SAR COMPLIANCE TESTING OF 3 COM
PALM VII WIRELESS PDA

FINAL TECHNICAL REPORT

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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 recently issued Supplement C (Edition 97-01) to OET Bulletin 65 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 [2].

For 3 Com Palm VII wireless PDA (FCCID # DF63C80500, Confirmation # 93611), we have used the experimental measurement techniques to determine the SAR distributions from which the peak 1-g SARs are obtained for a variety of tilt angles of the antenna (60°, 90°, 135°, and 180°) relative to the base of the palm held PDA (see e.g. Figs. 1a, b where the angles of the antenna relative to the base of the PDA are 180° and 90°, respectively). It was observed that the unit does not radiate much power for angles less than about 60° -- hence a minimum angle of 60° relative to the base of the PDA was used for the SAR measurements. Also, since the PDA is used as a palm-held device, it was decided to use a box phantom of external dimensions 30 × 50 cm filled with a tissue-simulant material to a depth of 15 cm. This box phantom used in the past for the IEEE-SCC 34 suggested FDTD-validation runs is made of acrylic ($\varepsilon_r = 2.56$) of thickness 6.55 mm. In consultation with Mr. Kwok Chan of the FCC, it was decided that this would be an appropriate thickness for the box phantom since a thinner plastic base may not be able to support the weight of the tissue-simulant fluid. A photograph of this tissue-simulant phantom with the Palm VII wireless PDA mounted underneath it is shown in Fig. 2.

II. The 3 Com Palm VII Wireless PDA

The 3 Com Palm VII Wireless PDA (FCCID# DF63C80500) transmits data in the frequency band 896-901 MHz. It is capable of transmitting data as pulses with peak powers as high as 34.4 dBm (2.75 W). However, if such high-power pulses are used with a fairly high duty cycle (which may be as high as 79.6%), the rechargeable NiCad battery used by the PDA does not last more than 70-100 seconds. The output power drops off drastically and the NiCad battery must be recharged with the AA batteries mounted into the PDA -- a process that typically takes about one hour. The manufacturer has determined, however, that the PDA may operate up to 20-30 minutes, the time required for SAR testing, provided a lower duty cycle of about 7 percent rather than the maximum possible 79.6% duty cycle is used.

The two 3 Com Palm VII Wireless PDAs used for SAR testing were programmed so that they could be operated with a duty cycle of 7 percent. Alternatively, these units could also be programmed so that they would operate with a maximum pulsed power output of 23.3 dBm (215 mW) with a 19.7% duty cycle. The second mode of operation was used to simulate the PDA in the e-mail transmit mode where a 6000 byte message may be sent with a duty cycle as high as 36%. It was determined by the engineers at 3 Com that a duty cycle of 36% could not be sustained even at reduced pulsed powers of 23.3 dBm (215 mW) because of the limitation of energy available from the NiCad battery between recharges. The second mode used for SAR testing requiring about 20 minutes used, therefore, peak power pulses of 23.3 dBm (275 mW) and a duty cycle of 19.7%.

It is interesting to compare the time-averaged powers used for the aforementioned two modes of the PDA used for SAR compliance testing. For mode 1 with a peak power of 34.4 dBm (2.75 W) for the pulses and a duty cycle of 7 percent, the time-averaged power is 192.8 mW. For mode 2, on the other hand, with peak pulsed power of 23.3 dBm (215 mW) but with increased duty cycle of 19.7%, the time-averaged power is considerably lower and only 38.3 mW. Since the SARs are proportional to the time-averaged powers, considerably lower SARs are expected and have indeed been observed (see Table 10) for the latter mode as compared to mode 1 with the duty cycle of 7 percent.

III. Need for Using an External dc Supply

It was determined early in the SAR compliance testing that the internal NiCad batteries of the two PDAs supplied for SAR compliance testing would often drop off in voltage in the middle of the SAR tests leading to considerably reduced radiated powers. To obviate this problem, we, therefore, decided to use a 4.5 volt external dc power supply (B. K. Precision Inc., Model 1601) -- hence the black and red leads from this power supply seen in Figs. 1 and 2, respectively.

Even though the PDA may often be used with the antenna in the vertical 90° position shown in Fig. 1b, we decided to determine the SAR distributions for the various tilt angles of 60°, 90°, 135°, and 180° to cover all possible positions of the antenna that may indeed be used by the consumers. As aforementioned, angles lower than about 60° resulted in negligible powers being radiated (as determined by SARs) and were, therefore, not used.

As seen in Section VII, the highest local SARs were measured for the 180° or horizontal configuration of the PDA antenna for the locations of the phantom close to the region of the antenna about 1.5-2.5 cm from its base. Since the Palm VII PDA cross sectional dimensions without the antenna are 13.3×8.1 cm just enough to fit the palm, it may be argued that this region of the antenna (1.5-2.5 cm from its base) would never be very close to the tissues. Recognizing that some individuals may indeed have larger hands, the SARs for this region were measured, nevertheless, in the interest of establishing the worst case exposure conditions.

IV. The Tissue-Simulant Model

Since the PDA is used as a palm-held device, it is necessary to use a relatively flat tissue-equivalent phantom to simulate this region of the body. One such phantom is an acrylic box phantom of external dimensions 30 × 50 cm that has previously been used for IEEE-SCC34 suggested FDTD validation runs. In consultation with Mr. Kwok Chan of FCC, it was decided that it would be appropriate to use this phantom for SAR compliance testing of the PDA. This phantom was filled with a tissue-simulant fluid to a depth of 15 cm which is considerably in excess of the penetration depth of the electromagnetic fields at 900 MHz emanating from the PDA. The tissue-simulant fluid had a composition of 40.4% water, 56.0% sugar, 2.5% salt ($NaC\ell$) and 1.0% HEC. For this composition, we have measured $\varepsilon_r = 41.5 \pm 1.4$ and $\sigma = 1.12 \pm 0.05$ S/m at the PDA frequency of 900 MHz using the HP model 85070 Dielectric Probe in conjunction with HP Model 8720C Network Analyzer (50 MHz - 20 GHz). It is recognized that the human palm has considerable amount of bone with fairly low values for ε_r and σ. To the extent that the fluid used has a fairly high σ, it should help in avoiding underestimating the SARs [2].

The SAR distributions given in Section VII were measured using the University of Utah automated 3-D stepper-motor driven SAR measurement system described in [3].

V. The E-Field Probe

The non-perturbing implantable E-field probe used in the SAR measuring system was originally developed by Bassen et al. [4] and is now manufactured by L3/Narda Microwave Corporation, Hauppauge, New York as Model 8021 E-field probe. In this probe, three orthogonal miniature dipoles are placed on a triangular beam substrate. Each dipole is loaded with a small Schottky diode and connected to the external circuitry by high resistance (2 MΩ ± 40%) leads to reduce secondary pickups. The entire structure is then encapsulated with a low dielectric constant insulating material. The probe thus constructed has a very small (4 mm) diameter, which results in a relatively small perturbation of the internal electric field.

As given in [3], this probe has been tested for the **square law behavior** of dc voltage output that is proportional to the square of the internal electric field ($|E_i|^2$). For the present Narda Model 8021 E-field probe, the departure from the square law behavior at 900 MHz has been measured to be less than ± 3 percent.

Another important characteristic of the probe that affects the measurement accuracy is its isotropy. Since the orientation of the induced electric field is generally unknown, the E-field probe should be relatively isotropic in its response to the orientation of the E-field. Shown in Figs. 3a, 3b are the test results of the E-field probe used in our setup at 840 and 1900 MHz, respectively. The previously described box phantom of dimensions 30 × 15 × 50 cm along x, y and z dimensions, respectively, was also used for these measurements. This phantom was filled to a depth of 15 cm with a tissue-simulant fluid of composition given in Section IV. The E-field probe was rotated around its axis from 0 to 360° in incremental steps of 60°. An isotropy of less than ± 0.23 dB (± 5.5%) was observed for this E-field probe both at 840 and 1900 MHz.

Calibration of the E-Field Probe

Since the voltage output of the E-field probe is proportional to the square of the internal electric field ($|E_i|^2$), the SAR, given by $\sigma|E_i|^2/\rho$ is, therefore, proportional to the voltage output of the E-field probe by a proportionality constant C. The constant C is defined as the calibration factor, and is frequency and material dependent. It is measured to calibrate the probe at the various frequencies of interest using the appropriate tissue-simulating materials for the respective frequencies.

Canonical geometries such as waveguides, rectangular slabs and layered or homogeneous spheres have, in the past, been used for the calibration of the implantable E-field probe [5-7]. Since the Finite Difference Time Domain (FDTD) has been carefully validated to solve electromagnetic problems for a variety of geometries [8, 9], we were able to calibrate the Narda E-field probe by comparing the measured variations of the probe voltage ($\approx |E_i|^2$) against the FDTD-calculated variations of SARs for a box phantom of dimensions 30 × 15 × 50 cm used previously for the data given in Figs. 3a, b, respectively. For these measurements, we placed the nominal half-wave dipoles of lengths

178 mm and 77 mm at 840 and 1900 MHz, respectively, at several distances d (see inserts of Figs. 4a, 4b, and 5a, 5b) from the outer surface of the acrylic (ε_r = 2.56) box of thickness 6.55 mm. Shown in Figs. 4a, 4b and 5a, 5b are the comparisons between the experimentally measured and FDTD-calculated variations of the SAR distributions for this box phantom. Since there are excellent agreements between the calculated SARs and the measured variations of the voltage output of the E-field probe for four different separations d of the half wave dipoles at each of the two frequencies, it is possible to calculate the calibration factors at the respective frequencies. For the Narda Model 8021 E-field probe used in our setup, the calibration factors are determined to be 0.49 and 0.84 (mW/kg)/μV at 840 and 1900 MHz, respectively.

VI. Measurement Uncertainty

The University of Utah automated SAR measuring setup shown in Fig. 2 has been used for the testing of ten personal wireless devices including some research test samples, five each at 835 and 1900 MHz, respectively. Given in Table 1 is the comparison of the numerical and measured peak 1-g SARs for these devices using the human-shaped experimental phantom model described in [3] and the FDTD-based numerical procedure used for calculations of SAR distributions for an anatomically-based model of the head of an adult male. The measured and calculated SARs for the ten telephones which have quite different operational modes (TDMA, CDMA, etc.) and antenna structures (helical, monopole, or helix-monopole) vary from 0.13 to 5.41 W/kg. Even though widely different peak 1-g SARs are obtained because of the variety of antennas and handsets, agreement between the calculated and the measured data is excellent and generally within ± 25%. This is particularly remarkable since an MRI-derived, 16-tissue anatomically-based model of the adult human head is used for FDTD calculations and a relatively simplistic two tissue phantom model is used for experimental peak 1-g SAR measurements.

We estimate the uncertainty of our measuring system to be ± 12.5 percent. As seen in Table 1, an agreement within ± 25 percent is obtained for the peak 1-g SARs calculated using the Utah FDTD Code and the Utah Experimental Phantom Model for ten assorted wireless devices using a variety of antennas and handset dimensions. Since both the numerical and experimental methods are completely independent methods, and each is prone to its own set of errors, an uncertainty of $\pm$ 12.5 percent can be ascribed to each of the methods.

VII. The Measured SAR Distributions for the 3 Com Palm VII PDA

As shown in Fig. 2, the SAR distributions were measured for the 3 Com Palm VII PDA with its base in contact with the underside of the box phantom.

The highest SAR regions for each antenna configurations (180°, 135°, 90°, and 60°) vis à vis the model were determined in the first instance by using coarser sampling with a step size of 8.0 mm over three overlapping scan areas for a total scan area of 8.0×9.6 cm. After identifying the region of the highest SAR for each of the eight cases (four antenna configurations each from the two modes with duty cycles of 7% and 19.7%, respectively), the SAR distributions were measured with a resolution of 2 mm in order to obtain the peak 1 cm^3 or 1-g SAR.

In Tables 2-5 and Tables 6-9, we give the measured SAR distributions for four different configurations of the antenna (180°, 135°, 90%, and 60° relative to the base of the PDA) for the aforementioned modes 1 and 2 of the PDA, respectively. It may be recalled that for mode 1, the PDA is radiating pulses with peak powers as high as 34.4 dBm (2.75 W) but with a duty cycle of 7%. The time-averaged radiated power for mode 1 is estimated to be 192.8 mW. For mode 2, on the other hand, the PDA is radiating pulses with peak powers of 23.3 dBm (215 mW) but with a duty cycle of 19.7%. The time-averaged radiated power for mode 2 is, therefore, considerably lower and only about 38.3 mW.

The peak 1-g SARs measured for four different configurations of the antennas for each of the two modes are summarized in Table 10. Because of the considerably lower time-averaged radiated power used for mode 2, the 1-g SARs for mode 2 are considerably smaller than those for mode 1 for each of the orientations of the antenna.

VIII. Comparison of the Data With FCC 96-326 Guidelines

According to the FCC 96-326 Guidelines [1], the peak SAR for any 1-g of tissues in the body should not exceed 1.6 W/kg except for the extremities such as the hands and the feet, where the SARs for any 10-g of tissues must be less than 4.0 W/kg. From Table 10, we can see that the peak 1-g SARs are fairly small and well within the FCC 96-326 SAR Guidelines. The peak 10-g SARs for the same regions are likely to be even smaller, but have not been measured here. Even for the 180° orientation of the antenna for mode 1, the highest 1-g SAR of 0.947 W/kg occurs for the region of the antenna that is approximately 1.5 - 2.5 cm above its base. This is a region that may often be away from the fingers. Furthermore, the 60-135° configurations of the antenna are more likely to be used for the operators of the PDA and, for these configurations, the peak 1-g SARs are fairly small and generally less than 0.313 W/kg.

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Table 1. Comparison of the experimentally measured and FDTD-calculated peak 1-g SARs for ten wireless telephones, five each at 835 and 1900 MHz, respectively.

	Time-Averaged Radiated Power mW	Using Experimental Model W/kg	Numerical Method W/kg
Cellular Telephones at 835 MHz			
Telephone A	600	4.02	3.90
Telephone B	600	5.41	4.55
Telephone C	600	4.48	3.52
Telephone D	600	3.21	2.80
Telephone E	600	0.54	0.53
PCS Telephones at 1900 MHz			
Telephone A′	125	1.48	1.47
Telephone B′	125	0.13	0.15
Telephone C′	125	0.65	0.81
Telephone D′	125	1.32	1.56
Telephone E′	99.3	1.41	1.25

Table 2. **Antenna orientation of 180° (see Fig. 1a). The SARs measured for the 3 Com Palm VII Wireless PDA for mode 1 using 34.4 dBm (2.75 W) pulses with a 7% duty cycle.** Estimated time-averaged radiated power of 192.8 mW. The SARs in W/kg are measured with a step size of 2 mm for the highest SAR region of the model.

1-g SAR = 0.947 W/kg

a. At depth of 1 mm

0.884	1.134	1.322	1.361	1.345
1.253	1.287	1.352	1.271	1.159
1.367	1.387	1.388	1.561	1.344
1.412	1.502	1.586	1.643	1.596
0.617	0.831	1.067	1.269	1.310

b. At depth of 3 mm

0.879	1.024	1.129	1.147	1.125
1.109	1.132	1.138	1.057	0.954
1.118	1.155	1.166	1.260	1.129
1.160	1.203	1.228	1.225	1.177
0.715	0.851	0.985	1.093	1.108

c. At depth of 5 mm

0.850	0.918	0.962	0.964	0.941
0.963	0.973	0.942	0.871	0.785
0.918	0.962	0.978	1.014	0.947
0.950	0.960	0.944	0.903	0.858
0.765	0.840	0.899	0.940	0.935

d. At depth of 7 mm

0.797	0.815	0.821	0.813	0.792
0.814	0.811	0.765	0.714	0.651
0.766	0.807	0.823	0.822	0.797
0.765	0.798	0.810	0.807	0.792
0.784	0.773	0.736	0.677	0.640

e. At depth of 9 mm

0.721	0.716	0.705	0.694	0.678
0.663	0.646	0.606	0.583	0.553
0.662	0.692	0.703	0.686	0.680
0.663	0.641	0.601	0.546	0.522
0.716	0.726	0.716	0.696	0.678

Table 3. **Antenna orientation of 135°. The SARs measured for the 3 Com Palm VII Wireless PDA for mode 1 using 34.4 dBm (2.75 W) pulses with a 7% duty cycle.** Estimated time-averaged radiated power of 192.8 mW. The SARs in W/kg are measured with a step size of 2 mm for the highest SAR region of the model.

1-g SAR = 0.313 W/kg

a. At depth of 1 mm

0.487	0.560	0.502	0.474	0.477
0.509	0.496	0.511	0.503	0.516
0.504	0.506	0.519	0.253	0.495
0.421	0.350	0.267	0.193	0.489
0.175	0.471	0.557	0.424	0.465

b. At depth of 3 mm

0.402	0.405	0.403	0.387	0.373
0.413	0.398	0.410	0.405	0.405
0.402	0.409	0.417	0.253	0.400
0.343	0.304	0.260	0.223	0.397
0.213	0.389	0.409	0.363	0.384

c. At depth of 5 mm

0.329	0.287	0.321	0.309	0.290
0.334	0.314	0.327	0.324	0.314
0.319	0.329	0.332	0.246	0.322
0.278	0.264	0.249	0.238	0.321
0.235	0.320	0.297	0.309	0.316

d. At depth of 7 mm

0.266	0.208	0.256	0.240	0.228
0.270	0.244	0.261	0.259	0.244
0.257	0.265	0.266	0.231	0.259
0.226	0.229	0.232	0.237	0.260
0.239	0.264	0.218	0.263	0.260

e. At depth of 9 mm

0.216	0.166	0.208	0.181	0.187
0.222	0.189	0.214	0.211	0.195
0.214	0.219	0.217	0.210	0.212
0.187	0.199	0.211	0.221	0.214
0.226	0.221	0.174	0.223	0.217

Table 4. **Antenna orientation of 90° (see Fig. 1b). The SARs measured for the 3 Com Palm VII Wireless PDA for mode 1 using 34.4 dBm (2.75 W) pulses with a 7% duty cycle.** Estimated time-averaged radiated power of 192.8 mW. The SARs in W/kg are measured with a step size of 2 mm for the highest SAR region of the model.

1-g SAR = 0.103 W/kg

a. At depth of 1 mm

0.150	0.154	0.160	0.161	0.147
0.168	0.167	0.162	0.153	0.146
0.168	0.176	0.176	0.171	0.166
0.098	0.096	0.113	0.131	0.134
0.153	0.159	0.152	0.141	0.144

b. At depth of 3 mm

0.122	0.126	0.129	0.128	0.118
0.127	0.130	0.130	0.126	0.121
0.130	0.135	0.136	0.132	0.127
0.088	0.091	0.102	0.112	0.113
0.122	0.129	0.124	0.120	0.117

c. At depth of 5 mm

0.099	0.103	0.103	0.101	0.094
0.096	0.102	0.104	0.103	0.100
0.099	0.103	0.103	0.101	0.096
0.079	0.085	0.091	0.096	0.096
0.096	0.103	0.101	0.100	0.094

d. At depth of 7 mm

0.079	0.083	0.082	0.080	0.076
0.074	0.080	0.084	0.085	0.083
0.077	0.080	0.079	0.078	0.075
0.071	0.078	0.081	0.083	0.082
0.076	0.082	0.081	0.082	0.076

e. At depth of 9 mm

0.064	0.067	0.067	0.065	0.064
0.061	0.067	0.070	0.071	0.071
0.063	0.064	0.064	0.063	0.062
0.065	0.070	0.071	0.072	0.071
0.062	0.065	0.066	0.067	0.063

Table 5. **Antenna orientation of 60°. The SARs measured for the 3 Com Palm VII Wireless PDA for mode 1 using 34.4 dBm (2.75 W) pulses with a 7% duty cycle.** Estimated time-averaged radiated power of 192.8 mW. The SARs in W/kg are measured with a step size of 2 mm for the highest SAR region of the model.

1-g SAR = 0.137 W/kg

a. At depth of 1 mm

0.245	0.250	0.247	0.234	0.219
0.232	0.244	0.247	0.242	0.226
0.222	0.210	0.184	0.145	0.118
0.218	0.238	0.247	0.243	0.219
0.222	0.240	0.242	0.238	0.217

b. At depth of 3 mm

0.178	0.180	0.178	0.172	0.165
0.180	0.187	0.188	0.184	0.173
0.169	0.160	0.146	0.125	0.109
0.170	0.181	0.185	0.184	0.168
0.163	0.172	0.172	0.169	0.157

c. At depth of 5 mm

0.127	0.126	0.125	0.125	0.123
0.139	0.141	0.140	0.137	0.130
0.126	0.121	0.115	0.107	0.100
0.132	0.135	0.136	0.136	0.127
0.118	0.119	0.119	0.117	0.111

d. At depth of 7 mm

0.091	0.090	0.090	0.093	0.093
0.107	0.107	0.105	0.103	0.098
0.094	0.092	0.092	0.092	0.091
0.102	0.101	0.100	0.100	0.095
0.086	0.083	0.082	0.082	0.080

e. At depth of 9 mm

0.071	0.070	0.070	0.074	0.075
0.085	0.084	0.081	0.080	0.078
0.073	0.073	0.076	0.079	0.081
0.081	0.079	0.077	0.077	0.074
0.067	0.063	0.063	0.063	0.064

Table 6. **Antenna orientation of 180° (see Fig. 1a). The SARs measured for the 3 Com Palm VII Wireless PDA for mode 2 using 23.3 dBm (0.215 W) pulses with a 19.7% duty cycle.** Estimated time-averaged radiated power of 38.3 mW. The SARs in W/kg are measured with a step size of 2 mm for the highest SAR region of the model.

1-g SAR = 0.227 W/kg

a. At depth of 1 mm

0.305	0.314	0.286	0.270	0.244
0.329	0.299	0.251	0.251	0.237
0.227	0.252	0.321	0.257	0.227
0.297	0.290	0.285	0.284	0.260
0.298	0.294	0.269	0.322	0.292

b. At depth of 3 mm

0.267	0.283	0.255	0.246	0.231
0.281	0.256	0.220	0.221	0.213
0.217	0.235	0.262	0.215	0.218
0.263	0.274	0.260	0.252	0.236
0.261	0.260	0.248	0.285	0.255

c. At depth of 5 mm

0.237	0.255	0.229	0.224	0.218
0.244	0.220	0.194	0.196	0.192
0.205	0.218	0.214	0.1831	0.209
0.234	0.257	0.237	0.224	0.215
0.230	0.232	0.231	0.252	0.225

d. At depth of 7 mm

0.214	0.231	0.206	0.204	0.205
0.215	0.191	0.174	0.176	0.175
0.193	0.201	0.176	0.162	0.200
0.212	0.237	0.216	0.201	0.197
0.205	0.209	0.217	0.223	0.204

e. At depth of 9 mm

0.198	0.210	0.187	0.186	0.193
0.196	0.169	0.160	0.160	0.160
0.178	0.185	0.148	0.150	0.191
0.197	0.216	0.196	0.183	0.183
0.185	0.193	0.206	0.198	0.191

Table 7. **Antenna orientation of 135°. The SARs measured for the 3 Com Palm VII Wireless PDA for mode 2 using 23.3 dBm (0.215 W) pulses with a 19.7% duty cycle.** Estimated time-averaged radiated power of 38.3 mW. The SARs in W/kg are measured with a step size of 2 mm for the highest SAR region of the model.

1-g SAR = 0.053 W/kg

a. At depth of 1 mm

0.096	0.093	0.083	0.075	0.067
0.091	0.086	0.080	0.073	0.066
0.080	0.083	0.077	0.072	0.066
0.078	0.076	0.071	0.068	0.063
0.070	0.068	0.068	0.066	0.061

b. At depth of 3 mm

0.073	0.072	0.066	0.062	0.057
0.071	0.068	0.065	0.061	0.057
0.064	0.066	0.063	0.060	0.056
0.063	0.062	0.060	0.057	0.055
0.058	0.057	0.057	0.056	0.053

c. At depth of 5 mm

0.055	0.055	0.053	0.052	0.049
0.054	0.054	0.053	0.051	0.049
0.051	0.053	0.051	0.050	0.048
0.051	0.050	0.050	0.049	0.047
0.048	0.049	0.049	0.048	0.047

d. At depth of 7 mm

0.042	0.043	0.043	0.043	0.042
0.042	0.043	0.043	0.043	0.042
0.042	0.043	0.043	0.042	0.042
0.041	0.042	0.042	0.042	0.041
0.040	0.042	0.042	0.042	0.041

e. At depth of 9 mm

0.034	0.035	0.036	0.037	0.036
0.035	0.035	0.037	0.037	0.037
0.035	0.036	0.037	0.037	0.037
0.035	0.036	0.037	0.036	0.037
0.035	0.036	0.036	0.037	0.037

Table 8. **Antenna orientation of 90°** (see **Fig. 1b). The SARs measured for the 3 Com Palm VII Wireless PDA for mode 2 using 23.3 dBm (0.215 W) pulses with a 19.7% duty cycle.** Estimated time-averaged radiated power of 38.3 mW. The SARs in W/kg are measured with a step size of 2 mm for the highest SAR region of the model.

1-g SAR = 0.054 W/kg

a. At depth of 1 mm

0.079	0.090	0.096	0.090	0.086
0.082	0.092	0.099	0.099	0.091
0.085	0.096	0.102	0.102	0.093
0.080	0.091	0.097	0.096	0.092
0.076	0.084	0.088	0.089	0.085

b. At depth of 3 mm

0.060	0.067	0.070	0.068	0.065
0.062	0.069	0.072	0.073	0.068
0.063	0.070	0.074	0.074	0.069
0.060	0.068	0.071	0.071	0.069
0.058	0.063	0.066	0.066	0.065

c. At depth of 5 mm

0.046	0.049	0.051	0.050	0.049
0.047	0.050	0.052	0.052	0.051
0.046	0.051	0.052	0.053	0.051
0.045	0.049	0.051	0.051	0.050
0.044	0.046	0.049	0.049	0.048

d. At depth of 7 mm

0.035	0.036	0.037	0.038	0.038
0.035	0.037	0.037	0.037	0.038
0.035	0.036	0.037	0.038	0.038
0.034	0.036	0.037	0.037	0.037
0.033	0.035	0.036	0.036	0.036

e. At depth of 9 mm

0.028	0.029	0.029	0.030	0.030
0.028	0.029	0.029	0.029	0.030
0.028	0.028	0.028	0.029	0.030
0.027	0.028	0.028	0.029	0.029
0.027	0.028	0.029	0.028	0.029

Table 9. **Antenna orientation of 60°. The SARs measured for the 3 Com Palm VII Wireless PDA for mode 2 using 23.3 dBm (0.215 W) pulses with a 19.7% duty cycle.** Estimated time-averaged radiated power of 38.3 mW. The SARs in W/kg are measured with a step size of 2 mm for the highest SAR region of the model.

1-g SAR = 0.047 W/kg

a. At depth of 1 mm

0.062	0.067	0.068	0.068	0.064
0.071	0.074	0.073	0.070	0.069
0.072	0.073	0.075	0.072	0.069
0.073	0.075	0.078	0.071	0.069
0.072	0.074	0.073	0.071	0.068

b. At depth of 3 mm

0.049	0.053	0.054	0.055	0.053
0.054	0.057	0.057	0.056	0.056
0.055	0.057	0.058	0.058	0.056
0.056	0.058	0.060	0.057	0.056
0.055	0.057	0.057	0.057	0.055

c. At depth of 5 mm

0.040	0.042	0.044	0.045	0.045
0.041	0.043	0.045	0.045	0.046
0.042	0.044	0.045	0.046	0.046
0.042	0.044	0.046	0.046	0.046
0.042	0.043	0.044	0.045	0.045

d. At depth of 7 mm

0.032	0.034	0.036	0.037	0.038
0.032	0.034	0.035	0.037	0.038
0.033	0.035	0.036	0.037	0.037
0.032	0.034	0.035	0.037	0.038
0.032	0.033	0.035	0.036	0.037

e. At depth of 9 mm

0.028	0.029	0.030	0.031	0.032
0.026	0.028	0.029	0.031	0.032
0.027	0.029	0.030	0.031	0.032
0.026	0.028	0.029	0.032	0.032
0.026	0.027	0.029	0.030	0.031

Table 10. Summary of the measured peak 1-g SARs for the 3-Com Palm VII Wireless PDA

	Antenna Tilt Angle	Table	Peak 1-g SAR W/kg
Mode 1 34.4 dBm pulses, 7% duty cycle, $\overline{P}_{rad}$ = 192.8 mW	180°	2	0.947
	135°	3	0.313
	90°	4	0.103
	60°	5	0.137
Mode 2 23.3 dBm pulses, 19.7% duty cycle, $\overline{P}_{rad}$ = 38.3 mW	180°	6	0.227
	135°	7	0.053
	90°	8	0.054
	60°	9	0.047

(a)

(b)

Fig. 1. Photograph of the 3 Com Palm VII Wireless PDA with two representative orientations of the antenna:

a. Antenna at an angle of 180° relative to the base of the PDA.
b. Antenna vertical at an angle of 90° relative to the base of the PDA.

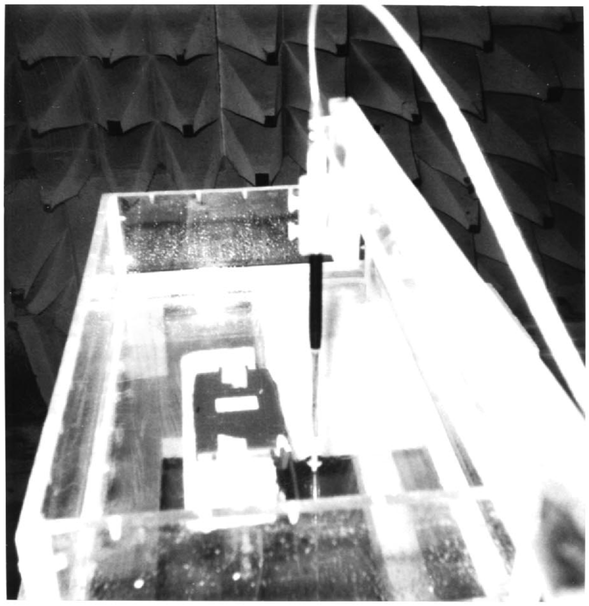

Fig. 2. The phantom model used for determination of the SARs due to the 3 Com Palm VII Wireless PDA. The model is filled with a tissue-simulant fluid to measure the SAR distributions for the various orientations of the PDA antenna.

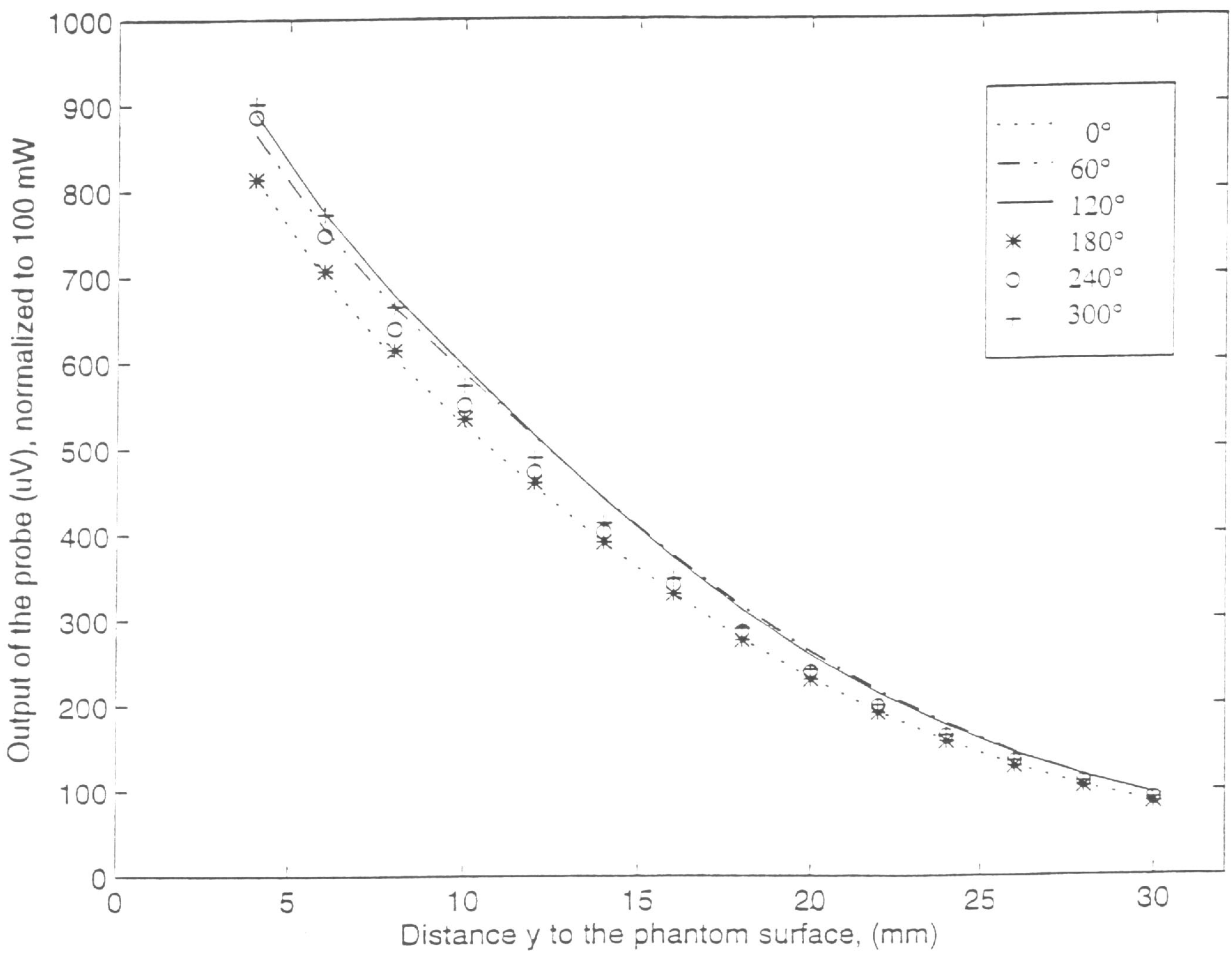

Fig. 3a. Test for isotropy: The model shown in Fig. 2 was used with nominal half wavelength dipole radiator of length 178 mm at 840 MHz.

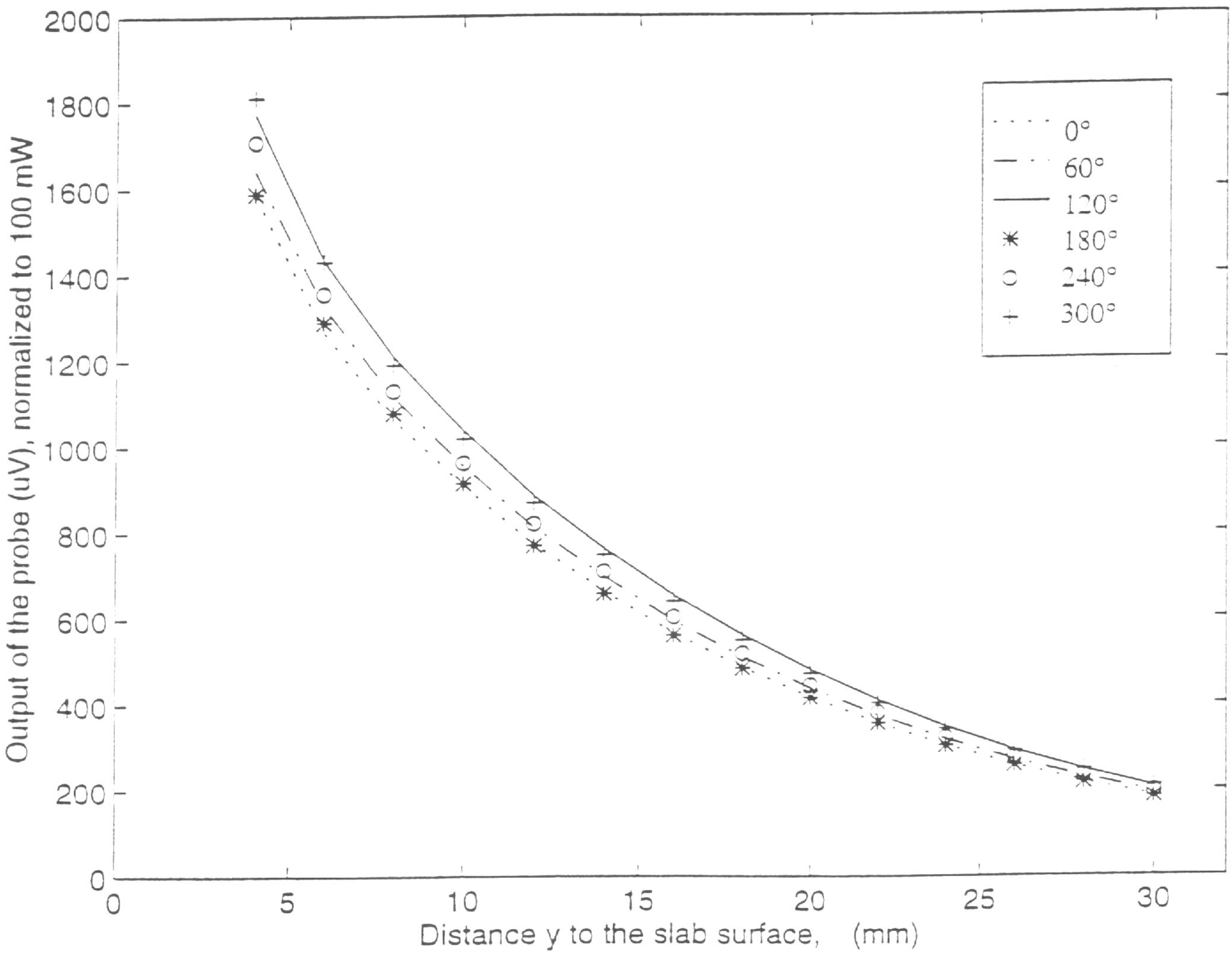

Fig. 3b. Test for isotropy: The model shown in Fig. 2 was used with nominal half wavelength dipole radiator of length 77 mm at 1900 MHz.

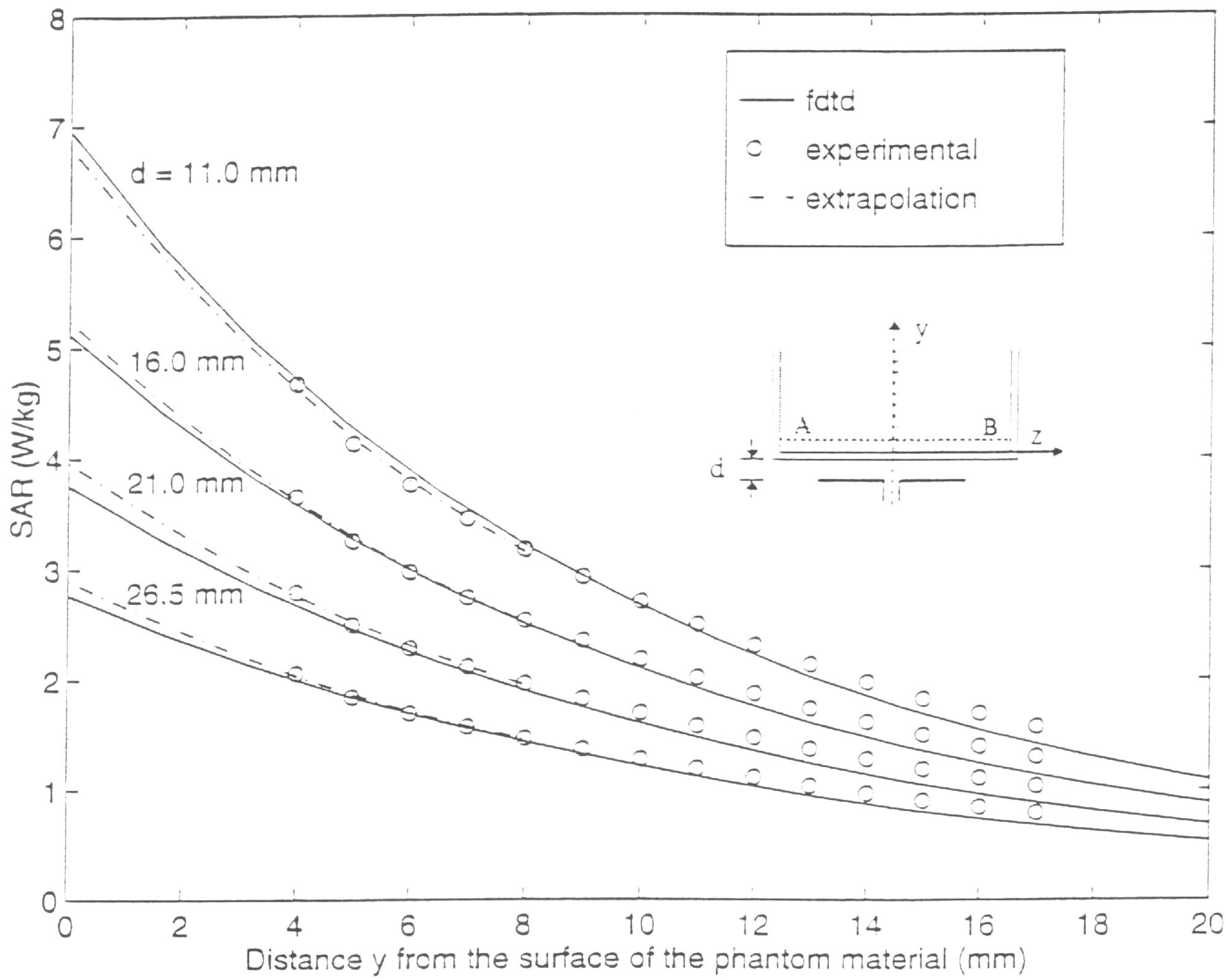

Fig. 4a. Comparison of the calculated and measured SAR variations for a box phantom of dimensions 30 × 15 × 50 cm; 840 MHz; $\lambda/2$ dipole antenna; 0.5 W radiated power. Calibration factor for the Narda Model 8021 probe at 840 MHz = 0.49 (mW/kg)/µV. Measured for the phantom material ε_r = 41.1, σ = 1.06 S/m.

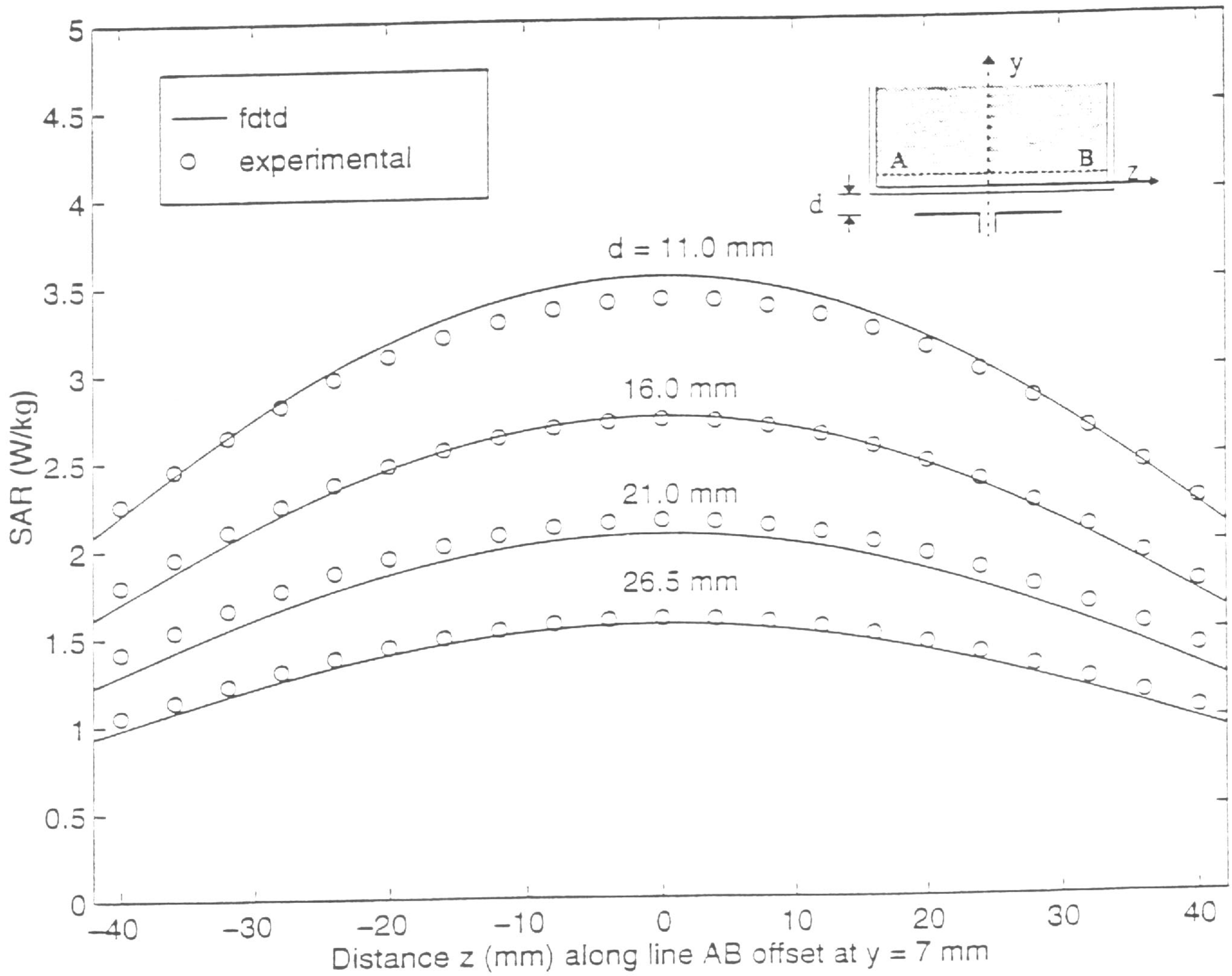

Fig. 4b. Comparison of the calculated and measured SAR variations for a box phantom of dimensions 30 × 15 × 50 cm for a line AB parallel to the z axis at a distance y = 7 mm from the surface of the phantom material; 840 MHz; λ/2 dipole antenna; 0.5 W radiated power. Calibration factor for the Narda Model 8021 probe at 840 MHz = 0.49 (mW/kg)/μV. Measured for the phantom material ε_r = 41.1, σ = 1.06 S/m.

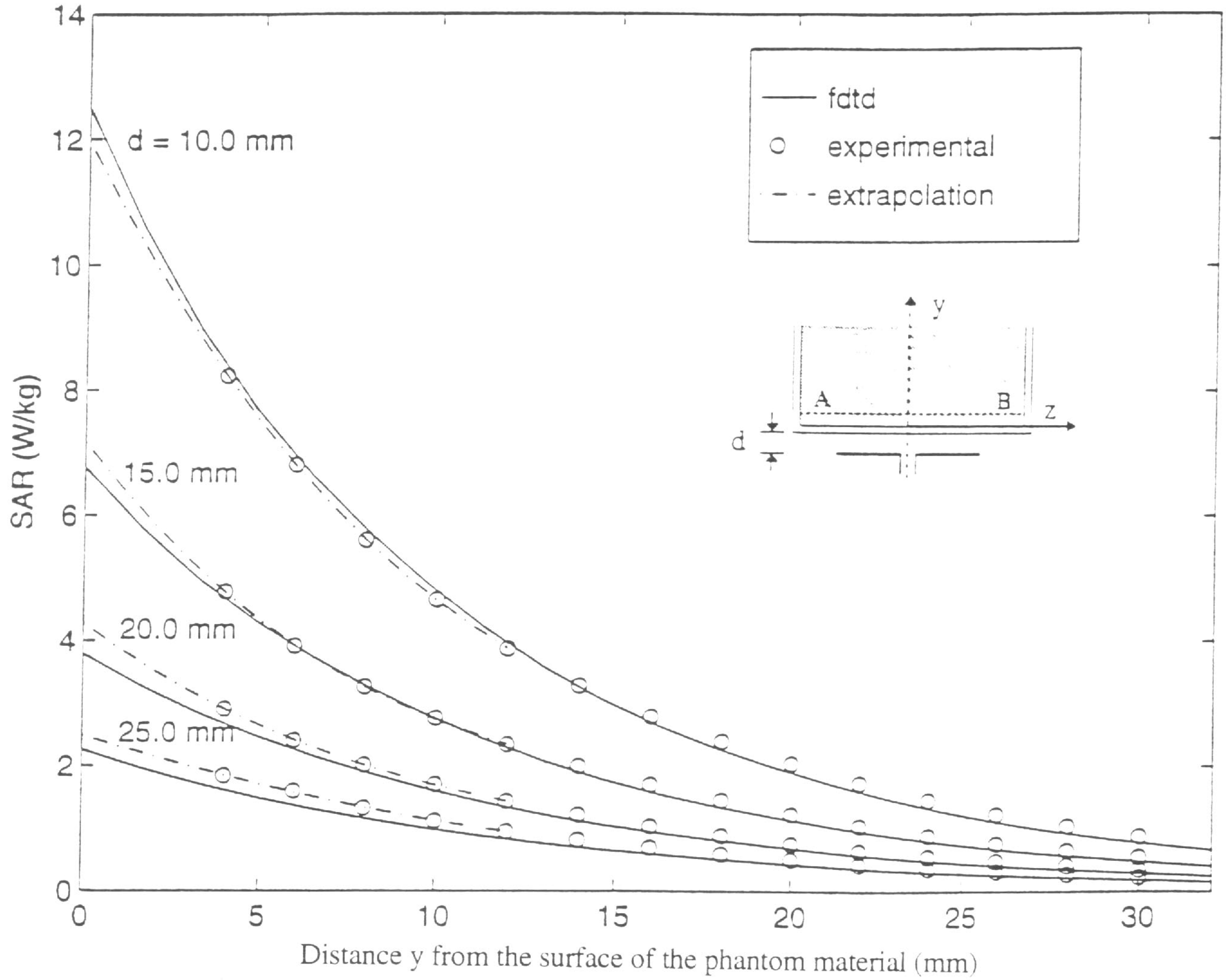

Fig. 5a. Comparison of the calculated and measured SAR variations for a box phantom of dimensions 30 × 15 × 50 cm; 1900 MHz; $\lambda/2$ dipole antenna; 0.5 W radiated power. Calibration factor for the Narda Model 8021 probe at 1900 MHz = 0.84 (mW/kg)/μV. Measured for the phantom material $\varepsilon_r = 45.5$, $\sigma = 1.31$ S/m.

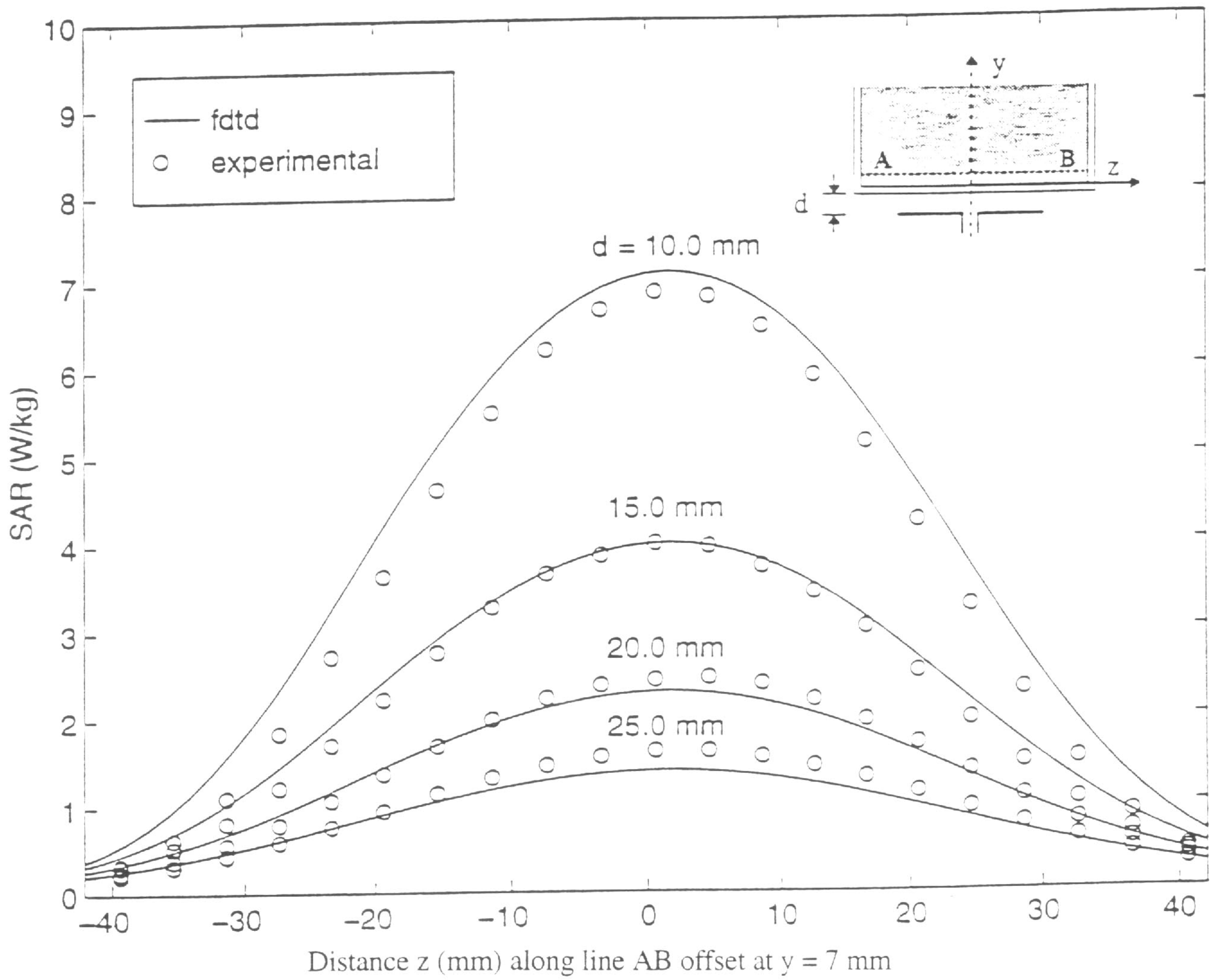

Fig. 5b. Comparison of the calculated and measured SAR variations for a box phantom of dimensions 30 × 15 × 50 cm for a line AB parallel to the z axis at a distance y = 7 mm from the surface of the phantom material; 1900 MHz; λ/2 dipole antenna; 0.5 W radiated power. Calibration factor for the Narda Model 8021 probe at 1900 MHz = 0.84 (mW/kg)/μV. Measured for the phantom material ε_r = 45.5, σ = 1.31 S/m.