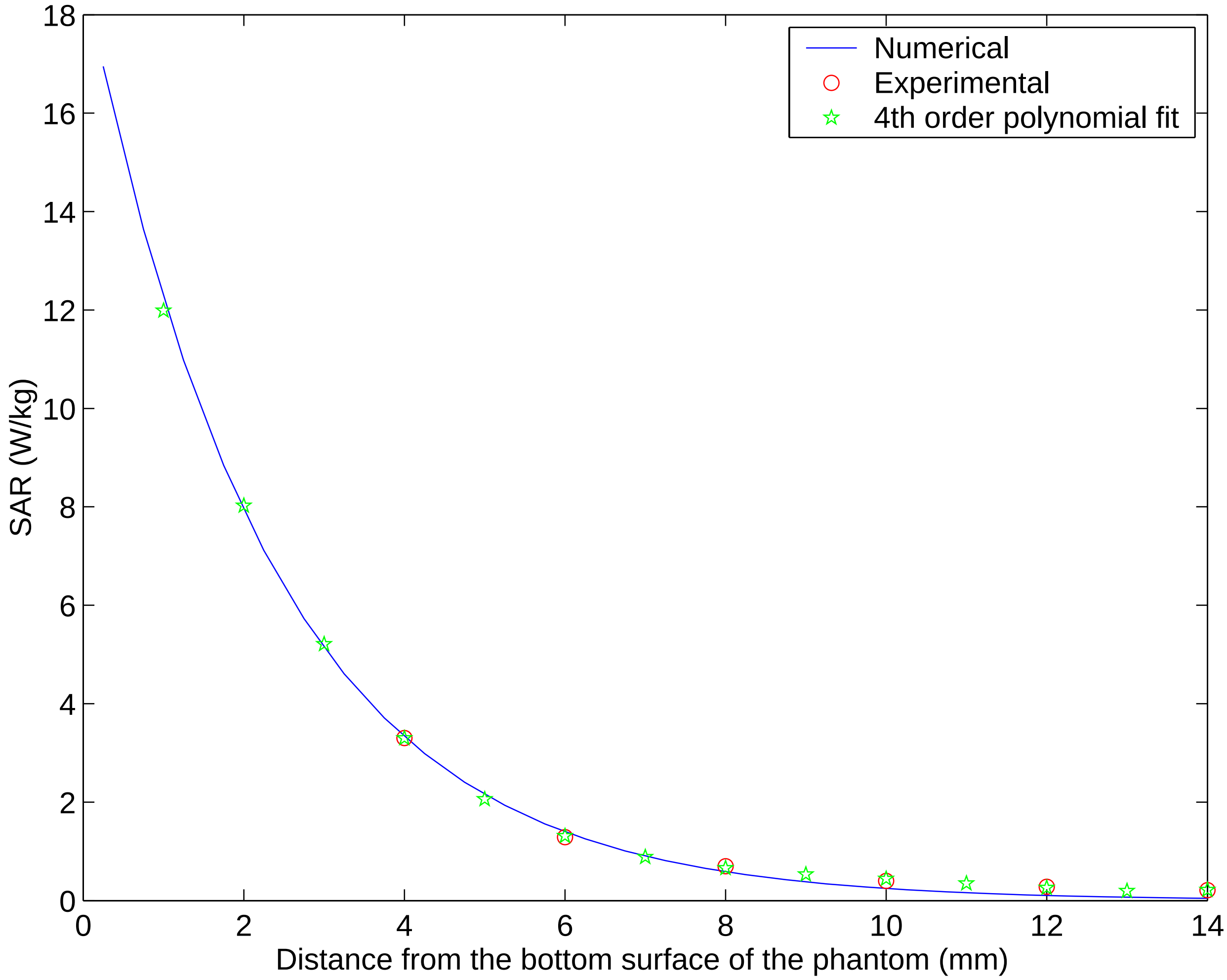
1. Hewlett Packard (HP) Model 83620A Synthesized Sweeper (10 MHz-20 GHz).
2. Coaxial line.
3. Coaxial to waveguide adapter.
4. 20 dB crossguide coupler (may be reversed to measure incident power).
5. HP Model G281A coaxial to waveguide adapter
6. HP Model 8482A power sensor.
7. HP Model 436A power meter.
8. Narda Microline® Slide Screw Tuner Model 22CI.
9. Radiating open end of the waveguide.

Fig. 11. The microwave circuit arrangement used for SAR system verification for the 802.11a band.



a. 5.25 GHz.

Fig. 12. Experimentally measured, extrapolated and FDTD-calculated variation of the SAR with depth in the body-simulant planar phantom. Radiated power = 100 mW.



b. 5.80 GHz.

Fig. 12. Experimentally measured, extrapolated and FDTD-calculated variation of the SAR with depth in the body-simulant planar phantom. Radiated power = 100 mW.

Fig. 13. Photograph of the Hewlett Packard Model 85070B Dielectric Probe. This is an open-circuited coaxial line probe.

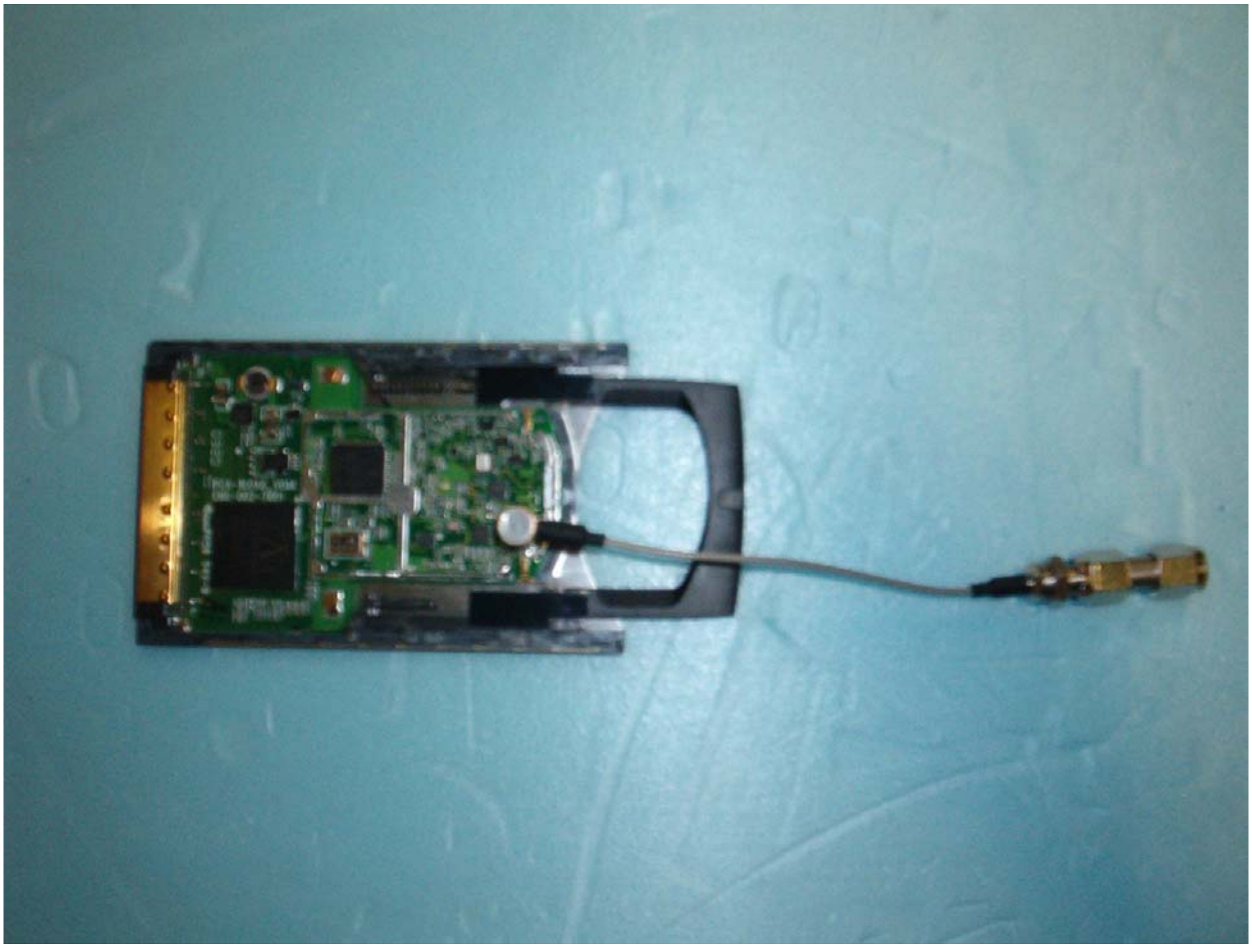
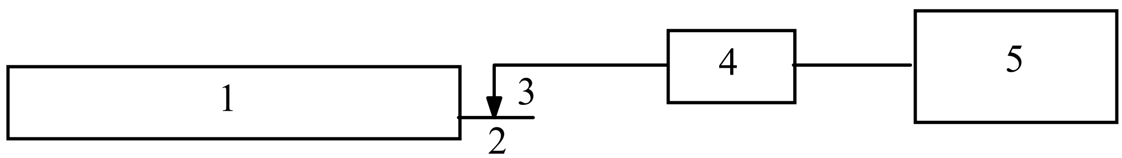


Fig. 14. Photograph of the 3Com 802.11 a/b/g Cardbus Card with coaxial output for conducted power measurements.



1. The host computer.
2. 3Com Cardbus Card.
3. Coaxial output for conducted power measurements.
4. HP Model 8481A Power Sensor.
5. HP Model 436A Power Meter.

Fig. 15. The microwave circuit arrangement used for conducted power measurements for the 3Com 802.11 a/b/g Cardbus Card Model SL-3040.