SAR COMPLIANCE TESTING OF UNIDEN MINI 200

PORTABLE CELLULAR TELEPHONE

FCC ID: AMWUH Ø45

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FINAL TECHNICAL REPORT

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Submitted to:

Mr. Joseph W. Jackson
Communication Certification Laboratory
1940 West Alexander Street
West Valley City, Utah 84119

Submitted by:

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

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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 Uniden Mini 200 Portable Cellular Telephone (FCC ID# AMWUH045), we have used the experimental measurement techniques to determine the SAR distributions from which the peak 1-g SARs are obtained, as recommended in [2], both when the antenna is fully extended (completely pulled out) or left retracted. Also as recommended in [2], the telephone is placed against the right ear with the antenna located towards the front of the head. This allows a longer portion of the antenna to be in close proximity to the head resulting in higher SARs allowing thereby the worst case determination of absorbed energy in the user's head [3]. Also as recommended in [2], the handset is tested without the model of a hand to determine once again the worst case SAR distribution.

II. The Uniden Mini 200 Portable Cellular Telephone

The Uniden Mini 200 Portable Cellular Telephone is an AMPS telephone that works in the frequency band 825-849 MHz for transmission frequencies (Channels 001-799). In the test mode, an internal attenuator can be adjusted for settings 0, 1, 2 ··· 7 with the power output being maximum for setting 0 and minimum for setting 7 of the attenuator.

We have measured the power fed to the antenna by using a coaxial cable which is connected to an output port at the base of the retractable whip antenna. The power output of the Uniden Mini 200 Portable Cellular Telephone was measured at the midband frequency of approximately 835 MHz (Channel 333) for internal attenuator settings 0, 1, 2, ··· 7 by using Hewlett Packard (HP) Model 436A Power Meter with HP Model 8481 Power Sensor. Given in Table 1 is the measured variation of power output of this cellular telephone for the various attenuator settings. As expected, the maximum power (300 mW) is measured for power level (attenuator) setting 0. Interestingly, the power output is also identical for settings 1 and 2 of the attenuator, but diminishes rapidly thereafter to a considerably lower power of 3.8 mW only at the attenuator setting 7.

Having ascertained that the maximum power is obtained for the power level (attenuator) setting 0, we measured the output power and frequencies for several transmission channels selected at the low end, the midband and the high end of the transmission band 825-849 MHz. The data thus measured is given in Table 2. For the data given in Tables 1 and 2, the frequencies were measured using the EIP Model 578 Source-Locking Microwave Counter. Since the power output was maximum at the low to midband frequencies, all of the SAR measurements were, therefore, done for the cellular telephone set to the maximum radiated power level setting of 0 at a midband frequency of 835 MHz (Channel 333). As seen from Table 1, this corresponds to a radiated power of 300 mW.

III. The Tissue-Simulant Model

For measurements of SAR distributions, we have used the Utah Experimental Model that is described in detail in Appendix A [4]. This model uses a lossy outer shell of the following approximate dimensions:

Axial length from chin to top of the head = 26 cm
Distance from location of the ear canal to top of the head = 14.7 cm
Width from side to side = 16.5 cm

These dimensions are typical for adult human beings. The shell thickness of the head and neck model is approximately 4-7 mm, which is typical of the human skull thickness. The thickness for the ear region is, however, considerably less and is only about 3 mm.

This experimental model shown in Fig. 1 has, in the past, been used for comparison of the measured peak 1-g SARs with those obtained with the Utah FDTD Code for ten wireless telephones, five at 835 MHz and five for PCS (1900 MHz) frequencies [see Table 6 of Appendix A]. The numerical SARs were obtained using the anatomically-based, 15-tissue Utah model of the head and neck with a resolution of $1.974 \times 1.974 \times 3.0$ mm that has been described in the scientific literature through numerous publications (see e.g. references 3, 5). The measured and calculated 1-g SARs for these ten telephones, including some research test samples from diverse manufacturers using a variety of radiating antennas for different source-based time-averaged powers are compared in Table 3 (taken from Table 6 of Appendix A). Even though widely different peak 1-g SARs from 0.13 to 5.41 W/kg are obtained because of the variety of antennas and handsets, agreement between the calculated and the measured data is excellent and generally within $\pm$ 25 percent.

These tests validate the Utah Experimental Phantom Model as being capable of giving peak 1-g SARs that are in good agreement with the SARs obtained with the realistic, anatomically-based model of the human head and neck both at 835 and 1900 MHz.

The head and neck and the upper part of the torso of the model are filled with a liquid with measured electrical properties (dielectric constant and conductivity) close to the average properties of the brain for white and gray matters at 835 MHz which is close to the midband transmission frequency for this telephone. A composition suggested by Hartsgrove et al. [6] consists of 40.4% water, 56.0% sugar, 2.5 percent salt ($NaC\ell$) and 1.0% HEC. As measured in our laboratory using the HP Model 85070B Dielectric Probe in conjunction with HP Model 8720C Network Analyzer (50 MHz-20 GHz), this composition gives a measured $\varepsilon_r = 41.1 \pm 1.4$ and $\sigma = 1.06 \pm 0.05$ S/m. From reference 7, we obtained the desired dielectric properties to simulate the brain tissue at 835 MHz to be $\varepsilon_r = 45.3$ and $\sigma = 0.92$ S/m. Thus the measured properties for the brain-simulant fluid used for experimental SAR measurements are close to the desired values. To the extent that the conductivity σ is slightly higher and the permittivity ε_r is somewhat lower than the desired values for the brain tissue, it should help in avoiding underestimating the SAR [2].

IV. The E-Field Probe

The non-perturbing implantable E-field probe used in the setup was originally developed by Bassen et al. [8] 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.

Test for Square Law Region

It is necessary to operate the E-field probe in the square law region for each of the diodes so that the sum of the dc voltage outputs from the three dipoles is proportional to the square of the internal electric field ($|E_i|^2$). Fortunately, the personal wireless devices induce SARs that are generally less than 5-6 W/kg even for closest locations of the head [3]. For compliance testing, it is, therefore, necessary that the E-field probe be checked for square law behavior for SARs up to such values that are likely to be encountered. Such a test may be conducted using a canonical lossy body such as a rectangular box or a sphere irradiated by a dipole. By varying the radiated power of the dipole, the output of the probe should increase linearly with the applied power for each of the test locations.

Shown in Figs. 2a, 2b are the results of the tests performed to check the square law behavior of the E-field probe used in our setup at 840 and 1900 MHz, respectively. For these measurements, we have used a rectangular box of dimensions 30 × 15 × 50 cm that was irradiated by the corresponding half wave dipoles with different amounts of radiated powers from 200-800 mW. Since the dc voltage outputs of the probe are fairly similar when normalized to a radiated power of 100 mW, the square law behavior is demonstrated and an output voltage that is proportional to $|E_i|^2$ is obtained within ± 3 percent.

Test for Isotropy of the Probe

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 brain-simulant materials (Table 4). 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 [9-11]. Since the Finite Difference Time Domain (FDTD) has been carefully validated to solve electromagnetic problems for a variety of geometries [12, 13], 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. 2 and 3, 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.

V. Experimental Results: Canonical Problems

To further validate the system, it has been used to measure the peak 1-g SAR for the above-mentioned box phantom and a glass sphere model of thickness 5 mm, external diameter = 223 mm and assumed dielectric constant ε_r = 4.0. This sphere model is once again filled with the corresponding brain-simulant fluids of compositions given in Table 4. Shown in Figs. 6a, 6b and 7a, 7b are the measured and FDTD-calculated SAR distributions inside the sphere for various separations d between the dipole and the sphere (see insert for Figs. 6, 7). Comparison of the measured and FDTD-calculated peak 1-g SARs for both phantom geometries are given in Tables 5 and 6, respectively. As can be seen, the agreement between experimental measurement and numerical simulation is excellent and generally within ± 10 percent for both rectangular and spherical phantoms.

VI. Measurement Uncertainty: Test Runs With Cellular Telephones

The automated setup shown in Fig. 2 of Appendix A has been used for the testing of ten commercial personal wireless devices five each at 835 and 1900 MHz, respectively. Given in Table 3 is the comparison of the numerical and measured peak 1-g SARs for these devices using our experimental phantom model and the FDTD-based numerical procedure used for calculations of SAR distributions for an anatomically-based model of the head of an adult male [4]. 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 3, 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 ± 12.5 percent can be ascribed to each of the methods.

VII. The Measured SAR Distributions for Uniden Mini 200 Telephone

As suggested in Supplement C (Edition 97-01) to the FCC OET Bulletin 65 [2], the SAR measurements are conducted with the Uniden Mini 200 Portable Cellular Telephone pressed against the model of the head such that the center of the ear piece is aligned against the location of the ear canal. Furthermore, the handset is oriented such that the center line of the body of the handset is in the plane passing through the two ear canals and the tip of the mouth.

For two possible configurations of the antenna i.e. completely pulled out or left retracted, respectively, the regions of the maximum SARs were located in the first instance by searching coarser regions of dimensions 4.8 $\times$ 8.0 cm close to the antenna and the central region of the handset where it is in contact with the cheek. For this cellular telephone, the highest SARs were measured for the upper region of the ear that is close to the base of the antenna.

After having identified the regions of the highest SARs for both configurations of the antenna, these regions were measured with a finer resolution of 2.0 mm with the Uniden Cellular Telephone radiating maximum power (300 mW) at a midband frequency of 835 MHz (Channel 333). We summarize in Tables 7 and 8 the detailed SAR distributions that have been measured for the highest SAR region of the head for Uniden Mini 200 Portable Cellular Telephone. From these measurements, the peak 1-g SARs are calculated to be 1.02 and 0.84 W/kg for antenna pulled out or left retracted, respectively.

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 tissue should not exceed 1.6 W/kg. We have determined the peak 1-g SARs to be 1.02 and 0.84 W/kg for the Uniden Mini 200 Portable Cellular Telephone for antenna pulled out or left retracted, respectively. Both of these values are lower than 1.6 W/kg suggested in the FCC 96-326 Guidelines [1].

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Table 1. The measured power output of the Uniden Mini 200 Portable Cellular Telephone for Channel 333 (834.988 MHz) for different settings of the internal attenuator.

Attenuator Setting	Power (mW)
0	300.0
1	300.0
2	300.0
3	146.0
4	58.7
5	23.2
6	9.1
7	3.8

Table 2. The measured frequencies and maximum output power for various transmission channels of Uniden Mini 200 Portable Cellular Telephone.

Channel #	Frequency (MHz)	Max Output Power (mW)
001	825.028	298
111	828.328	286
222	831.658	285
333	834.988	300
444	838.318	271
555	841.648	296
666	844.978	289
799	848.968	258

Table 3. Comparison of the experimentally measured and FDTD-calculated peak 1-g SARs for ten commercial wireless devices, 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 4. Compositions used for brain-equivalent materials.

840 MHz		1900 MHz	
Water	40.4%	Water	60.0%
Sugar	56.0%	Sugar	18.0%
Salt (NaCl)	2.5%	PEP	20.0%
HEC	1.0%	Salt (NaCl)	0.4%
		TX 151	1.6%
$\varepsilon_r = 41.1 \pm 1.4$		$\varepsilon_r = 45.5 \pm 1.7$	
$\sigma = 1.06 \pm 0.05$ S/m		$\sigma = 1.31 \pm 0.06$ S/m	

Table 5. Box phantom: Comparison of the measured and FDTD-calculated peak 1-g SARs for four spacings each at 840 and 1900 MHz, radiated power normalized to 0.5 W.

Frequency (MHz)	Distance (mm) Between λ/2 Dipole and the Box	SAR (W/kg)		Difference (%)
		Measured	FDTD	
840	17.5	4.58	4.20	+8.3
840	22.5	3.53	3.65	-3.4
840	27.5	2.69	3.00	-10.2
840	33.0	1.95	2.24	-12.9
1900	16.5	7.45	7.46	-0.1
1900	21.5	4.24	4.18	+1.4
1900	26.5	2.71	2.91	-7.9
1900	31.5	1.77	1.75	+1.1

Table 6. Sphere phantom: Comparison of the measured and FDTD-calculated peak 1-g SARs for three spacings each at 840 and 1900 MHz, radiated power normalized to 0.5 W.

Frequency (MHz)	Distance (mm) Between λ/2 Dipole and the Box	SAR (W/kg)		Difference (%)
		Measured	FDTD	
840	5	6.78	6.77	+0.23
840	15	3.41	3.27	+4.22
840	25	1.85	1.68	+9.51
1900	5	17.45	18.01	-3.21
1900	15	4.96	5.05	-1.81
1900	25	1.69	1.77	-4.73

Table 7. **Uniden Mini 200 Portable Cellular Telephone. Antenna pulled out.** The SAR distribution (in W/kg) measured with a step size of 2 mm for the highest SAR region of the head.

a. At depth of 1 mm

1.264	1.270	1.266	1.247	1.219
1.304	1.337	1.338	1.340	1.292
1.331	1.327	1.355	1.321	1.276
1.290	1.297	1.302	1.299	1.281
1.208	1.204	1.202	1.188	1.176

b. At depth of 3 mm

1.103	1.118	1.124	1.113	1.091
1.139	1.174	1.180	1.184	1.148
1.166	1.172	1.197	1.174	1.139
1.150	1.162	1.168	1.166	1.151
1.098	1.106	1.106	1.096	1.082

c. At depth of 5 mm

0.960	0.982	0.994	0.989	0.972
0.992	1.027	1.037	1.043	1.016
1.017	1.030	1.054	1.039	1.013
1.018	1.035	1.042	1.043	1.030
0.988	1.007	1.010	1.003	0.990

d. At depth of 7 mm

0.835	0.859	0.875	0.875	0.862
0.861	0.896	0.909	0.917	0.897
0.885	0.902	0.925	0.916	0.897
0.896	0.916	0.925	0.928	0.918
0.880	0.906	0.913	0.909	0.898

e. At depth of 9 mm

0.727	0.752	0.769	0.772	0.762
0.749	0.782	0.796	0.806	0.791
0.768	0.789	0.812	0.807	0.792
0.783	0.806	0.817	0.822	0.815
0.772	0.804	0.815	0.814	0.806

Table 8. **Uniden Mini 200 Portable Cellular Telephone. Antenna retracted.** The SAR distribution (in W/kg) measured with a step size of 2 mm for the highest SAR region of the head.

a. At depth of 1 mm

1.070	1.084	1.066	1.053	1.022
1.105	1.115	1.098	1.073	1.045
1.147	1.149	1.149	1.107	1.064
1.108	1.134	1.106	1.061	1.059
1.060	1.058	1.054	1.035	0.984

b. At depth of 3 mm

0.936	0.954	0.944	0.935	0.910
0.961	0.976	0.967	0.949	0.926
0.989	0.997	1.001	0.970	0.936
0.960	0.984	0.965	0.933	0.929
0.925	0.928	0.926	0.911	0.870

c. At depth of 5 mm

0.815	0.836	0.831	0.827	0.806
0.832	0.850	0.848	0.835	0.816
0.850	0.862	0.869	0.847	0.821
0.828	0.851	0.839	0.817	0.813
0.803	0.811	0.811	0.799	0.767

d. At depth of 7 mm

0.709	0.730	0.729	0.728	0.710
0.720	0.739	0.741	0.732	0.717
0.729	0.744	0.753	0.738	0.717
0.712	0.734	0.727	0.712	0.709
0.694	0.705	0.707	0.698	0.673

e. At depth of 9 mm

0.617	0.637	0.638	0.638	0.623
0.624	0.641	0.646	0.640	0.627
0.627	0.642	0.653	0.642	0.625
0.613	0.634	0.630	0.620	0.618
0.599	0.611	0.615	0.609	0.589

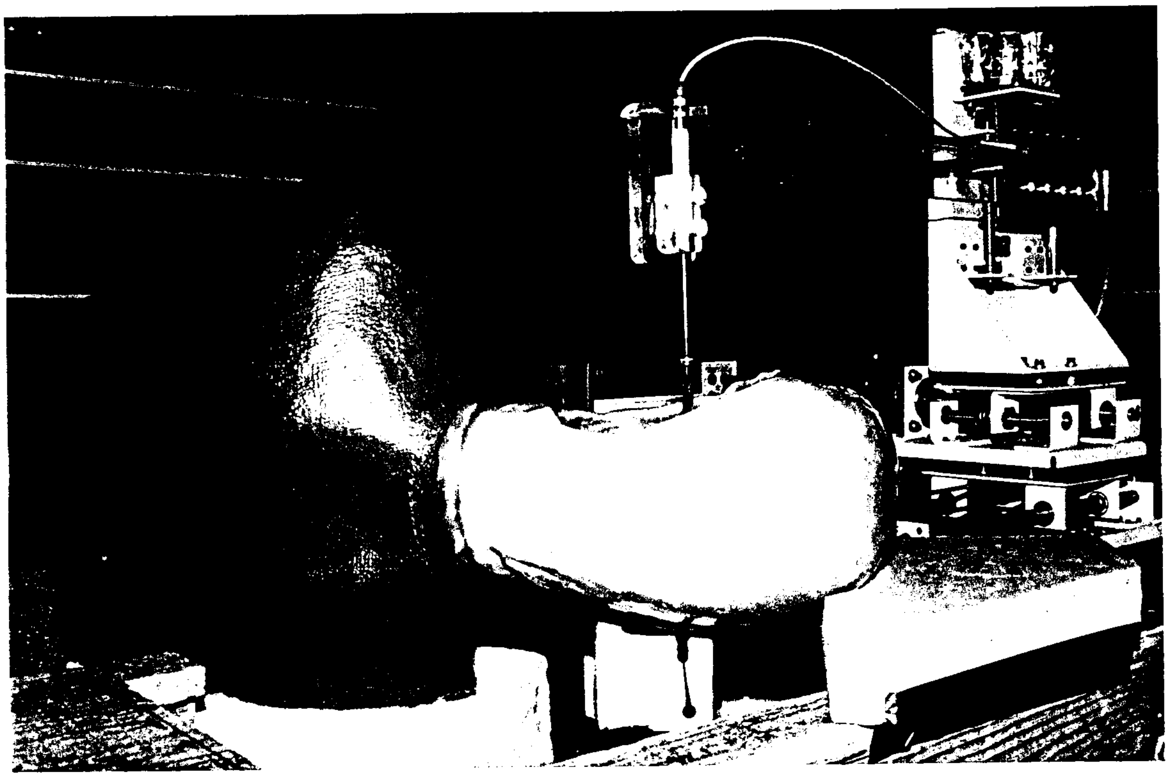

Fig. 1. The phantom model used for measurement of the SAR distribution for Uniden Mini 200 Portable Cellular Telephone.

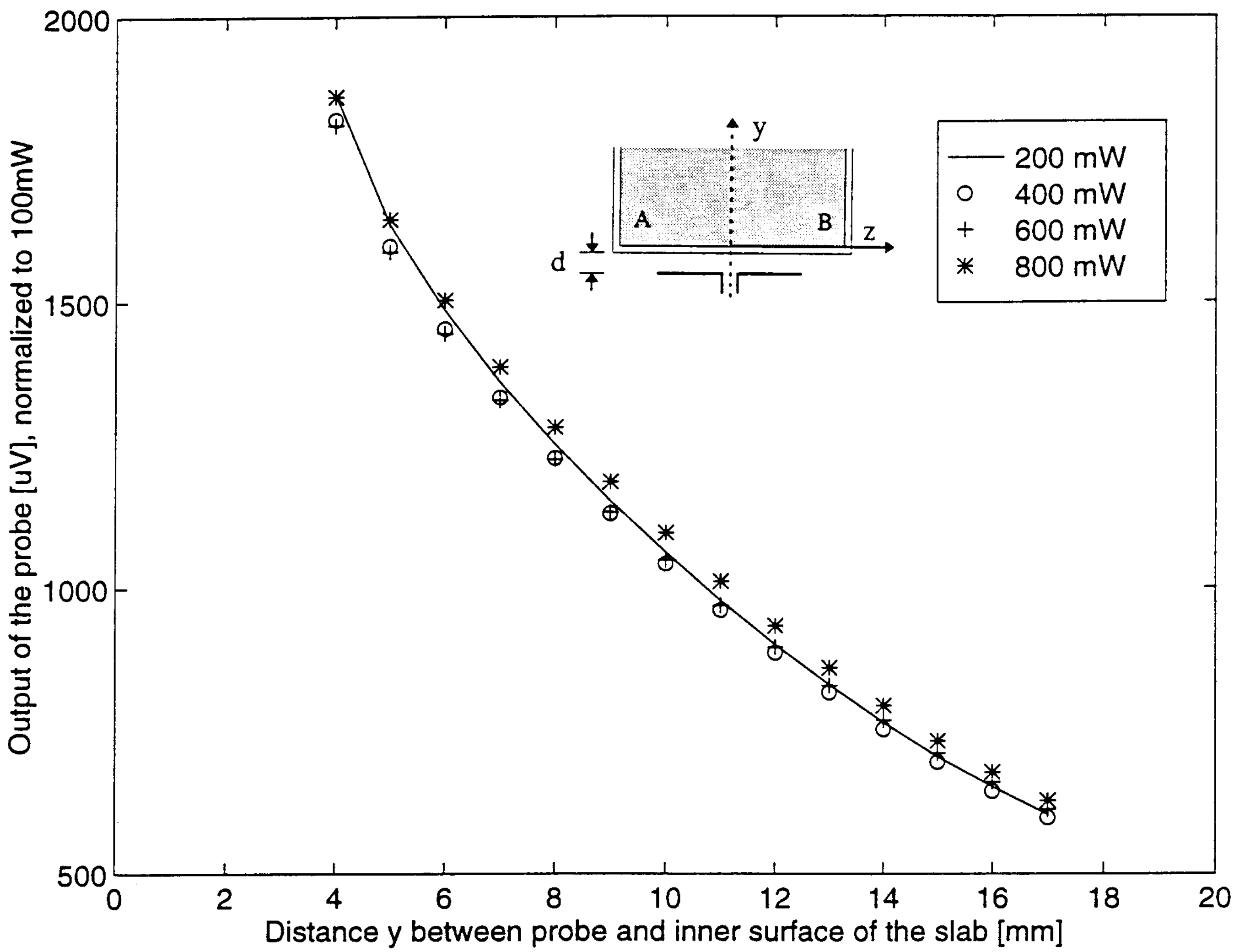

Fig. 2a. Test for square-law behavior at 840 MHz: Variation of the output voltage (proportional to $|E_i|^2$) for different radiated powers normalized to 0.1 W.

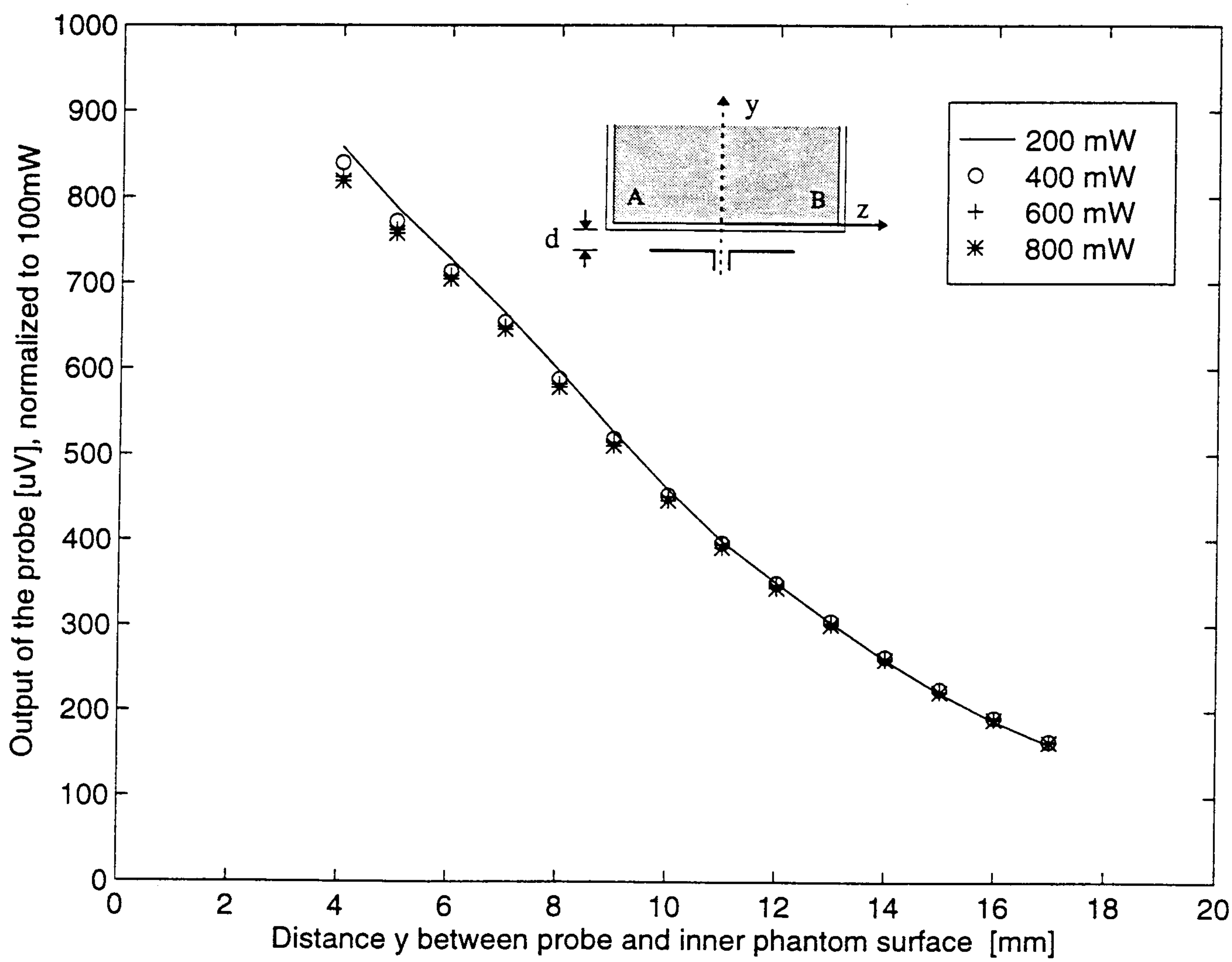

Fig. 2b. Test for square-law behavior at 1900 MHz: Variation of the output voltage (proportional to $|E_i|^2$) for different radiated powers normalized to 0.1 W.

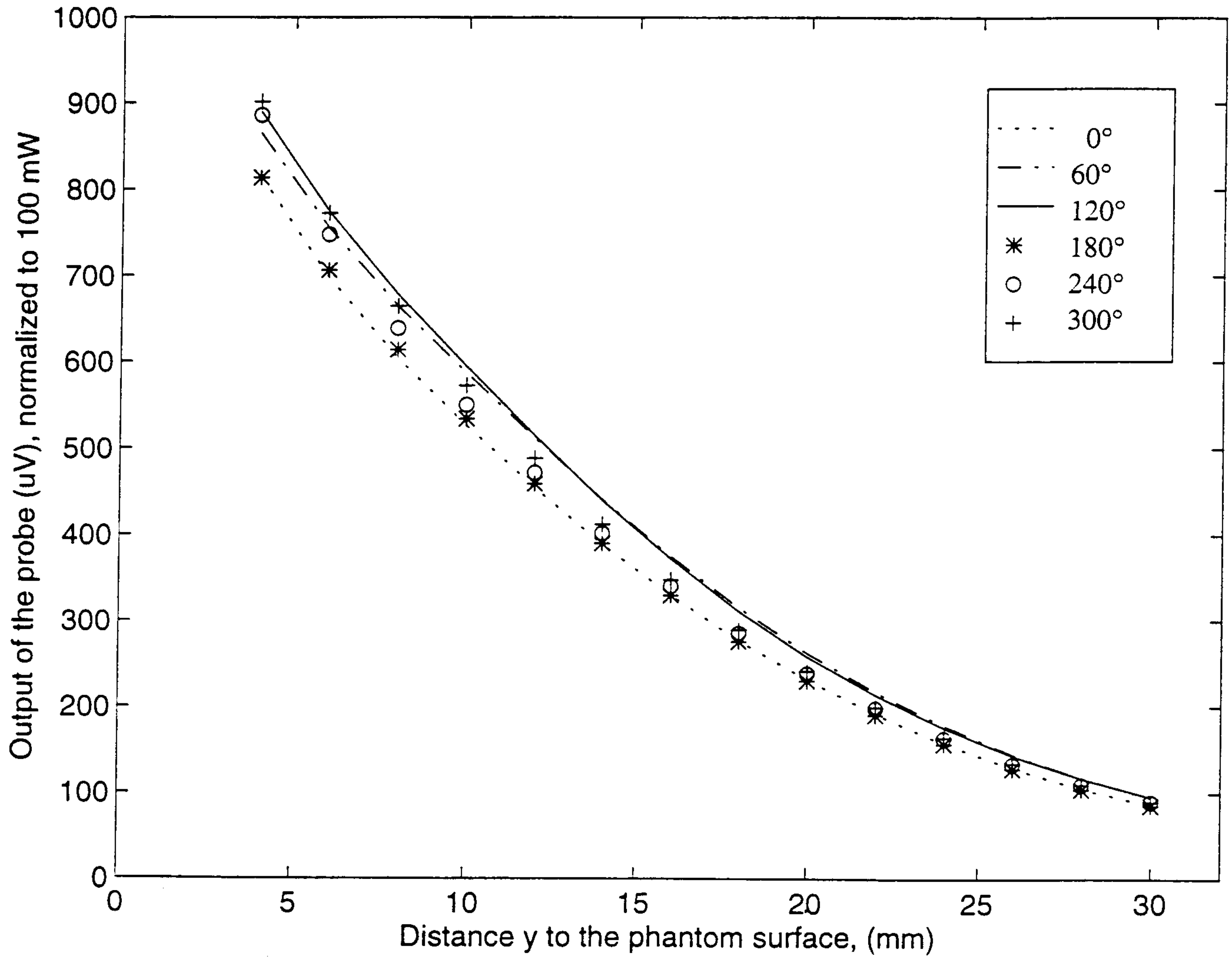

Fig. 3a. Test for isotropy: The model shown in Fig. 1 was used with nominal half wavelength dipole radiator of length 178 mm at 840 MHz.

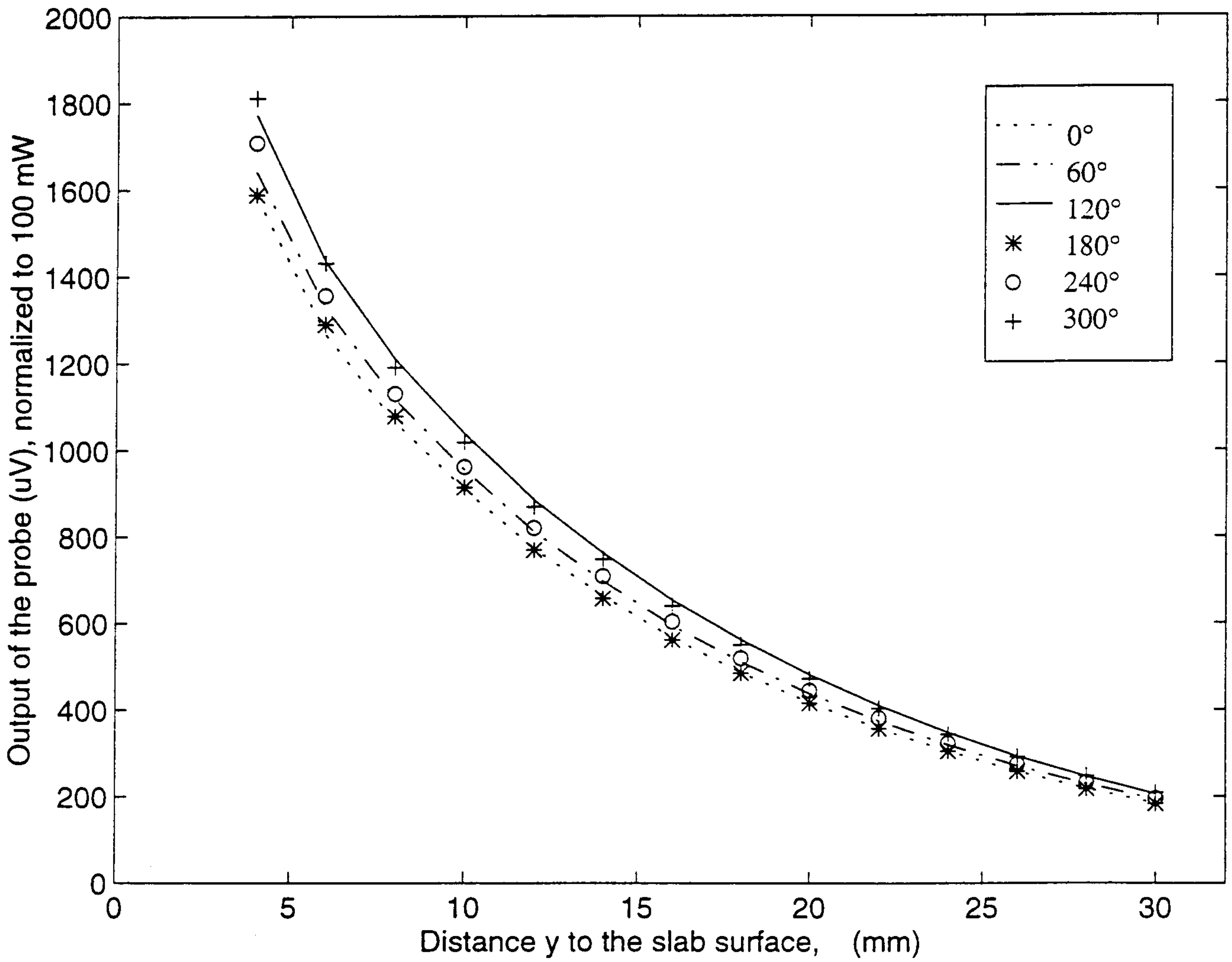

Fig. 3b. Test for isotropy: The model shown in Fig. 1 was used with nominal half wavelength dipole radiator of length 77 mm at 1900 MHz.

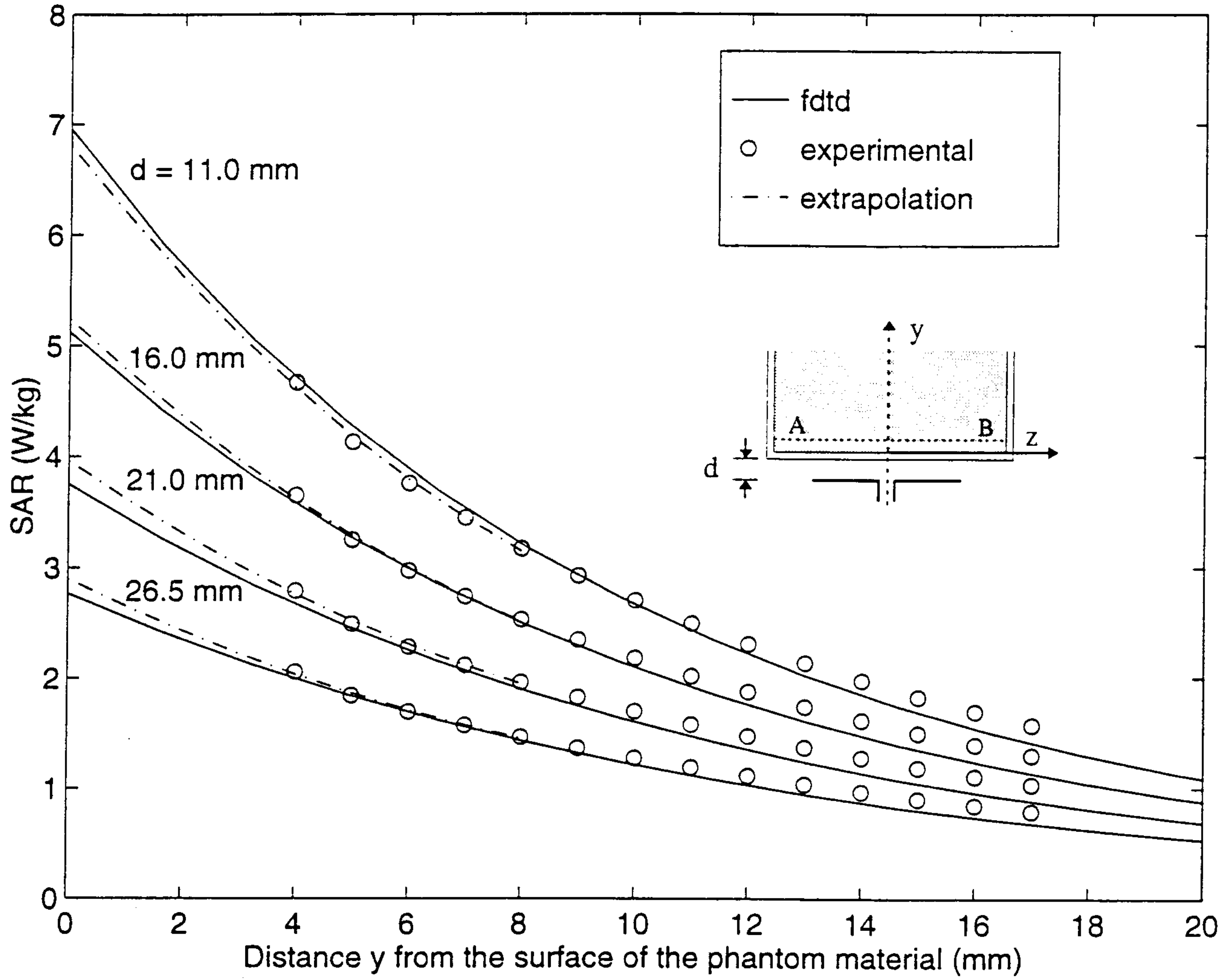

Fig. 4a. Comparison of the calculated and measured SAR variations for a box phantom of dimensions 30 × 15 × 50 cm; 840 MHz; λ/2 dipole antenna; 0.5 W radiated power. Calibration factor for the Narda Model 8021 probe at 840 MHz = 0.49 (mW/kg)/μV. Measured for the phantom material $\varepsilon_r = 41.1$,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

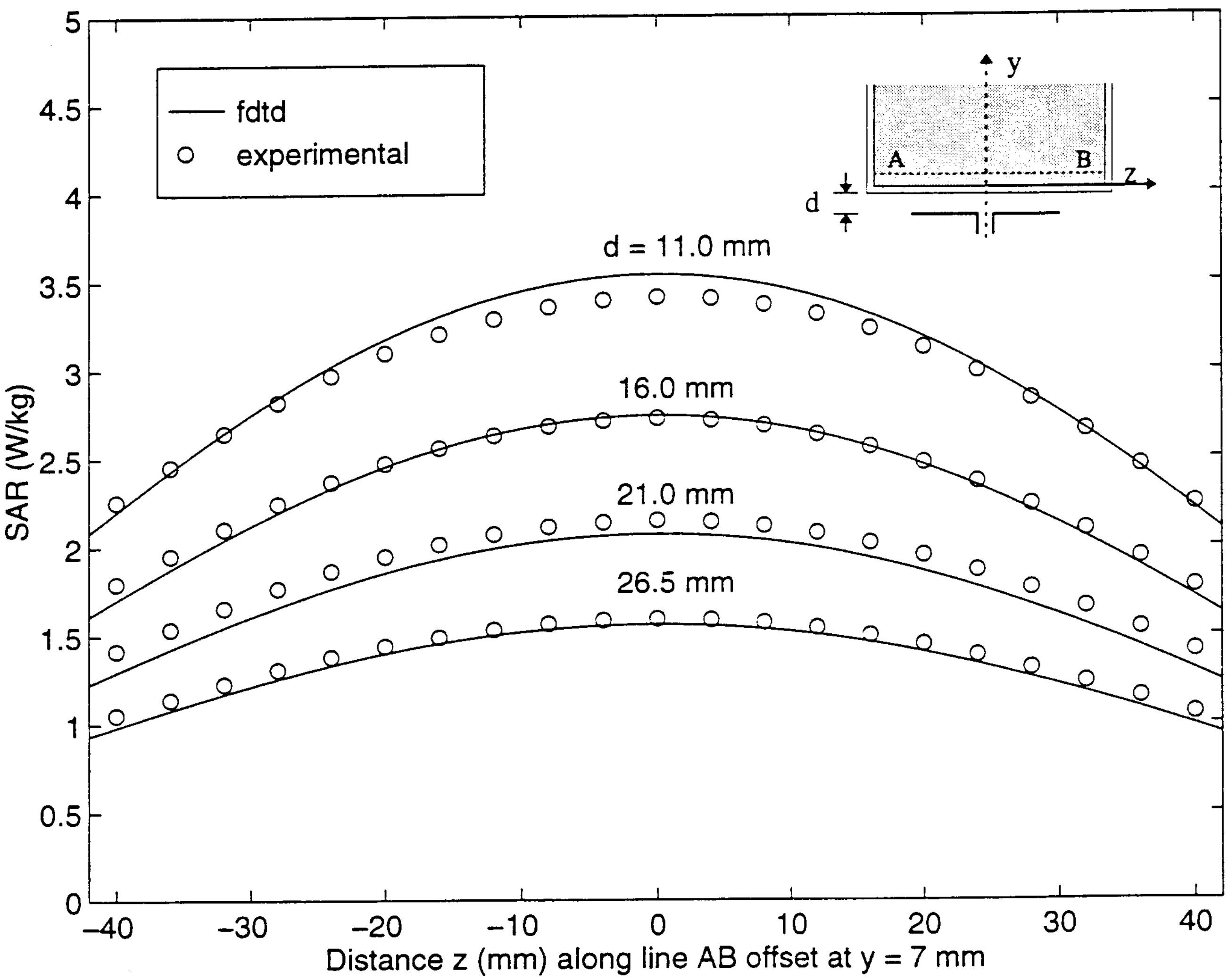

Fig. 4b. Comparison of the calculated and measured SAR variations for a box phantom of dimensions 30 × 15 × 50 cm for a line AB parallel to the z axis at a distance y = 7 mm from the surface of the phantom material; 840 MHz; $\lambda/2$ dipole antenna; 0.5 W radiated power. Calibration factor for the 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.

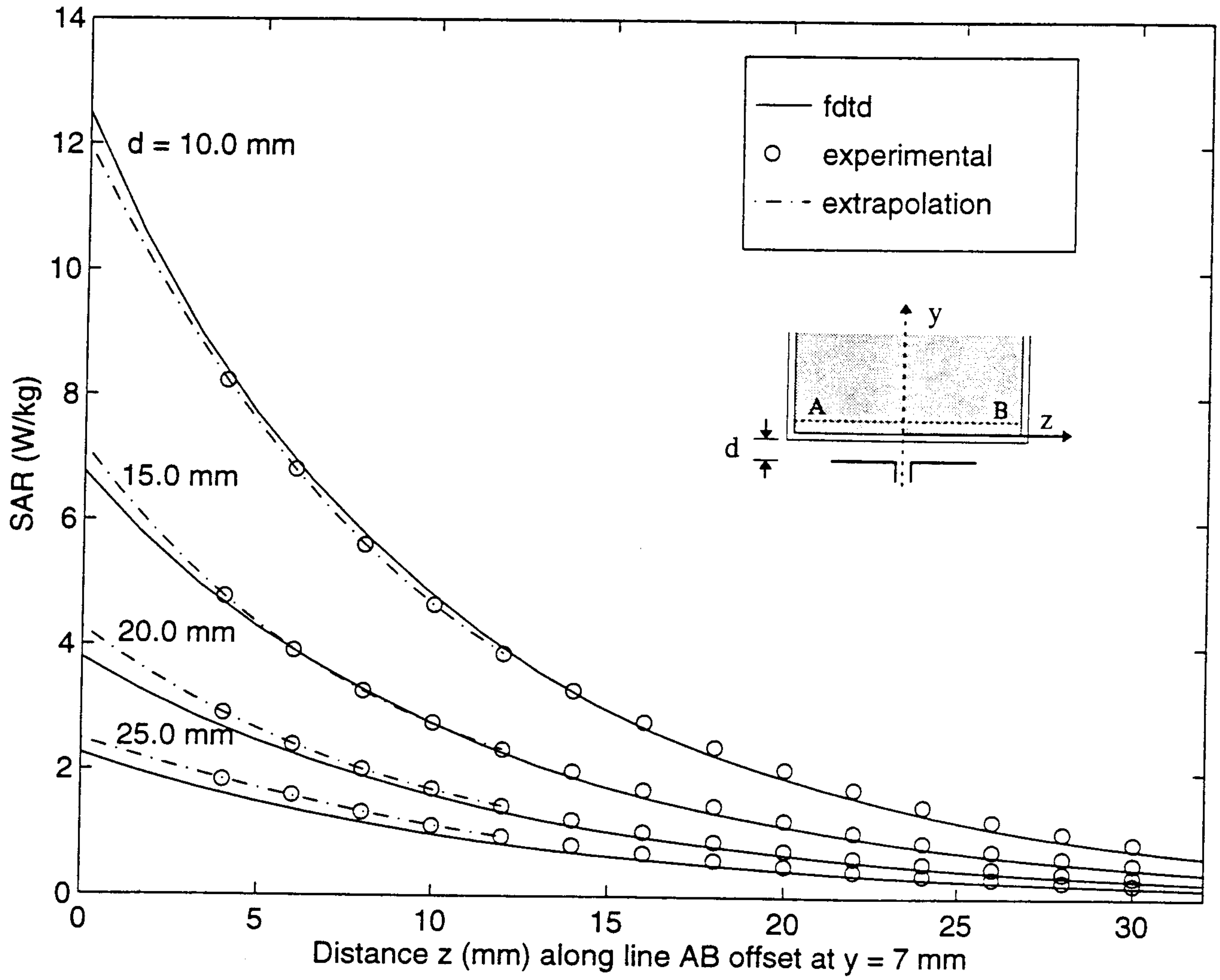

Fig. 5a. Comparison of the calculated and measured SAR variations for a box phantom of dimensions 30 × 15 × 50 cm; 1900 MHz; λ/2 dipole antenna; 0.5 W radiated power. Calibration factor for the Narda Model 8021 probe at 1900 MHz = 0.84 (mW/kg)/μV. Measured for the phantom material $\varepsilon_r = 45.5$,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

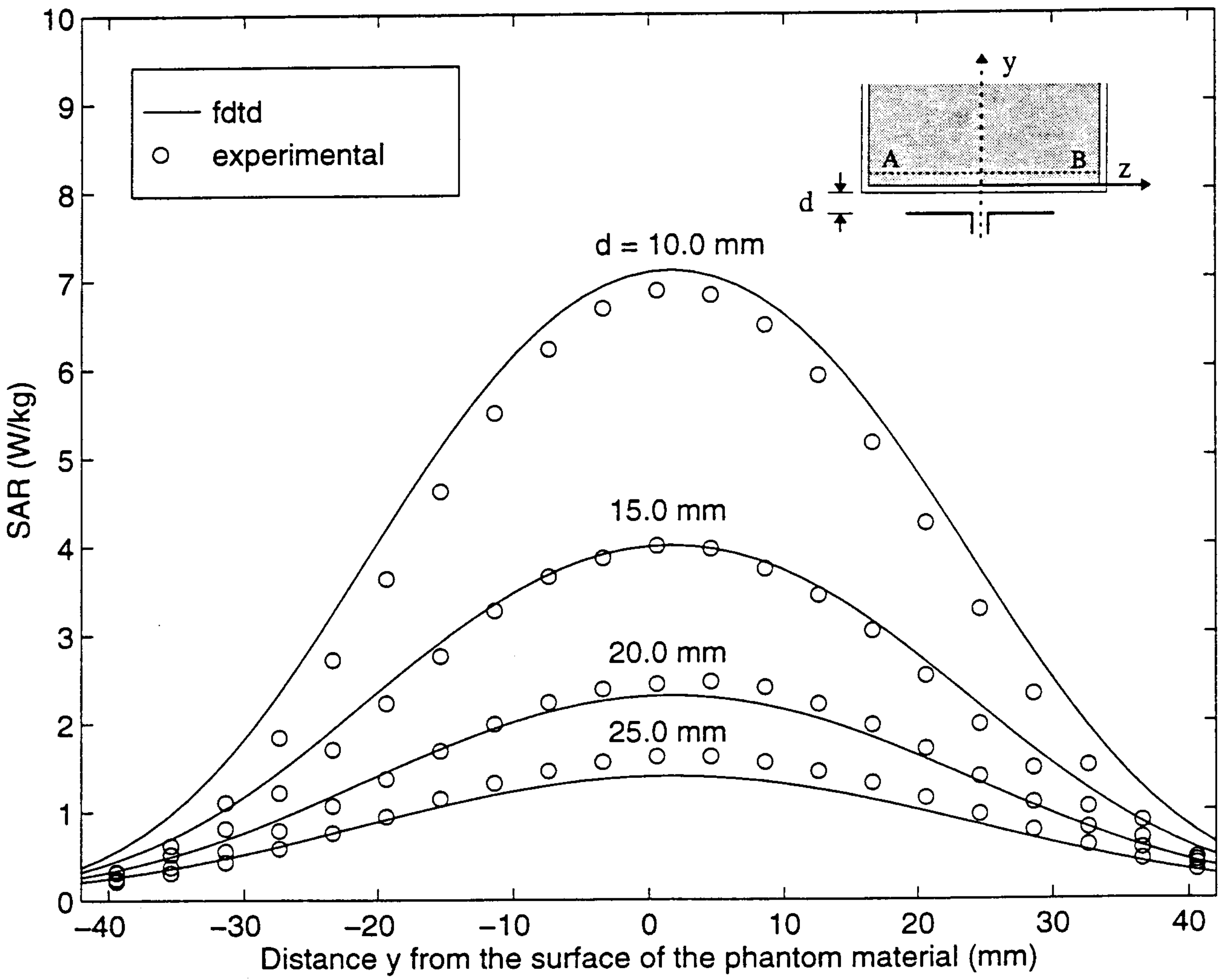

Fig. 5b. Comparison of the calculated and measured SAR variations for a box phantom of dimensions 30 × 15 × 50 cm for a line AB parallel to the z axis at a distance y = 7 mm from the surface of the phantom material; 1900 MHz; λ/2 dipole antenna; 0.5 W radiated power. Calibration factor for the Narda 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.

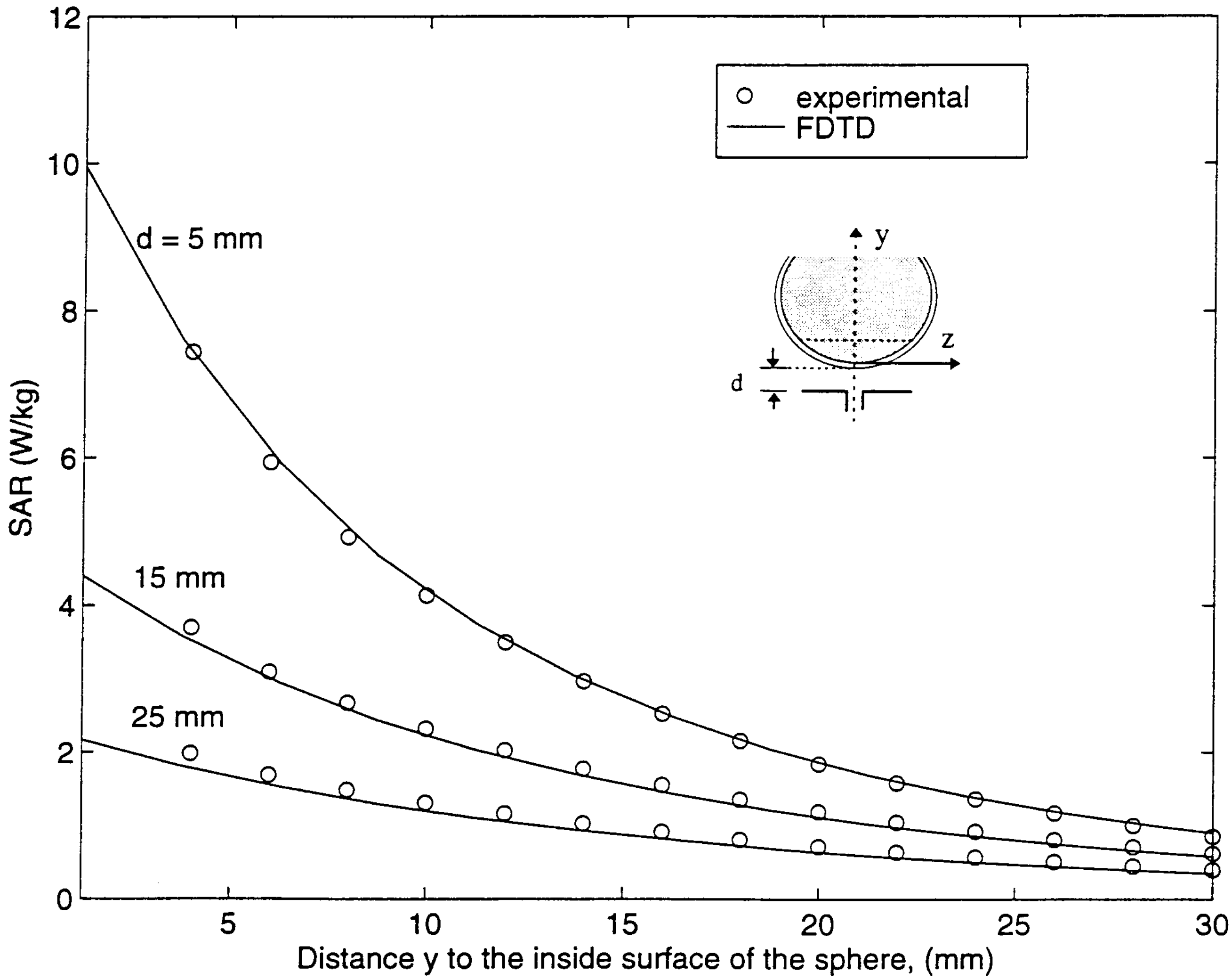

Fig. 6a. Comparison of measured and FDTD-calculated SAR variations at 840 MHz for a glass sphere model of outer diameter 22.3 cm and thickness 5 mm. SARs normalized to a radiated power of 0.5 W. Calibration factor = 0.49 (mW/kg)/μV. Measured for the phantom material $\varepsilon_r = 41.1$, $\sigma = 1.06$ S/m.

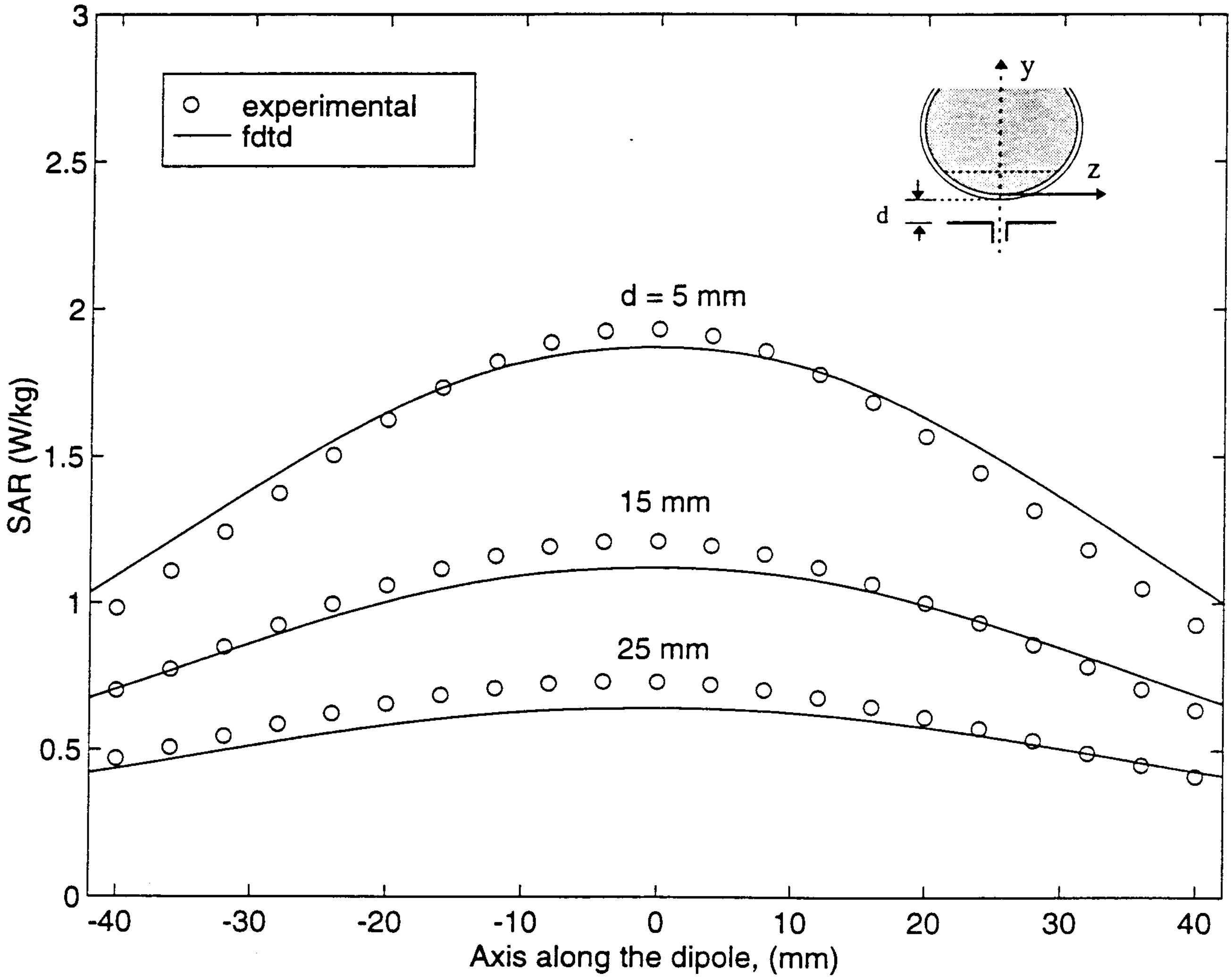

Fig. 6b. Comparison of calculated and measured SAR variations at 840 MHz for a plane at a distance of 20 mm from the lowest point on the inside of the sphere. SARs normalized to a radiated power of 0.5 W. Calibration factor = 0.49 (mW/kg)/μV. Measured for the phantom material $\varepsilon_r = 41.1$, $\sigma = 1.06$ S/m.

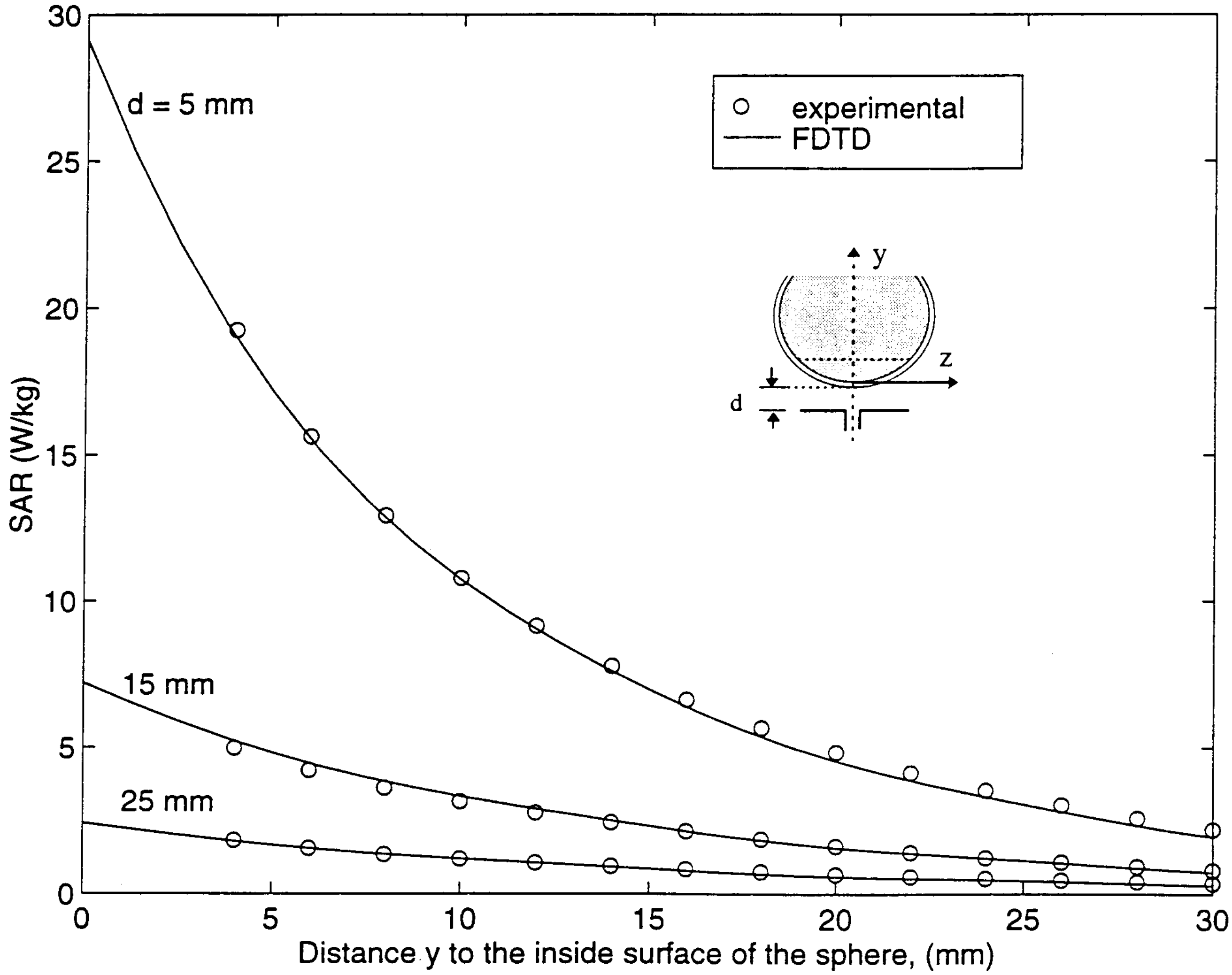

Fig. 7a. Comparison of measured and FDTD-calculated SAR variations at 1900 MHz for a glass sphere model of outer diameter 22.3 cm and thickness 5 mm. SARs normalized to a radiated power of 0.5 W. Calibration factor = 0.84 (mW/kg)/μV. Measured for the phantom material $\varepsilon_r = 45.5$, $\sigma = 1.31$ S/m.

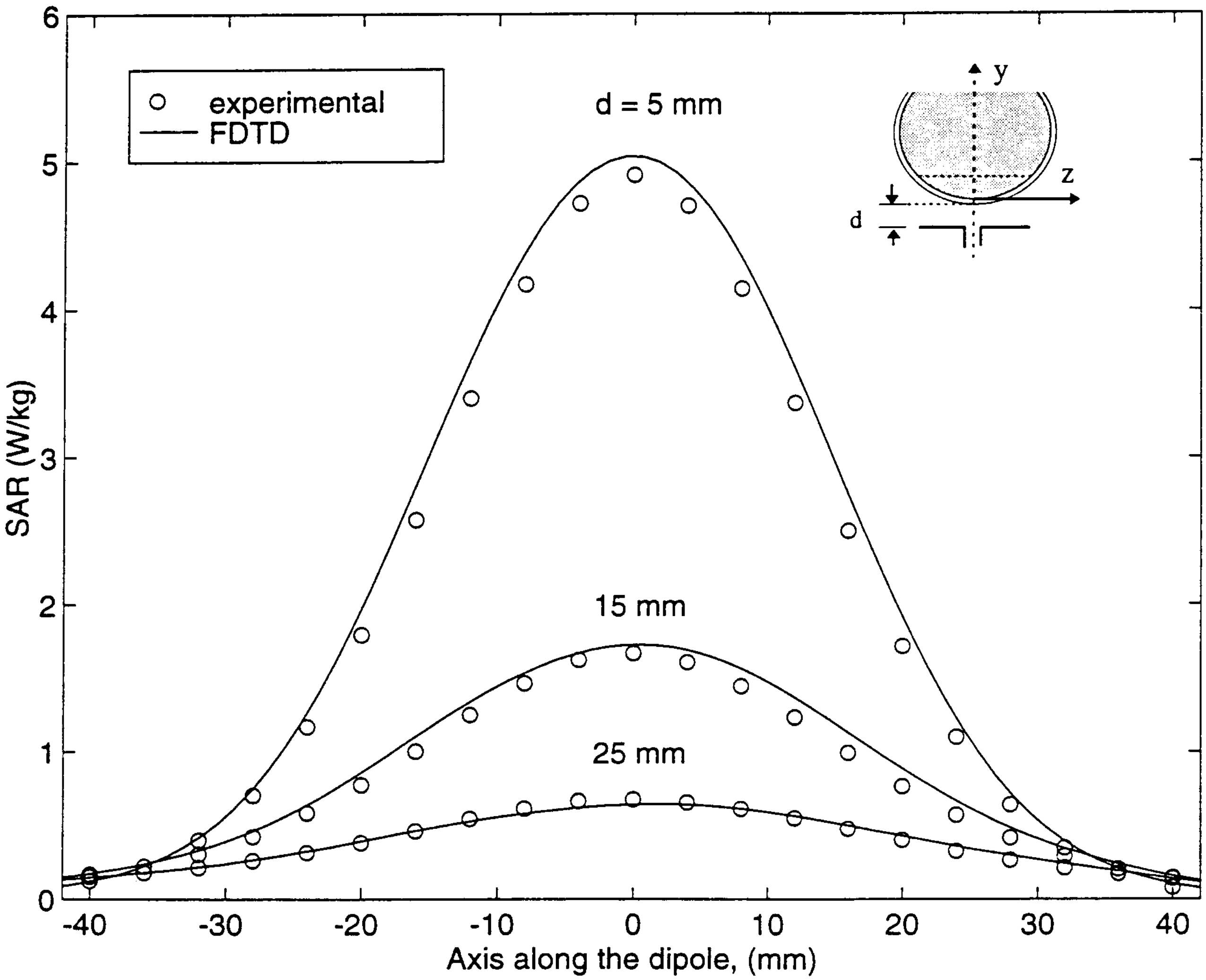

Fig. 7b. Comparison of calculated and measured SAR variations at 1900 MHz for a plane at a distance of 20 mm from the lowest point on the inside of the sphere. SARs normalized to a radiated power of 0.5 W. Calibration factor = 0.84 (mW/kg)/μV. Measured for the phantom material $\varepsilon_r = 45.5$, $\sigma = 1.31$ S/m.