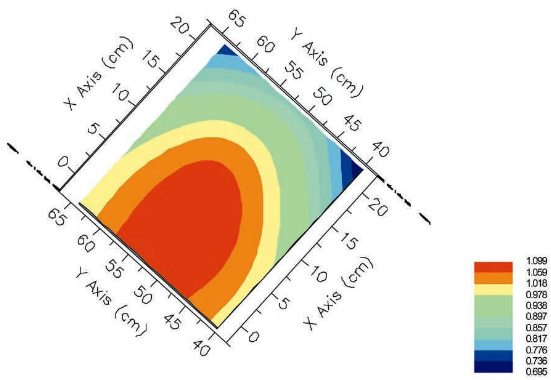
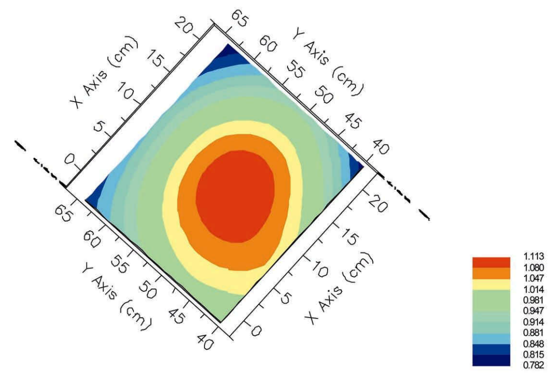
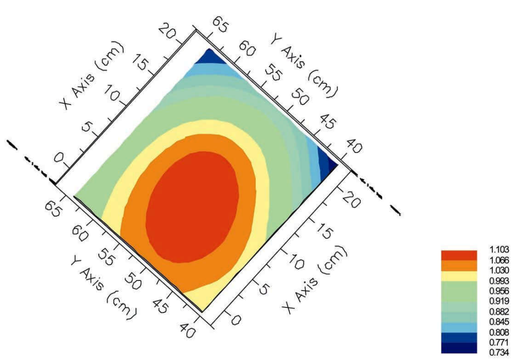
Contour at z=3



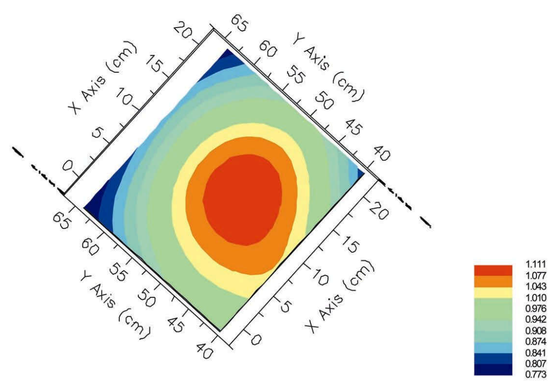
Contour at z=6 mm



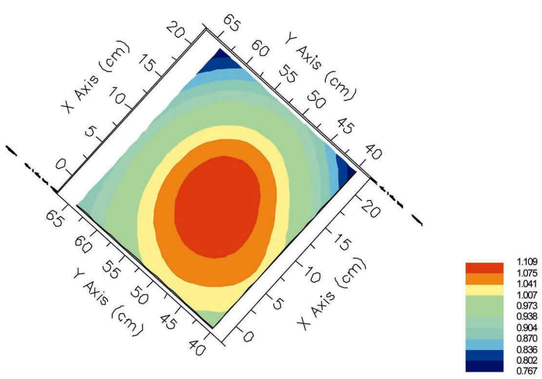
Contour at z=4 mm



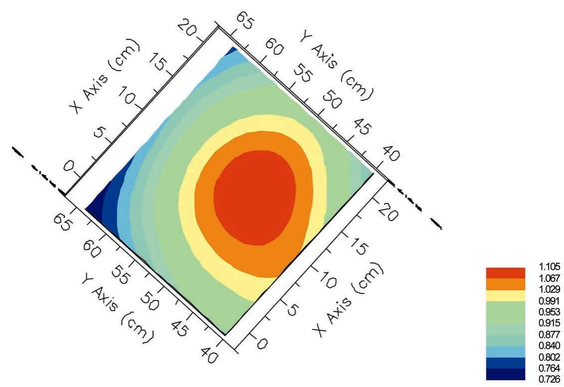
Contour at z=7 mm



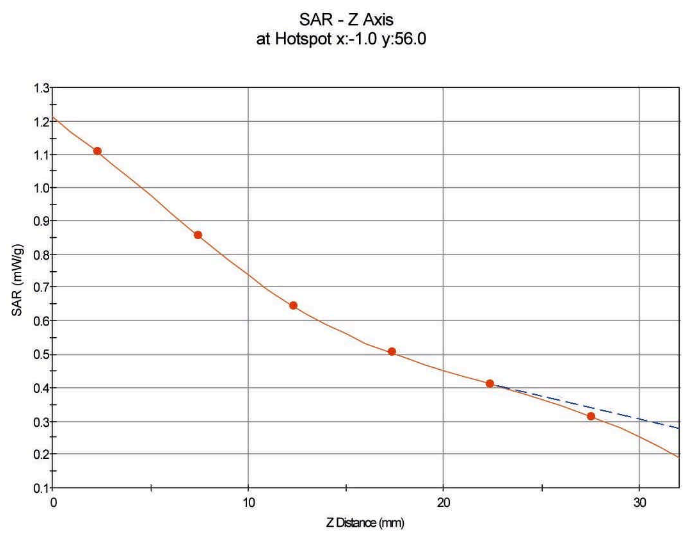
Contour at z=5 mm



Contour at z=8 mm



Free Space z-axis Scan (with expected behavior line. +20 mm is well beyond distance tolerance for freespace calibration).



MEASUREMENT UNCERTAINTIES

a	b	c	d	e= f(d,k)	f	g	h = cxf/e	i = cxg/e	k
Uncertainty Component	**Sec.**	**Tol. (± %)**	**Prob. Dist.**	**Div.**	**c_i (1 - g)**	**c_i (10 - g)**	**1 - g u_i (± %)**	**10 - g u_i (± %)**	**v_i**
Measurement System									
Probe Calibration	E1.1	11.36	R	Ö3	1	1	6.56	6.56	¥
Axial Isotropy	E1.2	3.37	R	Ö3	0.5	0.5	0.97	0.97	¥
Hemispherical Isotropy	E1.2	4.78	R	Ö3	1	1	2.8	2.8	¥
Boundary Effect	E1.3	11.0	R	Ö3	1	1	6.4	6.4	¥
Linearity	E1.4	5.88	R	Ö3	1	1	3.4	3.4	¥
System Detection Limits	E1.5	1.0	R	Ö3	1	1	0.6	0.6	¥
Readout Electronics	E1.6	1.0	R	1	1	1	1.0	1.0	¥
Response Time	E1.7	0.8	R	Ö3	1	1	0.5	0.5	¥
Integration Time	E1.8	1.7	R	Ö3	1	1	1.0	1.0	¥
RF Ambient Conditions	E5.1	1.2	R	Ö3	1	1	0.7	0.7	¥
Probe Positioner Mechanical Tolerance	E5.2	0.4	R	Ö3	1	1	0.2	0.2	¥
Probe Positioning w/ respect to Phantom Shell	E5.3	2.9	R	Ö3	1	1	1.7	1.7	¥
Extrapolation, Interpolation & Integration Algorithms for Max. SAR Evaluation	E4.2	3.9	R	Ö3	1	1	2.3	2.3	¥
Test Sample Related									
Test Sample Positioning	E3.2.1	10.6	R	Ö3	1	1	6.1	6.1	11
Device Holder Uncertainty	E3.1.1	8.7	R	Ö3	1	1	5.0	5.0	8
Output Power Variation - SAR drift measurement	5.6.2	5.0	R	Ö3	1	1	2.9	2.9	¥
Phantom & Tissue Parameters									
Phantom Uncertainty (Shape & Thickness tolerances)	E2.1	4.0	R	Ö3	1	1	2.3	2.3	¥
Liquid Conductivity - deviation from target values	E2.2	5.0	R	Ö3	0.7	0.5	2.0	1.4	¥
Liquid Conductivity - measurement uncertainty	E2.2	10.0	R	Ö3	0.7	0.5	4.0	2.9	¥
Liquid Permittivity - deviation from target values	E2.2	5.0	R	Ö3	0.6	0.5	1.7	1.4	¥
Liquid Permittivity - measurement uncertainty	E2.2	5.0	R	Ö3	0.6	0.5	1.7	1.4	¥
Combined Standard Uncertainty (k=1)			RSS				14.74	14.33	
Expanded Uncertainty (k=2) (95% CONFIDENCE LEVEL)							29.5	28.7	

The above measurement uncertainties are according to IEEE Std. 1528-200X (January, 2002)

THERMAL ASSESSMENT UNCERTAINTY AT 5.8 GHz

Uncertainty Component	a Tol. (±%)	Probability Distribution	b Divisor	c c_i	Standard Deviation
E-Field Probe Positioning	3.279	Normal	1	1	3.28
Temp. Probe Positioning	3.279	Normal	1	1	3.95
E-field Probe Linearity	5.88	Rectangular	Ö3	1	3.4
Temp. Probe Drift and noise	11.36	Rectangular	Ö3	1	6.56
Temp. Probe Linearity	11.36	Rectangular	Ö3	1	6.56
Liquid Conductivity	5	Rectangular	Ö3	1	2.89
Liquid Specific Heat	2	Rectangular	Ö3	1	1.15
Liquid Density	1.005	Rectangular	Ö3	1	0.58
Combined Standard Uncertainty					11.36

MISCELLANEOUS RELEVANT CALCULATIONS

E-Field/Temperature Probe Positioning:

$Tolerance = 100 \times \frac{d}{d/2}$ = 100 X 0.10 / (6.1/2) = 3.279 %

Liquid Density:

$Tolerance = 100 \times \sqrt{\Delta X_1{}^2 + \Delta X_2{}^2}$ = 100 X (0.1%^{2} + 1%^{2})$^{1/2}$ = 1.005 %

Temperature Probe Drift & Noise:

$Tolerance = 100 \times \frac{T_{\max} - T_{\min}}{\Delta T_{\min}}$ = 100 X 1/0.088 = 11.36 %

Temperature Probe Linearity:

$Tolerance = 100 \times \frac{dT_{\max}}{\Delta T_{\min}}$ = 0.01/0.088 = 11.36 %

E-Field Probe Linearity:

$Tolerance = 100 \times \frac{\left|P_0{}^2 - P_1{}^2\right|}{P_o}$ = 100 X (0.750^2 - 0.720^2)/0.75 = 5.88%

Input Power and SAR Drift Measurement:

$Tolerance \approx 100 \times -2a\Delta x$ = 100 X (-2)(1/6.1) = 16.4%

HEMISPHERICAL ISOTROPY UNCERTAINTY

Uncertainty Component	a Tol. (± %)	Probability Distribution	b *Divisor*	c c_i	$u_i = (a/b) \times c$ Standard Uncertainty (± %)
SAR Deviation from Average	6.6	R	$\sqrt{3}$	1	3.81
Probe Positioning	5.0	R	$\sqrt{3}$	1	2.89
Combined Standard Uncertainty					4.78

Sample Photographs:

SAR % Deviation Data:

	0	30	60	90	120
0	0.037	0.042	0.062	0.015	0.016
10	0.032	0.041	0.062	0.009	0.006
20	0.027	0.038	0.060	-0.005	-0.004
30	0.007	0.024	0.053	-0.020	-0.016
40	-0.006	0.011	0.039	-0.036	-0.033
50	-0.021	-0.009	0.016	-0.048	-0.044
60	-0.039	-0.031	-0.008	-0.063	-0.055
70	-0.055	-0.048	-0.031	-0.059	-0.062
80	-0.065	-0.062	-0.049	-0.059	-0.062
90	-0.060	-0.063	-0.058	-0.016	-0.054
100	-0.052	-0.057	-0.056	-0.033	-0.041
110	-0.035	-0.044	-0.045	-0.018	-0.025
120	-0.014	-0.024	-0.022	0.000	-0.006
130	0.009	-0.001	0.003	0.022	0.013
140	0.029	0.020	0.026	0.027	0.028
150	0.043	0.038	0.046	0.040	0.039
160	0.048	0.045	0.054	0.046	0.043
170	0.044	0.041	0.050	0.045	0.043
180	0.033	0.030	0.037	0.041	0.032
190	0.017	0.010	0.016	0.032	0.023
200	-0.002	-0.009	-0.008	0.021	0.008
210	-0.019	-0.028	-0.030	0.011	0.002
220	-0.034	-0.043	-0.045	0.000	-0.009
230	-0.042	-0.048	-0.051	-0.011	-0.023
240	-0.044	-0.047	-0.047	-0.020	-0.030
250	-0.040	-0.039	-0.036	-0.026	-0.036
260	-0.031	-0.024	-0.019	-0.027	-0.030
270	-0.019	-0.010	0.000	-0.026	-0.025
280	-0.006	0.005	0.018	-0.021	-0.017
290	0.007	0.019	0.032	-0.012	-0.007
300	0.019	0.028	0.041	0.001	0.003
310	0.037	0.032	0.044	0.015	0.015
320	0.039	0.034	0.046	0.024	0.020
330	0.055	0.038	0.048	0.032	0.026
340	0.057	0.039	0.053	0.035	0.028
350	0.061	0.040	0.054	0.035	0.024

Gradations of 30 degree angles were obtained with precision holder shown in photograph. The dipole was rotated by 90 degree angles to obtain the other angles.

Max: 6.2%
Min: -6.5%
Tolerance: **± 6.6%**

From Kuster and Balzano[1] (1),

$$SAR_{surface} = \frac{s}{r}\frac{mw}{\sqrt{s^2+e^2w^2}}\left(1+c_{corr}g_{pw}\right)^2 H_{tinc}{}^2 = \frac{s}{r}\frac{mw}{\sqrt{s^2+e_o{}^2e_r{}^2w^2}} H_{tinc}{}^2 \cdot \left(1+c_{corr}g_{pw}\right)^2$$

$$= \frac{s}{r}\frac{mw}{\sqrt{s^2+e_r^2e_0^2w^2}} H_{tinc}^2 \cdot \begin{cases} \left[1+\left(\dfrac{2\left|\sqrt{e_re_0 - s/iw}\right|}{\left|\sqrt{e_re_0 - s/iw} + \sqrt{e_0}\right|} - 1\right)\right]^2, & d \ge \dfrac{2}{25}\dfrac{l_0}{g_{pw}} \\ \left\{1+\left(\dfrac{2\left|\sqrt{e_re_0 - s/iw}\right|}{\left|\sqrt{e_re_0 - s/iw} + \sqrt{e_0}\right|} - 1\right)\sin\left[\dfrac{p}{2}\dfrac{25}{2}\dfrac{d}{l_0}\left(\dfrac{2\left|\sqrt{e_re_0 - s/iw}\right|}{\left|\sqrt{e_re_0 - s/iw} + \sqrt{e_0}\right|} - 1\right)\right]\right\}^2, & d < \dfrac{2}{25}\dfrac{l_0}{g_{pw}} \end{cases}$$

$m_o = 1.257\times10^{-6}\, kg.m/A^2s^2$

$w = 2p.f = 2p.(5.8\times10^{9}) = 3.644\times10^{10}\, s^{-1}$

$g_{pw} = 0.7236m$

$s = 5.27 \quad s^3A^2/m^3kg$

$e_o = 8.85\times10^{-12}\, s^4A^2/kg.m^3$

$e_r = 35.3$

$l_o = 0.0517m$

Since $d \ge 0.08\dfrac{l_o}{g_{pw}}$, and $H_{tinc} = \dfrac{I_{fp}}{2pd}$:

$$SAR_{surface} = \frac{s}{r}\frac{mwH_{tinc}{}^2}{\sqrt{s^2+e_o{}^2e_r{}^2w^2}} \cdot \left(\frac{2\left|\sqrt{e_oe_r - \frac{s}{w}i}\right|}{\left|\sqrt{e_oe_r - \frac{s}{w}i} + \sqrt{e_o}\right|}\right)^2$$

$$= \frac{s}{2rpd}\frac{mwI_{fp}{}^2}{\sqrt{s^2+e_o{}^2e_r{}^2w^2}} \cdot \left(\frac{2\left|\sqrt{e_oe_r - \frac{s}{w}i}\right|}{\left|\sqrt{e_oe_r - \frac{s}{w}i} + \sqrt{e_o}\right|}\right)^2$$

[1] Adopted from N. Kuster and Q. Balzano, “Experimental and Numerical Dosimetry,” *Mobile Communications Safety*, London: Chapman & Hall, 1997.

$$SAR_{avg} \approx \frac{d}{2\Delta x} SAR_{surface} (1 - e^{-\frac{2\Delta x}{d}})$$

For 1 Watt feedpoint power,

$$SAR_{avg} \approx \frac{(6.13)}{2(10)} (289.62)(1 - e^{-\frac{2(10)}{(6.13)}})$$

SAR_{avg}= 85.4 W/kg (1g SAR approximated via Kuster-Balzano equation)

Considering that this model is only well suited for 300-3000MHz frequencies[2], a linear extrapolation from known frequencies and validation targets (IEEE Std P1528, Table 7.1) were used as an approximation of the validation target at 5.8 GHz.

	IEEE P1528 Standard	Points from linearity extrapolation approximation	Linearity Deviation from Standard	Kuster-Balzano Approximation Substituted Values	Kuster-Balzano Deviation from Standard
Frequency	**1g SAR**	1g	1g	1g	1g
1900	**39.7**	38.6504	-2.6%	40.8	2.8%
2450	**52.4**	51.8504	-1.0%	54.7	4.4%
3000	**63.8**	65.0504	2.0%	66.4	4.1%

The SAR system was verified at a normalized value of 137.6 W/kg averaged over 1 gram (higher than Kuster-Balzano estimation). This deviated from the approximated target by +4%.

From the analysis, PCTEST has chosen a cautious approximation of the 1 gram target above 3 GHz.

[2] Kuster/Balzano 1992; IEEE P1528-200X Draft 6.5, Sec X5