

APPENDIX I

SAR COMPLIANCE TESTING OF ASKEY COMPUTER CORPORATION MODEL WLL220 MINI PCI CARD BUILT INTO COMPAL MODEL ACY25 NOTEBOOK COMPUTER

FCC ID: H8NWLL220C
Host Computer: Compal Model ACY25

March 20, 2003

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TABLE OF CONTENTS

I. Introduction	1
II. The SAR Measurement System	2
The Flat Phantom	3
III. Calibration of the E-Field Probe	3
IV. SAR System Verification	4
V. Tissue Simulant Fluid for the Frequency Band 5.2 to 5.8 GHz	5
VI. The Measured SAR Distributions.....	7
VII. Comparison of the Data with FCC 96-326 Guidelines	9
REFERENCES	10
TABLES	12-22
FIGURES	23-48
APPENDIX A (separate pdf file)	
APPENDIX B	49
APPENDIX C	51

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I. Introduction

The U.S. Federal Communications Commission (FCC) has adopted limits of human exposure to RF emissions from mobile and portable devices that are regulated by the FCC [1]. The FCC has also issued Supplement C (Edition 97-01) to OET Bulletin 65 [2] and a more recent version of the same [3] defining both the measurement and the computational procedures that should be followed for evaluating compliance of mobile and portable devices with FCC limits for human exposure to radiofrequency emissions.

We have used the measurement procedure for SAR compliance testing of the Askey Corporation Model WLL220 Mini PCI Card built into Compal Model ACY25 Notebook Computer (FCC ID# H8NWLL220C). The photographs of the Model ACY25 Notebook Computer with built-in Model WLL220 Mini PCI Card are given in Figs. 1a, b, c, and Fig. 2, respectively. As seen in Fig. 2, two 802.11a antennas marked "A" and "B" antennas are built close to the right and left edges of the keyboard, respectively. Even though two 802.11a antennas are built into the base of the PC for diversity, only one of the two antennas are active at any given time. Each of the Askey Model WLL220 802.11a wireless antennas operates over the frequency band 5.15 to 5.80 GHz in normal or turbo modes with conducted power levels given in Table 1.

For SAR measurements, two configurations of the wireless PC relative to the experimental 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 [3]) was used for SAR measurements and

the bottom side of the laptop computer shown in Fig. 1b was pressed against it. The SARs were measured both for the "A" and "B" antennas individually (see Figs. 3a, b).

- b. **Configuration 2** -- Edge-on position. This configuration corresponds to a bystander close to the right or left edges of the PC base at a distance of 0 cm. For this configuration, the right or the left edge of the PC base is placed at 90° relative to the flat phantom at a distance of 0 cm as shown in Figs. 4a, b, respectively. As for Configuration 1, here too, the SARs were measured both for the "A" and "B" antennas individually (see Figs. 4a,b).

II. The SAR Measurement System

The University of Utah SAR Measurement System has been described in peer-reviewed literature [Ref. 8 -- attached here as Appendix A]. A photograph of the SAR Measurement System is given in Fig. 5. 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 [5]. 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 GPIB interface. The setup is carefully grounded and shielded to reduce the noise due to the electromagnetic interference (EMI). A cutout in a wooden table of dimensions 38.1×21.6 cm allows placement of a plastic holder (shown in Fig. 6) on which the laptop computer with the 802.11 a/b wireless antennas (see Figs. 1 and 2) is supported. A plastic holder (see Fig. 6) 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. 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 right or the left edge of the keyboard base with the 802.11 a/b "A" or "B" wireless antennas was pressed against the bottom of the flat phantom with a spacing of 0 cm (see Figs. 4a, b).

The Flat Phantom

As recommended in Supplement C Edition 01-01 to OET Bulletin 65 [3], a planar phantom model with inside dimensions $12" \times 16.5"$ (30.5×41.9 cm) and base thickness 2.0 ± 0.2 mm was used for SAR measurements (see Figs. 3-5).

III. Calibration of the E-Field Probe

The IEEE Draft Standard P1528 [4] suggests a recommended procedure for probe calibration (see Section 4.4.1 of [4]) for frequencies above 800 MHz where waveguide size is manageable. Calibration using a rectangular waveguide is recommended. As in some previously reported SAR measurements at 6 GHz [5], 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. 7a, b). The triaxial (3 dipole) E-field probe shown in Fig. 8 was originally developed by Howard Bassen and colleagues of FDA and has been manufactured under license by Narda Microwave Corporation, Hauppauge, 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 [8] 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 $\pm 3\%$.

As suggested in the Draft Standard P1528, the waveguide (WR 159) filled with the tissue-simulant fluid was maintained vertically. From microwave field theory [see e.g. ref. 9],

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)/ μ V with a variability of less than $\pm 2\%$ 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. 9) and the fact that the bandwidth of 550 MHz for the entire set of measurements is on the order of $\pm 5\%$ of the midband frequencies..

The date for the calibration of the E-field probe closest to the SAR tests given here was March 17, 2003.

IV. SAR System Verification

Since we do not have a dipole for the 5 GHz band, a half wave dipole at 1900 MHz was used instead for SAR system verification.* This dipole of length 76.0 mm and diameter 1.5 mm and $h = 39.5$ mm is shown in Fig. 9. As recommended in OET65 Supplement C [3], we used a spacing of 10 mm from the dipole to the tissue-simulant fluid composed of 40.4% water, 58.0% sugar, 0.5% salt (NaCl), 1% HEC, and 0.1% bactericide. The microwave circuit arrangement used for system verification is sketched in Fig. 10. 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 1900 MHz are $\epsilon_r = 53.1 \pm 1.3$ and $\sigma = 1.44 \pm 0.09$ S/m.

* Use of an open-ended, air-filled waveguide is an appropriate substitute for a hard-to-fabricate dipole in the 5-5.8 GHz band. We are presently developing this system for SAR system verification at 5.25 and 5.8 GHz. This development will be completed by the first week of April 2003.

The measured properties are close to the values of $\epsilon_r = 54.0$ and $\sigma = 1.45$ S/m given in OET Supplement C [3].

The measured SAR distribution for the peak 1-g SAR region using this system verification dipole for the day of SAR measurements, March 17, 2003, is given in Appendix B. Also given in Appendix B is the dipole SAR plot for this date of device testing. The peak 1-g SAR is 35.41 W/kg. The measured 1-g SAR is in excellent agreement with the FDTD-calculated 1-g SAR of 35.8 W/kg for this dipole. Also as expected, the measured SAR plot is quite symmetric.

V. Tissue Simulant Fluid for the Frequency Band 5.2 to 5.8 GHz

In OET 65 Supplement C [3], the dielectric parameters suggested for body phantom are given only for 3000 and 5800 MHz. These are listed in Table 2 here. Using linear interpolation, we can obtain the dielectric parameters to use for the frequency band between 5.2 to 5.8 GHz. The desired dielectric properties thus obtained are also given in Table 2. From Table 2, 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 $\pm 1\%$ 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: $\epsilon_r = 48.5 \pm 1.7$ and $\sigma = 5.40 \pm 0.08$ S/m. From Table 2, we obtain the desired dielectric properties to simulate the body tissue at the midband frequency of 5.30 GHz to be $\epsilon_r = 48.9$ 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. 11) is an open-circuited transmission-line (coaxial line) probe similar to that described in Section B.1.2 of the Draft IEEE Standard 1528 [4]. The theory of the open-circuited coaxial line method has been described in scientific literature [10-12]. We have previously used this method in determining the dielectric properties of tissue-simulant materials at 6 GHz [5]. 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 [5]

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

where Z_o is the characteristic impedance (50Ω) 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 $\text{Im}(\epsilon^*)$, we can obtain the conductivity σ from the relationship

$$\sigma = \frac{\text{Im}(\epsilon^*)}{\omega \epsilon_o} \quad (2)$$

VI. The Measured SAR Distributions

The RF power output measured for the Askey Model WLL220 802.11a Wireless Antenna is given in Table 1. For SAR measurements, we selected frequencies of 5.26 GHz and 5.745 GHz for the normal mode and 5.29 and 5.76GHz for the turbo mode. These frequencies and modes were selected both for their highest power outputs as well as to cover the different frequency modes planned for this wireless device. As recommended in Supplement C, Edition 01-01 [3], the stability of the conducted power was determined by repeated SAR measurements at the same location for each of the selected channels. The variability of the SAR thus determined for three repeated measurements over a 60-minute time period was within ± 0.1 dB ($\pm 2.5\%$).

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 8.0×9.6 cm. The data thus obtained is resolved into a 4 x 4 times larger grid i.e. a grid involving 40 x 28 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 cm³ 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 to obtain values at 1, 3, 5, 7 and 9 mm height and used to obtain 1-g SARs. The uncertainty analysis of the University of Utah SAR measurement system is given in Appendix C. The combined standard uncertainty is $\pm 8.3\%$.

As previously mentioned, two Askey Model WLL220 802.11 a/b antennas are built close to the two edges of the keyboard base for this PC (see Fig. 2). Even though two 802.11a antennas marked "A" and "B" are built into the base of the PC for diversity, only one of the two antennas are active at any given time. For the present measurements, we have determined the SAR distributions for both of the "A" and "B" antennas for the Lap-top and Edge-on positions,

respectively. The SARs were extremely low and within the noise limit (on the order of 0.02 W/kg) for the Above-lap Configuration 1 for both antennas "A" and "B" at all measured frequencies (see Table 11). For the Edge-on Configuration 2 also, the SARs were extremely low for a spacing of 1.5 cm. However, for a spacing of 0 cm i.e. with the PC edge at 90° and pressed against the bottom of the phantom, the SAR distributions were not difficult to measure. This spacing of 0 cm was, therefore, used for all measurements for this Edge-on Configuration 2. The coarse scans for the various measurements for the Edge-on Configuration 2 (defined in Section I) are shown in Figs. 12a-d and 13a-d, respectively. In these figures, the two axes are marked in units of the step size of 8 mm. The highest SAR region shown in maroon color is immediately above the region of the radiating antenna as illustrated in Fig. 2. Given in Tables 3-10 are the SAR distributions for the peak SAR region of volume $10 \times 10 \times 10$ mm for which the coarse scans are given in Figs. 12a-d and 13a-d, 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 $5 \times 5 \times 5$ 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 over the 80-minute period needed for measurements at the four frequencies was $23.2 \pm 0.2^\circ\text{C}$.

As mentioned in Section I, Configuration 2 corresponds to the placement of the right or left edge of the PC at 90° at a distance of 0 cm from the bottom of the flat phantom (see Figs. 4a and 4b). This configuration corresponds to a situation when a bystander is standing in contact with the right or the left edges of the PC base. The z-axis scan plots taken at the highest SAR locations for each set of tests are given in Fig. 14 and 15, respectively.

The peak 1-g SARs for the various configurations of the Askey Corporation Model WLL220 Mini PCI Card built into Compal Model ACY25 Notebook Computer (FCC ID#H8NWLL220C) are summarized in Table 11. 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 [1], the peak SAR for any 1-g of tissue should not exceed 1.6 W/kg. For the Askey Corporation Model WLL220 Mini PCI Card built into Compal Model ACY25 Notebook Computer (FCC ID# H8NWLL220C), the measured peak 1-g SARs vary from 0 to 0.512 W/kg which are smaller than 1.6 W/kg.

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Table 1. Average conducted RF power outputs measured at various frequencies for the Askey Corporation Model WLL220 Mini PCI Card for base and turbo modes.

Channel	Frequency GHz	Conducted Output Power (dBm)
Normal Mode		
1	5.18	15.63
4	5.24	16.07
5	5.26	20.22
8	5.32	17.87
9	5.745	18.92
12	5.805	18.33
Turbo Mode		
1	5.21	15.72
2	5.25	15.65
3	5.29	20.25
4	5.76	18.88
5	5.80	16.28

Table 2. Dielectric parameters for body phantom for the frequency band 5.2 to 5.8 GHz [3].

Frequency GHz	ϵ_r	σ S/m	Reference
3.0	52.0	2.73	Ref. 3
5.8	48.2	6.00	Ref. 3
5.2	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 3. **Edge-on position (Configuration 2).** The SARs measured for the Askey WLL220 Mini PCI Card Antenna "A" for the normal mode at 5.26 GHz.

1-g SAR = 0.512 W/kg

a. At depth of 1 mm

0.719	0.992	1.124	1.033	0.754
0.865	1.136	1.211	1.028	0.792
0.901	1.148	1.204	1.046	0.774
0.865	1.032	1.095	0.946	0.707
0.801	0.924	0.985	0.848	0.712

b. At depth of 3 mm

0.520	0.699	0.772	0.720	0.542
0.612	0.781	0.825	0.720	0.570
0.634	0.794	0.834	0.736	0.568
0.616	0.726	0.761	0.669	0.528
0.579	0.658	0.693	0.621	0.523

c. At depth of 5 mm

0.364	0.469	0.499	0.476	0.376
0.414	0.505	0.527	0.480	0.396
0.426	0.519	0.546	0.493	0.404
0.420	0.487	0.500	0.451	0.385
0.405	0.450	0.466	0.441	0.378

d. At depth of 7 mm

0.251	0.304	0.306	0.303	0.255
0.271	0.307	0.316	0.306	0.268
0.277	0.322	0.339	0.318	0.284
0.278	0.313	0.312	0.294	0.278
0.278	0.300	0.303	0.309	0.275

e. At depth of 9 mm

0.180	0.201	0.193	0.200	0.180
0.183	0.188	0.193	0.200	0.188
0.188	0.205	0.214	0.210	0.208
0.190	0.205	0.196	0.197	0.207
0.197	0.207	0.205	0.223	0.217

Table 4. **Edge-on position (Configuration 2).** The SARs measured for the Askey WLL220 Mini PCI Card Antenna "A" for the normal mode at 5.745 GHz.

1-g SAR = 0.372 W/kg

a. At depth of 1 mm

0.512	0.731	0.828	0.775	0.565
0.602	0.836	0.923	0.841	0.559
0.621	0.810	0.888	0.763	0.549
0.556	0.723	0.766	0.653	0.538
0.511	0.608	0.659	0.612	0.456

b. At depth of 3 mm

0.376	0.514	0.570	0.540	0.414
0.430	0.571	0.634	0.581	0.409
0.443	0.568	0.614	0.529	0.395
0.402	0.515	0.545	0.466	0.393
0.381	0.437	0.471	0.444	0.346

c. At depth of 5 mm

0.271	0.346	0.372	0.359	0.295
0.298	0.369	0.411	0.380	0.292
0.306	0.381	0.401	0.349	0.276
0.283	0.354	0.373	0.322	0.281
0.279	0.305	0.325	0.313	0.261

d. At depth of 7 mm

0.197	0.227	0.233	0.232	0.211
0.206	0.229	0.255	0.240	0.208
0.209	0.248	0.249	0.223	0.192
0.198	0.240	0.250	0.220	0.202
0.205	0.211	0.222	0.221	0.199

e. At depth of 9 mm

0.154	0.158	0.155	0.158	0.160
0.153	0.151	0.165	0.159	0.156
0.152	0.170	0.159	0.150	0.143
0.148	0.172	0.175	0.161	0.158
0.158	0.154	0.162	0.167	0.161

Table 5. **Edge-on position (Configuration 2).** The SARs measured for the Askey WLL220 Mini PCI Card Antenna "A" for the turbo mode at 5.29 GHz.

1-g SAR = 0.350 W/kg

a. At depth of 1 mm

0.410	0.487	0.585	0.558	0.446
0.445	0.592	0.652	0.598	0.495
0.489	0.625	0.664	0.623	0.524
0.500	0.615	0.650	0.599	0.503
0.510	0.592	0.606	0.579	0.456

b. At depth of 3 mm

0.333	0.382	0.438	0.418	0.351
0.353	0.449	0.489	0.452	0.381
0.375	0.471	0.503	0.473	0.409
0.388	0.468	0.490	0.458	0.399
0.393	0.449	0.460	0.446	0.366

c. At depth of 5 mm

0.272	0.300	0.324	0.309	0.277
0.280	0.337	0.360	0.338	0.291
0.286	0.351	0.376	0.354	0.318
0.301	0.351	0.365	0.347	0.317
0.301	0.337	0.346	0.341	0.295

d. At depth of 7 mm

0.227	0.239	0.243	0.231	0.223
0.227	0.255	0.267	0.256	0.225
0.223	0.264	0.282	0.268	0.252
0.237	0.267	0.274	0.266	0.255
0.235	0.256	0.263	0.264	0.241

e. At depth of 9 mm

0.197	0.199	0.197	0.185	0.191
0.194	0.205	0.208	0.206	0.183
0.185	0.209	0.221	0.214	0.210
0.197	0.213	0.217	0.214	0.214
0.194	0.207	0.212	0.214	0.205

Table 6. **Edge-on position (Configuration 2).** The SARs measured for the Askey WLL220 Mini PCI Card Antenna "A" for the turbo mode at 5.76 GHz.

1-g SAR = 0.267 W/kg

a. At depth of 1 mm

0.364	0.447	0.511	0.447	0.349
0.422	0.523	0.529	0.491	0.363
0.429	0.517	0.537	0.433	0.355
0.367	0.493	0.478	0.422	0.365
0.386	0.429	0.412	0.397	0.320

b. At depth of 3 mm

0.279	0.337	0.370	0.335	0.275
0.318	0.380	0.389	0.365	0.275
0.331	0.379	0.389	0.325	0.278
0.291	0.365	0.357	0.319	0.276
0.296	0.331	0.314	0.308	0.256

c. At depth of 5 mm

0.213	0.250	0.262	0.248	0.217
0.237	0.271	0.280	0.267	0.208
0.253	0.272	0.275	0.242	0.218
0.231	0.265	0.262	0.239	0.208
0.227	0.252	0.238	0.238	0.206

d. At depth of 7 mm

0.169	0.186	0.187	0.187	0.175
0.180	0.193	0.202	0.198	0.162
0.196	0.196	0.195	0.183	0.175
0.186	0.194	0.194	0.181	0.160
0.178	0.193	0.183	0.185	0.170

e. At depth of 9 mm

0.144	0.146	0.145	0.152	0.148
0.146	0.147	0.156	0.157	0.137
0.159	0.151	0.148	0.149	0.149
0.157	0.151	0.153	0.145	0.134
0.149	0.153	0.150	0.150	0.149

Table 7. **Edge-on position (Configuration 2).** The SARs measured for the Askey WLL220 Mini PCI Card Antenna "B" for the normal mode at 5.26 GHz.

1-g SAR = 0.507 W/kg

a. At depth of 1 mm

0.673	0.902	1.049	1.052	0.861
0.709	0.995	1.151	1.140	0.990
0.740	0.972	1.175	1.151	0.970
0.739	0.913	1.075	1.045	0.928
0.654	0.810	0.910	0.898	0.825

b. At depth of 3 mm

0.494	0.640	0.731	0.727	0.606
0.522	0.693	0.796	0.786	0.687
0.539	0.685	0.809	0.799	0.685
0.536	0.651	0.748	0.731	0.663
0.489	0.586	0.647	0.642	0.598

c. At depth of 5 mm

0.354	0.435	0.484	0.476	0.409
0.374	0.459	0.521	0.512	0.453
0.381	0.462	0.526	0.525	0.464
0.377	0.446	0.493	0.488	0.456
0.358	0.410	0.442	0.444	0.419

d. At depth of 7 mm

0.254	0.287	0.306	0.297	0.268
0.265	0.292	0.326	0.318	0.288
0.265	0.303	0.326	0.329	0.307
0.262	0.298	0.311	0.314	0.307
0.262	0.284	0.295	0.302	0.290

e. At depth of 9 mm

0.192	0.196	0.199	0.190	0.184
0.195	0.192	0.211	0.204	0.191
0.192	0.207	0.210	0.212	0.213
0.191	0.207	0.201	0.210	0.215
0.202	0.206	0.206	0.217	0.210

Table 8. **Edge-on position (Configuration 2).** The SARs measured for the Askey WLL220 Mini PCI Card Antenna "B" for the normal mode at 5.745 GHz.

1-g SAR = 0.348 W/kg

a. At depth of 1 mm

0.540	0.650	0.660	0.586	0.494
0.584	0.665	0.696	0.610	0.493
0.617	0.690	0.690	0.588	0.484
0.589	0.696	0.685	0.592	0.487
0.562	0.653	0.650	0.591	0.500

B. At depth of 3 mm

0.398	0.467	0.467	0.424	0.367
0.423	0.482	0.494	0.438	0.371
0.447	0.501	0.497	0.427	0.366
0.427	0.499	0.484	0.433	0.365
0.416	0.468	0.466	0.433	0.381

c. At depth of 5 mm

0.288	0.325	0.319	0.300	0.269
0.297	0.340	0.339	0.307	0.275
0.316	0.353	0.346	0.303	0.274
0.303	0.347	0.329	0.310	0.272
0.303	0.326	0.324	0.312	0.290

d. At depth of 7 mm

0.211	0.226	0.218	0.214	0.201
0.208	0.240	0.232	0.216	0.206
0.223	0.246	0.238	0.216	0.208
0.216	0.237	0.221	0.222	0.206
0.223	0.226	0.226	0.228	0.225

e. At depth of 9 mm

0.165	0.168	0.162	0.166	0.161
0.155	0.181	0.172	0.166	0.164
0.170	0.181	0.172	0.165	0.169
0.167	0.171	0.159	0.169	0.167
0.176	0.169	0.169	0.180	0.187

Table 9. **Edge-on position (Configuration 2).** The SARs measured for the Askey WLL220 Mini PCI Card Antenna "B" for the turbo mode at 5.29 GHz.

1-g SAR = 0.342 W/kg

a. At depth of 1 mm

0.404	0.532	0.572	0.545	0.506
0.459	0.570	0.655	0.637	0.526
0.476	0.601	0.639	0.644	0.552
0.469	0.565	0.595	0.623	0.554
0.456	0.505	0.582	0.545	0.504

B. At depth of 3 mm

0.329	0.402	0.429	0.418	0.387
0.367	0.439	0.486	0.470	0.401
0.372	0.449	0.466	0.478	0.419
0.367	0.428	0.447	0.467	0.423
0.356	0.388	0.440	0.419	0.393

c. At depth of 5 mm

0.267	0.300	0.317	0.318	0.294
0.292	0.335	0.354	0.340	0.302
0.289	0.330	0.332	0.347	0.314
0.286	0.320	0.330	0.345	0.320
0.278	0.296	0.329	0.319	0.304

d. At depth of 7 mm

0.220	0.226	0.235	0.245	0.228
0.235	0.257	0.257	0.246	0.229
0.228	0.243	0.239	0.253	0.237
0.227	0.240	0.246	0.255	0.245
0.220	0.230	0.248	0.245	0.237

e. At depth of 9 mm

0.187	0.181	0.182	0.199	0.188
0.197	0.205	0.196	0.189	0.182
0.189	0.188	0.185	0.194	0.189
0.190	0.188	0.192	0.199	0.197
0.183	0.189	0.197	0.197	0.193

Table 10. **Edge-on position (Configuration 2).** The SARs measured for the Askey WLL220 Mini PCI Card Antenna "B" for the turbo mode at 5.76 GHz.

1-g SAR = 0.226 W/kg

a. At depth of 1 mm

0.257	0.326	0.354	0.327	0.304
0.303	0.341	0.371	0.370	0.333
0.308	0.377	0.402	0.413	0.353
0.312	0.375	0.397	0.375	0.339
0.323	0.388	0.382	0.386	0.340

B. At depth of 3 mm

0.209	0.254	0.271	0.254	0.240
0.237	0.261	0.276	0.277	0.259
0.248	0.283	0.306	0.310	0.275
0.249	0.290	0.304	0.290	0.265
0.250	0.293	0.288	0.293	0.268

c. At depth of 5 mm

0.171	0.198	0.207	0.198	0.190
0.186	0.200	0.204	0.206	0.202
0.200	0.211	0.231	0.230	0.215
0.200	0.224	0.230	0.222	0.206
0.195	0.219	0.216	0.222	0.212

d. At depth of 7 mm

0.143	0.158	0.162	0.159	0.154
0.150	0.157	0.155	0.157	0.162
0.164	0.160	0.180	0.175	0.172
0.165	0.176	0.177	0.173	0.165
0.158	0.168	0.165	0.172	0.172

e. At depth of 9 mm

0.125	0.133	0.137	0.136	0.133
0.129	0.132	0.129	0.131	0.139
0.140	0.131	0.150	0.144	0.148
0.143	0.147	0.144	0.142	0.140
0.139	0.138	0.134	0.144	0.149

Table 11. The peak 1-g SARs measured for the Askey Computer Corporation Model WLL220 Mini PCI Card built into Compal Model ACY25 Notebook Computer (FCC ID# H8NWLL220C).

1-g SAR in W/kg

PC position relative to the flat phantom	Spacing to the bottom of the phantom	Antenna	5.26 GHz normal mode	5.745 GHz normal mode	5.29 GHz turbo mode	5.76 GHz turbo mode
Configuration 1 – "Above-lap" position; bottom of PC pressed against bottom of the flat phantom (see Figs. 3a,b)	0 cm	"A"	<0.02*	<0.02*	<0.02*	<0.02*
		"B"	<0.02*	<0.02*	<0.02*	<0.02*
Configuration 2 – "Edge-on" placement; right or left edge of the PC at 90° and at a distance of 0 cm from the base of the phantom (see Figs. 4a, 4b)	0 cm	"A"	0.512	0.372	0.350	0.267
		"B"	0.507	0.348	0.342	0.226

* Too low to measure, within the noise limits of the SAR measurement system.



a. Top cover closed.

Fig. 1. Photograph of the Compal Model ACY25 Notebook Computer with built-in Askey Corporation Model WLL220 Mini PCI Card.



b. View from bottom side of the laptop computer.

Fig. 1. Photograph of the Compal Model ACY25 Notebook Computer with built-in Askey Corporation Model WLL220 Mini PCI Card.



c. Top cover with screen open.

Fig. 1. Photograph of the Compaq Model ACY25 Notebook Computer with built-in Askey Corporation Model WLL220 Mini PCI Card.

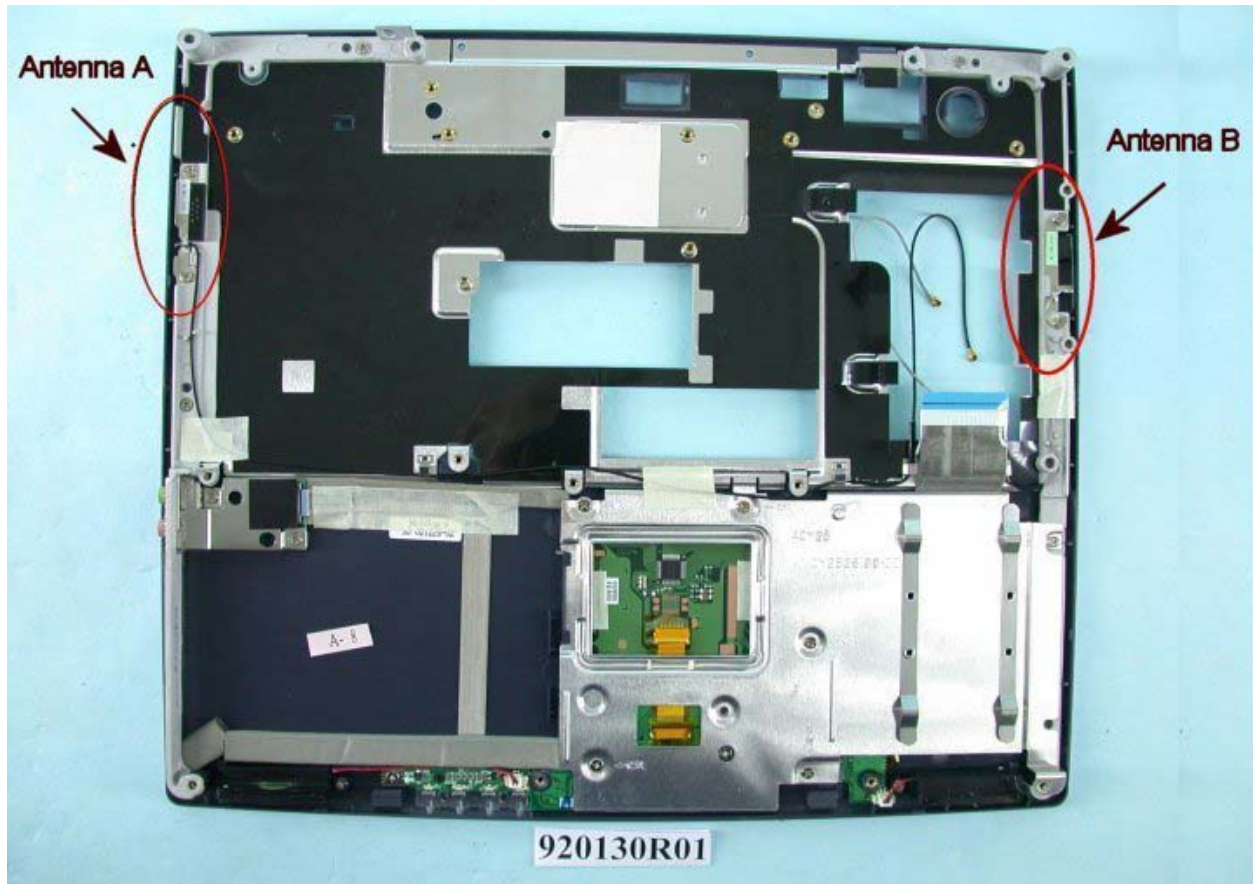
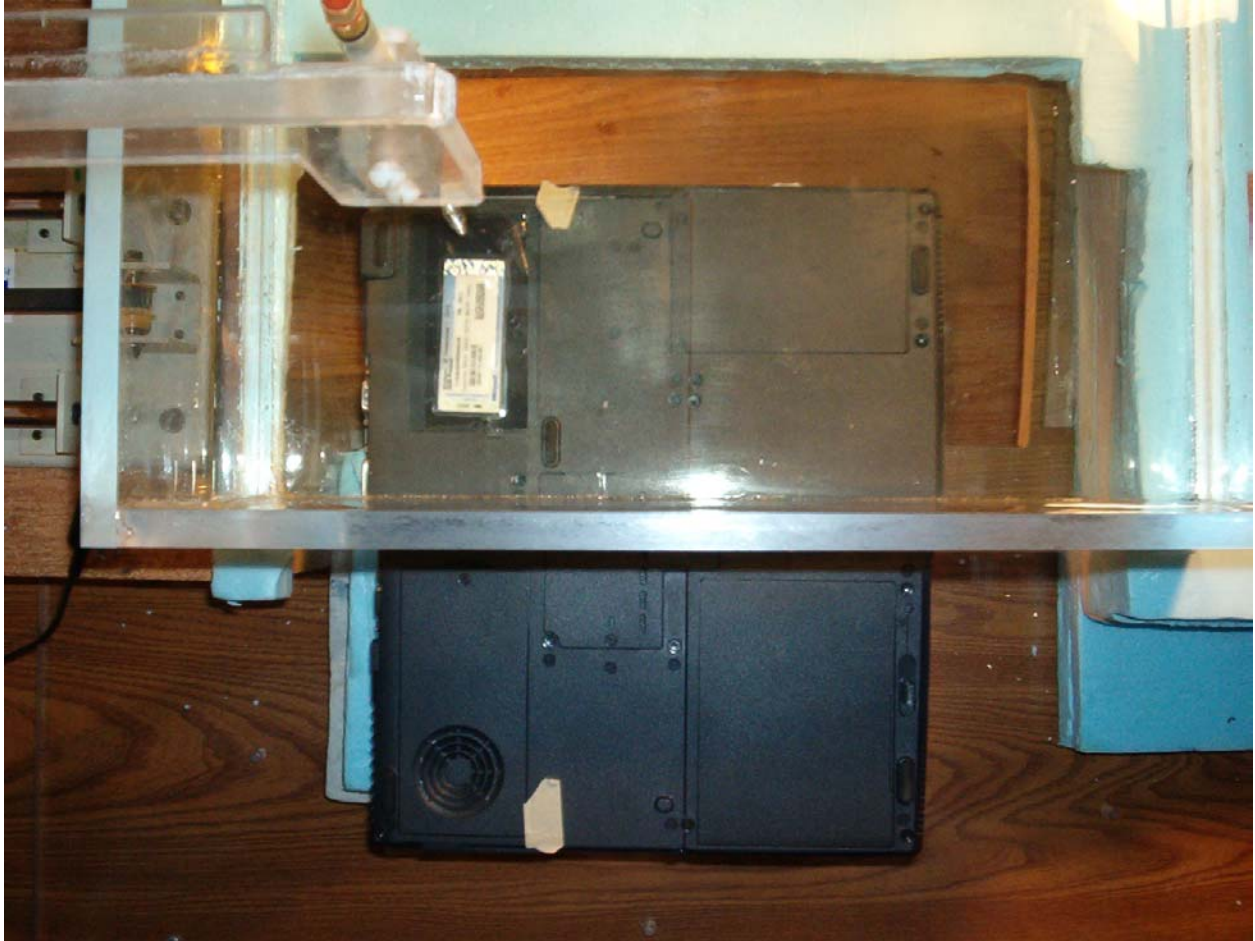


Fig. 2. Photograph of the base of the Compal Model ACY25 Notebook Computer showing the relative locations of Askey Model WLL220 802.11a Wireless Antennas marked as "A" and "B" antennas.



a. The right half of the PC with antenna "A" pressed against the planar phantom.

Fig. 3. Photograph of the bottom of the Model ACY25 Notebook Computer with built-in Askey Model WLL220 Mini PCI Card 802.11a Wireless Antennas pressed against the base of the planar phantom. This is **Configuration 1 – Laptop position** for SAR testing.



b. The left half of the PC with antenna "B" pressed against the planar phantom.

Fig. 3. Photograph of the bottom of the Model ACY25 Notebook Computer with built-in Askey Model WLL220 Mini PCI Card 802.11a Wireless Antennas pressed against the base of the planar phantom. This is **Configuration 1 – Laptop position** for SAR testing.



- a. The right edge with antenna "A" pressed against the bottom of the planar phantom.

Fig. 4. Photograph of the Model ACY25 Notebook Computer with edge of the PC at 90° pressed against the base of the planar phantom. This is **Configuration 2** for SAR testing and represents the case of a bystander in contact (at a spacing of 0 cm) from the side of the laptop computer.



- b. The left edge with antenna "B" pressed against the bottom of the planar phantom.

Fig. 4. Photograph of the Model ACY25 Notebook Computer with edge of the PC at 90° pressed against the base of the planar phantom. This is **Configuration 2** for SAR testing and represents the case of a bystander in contact (at a spacing of 0 cm) from the side of the laptop computer.

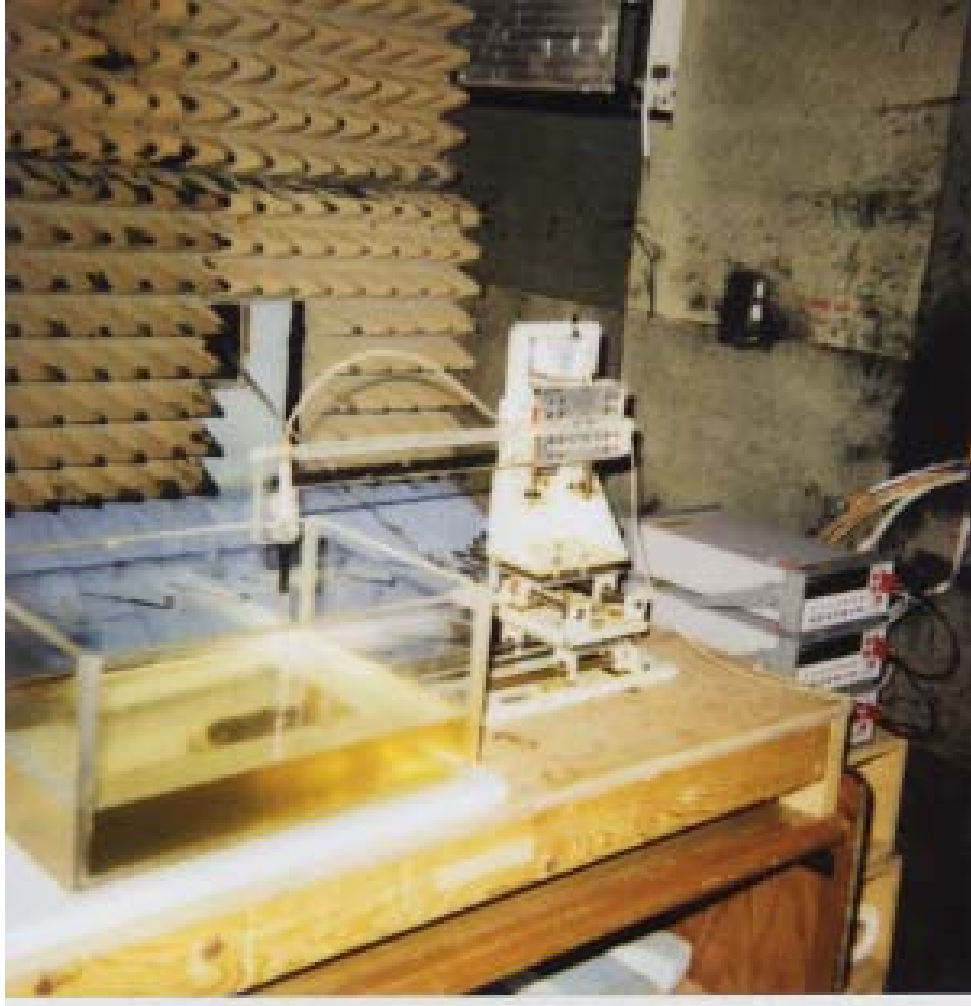


Fig. 5. Photograph of the three-dimensional stepper-motor-controlled SAR measurement system using a planar phantom (see Figs. 3 and 4 for a detailed examination of the placement of the Model ACY25 Notebook Computer with Askey Model WLL220 802.11a Wireless Antennas relative to this phantom).

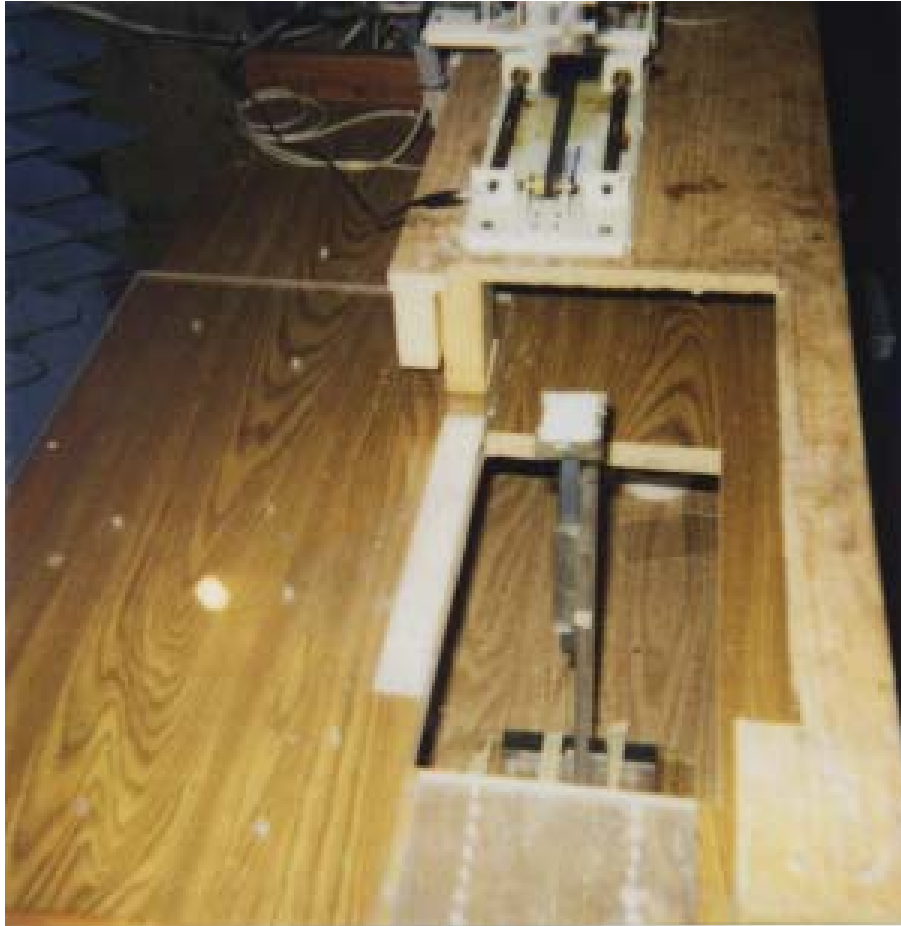


Fig. 6. The plastic holder used to support the portable PC with the Askey WLL220 Mini PCI Card (shown in Figs. 1,2).

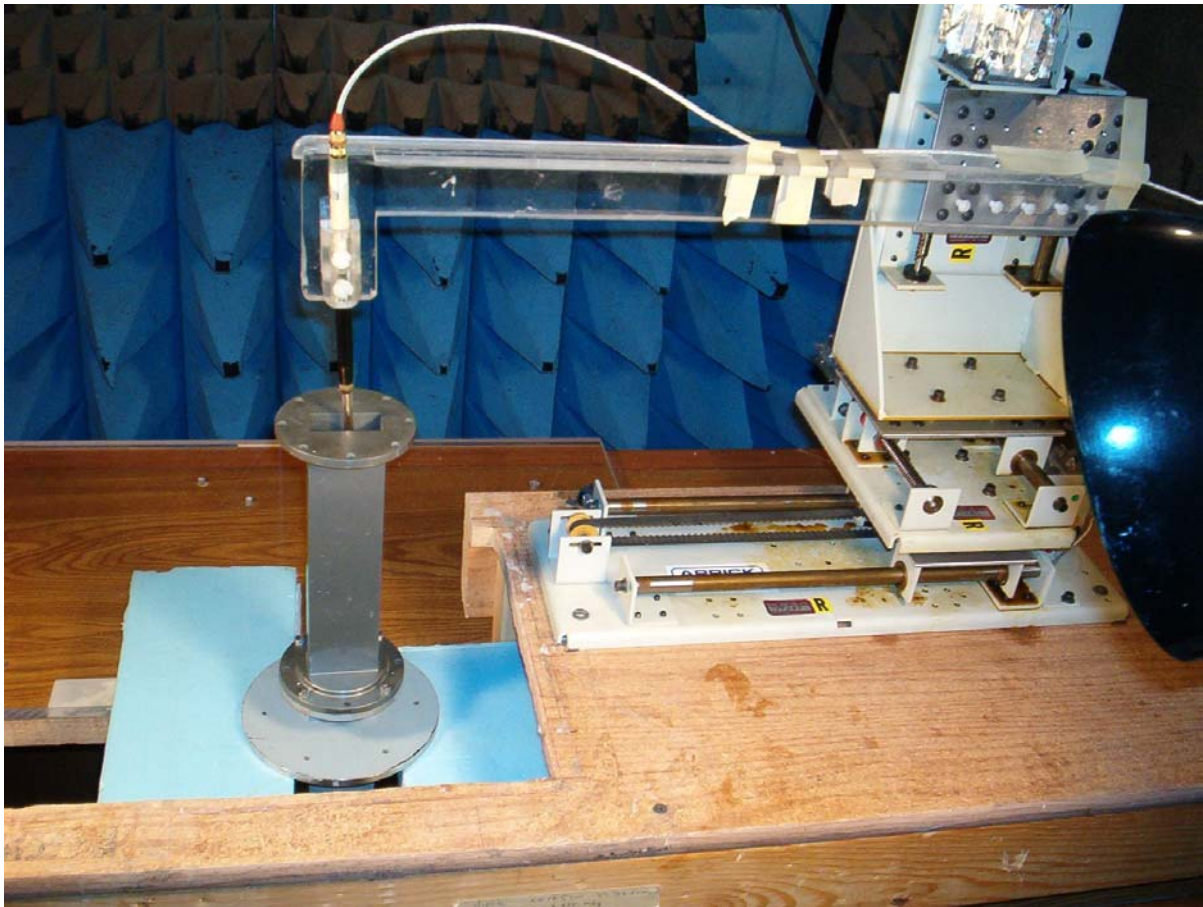


Fig. 7a. A photograph of the waveguide setup used for calibration of the Narda Model 8021 E-field probe in the frequency band 5.2-5.8 GHz.

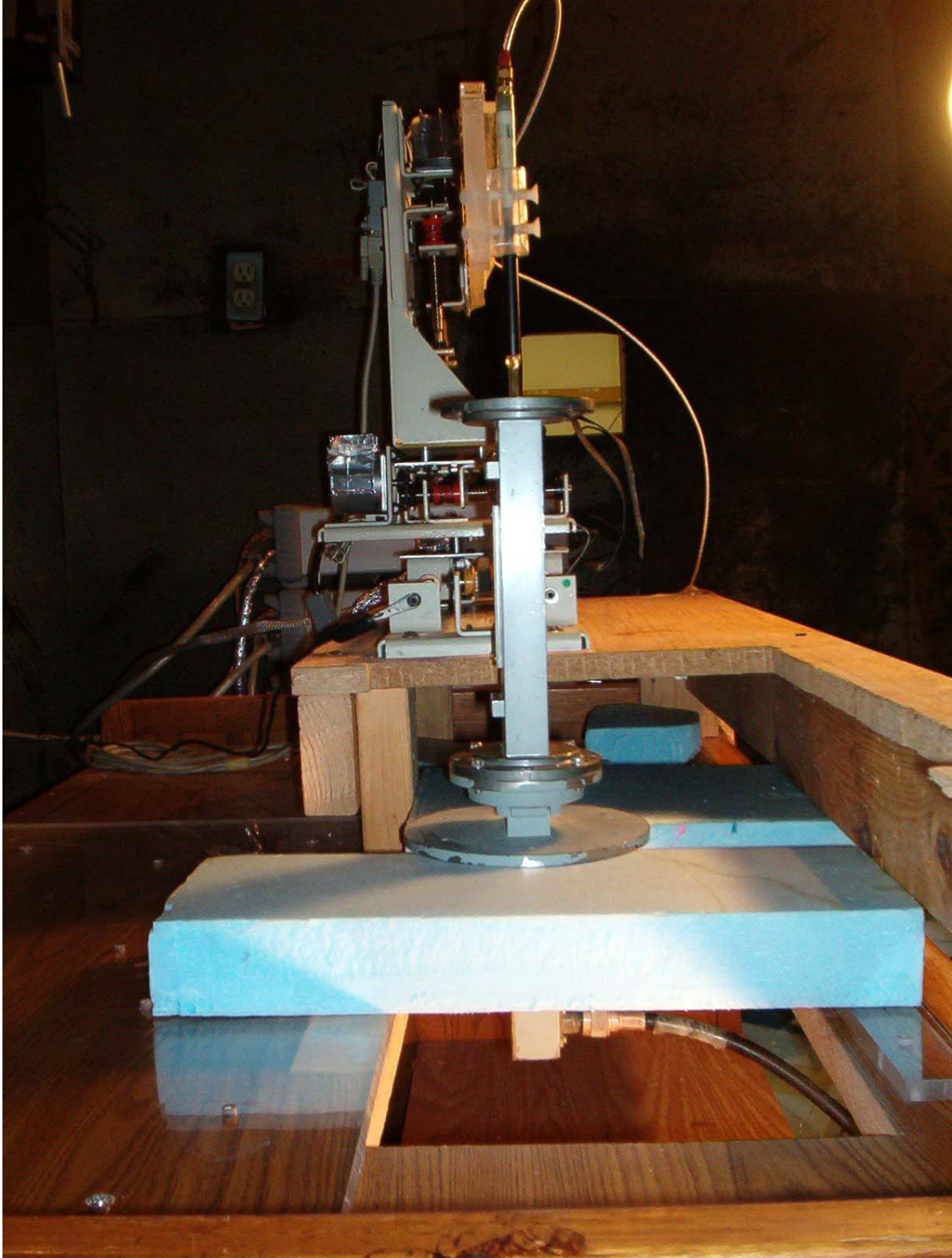


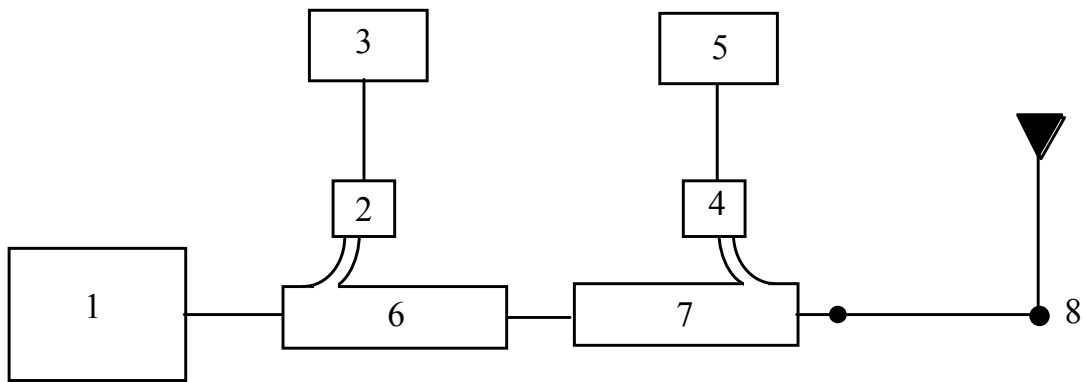
Fig. 7b. Photograph of the waveguide setup showing also the coax to waveguide coupler at the bottom used to feed power to the vertical waveguide containing the tissue-simulant fluid.



Fig. 8. Photograph of the Narda Model 8021 Broadband Electric Field Probe used for SAR measurements.



Fig. 9. Photograph of the half-wave dipole at 1900 MHz used for system verification.

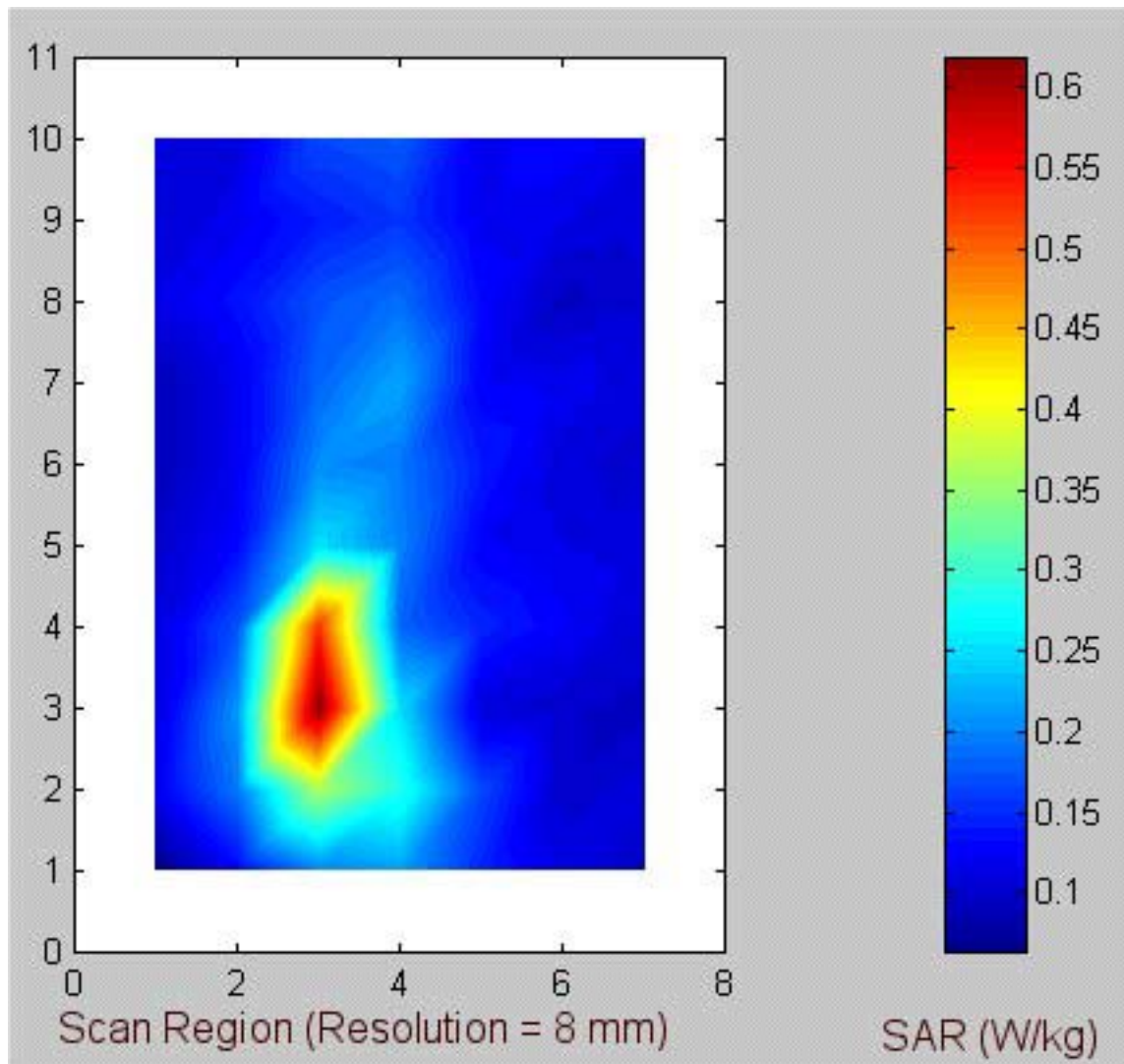


1. RF generator, MCL Model 15222 with Model 6051 plug-in (1000-2000 MHz).
2. HP Model 8481A power sensor.
3. HP Model 436A power meter.
4. HP Model 8482A power sensor.
5. HP Model 436A power meter.
6. Narda Model 3042B-30, 30 dB coaxial directional coupler.
7. Narda Model 3042-10, 10 dB coaxial directional coupler.
8. Reference dipole antenna.

Fig. 10. The microwave circuit arrangement used for SAR system verification.

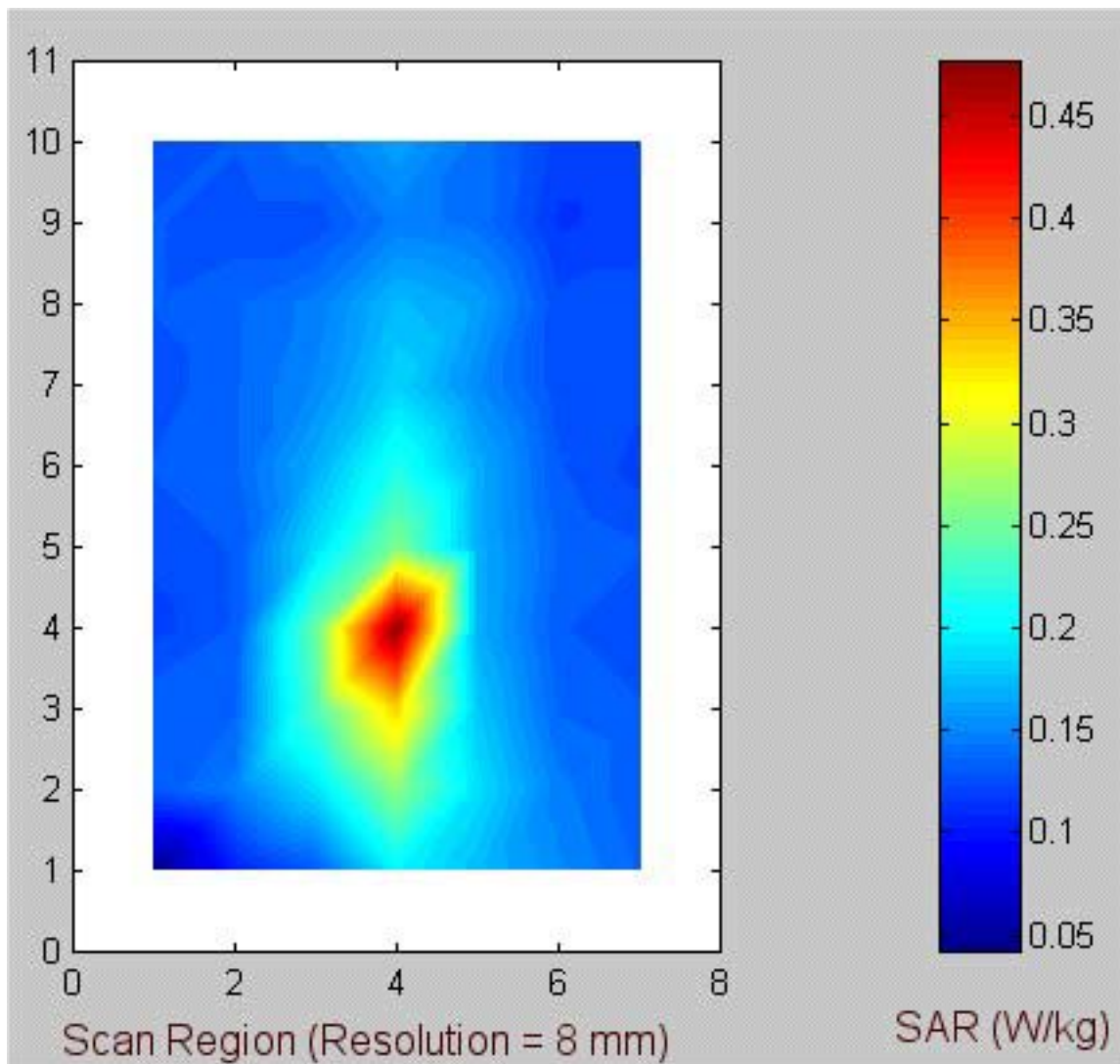


Fig. 11. Photograph of the Hewlett Packard Model 85070B Dielectric Probe. This is an open-circuited coaxial line probe.



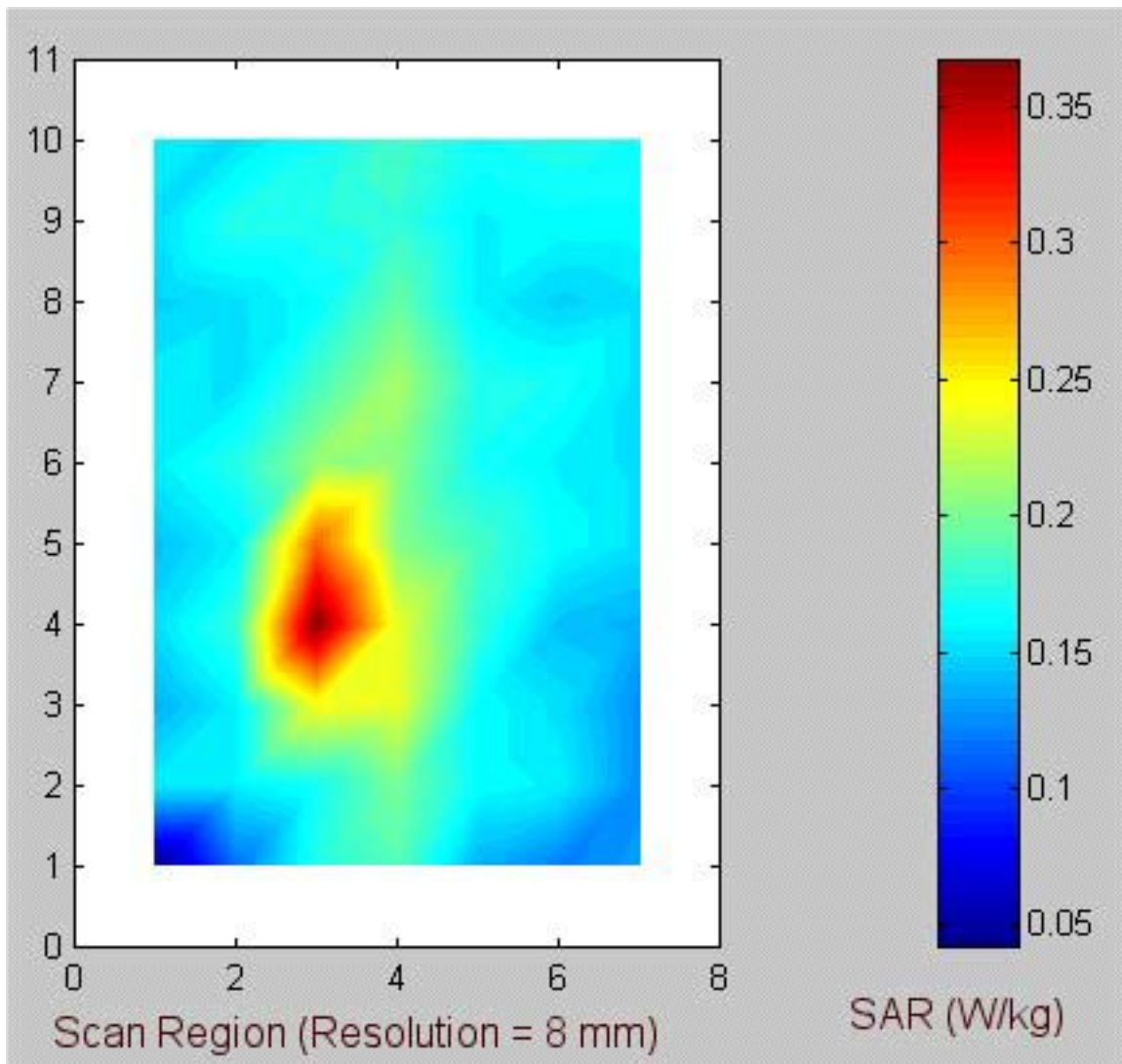
a. 5.26 GHz normal mode – antenna "A" (see Table 3 for the peak 1-g SAR).

Fig. 12. Coarse scans for the SAR measurements for the right side **Edge-on position** of the PC relative to the flat phantom (Configuration 2, see Fig. 4a). The right edge of the PC with antenna "A" was placed at 90° pressed against the bottom of the flat phantom at a distance of 0 cm.



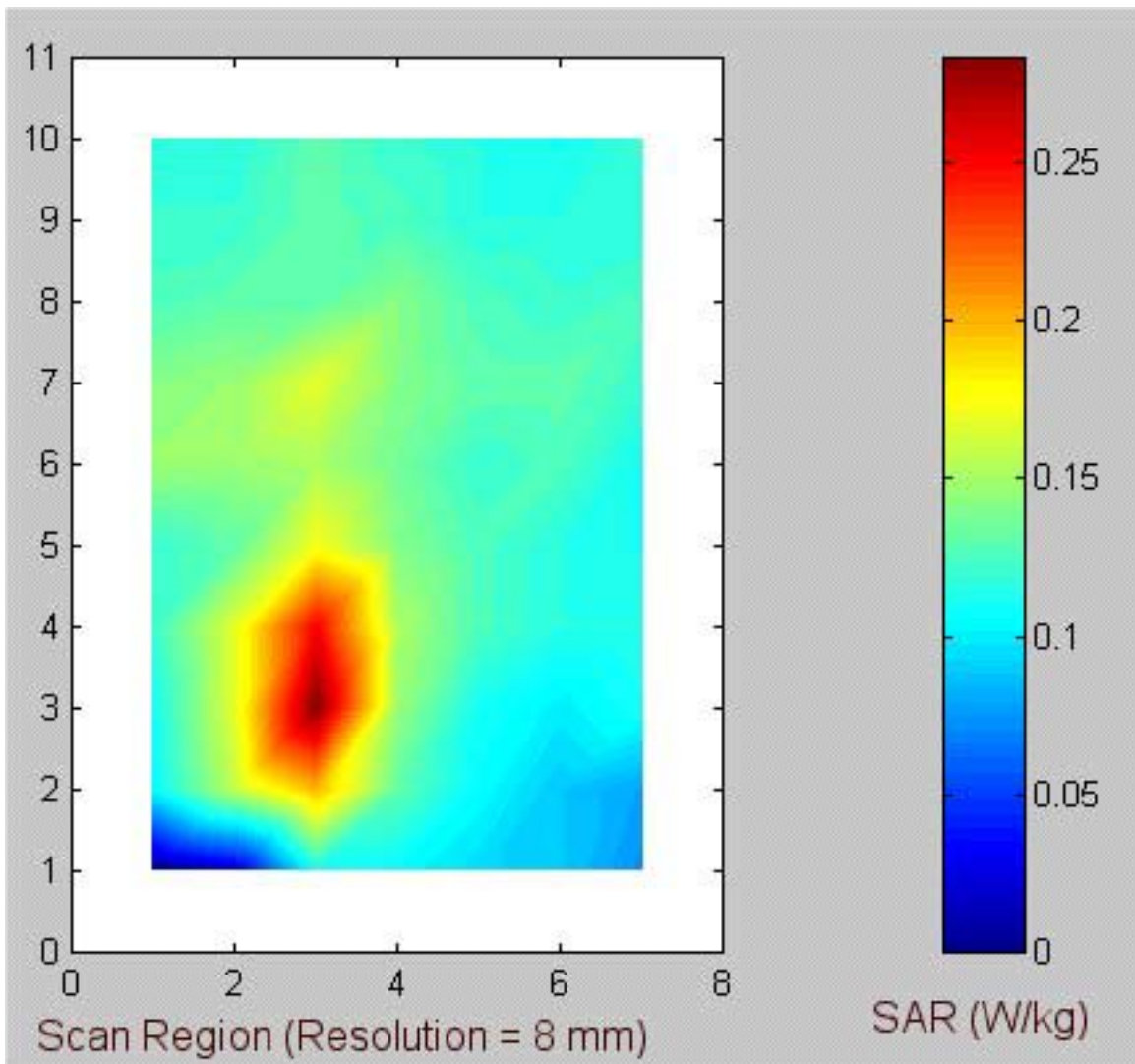
b. 5.745 GHz normal mode – antenna "A" (see Table 4 for the peak 1-g SAR).

Fig. 12. Coarse scans for the SAR measurements for the right side **Edge-on position** of the PC relative to the flat phantom (Configuration 2, see Fig. 4a). The right edge of the PC with antenna "A" was placed at 90° pressed against the bottom of the flat phantom at a distance of 0 cm.



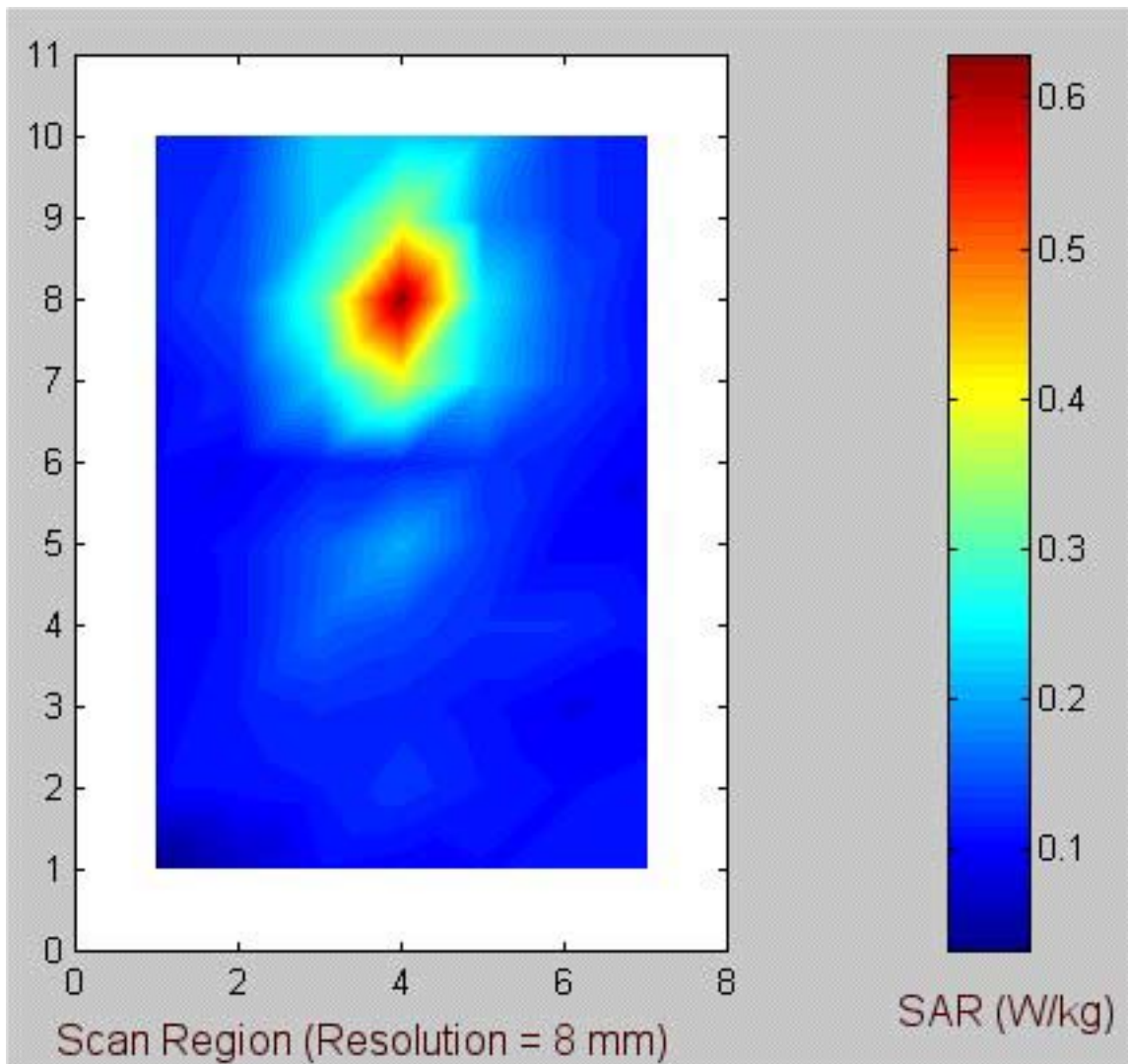
c. 5.29 GHz turbo mode – antenna "A" (see Table 5 for the peak 1-g SAR).

Fig. 12. Coarse scans for the SAR measurements for the right side **Edge-on position** of the PC relative to the flat phantom (Configuration 2, see Fig. 4a). The right edge of the PC with antenna "A" was placed at 90° pressed against the bottom of the flat phantom at a distance of 0 cm.



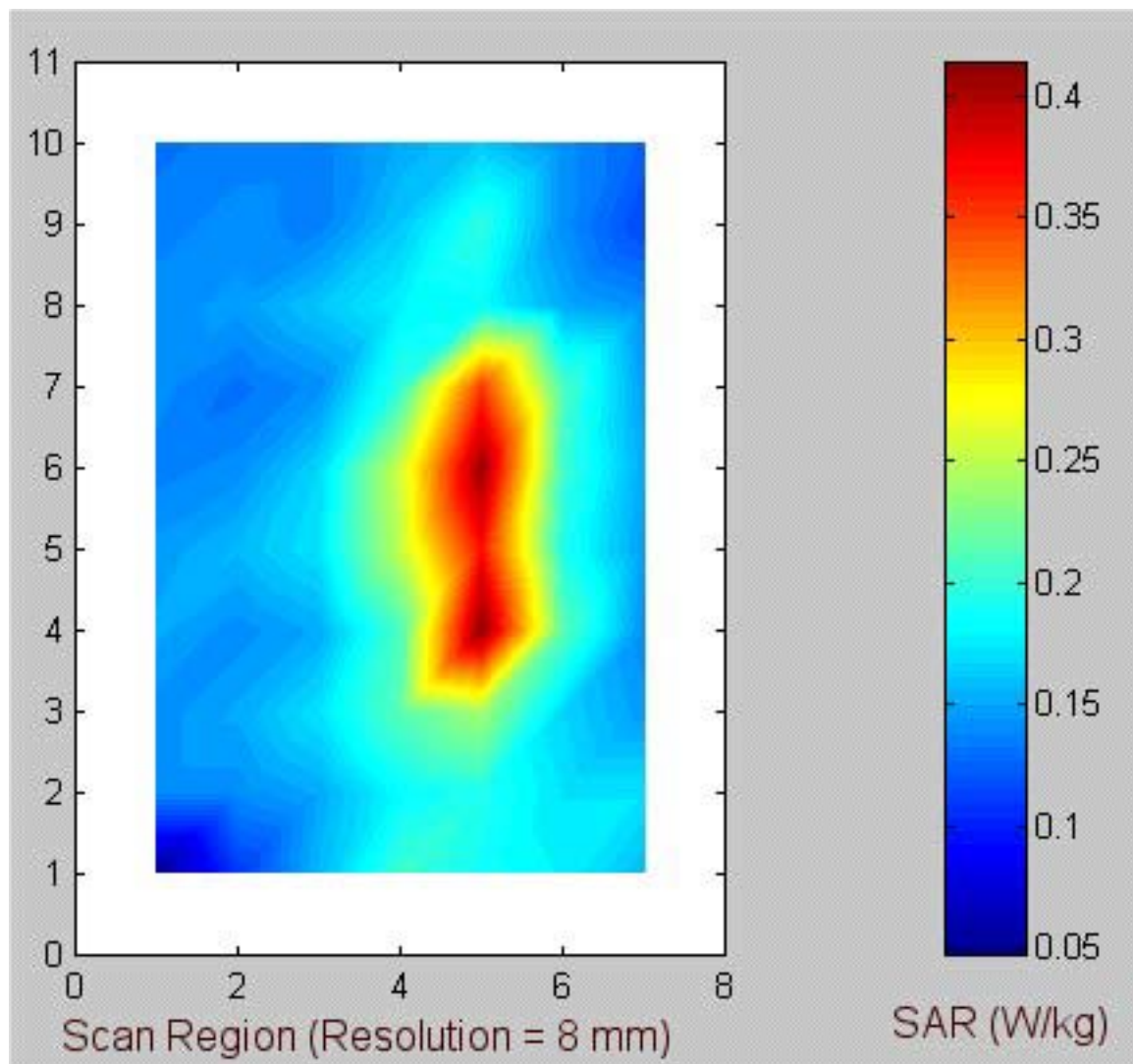
d. 5.76 GHz turbo mode – antenna "A" (see Table 6 for the peak 1-g SAR).

Fig. 12. Coarse scans for the SAR measurements for the right side **Edge-on position** of the PC relative to the flat phantom (Configuration 2, see Fig. 4a). The right edge of the PC with antenna "A" was placed at 90° pressed against the bottom of the flat phantom at a distance of 0 cm.



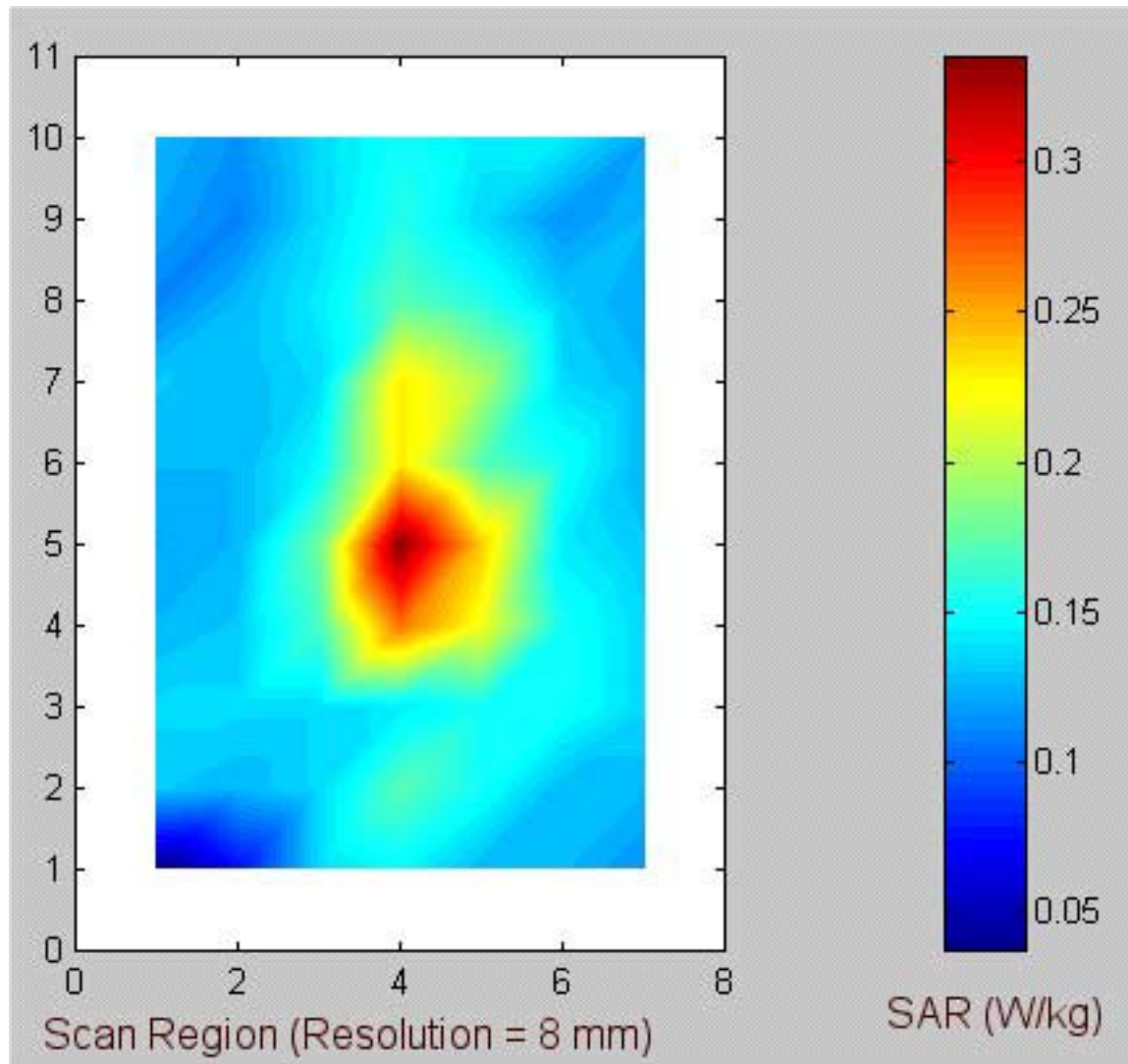
a. 5.26 GHz normal mode – antenna "B" (see Table 7 for the peak 1-g SAR).

Fig. 13. Coarse scans for the SAR measurements for the left side **Edge-on position** of the PC relative to the flat phantom (Configuration 2, see Fig. 4b). The left edge of the PC with antenna "B" was placed at 90° pressed against the bottom of the flat phantom at a distance of 0 cm.



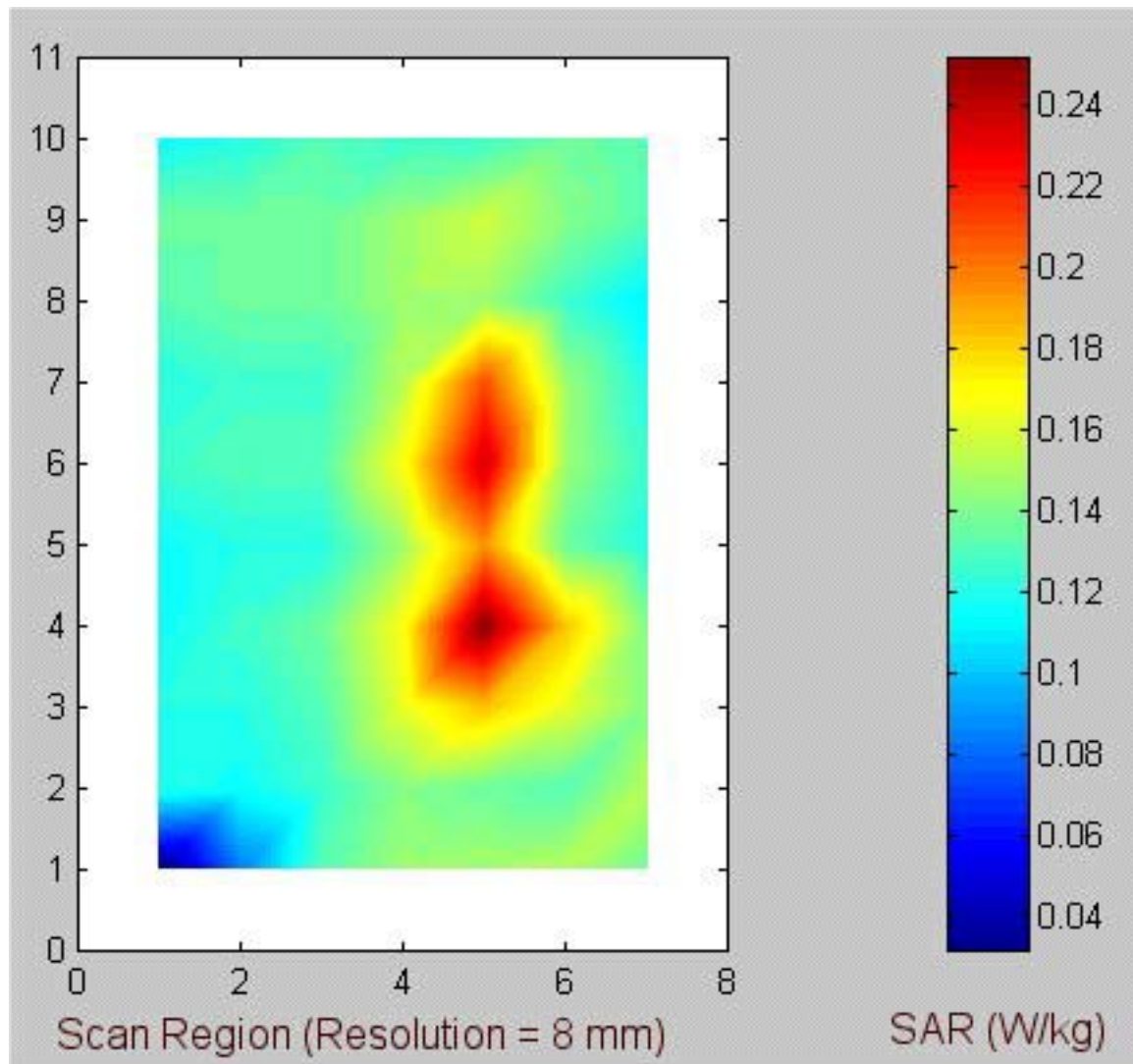
b. 5.745 GHz normal mode – antenna "B" (see Table 8 for the peak 1-g SAR).

Fig. 13. Coarse scans for the SAR measurements for the left side **Edge-on position** of the PC relative to the flat phantom (Configuration 2, see Fig. 4b). The left edge of the PC with antenna "B" was placed at 90° pressed against the bottom of the flat phantom at a distance of 0 cm.



c. 5.29 GHz turbo mode – antenna "B" (see Table 9 for the peak 1-g SAR).

Fig. 13. Coarse scans for the SAR measurements for the left side **Edge-on position** of the PC relative to the flat phantom (Configuration 2, see Fig. 4b). The left edge of the PC with antenna "B" was placed at 90° pressed against the bottom of the flat phantom at a distance of 0 cm.



d. 5.76 GHz turbo mode – antenna "B" (see Table 10 for the peak 1-g SAR).

Fig. 13. Coarse scans for the SAR measurements for the left side **Edge-on position** of the PC relative to the flat phantom (Configuration 2, see Fig. 4b). The left edge of the PC with antenna "B" was placed at 90° pressed against the bottom of the flat phantom at a distance of 0 cm.

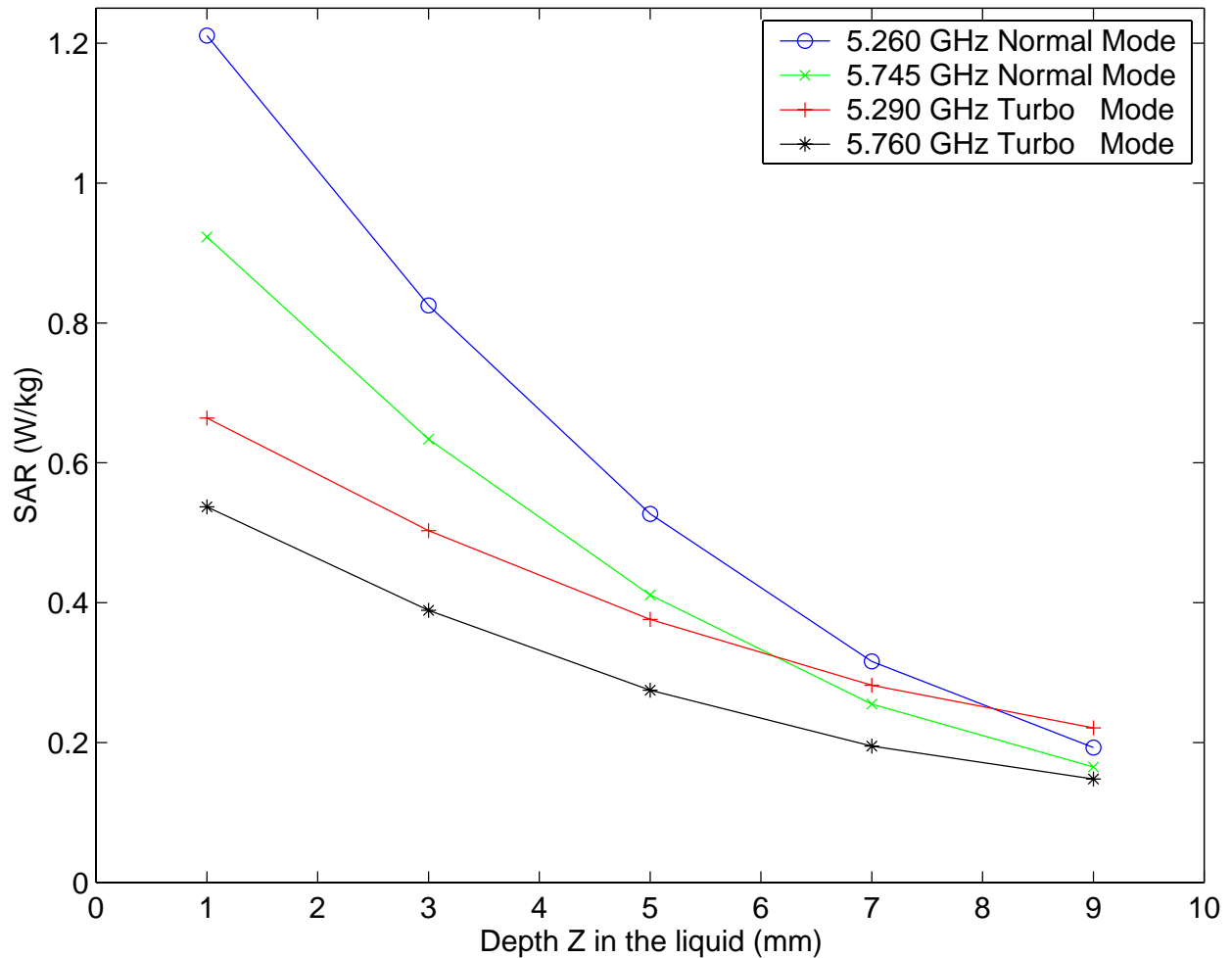


Fig. 14. Plot of the SAR variations as a function of depth Z in the liquid for locations of the highest SAR (from Tables 3-6 for **Edge-on position**) for Askey Model WLL220 802.11a Antenna "A" built into Compal Model ACY25 Notebook Computer.

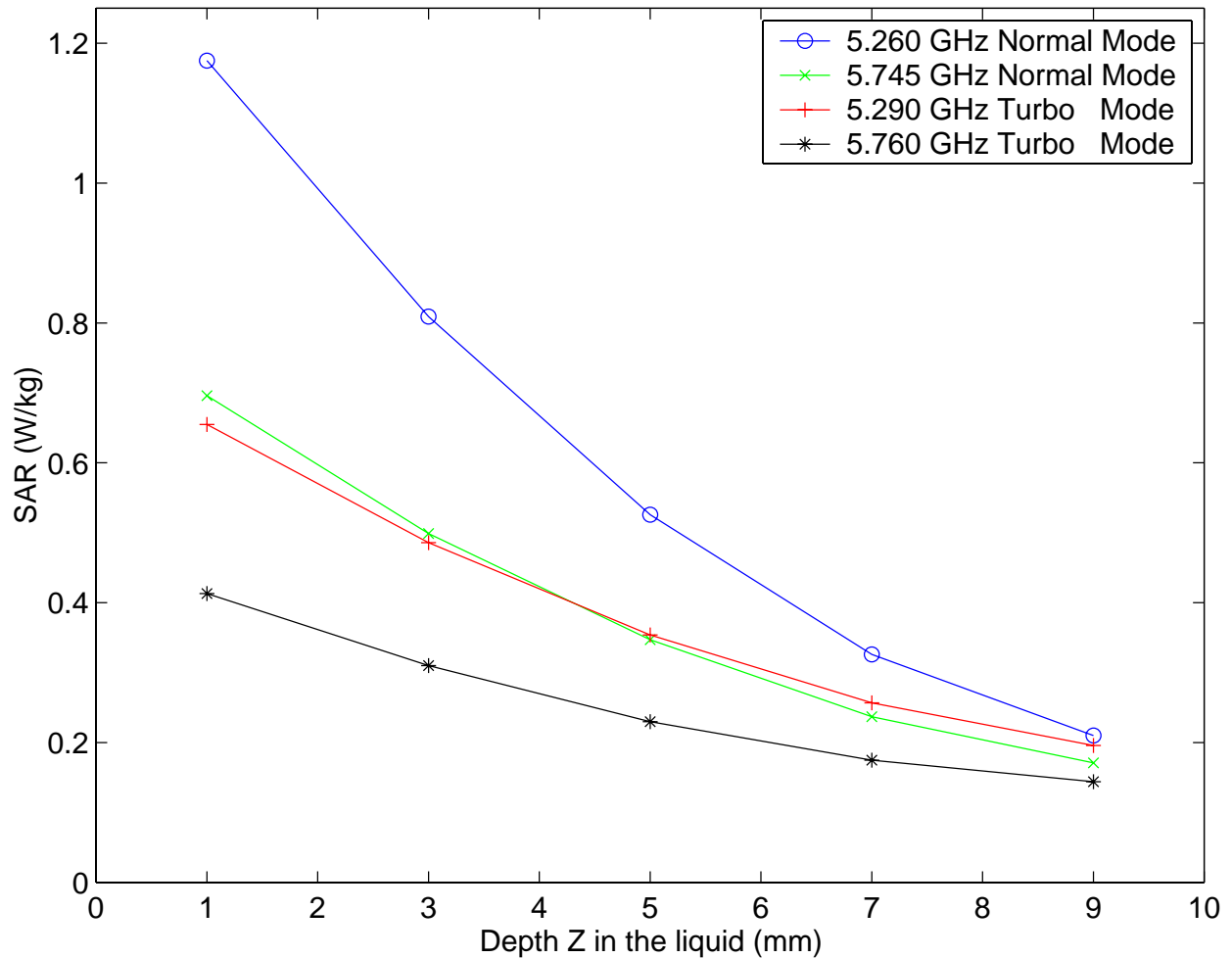


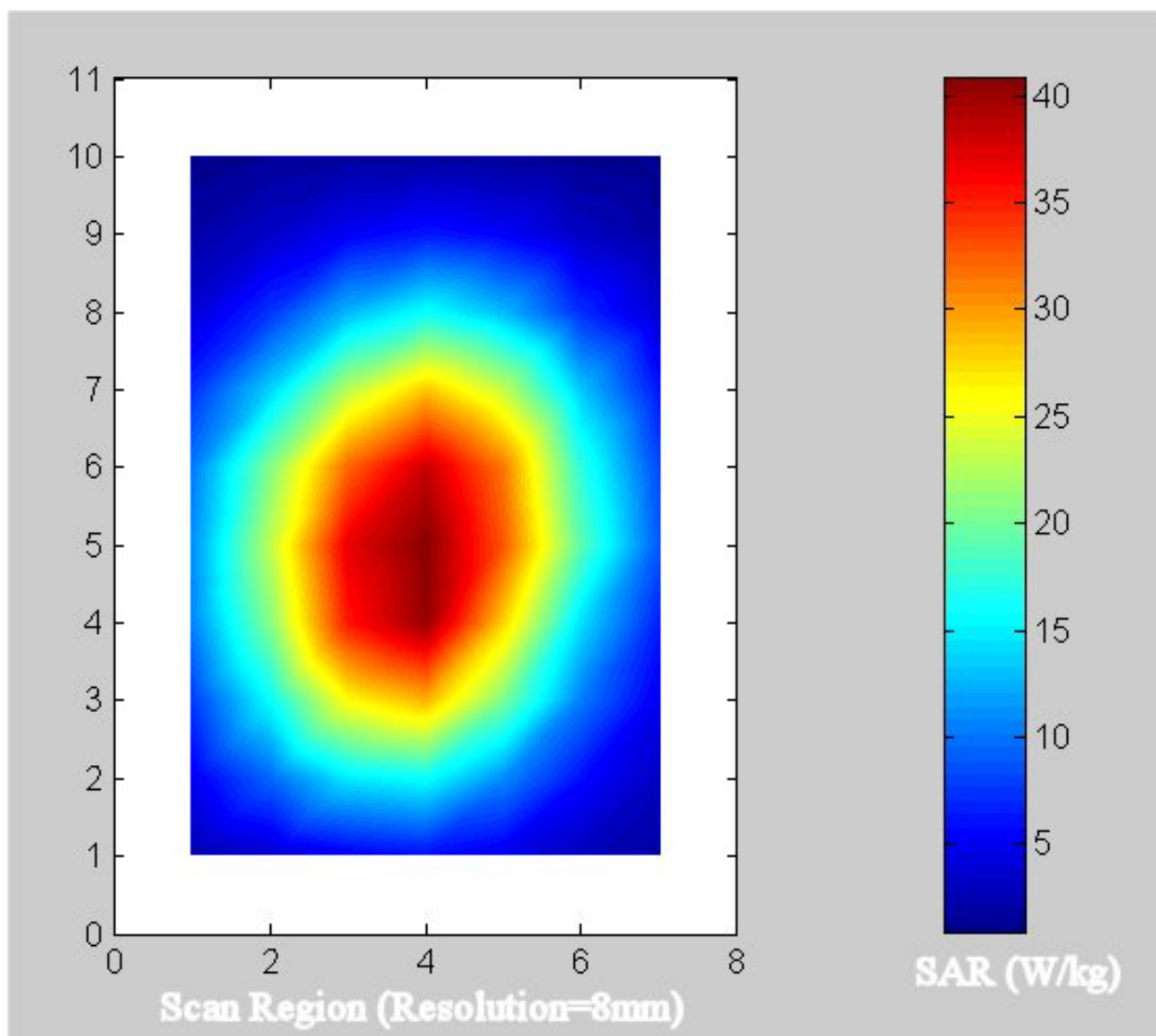
Fig. 15. Plot of the SAR variations as a function of depth Z in the liquid for locations of the highest SAR (from Tables 7-10 for **Edge-on position**) for Askey Model WLL220 802.11a Antenna "B" built into Compal Model ACY25 Notebook Computer.

APPENDIX B

SAR System Verification for March 17, 2003

The measured SAR distribution for the peak 1-g SAR region using a dipole at 1900 MHz

For March 17, 2003 - The dipole SAR Plot



1-g SAR = 35.410 W/kg

a. At depth of 1 mm

55.975	57.821	57.376	54.858	50.920
56.306	58.634	58.574	56.413	52.680
56.370	58.827	59.337	57.364	53.764
55.802	58.619	59.111	57.589	54.099
54.421	57.300	57.841	56.371	52.892

b. At depth of 3 mm

43.825	45.049	44.619	42.775	39.930
44.068	45.599	45.445	43.835	41.108
44.084	45.720	45.814	44.446	41.779
43.641	45.512	45.721	44.513	41.964
42.516	44.498	44.781	43.645	41.051

c. At depth of 5 mm

33.610	34.351	33.957	32.662	30.617
33.782	34.697	34.487	33.331	31.421
33.761	34.770	34.696	33.669	31.767
33.418	34.558	34.562	33.618	31.843
32.571	33.788	33.886	33.021	31.242

d. At depth of 7 mm

25.310	25.728	25.390	24.521	23.252
25.447	25.928	25.698	24.902	23.616
25.399	25.958	25.783	25.033	23.731
25.135	25.748	25.623	24.904	23.708
24.492	25.169	25.145	24.510	23.347

e. At depth of 9 mm

18.963	19.180	18.918	18.350	17.497
19.065	19.291	19.082	18.547	17.694
18.999	19.285	19.081	18.539	17.663
18.795	19.080	18.913	18.370	17.586
18.291	18.642	18.560	18.101	17.386

APPENDIX C

Uncertainty Analysis

The uncertainty analysis of the University of Utah SAR Measurement System is given in Table A.1. Several of the numbers on tolerances are obtained by following procedures similar to those detailed in [8], while others have been obtained using methods suggested in [4].

Table B.1. Uncertainty analysis of the University of Utah SAR Measurement System.

Uncertainty Component	Tolerance ± %	Prob. Dist.	Div.	C _i 1-g	1-g u _i ± %
Measurement System					
Probe calibration	2.0	N	1	1	2.0
Axial isotropy	4.0	R	$\sqrt{3}$	$(1-c_p)^{1/2}$	1.6
Hemispherical isotropy	5.5	R	$\sqrt{3}$	$\sqrt{c_p}$	0.0
Boundary effect	0.8	R	$\sqrt{3}$	1	0.5
Linearity	3.0	R	$\sqrt{3}$	1	1.7
System detection limits	1.0	R	$\sqrt{3}$	1	0.6
Readout electronics	1.0	N	1	1	1.0
Response time	0.0	R	$\sqrt{3}$	1	0.0
Integration time	0.5	R	$\sqrt{3}$	1	0.3
RF ambient conditions	0	R	$\sqrt{3}$	1	0
Probe positioner mechanical tolerance	0.5	R	$\sqrt{3}$	1	0.3
Probe positioning with respect to phantom shell	2.0	R	$\sqrt{3}$	1	1.2
Extrapolation, interpolation, and integration algorithms for max. SAR evaluation	5.0	R	$\sqrt{3}$	1	2.9
Test Sample Related					
Test sample positioning	3	R	$\sqrt{3}$	1	1.7
Device holder uncertainty	3	R	$\sqrt{3}$	1	1.7
Output power variation - SAR drift measurement	5	R	$\sqrt{3}$	1	2.9
Phantom and Tissue Parameters					
Phantom uncertainty - shell thickness tolerance	10.0	R	$\sqrt{3}$	1	5.8
Liquid conductivity - deviation from target values	0.4	R	$\sqrt{3}$	0.7	0.2
Liquid conductivity - measurement uncertainty	1.5	R	$\sqrt{3}$	0.7	0.6
Liquid permittivity - deviation from target values	0.8	R	$\sqrt{3}$	0.6	0.3
Liquid permittivity - measurement uncertainty	3.5	R	$\sqrt{3}$	0.6	1.2
Combined Standard Uncertainty		RSS			8.3
Expanded Uncertainty (95% Confidence Level)					16.6