SAR COMPLIANCE TESTING OF TECOM MODEL T-2000A WIRELESS DEVICE

FINAL TECHNICAL REPORT

May 16, 2000

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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].

Even though the TECOM Model T-2000A is mostly used as a holster mounted signal and data transmission and reception device much of the time with a duty cycle considerably smaller than unity, it may also be used as a handheld wireless telephone for voice communications. For this application, it is held against the head much as a cellular telephone. The SAR compliance testing has, therefore, focused on its use as a voice communication device because of a near continuous wave (CW) operation of the TECOM Model T-2000A in this mode. For SAR compliance testing, we have used the tissue-simulant model of the human head described in [3] and have used CW operation of the TECOM Model T-2000A. As recommended in [2], the TECOM Model T-2000A wireless device was placed against the left ear with the antenna located towards the front of the head. This allows the antenna to be in close proximity to the model of the head resulting in higher SARs allowing, thereby, the worst case determination of absorbed energy in the user's head [4]. Also as recommended in [2], the SAR distributions were measured without the model of a hand to determine the worst case SARs.

II. The TECOM Model T-2000A Wireless Device

As aforementioned, the TECOM Model T-2000A may be used both for signal and data transmission and reception as well as for voice communications. Transmission

frequencies used in this device vary from 806 to 821 MHz while the reception frequencies vary from 851 to 866 MHz. For each of the transmission frequencies, the TECOM Model T-2000A can operate at eight possible power levels 0-7 with the maximum time-averaged power output as high as 500 mW for the saturation levels 0, 1, and 2. For SAR testing, we have used the low band (806 MHz), the mid band (813.5 MHz) and the high band (821 MHz) and have used the power level "0" for the maximum power output of 500 mW for each of these frequencies.

For the TECOM Model T-2000A Wireless Device, it is possible to remove the antenna and use instead a power sensor to measure the output power of the device. By using a Hewlett Packard (HP) Model 436A Power Meter with HP Model 8481 Power Sensor, we measured the power output of the device to be 500 ± 5 mW at the low band, the mid band, and the high band frequencies used for SAR measurements, respectively.

III. The Tissue-Simulant Model

For measurements of SAR distributions, we have used the Utah Experimental Model that is described in detail in [3]. 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 1]. 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 4, 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 1 [3]. 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 ± 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 in the frequency band 806-821 MHz. This corresponds to $\varepsilon_r = 43.7$ and $\sigma = 0.86$ S/m. For a composition of 41.0% water, 56.0% sugar, 2.0% salt (NaCℓ) and 1.0% HEC, we have measured the values of $\varepsilon_r = 41.1 \pm 1.4$ and $\sigma = 0.91 \pm 0.04$ S/m at the center band frequency of 813.5 MHz using the HP Model 85070 B Dielectric Probe in conjunction with HP Model 8720 C Network Analyzer (50 MHz - 20 GHz). Since these values are very close to the desired values for ε_r and σ, this composition was, therefore, used as the biological phantom material to fill the model shown in Fig. 1.

The SAR distributions were measured using the automated 3-D stepper-motor driven SAR measurement system described in [3].

IV. The Measured SAR Distributions for TECOM Model T-2000A Wireless Device

As suggested in Supplement C (Edition 97-01) to the FCC OET Bulletin 65 [2], the SAR measurements have been conducted with the TECOM Model T-2000A Wireless

Device pressed against the model of the head such that the center of the speaker 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.

The highest SAR regions for each of the frequencies (806, 813.5, and 821 MHz) 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 regions of the highest SAR for each of the frequencies, the SAR distributions were measured with a resolution of 2 mm in order to obtain the peak 1 cm^3 or 1-g SAR.

The measured SAR distributions for time-averaged power outputs of 500 ± 5 mW are given in Tables 2-4, respectively. The peak 1-g SARs thus determined are given in Table 5 and are within ±2.5 percent of each other at the three frequencies of 806, 813.5, and 821 MHz, respectively. As given in [3], we estimate the uncertainty of measurements for this SAR measurement system to be less than ±10 percent. The peak 1-g SARs measured here are, therefore, less than the peak 1-g SAR of 1.6 W/kg suggested in the FCC 96-326 Guidelines [1].

V. 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. For a maximum radiated power of 500 ± 5 mW for the TECOM Model T-2000A Wireless Device, we measure peak 1-g SARs on the order of 1.34 to 1.38 W/kg over the entire band of transmission frequencies. These values are lower than 1.6 W/kg suggested in the FCC 96-326 Guidelines [1].

REFERENCES

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2. K. Chan, R. F. Cleveland, Jr., and D. L. Means, "Evaluating Compliance With FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," Supplement C (Edition 97-01) to OET Bulletin 65, December, 1997. Available from Office of Engineering and Technology, Federal Communications Commission, Washington D.C., 20554.

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3. O. P. Gandhi, G. Lazzi and C. M. Furse, "Electromagnetic Absorption in the Human Head and Neck for Mobile Telephones at 835 and 1900 MHz," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 44, pp. 1884-1897, 1996.

5. O. P. Gandhi, "FDTD in Bioelectromagnetics: Safety Assessment and Medical Applications," Chapter 11, pp. 613-651 in *Advances in Computational Electrodynamics: The FDTD Method*, edited by A. Taflove, Artech House Inc., Dedham, MA, 1998.

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 [3].

	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. **The SARs measured for the TECOM Model T-2000A Wireless Device radiating a time-averaged (CW) power of 500 ± 5 mW at the low band frequency of 806 MHz (Channel 1).** 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 = 1.376 W/kg

a. At depth of 1 mm

1.779	1.900	1.836	1.760	1.688
1.853	1.864	1.868	1.768	1.674
1.871	1.804	1.785	1.736	1.653
1.729	1.770	1.740	1.700	1.661
1.732	1.700	1.656	1.673	1.593

b. At depth of 3 mm

1.548	1.622	1.598	1.551	1.506
1.615	1.623	1.618	1.552	1.473
1.615	1.594	1.562	1.529	1.463
1.532	1.550	1.530	1.512	1.472
1.526	1.513	1.489	1.481	1.426

c. At depth of 5 mm

1.345	1.387	1.388	1.363	1.341
1.405	1.412	1.401	1.359	1.295
1.395	1.409	1.364	1.343	1.292
1.351	1.356	1.345	1.341	1.303
1.345	1.345	1.335	1.310	1.275

d. At depth of 7 mm

1.169	1.194	1.208	1.196	1.194
1.226	1.232	1.217	1.187	1.139
1.210	1.247	1.191	1.178	1.142
1.186	1.187	1.184	1.189	1.154
1.189	1.194	1.192	1.160	1.138

e. At depth of 9 mm

1.021	1.045	1.055	1.050	1.065
1.076	1.083	1.065	1.037	1.006
1.062	1.108	1.043	1.033	1.010
1.038	1.044	1.047	1.056	1.024
1.058	1.062	1.063	1.031	1.015

Table 3. **The SARs measured for the TECOM Model T-2000A Wireless Device radiating a time-averaged (CW) power of 500 ± 5 mW at the mid band frequency of 813.5 MHz (Channel 600).** 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 =1.340 W/kg

a. At depth of 1 mm

1.540	1.639	1.740	1.818	1.802
1.605	1.719	1.782	1.820	1.801
1.633	1.729	1.772	1.813	1.779
1.620	1.700	1.745	1.755	1.718
1.583	1.655	1.687	1.682	1.660

b. At depth of 3 mm

1.359	1.434	1.512	1.573	1.561
1.410	1.500	1.546	1.577	1.562
1.439	1.513	1.547	1.579	1.551
1.437	1.499	1.534	1.543	1.512
1.418	1.475	1.498	1.493	1.476

c. At depth of 5 mm

1.198	1.254	1.314	1.359	1.350
1.237	1.307	1.340	1.365	1.353
1.266	1.322	1.348	1.373	1.351
1.273	1.320	1.347	1.354	1.328
1.268	1.311	1.328	1.323	1.308

d. At depth of 7 mm

1.058	1.099	1.143	1.177	1.171
1.087	1.141	1.163	1.183	1.173
1.115	1.157	1.175	1.194	1.177
1.127	1.162	1.182	1.188	1.166
1.131	1.163	1.176	1.171	1.158

e. At depth of 9 mm

0.938	0.968	1.001	1.027	1.022
0.959	1.000	1.015	1.031	1.024
0.984	1.016	1.029	1.044	1.030
0.999	1.025	1.040	1.045	1.026
1.009	1.033	1.042	1.037	1.026

Table 4. **The SARs measured for the TECOM Model T-2000A Wireless Device radiating a time-averaged (CW) power of 500 ± 5 mW at the high band frequency of 821 MHz (Channel 1200).** 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 = 1.351 W/kg

a. At depth of 1 mm

1.576	1.678	1.776	1.852	1.831
1.637	1.754	1.812	1.846	1.820
1.658	1.752	1.789	1.824	1.788
1.635	1.710	1.747	1.753	1.713
1.585	1.677	1.660	1.643	1.621

b. At depth of 3 mm

1.391	1.468	1.544	1.602	1.586
1.440	1.530	1.573	1.600	1.580
1.463	1.535	1.562	1.590	1.560
1.452	1.510	1.539	1.544	1.510
1.423	1.484	1.476	1.462	1.442

c. At depth of 5 mm

1.226	1.282	1.340	1.385	1.373
1.264	1.334	1.363	1.385	1.370
1.288	1.342	1.362	1.383	1.359
1.287	1.330	1.353	1.357	1.328
1.274	1.310	1.309	1.298	1.278

d. At depth of 7 mm

1.082	1.122	1.166	1.200	1.191
1.111	1.164	1.184	1.201	1.189
1.135	1.174	1.188	1.204	1.184
1.140	1.172	1.189	1.192	1.167
1.139	1.157	1.160	1.150	1.132

e. At depth of 9 mm

0.959	0.988	1.021	1.046	1.040
0.981	1.021	1.033	1.047	1.038
1.002	1.031	1.041	1.053	1.037
1.011	1.034	1.047	1.049	1.028
1.016	1.023	1.027	1.019	1.003

Table 5. Summary of the measured peak 1-g SARs for the TECOM Model T-2000A Wireless Device for the maximum radiated power of 500 ± 5 mW (27.0 dBm).

Frequency MHz	1-g SAR (W/kg)
806 (Channel 1)	1.376
813.5 (Channel 600)	1.340
821.0 (Channel 1200)	1.351

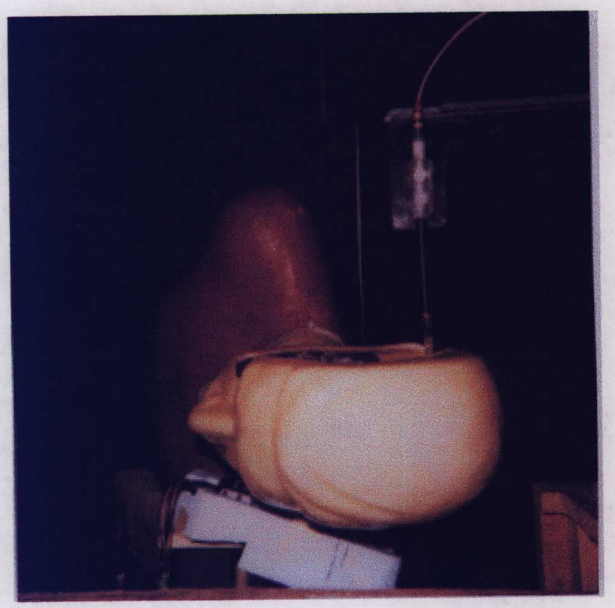

Fig. 1. The TECOM Model T-2000A Wireless Device held against the phantom model used for measurement of the SAR distribution.

ADDENDUM TO THE REPORT

SAR COMPLIANCE TESTING OF TECOM MODEL T-2000A

WIRELESS DEVICE

FINAL TECHNICAL REPORT

November 21, 2000

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ADDENDUM TO THE REPORT

SAR COMPLIANCE TESTING OF TECOM MODEL T-2000A
WIRELESS DEVICE

I. Body Worn SAR Compliance Testing of TECOM Model T-2000A

In the previous report entitled SAR Compliance Testing of TECOM Model T-2000A Wireless Device dated May 16, 2000, only the measured peak 1-g SAR for this Wireless Device held against the phantom model of the head were reported. Since the device is also to be used as a holster-mounted device held against the waist, additional SAR testing has, therefore, been performed. The TECOM Model T-2000A Wireless Device mounted in a holster is shown in Fig. 1. In Fig. 1a, it should be noted that the antenna is turned further away from the back side of the holster whch is placed against the body. This helps to increase the separation between the antenna and the body when the holster is mounted on say a belt around the waist.

For SAR compliance testing, a rectangular box phantom model shown in Fig. 2 is used. This box phantom of external dimensions 30×50 cm is filled with a tissue-simulant fluid up to a depth of 15.5 cm. To maintain flatness of the phantom, the rectangular box is made of acrylic ($\varepsilon_r = 2.56$) of thickness 6.35 mm. The tissue-simulant fluid uses a composition developed at the University of Utah which consists of 61.0% water, 36.0% sugar, 2.0% salt ($NaC\ell$) and 1.0% HEC. For this composition, we have measured the values of $\varepsilon_r = 55.5 \pm 1.5$ and $\sigma = 0.93 \pm 0.05$ S/m at the TECOM Model T-2000A center band frequency of 813.5 MHz using the Hewlett Packard (HP) Model 85070B Dielectric Probe in conjunction with HP Model 8720C Network Analyzer (50 MHz-20 GHz). The measured values of ε_r and σ are very close to the FCC website recommended values for muscle of $\varepsilon_r = 56.17$ and $\sigma = 0.939$ S/m.

II. The Measured SAR Distributions

The measured SAR distributions for the TECOM Model T-2000A Holster-Mounted Wireless Device held against the planar box phantom for the low-end channel 1 (806 MHz),

midband channel 600 (813.5 MHz) and high-end channel 1200 (821 MHz) are given in Tables 1, 2, and 3, respectively. For each of the three channels, the radiated power was measured by unscrewing the antenna and using the Hewlett Packard (HP) Model 436A Power Meter with HP Model 8481 Power Sensor. The power output for each of the three channels was measured to be 500 ± 5 mW.

The peak 1-g SAR values are tabulated in Table 4. All of the peak 1-g SARs are less than the FCC 96-326 guideline of 1.6 W/kg.

Table 1. **The SARs measured for the TECOM Model T-2000A Wireless Device radiating a time-averaged (CW) power of 500 ± 5 mW at the low-end frequency of 806 MHz (Channel 1).** 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 = 1.363 W/kg

a. At depth of 1 mm

1.835	1.844	1.835	1.823	1.829
1.853	1.859	1.858	1.849	1.859
1.821	1.820	1.819	1.837	1.848
1.722	1.716	1.718	1.715	1.710
1.634	1.633	1.631	1.639	1.643

b. At depth of 3 mm

1.586	1.603	1.607	1.606	1.613
1.595	1.612	1.621	1.624	1.632
1.567	1.577	1.587	1.603	1.611
1.492	1.496	1.504	1.503	1.496
1.423	1.426	1.428	1.432	1.436

c. At depth of 5 mm

1.365	1.387	1.399	1.407	1.412
1.366	1.390	1.405	1.416	1.423
1.341	1.358	1.375	1.390	1.396
1.285	1.297	1.308	1.310	1.302
1.233	1.239	1.244	1.245	1.247

d. At depth of 7 mm

1.173	1.197	1.213	1.224	1.228
1.166	1.193	1.211	1.226	1.231
1.143	1.163	1.184	1.197	1.201
1.102	1.118	1.131	1.134	1.126
1.063	1.071	1.078	1.078	1.077

e. At depth of 9 mm

1.009	1.032	1.047	1.058	1.060
0.996	1.021	1.040	1.054	1.057
0.972	0.993	1.013	1.025	1.026
0.942	0.959	0.973	0.977	0.971
0.914	0.923	0.930	0.930	0.925

Table 2. **The SARs measured for the TECOM Model T-2000A Wireless Device radiating a time-averaged (CW) power of 500 ± 5 mW at the mid band frequency of 813.5 MHz (Channel 600).** 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 =1.166 W/kg

a. At depth of 1 mm

1.548	1.547	1.544	1.541	1.544
1.550	1.546	1.546	1.535	1.532
1.556	1.552	1.542	1.542	1.534
1.554	1.551	1.545	1.551	1.552
1.517	1.510	1.511	1.506	1.507

b. At depth of 3 mm

1.339	1.338	1.332	1.324	1.314
1.340	1.338	1.335	1.322	1.311
1.347	1.344	1.336	1.329	1.315
1.345	1.343	1.336	1.333	1.324
1.320	1.314	1.311	1.301	1.297

c. At depth of 5 mm

1.152	1.152	1.145	1.134	1.116
1.153	1.153	1.149	1.135	1.119
1.160	1.159	1.153	1.141	1.124
1.160	1.157	1.151	1.142	1.127
1.144	1.139	1.134	1.120	1.113

d. At depth of 7 mm

0.988	0.989	0.982	0.970	0.949
0.989	0.991	0.987	0.974	0.957
0.996	0.996	0.993	0.979	0.962
0.997	0.995	0.991	0.977	0.960
0.988	0.985	0.979	0.965	0.955

e. At depth of 9 mm

0.846	0.849	0.844	0.832	0.814
0.847	0.852	0.850	0.839	0.823
0.855	0.856	0.856	0.844	0.828
0.857	0.857	0.854	0.842	0.824
0.854	0.852	0.846	0.833	0.823

Table 3. **The SARs measured for the TECOM Model T-2000A Wireless Device radiating a time-averaged (CW) power of 500 ± 5 mW at the high band frequency of 821 MHz (Channel 1200).** 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 = 1.186 W/kg

a. At depth of 1 mm

1.538	1.545	1.555	1.559	1.569
1.603	1.612	1.623	1.636	1.640
1.610	1.621	1.634	1.639	1.646
1.614	1.622	1.622	1.622	1.629
1.649	1.645	1.638	1.639	1.643

b. At depth of 3 mm

1.297	1.308	1.319	1.329	1.339
1.349	1.360	1.375	1.390	1.396
1.357	1.371	1.387	1.397	1.405
1.366	1.375	1.383	1.389	1.396
1.395	1.398	1.399	1.404	1.410

c. At depth of 5 mm

1.087	1.101	1.112	1.125	1.135
1.127	1.139	1.157	1.172	1.179
1.137	1.152	1.169	1.183	1.191
1.148	1.159	1.172	1.182	1.188
1.171	1.180	1.187	1.195	1.200

d. At depth of 7 mm

0.908	0.923	0.934	0.947	0.956
0.939	0.951	0.969	0.983	0.989
0.949	0.965	0.981	0.996	1.003
0.961	0.972	0.989	1.000	1.005
0.979	0.990	1.001	1.010	1.014

e. At depth of 9 mm

0.760	0.776	0.785	0.796	0.802
0.783	0.796	0.812	0.823	0.827
0.794	0.809	0.824	0.836	0.842
0.805	0.816	0.833	0.844	0.848
0.818	0.830	0.841	0.850	0.850

Table 5. Summary of the measured peak 1-g SARs for the TECOM Model T-2000A Wireless Device in a holster held against the planar box phantom model for the maximum radiated power of 500 ± 5 mW (27.0 dBm).

Frequency MHz	1-g SAR (W/kg)
806 (Channel 1)	1.363
813.5 (Channel 600)	1.166
821.0 (Channel 1200)	1.186

a. Side view. Note that the antenna is turned away from the back side of the holster.

b. Back side of the holster placed against the bottom of the planar phantom model for SAR testing.

Fig. 1. Photographs of TECOM Model T-2000A Wireless Device mounted in a holster.

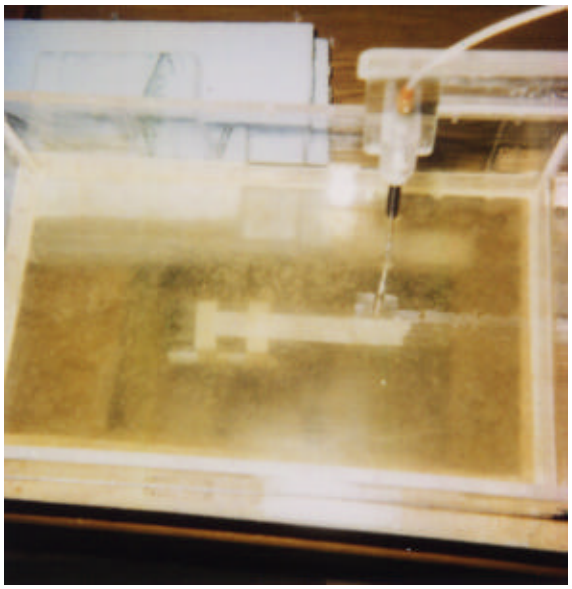

Fig. 2. Photograph of the planar box phantom model used for SAR measurements.