SAR COMPLIANCE TESTING OF ARIMA COMPUTER CORPORATION TABLET PC

WITH BUILT-IN 802.11 a/b WIRELESS LAN MODULE

MODEL: NEC VERSA LitePad Model T400
FCC ID: ID4-NEC-LITEPAD

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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 Arima Computer Corporation Tablet PC Model NEC VERSA LitePad with built-in 802.11 a/b Wireless LAN Module (FCC ID# ID4-NEC-LITEPAD). Some photographs of the Arima Corporation Tablet PC are given as Figs. 1a-d. From these photographs, it can be seen that the Tablet PC uses a pivoted blade-type Wireless LAN Antenna that can be parallel or perpendicular to the Tablet (see Figs. 1a-d). Also, the video screen can be programmed so that it reads either parallel or perpendicular to the larger dimension of the Tablet. The Wireless LAN Module operates over the bands 5.15 to 5.35 GHz and 5.725 to 5.825 GHz with measured RF power outputs given in Table 1.

Recognizing that the Tablet PC may be operated with the Wireless LAN Antenna either parallel or perpendicular to the plane of the Tablet, both configurations of the antennas were used for SAR measurements. The configurations of the Tablet PC vis à vis the body used for SAR measurements are as follows:

a. **Configuration 1** is for the Tablet PC held against the chest or in the arm say the left arm. For this configuration, a planar phantom model with inside dimensions 12" × 16.5" (30.5 × 41.9 cm) and a base thickness of 2.0 ± 0.2 mm (recommended in [3]) was used for SAR measurements and the edge of the Tablet PC with Wireless LAN Antenna was pressed against the base of the planar phantom. As shown in Figs. 3a and b, both of the orientations of the Wireless LAN Antenna i.e. parallel or perpendicular to the Tablet were used for SAR measurements.

b. **Configuration 2** is for the Tablet PC placed on a user's lap. As for Configuration 1, here too, the planar phantom model of the above dimensions was used and the base of the Tablet PC was pressed against it (see Figs. 4a, b). For Configuration 2 also, both of the orientations of the Wireless LAN Antenna, parallel or perpendicular to the Tablet, were used for SAR measurements.

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 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 of dimensions 38.1 × 21.6 cm allows placement of a plastic holder (shown in Fig. 6) on which the Tablet PC with Wireless LAN Antenna (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 Tablet PC (for Configuration 2) is pressed against the base of the flat phantom for determination of

SAR for Above-lap position (see Figs. 4a, b). Similarly, for "Edge-on" SAR determination, Configuration 1, the laptop computer is mounted sideways (at 90°) on the plastic holder and moved up so that the edge of the Tablet PC with the Wireless LAN Antenna is pressed against the bottom of the flat phantom (see Figs. 3a, b). For both Configurations 1 and 2, the SAR distributions are measured for antenna parallel as well as perpendicular to the Tablet of the PC.

The Flat Phantom

As recommended in Supplement C Edition 01-01 to OET Bulletin 65 [3], 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. 3, 4).

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, 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 [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 ± 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)/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 0.1 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 ± 5% of the midband frequencies..

The date for the calibration of the E-field probe closest to the SAR tests given here was March 26, 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

* 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.

parameters of the body-simulant fluid at 1900 MHz are $\varepsilon_r = 53.1 \pm 1.3$ and $\sigma = 1.44 \pm 0.09$ S/m. The measured properties are close to the values of $\varepsilon_r = 54.0$ 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 26, 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 36.429 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 ± 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 2, 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. 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]

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

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

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

VI. The Measured SAR Distributions

The RF power output measured for the Arima Corporation Tablet PC Wireless LAN Antenna is given in Table 1. For SAR measurements, we selected frequencies of 5.26 and 5.745 GHz. These frequencies were selected both for their highest power outputs as well as to cover the two different frequency bands 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 (± 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 was resolved into a 4 × 4 times larger grid i.e. a grid involving 40 × 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 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 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 ± 8.3%.

As previously mentioned, the Wireless LAN Antenna can be operated when it is parallel or perpendicular to the Tablet. For the present measurements, we have determined the SAR distributions for both of these orientations of the antenna for both Configurations 1 and 2 defined in Section I. The coarse scans for the various measurements are given in Figs. 12 and 13 for Configurations 1 and 2, 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 in each of the cases. Given in Tables 3-6 are the SAR distributions for the peak SAR region of volume 10 ×10 × 10 mm for which the coarse scans are given in Figs. 12a-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 × 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 over the 80-minute period needed for measurements at the four frequencies was $23.3 \pm 0.2^{\circ}C$. As expected, the SARs are extremely low and within the noise limit of the SAR measurement system (~0.02 W/kg) for Configuration 1 – Above-lap position when the Wireless LAN Antenna is perpendicular to the Tablet as shown in Fig. 3b. For the cases when the wireless antenna is parallel to the Tablet (Fig. 3a), the SAR distributions are measurable. The coarse scan measurements for the Above-lap Configuration 1 at 5.26 and 5.745 GHz for this orientation of the Wireless LAN Antenna are given in Figs. 13a, b, respectively. The corresponding SAR distributions for the peak 1-g SAR for this Above-lap Configuration 1 are given in Tables 7, 8, respectively.

The peak 1-g SARs for the various configurations of the Arima Computer Corporation Tablet PC are summarized in Table 9. All of the measured 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 Arima Corporation Tablet PC Model NEC VERSA LitePad (FCC ID# ID-4-NEC-LITEPAD), the measured peak 1-g SARs vary from 0 to 0.327 W/kg which are smaller than 1.6 W/kg.

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Table 1. Conducted RF power outputs measured at various frequencies for the Arima Computer Corporation

Channel	Frequency GHz	Output Power dBm
5.15-5.35 GHz Band		
1	5.18	12.53
4	5.24	12.73
5	5.26	12.86
8	5.32	12.73
5.725-5.825 GHz Band		
1	5.745	13.75
2	5.765	13.64
3	5.785	13.50
4	5.805	13.37

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 1).** The SARs measured for the Tablet PC Wireless LAN Antenna parallel to the Tablet at 5.26 GHz.

1-g SAR = 0.188 W/kg

a. At depth of 1 mm

0.227	0.279	0.289	0.253	0.217
0.248	0.282	0.303	0.262	0.189
0.246	0.284	0.274	0.250	0.230
0.223	0.253	0.278	0.237	0.217
0.221	0.218	0.210	0.212	0.198

b. At depth of 3 mm

0.198	0.235	0.240	0.214	0.197
0.213	0.234	0.247	0.222	0.178
0.210	0.235	0.226	0.209	0.198
0.189	0.210	0.230	0.198	0.189
0.189	0.198	0.188	0.184	0.173

c. At depth of 5 mm

0.174	0.200	0.201	0.185	0.181
0.185	0.196	0.203	0.191	0.168
0.182	0.196	0.189	0.178	0.172
0.163	0.178	0.192	0.170	0.168
0.165	0.180	0.170	0.163	0.156

d. At depth of 7 mm

0.157	0.175	0.173	0.165	0.167
0.165	0.169	0.171	0.167	0.157
0.161	0.167	0.164	0.155	0.153
0.144	0.156	0.165	0.152	0.153
0.148	0.166	0.158	0.148	0.147

e. At depth of 9 mm

0.145	0.160	0.157	0.155	0.157
0.153	0.152	0.151	0.152	0.147
0.147	0.150	0.150	0.142	0.141
0.132	0.144	0.148	0.144	0.143
0.139	0.154	0.151	0.140	0.144

Table 4. **Edge-on position (Configuration 1).** The SARs measured for the Tablet PC Wireless LAN Antenna perpendicular to the Tablet at 5.26 GHz.

1-g SAR = 0.327 W/kg

a. At depth of 1 mm

0.163	0.104	0.492	0.485	0.468
0.528	0.601	0.647	0.604	0.521
0.622	0.713	0.739	0.686	0.579
0.587	0.661	0.659	0.615	0.478
0.472	0.548	0.537	0.477	0.362

b. At depth of 3 mm

0.156	0.138	0.378	0.370	0.354
0.394	0.441	0.468	0.448	0.388
0.456	0.514	0.532	0.494	0.423
0.436	0.492	0.488	0.457	0.368
0.370	0.411	0.407	0.368	0.299

c. At depth of 5 mm

0.151	0.161	0.288	0.279	0.265
0.288	0.317	0.329	0.326	0.284
0.327	0.360	0.371	0.346	0.302
0.318	0.357	0.354	0.332	0.281
0.288	0.304	0.305	0.282	0.248

d. At depth of 7 mm

0.148	0.173	0.222	0.212	0.202
0.213	0.229	0.231	0.236	0.210
0.234	0.252	0.257	0.240	0.216
0.232	0.257	0.255	0.241	0.218
0.226	0.226	0.231	0.219	0.208

e. At depth of 9 mm

0.148	0.174	0.180	0.169	0.164
0.166	0.176	0.174	0.180	0.166
0.178	0.188	0.188	0.176	0.165
0.178	0.191	0.192	0.184	0.178
0.185	0.178	0.184	0.180	0.179

Table 5. **Edge-on position (Configuration 1).** The SARs measured for the Tablet PC Wireless LAN Antenna parallel to the Tablet at 5.745 GHz.

1-g SAR = 0.217 W/kg

a. At depth of 1 mm

0.250	0.301	0.338	0.321	0.274
0.226	0.296	0.328	0.316	0.292
0.239	0.287	0.302	0.334	0.253
0.230	0.268	0.272	0.282	0.267
0.239	0.241	0.231	0.243	0.268

b. At depth of 3 mm

0.221	0.259	0.276	0.270	0.243
0.210	0.253	0.274	0.259	0.245
0.211	0.240	0.256	0.272	0.224
0.207	0.231	0.242	0.241	0.230
0.215	0.210	0.209	0.216	0.237

c. At depth of 5 mm

0.199	0.225	0.229	0.231	0.217
0.197	0.220	0.231	0.216	0.208
0.188	0.203	0.220	0.224	0.201
0.189	0.203	0.218	0.209	0.203
0.196	0.186	0.191	0.196	0.212

d. At depth of 7 mm

0.183	0.200	0.198	0.202	0.197
0.186	0.196	0.200	0.185	0.182
0.172	0.178	0.195	0.190	0.182
0.175	0.182	0.201	0.187	0.184
0.181	0.171	0.178	0.182	0.194

e. At depth of 9 mm

0.174	0.184	0.181	0.185	0.182
0.177	0.181	0.179	0.166	0.166
0.161	0.163	0.181	0.171	0.169
0.165	0.170	0.191	0.175	0.175
0.170	0.162	0.170	0.175	0.181

Table 6. **Edge-on position (Configuration 1).** The SARs measured for the Tablet PC Wireless LAN Antenna perpendicular to the Tablet at 5.745 GHz.

1-g SAR = 0.253 W/kg

a. At depth of 1 mm

0.366	0.383	0.396	0.371	0.352
0.387	0.429	0.460	0.429	0.387
0.392	0.403	0.420	0.424	0.380
0.334	0.356	0.357	0.340	0.324
0.269	0.306	0.293	0.292	0.273

b. At depth of 3 mm

0.296	0.303	0.313	0.296	0.284
0.305	0.331	0.348	0.335	0.312
0.311	0.315	0.331	0.334	0.303
0.267	0.287	0.290	0.281	0.268
0.234	0.256	0.248	0.246	0.236

c. At depth of 5 mm

0.242	0.241	0.249	0.238	0.231
0.242	0.256	0.262	0.263	0.253
0.248	0.246	0.262	0.263	0.243
0.216	0.233	0.235	0.234	0.224
0.207	0.216	0.212	0.210	0.208

d. At depth of 7 mm

0.203	0.197	0.203	0.196	0.193
0.198	0.204	0.204	0.212	0.210
0.202	0.199	0.211	0.213	0.200
0.182	0.193	0.195	0.199	0.192
0.186	0.187	0.186	0.185	0.188

e. At depth of 9 mm

0.179	0.173	0.177	0.171	0.170
0.172	0.175	0.172	0.181	0.182
0.175	0.171	0.179	0.183	0.174
0.164	0.168	0.167	0.176	0.172
0.172	0.168	0.170	0.170	0.175

Table 7. **Above-lap position (Configuration 2).** The SARs measured for the Tablet PC Wireless LAN Antenna parallel to the Tablet at 5.26 GHz.

1-g SAR = 0.173 W/kg

a. At depth of 1 mm

0.191	0.204	0.234	0.207	0.177
0.206	0.206	0.242	0.222	0.198
0.181	0.224	0.206	0.180	0.192
0.173	0.206	0.214	0.182	0.158
0.192	0.191	0.194	0.197	0.186

b. At depth of 3 mm

0.176	0.186	0.206	0.182	0.171
0.182	0.193	0.207	0.191	0.184
0.171	0.191	0.187	0.169	0.183
0.170	0.185	0.194	0.175	0.157
0.178	0.178	0.182	0.184	0.181

c. At depth of 5 mm

0.164	0.172	0.183	0.163	0.163
0.164	0.182	0.181	0.167	0.173
0.163	0.165	0.170	0.161	0.175
0.167	0.170	0.179	0.169	0.156
0.168	0.168	0.173	0.173	0.176

d. At depth of 7 mm

0.155	0.162	0.167	0.149	0.155
0.155	0.172	0.162	0.152	0.165
0.156	0.148	0.157	0.156	0.167
0.164	0.160	0.168	0.163	0.155
0.162	0.161	0.166	0.166	0.170

e. At depth of 9 mm

0.148	0.155	0.156	0.142	0.146
0.153	0.163	0.152	0.146	0.159
0.151	0.139	0.146	0.154	0.161
0.161	0.156	0.162	0.158	0.154
0.159	0.157	0.161	0.162	0.163

Table 8. **Above-lap position (Configuration 2).** The SARs measured for the Tablet PC Wireless LAN Antenna parallel to the Tablet at 5.745 GHz.

1-g SAR = 0.208 W/kg

a. At depth of 1 mm

0.226	0.228	0.224	0.211	0.230
0.238	0.223	0.243	0.243	0.248
0.266	0.257	0.276	0.262	0.274
0.283	0.280	0.264	0.275	0.260
0.277	0.282	0.220	0.237	0.217

b. At depth of 3 mm

0.210	0.206	0.207	0.193	0.208
0.210	0.204	0.218	0.223	0.225
0.233	0.229	0.242	0.228	0.235
0.236	0.240	0.231	0.235	0.228
0.237	0.241	0.208	0.215	0.209

c. At depth of 5 mm

0.197	0.189	0.194	0.181	0.190
0.190	0.190	0.200	0.207	0.207
0.207	0.208	0.215	0.203	0.206
0.202	0.210	0.207	0.204	0.204
0.208	0.209	0.198	0.197	0.201

d. At depth of 7 mm

0.186	0.179	0.184	0.174	0.177
0.177	0.180	0.189	0.194	0.193
0.189	0.192	0.196	0.187	0.186
0.180	0.188	0.191	0.184	0.187
0.190	0.187	0.189	0.185	0.196

e. At depth of 9 mm

0.177	0.175	0.178	0.173	0.169
0.172	0.175	0.186	0.185	0.183
0.179	0.183	0.185	0.179	0.176
0.171	0.176	0.183	0.175	0.177
0.183	0.175	0.182	0.179	0.192

Table 9. The peak 1-g SARs measured for the Arima Computer Corporation Tablet PC Model NEC VERSA LitePad (FCC ID# ID-4-NEC-LITEPAD).

1-g SAR in W/kg

Tablet PC position relative to the flat phantom	Spacing to the bottom of the phantom	Orientation of antenna relative to plane of the Tablet	5.26 GHz	5.745 GHz
Configuration 1 – Edge-on position; PC edge with Wireless LAN Antenna pressed against the bottom of the flat phantom (see Figs. 3a, 3b)	0 cm	Parallel Perpendicular	0.188 0.327	0.217 0.253
Configuration 2 – Above-lap position; bottom of PC pressed against bottom of the flat phantom (see Figs. 4a, 4b)	0 cm	Parallel Perpendicular	0.173 < 0.02*	0.208 < 0.02*

* Too small to measure, within the noise limit of the SAR measurement system.

a. Video screen parallel to the larger dimension of the PC, antenna parallel to the Tablet.

Fig. 1. Photograph of the Arima Computer Corporation Tablet PC Model NEC VERSA LitePad.

b. Video screen parallel to the larger dimension of the PC, antenna perpendicular to the Tablet.

Fig. 1. Photograph of the Arima Computer Corporation Tablet PC Model NEC VERSA LitePad.

c. Video screen perpendicular to the larger dimension of the PC, antenna parallel to the Tablet.

Fig. 1. Photograph of the Arima Computer Corporation Tablet PC Model NEC VERSA LitePad.

d. Video screen perpendicular to the larger dimension of the PC, antenna perpendicular to the Tablet.

Fig. 1. Photograph of the Arima Computer Corporation Tablet PC Model NEC VERSA LitePad.

Fig. 2. Photograph of the back side of the Arima Computer Corporation Tablet PC Model NEC VERSA LitePad.

a. Wireless LAN antenna parallel to the Tablet.

Fig. 3. Photograph of the edge of the Tablet PC with Wireless LAN Antenna pressed against the base of the planar phantom. This is **Configuration 1** for SAR testing that corresponds to the Tablet PC pressed against the chest or an individual standing next to the antenna for the Tablet PC held in the arm.

b. Wireless LAN antenna perpendicular to the Tablet.

Fig. 3. Photograph of the edge of the Tablet PC with Wireless LAN Antenna pressed against the base of the planar phantom. This is **Configuration 1** for SAR testing that corresponds to the Tablet PC pressed against the chest or an individual standing next to the antenna for the Tablet PC held in the arm.

a. Wireless LAN antenna parallel to the Tablet.

Fig. 4. Photograph of the bottom of the Tablet PC with Wireless LAN Antenna pressed against the base of the planar phantom. This is **Configuration 2** for SAR testing (for the Tablet PC held in the laptop position).

b. Wireless LAN antenna perpendicular to the Tablet.

Fig. 4. Photograph of the bottom of the Tablet PC with Wireless LAN Antenna pressed against the base of the planar phantom. This is **Configuration 2** for SAR testing (for the Tablet PC held in the laptop position).

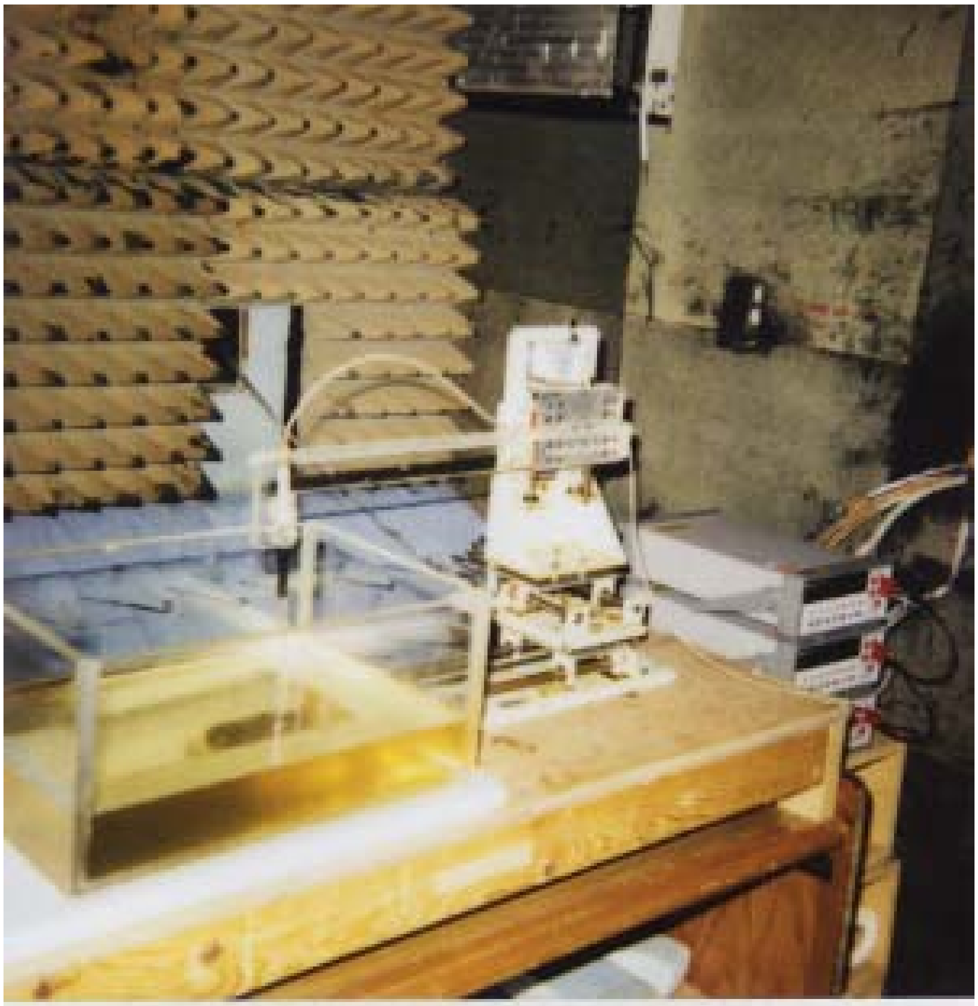


Fig. 5. Photograph of the three-dimensional stepper-motor-controlled SAR measurement system using a planar phantom (see Figs. 3 and 4 for a detailed examination of the placement of Tablet PC relative to this phantom).

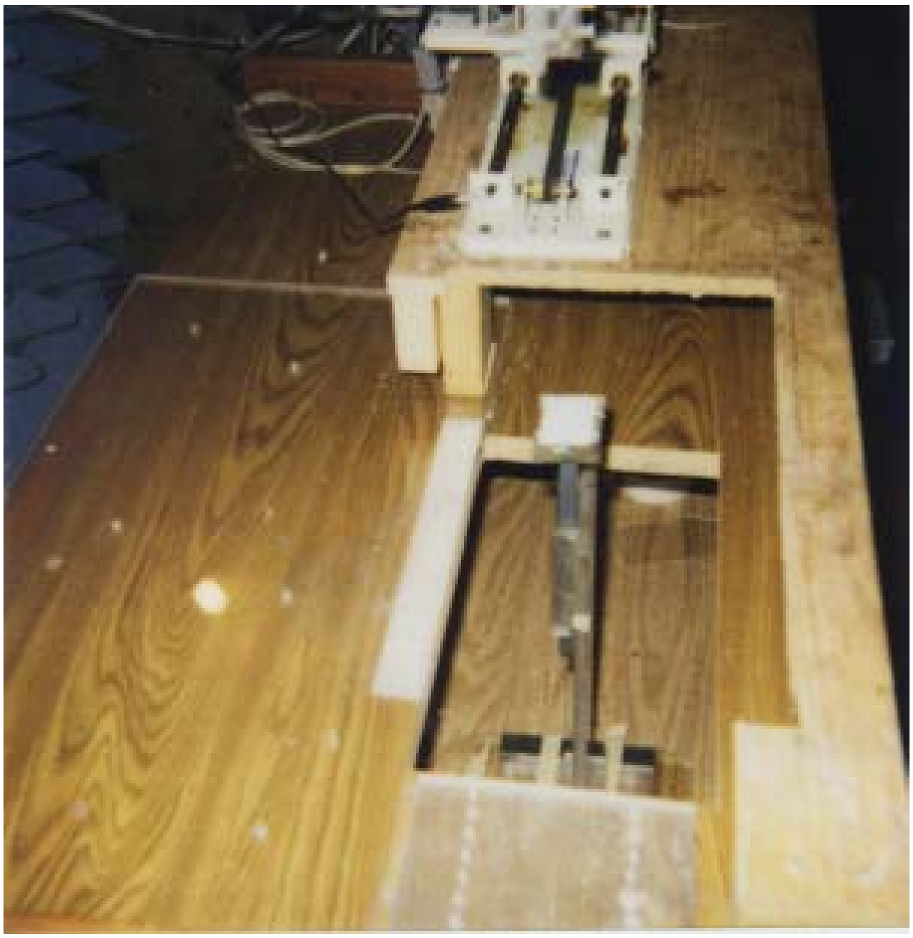


Fig. 6. The plastic holder used to support the Tablet PC (shown in Figs. 1, 2).

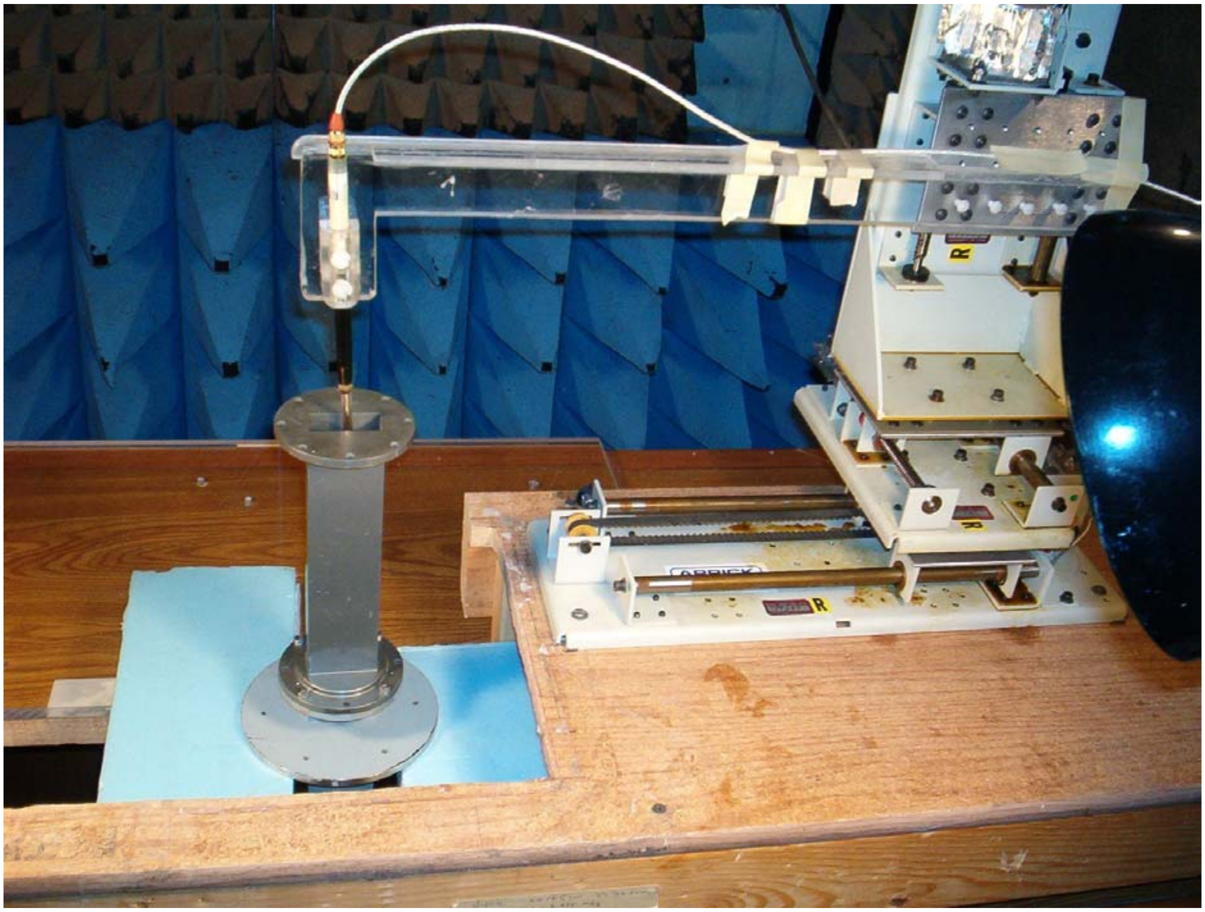


Fig. 7a. A photograph of the waveguide setup used for calibration of the Narda Model 8021 E-field probe in the frequency band 5.2-5.8 GHz.

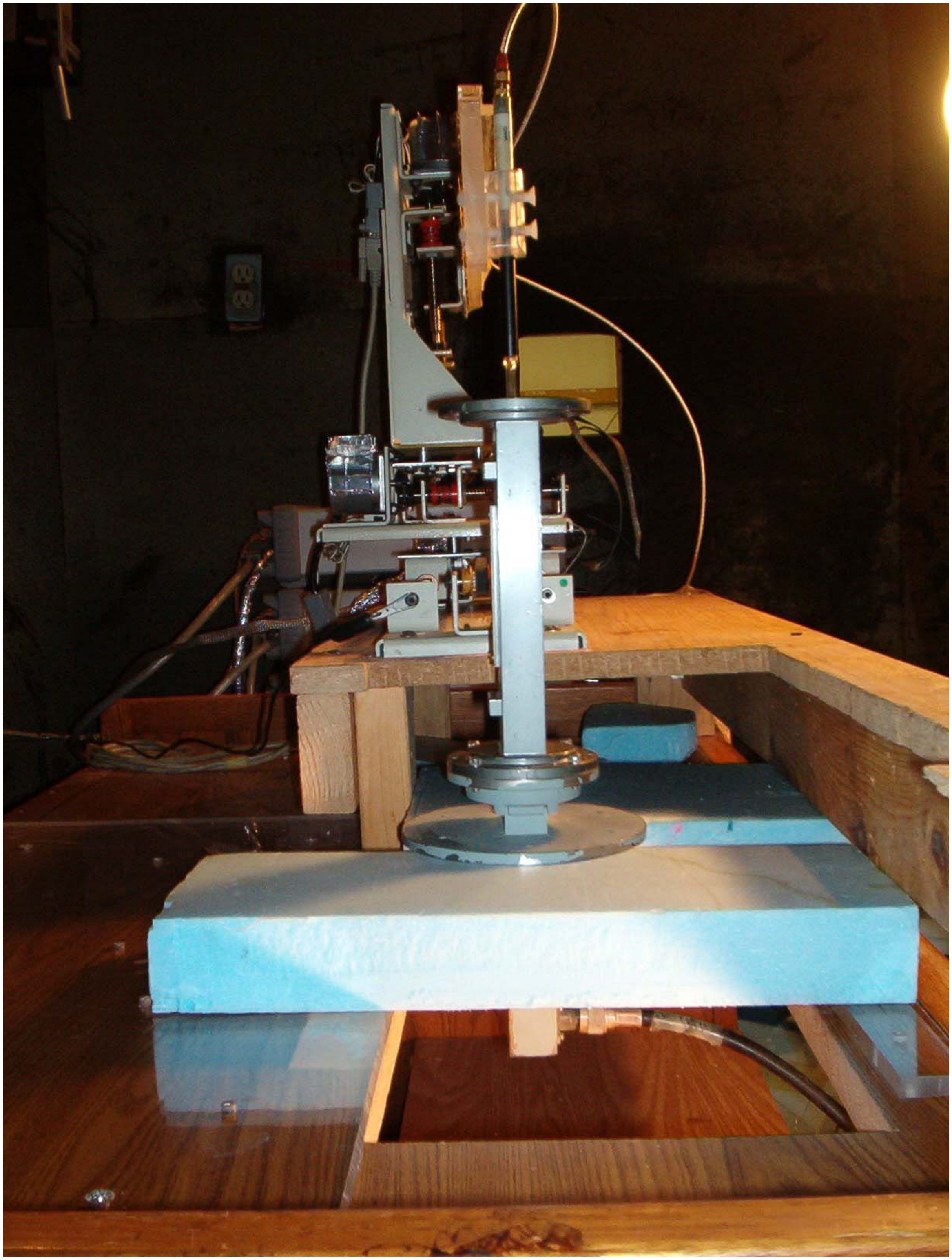
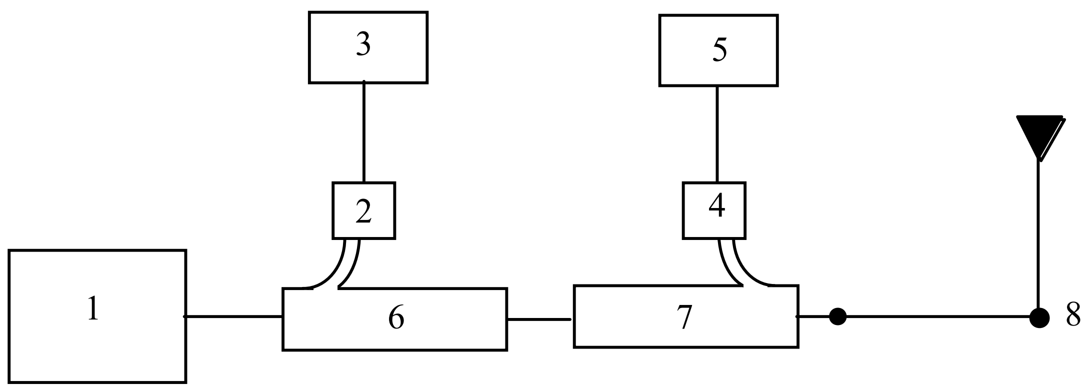


Fig. 7b. Photograph of the waveguide setup showing also the coax to waveguide coupler at the bottom used to feed power to the vertical waveguide containing the tissue-simulant fluid.

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

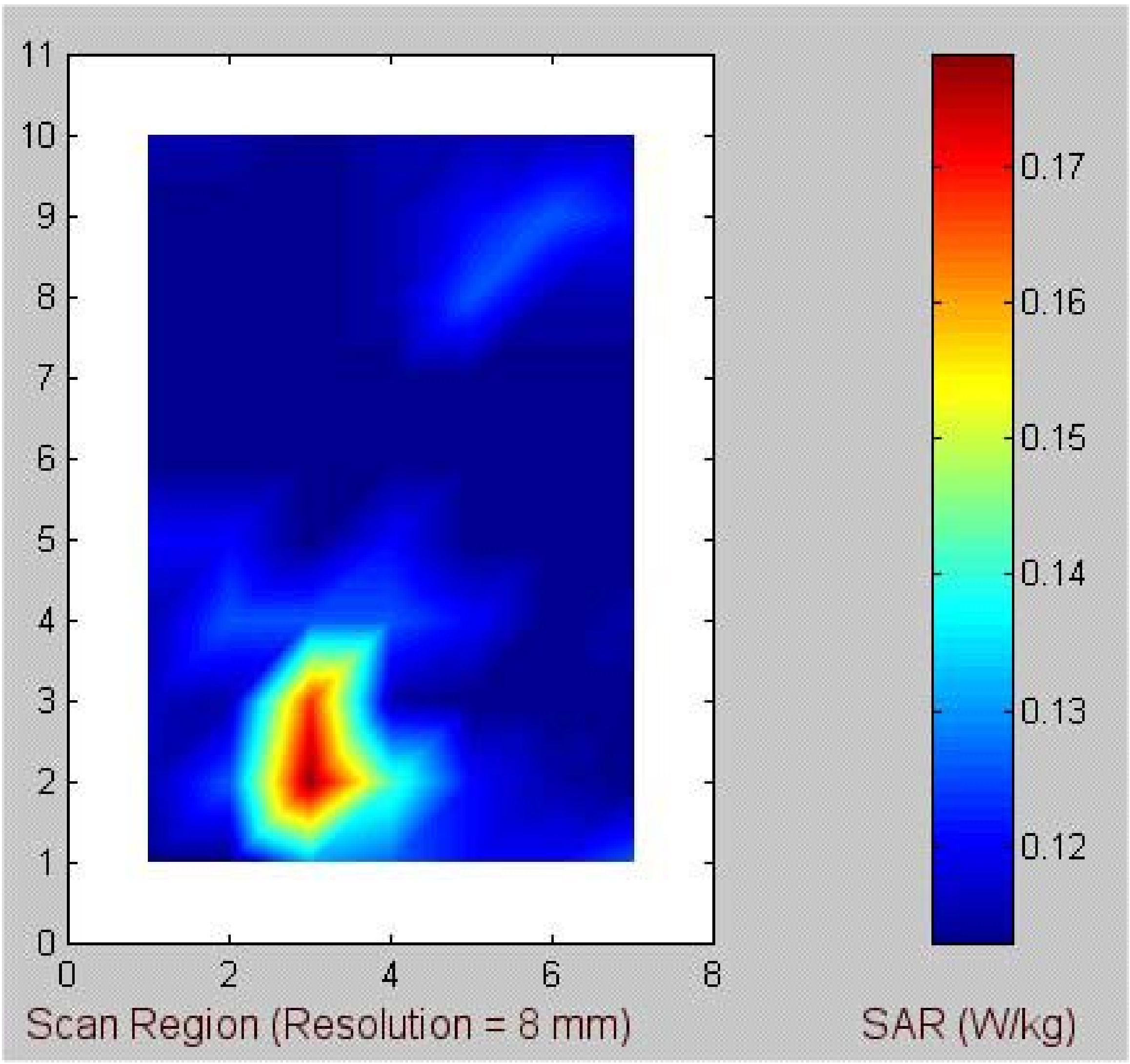
Fig. 9. Photograph of the half-wave dipole at 1900 MHz used for system verification.



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.

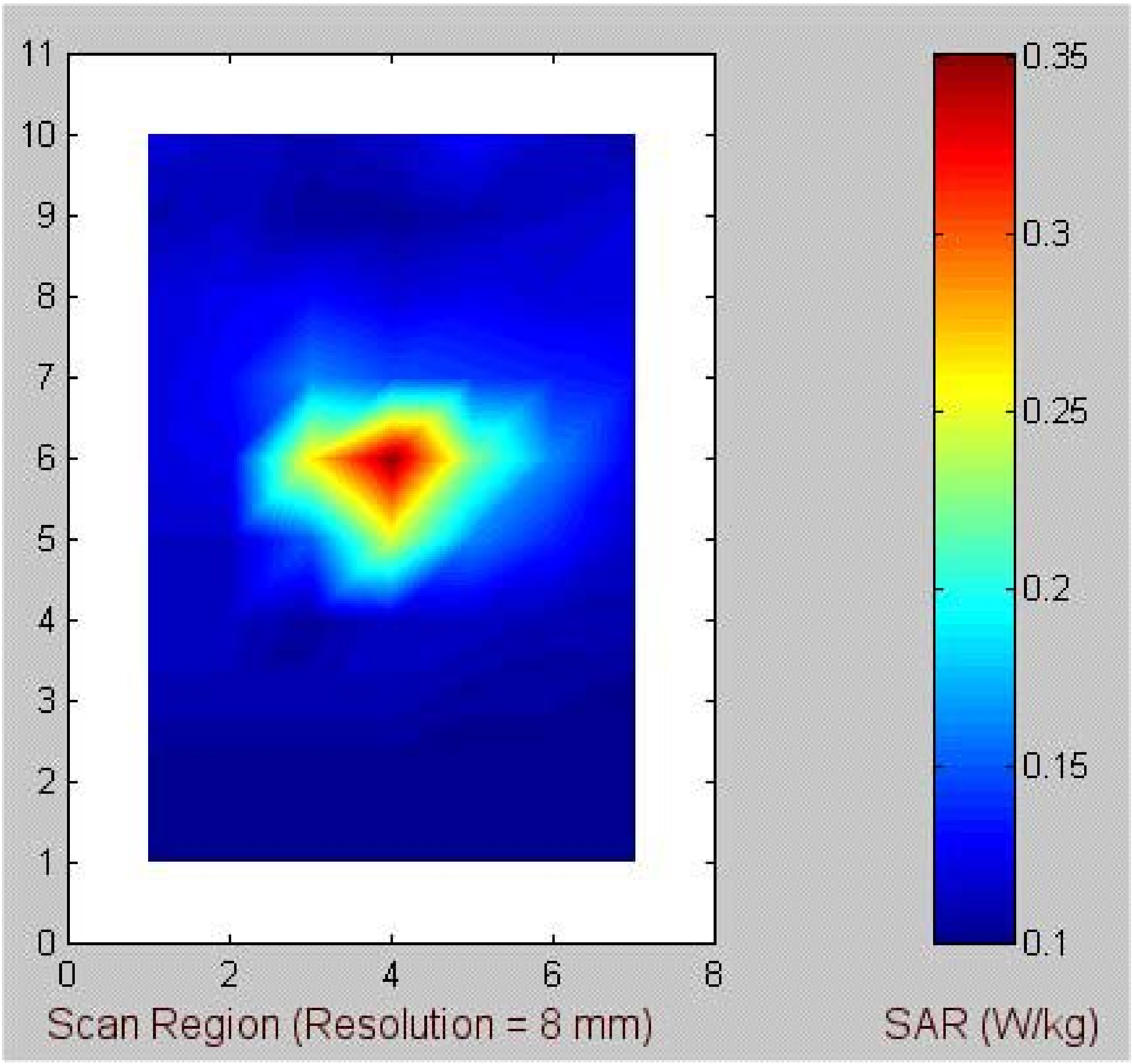
Fig. 10. The microwave circuit arrangement used for SAR system verification.

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



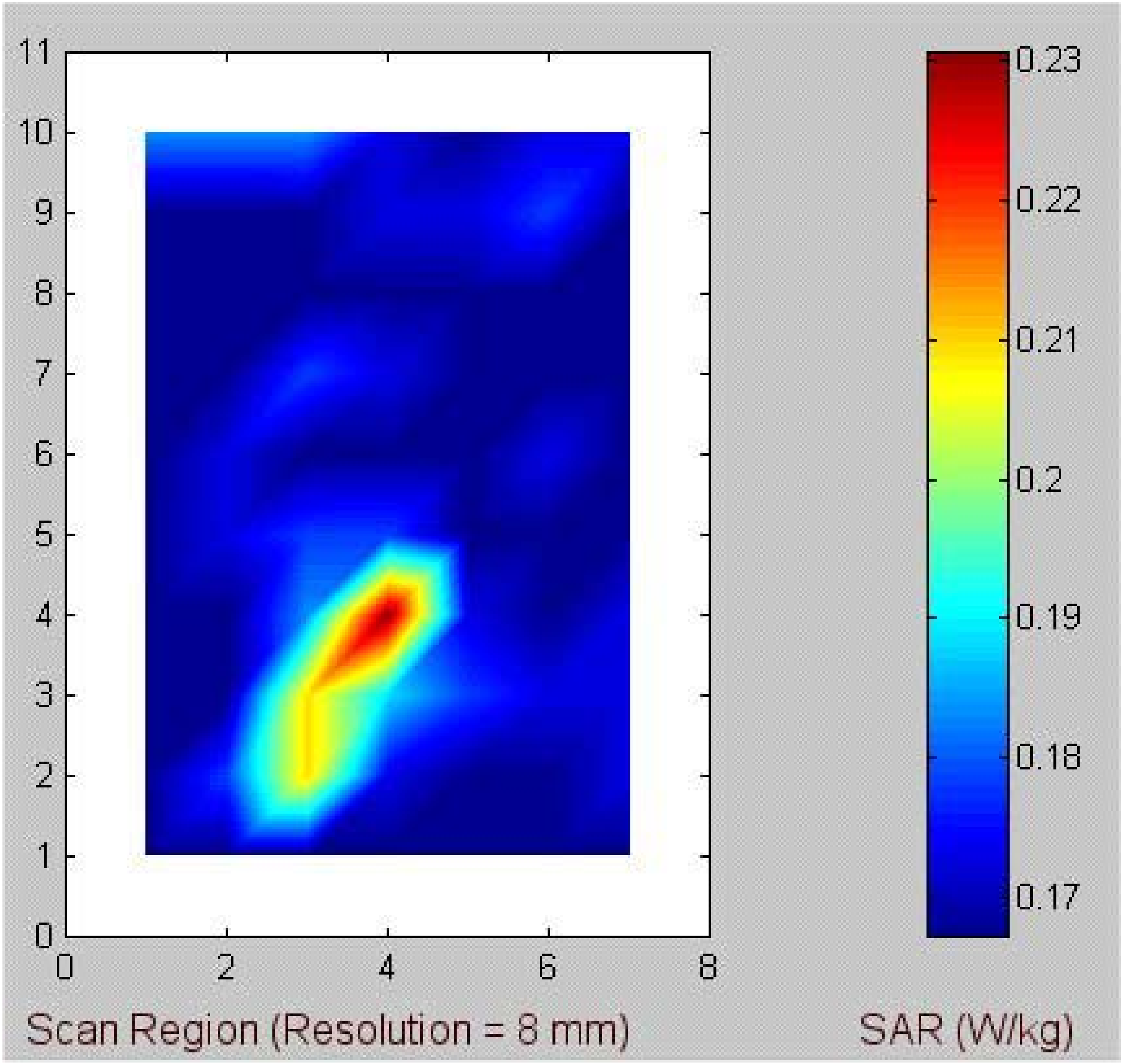
a. 5.26 GHz – antenna parallel to the Tablet (see Table 3 for peak 1-g SAR).

Fig. 12. Coarse scans for the SAR measurements for **Configuration 1 – Edge-on position** of the Tablet PC relative to the flat phantom (see Figs. 3a, 3b). This corresponds to the Wireless LAN Antenna of the Tablet PC pressed against the chest or an individual next to the antenna for the Tablet in the armheld position.



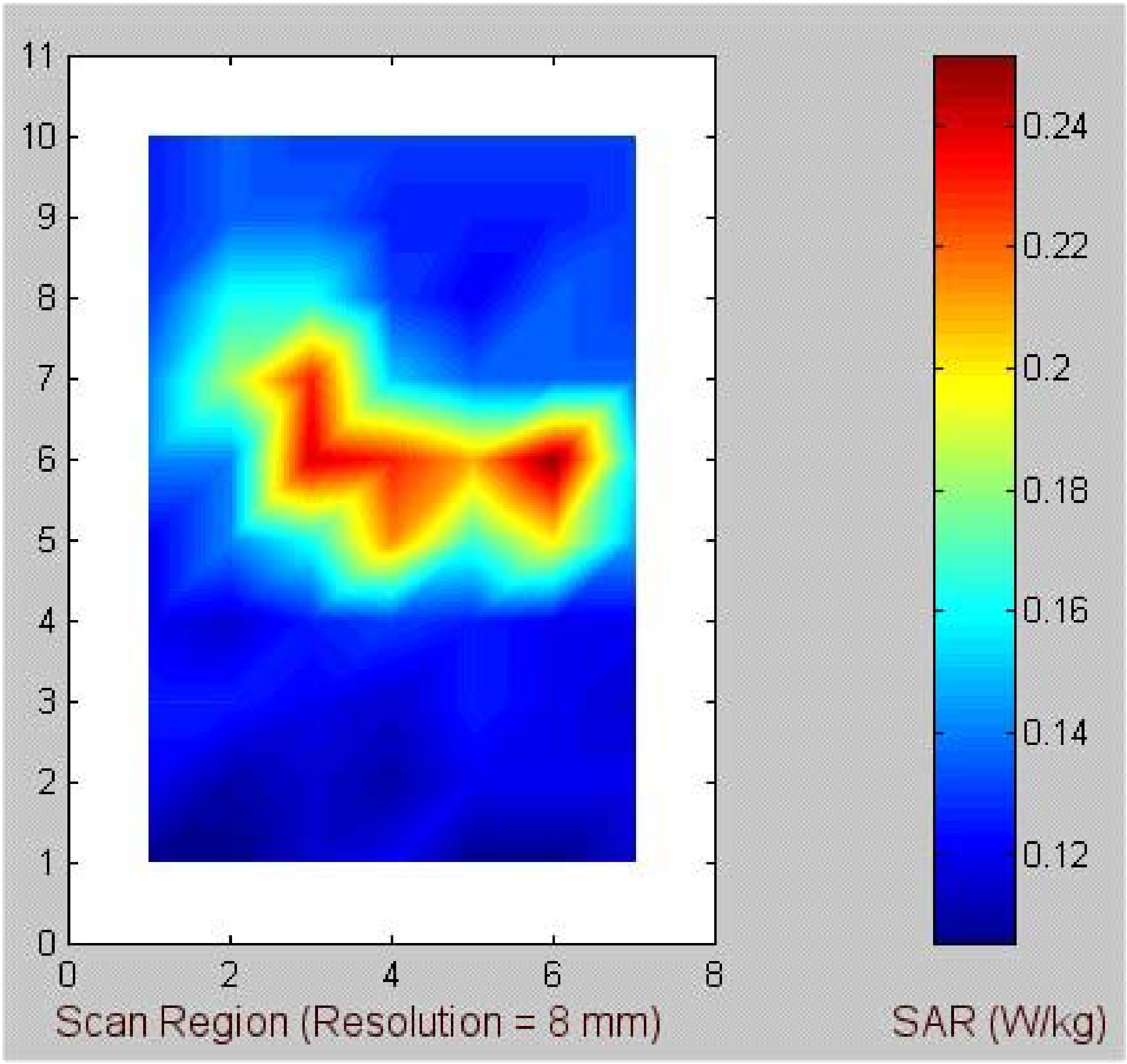
b. 5.26 GHz – antenna perpendicular to the Tablet (see Table 4 for peak 1-g SAR).

Fig. 12. Coarse scans for the SAR measurements for **Configuration 1 – Edge-on position** of the Tablet PC relative to the flat phantom (see Figs. 3a, 3b). This corresponds to the Wireless LAN Antenna of the Tablet PC pressed against the chest or an individual next to the antenna for the Tablet in the armheld position.



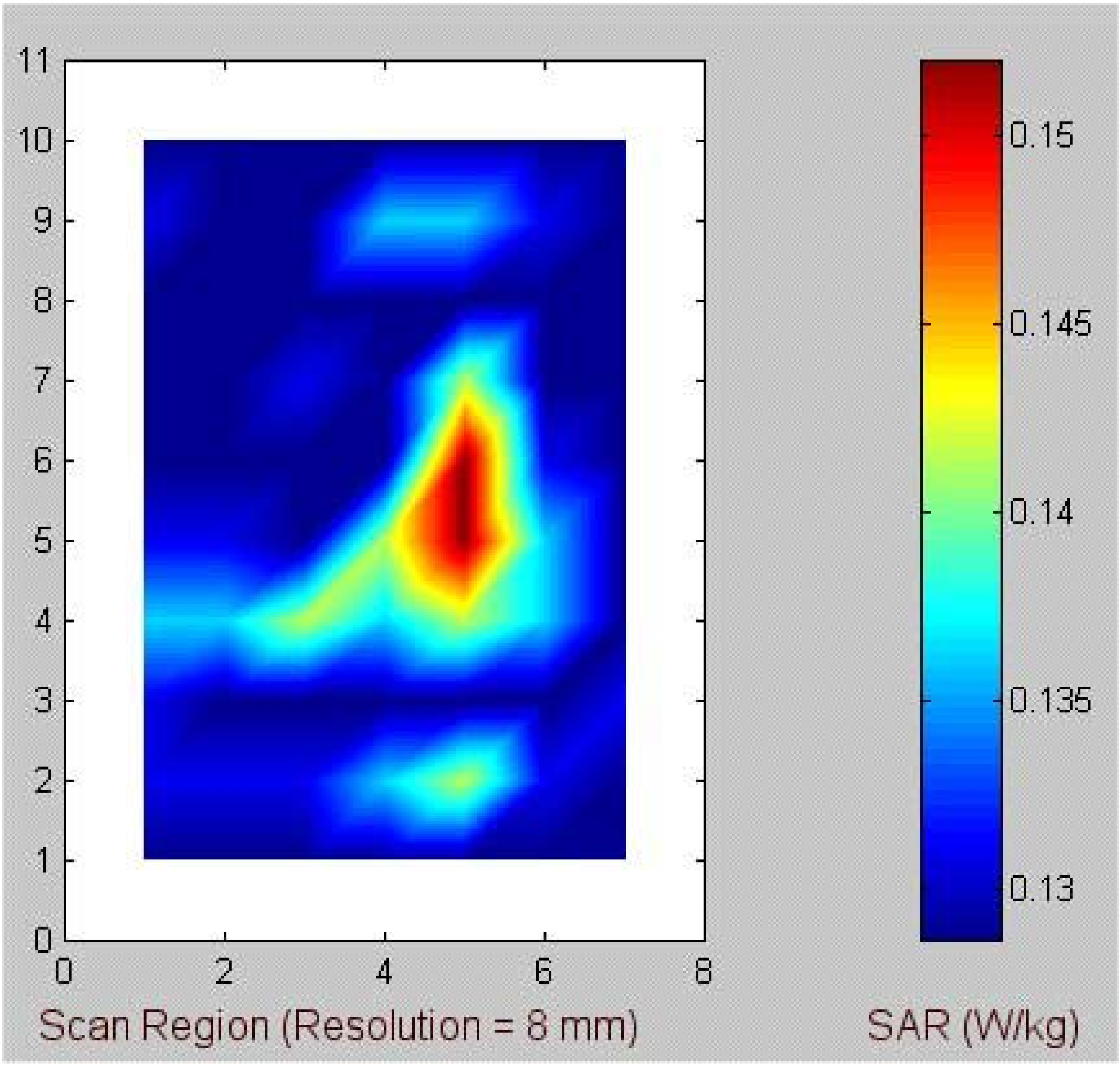
c. 5.745 GHz – antenna parallel to the Tablet (see Table 5 for peak 1-g SAR).

Fig. 12. Coarse scans for the SAR measurements for **Configuration 1 – Edge-on position** of the Tablet PC relative to the flat phantom (see Figs. 3a, 3b). This corresponds to the Wireless LAN Antenna of the Tablet PC pressed against the chest or an individual next to the antenna for the Tablet in the armheld position.



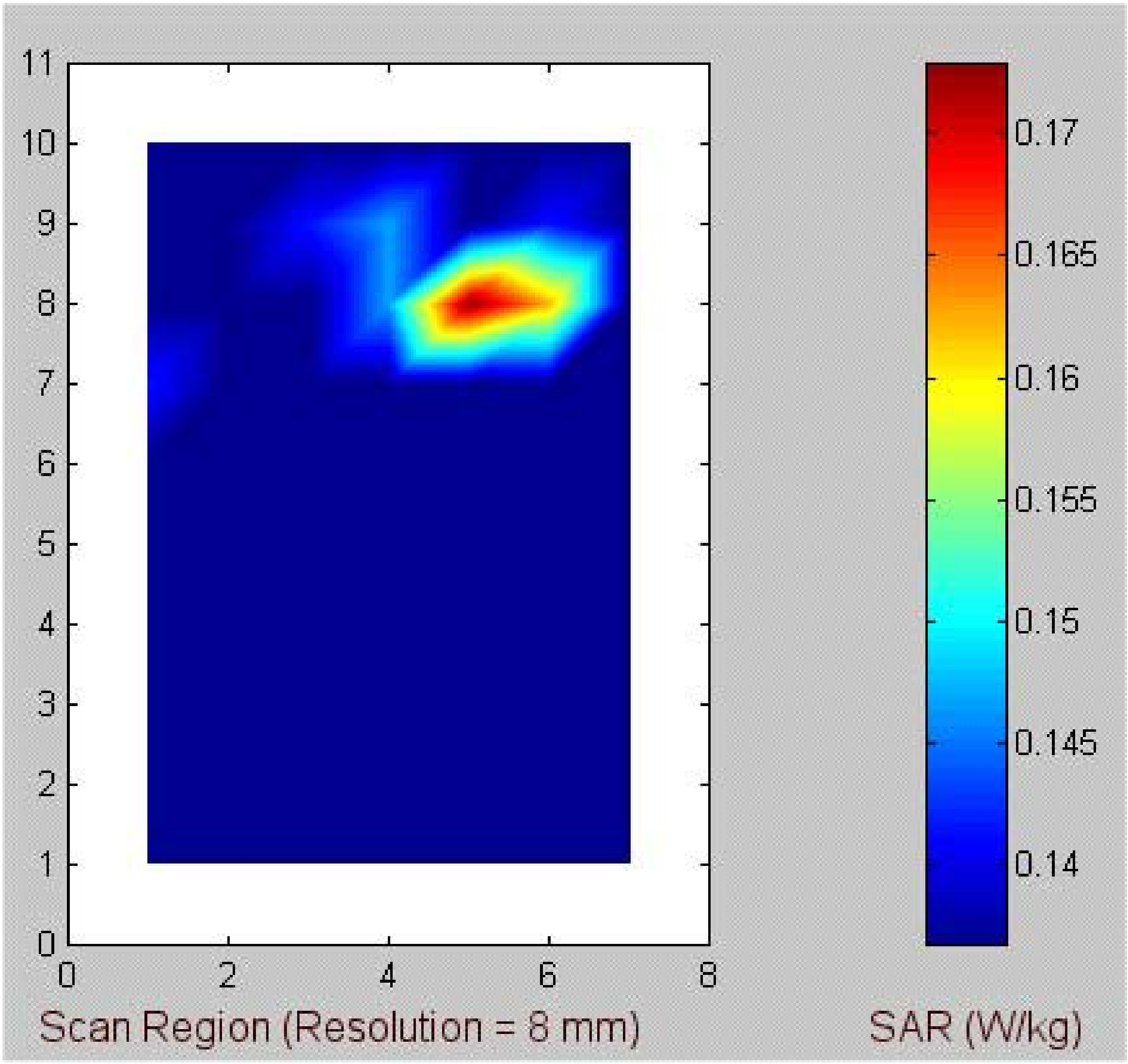
d. 5.745 GHz – antenna perpendicular to the Tablet (see Table 6 for peak 1-g SAR).

Fig. 12. Coarse scans for the SAR measurements for **Configuration 1 – Edge-on position** of the Tablet PC relative to the flat phantom (see Figs. 3a, 3b). This corresponds to the Wireless LAN Antenna of the Tablet PC pressed against the chest or an individual next to the antenna for the Tablet in the armheld position.



a. 5.26 GHz – antenna parallel to the Tablet (see Table 7 for peak 1-g SAR).

Fig. 13. Coarse scans for the SAR measurements for **Configuration 2 – Above lap position** of the Tablet PC relative to the flat phantom (see Figs. 4a, 4b).



b. 5.745 GHz – antenna parallel to the Tablet (see Table 8 for peak 1-g SAR).

Fig. 13. Coarse scans for the SAR measurements for **Configuration 2 – Above lap position** of the Tablet PC relative to the flat phantom (see Figs. 4a, 4b).

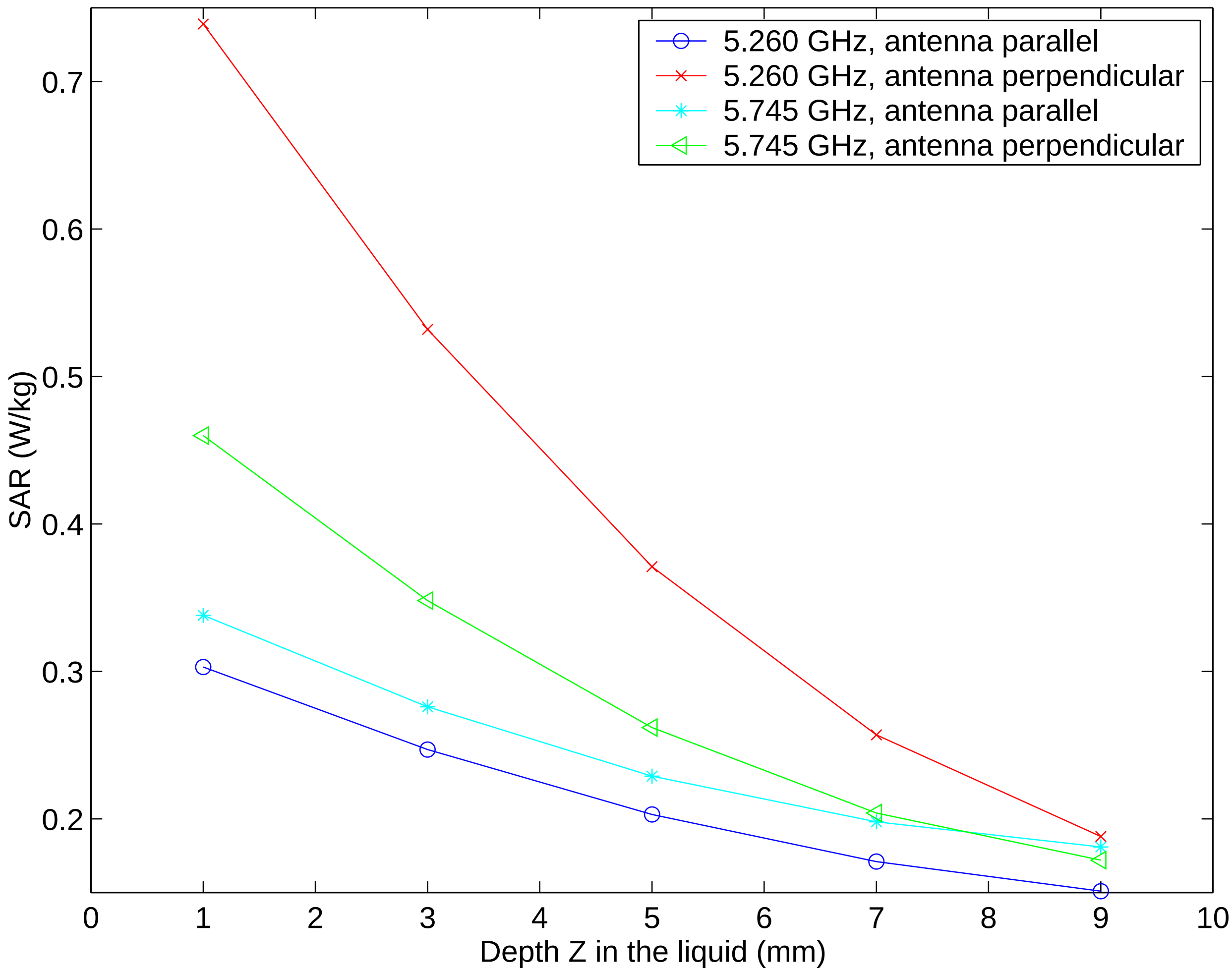


Fig. 14. Plot of the SAR variations as a function of depth Z in the liquid for locations of the highest SAR (from Tables 3-6 for **Configuration 1 – Edge-on position**)

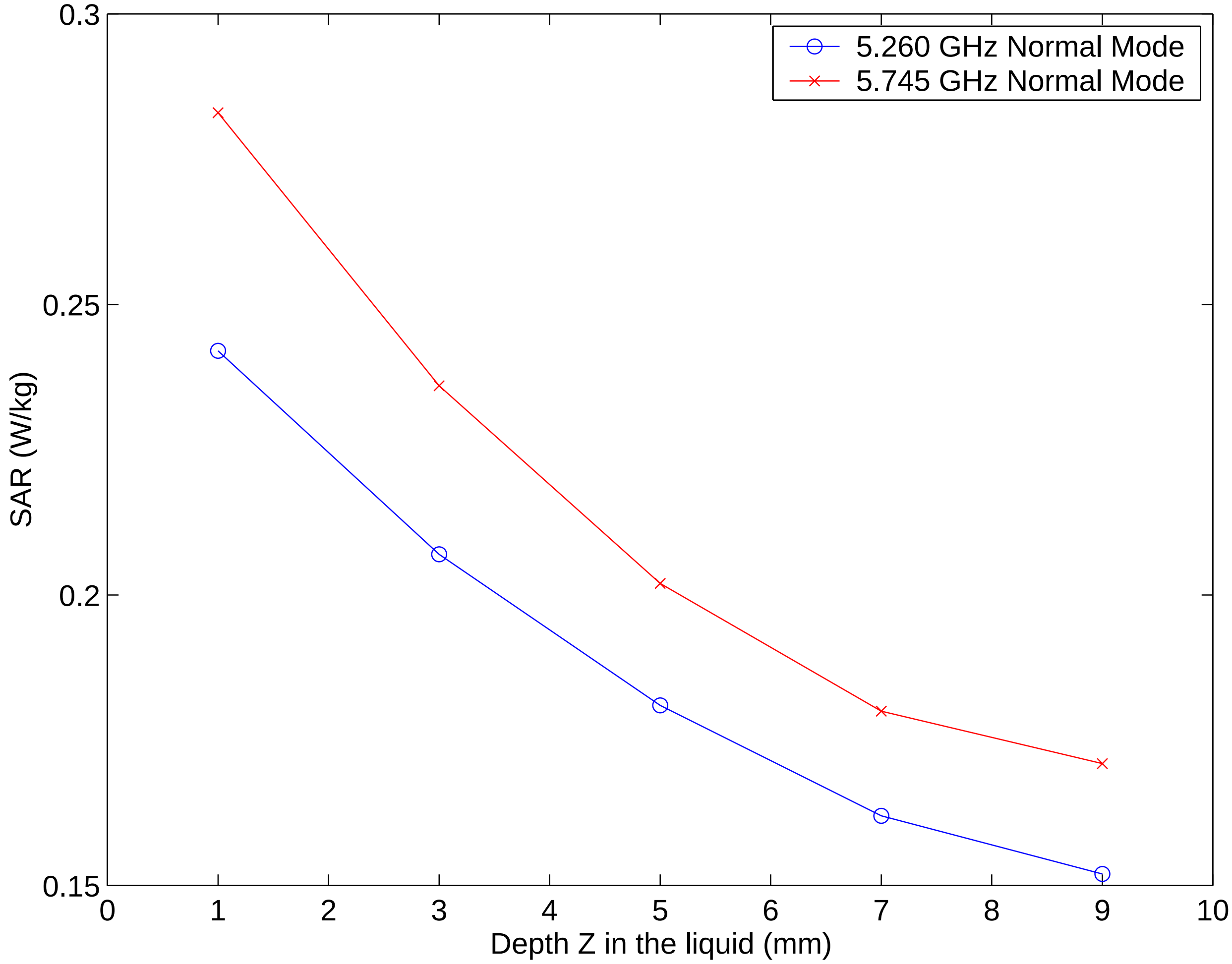


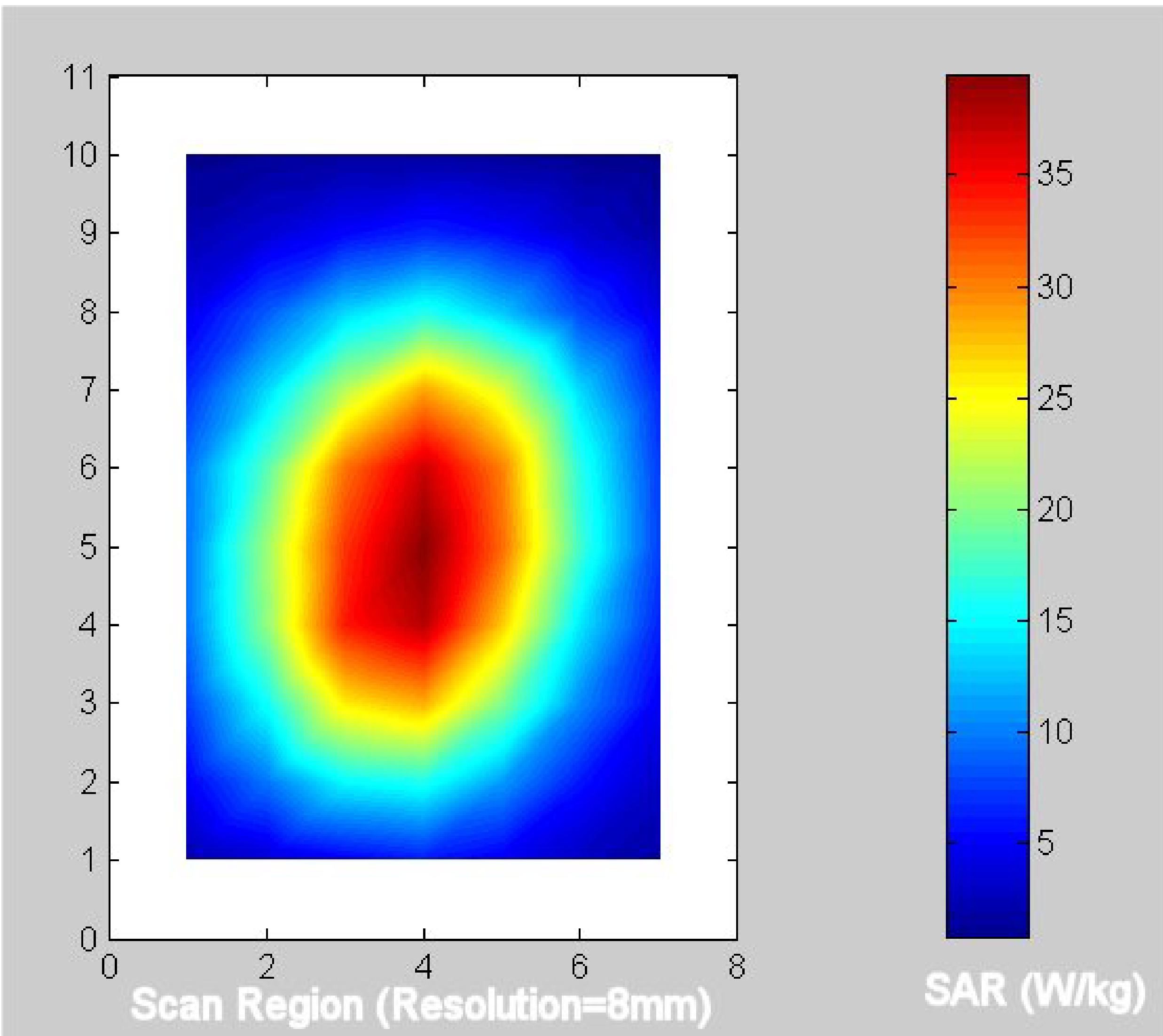
Fig. 15. Plot of the SAR variations as a function of depth Z in the liquid for locations of the highest SAR (from Tables 7, 8 for **Configuration 2 – Above-lap position**). The Wireless LAN Antenna is parallel to the flat phantom.

APPENDIX B

SAR System Verification for March 26, 2003

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

For March 26, 2003 - The dipole SAR Plot



1-g SAR = 36.429 W/kg

a. At depth of 1 mm

53.762	55.836	59.589	59.799	57.057
54.483	57.559	60.777	58.611	58.029
55.664	60.909	61.279	60.588	57.654
53.729	57.063	60.271	62.851	60.032
54.595	58.035	58.456	61.047	57.326

b. At depth of 3 mm

42.335	43.720	45.971	45.961	44.058
42.792	44.951	47.136	45.659	44.766
43.260	46.801	47.574	46.852	45.031
42.424	44.768	46.913	48.267	46.197
42.459	45.108	45.779	46.933	44.942

c. At depth of 5 mm

32.612	33.483	34.626	34.479	33.229
32.906	34.321	35.683	34.753	33.739
32.874	35.106	36.070	35.379	34.366
32.785	34.362	35.666	36.147	34.682
32.304	34.265	35.046	35.206	34.431

d. At depth of 7 mm

24.594	25.125	25.552	25.353	24.569
24.824	25.669	26.420	25.895	24.949
24.505	25.825	26.766	26.169	25.660
24.813	25.845	26.532	26.493	25.488
24.131	25.506	26.259	25.866	25.793

e. At depth of 9 mm

18.279	18.646	18.751	18.583	18.079
18.547	18.994	19.347	19.083	18.397
18.154	18.956	19.662	19.220	18.913
18.506	19.218	19.509	19.305	18.616
17.940	18.831	19.417	18.914	19.029
18.998	19.502	19.648	19.372	18.742

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