This document was generated in response to a request for additional technical information by Martin Perrine in regards to the approval of the Permissive Class II application of the KWC-2255. The information included in related to the two specific topics discussed in the following email received by Lin Lu on Feb. 6, 2002:

From: oetech@fccsun34w.fcc.gov
Date: Wed, 6 Feb 2002 17:17:41 -0500 (EST)
To: LLu@qcpi.com
Subject: Request for additional information

To: Lin Lu, Kyocera Wireless Corp.
From: Martin Perrine
mperrine@fcc.gov
FCC Application Processing Branch
Re: FCC ID OVFKWC-2255
Applicant: Kyocera Wireless Corp
Correspondence Reference Number: 21950
731 Confirmation Number: EA937655

Based on your response to correspondence 21913 the FCC requests that you address the following items.

A) In regards to your answer to question 1 we found the probe certificates however we could not find the conversion factors for muscle liquid at 835 and 1900 MHZ. Please locate for us or justify the values chosen.

B) In regards to your answer to question 2, validation in brain simulating liquid at both 835 and 1900 (or 1800 MHZ) is acceptable per supplement C. Please validate your system accordingly and provide sample SAR testing at the highest SAR location in each band to confirm previous measurements.

1) **Conversion factors for muscle liquid at 835 and 1900 MHZ. Please justify the values chosen**

Schmid & Partner Engineering has done a mathematically estimation for probe conversion factors in muscle tissues, based on conversion factors in brain tissues.

According to DASY3-user manual Page 49 and the email from Schmid & Partner Engineering AG, the probe conversion factor in muscle tissue was set to 3% lower than for brain tissue in 900MHz frequency, i.e., 5.7 $_{(brain)}$ – 3% of 5.7 = 5.53 $_{(muscle)}$. And the probe conversion factor in muscle tissue was set to 10% lower than for brain tissue in 1800MHz, i.e., 4.94 $_{(brain)}$ – 10% of 4.94 = 4.5 $_{(muscle)}$. DASY3-user manual and SPEAG email are attached at the end of this report

2) **Validation data in brain stimulating liquid at both 900MHz and 1800MHz and sample SAR testing data in muscle stimulating liquid at the highest SAR location in each band**

As your request, the validation tests in brain stimulating liquid at both bands were conducted and the sample SAR testing in muscle liquid at the highest SAR location in each band was re-performed to confirm previous measurements. The same handset and body-worn accessories were used for this retest. The conducted power level setting for the retest was kept the same as the previous setting, i.e., 26 dBm for FM mode and 23.2 dBm for PCS CDMA mode.

The table below shows the results of the validation testing. Our validation plots and the manufacturer validation data sheets are attached in the following pages.

	Freq.	Brain Liquid Parameters		Validation value when input power=10mW	Validation Date
		Permitivity	Conductivity		
manufacturer validation	900MHz	42.3	0.85 mho/m	0.0944 mW/g	
manufacturer validation	1800MHz	39.5	1.70 mho/m	0.399 mW/g	
Our validation	900MHz	41.7	0.85 mho/m	0.0939 mW/g	Feb. 07, 2002
Our validation	1800MHz	42.1	1.69 mho/m	0.395 mW/g	Feb. 07, 2002

Our validation data is well in conformity with manufacturer validation data.

The following table shows the comparison between the previous data and re-tested data in the highest SAR location.

	Freq.	Brain Liquid Parameters		SAR at the Worst Location	Location	Power Drift (Before & After testing)
		Permitivity	Conductivity			
Previous data	835MHz	55.1	0.96 mho/m	0.436 mW/g	FM mode, Ch383, Antenna Ret.	-0.01 dBm
Re-tested data	835MHz	55.2	0.92 mho/m	0.404 mW/g	same as the above	0.00 dBm
Previous data	1800MHz	54.3	1.56 mho/m	0.260 mW/g	PCS CDMA mode, Ch25, Antenna Ret.	-0.15 dBm
Re-tested data	1800MHz	53.3	1.60 mho/m	0.284 mW/g	same as the above	0.02 dBm

Considering of the +/- 23.8% (K=2) measurement uncertainty reported in the previous report, the re-test data is in a good agreement with the previous data.

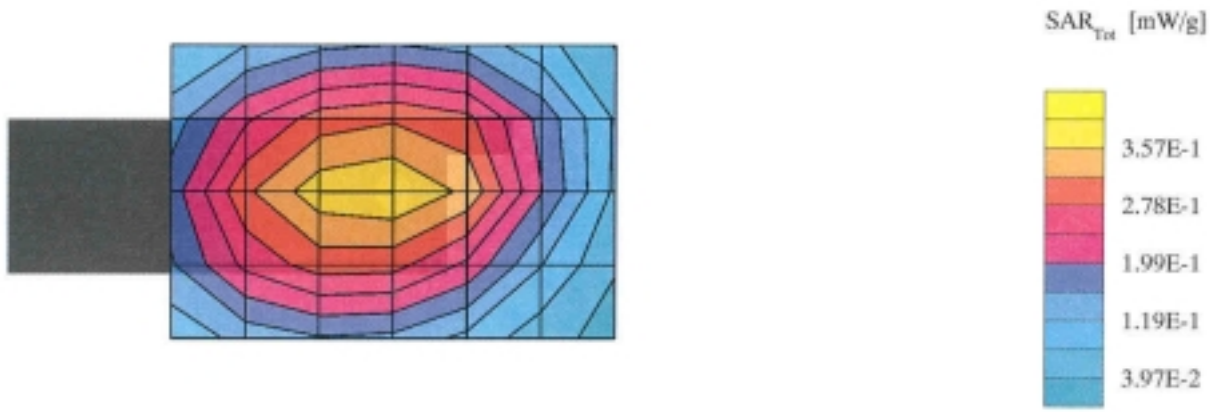
Note that the probe SN1353 used for the previous SAR testing has reached 12 month calibration interval. It has been sent to manufacturer for re-calibration. The probe SN1348 was used for the SAR re-test. The probe (SN1348) calibration certification and complete data report are attached in the following pages. The probe conversion factors in muscle liquid were chosen as 5.66 (5.83 – 3% of 5.83) in 835MHz and 4.62 (5.13 – 10% of 5.13) in 1800MHz.

Re-Tested SAR Plots

KWC 2255, Worst Case in Cellular, FM Ch383, 02-07-02

SAM Phantom; Flat Section
Probe: ET3DV5 - SN1348; ConvF(5.66,5.66,5.66); Crest factor: 1.0
Muscle 835 MHz: $\sigma = 0.92$ mho/m $\varepsilon_r = 55.2$ $\rho = 1.00$ g/cm^3

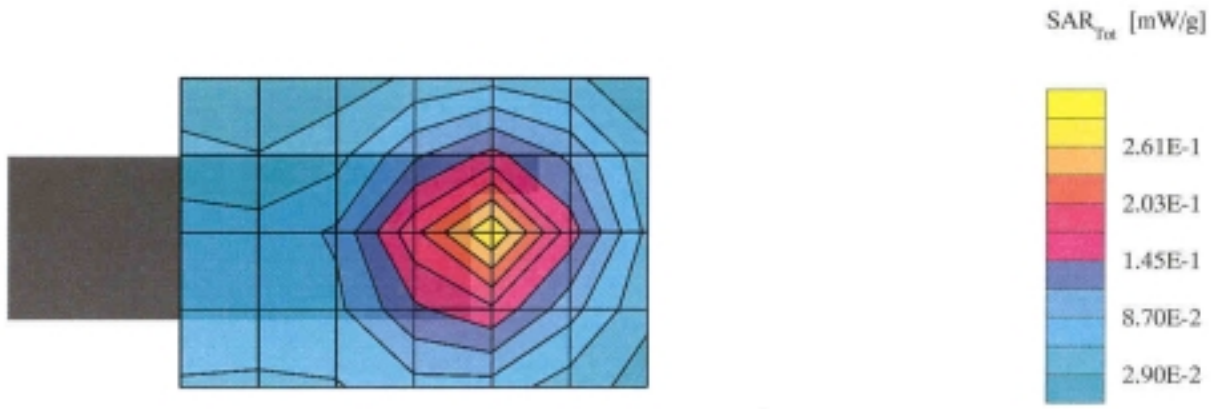
Cubes (2): SAR (1g): 0.404 mW/g ± 0.09 dB, SAR (10g): 0.301 mW/g ± 0.08 dB, (Worst-case extrapolation)
Powerdrift: 0.00 dB



KWC 2255, Worst Case in PCS, Ch25, 02-07-02

SAM Phantom; Flat Section
Probe: ET3DV5 - SN1348; ConvF(4.62,4.62,4.62); Crest factor: 1.0
Muscle 1800 MHz: σ = 1.60 mho/m ε_r = 53.3 ρ = 1.00 g/cm^3

Cubes (2): SAR (1g): 0.284 mW/g ± 0.16 dB, SAR (10g): 0.166 mW/g ± 0.15 dB, (Worst-case extrapolation)
Powerdrift: 0.02 dB



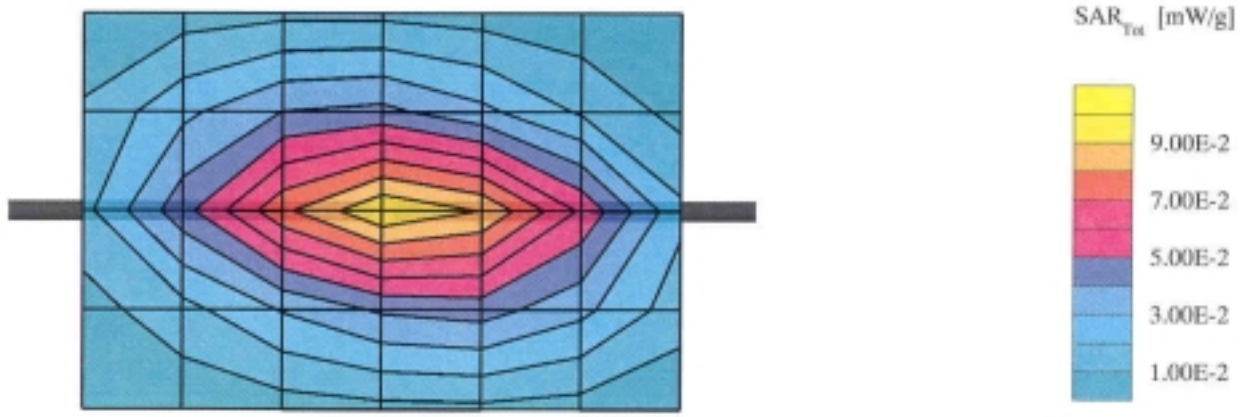
Validation Plots

02/07/02

Validation in 900MHz Brain Liquid. Target Value = 0.0944 mW/g, 02-07-2002

SAM Phantom; Flat Section
Probe: ET3DV5 - SN1348; ConvF(5.83,5.83,5.83); Crest factor: 1.0
Brain 900 MHz: $\sigma = 0.85$ mho/m $\varepsilon_r = 41.7$ $\rho = 1.00$ g/cm^3

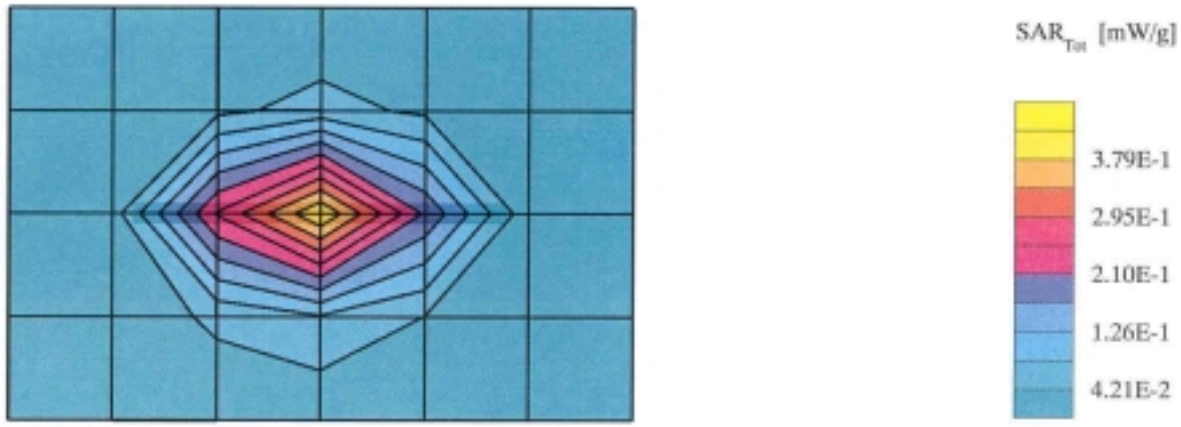
Cubes (2): SAR (1g): 0.0939 mW/g ± 0.05 dB, SAR (10g): 0.0608 mW/g ± 0.05 dB, (Worst-case extrapolation)
Powerdrift: -0.01 dB



Validation in 1800MHz Brain Liquid. Target Value = 0.399 mW/g, 02-07-2002

SAM Phantom; Flat Section
Probe: ET3DV5 - SN1348; ConvF(5.13,5.13,5.13); Crest factor: 1.0
Brain 1800 MHz: σ = 1.69 mho/m ε_r = 42.1 ρ = 1.00 g/cm^3

Cubes (2): SAR (1g): 0.395 mW/g ± 0.09 dB, SAR (10g): 0.198 mW/g ± 0.12 dB, (Worst-case extrapolation)
Powerdrift: -0.00 dB



Manufacturer Validation Data Sheets

Schmid & Partner
Engineering AG

Staffelstrasse 8, 8045 Zurich, Switzerland, Telefon +41 1 280 08 60, Fax +41 1 280 08 64

DASY

Dipole Validation Kit

Type: D900V2

Serial: 024

Manufactured: December 1997
Calibrated: January 1998

1. Measurement Conditions

The measurements were performed in the flat section of the new generic twin phantom (shell thickness 2mm) filled with brain simulating sugar solution of the following electrical parameters at 900 MHz:

Relative Dielectricity	**42.3**	± 5%
Conductivity	**0.85 mho/m**	± 5%

The DASY3 System (Software version 1.0a) with a dosimetric E-field probe ET3DV4 (SN:1302, Conversion factor 5.5) was used for the measurements.

The dipole was mounted on the small tripod so that the dipole feedpoint was positioned below the centre marking of the flat phantom section and the dipole was oriented parallel to the body axis (the long side of the phantom). The standard measuring distance was 15mm from dipole centre to the solution surface. The included distance holder was used during measurements for accurate distance positioning.

The coarse grid with a grid spacing of 15mm was aligned with the dipole. The 5x5x7 fine cube was chosen for cube integration. Probe isotropy errors were cancelled by measuring the SAR with normal and 90° turned probe orientations and averaging. The dipole input power (forward power) was 250mW ± 3 %. The results are normalised to 1W input power.

2. SAR Measurement

Standard SAR-measurements were performed with the phantom according to the measurement conditions described in section 1. The results have been normalised to a dipole input power of 1W (forward power). The resulting averaged SAR-values are:

averaged over 1 cm^3 (1 g) of tissue:	**9.44 mW/g**
averaged over 10 cm^3 (10 g) of tissue:	**6.16 mW/g**

Note: If the liquid parameters for validation are slightly different from the ones used for initial calibration, the SAR-values will be different as well. The estimated sensitivities of SAR-values and penetration depths to the liquid parameters are listed in the DASY Application Note 4: 'SAR Sensitivities'.

3. Dipole Impedance and return loss

The impedance was measured at the SMA-connector with a network analyser and numerically transformed to the dipole feedpoint. The transformation parameters from the SMA-connector to the dipole feedpoint are:

Electrical delay:	**1.397 ns**	(one direction)
Transmission factor:	**0.988**	(voltage transmission, one direction)

The dipole was positioned at the flat phantom sections according to section 1 and the distance holder was in place during impedance measurements.

Feedpoint impedance at 900 MHz:	Re{Z} = **50.2 Ω**
	Im {Z} = **-0.0 Ω**
Return Loss at 900 MHz	**- 54.9 dB**

4. Handling

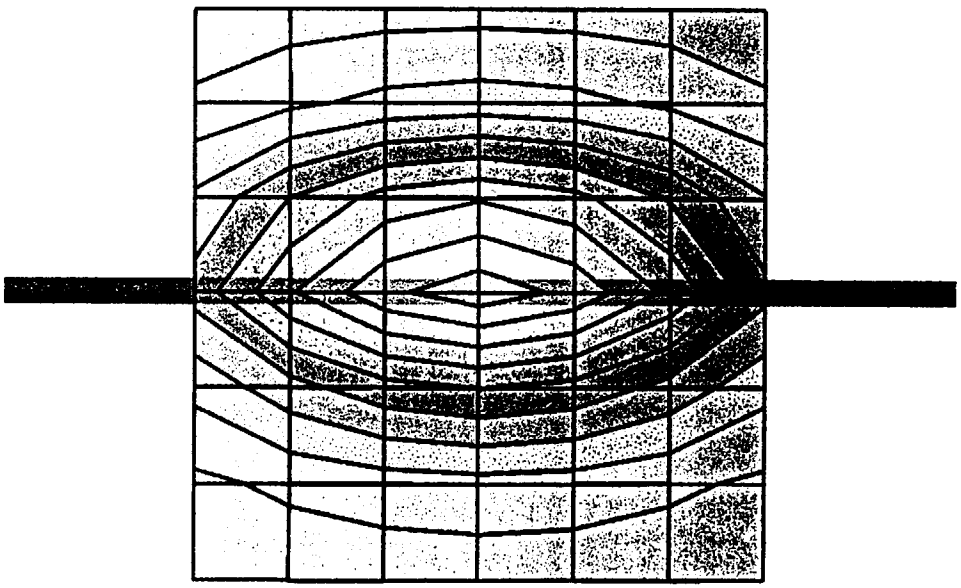
The dipole is made of standard semirigid coaxial cable. The centre conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals.

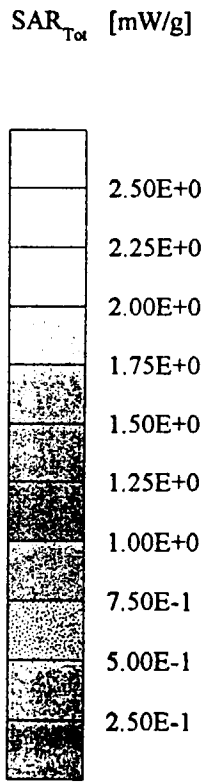
Do not apply excessive force to the dipole arms, because they might bend. If the dipole arms have to be bent back, take care to release stress to the soldered connections near the feedpoint; they might come off.

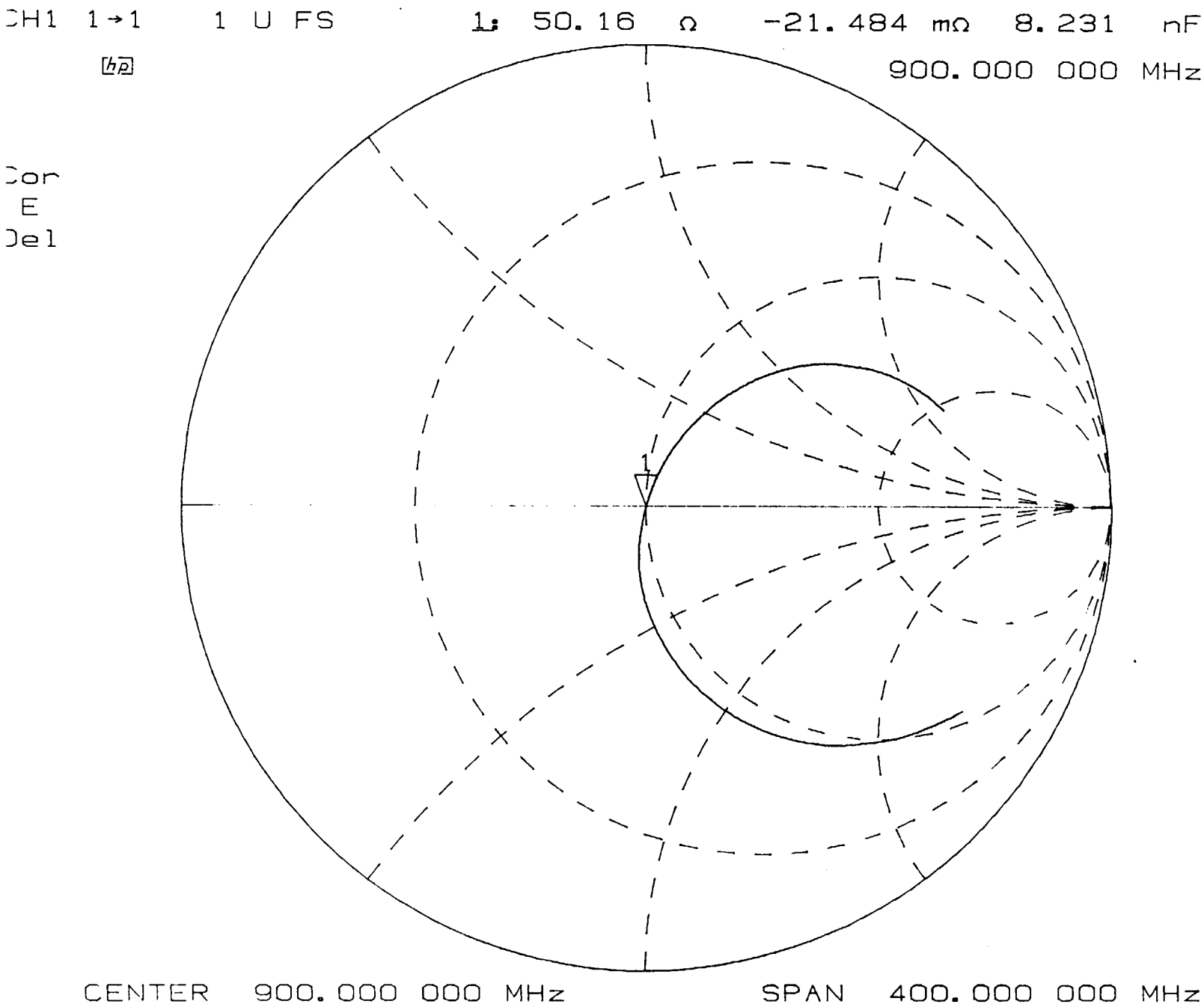
After prolonged use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

alidation Dipole D900V2 SN:024, d = 15mm

:quency: 900 [MHz]; Antanna Input Power: 250 [mW]
neric Twin Phantom; Flat Section; Grid Spacing: Dx = 15.0, Dy = 15.0, Dz = 10.0 [mm]
›be: ET3DV5 - SN1302 DAE3; ConvF(5.40,5.40,5.40); Crest factor: 1.0; }: σ = 0.85 [mho/m] ε_r = 42.3 ρ = 1.00 [g/cm³]
bes (2): Peak: 3.58 [mW/g] ± 0.06 dB, SAR (1g): 2.36 [mW/g] ± 0.05 dB, SAR (10g): 1.54 [mW/g] ± 0.04 dB, (Worst-case extrapolation)
ıetration depth: 13.1 (12.1, 14.4) [mm]
werdrift: 0.03 dB







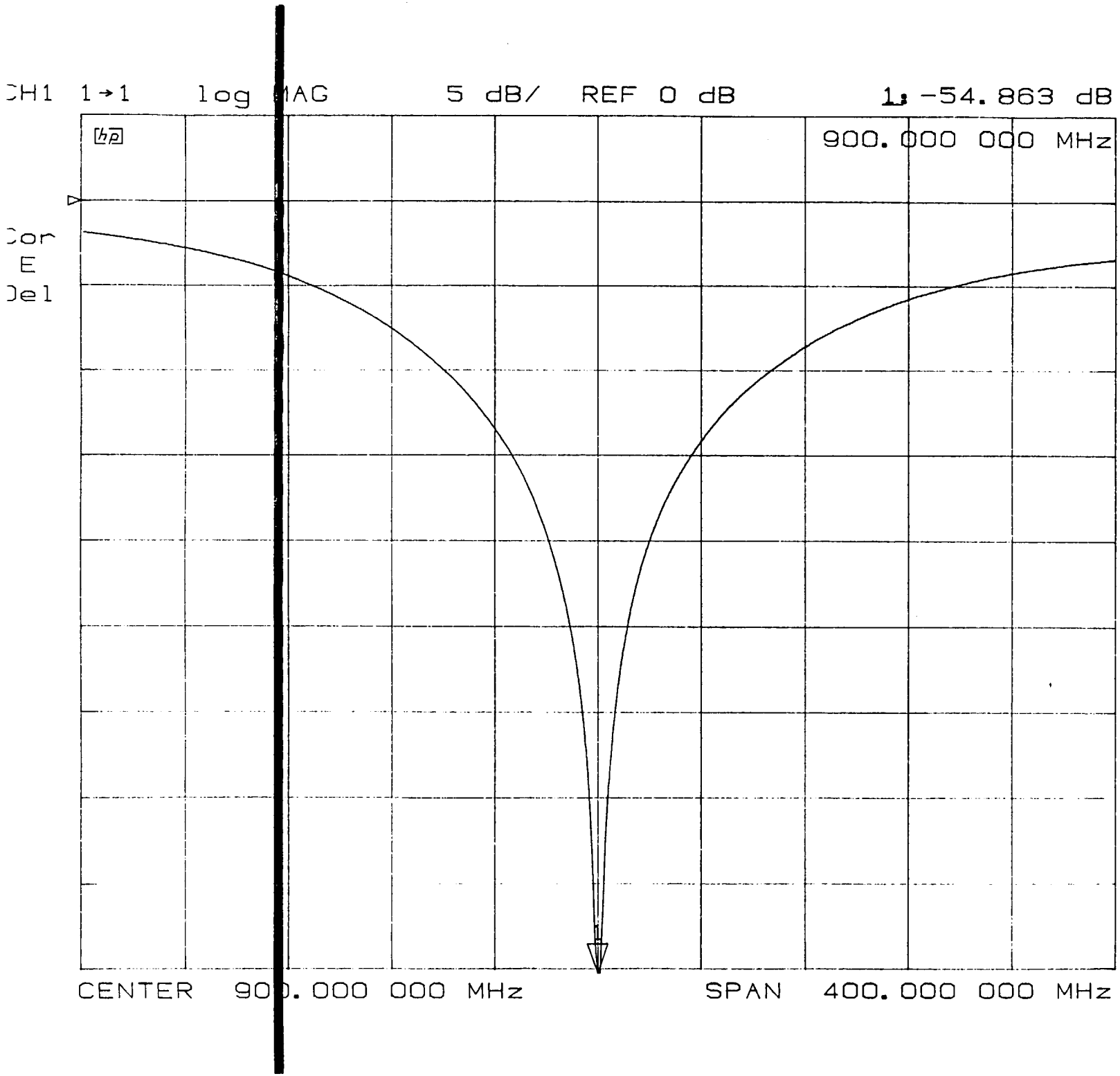
D900V2 SN: 024

S11

Flat phantom with brain simulating solution

d = 15mm

(distance from dipole center to solution)



D900V2 SN: 024

S11

Flat phantom with brain simulating solution

d = 15mm

(distance from dipole center to solution)

Staffelstrasse 8, 8045 Zurich, Switzerland, Telefon +41 1 280 08 60, Fax +41 1 280 08 64

DASY3

Dipole Validation Kit

Type: D1800V2

Serial: 220

Manufactured: December 1997
Calibrated: January 1998

1. Measurement Conditions

The measurements were performed in the flat section of the new generic twin phantom (shell thickness 2mm) filled with brain simulating sugar solution of the following electrical parameters at 1800 MHz:

Relative Dielectricity	**39.5**	± 5%
Conductivity	**1.70 mho/m**	± 10%

The DASY3 System (Software version 3.0b) with a dosimetric E-field probe ET3DV4 (SN:1302, conversion factor 4.6) was used for the measurements.

The dipole feedpoint was positioned below the centre marking and oriented parallel to the body axis (the long side of the phantom). The standard measuring distance was 10mm from dipole centre to the solution surface. The included distance holder was used during measurements for accurate distance positioning.

The coarse grid with a grid spacing of 15mm was aligned with the dipole. The 5x5x7 fine cube was chosen for cube integration. Probe isotropy errors were cancelled by measuring the SAR with normal and 90° turned probe orientations and averaging. The dipole input power (forward power) was 250mW ± 3 %. The results are normalised to 1W input power.

2. SAR Measurement

Standard SAR-measurements were performed with the head phantom according to the measurement conditions described in section 1. The results (see figure) have been normalised to a dipole input power of 1W (forward power). The resulting averaged SAR-values are:

averaged over 1 cm^3 (1 g) of tissue:	**39.9 mW/g**
averaged over 10 cm^3 (10 g) of tissue:	**20.1 mW/g**

Note: If the liquid parameters for validation are slightly different from the ones used for initial calibration, the SAR-values will be different as well. The estimated sensitivities of SAR-values and penetration depths to the liquid parameters are listed in the DASY Application Note 4: 'SAR Sensitivities'.

3. Dipole Impedanc and return loss

The impedance was measured at the SMA-connector with a network analyser and numerically transformed to the dipole feedpoint. The transformation parameters from the SMA-connector to the dipole feedpoint are:

Electrical delay:	**1.178 ns**	(one direction)
Transmission factor:	**0.993**	(voltage transmission, one direction)

The dipole was positioned at the flat phantom sections according to section 1 and the distance holder was in place during impedance measurements.

Feedpoint impedance at 1800 MHz:	Re{Z} = **49.5 Ω**
	Im {Z} = **0.6 Ω**
Return Loss at 1800 MHz	**- 42.1 dB**

4. Handling

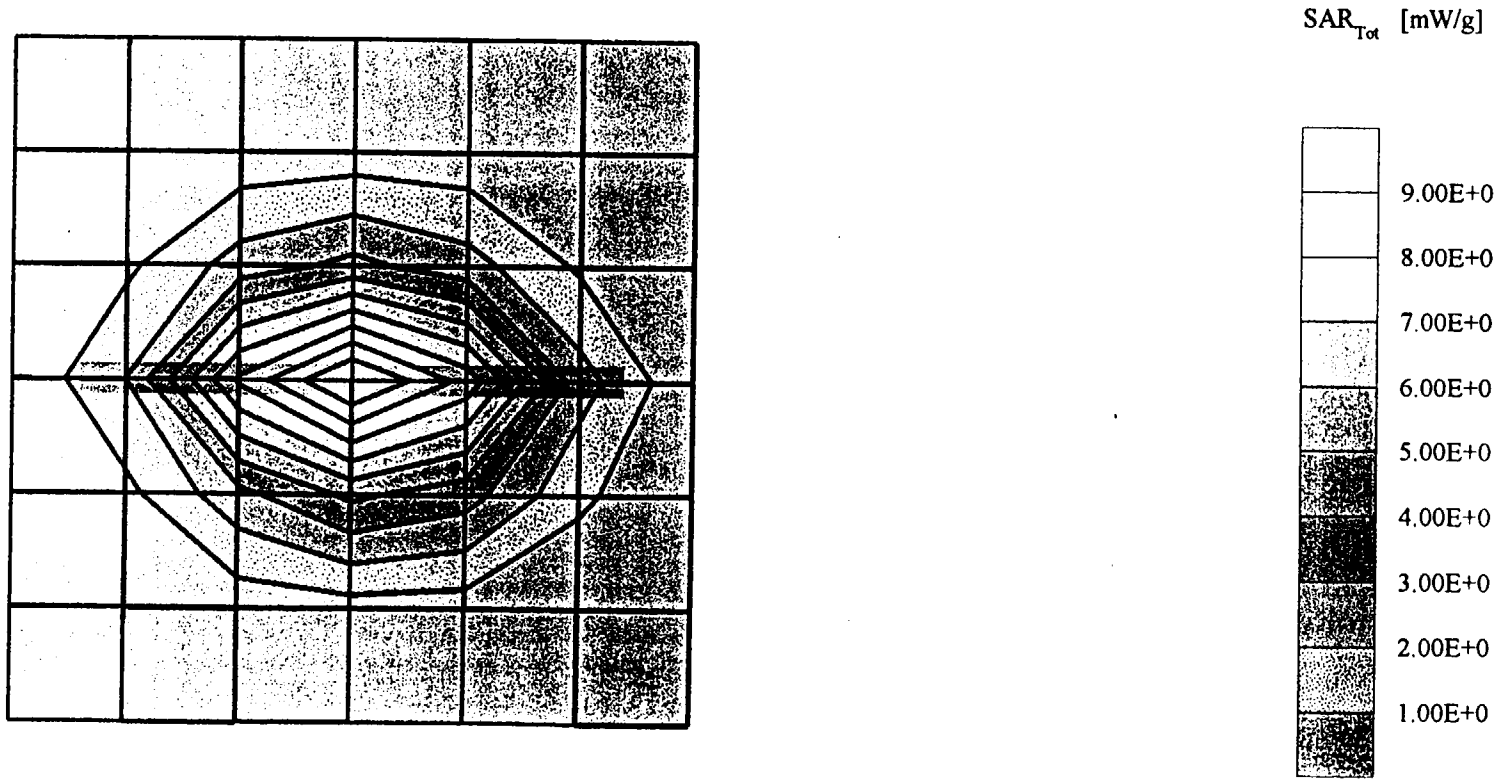
The dipole is made of standard semirigid coaxial cable. The centre conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals.

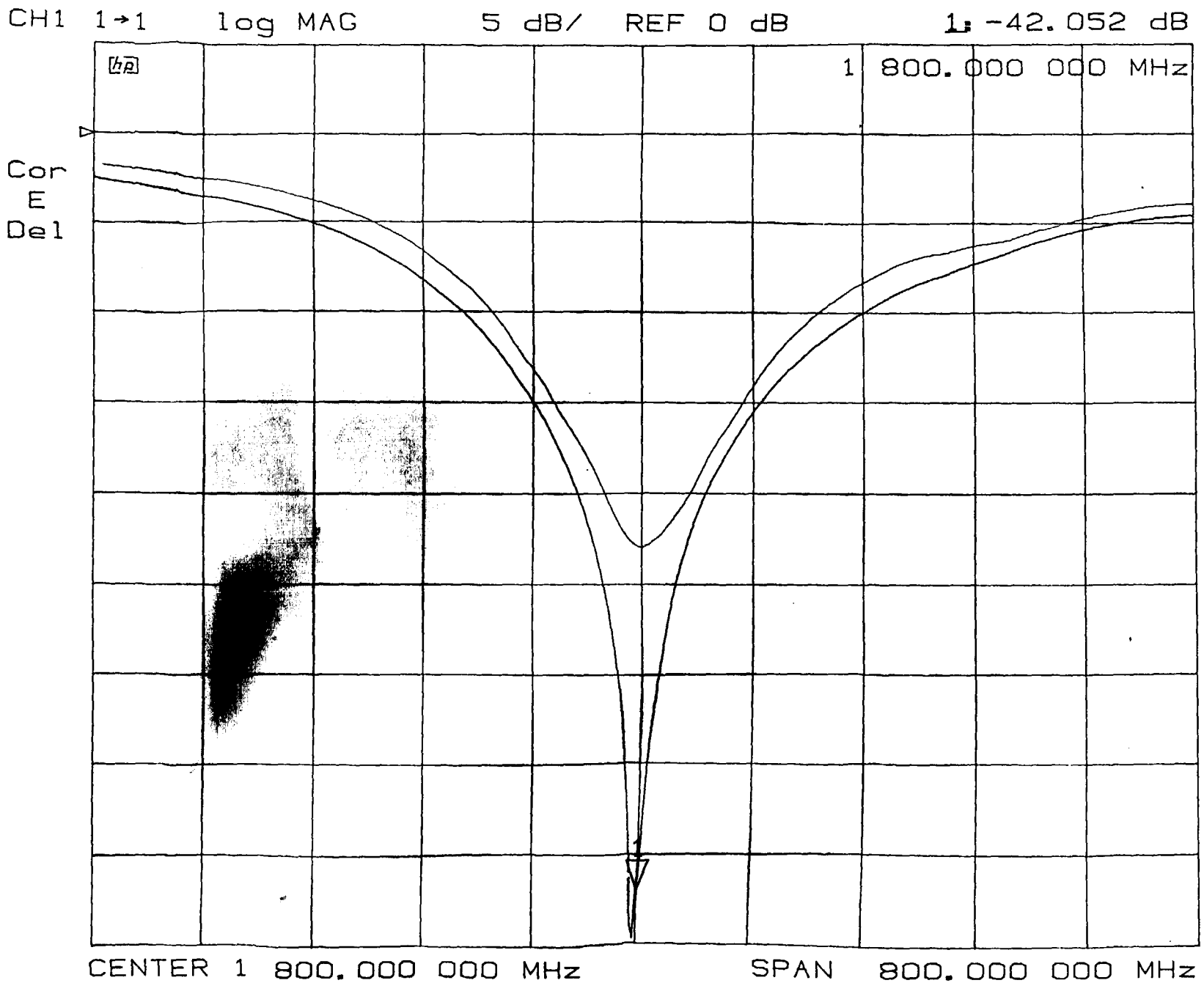
Do not apply excessive force to the dipole arms, because they might bend. If the dipole arms have to be bent back, take care to release stress to the soldered connections near the feedpoint; they might come off.

After prolonged use with 40W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

Validation Dipole D1800V2 SN:220, d = 10mm

Frequency: 1800 [MHz]; Antanna Input Power: 250 [mW]
Generic Twin Phantom; Flat Section; Grid Spacing: Dx = 15.0, Dy = 15.0, Dz = 10.0 [mm]
Probe: ET3DV5 - SN1302 DAE3; ConvF(4.60,4.60,4.60); Crest factor: 1.0; }: σ = 1.70 [mho/m] ε_r = 39.5 ρ = 1.00 [g/cm^3]
Cubes (2): Peak: 19.2 [mW/g] ± 0.06 dB, SAR (1g): 9.97 [mW/g] ± 0.05 dB, SAR (10g): 5.02 [mW/g] ± 0.04 dB, (Worst-case extrapolation)
Penetration depth: 7.4 (7.2, 8.0) [mm]
Powerdrift: 0.03 dB





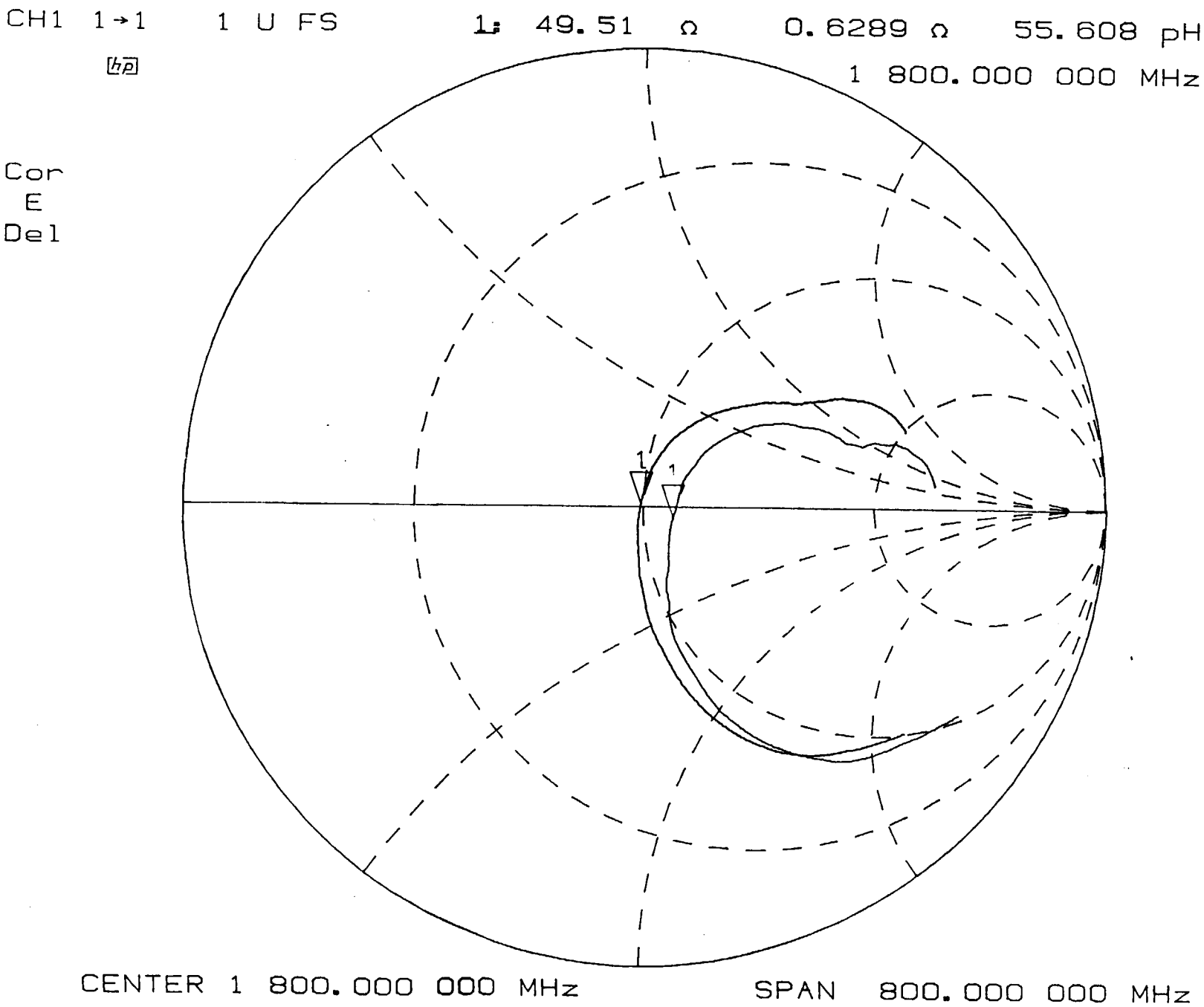
D1800V2 SN

S11

Flat phantom wi
brain simulating
solution

blk: d = 10mm
red: d = 20mm

(distance from dipo
center to solution)



D1800V2 SN

S11

Flat phantom wi
brain simulating
solution

blk: d = 10mm
red: d = 20mm

(distance from dipo
center to solution)

Dielectric Data Sheets

(used for SAR re-test)

Reference math : OFF Title: 02-07-02

835 MHz Muscle

Pt#	Frequency (GHz)	Data real	Data imag
1	0.000100000	3582.54	-2054.27
2	0.015099500	66.57	367.02
3	0.030099000	67.37	176.89
4	0.045098500	66.71	118.57
5	0.060098000	65.13	90.07
6	0.075097500	65.08	73.30
7	0.090097000	64.99	62.20
8	0.105096500	64.47	54.33
9	0.120096000	63.97	48.45
10	0.135095500	63.54	43.77
11	0.150095000	63.37	40.27
12	0.165094500	63.08	37.48
13	0.180094000	62.91	34.98
14	0.195093500	62.59	32.89
15	0.210093000	62.24	31.31
16	0.225092500	62.06	29.82
17	0.240092000	61.80	28.67
18	0.255091500	61.49	27.55
19	0.270091000	61.35	26.61
20	0.285090500	61.12	25.70
21	0.300090000	60.91	25.03
22	0.315089500	60.64	24.37
23	0.330089000	60.55	23.72
24	0.345088500	60.29	23.20
25	0.360088000	60.11	22.78
26	0.375087500	59.90	22.34
27	0.390087000	59.71	21.94
28	0.405086500	59.59	21.64
29	0.420086000	59.40	21.32
30	0.435085500	59.21	20.99
31	0.450085000	59.06	20.78
32	0.465084500	58.92	20.56
33	0.480084000	58.71	20.34
34	0.495083500	58.54	20.09
35	0.510083000	58.36	20.01
36	0.525082500	58.22	19.82
37	0.540082000	58.07	19.63
38	0.555081500	57.93	19.48
39	0.570081000	57.76	19.36
40	0.585080500	57.60	19.28
41	0.600080000	57.47	19.16
42	0.615079500	57.29	19.04
43	0.630079000	57.15	18.98
44	0.645078500	57.00	18.92
45	0.660078000	56.85	18.86
46	0.675077500	56.71	18.77
47	0.690077000	56.55	18.73
48	0.705076500	56.42	18.66
49	0.720076000	56.27	18.65
50	0.735075500	56.14	18.55
51	0.750075000	56.01	18.52
52	0.765074500	55.87	18.48
53	0.780074000	55.72	18.46
54	0.795073500	55.54	18.42
55	0.810073000	55.45	18.40
56	0.825072500	55.29	18.40
57	0.840072000	55.19	18.37 → $\sigma = 0.92$ mho/m
58	0.855071500	55.03	18.35
59	0.870071000	54.87	18.33
60	0.885070500	54.75	18.31
61	0.900070000	54.65	18.31
62	0.915069500	54.53	18.30
63	0.930069000	54.41	18.31
64	0.945068500	54.27	18.27
65	0.960068000	54.13	18.25
66	0.975067500	53.98	18.23
67	0.990067000	53.90	18.24
68	1.005066500	53.76	18.25
69	1.020066000	53.64	18.30
70	1.035065500	53.56	18.28

71	1.050065000	53.42	18.26
72	1.065064500	53.29	18.29
73	1.080064000	53.13	18.30
74	1.095063500	53.01	18.33
75	1.110063000	52.90	18.31
76	1.125062500	52.79	18.28
77	1.140062000	52.69	18.29
78	1.155061500	52.59	18.30
79	1.170061000	52.50	18.32
80	1.185060500	52.38	18.34
81	1.200060000	52.24	18.37
82	1.215059500	52.12	18.40
83	1.230059000	52.02	18.42
84	1.245058500	51.90	18.42
85	1.260058000	51.78	18.43
86	1.275057500	51.67	18.42
87	1.290057000	51.55	18.43
88	1.305056500	51.45	18.44
89	1.320056000	51.36	18.47
90	1.335055500	51.23	18.50
91	1.350055000	51.15	18.49
92	1.365054500	51.04	18.53
93	1.380054000	50.93	18.53
94	1.395053500	50.83	18.55
95	1.410053000	50.73	18.57
96	1.425052500	50.63	18.60
97	1.440052000	50.53	18.63
98	1.455051500	50.44	18.66
99	1.470051000	50.33	18.69
100	1.485050500	50.21	18.70
101	1.500050000	50.11	18.70
102	1.515049500	50.00	18.73
103	1.530049000	49.88	18.76
104	1.545048500	49.79	18.77
105	1.560048000	49.67	18.80
106	1.575047500	49.56	18.81
107	1.590047000	49.46	18.81
108	1.605046500	49.35	18.82
109	1.620046000	49.27	18.83
110	1.635045500	49.17	18.85
111	1.650045000	49.09	18.88
112	1.665044500	48.98	18.88
113	1.680044000	48.87	18.88
114	1.695043500	48.79	18.93
115	1.710043000	48.70	18.92
116	1.725042500	48.61	18.95
117	1.740042000	48.52	18.96
118	1.755041500	48.43	18.98
119	1.770041000	48.31	19.00
120	1.785040500	48.24	19.04
121	1.800040000	48.15	19.06
122	1.815039500	48.06	19.07
123	1.830039000	47.96	19.07
124	1.845038500	47.86	19.08
125	1.860038000	47.75	19.10
126	1.875037500	47.66	19.12
127	1.890037000	47.58	19.13
128	1.905036500	47.50	19.13
129	1.920036000	47.41	19.13
130	1.935035500	47.31	19.14
131	1.950035000	47.23	19.13
132	1.965034500	47.18	19.16
133	1.980034000	47.10	19.17
134	1.995033500	47.03	19.17
135	2.010033000	46.98	19.18
136	2.025032500	46.90	19.20
137	2.040032000	46.84	19.24
138	2.055031500	46.76	19.28
139	2.070031000	46.69	19.32
140	2.085030500	46.62	19.36
141	2.100030000	46.53	19.37
142	2.115029500	46.43	19.40
143	2.130029000	46.35	19.42
144	2.145028500	46.26	19.45

Reference math : OFF Title: 02-07-02

1800 MHz Muscle

Pt#	Frequency (GHz)	Data real	Data imag
1	0.000100000	219.70	-73.26
2	0.015099500	67.01	9.44
3	0.030099000	66.76	4.80
4	0.045098500	66.54	4.37
5	0.060098000	66.22	4.64
6	0.075097500	66.16	3.96
7	0.090097000	66.25	4.22
8	0.105096500	66.08	4.31
9	0.120096000	65.73	4.39
10	0.135095500	65.41	4.51
11	0.150095000	65.50	4.70
12	0.165094500	65.19	4.89
13	0.180094000	65.20	4.96
14	0.195093500	65.04	5.11
15	0.210093000	64.79	5.37
16	0.225092500	64.66	5.50
17	0.240092000	64.53	5.61
18	0.255091500	64.46	5.85
19	0.270091000	64.31	5.96
20	0.285090500	64.14	6.09
21	0.300090000	64.04	6.25
22	0.315089500	63.85	6.43
23	0.330089000	63.76	6.55
24	0.345088500	63.63	6.75
25	0.360088000	63.52	6.86
26	0.375087500	63.36	7.05
27	0.390087000	63.25	7.23
28	0.405086500	63.13	7.36
29	0.420086000	62.99	7.50
30	0.435085500	62.90	7.65
31	0.450085000	62.79	7.78
32	0.465084500	62.71	7.96
33	0.480084000	62.52	8.04
34	0.495083500	62.37	8.25
35	0.510083000	62.30	8.45
36	0.525082500	62.16	8.57
37	0.540082000	62.06	8.68
38	0.555081500	61.93	8.79
39	0.570081000	61.79	8.93
40	0.585080500	61.68	9.07
41	0.600080000	61.57	9.19
42	0.615079500	61.45	9.34
43	0.630079000	61.35	9.45
44	0.645078500	61.23	9.59
45	0.660078000	61.08	9.71
46	0.675077500	60.98	9.82
47	0.690077000	60.86	9.97
48	0.705076500	60.74	10.09
49	0.720076000	60.64	10.22
50	0.735075500	60.53	10.32
51	0.750075000	60.42	10.46
52	0.765074500	60.31	10.54
53	0.780074000	60.20	10.68
54	0.795073500	60.06	10.78
55	0.810073000	59.95	10.90
56	0.825072500	59.83	11.02
57	0.840072000	59.71	11.11
58	0.855071500	59.59	11.23
59	0.870071000	59.48	11.34
60	0.885070500	59.38	11.41
61	0.900070000	59.27	11.53
62	0.915069500	59.15	11.63
63	0.930069000	59.07	11.74
64	0.945068500	58.95	11.82
65	0.960068000	58.82	11.89
66	0.975067500	58.70	12.00
67	0.990067000	58.60	12.08
68	1.005066500	58.49	12.21
69	1.020066000	58.40	12.34
70	1.035065500	58.31	12.42

71	1.050065000	58.19	12.49
72	1.065064500	58.07	12.60
73	1.080064000	57.95	12.68
74	1.095063500	57.82	12.76
75	1.110063000	57.71	12.86
76	1.125062500	57.62	12.91
77	1.140062000	57.53	12.98
78	1.155061500	57.45	13.07
79	1.170061000	57.37	13.15
80	1.185060500	57.27	13.25
81	1.200060000	57.14	13.35
82	1.215059500	57.03	13.44
83	1.230059000	56.93	13.53
84	1.245058500	56.82	13.58
85	1.260058000	56.70	13.66
86	1.275057500	56.60	13.74
87	1.290057000	56.49	13.82
88	1.305056500	56.43	13.88
89	1.320056000	56.33	13.97
90	1.335055500	56.22	14.03
91	1.350055000	56.14	14.10
92	1.365054500	56.04	14.19
93	1.380054000	55.91	14.25
94	1.395053500	55.82	14.34
95	1.410053000	55.75	14.42
96	1.425052500	55.66	14.48
97	1.440052000	55.56	14.56
98	1.455051500	55.47	14.63
99	1.470051000	55.35	14.71
100	1.485050500	55.24	14.79
101	1.500050000	55.16	14.85
102	1.515049500	55.04	14.92
103	1.530049000	54.93	15.00
104	1.545048500	54.86	15.05
105	1.560048000	54.73	15.10
106	1.575047500	54.62	15.17
107	1.590047000	54.52	15.22
108	1.605046500	54.42	15.27
109	1.620046000	54.35	15.34
110	1.635045500	54.26	15.40
111	1.650045000	54.17	15.46
112	1.665044500	54.08	15.49
113	1.680044000	53.97	15.54
114	1.695043500	53.87	15.61
115	1.710043000	53.80	15.67
116	1.725042500	53.72	15.72
117	1.740042000	53.63	15.79
118	1.755041500	53.54	15.84
119	1.770041000	53.43	15.89
120	1.785040500	53.34	15.96
121	1.800040000	53.26	16.02 → $\sigma = 1.6$ mho/m
122	1.815039500	53.17	16.07
123	1.830039000	53.07	16.11
124	1.845038500	52.98	16.16
125	1.860038000	52.88	16.20
126	1.875037500	52.79	16.26
127	1.890037000	52.69	16.30
128	1.905036500	52.62	16.33
129	1.920036000	52.54	16.38
130	1.935035500	52.45	16.42
131	1.950035000	52.37	16.43
132	1.965034500	52.31	16.47
133	1.980034000	52.23	16.51
134	1.995033500	52.17	16.54
135	2.010033000	52.11	16.59
136	2.025032500	52.05	16.64
137	2.040032000	52.00	16.72
138	2.055031500	51.92	16.78
139	2.070031000	51.85	16.85
140	2.085030500	51.76	16.91
141	2.100030000	51.68	16.97
142	2.115029500	51.60	17.02
143	2.130029000	51.52	17.08
144	2.145028500	51.44	17.15

Probe Certificate and Data Report

Schmid & Partner
Engineering AG

Zeughausstrasse 43, 8004 Zurich, Switzerland, Phone +41 1 245 97 00, Fax +41 1 245 97 79

Calibration Certificate

Dosimetric E-Field Probe

Type:	**ET3DV5**
Serial Number:	**1348**
Place of Calibration:	**Zurich**
Date of Calibration:	**June 18, 2001**
Calibration Interval:	**12 months**

Schmid & Partner Engineering AG hereby certifies, that this device has been calibrated on the date indicated above. The calibration was performed in accordance with specifications and procedures of Schmid & Partner Engineering AG.

Wherever applicable, the standards used in the calibration process are traceable to international standards. In all other cases the standards of the Laboratory for EMF and Microwave Electronics at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland have been applied.

Calibrated by:	Nikolaski Neviana
Approved by:	Bokovic Katja

DASY3 - Parameters of Probe: ET3DV5 SN:1348

Sensitivity in Free Space

NormX	**1.47**	$\mu V/(V/m)^2$
NormY	**1.68**	$\mu V/(V/m)^2$
NormZ	**1.93**	$\mu V/(V/m)^2$

Diode Compression

DCP X	**94**	mV
DCP Y	**94**	mV
DCP Z	**94**	mV

Sensitivity in Tissue Simulating Liquid

Brain **450 MHz** ε_r **= 48 ± 5%** σ **= 0.50 ± 10% mho/m**

ConvF X	**6.19**	extrapolated	Boundary effect:	
ConvF Y	**6.19**	extrapolated	Alpha	**0.76**
ConvF Z	**6.19**	extrapolated	Depth	**1.38**

Brain **900 MHz** ε_r **= 42.5 ± 5%** σ **= 0.86 ± 10% mho/m**

ConvF X	**5.83**	± 7% (k=2)	Boundary effect:	
ConvF Y	**5.83**	± 7% (k=2)	Alpha	**0.70**
ConvF Z	**5.83**	± 7% (k=2)	Depth	**1.63**

Brain **1500 MHz** ε_r **= 41 ± 5%** σ **= 1.32 ± 10% mho/m**

ConvF X	**5.36**	interpolated	Boundary effect:	
ConvF Y	**5.36**	interpolated	Alpha	**0.62**
ConvF Z	**5.36**	interpolated	Depth	**1.95**

Brain **1800 MHz** ε_r **= 41 ± 5%** σ **= 1.69 ± 10% mho/m**

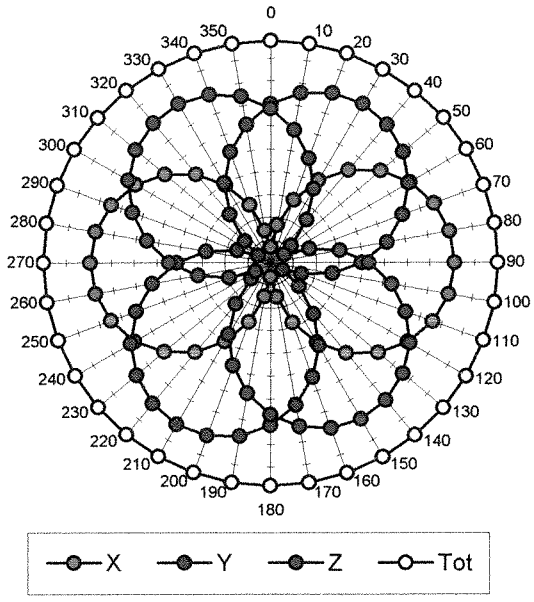
ConvF X	**5.13**	± 7% (k=2)	Boundary effect:	
ConvF Y	**5.13**	± 7% (k=2)	Alpha	**0.58**
ConvF Z	**5.13**	± 7% (k=2)	Depth	**2.11**

Sensor Offset

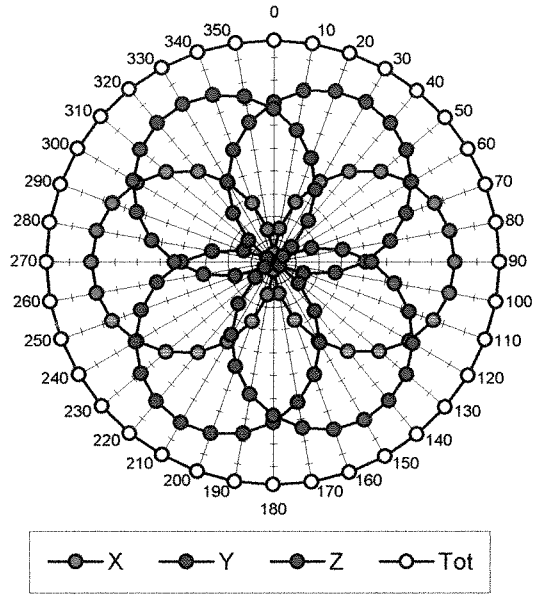
Probe Tip to Sensor Center	**2.7**	mm
Optical Surface Detection	**1.5 ± 0.2**	mm

Receiving Pattern (ϕ), θ = 0°

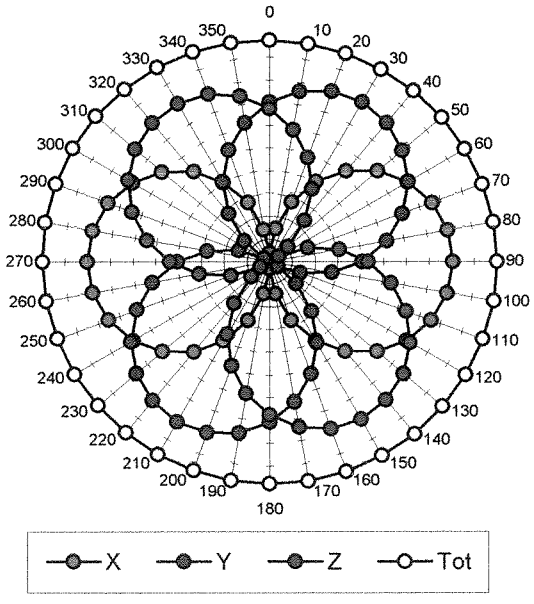
f = 30 MHz, TEM cell ifi110



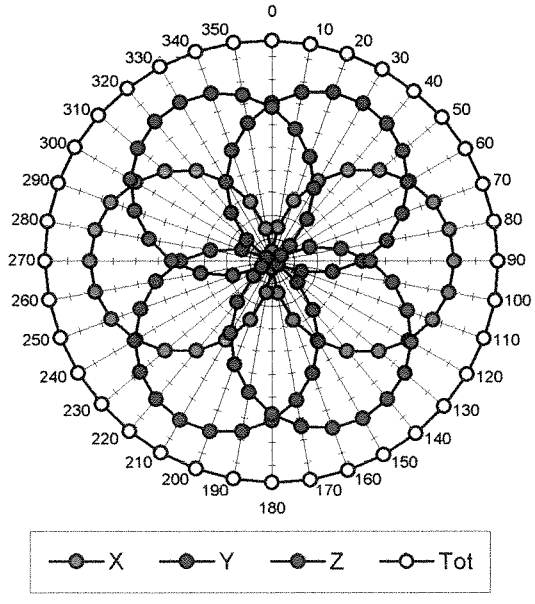
f = 100 MHz, TEM cell ifi110

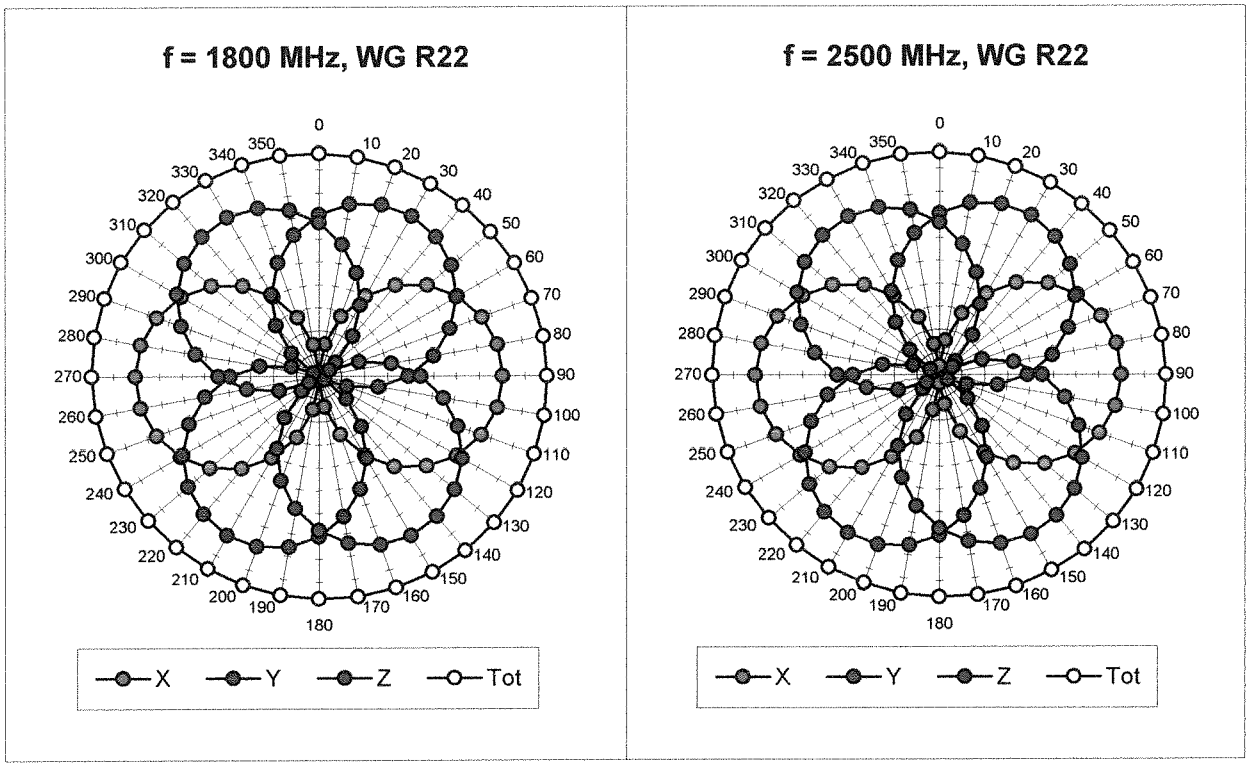


f = 300 MHz, TEM cell ifi110

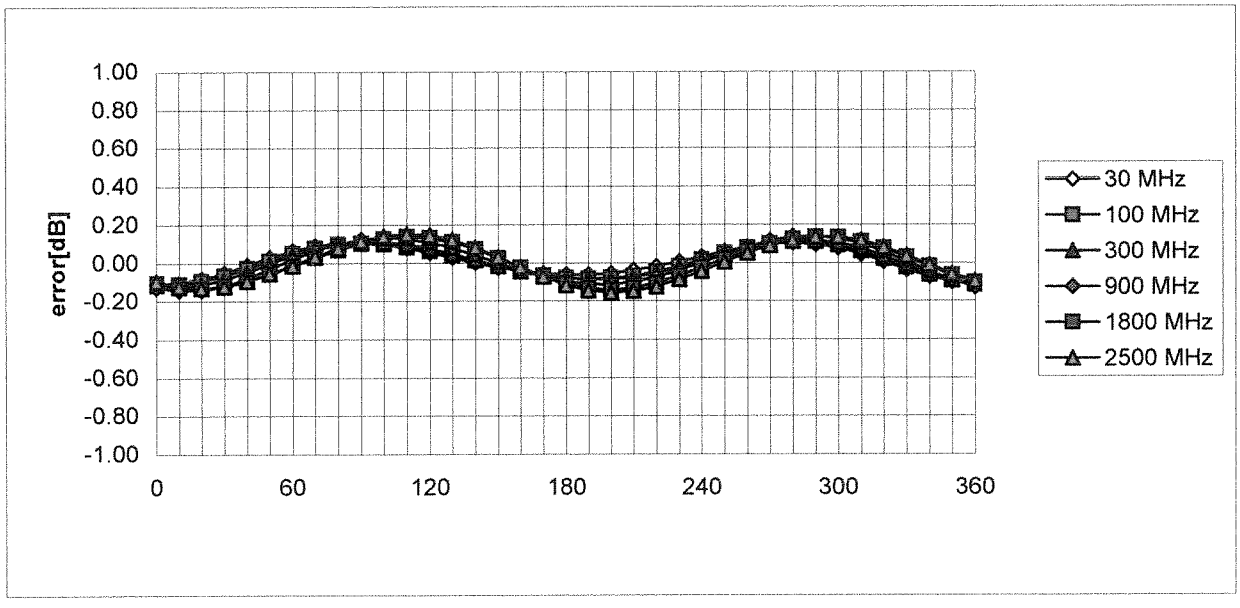


f = 900 MHz, TEM cell ifi110



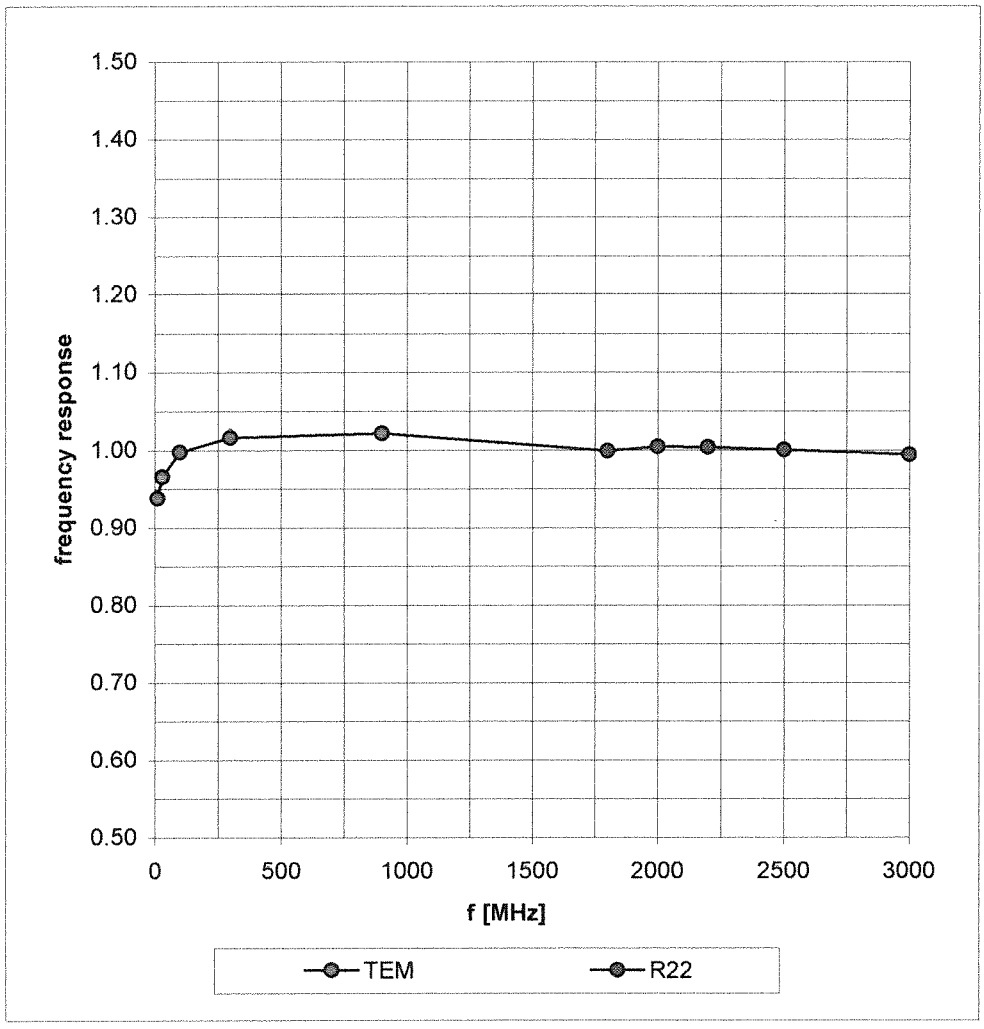


Isotropy Error (ϕ), θ = 0°



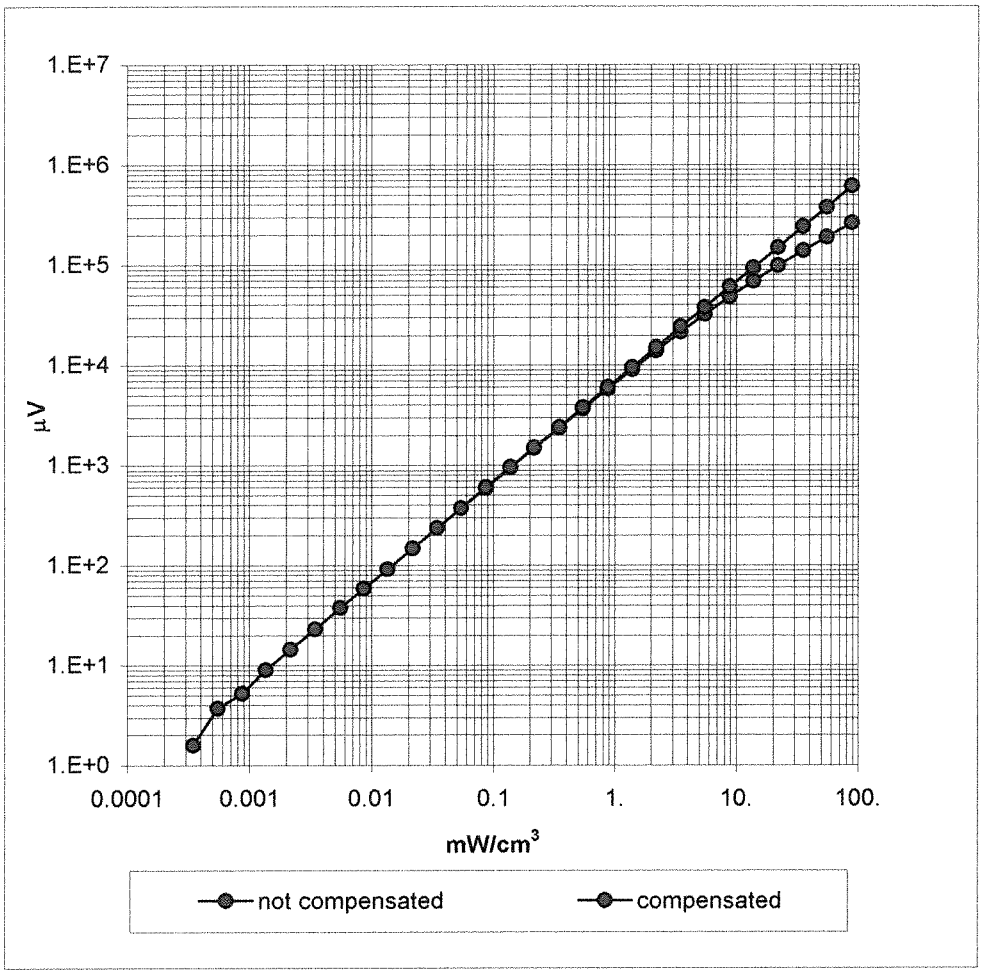
Frequency Response of E-Field

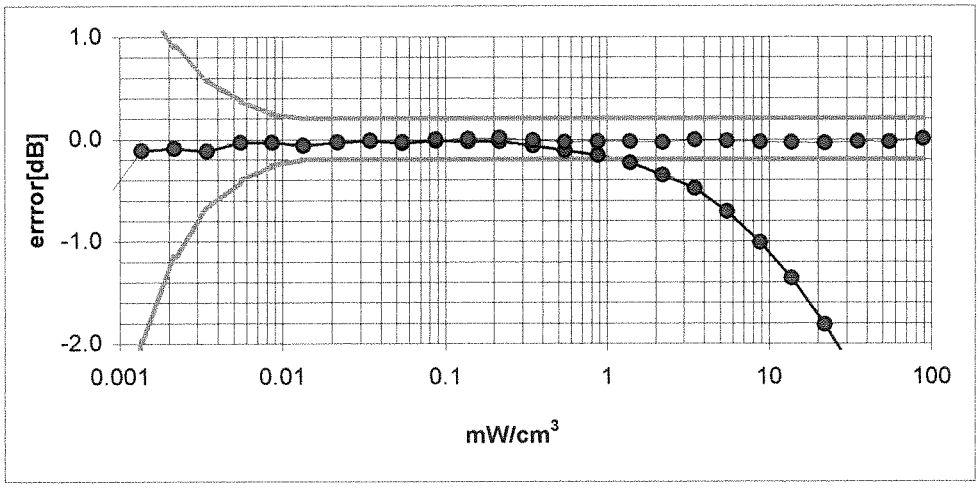
(TEM-Cell:ifi110, Waveguide R22)



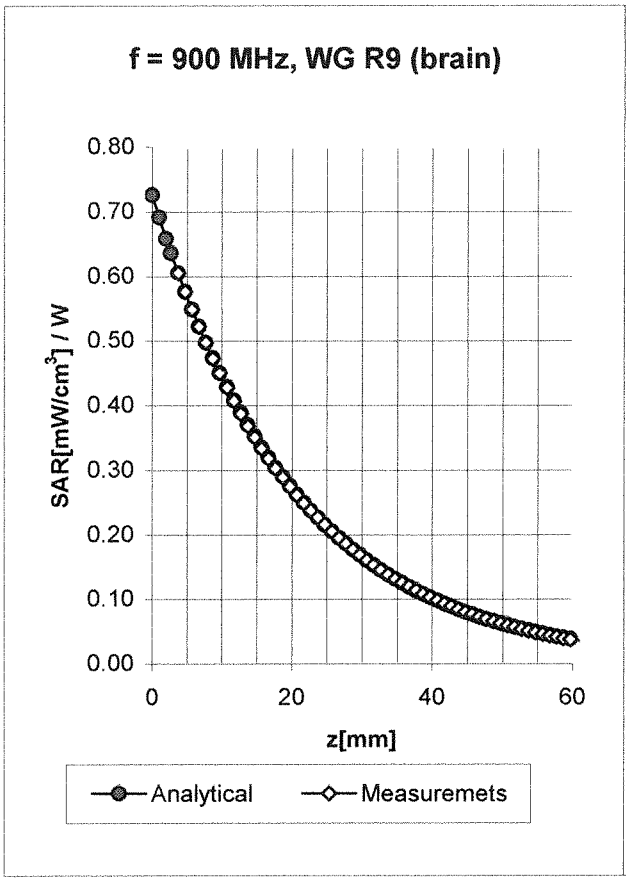
Dynamic Range f(SAR_{brain})

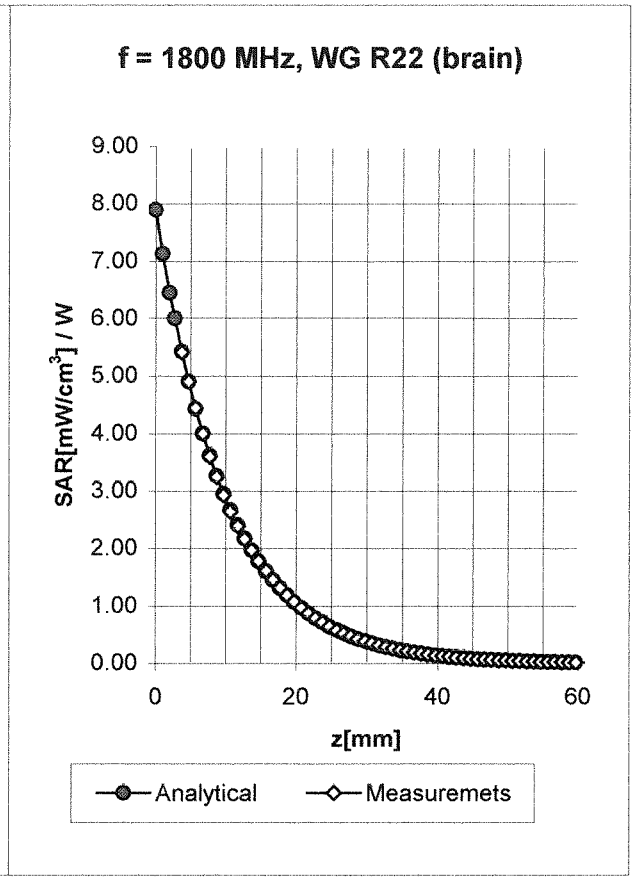
(TEM-Cell:ifi110)





Conversion Factor Assessment





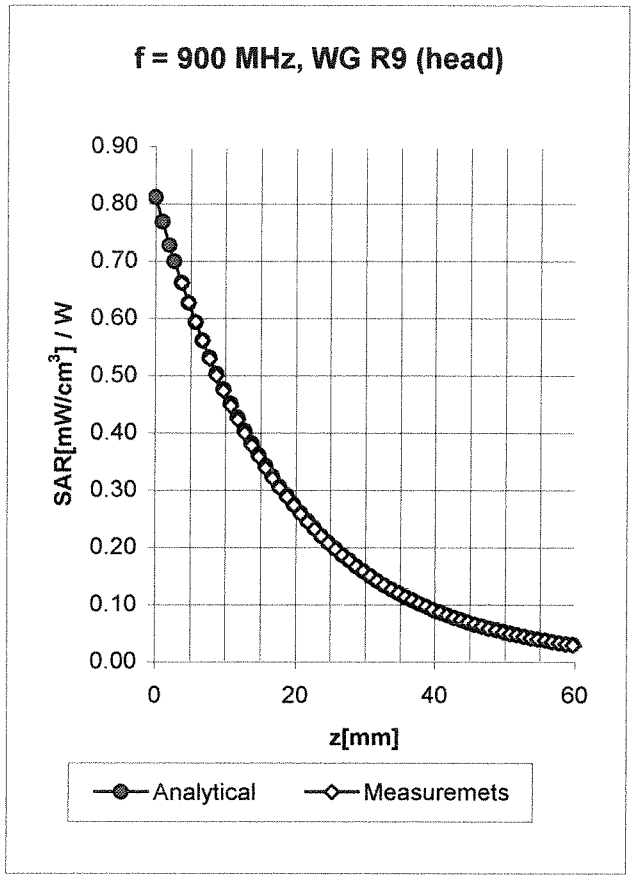
Brain **900 MHz** ε_r **= 42.5 ± 5%** σ **= 0.86 ± 10% mho/m**

ConvF X	**5.83**	± 7% (k=2)	Boundary effect:	
ConvF Y	**5.83**	± 7% (k=2)	Alpha	**0.70**
ConvF Z	**5.83**	± 7% (k=2)	Depth	**1.63**

Brain **1800 MHz** ε_r **= 41 ± 5%** σ **= 1.69 ± 10% mho/m**

ConvF X	**5.13**	± 7% (k=2)	Boundary effect:	
ConvF Y	**5.13**	± 7% (k=2)	Alpha	**0.58**
ConvF Z	**5.13**	± 7% (k=2)	Depth	**2.11**

Conversion Factor Assessment



Head	**900 MHz**	ε_r **= 42 ± 5%**	σ **= 0.97 ± 10% mho/m**

ConvF X	**6.00**	± 7% (k=2)	Boundary effect:	
ConvF Y	**6.00**	± 7% (k=2)	Alpha	**1.45**
ConvF Z	**6.00**	± 7% (k=2)	Depth	**1.19**

SPEAG's email

X-Sender: pokovic.speagcom@mail.speag.com
Message-Id: <v04210106b5530a3b8cba@[192.168.0.106]>
Date: Thu, 25 May 2000 18:53:22 +0200
To: llu@qualcomm.com
From: Katja Pokovic <pokovic@speag.com>
Subject: probe 1348 - estimate for muscle tissue
Cc: egger@speag.com
Content-Type: text/plain; charset="us-ascii" ; format="flowed"
X-UIDL: f094fb92ae0ff3f05efa23d23d38e279

hi,

i hope this time it will work out!

so the very quick estimate is that the conversion factor will be
about 10% lower for muscle tissue at 1800 MHz (eps=54.3, sig=1.45)
compared to the brain tissue at the same frequency (i.e.,at 1800 MHz
with eps=40.5, sig=1.69).
the document will be fax to you soon.
best, katja

Katja Pokovic
Schmid & Partner
Engineering AG

Zeughausstrasse 43, 8004 Zurich, Switzerland
Phone +41 1 245 9707, Fax +41 1 245 9779
WWW http://www.speag.com

DASY3 - User Manual

Content

1. Introduction

2. Hardware

3. Robot

4. Software

5. Troubleshooting

COPYRIGHT

Copyright © 1994-1999 Schmid & Partner Engineering AG. All rights reserved.

This document is being furnished by Schmid & Partner Engineering AG for information purposes only to licensed users of the DASY3 software product and is furnished on an "AS IS" basis, that is, without any warranties, whatsoever, express or implied.

Other brand and product names are trademarks or registered trademarks of the respective holders. Microsoft is a registered trademark and Windows, Windows NT are registered trademarks of the Microsoft Corporation.

Information in this document is subject to change without notice. The software described in this document is furnished under a license agreement. The software may be used or copied only in accordance with the terms of those agreements. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or any means electronic or mechanical, including photocopying and recording for any purpose other than the purchaser's personal use without the written permission of Schmid & Partner Engineering AG.

Schmid & Partner Engineering AG
Staffelstrasse 8
8045 Zürich
Switzerland

Visit our Web site: http://www.speag.com

1. Introduction

This manual is a print-out of the online help system supplied with the DASY3 software. Therefore references are based on chapters and not on pages and an index is not available.

The DASY3 manual contains three parts, the user manual, the software reference guide and a selection of application notes. It has been completely revised and extended for DASY3 software version 3.1c. General information about DASY3 components and dosimetric measurements is also included, which will answer many of the 'frequently asked questions' from our customers. To skip ahead to do some measurements right now, go to section 1.1: shortcut for casual users for the basic information to start the system.

The user manual gives a basic understanding of the system components and how they work together for complex measurement tasks. The principal procedures for positioning, measurement and data evaluation are explained. The user manual contains sections on the hardware, robot and software. It is organized thematically and does not explain each software element; however it does contain all necessary links to the software reference guide. After reading through the user manual, you should be able to:

- Manage all parameters properly and know which parameters are crucial for a specific function.
- Devise your own measurement tasks by using and combining components and procedures.
- Supervise the proper functioning of the system and detect any deviations.
- Do basic troubleshooting of the system.

The software reference guide is according to after the software menu structure and briefly explains the function of all input and output elements in the user interface. It does not explain the detailed reason or the remote effects of the inputs or outputs, but contains links to the user manual for that purpose.

The application notes contain detailed information about selected themes. Some are related to the DASY3 system (e.g., assessment of the measurement uncertainty in the DASY3 system or validation procedures), while others give more general information about dosimetry or field measurements (e.g., SAR sensitivity on liquid parameters, recipes for tissue simulating solutions). The list of application notes will be updated continuously; new application notes can be downloaded from our web-site (www.speag.com).

All sections are written as hypertext, containing numerous links to other locations. Links to locations in other parts of the manual are marked (UM:<name>, RG:<name>, AN:<name>)

To **print the manual** select either the topic (left pane) User Manual or Software Reference Guide. Select menu command **Print** from menu and choose **Print the selected heading and all subtopics** .

Some sections of the manual deal with special measurements that are only available with special components (e.g., temperature probes) or with uncommon setups for special tasks. You can skip those, however they might contain clues for other applications. If you have questions beyond the manual, do not hesitate to send us E-mail. We are also glad to receive critiques or recommendations regarding the manual (or the system) which will help for further improvements.

Schmid & Partner Engineering AG (SPEAG) is a spin-off company of the Federal Institute of Technology (ETH) in Zurich and continues to have many joint projects with the group for Bioelecromagnetics (BIOEM/EMC) at ETH. In the numerous publications of that group you can find much information related with the DASY system. For more information see
www.ifh.ee.ethz.ch/bioem/bioemV2/infofiles/publics.html

1.1 Shortcut for casual users

The DASY3 system is highly configurable. After the initial setup by SPEAG or its representative, all system components are installed. Also installed are document files with predefined measurement procedures for complex tasks, such as system validation and compliance testing according to FCC or CENELEC recommendations. The system can be used immediately without first working through the whole manual. However, there are still some settings necessary for the system to run properly. The following list shows the minimum necessary manipulations for a complete measurement and includes links to the corresponding sections in the manual:

- Turn all systems on (obvious, but read this section for important information). (2.11 Switching on)
- Check (and change if necessary) the active system components in the software with the actually mounted components. Here you can also switch between phantom sections for measurements. By default, the system always comes up with the last used settings. (RG: 2. System Configuration)
- Optional: Align the probe in the lightbeam for accurate positioning. (RG: 4.2 User Interface)
- Optional: Teach the phantom position with respect to the robot. This is only necessary if the phantom has been moved since its last use. Do not worry about this if you have a DASY3compact system, since the robot and the phantom are mounted together. (RG: 2.7 Install Phantom)
- If the liquid has been standing for some time, stir it to ensure homogeneous parameters. Check the liquid parameters and enter the new values into the software. Due to water evaporation, the parameters change slowly over time and should be measured regularly (every week). If the parameters have drifted too much, the liquid should be readjusted by adding water. (2.8 Simulation Liquids), (RG: 2.3 Medium)
- If you will measure a device type that has not previously been measured, you must enter its frequency and modulation duty cycle (crest factor). If you want to have a simple 3D picture of the device in the graphics, you can enter its dimensions here. (RG: 2.4 Device)
- Bring the device into a controlled radiating state and mount it on the device holder. For validation purposes connect the validation dipole to a known source and mount it beneath the flat phantom section.
- Open the corresponding predefined document file (read only file) and save it as your document. (4.8: Predefined files and examples)
- Select all scans in the document and press start. Wait for the robot to finish measurements.
- For visualization, select all (measured) scans and chose a graphic format for display. You can change and print the view. (RG: 7. Graphics)
- Upon completion, turn the system off. (2.12 switching off)

If you want to do more, and there is much more to do, please refer to the rest of the manual.

1.2 Installation

The initial system installation is generally done by SPEAG or its representative. This includes also a thorough testing of the robot and the system performance in the final environment. Upgrades, installation of new components or configuration changes can be done by the customer. Since there are many possible combinations, the installation procedures for hardware are explained with the corresponding component. Software installation has its own chapter 4.2 Installation and update. Below is a list with references to all sections dealing with installation questions. Except for system validation, no special instruments are necessary.

- Installation and configuration of the PC-board (2.2 DASY3 PC-board)
- Connecting all components (2.1 System components)
- Installing the lightbeam switch (2.10 Light beam)
- Software installation and update (4.2 Installation and update)
- Checking the environment EM noise in the system (AN: System Noise)
- System validation (AN: Validation and System Check)

2. Hardware

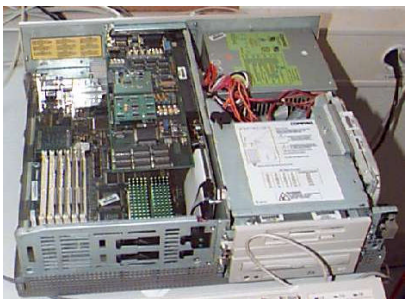
2.1 System components

The system configuration is described in the application note AN: System Description and Setup.

Further information is available about:

- 2.2 DASY3 PC-board
- 2.3 Data acquisition electronics
- 2.4 Probes
- 2.5 Generic twin phantom
- 2.6 Device holder
- 2.7 Proximity sensor
- 2.8 Simulation liquids
- 2.9 Validation dipoles
- 2.10 Light beam
- 3. Robot

2.2 DASY3 PC-board



The PC-Plug-in card uses one standard medium-sized ISA-slot. It contains all necessary circuitry for the operation of the DASY3 software with either the DAE2 or DAE3 electronic box. Room for peripheral extensions (parallel I/O, ...) is provided on the board.

The card contains a 24 bit 66 MHz data signal processor (DSP) and 96k x 24bit 12ns memory-bank. The DSP does all the real-time data evaluation for field measurements and surface detection, controls the robot movements and handles the safety operation. The PC-operating system cannot interfere with these time critical processes. The signal processor and all connections are supervised by watchdog. The disconnection of any of the cables to the board will automatically disarm the robot and disable all program controlled robot movements.

Calibration: No calibration is required.

The base address can be selected with jumpers (A4 to A9) on the board. The base address in the software must be set according to the jumpers setting (RG: 2.2.3 DASY3 PC-Board).

Note:	The new values in the software are only active after a complete shutdown and reboot of the computer.

Connections:

1. DB9 female: Data link to the data acquisition electronics (DAE3 or DAE2) via electro optic converter (EOC) mounted on the robot arm. The cable is connected to the back panel of the robot or to the free-standing EOC in the DASY3mini version.

2. Subminiature (Binder 712, Amphenol) connector 3p male: Emergency stop to the robot

3. DB9 male: RS232 connection to robot controller (SIO Board)

2.3 Data Acquisition

Description

The data acquisition electronics (DAE3) consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the PC-card is accomplished through an optical downlink for data and status information and an optical uplink for commands and clock.

The mechanical probe mounting device includes two different sensor systems for frontal and sidewise probe contacts. They are used for mechanical surface detection and probe collision detection.

The input impedance of the DAE3 box is 200 MOhm; the inputs are symmetrical and floating. Common mode rejection is above 80 dB.

Note: Due to the high impedance the offset voltage might drift several tenths of microvolts if the inputs are left open. To take advantage of the high sensitivity of the input electronic, a properly designed grounding and power distribution system in the laboratory is necessary. See AN: System Noise for further information.

Important: Keep the DAE dry; absolutely avoid condensing humidity in the DAE-box.

Calibration: Required once a year.

Batteries

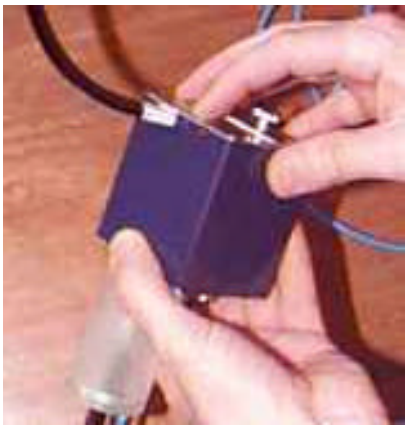
The DAE works with either two standard 9V batteries or two 9V (actually 8.4V) accus. As the electronics automatically powers down unused components during breaks or between measurements, the battery lifetime depends on system usage. Typical lifetimes are >20 hours for batteries and >10 hours for accus. Remove the batteries if you do not use the DAE for a long time.

Note: The use of accus is highly recommended. In some countries (USA) the commercially available "9V" accus have a nominal voltage of 6.2V instead of the usual 8.4V. The DAE is designed to work with 8.4V accus and will give a low battery error with the 6.2V accus.

Cable connections

Connect the twin optical cable from the DAE3 to the electro optical convertor (EOC), and the special data cable from the EOC to the PC-Board. Shown is the DASY3mini system. In DASY systems with a robot, the EOC is mounted on the robot arm and an internal data link is used from the EOC to the robot back panel. Thus, the data cable to the PC-Board is connected to the robot back panel.

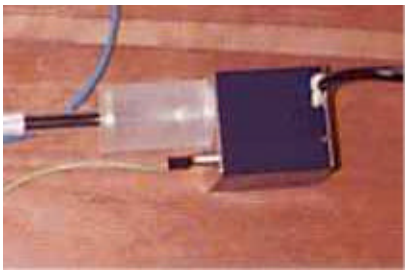
Power on/off switch



To switch on briefly press the push button on the top of the electronic box shortly (less than a second). Pressing it for more than two seconds turns the electronics box off.

The box will turn off automatically 15 minutes after switching off the computer.

Grounding pin



The pin in the front of the DAE gives a defined mounting position in the robot arm holder (important for field component measurements). It can also be used as a grounding pin to connect the DAE to the radiation source ground. See AN: System Noise for more information.

2.4 Probes

The DASY3 system can support many different probe types.

Dosimetric Probes: These probes are specially designed and calibrated for use in liquids with high permittivities. They should not be used in air, since the spherical isotropy in air is poor (±2dB). The dosimetric probes have special calibrations in liquid at different frequencies.

Free Space Probes: These are electric and magnetic field probes specially designed for measurements in free space. The z-sensor is aligned to the probe axis and the rotation angle of the x-sensor is specified. This allows the DASY system to automatically alig the probe to the measurement grid for field component measurement. The free space probes are generally not calibrated in liquid. (The H-field probes can be used in liquids withouth any change of parameters.)

Temperature Probes: Small and sensitive temperature probes for general use. They use a completely different parameter set and different evaluation procedures. Temperature rise features allow direct SAR evaluations with these probes.

Optical Surface Detection: Some probes have a built in optical surface detection system. This option is mainly used for dosimetric measurements in liquid filled phantoms.

Note: All probes have one characteristic in common - they are fragile and valuable !

The following points are important for a long probe life:

- Handle the probes very carefully. Store them safely when not in use.
- Use the dummy probe for training purposes and for experimenting with new setups.
- Clean the dosimetric probes with water after use. Use soft towels or paper only. Never use knives or hard tools at the probe tips with optical surface detection.
- Do not the place the probes with (transparent) PMMA enclosures in organic solvents, including glycol-solutions. The newer probes (later than 2Q99) have a (black opaque) PEEK enclosure and can be used in most solvents, acids and lyes. Please contact SPEAG for information about special solutions.
- Never try to open the probes. The calibration (or the probe) will be lost.

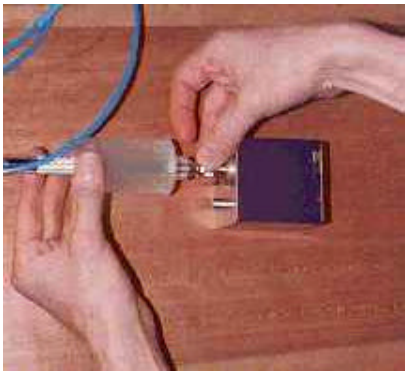
Probe mounting

A very high repeatability of the position of the probe tip is crucial for accurate measurements. This requires a very stable probe mounting. However, to avoid probe destruction in collisions, the probe should be mounted flexibly. The DASY probes use a precise connector and an additional holder for the probe, consisting of a plastic tube and a flexible silicon ring to center probe. The connector at the DAE is flexibly mounted and held in default position with magnets and springs. Two switching systems in the connector mount detect frontal and lateral probe collisions and trigger the necessary software response (see 3.6 Probe collision). This mounting gives a position repeatability of 0.1mm at the probe tip even with horizontally aligned probes, but allows axial movements of 2cm and lateral movements of 5cm without destroying the probe. The absolute accuracy at the probe tip is not ensured with the mounting alone. Use

the light beam option (see 2.10 Light beam) to align the probe tip accurately to the robot coordinate system.

Assembling the probe holder tube

For probes with optical surface detection, the probe holder tube must be pushed over the probe connector first, in other probes it can be pushed over from the tip. Make sure that the silicon ring is flat and centered. Otherwise, loosen the silicon ring holder and reposition the ring. Connect the probe as shown in the figure (over a table; just in case it falls down). The connector has a fine thread. Make sure that it catches correctly. If not, the connector ring only makes one turn and the probe is angled. If there is a problem in connecting the ring, push the connector completely into the DAE and try again. Never turn the probe, only the connector ring. Don't force the connector to a wrong position.


Connecting the probe

Fix the probe holder tube and mount the DAE on the DAE holder on the robot arm. The ground pin on the front of the DAE goes into the hole in the holder.

2.5 Generic twin phantom

The generic twin phantom is a fiberglass shell phantom with 2 mm shell thickness. It has three measurement areas:

- Left hand
- Right hand
- Flat phantom

The phantom table comes in two sizes: A 100x50x85 cm (LxWxH) table for use with free standing robots or as a second phantom and a 100x75x85 cm (LxWxH) table with reinforcements for table mounted robots.

The bottom plate contains three pair of bolts for locking the device holder. The device holder positions are adjusted to the standard measurement positions in the three sections. Only one device holder is necessary if two phantoms are used (e.g., for different solutions).

A white cover is provided to tap the phantom during off-periods to prevent water evaporation and changes in the liquid parameters. Free space scans of devices on the cover are possible; however the optical surface detector is not working properly at the cover surface. Place a white paper on the cover when using optical surface detection.

On the phantom top, three reference markers are provided to identify the phantom position with respect to the robot (see RG: 2.7 Installing the Generic Twin Phantom).

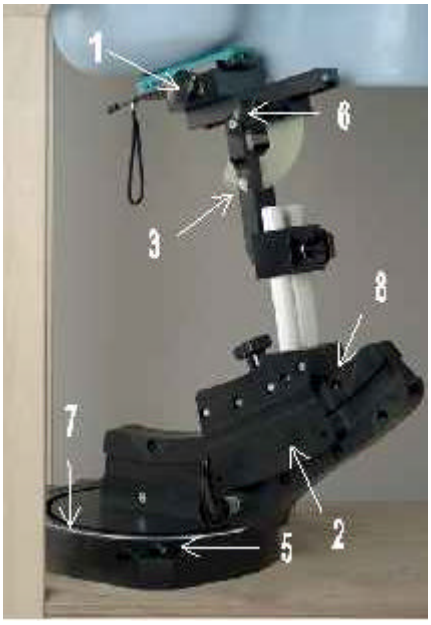
The phantom can be used with the following tissue simulating liquids:

- Water-sugar solutions can be left permanently in the phantom. Always cover the liquid if the system is not in use, otherwise the parameters will change due to water evaporation.
- Glycol solutions should be used with care. As glycol is a softener for most plastics, the solution should be taken out of the phantom and the phantom should be dried when the system is not used (also overnight!). A test has shown a slight coloring of the inner surface after 3 months of continuously being filled with 1.8 GHz Glycol solution.
- Do not use other organic solvents without previously testing the phantom resistiveness.

2.6 Device holder for generic twin phantom

The SAR in the phantom is approximately inversely proportional to the square of the distance between the source and the liquid surface. For a source at 5mm distance, a positioning uncertainty of ±0.5mm would produce a SAR uncertainty of ±20%. An accurate device positioning is therefore crucial for accurate and repeatable measurements. The positions in which the devices must be measured will be defined by the standards. The CENELEC "standard" (European Specification ES59005) cites 4 measurement positions. The FCC positions are not yet completely defined.

The DASY3 holder is designed to cope with different positions given in the standard. It has two scales for the device rotation (with respect to the body axis) and the device inclination (with respect to the line between the ear openings). The plane between the ear openings and the mouth tip has a rotation angle of 65º. The intended use position in the CENELEC document is has a rotation angle of 65º and an inclination angle of 80º. The rotation centers for both scales is the ear opening. Thus the device needs no repositioning when changing the angles. The device rotation around the device axis is not changed in the holder. In the CENELEC standard it is always 0º. If the standard changes, a support will be provided with the new angle.



1. Put the phone in the clamp mechanism (1) and hold it straight while tightening. (Curved phones or phones with asymmetrical ear pieces should be positioned so that the ear piece is in the symmetry plane of the clamp).

2. Adjust the sliding carriage (2) to 90º. Then adjust the phone holder angle (3) until the reference line of the phone is horizontal (parallel to the flat phantom bottom). The phone reference line is defined as the front tangential line between the ear piece and the center of the device bottom (or the center of the flip hinge). For devices with parallel front and back sides, the phone holder angle (3) is 0º.

3. Place the device holder at the desired phantom section and move it securely against the positioning pins (4). The screw in front of the turning plate can be applied for correct positioning (5). (Do not tighten it too strongly).

4. Shift the phone clamp (6) so that the ear piece is exactly below the ear marking of the phantom.

The phone is now correctly positioned in the holder for all standard phantom measurements, even after changing the phantom or phantom section.

5. Adjust the device position angles to the desired measurement position. The rotation scale (7) gives the tilt angle from the body axis. C1 denotes the intended use position (plane through ear openings and mouth); C2 is the 30°-tilt position according to CENELEC. The angle of the sliding carriage (8) gives the inclination angle of the phone (80º = intended use position).

6. After fixing the device angles, move the phone fixture up until the phone touches the ear marking. (The point of contact depends on the design of the device and the positioning angle).

Note: Always lower the phone fixture prior to changing the device angles.

If the ear piece of the phone is shifted horizontally after changing the device angles, the phone or the device holder is not correctly positioned.

2.7 Proximity sensor

Some probes are equipped with an optical multifiber line ending at the front of the probe tip. It is connected to the EOC box on the robot arm and provides an automatic detection of the phantom surface. Half of the fibers are connected to a pulsed infrared transmitter, the other half to a synchronized receiver. If the probe approaches the surface, the reflection from the surface produces a coupling from the transmitting to the receiving fibers. This reflection increases first during the approach, reaches a maximum and then decreases. If the probe is flatly touching the surface, the coupling is zero. The distance of the coupling maximum to the surface is independent of the surface reflectivity and largely independent of the surface to probe angle. The DASY3 software reads the reflection during a software approach and looks for the maximum using a 2nd order fitting. The approach is stopped at reaching the maximum.

The optical surface detection works in transparent liquids and on diffuse reflecting surfaces with a repeatability of better than ±0.1mm. The distance of the maximum depends on the fiber and the surrounding media. It is typically 0.8mm to 1mm in air and 1.5mm to 2mm in sugar solutions. The distance can be measured with the surface check (RG: 6.9) scan in the flat phantom. The actual value must be entered in the probe setup (RG: 2.6) data and is used for the extrapolation routine (see 4.6.3 Surface Detection).

Note:

- The connector of the optical link has a notch. Make sure it is correctly positioned and fixed.
- Always clean the probe tip after removing it from the tissue simulating solution to avoid crystallized sugar at the optical detector end.

Installation and checking

The signal from the surface detector can be visualized in themultimeter (RG: 3 Mutlimeter Option) option. A special measurement profile "proximity sensor" enables the display of the AD-values from the 16bit ADC. In the scope window you must select the component button to see the proximity values.

The sensitivity of the proximity sensor can be adjusted inside the EOC box on the robot arm. However, since the system searches for the location of the reflection maxima, the sensitivity setting has no influence on the detection distance. The sensitivity is set during the system installation so that (1) an AD overflow never occurs, even on strong reflecting surfaces and (2) there is sufficient signal to avoid noise problems.

The sensitivity is best set to an AD-value between 30000 - 50000 in the reflection maxima on a white paper in air. This gives a typical AD-value between 10000 and 25000 in sugar solutions. The sensitivity setting should only be changed when the AD values are far off these values.

2.8 Simulation liquids

Parameters

The parameters of the simulating solution strongly influence the SAR in the solution. (see 4.5.2 Liquid Parameters and SAR). The measurement standards will specify the parameters for the different frequencies. At the moment, no parameters are defined.

The DASY3 parameters used so far are based on numerical evaluations of several MRI scanned heads with 13 different tissue types. The parameters of the homogeneous heads are selected to produce a SAR value that covers statistically 90% of the user group (incl. children).

The FCC has proposed parameters that are the algebraic average of white and gray brain matter. The parameters are from a cole-cole approximation formula derived from the studies of Dr. Camelia Gabriel. The data can be calculated online at the web-site http://www.fcc.gov/fcc-bin/dielec.sh. However, these parameters are not final and liquids with higher conductivities are accepted.

SPEAG will contact all customers if final standard specifications will require new liquids or recipes.

Parameter measurements

Several measurement systems are available for measuring the dielectric parameters of liquids:

- The **open coax** test method (e.g., HP85070 dielectric probe kit) is easy to use, but has only moderate accuracy. It is calibrated with open, short, and deionized water and the calibration is a critical process. The application note AN:Testing Tissue Simulating Liquids Using HP85070 gives some tips for using the HP probe kit.

- The **transmission line** method (e.g., model 1500T from DAMASKOS, Inc.) measures the transmission and reflection in a liquid filled high precision line. It needs standard two port calibration and is probably more accurate than the open coax method.

- The **reflection line** method measures the reflection in a liquid filled shorted precision line. The method is not suitable for these liquids because of its low sensitivity.

- The **slotted line** method scans the field magnitude and phase along a liquid filled line. The evaluation is straightforward and only needs a simple response calibration. The method is very accurate, but can only be used in high loss liquids and at frequencies above 100 to 200MHz. Cleaning the line can be tedious.

All methods use network analyzers for the measurements. The commercial versions of the first three methods use computer software for the evaluations and for controlling the NW.

The following points are important for accurate measurements in all methods:

- The liquid must not contain any air bubbles in the measurement area.

- The test setup must not change the temperature of the liquid, since the liquid parameters are temperature dependent.

Recipes

The tissue simulating liquids match the electric parameters of the simulated tissue over a limited frequency range. Unfortunately, it is not possible to match a homogeneous liquid to the tissue cell structure over the complete frequency band of interest (at least, no recipes are known). Therefore, different liquids are used for the 900MHz (835MHz) band and the 1800MHz (1900MHz) band.

Sugar-Water solutions use sugar to reduce the permittivity of water and salt to increase the conductivity. Some recipes are given in the application note AN: Recipes for Brain Tissue Simulating Liquids. Unfortunately, adding sugar to the water also increases the conductivity. At higher frequencies (>1200MHz) it is not possible to match the average brain parameters; the conductivity of the solution is considerably higher. Nevertheless, the sugar-water solution is used at higher frequencies because (1) it is much easier to handle and (2) numerical simulations indicate that a higher conductivity is necessary to reliably cover the real exposure.

The parameters change with the temperature:

- The permittivity increases about 0.5% per °C temperature increase
- The conductivity decreases about 1% per °C temperature increase

The given recipes are for a liquid temperature of 22°C. When the liquid is in the open for a long time, the water evaporation changes the composition and the parameters. Adding water is sufficient to return the parameters to their initial value.

Glycol-Water solutions use organic solvents to decrease the water permittivity. With water, glycol and salt almost any parameters are possible. The selected solvent has a low toxicity and a low damp pressure to avoid evaporation. Anyhow, good air circulation in the laboratory is necessary. Glycol is a strong plastic softener and affects most plastics over time.

Do not use glycol solutions with probes that have transparent PMMA enclosures. The new probes (2Q99) with black PEEK enclosures can withstand the glycol solutions.

The Fiberglass generic twin phantom is affected by the glycol solutions over a long period. Always empty and dry the phantom after use.

2.9 Validation dipoles

The DASY software includes predefined procedures for system validation. For that purpose a well defined SAR distribution in the flat section of the generic twin phantom is produced. A detailed descripton of the procedure can be found in the application note AN:Validation and System Check.

Several dipoles are available for different frequencies (835MHz, 900MHz, 1640MHz, 1800MHz, 1900MHz). The dipoles are highly symmetric and matched at the center frequency for the specified liquid and distance to the phantom. The accurate distance between the liquid surface and the dipole center is achieved with a distance holder that snaps on the dipole. The dipoles come with their corresponding distance holder and a tripod holder to fix it underneath the flat phantom.

The input power at the SMA-connector of the dipole must be specified with high accuracy (<3%), since the SAR error for this well defined setup is very small.

2.10 Light beam

The lightbeam switch allows an automatic "tooling" of the probe. During the process the actual position of the probe tip with respect to the robot arm is measured, as well as the probe length and the horizontal probe offset. The software then corrects all movements, so that the robot coordinates are valid for the probe tip. The repeatability of this process is better than 0.1mm. If a position has been teached with an aligned probe, the same position will be reached with another aligned probe within 0.1mm, even if the other probe has different dimensions. During probe rotations, the probe tip will keep its actual position.

Installation

In all newer systems, the lightbeam is included and will be installed during the system setup. For other systems and changes read the instructions below.

The lightbeam switch must be installed in a fixed position with respect to the robot which is easily and safely reachable with a vertically aligned probe. For the DASY3compact system this would be a vertical position at the table near the back corners, either at one of the sides or the back side. The lightbeam arm should stand above the table level. For DASY3 systems with RX90 or RX90L robots the lightbeam is mounted on a special holder which is fixed underneath the robot. For the RX90L robot, an additional holder brings the lightbeam higher up.

The free ends of the cable from the lightbeam are connected to the extension terminals of the robot. These are found in the grey box connected to the robot back side or open on the upper back side of the controller cabinet behind the panel. The wires are connected as follows:

- brown wire to terminal 14
- green wire to terminal 15
- white wire to terminal 16
- black wire (shield) to any ground terminal

Checking the lightbeam

The lightbeam can be tested from the monitor window in the DASY software (RG: 3. Monitor). Entering the command **signal(3)** in the monitor command line will turn on the power to the lightbeam. The lightbeam uses a visible red LED signal. The command**signal(-3)** turns off the lightbeam power.

The signal from the lightbeam can be displayed on the teach pendant: First press the "**display**" button; then select the "**Digital I/O**" option from the upcoming menu on the teach pendant; last select the "**in**" option. The digital input from the lightbeam is the third digit from the right in the teach pendant display. It should be 1 with the lightbeam powered and 0 with the lightbeam off or interrupted.

Software setup

After the mechanical installation, the lightbeam position must be installed in the software. This procedure must also be repeated if you import a new robot configuration file. Start the system with a well defined and correctly positioned and vertically aligned probe (e.g., the dummy or dosimetric probe). A software option leads to the automatic lightbeam recognition procedure by teaching two points in the lightbeam. The procedure is described in the software reference guide:RG: 2.8 Robot (Teaching the light beam)

2.11 Switching on

It is not necessary to follow a strict procedure while switching the system on. Every component will boot up and the DASY3 software will start communication when they are ready. However, you will miss all boot messages (e.g., error messages) from the robot if you start the robot before the DASY3 program. The recommended procedure is as follows:

- Start the DASY3 program.
- Click on the robot button . There will be a bunch of error messages in the upcoming state window because the communication is missing; just click on OK. This will bring up the empty monitor window for all robot communications.
- Turn on the robot. In the monitor window (see RG: 4. Robot and Phantom Handling), you can follow the boot process. It takes about one minute. After completion, the communication stops and the teach pendant displays the message <NO PROGRAM PRIMED>.
- Mount the DAE with the probe and turn it on.
- Click on the robot button again. If the DAE is not communicating or sending an error message, the DAE state window (RG: 3.5) will appear; connect the DAE, turn it on or see troubleshooting. Otherwise, the robot state window (RG: 4.1) appears with the message <emergency stop active>. Click on the <release emergency stop> button. If the message persists, see 5.Troubleshooting. Otherwise, click on the <Arm Power On> button in the state window. This activates the ON button on the remote control for 15 seconds (green blinking). Press the blinking ON button to power on the robot arm. If the robot arm is not powering (the green lamp on the remote control is not on) see troubleshooting. Otherwise, close the state window with the OK button.
- **Note:** Sometimes the error messages are not cleared automatically when the problem is solved (e.g., after changing the batteries in the DAE). Click on the check button in the state window to clear the error messages. If the state window is not open, clicking on the robot button will also check the system and clear old error messages.
- Select the active components in the setup menu (RG: 2.) if something has changed since the last use. The robot is now ready to use and all robot buttons and the pull-down menus are activated.
- Align the probe. After starting up, a default tool is set for the selected probe. Since the probe is probably not exactly aligned with the sixth robot axis, the robot world coordinates will not give the exact position of the probe tip but will normally be about 1 to 3 mm offset. Click the align probe in light beam button (see also 2.10 Light beam) to correct the probe offset (RG: 4.2 User Interface). This is optional for dosimetric measurements, since the offset only affects the device location in the graphics. However, aligning the probe is highly recommended especially for free space measurements. If the probe alignment gives an error message see output in monitor window (RG: 4. Robot and Phantom Handling).
- Sometimes the robot movement buttons and section pull-down options are blanked after start up. Then the phantom might not be installed (see install phantom (RG 4.2)) or contains invalid data. Check the phantom data in the setup. If only the move to start (RG 4.2) button is active, then the phantom is far away from the actual probe position and a direct movement to phantom points is not save. Make sure that the way to the phantom start point is not obstructed and click the move to start (RG 4.2) button.

2.12 Switching off

If the green light on the remote control box is on, the arm is powered. That means that the breaks in the joints are released and the robot is held in position by the motors.

Warning: Never turn the robot main power off while the robot arm is still powered.

This might produce uncontrolled movements of the robot arm (up to 10cm in older systems) and damage the probe.

The recommended turn off sequence is as follows:

- Bring the probe in a position where it can be easily cleaned or removed (e.g., the start position of the phantom). The probe should not be very near other objects and out of the way (most probes brake when people move into them while manipulating the phantoms). Some robot arm positions might produce robot problems during startup (see 3.5.1 Robot calibration). Select a different turn off position if you encounter such problems.

- Turn off the robot arm power. This can be done by pressing the on/off button on the teach pendant or by selecting **disable arm power** in the **robot** pull-down menu. Switching off the DAE or closing the DASY3 program will also turn off the robot arm power.

- Turn the main power of the robot off.

- Turn the DAE off. Closing the DASY software will also turn the DAE off in newer systems. All DAE will turn off automatically after loosing communications with the PC for about 15 minutes.

- Save all open documents and close the DASY program. The last settings are automatically saved for future use.

3.0 Robot

Description

The DASY3 system uses the high precision industrial robots RX60L, RX90, RX90L fromStäubli SA (France). The RX robot series offers many features that are important for our application:

- High precision (repeatability 0.02mm)
- High reliability (industrial design)
- Low maintenance costs (virtually maintenance free due to direct drive gears; no belt drives)
- Jerk-free straight movements (brushless synchron motors; no stepper motors)
- Low ELF interference (the closed metallic construction shields from motor control fields)

Robot arm break release

The robot arm uses brushless syncron motors on all axes. During normal operation, the robot arm is held in position by the motor signals. When the arm power is turned off, the robot is held by brakes on axes 1 to 4. The brakes are only released by applying power.

Note: The transition from motor held position to brake held position can produce some movement at the probe tip. Never turn the arm power off, when the probe is near other objects.

To move the robot arm without starting the software, the brakes can be released manually. The controller must be turned on, but the software is not necessary. A turn knob on the back side of the robot arm lets you select the axis, on which to release the brakes. Pressing the push button on the robot arm then releases the brake on the selected axis:

Warning: Hold the arm when releasing the brakes on axis 2 or 3. Otherwise the the arm will collapse and might destroy the probe or the robot.

Do not forget to switch the turn knob back to the 0-position. Otherwise the robot arm will stay in "emergency stop".

Robot controller

The robot uses its own controller with a built in VME-bus computer. It is delivered with a 19" cabinet with the dimensions 55 x 78 x 80 cm (width x length x height). The cabinet can be placed up to 10m from the robot (special cables from Stäubli required). The main power switch is on the controller. All other functions are remotely controlled.

The controller needs a 3 phase power supply. The controller can be configured for the standard power line voltages of most countries.

3.1 Safety

3.1.1 General safety considerations

Most countries have special regulations regarding personal safety in a robot environment. Although the DASY3 system provides safety features, the customer remains responsible for compliance with the specific robot safety regulations of the corresponding country.

The safety features provided in the DASY system are:

- An external red warning lamp indicates if the robot arm is powered and the robot is under software control. The lamp must be mounted, where it is clearly visible before entering the robot workspace.
- The DASY software inhibits speed settings above 20% of the maximum robot speed. Higher speed settings entered in the monitor window are automatically reduced to highest permitted speed.
- An emergency stop button is provided on the remote control box, which should be placed within easy reach of the operator.
- The extension box provides free terminals to connect additional safety products like switching floor mats, door switches, etc. These features can be disabled with the key switch on the remote control box in manual mode (used for manual robot operations). In manual mode the blue lamp is on and all automatic movements are disabled.
- Any contact with the probe during automatic or manual robot movements will immediately stop the movement or turn off the robot arm power.
- Disconnecting the electronics box (e.g., for probe changes) will turn off the robot arm power.
- The robot controller can be rewired to reduce the voltage to the motor amplifiers. This special safety mode is called "turtle mode" (see 3.7.2 Turtle mode operation). Stäubli offers the controller optionally with switchable turtle mode for manual operations. The DASY system works well with reduced voltage. See the installation documents if the voltage has been reduced.

The customer must provide the following minimum requirements for safe robot operations:

- The system must be placed so that nobody not involved in the measurement process enters the working area of the robot (e.g., no light switch behind the robot). The safe area around the robot must be clearly marked (warning signs, floor markings, barriers, shielded room).
- Only instructed persons should operate the system.
- The bulb in the red warning lamp must be replaced when blown.
- The operator may enter the robot working area (e.g., for installation, teaching, etc.) only with the arm power turned off or with the teach pendant in hand with the "dead man switch" functional.

- Before any manipulation on the arm (e.g., changing probes or manual break release), make sure the robot arm power is off.
- Before any maintenance in the controller cabinet, disconnect the main power cord.
- Do not keep any flammable or corrosive materials in the working range of the robot.

See also the safety regulations in the robot manual provided by St äubli (Chapter 1 Safety).

3.1.3 Safety chain

The robot system provides a "safety chain" for emergency stops. This is a single wire link passing through all safety components. Any interruption of the safety chain will immediately remove the high voltage supply from the motor amplifiers and the release voltage from the breaks in the robot arm joints. An open safety chain is indicated with the red "fault" lamp on the front panel of the robot controller. (Note: In case the safety chain fuse or the fault lamp is blown, a red LED marked "ESTOP" on the SIO-board of the robot controller also indicates an open safety chain). The safety chain includes the following components:

- Emergency switch on the front panel (self locking knob)
- Emergency switch on the remote control (self locking knob)
- Emergency switch on the teach pendant (self locking knob)
- "Dead man switch" on the teach pendant
- Turn knob on the back panel of the robot arm (used to enable the manual break release knob)
- Relay on the DASY3 PC-board. If the PC is turned off or the cable is disconnected, the safety chain is open. The DASY3 software activates this relay either during normal system operation or after an "emergency stop override" for robot maintenance. See 3.6 Probe collision detection for more information.
- Optional safety circuitry via terminals 19 and 20 of the robot extensions (see3.2.2 Robot extensions)

The safety chain is also open, if any of the extension cables J11 or J12 (sub-d connecters to the back side of the robot controller) or the teach pendant cable are disconnected from the controller. The blind connector supplied by Stäubli must be used to operate the robot without these extensions.

Note:	**The emergency stop buttons should be used for emergencies only. Turning the arm power off or stopping an ongoing movement should be done using the software.**

3.2 Setup and connections

Drawings for the system setup and robot interconnection can be seen in the application note AN:System Description and Setup.

3.2.1 Signal lines

The DASY3 system uses several interlinked programs:

- The actual DASY3 program written in C++ and running under Windows 95, Windows 98 or Windows NT. The priority of the DASY program is determined from the operating system. It can operate fully in the background.
- The signal processor program running on the PC board written in assembler and C. It is responsible for safety of the timecritical operations and controls the low-level links to the robot and the DAE.
- Up to three programs written in V+ run simultaneously on the real time multitasking robot controller. They control the robot movements and background safety operations.

The software on the robot controller are automatically downloaded from the DASY3 program. During a software update, no robot operations are necessary. Since downloading is slow, the robot software is also stored on the hard disk in the robot controller. Automatic program start on the controller is enabled, when the top microswitch on the controller SIO-board is in the "ON" position. The DASY3 software still checks the robot software version on the controller and automatically downloads newer versions after a DASY update.

Two serial links connect the robot controller to the PC:

- A high level link connects the DASY3 software through a serial "COM" port to the "Monitor" connector of the robot controller. It is used to display the robot communication, download software, send DASY3 commands and receive robot messages.
- A low level link connects the signal processor on the plug-in board with a direct software controlled serial port on the robot controller. The two processes exchange coded data for real time critical operations (e.g., surface detection or emergency movement abort). This link is supervised by watchdog; disconnecting this line will immediately produce an emergency stop.

The status of both lines is displayed in the status window of the DASY3 software.

3.2.2 Robot extensions

For hardware extensions, the DASY3 system uses a terminal row connected to the robot extension connectors J11 and J12 on the back side of the robot controller. The terminal row is either built into a grey connector box or built into the controller cabinet behind the back panel. It provides terminals for the following extensions:

- Safety lamp (red/blue). The lamps can be tested from the monitor window in the DASY software. The command **signal(1)** turns the red light on, the command **signal(2)** turns the blue light on. The commands **signal(-1)** and **signal(-2)** turn the lights off again. Using DASY3 will also bring the lamps back to the correct state.

- The remote control provides an emergency stop button, a key switch for manual/automatic mode and an on/off push button. The key switch must be in auto mode for normal operation and during the robot boot process. The on/off push button turns the arm power on and off (see 2.11 Switching on and 2.12 Switching off).

- A cable to the DASY plug-in board for emergency stop. (see 3.1.2 Safety chain)

- A connection to the light beam unit for probe alignment. (see 2.10 Light Beam)

- Four terminals are provided for optional safety circuitry (switching mats, locks). Terminal 17 (24V, 2A fused) and terminal 18 (0V) can be used to supply special circuitry. Terminals 19 and 20 are in the safety chain and must be shorted when no circuitry is connected.

3.3 Robot software and elementary commands

3.3.1 Monitor window, V+

All common operations in the DASY3 system can be accessed through the DASY3 user interface. However, sometimes it is necessary to access the robot directly to enter commands or to display error messages from the robot. This can be done in the monitor tab (RG: 4. Robot) in the DASY3 robot window which displays the monitor of the robot controller. All communications on the serial link between the DASY3 software and the robot are displayed. Commands can be sent to the robot or programs on the robot controller can be written in the robot command language V+. Check the Stäubli documents for a description of the V+ language.

The robot window must be opened in the DASY3 software to access the robot. It is recommended to open the monitor tab before switching on the robot controller. That way you can see all error messages that might be displayed during the robot boot process.

3.3.2 Elementary robot commands

The following table shows a few V+ commands that might be useful. Other commands necessary for diagnostic or special robot procedures are explained in the corresponding sections. The commands can be entered with upper or lower case letters. In the table the upper case denotes controller instructions and lower case is used as spaceholder for necessary parameters.

Command	Description
SPEED v	The speed (v) of the robot can be set as a percentage of the maximum speed (100) with a value between zero and 100. For safety reasons the speed is restricted to 20.
WHERE	Shows the actual probe tip location in the robot world coordinate system
EX DA3.WHERE	Shows the actual probe tip location in the phantom coordinate system
STAT	Returns the current robot status (speed information, current robot mode, program tasks, etc.)
DO DEPARTS xx	Moves the probe the distance xx in mm backwards on a straight line. This is a safe operation (for positive xx) that can be used when the probe is stuck in the surface.

Note: All commands starting with **"EX DA3."** are software commands for DASY3 programs which are downloaded to the controller. They are stored in two files on the harddisk (auto.v2 and da3.pg), which should not be deleted or edited. If you want to use the robot without the DASY3 software, switch off the top microswitch on the SIO-board on the controller and reboot the controller. To clear the emergency-stop of the DASY3 plug-in board select Robot:Overwrite E-Stop from the robot menu in the DASY3 software.

3.4 Robot coordinate system

The teach pendant allows manual control of robot movements in three different modes, "WORLD", "TOOL" or "JOINT". After pressing the"**MAN/HALT**" button one of the modes is selected, indicated by a LED above the emergency stop button. (The "FREE" mode can be selected, but is always disabled). Pressing the "**MAN/HALT**" button again selects the next following mode. The buttons "**X/1**" to "**RZ/6**" on the right side select the coordinate axis or joint to be moved. The movements are executed with different speeds by pressing the "+" and "-" fields. The movements are completely different for the three modes, therefore:

Always make sure you have selected the correct mode for manual movements !!!

Always start a movement with low speed and check the movement !!!

World coordinates

The world coordinate system is an absolute coordinate system with the origin at the intersection of joints 1 and 2 of the robot arm. The z-axis is vertical and the x-axis goes straight to the front of the robot. The movement buttons **X, Y, Z** in **WORLD** mode enable straight movements in the world coordinate axes. The movement buttons RX, RY, RZ enable rotations around the coordinate axes. If the DASY software has started, the rotation center is the tip of the actual probe.

The world coordinates of the probe tip can be displayed in the monitor tab by entering the robot command "**WHERE**", or continuously on the teach pendant by pressing the "**DISPLAY**" button and selecting the "**WORLD**" option. The coordinates X, Y, Z are given in mm; the angles Yaw, Pitch, Roll in degree. Yaw, Pitch, Roll is a standard denotation of orientations in space (used in robotics, avionics etc). Any orientation can be derived with these angles from the origin system as follows: (1) Yaw is a positive rotation around the z-axis. (2) Pitch is a positive rotation around the new y-axis after applying Yaw. (3) Roll is a positive rotation around the new z-axis after applying Yaw and Pitch.A vertical downward aligned probe has the angles 0°, 180°, xx (any probe rotation angle).

Aligning the probe manually could be tedious. The DASY software allows automatic alignment of the probe to the nearest world coordinate axis. (See RG: 4.2 Align Probe)

Tool coordinates

The tool coordinate system has its origin at the probe tip and is oriented with respect to the probe. The z-axis looks in the probe direction. For dosimetric probes the x-axis is normal to front of the DAE holder. For probes with probe oriented sensors, the x-axis is in the direction of the X-sensor in the probe. The movements and rotations in the tool mode are based on this system and depend on actual orientation of the probe. A +Z movement is always in the positive direction of the actual probe.

Note: For vertically downward aligned probes a +Z movement in the tool mode is down, in the world mode it is up. Heed the warnings above.

Joint angles

In the joint mode each robot joint axis can be moved individually. The joint numbers and directions are marked on the robot arm. The joint angles can be displayed on the teach pendant by pressing the "**DISPLAY**" button and selecting the "**JOINT**" option.

Note: Always change back to "WORLD" option before your press the "COMP/PWR" button.

Each joint angle in the robot has a lower and upper limit. These limits are imposed by software and can be changed (see 3.7.1 Joint Angle Limitations). If the user or a program tries to move any joint beyond its limits, the movement will stop at the limit and an error message (**joint <x> out of range**) is displayed in the monitor tab and on the teach pendant.

Note: In manual world mode and tool mode the robot only moves along the selected coordinates and keeps all other coordinates and angles constant. All joints will rotate synchronously for the movement. Even in straight movements, a joint limit can be reached and the movement will stop.

Phantom coordinates

Some phantoms have their own coordinate system. These coordinates are used exclusively by the DASY3 system; manual movements in the phantom coordinates are not possible. However, the probe can be automatically aligned to the phantom coordinate system. (RG: 4.2 Align Probe to Phantom)

3.5 Absolute position recognition and recovery

3.5.1 Calibration

The RX robots use absolute position recognition. There is no need to bring the robot arm to a reference position after startup. The RX90 and RX90L robots use absolute angle resolvers in the joint axis. The RX60 robot uses incremental resolvers and battery backed counters (see next section).

The calibration procedures during the boot process of the robot controller reads the joint angles and calculates the absolute position of the robot arm and the position uncertainty. For some rare combinations of the robot joint angles, the uncertainty is above the limits and the robot cannot be calibrated. In the monitor tab the following message is displayed:

Prefer to move joint xx

The robot arm can be powered, but only in manual joint mode. Move the joint indicated in the message (either with the teach pendant or with switchs at back side of robot), turn the arm power off and reboot the controller. If the message persists, try to bring the robot in a normal position and reboot. You can use the emergency stop override (see RG: 4.1) if you want to turn the arm power on without mounting the DAE.

Note:	If you have problems with calibration in the park position (e.g. phantom start point), change the park position.

3.5.2 RX60 battery system and position recovery

The RX60 robot uses battery backed circuitry in the controller for absolute position recognition. The battery switch on the back side of the robot controller must be on (red).

The controller must be switched on for several hours each month to keep the battery charged.

If the system is not used for several months, turn off the battery switch to avoid deep discharge.

The absolute position in the RX60 robot is lost if (1) the cable between the robot and the controller is disconnected, (2) the battery switch is turned off while the controller is not powered or (3) the battery runs out of power. The robot boot process is interrupted with the request to recover the "V_REG" position. Continue as follows:

- Remove the DAE from the robot arm.
- Activate the "Overwrite E-stop" in the DASY software (seeRG: 4.1).
- Turn the arm power on. The controller will switch to manual joint mode.
- Bring the robot arm in an upright position, so that all arm markings are aligned (± 2° is sufficient, the robot will search the correct zero position).
- Follow the controller instructions on the monitor tab. The complete dialog is shown below (robot messages are in Courier letters, user input is bold). The robot number is the number on the Stäubli

documents followed by "**01**". (Example for the scribe file: C:\59718601.MRK)

```
Do you want to recover the V_REG position now (Y/N) ?  Y

*** V_REG POSITION RECOVERY ***
  AXIS RECOVERY STATUS
  (0: need to be recovered / 1: recovered)
  Axis 1 : 0 Axis 4 : 0
  Axis 2 : 0 Axis 5 : 0
  Axis 3 : 0 Axis 6 : 0
  => ROBOT NOT CALIBRATED <=
  (Note : all axes have to be recovered to calibrate the robot)
  0 => Exit
  1 => Recovery for axis 1
  2 => Recovery for axis 2
  3 => Recovery for axis 3
  4 => Recovery for axes 4, 5 and 6 (simultaneously)
  5 => Recovery for all axes
  Enter selection :  5

Enter the name of the scribe marks file (press ENTER to cancel)
(unit:\dir\name.ext - default '.ext' is '.MRK') :  C:\<robot number>.MRK

Please follow the instructions below :
1: Using the Teach Pendant or brakes release, move the arm to put
all the joints around the scribe marks.
Press ENTER when done
2: WARNING - Check if the arm is able to move.
Continue (Y/N) ?  Y
3: Push the 'Arm Power On' button and press  ENTER when done.


Running .. -
RPT.CAL RELEASE NUMBER D 241 612 01 C
The V_REG position is now recovered and the robot is calibrated.
Type 0 in the V_REG Position Recovery menu to exit.
Press ENTER

*** V_REG POSITION RECOVERY ***

  AXIS RECOVERY STATUS
  (0: need to be recovered / 1: recovered)
  Axis 1 : 1 Axis 4 : 1
  Axis 2 : 1 Axis 5 : 1
  Axis 3 : 1 Axis 6 : 1
  => ROBOT CALIBRATED <=
  (Note : all axes have to be recovered to calibrate the robot)
  0 => Exit
  Enter selection :  0
```

3.6 Probe collision detection

To protect the valuable probes from destruction, the DASY3 system includes hardware and software components to detect probe collisions and react accordingly. The DAE box has 2 switch systems in the probe fixture. The first system (probe touch) detects frontal probe collisions. During mechanical surface detection this switch is used to find the phantom surface. The second switch system (probe collision) detects lateral probe collisions or frontal probe collisions with more than 10mm penetration. The probe connector can be pushed 20mm into the DAE-box.

After detecting a probe collision, the software on the signal processor will abort any ongoing software controlled movement or turn the arm power off, if the collision occurs during manual movements. The robot must acknowledge the requested abort commands within a few milliseconds, otherwise the signal processor will make an emergency stop. After expected probe collisions during mechanical surface detection, the program continues normally. After unexpected probe collisions, the movement procedure is aborted and an error message is displayed.

The state of the two switch systems is displayed in the state window. (See RG: 4.1 State Information of Robot)

If only the probe touch switch is in, the robot arm will stay powered or can be turned on again. Use the "Lift probe" buttons to bring the probe away from the surface. (See RG: 4.2 Robot Toolbar Commands).

If the probe collision switch is in, the robot arm cannot be powered again. Lift the DAE in the holder, turn on the robot arm, move the probe backward and reposition the DAE. If you want to have exact the same probe positions as before, you must realign the probe in the light beam. (See RG: 4.2 Robot Toolbar Commands).

3.7 Robot options

3.7.1 Joint angle limitations

The working range of each joint in the robot can be limited by parameters written to the robot controller. This can help prevent possible collisions in cases where the robot is placed in a tight place. The joint limitations have been set during installation for optimum performance of the DASY system. If you change the joint limitation, please regard the following points:

- Do not limit the movements for normal DASY operations. If that happens, the robot will stop with the error message "Joint <n> out of range" displayed on the teach pendant and the monitor window of the DASY software.
- Do not decrease the lower joint limits on axis 3 or 5. Otherwise collisions with the black converterbox (EOC) on the robot might occur.
- Make sure that the robot is positioned so that the all axes are within the new limits. Otherwise the robot will refuse operation afterwards with the message "Joint <n> out of range".

The following describes the procedure to change the joint limits. Bold characters are software entries in the monitor window of the DASY software, always terminated with the enter-key.

1. Start the robot and the DASY software. The robot must be ready to run (calibrated).

2. Abort the DASY software by entering:

.abort 4
.abort 5
.zero
`Are you sure (Y/N)?` **Y**

3. Overwrite the DASY emergency stop by selecting the pull-down menu **Robot Overwrite E-Stop** .

4. Start the utility program on the controller. The name of the directory depends on the robot controller version; it always starts with **util_** or **ut_** . The directories can be displayed by entering the command **fdir**.

.cd util_4e3
.load spec.v2
`.PROGRAM a.spec()`
.ex 1 a.spec

5. Move through the menu

```
*** ADEPT ROBOT SPECIFICATION PROGRAM ***
  (Version 11.4C)
  Copyright (c) 1988-1996 by Adept Technology, Inc.
  Servo code version: 11.4C.3 Servo rate: 500 Hz
ROBOT 1: P60L_STD.SPC . D 241 647 00 A . MI6-RPT . 18/07/97 . V+11.4E3 V P2 .
  Restricted access mode (formerly CONFIG_R)
  0 => Exit to system monitor
  1 => Enter password to increase access
  2 => Perform hardware diagnostics
  3 => Edit robot specifications
  4 => Load robot specifications from a disk file
```

```
  5 => Save robot specifications to a disk file
  6 => Save ALL specifications to system disk
  Enter selection: 3

  *** ROBOT SPECIFICATIONS ***
ROBOT 1: P60L_STD.SPC . D 241 647 00 A . MI6-RPT . 18/07/97 . V+11.4E3 V P2 .
  0 => Exit to main menu
  1 => Edit robot initialization specs
  2 => Edit joint motion specs
  3 => Edit general motion specs
  Enter selection: 2
```

6. Change the joint motion limits. Repeat these steps for each axis you want to change. (Don't forget the - sign for negative angles !) Example:

```
*** ROBOT 1/JOINT 1 MOTION PARAMETERS ***
  0 => Exit
  1 => Change joint number
  2 => FINE nulling tolerance (cts).. 13
  3 => COARSE nulling tolerance (cts) 135
  4 => Lower joint limit (mm or deg). -160
  5 => Upper joint limit (mm or deg). 160
  Enter selection: 1
Enter joint number to edit: 5

*** ROBOT 1/JOINT 5 MOTION PARAMETERS ***
  0 => Exit
  1 => Change joint number
  2 => FINE nulling tolerance (cts).. 10
  3 => COARSE nulling tolerance (cts) 100
  4 => Lower joint limit (mm or deg).  -109.5
  5 => Upper joint limit (mm or deg). 120.5
  Enter selection: 4
  PARAMETER (Range -109.5 to 120.5) CURRENT VALUE NEW VALUE
Lower joint limit (mm or deg) -109.5 -75

*** ROBOT 1/JOINT 5 MOTION PARAMETERS ***
  0 => Exit
  1 => Change joint number
  2 => FINE nulling tolerance (cts).. 10
  3 => COARSE nulling tolerance (cts) 100
  4 => Lower joint limit (mm or deg). -75
  5 => Upper joint limit (mm or deg). 120.5
```

7. Save the changes and leave the utility program:

```
exit 0
exit to main menu 0
save all specifications to system disk 6
write to boot disk Y
boot disk (a/c)? C
OK to write (y/n)? Y
press return to continue
exit to system monitor 0
```

8. Reboot the robot immediately. Don't use any DASY3 buttons beforehand; otherwise the system will start downloading the robot programs again. If this happens, do not interrupt the download process. Wait until it is finished and then reboot the controller.

The maximum working range for the robots are:

	RX60L		RX90(L)	
	min	max	min	max
Axis 1:	-160°	+160°	-160°	+160°
Axis 2:	-127.5°	+127.5°	-137.5°	+137.5°
Axis 3:	-134.5°	+134.5°	-142.5°	+142.5°
Axis 4:	-270°	+270°	-270°	+270°
Axis 5:	-109.5°	+120.5°	-105°	+120°
Axis 6:	-270°	+270°	-270°	+270°

3.7.2 Turtle mode operation

The robot controller (only CS7(M) versions) in the DASY3 system has been rewired for "turtle mode" operation. In this mode the motor amplifier works with reduced voltage and the robot has less acceleration force. This mode is meant for safe operation during times when the operator has to be in the robot area. Stäubli offers an optional switching system to select normal or turtle mode from the front panel. As the high speed is not needed in the DASY system, the controllers are wired for turtle mode. This document describes how to bring the robot back to normal mode.

1. Switch the controller off and disconnect the main power line to the controller.

2. Disconnect the teach pendant cable at the bottom left side of the black front panel of the controller.

3. Unscrew the black front panel (4 screws) and turn it carefully away to the left side. You have to disconnect the cable to the PC-board with the LED's inside the front panel, in order to move the front panel out of the way for the following operations.

4. Behind the black front panel there are three large and numbered units of three fuses each. The numbers are: (7, 8, 9), (21, 22, 23) and (43, 44, 45). Fuse unit (43, 44, 45) is used for "turtle mode operation; unit (21, 22, 23) is used for normal mode operation. Open the fuse unit (21, 22, 23) and the fuse unit (43, 44, 45).

5. To switch to normal mode operation, remove the three fuses from group (43, 44, 45) and insert them to unit (21, 22, 23).

6. To switch to turtle mode operation, remove the fuses from group (21, 22, 23) and insert them to unit (43, 44, 45).

7. Close the fuse unit with the three inserted fuses. Never use fuses in both fuse units simultaneously!

8. Reconnect the cable to the LED-board of the front panel, close the front panel and reconnect the teach pendant.

9. Write down and inform all operators about the changes. The safety requirements are more stringent in normal operation mode, because the robot has much more force and acceleration.

3.7.3 Installing cabinet

1. Unpack the cabinet carefully (contains glass!).

2. Remove the top cover by loosening the screws at the corners.

3. Remove the cardboard-packed (and leave packed for now) glass door from the cabinet.

4. Fit support feet (4pc provided) into the hexagonal screws on the bottom side of the cabinet and adjust the feet for correct stability of the cabinet.

5. Place the cabinet in a convenient position.

6. Remove all cables from the robot controller and insert the unit carefully via the front opening of the cabinet. Preferably use the hooks supplied with the controller to lift and carry the controller. Make sure that the sheet metal supports of the controller do fit into the slots in the aluminum rails inside the cabinet. DO NOT lift or carry the controller by holding it at the metal handles on the lower part of the front panel!

7. Reconnect all cables to the controller, removing back plates temporary for convenience if necessary. Replace the serial link cables with those provided with the cabinet kit and lay them around the controller so that they leave the cabinet at the rear side opening. Install the extension cable for the teach panel in a similar way. At this point, you may earth the installation by connecting the common earth point of the cabinet (left back bottom corner) to a solid grounding point in your lab.

8. Carefully unpack the glass door and install it on the lower hinge pin and secure it with the top hinge pin provided with the small parts inside the packaging of the door.

9. Connect the earth cable of the top cover to the terminal in the right back corner of the cabinet using the washers and bolt provided (1. plain washer, 2. cable terminal, 3. indented washer, 4. bolt); see also the included original instruction sheet.

10. Secure the top cover with the 4 bolts and finish by covering them with the plastic caps provided.

3.7.4 Additional setup for RXB robots

Stäubli has discontinued production of the RX robots and CS7 controllers and replaced them with the corresponding RXB and CS7MB series. The specifications are the same, but the controller has changed (ethernet connection, no floppy disk support). To run the DASY3 system additional settings have to be specified after the installation. With the ethernet option data can be transferred to a PC (Network File System (NFS) has to be installed). For more information about the Ethernet option please follow the documentation in the Stäubli manual AdeptNet User's Guide (D.280.248.04.B- 11/96, Rev.A).

3.7.4.1 Additional DASY3 settings with RXB robots

1. Open the robot window in DASY3 and start the configuration program:

```
.cd util
.load config_c.v2
  .PROGRAM a.config_c()
.ex 1 a.config_c
```

2. Select the following two menus

```
  4 => Controller NVRAM
  4 => SET "SWITCHES" in the NVRAM
```

3. Adjust so that the settings are as below:

```
  User interface via VGB or serial port
  Enable V+ auto-start
  Boot sequence is A/B/C/D
  Enable auto-boot
  Disable DDT serial I/O on auxiliary CPU
```

4. Quit the program and restart the controller to apply the settings.

3.7.4.2 Enabling usage of PC Floppy for exchanging data with robot

1. Open the robot window in DASY3 and start the configuration program:

```
.cd util
.load config_c.v2
  .PROGRAM a.config_c()
.ex 1 a.config_c
```

2. Select the following two menus

```
  4 => Controller NVRAM
  4 => SET IP address in the NVRAM
```

3. Select a possible IP address and the same subnet mask you use in your network.

```
  IP address: 10.0.0.100
  IP subnet mask: 255.255.255.0
```

3. Select menu below

```
2 => V+ System Configuration Data
```

Change the mount 1 entry (Replace 'SERVER' with the PC network name) and the Node 1 entry (Replace 'SERVER' with the PC network name and the PC network IP address). Add an entry LOCAL_ID as specified below.

```
.NETWORK
LOCAL_ID = "/MACHINE 'RX' /UID 200 /GID 200"
MOUNT 1 = "/MOUNT 'a:\' /NODE 'SERVER' /PATH '/a'"
NODE 1 = "/NODE 'SERVER' /ADDRESS 10 0 0 2"
```

4. Setup the NFS-Server on the PC

Open the file nfs.zip which is supplied on the DASY3 CD (directory addons). Open the file install.txt and perform the installation on the PC as described therein.

5. Connect the ethernet cable between the network card of the computer and the AWC-board on the controller.

6. Quit the program and restart the controller to apply the settings.

7. Enter the following command to show the directory of the PC-Floppy on the controller

.fdir nfs>a:\

8. For troubleshooting see chapter five in manual AdeptNet or the install.txt file in the nfs.zip file.

4. Software

The DASY3 software is designed to work with DASY2 DAE or/and DASY3 hardware. It is written in Visual C++ (full 32-bit version) and runs under Windows 95/Windows98 or Windows NT. The software is built in a modular way with dynamic link libraries. This allows new components to be easily appended and to be changed according to existing components and to special customer needs without the necessity of rewriting the whole software.

The DASY3-Software makes use of all system components to allow field measurements on these hierarchical complexity levels.

4.1 Introduction

The DASY3 system combines a sophisticated measurement system with a variety of probes (E-field, H-field, temperature, ...) and a high precision 6-axis positioner. The combination allows for completely automated measurement scans and evaluations using both field and position information (e.g. volume averages, peak search, extrapolations, ...). The main purpose is for measurements in the near-field of radiators, where the field is highly non isotropic and the exact measurement location is of high importance. Special effort went into the important area of dosimetric measurements where the situation is complicated by the presence of phantoms and the need for probe calibrations in lossy media.

The dosimetric measurement system has many components (Phantom, Solution, Positioner, Source, Probe, Electronics, Evaluation procedures). All have their influence on the result described in the numerous parameters of each component.

The relative position and orientation of several objects in space is crucial for measurements and visualization (phantom, source, measurement locations, probe sensor orientation).

To keep so many parameters and settings under control could be a major headache and source to innumerous user errors. The main aim of SPEAG is to give the customer a system that is robust and reliable. This also means necessarily that the system is highly automated, easy to use and uses a sophisticated management of all necessary settings. This is achieved throughout the DASY3 software by following principal features.

- Every system component has its own configuration dataset with all necessary parameters. They can be exported and imported to the software and are delivered together with the components from SPEAG (see 4.4 Configuration files)
- Equally, all user settings (e.g., measurement grids, visualization) are stored in datasets that can be exported, imported and referenced in later measurements (see 4.4 Configuration files).
- Measurements can be defined on several hierarchical levels, from a simple local field measurement to complex batch procedures involving many field scans, evaluations, robot commands, etc. (see 4.5 Field measurements or 4.7 Field scans).
- The measurement documents include all parameters used so that the settings can be checked at any time (see 4.7.1 Document files).
- Different protected access levels can be set according to the user involvement with the system. While the casual user can start any previously defined measurement on the lowest level, they cannot erroneously change any crucial settings (see 4.4 Configuration files).
- A validation procedure tests the complete system for correct settings and undamaged components (see 4.9 System validation and checks).

4.2 Installation and update

To perform an **update** from a previous installation, perform the following steps:

1. Make a backup of your configuration files (either export all probes, devices, etc. to a floppy disk or copy the system configuration files core.cfg, robot.cfg and calib.cfg (located in the program directory of the previous installation) to another directory (or a floppy disk).
2. Perform a full DASY3 installation (4.2.1) with the CD-ROM to the same directory to which the old version was installed.
3. Start DASY3; if you want to measure Irdium phones, delete the current generic twin phantom in the **setup config** dialog and **import** the new configuration file 'generic twin.cfg' from the directory `\Predefined`).

4.2.1 Installation

The DASY3 software is license protected due to the graphics software package we use. If you do not know your license key, contact us with the volume serial number of your hard disk (c:\). (Run the ms-dos program from windows (menu Start Programs Command Prompt) and type in the command dir /p. In the first lines the volume serial number will be displayed (xxxx-xxxxx)).

- To install DASY3 for Windows 95/Windows98/Windows NT 4.0 insert the CD-ROM, run the program **setup.exe** in the directory 'DASY3\DISK1\' and perform the steps of the installation program. (To install the online user manual and software reference guide (help option selected in installation dialog **Select Components**) **Internet Explorer 4.0** or greater has to be installed on the computer before, otherwise a file error will appear (please reinstall without the help option selected).
- Restart your computer and start the DASY3 program.
- Select **Setup Config ...** from the menu and change to the **Configuration** tab in the dialog.
- Press the **Import** button in the dialog. A File Dialog will appear. Change to the directory 'Configuration data' on the CD-ROM and select all files (press SHIFT - Key and select the first and the last entry).

4.2.2 Verifying installation

If you are not sure whether you have all options installed, check if the following files are in the program directory:

File	Description
dasy3.exe, da3core.dll, da3full.dll, da3calib.dll	Main program and dynamic link libraries
da3boardv3.dll	DASY3 PC-board support
da3e3d.dll	E-field probe 3-dimensional
da3h3d.dll	H-field probe 3-dimensional
da3temp.dll, da3tempscan.dll	Temperature probe and temperature scan support
da3e1d.dll	E-field probe 1-dimensional

Imported configuration data is stored in the files **core.cfg** , **robot.cfg** and **calib.cfg** in the program directory.

4.2.3 New features DASY3 V3.1c

- Measurement support for satellite phone measurements. (4.8.2 Irdium Phones)
- Additional robot commands (probe rotation, probe lift and align probe to phantom). (RG: 6.8 Robot commands)
- New graphics features including (re-)position absolute to the origin point, dB-scale, scale on the bottom of the graphics and automatic adjusting of line thickness of isolines. (RG: 2.9 Graphic Formats)
- New scan which allows battery power measurements. (RG: 6.6 Time Sweep)
- New robot software for support of Light Beam. (2.10 Ligh Beam)
- Changes in User Interface.
- Support for one dimensional E-Field Probe. (2.6.1 E-Field Probe)
- New User Manual and Sofware Reference Guide.

Note: If you had DASY3 V1.0b installed please contact Schmid & Partner Enigneering AG for a new license key for the software if its not written on the CD-Rom. (Please have your volume serial number ready).

4.2.4 New features DASY3 V1.0b

- New robot command E-Stop overwrite, Enable power. (RG: 4.1 State information of robot)
- Movements between sections in liquid. (RG: 2.7.1 Sections)
- Reference point and origin in phantom. (RG: 2.7 Phantoms)
- Sound or message-beep to signal end or abort of measurements. (RG: 2.1 Access rights)
- Additional surface checks. (RG: 6.9 Surface check)
- Robot commands possible during measurements. (RG: 6.8 Robot commands)
- Free Space measurements (probe must no longer be parallel to z-axis of robot anymore). (4.6.2 Origin, drid and device orientations)

4.3 Access levels

If several people use the system, we recommend having one system operator (Administrator) who defines all measurement procedures and phantom settings. This prevents incorrect measurement data due to improper parameter settings from users who are not very familiar with the system. DASY3 software allows the configuration of different access modes. (RG: 2.1 Access rights)

4.4 Configuration files and parameter sets

Database for all components with their crucial parameters (RG: 2. System configuration):

Component	Installed by	Full (partial) access level for editing
Probe	SPEAG	Manufacturer (Administrator)
PC-board	SPEAG	Manufacturer (Administrator)
Data acquisition	SPEAG	Manufacturer (Calibration)
Measurement Profile	Administrator	Administrator
Medium	User	User
Device	User	User
Graphic format	Administrator	Administrator
Phantom	SPEAG/Administrator	Administrator
Robot	SPEAG	Manufacturer (Administrator)
Signal Generator	Administrator	Calibration
Power meter	Administrator	Calibration

Manipulation of datasets:

- view parameters (user)
- edit parameters (see table)
- create dataset (see table)
- delete dataset (administrator)
- import (admin) (device: user)
- export (admin) (device: user)
- example: installing

4.5 Field measurements

4.5.1 Data evaluation

The DASY3 field measurement unit can be used alone or can be called from jobs involving robot commands. The data acquisition is the same for both applications. The DAE3 electronics delivers 16bit digitized values at a rate of 7812 readings per second. The DAE3 switches between the required input channels and amplifications. For three channel measurements the rate is 2604 complete measurements per second. The incoming data are prefiltered on the PC-board and transferred at a slower rate to the DASY3 program, where the final filtering and integration takes place. The DASY3 software periodically requests a measurement with short-circuited inputs from the DAE3 to compensate for the amplifier offset and drift. Filter characteristics, measurement times, DAE3 amplification and autozero cycles can be selected in the measurement profile (4.5.4 Measurement profile).

The first step is the evaluation of the input voltage in microvolts at the DAE3 input using the calibration parameters of the DAE3 unit. This DAE3 input voltage is the primary unit in the DASY system from which all other units are derived. Probes with detector diode sensors are nonlinear. Below the diode compression point, the output voltage is proportional to the square of the applied RF-voltage; above the diode compression point it is linear to the RF-voltage. The compression characteristics of each DASY3 probe sensor are specified, and the correction is done automatically in the system.

Note: Due to the high probe impedance, the amplifier input voltage also depends on the input impedance and bias current of the amplifier. If the probes are used on a different amplifier type, their sensitivity and offset can be different.

Depending on the probe type, the E-field or H-field values are evaluated from the input signal and the probe calibration data. This evaluation includes linearization of the diode characteristics and frequency correction of the probe response (if necessary). The field evaluation is done separately for each sensor, same as the calibration. The field values can be displayed as components or as a total. (See AN: Data Storage and Evaluation for more detail on the evaluation). The total field value is the RSS value of the component values. For power related values, the total is the sum of the component values.

SAR or equivalent power density can be calculated from the field values, if they make sense in the actual setup. (E.g., SAR is only available for E-field probes in lossy media, while power density is only available in lossless media).

The multimeter option in the DASY3 software gives direct access to the field measurement unit. It can be used without powering the robot. The data can be displayed as values or as a function over time in the scope window. Single or continuous measurements and data export to ASCII-files are possible. For more details see RG: 3. Multimeter option .

Pulsed and modulated signals

The probes have low pass characteristics with a corner frequency of around 20Hz, due to the high probe impedances and the amplifier filters. The probe output does not follow the fast modulations of the RF signal, but gives an averaged (RMS) reading. For signal levels in the square law region of the detector diode, this gives the desired RMS value for any modulation scheme. However, for larger signal levels the averaged signal might be below the compression point, while the peak signal is in the compression area. In that case a compensation would be necessary for all levels above the compression range.

The DASY3 system allows to specification of **crest factor** of the signal source (RG: 2.4 Device). The crest factor is defined as the relation between peak power and average power in a signal. For pulsed signal the crest factor is identical to the duty cycle. (For signals that pulse between 100% and 50% power the crest factor is different from the duty cycle). The crest factor is used to calculate the peak power in the signal and perform the compensation of the diode compression on the peak power. The following list gives the necessary crest factor settings for different mobile phone systems:

System	Crest factor
Analog (NMT, AMPS)	**1**
GSM	**8**
PCS	**3**
DECT	**25**
CDMA	**1**

Note: CDMA in normal operation has a crest factor that varies with the traffic on the channel. However, in test mode CDMA devices give continuous output power.

4.5.2 Liquid parameters and SAR

The SAR depends strongly on the parameters of the simulating solution. In the DASY3 software, each solution has its own set of parameters. The liquid conductivity is used to calculate the SAR in mW/cm^3 from the electric field strength in the liquid (see AN: Data Storage and Evaluation). The density is additionally used to calculate the SAR in mW/g. Since the density has no influence at all on the field distribution in the phantom, it is not necessary to use tissue simulating liquids with matching densities. It is sufficient to enter the density of the simulated tissue (e.g., 1 to 1.06 g/cm^3 for brain) in the DASY3 software to get the correct SAR values for the simulated tissue (see RG: 2.3 Medium). The permittivity is not used in the SAR calculation. The thermal capacity is only used for SAR measurements with the temperature probe (2.6.3 Temperature probe).

It is difficult to produce a liquid with exactly matching parameters because the parameters drift with water evaporation and change with temperature. If the parameters are sufficiently close to the target parameters, it is not necessary to adjust the liquid composition. In addition, the actual parameters differ from the measured ones due to measurement uncertainties in the liquid measurement setup (see AN: Recipes for Brain Tissue Simulating Liquids). The following estimation of the SAR sensitivity on liquid parameters can help to decide what parameters are acceptable for a requested SAR uncertainty.

The liquid parameters influence the SAR distribution in different ways:

- The liquid conductivity in the software is used to calculate the SAR from the fields values. The assessed SAR changes linearly with the conductivity setting in the media setup (see RG: 2.3 Medium).

- The liquid permittivity and conductivity influence the actual coupling of the energy into the phantom. This effect depends on many factors (e.g., phantom shape, distance of the source, distance of the measurement location in the liquid). Since the parameters also influence the power decay in the liquid, the effect is different for surface values, 1g or 10g averaged values. The DASY3 system cannot compensate for these effects, but will measure the SAR distribution in the actually used (eventually wrong) liquid. AN: SAR Sensitivities gives an estimate of the SAR errors due to incorrect liquid parameters for some typical setups.

- The liquid has a loading effect on devices used in the immediate vicinity of the phantom. If the liquid differs considerably, the feedpoint impedance and the current distribution of the source can change.

- The probe sensitivity depends on the surrounding media. If the probe is used in liquids with other parameters than the calibration liquid, the measured E-field values will be slightly incorrect.

The effect of the first two points can be estimated. For small variations in the liquid parameters (<10%), the effect of the other points can be neglected. It is generally recommended to adjust the liquid parameters to the target parameters within better than 5%. Otherwise, the liquid uncertainty will produce a significant contribution to the total SAR uncertainty.

4.5.3 Connection between device, liquid, and probe parameters

The electric parameters of the simulation liquid are frequency dependent. Unluckily, this frequency dependency in the homogeneous simulation liquid is different than in the complex cellstructure of the simulated tissue. Since each solution can simulate the tissue only within a limited frequency range, several mixtures are necessary to cover the total MTE frequency range. Within a frequency bandwidth of at least 20%, the same solution can be used with small errors in the SAR. However, the measured parameters at the actual frequency should be used in the software (see RG: 2.3 Medium).

The DASY3 software checks the selected solution against the device frequency to prevent incorrect combinations which could lead to undetected measurement errors. To that purpose, each dataset for the media includes frequency range settings. If the frequency of the selected device is not within the range of the selected media, the system will issue an error message. It is highly recommended to use different media datasets for different frequencies, even for the same liquid. If one liquid is used for 835MHz and 900MHz two datasets with the corresponding parameters should be used (e.g., with frequency ranges 800 - 850 MHz and 870 - 920 MHz). The liquid parameters should be remeasured and adjusted in the software regularly (see RG: 2.3 Medium).

The probe conversion factor (and boundary effect) depends on the frequency and the liquid parameters. For each dosimetric probe, many different sets of conversion factors and boundary correction data can be defined (RG: 2.6.1 E-Field Probe). Each set includes range settings for permittivity, conductivity and frequency. The probe conversion factors can be selected manually or automatically (RG: 2.6.1 E-Field Probe). In the (recommended) automatic selection mode, the software searches for the first conversion factor in the list, whose permittivity and conductivity and frequency range covers the selected device frequency and liquid parameters. If no valid conversion factor can be found, the system will issue an error message when trying to measure SAR. The same error message appears if the manually selected conversion factors do not correspond with the device or the media.

Note: The system automatically selects the first valid conversion factor. If you define conversion factors with a reduced frequency and parameter range, make sure that this range is not already covered by an other set further up in the list.

The conversion factors are determined during probe calibration. SPEAG probes are by default calibrated at 900MHz and 1800MHz in brain simulating tissue. The range settings in the probe configuration file are selected to guarantee the specified probe uncertainties. If you want to perform SAR measurements in other liquids (e.g., 835MHz muscle tissue), the DASY3 system will complain. There are several ways to overcome the problem:

- Increase the range settings in the probe document, leaving the conversion factors as they are. This will permit the measurement, although with increased uncertainty. For small changes in the parameters or frequency the error is small (see box below).
- Add a new conversion factor set for the new liquid or frequency. The conversion factor can be estimated from the existing conversion factors (see box below).
- Order special calibrations for the probe.

The following sensitivities of the conversion factor can be used to estimate the conversion factor for other frequencies or media. They are assessed from special calibrations with the ET3DVx probe series. (They cannot be applied for other probe types!)

For frequency changes within the same media (not the same media parameters, they change also with the frequency and must be adjusted in the media settings!):

- In brain and muscle tissue between 750MHz and 1GHz, the conversion factor decreases approximately 1.3% per 100MHz frequency increase.
- In brain and muscle tissue between 1.6GHz and 2GHz, the conversion factor decreases approximately 1% per 100MHz frequency increase.

For muscle tissue around 900MHz (permittivity about 30% higher and conductivity about 15% higher than brain tissue):

- The conversion factor in muscle tissue is approximately 3% lower than for brain tissue for the same frequency.

For example:

An ET3DVx probe with a conversion factor 6.0 for 900MHz brain gives a conversion factor of 5.87 for 835MHz muscle tissue.

4.5.4 Measurement profiles

The DASY3 software allows the definition of several measurement profiles to determine how a single field or SAR value shall be assessed. The possibilities include measurement times, autozero cycles, gain settings, requested accuracy, or filters (see RG 2.5 Measurements profiles). The typical recommended settings for automatic SAR measurements are:

- Range: auto
- Sampling: notch line frequency
- Measurement time: 1s
- Autozero time: 1s
- Re-zeroing: 20
- Stop condition: none

Different settings can be used but generally only affect the result in special occasions. The following is a list of situations where other settings are recommended:

- The accuracy of very small signals can be increased with larger measurement times. However, measurement times larger than 5 seconds will not further increase the accuracy. For small signals it is much more important to have a good grounding system (see AN: System Noise).

- The noise during autozero cycles is smaller than during measurements. Autozero times above 2s do not bring any advantages.

- For measurement times above 1s, adding a stop condition (e.g., relative accuracy 0.1dB on the total) can speed up automatic scans with the robot. The system will end the actual measurement and continue to the next point as soon as the requested accuracy (based on statistical signal to noise evaluations) is reached.

- A measurement time of about 3 seconds is recommended for very accurate single point measurement, such as the reference and drift measurements in automated scans. This allows device power drift measurements with 0.01dB resolutions.

- The notch filter on the line frequency is recommended (for line frequency setups see RG: 2.2 Data acquisition). Other filter times are only useful if you encounter a strong noise component in the system (e.g., 16 2/3 Hz noise can be filtered with a 60 ms notch filter time).

- Disabling the filter is only interesting for **multimeter:scope** (see 3. Multimeter option) measurements. Without the filter, every measured value (7812 per second) is displayed. This gives useful information about system noise or source modulation.

- After warm-up of the DAE3 (about one minute) the drift is very low and rezeroing after all 20 measurements is sufficient. For normal signal values, rezeroing every 100 measurements would also be sufficient, but the speed gain is minor.

- For very low modulation frequencies, the measurement time (or the notch filter time) should be set to (a multiple of) the modulation period. Otherwise, the results become inconsistent.

- The auto range setting is generally recommended. For measurements of very small signals, the low range setting is possible. It speeds up the autozero cycle since only the low range is zeroed. However, even a single overrange (e.g., during a noise spike) will abort the measurement.

- The high range setting is preferable for pulsed signals with very low repetition rates. In auto range, the system would continuously change the range between pulses, which might slow down the measurements.

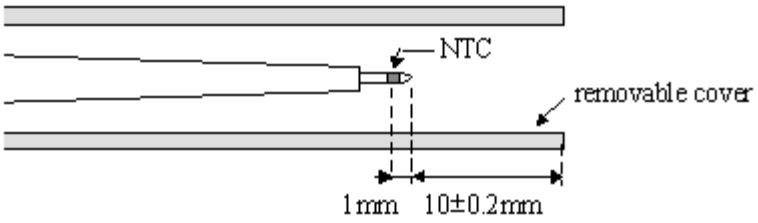
4.5.5 Temperature probe

Probe use and handling

The probe tip and body are made of PMMA material with Silicon seals. The probe can be used in water, sugar-water solutions, nutrient solutions, etc. The probe should not be used in alcohol or organic solvents.

The probe tip is very fragile; handle the probe with utmost care. Do not flex or bend the flexible sensor tip. Always leave the protection cover on the probe, except when making measurements.

The protective cover can be used as a position reference for accurate probe positioning, e.g., in a robot positioning system.



Procedure:

1. Make sure that the cover is correctly mounted.
2. Move to the surface with the cover in place.
3. Store the actual position.
4. Move the probe backwards and remove the cover.
5. Go back to the stored position.
6. Move the probe 10.0 mm forward. The probe tip is now just touching the surface. The active element is 1mm from the surface.

Important: Always clean the probe with warm water after use in liquid. When the probe has been used in sugar solutions, remove the cover and clean it separately. The cover might become stuck if the sugar crystallizes in its thread.

Calibration parameters

The following parameters must be used in the DASY3 system software. The parameters can be edited in the **Setup:Probe:Options** pull-down menu after selecting the temperature probe. To improve the accuracy within a limited temperature range, different parameter sets can be specified together with their temperature limits. The highlighted range in the **sensitivity** tab is active for measurements (see 2.6.3 Temperature Probe).

Data evaluation

The data acquisition electronics read the voltages over the NTC (Uy) and the shunt resistances (Ux, Uz). The temperature is evaluated as follows:

$$T[°C] = a \cdot \log\left(\frac{x}{1 - b \cdot x}\right) + c \qquad \text{with} \quad x = \frac{2 \cdot U_y}{U_x + U_z}$$

a, b, c = software parameters

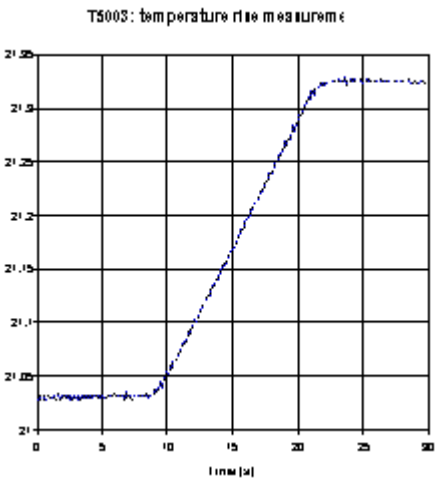
SAR - Measurements

The SAR in lossy media can be assessed by measuring the local temperature rise in the media during exposure:

$$SAR[W/kg] \approx c \cdot \frac{\Delta T}{\Delta t} \qquad \text{with } c = \text{heat capacity of the media in } J/(kg \cdot K)$$

- Make sure that the media is in thermal equilibrium before exposure, e.g., that there is no temperature gradient before exposure.
- The media should have ambient temperature. Otherwise convection processes might invalidate the measurement.
- Expose only during the measurement periods.
- Keep the exposure time and temperature rise as small as possible in order to prevent errors due to heat equalizing processes during measurement periods.
- After each exposure restore the media to thermal equilibrium (e.g., through stirring, etc.).
- Check the results for disturbing heat equalizing processes by repeating the measurements with different power levels and/or different exposure times. Convection processes have a non-linear behavior.

The optimal exposure time depends on the viscosity of the media. For water-salt solutions or dibutylglycol-solutions the measurement time should not exceed 5 seconds. For water-sugar solutions the measurement time can be up to 20 seconds. In jelly-like media even higher exposure times are possible.



The figure shows a typical temperature curve. The exposure is turned on and off during the acquisition period. The temperature must be constant before exposure for thermal equilibrium. The temperature rise during exposure should be a straight line. Any deviation is due to non-liner heat equalizing processes.

4.6 Phantoms, devices, grids

4.6.1 Phantom and sections

Robot based measurements in the DASY3 software are always performed in phantoms. A software phantom does not necessarily represent a physical object. It is a selection of room coordinates which define the measurement areas and control the robot movements. The robot coordinates are given for the probe tip (see 4.6.4 Probe alignment for more information).

Several phantoms (see RG: 2.7 Phantoms) can be defined in the system and can be referenced for measurement tasks. This allows fast and easy switching between different jobs. Two different phantom types are available, which use different coordinate systems to define room points:

- In the **phantom without reference points** , all points are given in the 'world coordinate system' of the robot (see 3.4 Robot coordinate system). This is the simplest and easiest way to make a measurement setup. It is used for free space measurements without a physical phantom object or for fast setups that are not kept for later reference.

- The **phantom with reference points** carries its own coordinate system. This is defined by three fixed reference points on the phantom. All other phantom points are referenced to this coordinate system. Before measurements, the robot must be told how the phantom is positioned with respect to the robot coordinates. This is done by teaching the three reference points in the phantom installation procedure (RG: 2.7 Phantom). The phantom position is stored in the software; however, the installation procedure must be repeated after moving the phantom. (In the DASY3 compact version, the Generic Twin Phantom always has the same position to the robot). A phantom validation procedure allows verification that the phantom has not been moved since its last use. The phantom with reference points is mostly used for physical phantoms where the setup can include a large number of points. Once defined, the phantom can be used in different locations by just teaching three points. The phantom data can be exported and the phantom can be moved to different DASY3 laboratories (e.g., the Generic Twin Phantom or setups for benchmark tests)

Each phantom must have a defined start point. This is a point above the phantom with sufficient distance to allow safe movements between phantoms. The start point can be used as the park position of the robot, where phantom manipulations or probe cleaning can be done safely. In the phantom mechanical or optical surface detection can be separately enabled. (E.g., in a transparent phantom the optical surface detection can be disabled, allowing only mechanical surface detection).

The measurements are performed in sections (see RG: 2.7.1 Sections). Each phantom in the DASY3 software consists of one or more sections. This allows the definition of different measurement areas within one single phantom, which is very useful in phantoms with reference points. Each section can consist of the following points or set of points:

- Each section must have an origin point and an origin direction. The measurement grid and the device location are both referenced to the section origin (see next section).

- The boundary points define a closed line. The software will prevent any automatic movements outside this line in the xy-plane of the phantom coordinate system. The boundary points are usually set inside the physical boundary of the section. Any grid points outside the boundary will not be measured. This allows easily setup of irregular grid shapes in complex phantoms.

- The user can define any arbitrary points in the section. These points can be referenced in robot movement commands. Combining movement commands and grids referenced to the actual probe position, complex procedures with multiple grids in different locations and with different

orientations can be defined.

The clearance distance and angle are used to define the movements between grid points. In free space, both values are normally set to zero, providing straight movements between points. In phantoms with curved surfaces, straight movements are not possible. See RG: 2.7.1 Sections for more details about the clearance settings. The liquid level determines the two startpoints of the section above and in the liquid.

The simplest phantom setup can consist of a start point and one origin point in one single section. This is sufficient for a free space scan above a mobile phone, even when measuring several grids.

An example for a complex phantom with reference points and several sections is the Generic Twin Phantom used in the DASY3 system.

4.6.2 Origin, grid and device orientations

The section (see RG: 2.7 Phantom) defines a measurement area, which can contain several measurement grids or user points and one closed boundary line that defines the maximum permissible movement range for the probe. Each section must have an origin point and an origin direction, which are used as reference for the position and orientation of the measurement grid and the device.

The **grid** can be shifted and rotated with respect to the origin (see RG: 2.7.2 Grids). The grids can also use the actual robot position for reference. Together with robot movement commands, the grid can use any user point as reference. The grid can be larger than the boundary; any point outside the boundary will not be measured. This allows measurement of the complete area of an arbitrarily shaped boundary.

Note: Grid points outside the boundary still reserve memory; the grid should not be much larger than the area defined by the boundary.

The **device** is always in reference to the origin. It can be additionally shifted and rotated in two angles (see RG: 6. Scans). The device position is only used for visualization in the 3D graphics. If no device shift is defined, the device is displayed with the device reference point at the origin point. If a section shell thickness is defined, the device is shifted by the shell thickness and the surface detection distance away from the origin. Additionally, each grid point is shifted in the display by the probe sensor offset distance in the direction of the probe. This assures that the each measurement point in the grid is displayed at the correct location with respect to the device.

Note: For relatively coarse grids, the graphic gives nicer pictures, if the grid lines are parallel to the device.

The DASY3 system gives different possibilities to define the origin points (see also RG: 2.7.1 Sections):

The device can be aligned to the world coordinate system of the robot. This is often the easiest way to setup a fast measurement in free space. Moving the probe manually in world coordinates gives the reference for the world system. After aligning the device, the probe can be brought to the origin location and the coordinates can be read (click **Get position**). The second point for the origin direction can be found by moving the probe in the corresponding world direction and clicking **Get 2nd pos** (see 2.7.1 Sections).

1. The Origin can be aligned to the device. Move the probe to the desired origin point and click **Get position**. Move the probe to a second point in the desired grid plane and click **Get 2nd pos**. The probe will measure in a plane through the two points. The plane can be at any angle to the world system. The probe is always aligned normal to the grid plane.

2. The measurement plane can be forced horizontal by clicking **Align vertical** after teaching the positions. The probe is aligned vertically and the default grid will be on a horizontal plane through the origin.

4.6.3 Surface detection

Measurements can be performed in a fixed plane or by following an arbitrary surface. In compliance test applications the highest integrated SAR values are the main concern. These values can be found mostly at the inner surface of the phantom and cannot be measured directly due to the sensor offset in the probe. To extrapolate the surface values, the measurement distances to the surface must be known accurately. A distance error of 0.5 mm could produce SAR errors of 6 % at 1800MHz. Using predefined location for measurements is not accurate enough. Any shift of the phantom (e.g., slight deformations after filling it with liquid) would produce high uncertainties. For an automatic and accurate detection of the phantom surface, the DASY3 system includes two different surface detecting systems.

Optical surface detection

The optical surface detection uses the proximity sensor built into some probes (see 2.7 Proximity sensor). The advantage of the optical surface detection is that it measures the surface distance in the center of the probe tip. This gives the correct distance even for angled surfaces, with an absolute error below± 0.2 mm for probe angles up to 30° normal to the surface. The repeatability in clear liquids is about± 0.05 mm. The optical surface detection is affected by reflections in the liquid; e.g., by small air bubbles or if the sugar-water distribution becomes inhomogeneous near the surface after long periods. Surface detection problems can be found easily with the built in surface check procedure (see RG: 6.9 Surface Check). Stirring the solution generally solves the problem.

The absolute stop distance from the surface depends on the probe and the optical characteristics of the liquid. It can be measured with the surface check procedure in the flat phantom. The correct stop distance must be entered in the probe parameters (see RG: 2.6 Probe), since it is used for extrapolation.

Mechanical surface detection

The mechanical surface detection uses the probe collision (see 3.6 Probe collision detection) detector built into the DAE box. It is extremely accurate if the probe is normal to the surface (± 0.05 mm). For angled probes, the distance increases, because the detection is at the edge of the probe tip. It can be used in any liquid with any kind of probe. If the surface is strongly angled to the probe, the probe slides along the surface and is deflected sideways. The second switch system in the DAE will detect this situation and the probe will move backward until the touch condition is cleared. However, there is some remaining uncertainty in the final probe position.

In the probe parameters, the desired distance to the surface can be entered. The detection is always at touch, but the probe will move backward from the surface the indicated distance before starting the measurement. If both systems are active, we recommended using the same distance in the mechanical detection as determined for the optical detection. If the optical detection fails, the mechanical detection takes over and places the probe at the same location.

The specified system uncertainty is for probe angles up to 30° normal to the surface. Both detection systems have increased uncertainties for higher probe angles. If measurements must be performed near the edge of the phantom, it is recommended to use non-vertical probe alignments to keep the probe approximately normal to the phantom surface. See 4.8.2 Satellite phones for an example of such a setup.

Extrapolation

Extrapolation routines are used to get SAR values between the lowest measurement points and the inner phantom surface. The extrapolation distance is determined by the surface detection distance and the probe sensor offset. Several measurements at different distances are necessary for the extrapolation. The routine uses a 4th order polynomial fitting for the extrapolation (see also AN: Spatial Peak SAR Evaluation).

Boundary effect

For measurements in the immediate vicinity of a phantom surface, the field coupling effects between the probe and the boundary influence the probe characteristics. These boundary effects disappear if the probe distance to the surface is larger than the probe tip diameter. The DASY3 system has two ways to cope with boundary effects.

In the so called **worst case extrapolation**, the boundary effect is minimized with different weighting factors for the lowest measurement points in the extrapolation. The procedure can be used for all probes, but the result can be a slight overestimation of the extrapolated surface points by 2% to 8%.

The **advanced extrapolation** can be used for probes which have the boundary effect characterized during the probe calibration. A numerical routine compensates the boundary effect (based on the distance to the surface) before doing the extrapolation.

4.6.4 Probe alignment

The positions in the DASY3 software are referenced to the probe tip. After startup or changing the probe, the software reads the mechanical probe specifications and calculates the default tool, i.e., the position of the probe tip with respect to the 6th robot axis. However, due to mechanical tolerances, the actual probe tip is not exactly in that position. The typical offset at the probe tip is up to 3mm.

When setting up the phantom with the actual probe, the offset in the probe tip is cancelled. However, after changing the probe or rebooting the system, the probe offset is generally different and the phantom appears shifted with respect to the probe tip. For SAR measurements with surface detection and maximum search this has no influence. The only effect will be a shift between the device and the measurement in the graphical output.

The mechanical probe offset is compensated completely after aligning the probe in the lightbeam. During this procedure, the system measures the actual probe offset and length. All further movements are then adjusted to the actual tip position. This allows a repeatability of better than 0.1mm even after changing probes. It is highly recommended to use this feature in systems with an installed lightbeam. (See 2.10 Light Beam).

4.7 Field scans and documents

4.7.1 Document files

Robot-based measurements are always done in document files (see RG: 5. Measurement documents). These are binary files containing the measurement setup, all involved parameters and the measured raw data in microvolts. The evaluation of other units is done each time the data are accessed for visualization on the graphics screen or exported. Some high level evaluations are performed immediately after the measurements, and their results are written into the document (see below). This system has the following advantages:

- The visualization and export is completely separate from the measurement. There is no need to decide on units, components, etc. before starting the measurement. All graphical options are available for all measurements.
- The inclusion of the setup and the parameters into the document allow backtracing the complete measurement from the document. This is particularly useful for troubleshooting or confirming the setup after the measurement.
- If the setup was incorrect (e.g., if the probe in the software setup is not the probe that was actually used in the measurement) it can be corrected afterwards and the data can be reevaluated with the correct parameters (requires administrator access, see RG: 5.1 User Interface (File Modify).

The measurement document contains a setup section and a job section. The job section (see RG 5. Measurement documents) contains a list of procedures which compose the actual measurement. These procedures ('jobs') can be selected from a list containing:

- Field scans in lines, planes or volumes
- Single point measurements (reference, drift or measurements over time)
- 1D or 2D probe rotations for probe calibrations and isotropy measurements
- Robot commands and movements
- Commands to control and read connected devices (power meter, signal generators)

After selecting a job, the parameters can be adjusted. To perform the measurement you select all requested jobs and click on start. The system will go through all jobs in a batch procedure.

Some frequently used measurements (such as FCC testing) can consist of many different jobs with complicated setups. In order to reuse the document, it can be saved before it is measured as a template for future measurements (see 4.8 Predefined files). To perform the measurement you open the predefined file, save it under a different name, and start the selected jobs.

Predefined files should be made read-only.

To enlarge the scope of the predefined files, the DASY3 system uses locked and referenced parameter descriptions (4.7.3) in the document files. This allows use of the same predefined file for measurements with different probes, media and devices or to exchange of predefined files between different DASY3 systems.

4.7.2 Locked and referenced parameters

The parameters in the DASY3 document files can appear either as written (locked) data or as references to the actual datasets in the system. The system automatically selects the necessary representation. What follows is a description of the parameters during the three lifecycles of the document file. This information is crucial to understand some effects or error messages when working with predefined files.

First step: Creating a new document

After creating a new document, the name of the actually active phantom is written to the file. The phantom and section data are not written to the file but are referenced through the phantom and section name. Any changes in the phantom parameters in the DASY system will affect the predefined files. All other parameters in the setting windows are referenced to the actually active software components (incl. time or file number). They can still change later.

When you select a coarse scan from the menu, you are asked to select the section, the grid and the measurement profile. The actual active settings appear as default values, but you can change them within the actual phantom. Their names will be stored as references to the corresponding system component. If you change the settings (e.g., the grid size) here, the change will affect the complete system.

All other scans (z-axis, cube scans, probe rotations, etc.) do not use a previously defined grid. For these scans the parameters are directly written to the document file with the exception of the measurement location, which is always referenced.

Plane and volume scans allow entering the device position (for later visualization of the device). This position is directly written to the file and cannot be changed later during measurement.

Second step: Opening a predefined document

After opening an unmeasured document, the references are set to the actually active probe, DAE, media and device. The phantom and grid references do not change their name. If the phantom or grid cannot be found any more (e.g., somebody changed the names) the measurement cannot not be started. The system will use the actual setup of the phantom.

Third step: Starting a measurement

When a job with a field measurement is started, all the actually active parameters (except the phantom) are written to the file and locked. This insures that the evaluation is done later with the parameters of the components used in the measurement. If only part of the scans are performed, the system must be brought to the same state to continue the measurements. Each document can only contain one probe, media or device. The measured data in microvolts and the coordinates for each point are written to the file.

The reference system makes it very easy to work with predefined files. All components that influence the field measurement (probe, electronics, media, device) are selected at the moment of the measurement and need not be specified before. The phantom is fully referenced, but its location and orientation is taken from its actual setup during measurement. This allows reuse of predefined files and even to exchange predefined files between laboratories.

For work with predefined files please consider the following points:

- Be careful when you change the names of phantoms, sections or grids. The predefined files won't recognize the new names.

- Select the actually used components in the DASY3 setup before starting the measurement.
- Once you have started a measurement and inadvertly saved it, the file is not much use anymore for further measurements. Therefore make your predefined files read-only and store them under a different file name befor you start to measure.
- When you continue a partially measured file, the setup (probe, electronics, media and device) must be the same as before. The phantom position can be different.
- If the parameters were incorrect during measurement, they can be changed after marking the file for modifications (see RG: 5.1 User Interface (File Modify)). The file modify marker must be removed before you can continue the measurements in the same file. After modifying the parameters, the high level evaluations must be repeated (see RG: 5.2 Evaluation).
- Each document can only contain one device, but the device can have different positions. It is also possible to measure different sections of the same phantom in one document.
- Scans can be interrupted and continued later. Errors in the system (e.g., low battery in the DAE) will also interrupt ongoing scans. Partially measured scans can be visualized if sufficient data are available.

4.7.3 High level evaluations

The DASY3 system allows evaluations which combine measured data and robot positions, such as:

- maximum search
- extrapolations
- boundary corrections
- peak search for 1g and 10g cube averaged SAR

The **maximum search** is automatically performed after each coarse scan measurement. It is based on splines in two or three dimensions. The procedure can find the maximum for most SAR distributions even with relatively large grid spacings. After the coarse scan measurement, the probe is automatically moved to a position at the interpolated maximum. The following scan can directly use this position for reference, e.g., for a finer resolution grid or the cube evaluations.

The **extrapolation** can be used in z-axis scans with automatic surface detection. The SAR values can be extrapolated to the inner phantom surface. The extrapolation distance is the sum of the probe sensor offset, the surface detection distance (see RG: 2.6 Probe) and the grid offset. The extrapolation is based on fourth order polynomal functions. The extrapolation is only available for SAR values.

The correction of the **probe boundary** effect in the vicinity of the phantom surface can be done in two different ways. In the standard (worst case) evaluation, the boundary effect is reduced by different weights for the lowest measured points in the extrapolation routine. The result is a slight overestimation of the extrapolated SAR values (2% to 8%) depending on the SAR distribution and gradient. The advanced evaluation makes a full compensation of the boundary effect before doing the extrapolation. This is only possible for probes with specifications on the boundary effect.

The **1g and 10g peak evaluations** are only available for the predefined cube 4x4x7 and cube 5x5x7 scans. The routines are verified and optimized for the grid dimensions used in these cube measurements. The measured volume of 32x32x35mm contains about 35g of tissue. The first procedure is an extrapolation (incl. boundary correction) to get the points between the lowest measured plane and the surface. The next step uses 3D interpolation to get all points within the measured volume in a 1mm grid (35000 points). In the last step, a 1g cube is placed numerically into the volume and its averaged SAR is calculated. This cube is the moved around until the highest averaged SAR is found. This last procedure is repeated for a 10g cube. If the highest SAR is found at the edge of the measured volume, the system will issue a warning: higher SAR values might be found outside of the measured volume. In that case the cube measurement can be repeated, using the new interpolated maximum as the center.

4.8 Predefined files and examples

4.8.1 FCC and CENELEC measurements

The following files exist as predefined templates in the directory`\Predefined`:

Filename:	Usage:
FCC left.da3	Intended use position, left hand
FCC right.da3	Intended use position, right hand
CEN intended left.da3	Intended use position, left hand
CEN intended right.da3	Intended use position, right hand
CEN touch left.da3	Touch position, left hand
CEN touch right.da3	Touch position, right hand
CEN 100° left.da3	100° position, left hand
CEN 100° right.da3	100° position, right hand
CEN 30° tilted left.da3	30°-tilted position, left hand
CEN 30° tilted right.da3	30°-tilted position, right hand

Perform the steps in chapter 1.1 Shortcut for casual users to perform a FCC or CENELEC measurement.

4.8.2 Satellite phones

The following files exist as predefined templates in the directory`\Predefined`:

Filename:	Usage:
Right Top.da3	curved head area straight above the ear, right hand
Left Top.da3	curved head area straight above the ear, left hand
Right Back.da3	upper back head area, right hand
Left Back.da3	upper back head area, left hand

The high antenna position in satellite phones usually gives a SAR distribution with the highest values in the upper head region. These regions cannot be measured accurately with the vertical probe position used in the FCC and CENELEC predefined procedures. However, they can be accessed easily with inclined probe orientations. For that purpose the Generic Twin Phantom includes two special sections: 'Left Upper Head' and 'Right Upper Head'. The boundaries in these sections are at the rim of the head phantoms. With vertical probe alignment, the probe will run into the phantom border!

Do not use these sections for normal measurements with vertical probes.

Each section has two user points 'Origin Top' and 'Origin Back' with probe inclination angles of 40 from the vertical axis. The 'Origin Top' position with the 'top grid' measures the curved head area straight above the ear. The 'Origin Back' position with the 'back grid' measures the upper back head area. The section origin is the ear position, and the device will be displayed at the ear as in the other head sections. Four predefined files are available with the complete setup for these measurements including surface check and reference measurements: Right Top.da3, Right Back.da3, Left Top.da3, Left Back.da3.

These files can only be used with DASY3 software versions 3.1c or higher.

The device position is the 'intended use' position with the angles 80° and 65°. When other positions are measured, the device position in the coarse scan (named 'Upper head' or 'Upper back head') and the cube scan can be changed (see RG: 6. Scans).

The following recommendations should be considered when using these sections:

- The probe should be aligned in the lightbeam and the phantom must be correctly installed. An offset in the phantom or probe position might lead to probe collisions during measurements.
- After installing the new 'Generic Twin Phantom' config file for the first time, please test all predefined procedures with the dummy probe.
- Use the grid specifications in the predefined file as they are. If you need a larger access area, you can define new grids or change the grid specifications. However, it is not certain, that the measurement will work properly, due to the strong phantom curvature in this area. Use the dummy probe to check your settings.
- You can generate your own sections and procedures with inclined probes. Follow the structure given in the predefined files for the jobs: (1) move to user point, (2) coarse scan at the actual position with surface detect, (3) move to surface, (4) cube scan at the actual position with surface detect. This will measure the cube around the peak value of the coarse scan. Do not use the cube scan with the setting 'Last evaluated maximum' - the system would try to measure the cube with vertical probe alignment. Use the dummy probe to check your setup.

4.9 System validation and checks

4.9.1 Noise level

See AN: System Noise and chapter 4.5 Field measurements for more information.

4.9.2 Validation

The following files exist as predefined templates in the directory`\Predefined`:

Filename:	Usage:
Validation 900 MHz.da3	for 900 MHz dipole, flat section
Validation 1800 MHz.da3	for 1800 MHz dipole, flat section

Perform the steps in chapter 1.1 Shortcut for casual users to perform a FCC or CENELEC measurement.

For further information see also AN:Validation and System Check and the calibration sheet of the validation dipole.

5. Troubleshooting

E-Stop/Controller problems

- Check that the probe is not colliding with an object (see 3.6 Probe collision detection).
- Check that the 3.1.3 Safety chain is closed.
- Check that no controller errors in the robot window are starting up during boot up. Look for messages which appear in stars (* xxxx *). If the message "Interlocked" appears, check that the key switch on the remote control is set to "AUTO" (see RG :3.2 Robot setup).
- Check whether the robot is calibrated or if a position recovery is necessary (message "Auto Calibration failed" during boot up) (see 3.5 Absolute position recognition and recovery).
- Check whether on the controller front panel LEDS (below the PTS 10-boards) are lighted, and if yes, note which ones (IT Warning, F0, F1, and F2) and on which axis (1..6) and give this information to SPEAG or your local Stäubli representative.
- Check whether on the controller front panel (on the BTS 10-boards) the LEDS Protection Enabled is lighted green and IT Limit is not lighted.

Spurious stops during measurements

- Check for proper connection of the battery connector to the DAE .