SAR EVALUATION REPORT

For

AMBIT Microsystems Corporation

4-1, Ming Shen Street, Tu Chen Industrial District.
Tu Chen, Taipei Hsien 236, Taiwan, R.O.C.

FCC ID: MCLT60H677

March 4, 2003

This Report Concerns: ☒ Original Report	**Equipment Type:** 802.11b Wireless PC Card
Test Engineer: Eric Hong	
Report No.: R0301172S	
Test Date: February 19, 2003	
Reviewed By: Benjamin Jing	
Prepared By: Bay Area Compliance Laboratory Corporation 230 Commercial Street Sunnyvale, CA 94085 Tel: (408) 732-9162 Fax: (408) 732 9164	

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SUMMARY

The US Federal Communications Commission has released the report and order "Guidelines for Evaluating the Environmental Effects of RF Radiation", ET Docket No. 93-62 in August 1996 [1].

The order requires routine SAR evaluation prior to equipment authorization of portable transmitter devices, including portable telephones. For consumer products, the applicable limit is 1.6 mW/g as recommended by the ANSI/IEEE standard C95.1-1992 [6] for an uncontrolled environment (Paragraph 65). According to the Supplement C of OET Bulletin 65 "Evaluating Compliance with FCC Guide-lines for Human Exposure to Radio frequency Electromagnetic Fields", released on Jun 29, 2001 by the FCC, the device should be evaluated at maximum output power (radiated from the antenna) under "worst-case" conditions for normal or intended use, incorporating normal antenna operating positions, device peak performance frequencies and positions for maximum RF energy coupling.

This report describes the methodology and results of experiments performed on wireless data terminal. The objective was to determine if there is RF radiation and if radiation is found, what is the extent of radiation with respect to safety limits. SAR (Specific Absorption Rate) is the measure of RF exposure determined by the amount of RF energy absorbed by human body (or its parts) – to determine how the RF energy couples to the body or head which is a primary health concern for body worn devices. The limit below which the exposure to RF is considered safe by regulatory bodies in North America is 1.6 mW/g average over 1 gram of tissue mass.

The test configurations were laid out on a specially designed test fixture to ensure the reproducibility of measurements. Each configuration was scanned for SAR. Analysis of each scan was carried out to characterize the above effects in the device.

The investigation was limited to the worst-case scenario from the device usage point of view. For the clarity of data analysis, and clarity of presentation, only one tissue simulation was used for the head and body simulation. This means that if SAR was found at the headset position, the magnitude of SAR would be overestimated comparing to SAR to a headset placed in the ear region.

There was no SAR of any concern measured on the device for any of the investigated configurations, please see following table for testing result summary:

Ambient Temperature (ºC): 23.0
Relative Humidity (%): 49.3

Worst case SAR reading

Antenna	EUT Position	Ch (MHz)	Conducted Power (dBm)	Setup condition (applicable checked) Antenna	Phantom	Measured	Limit
				Worst case SAR, averaged over 1g [mW/g]			
BY27	1.5cm Separation with Phantom	2437	16.37			0.140	1.6
	Face Touch Phantom	2437	16.37			0.164	1.6
	Bottom Touch Phatom	2437	16.37			0.0187	1.6
	Perpendicular to Phantom	2437	16.37			0.219	1.6
ZG1S	1.5cm Separation with Phantom	2437	16.37	Built-in	Flat	0.0170	1.6
	Face Touch Phantom	2437	16.37			0.0101	1.6
	Bottom Touch Phatom	2437	16.37			0.0121	1.6
	Perpendicular to Phantom	2437	16.37			0.0017	1.6
ZI1S	1.5cm Separation with Phantom	2437	16.37			0.0514	1.6
	Face Touch Phantom	2437	16.37			0.324	1.6
	Bottom Touch Phatom	2437	16.37			0.0535	1.6
	Perpendicular to Phantom	2437	16.37			0.0094	1.6

1 - REFERENCE

[1] Federal Communications Commission, \Report and order: Guidelines for evaluating the environmental effects of radiofrequency radiation", Tech. Rep. FCC 96-326, FCC, Washington, D.C. 20554, 1996.

[2] David L. Means Kwok Chan, Robert F. Cleveland, \Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields", Tech. Rep., Federal Communication Commission, O_ce of Engineering & Technology, Washington, DC, 1997.

[3] Thomas Schmid, Oliver Egger, and Niels Kuster, \Automated E-field scanning system for dosimetric assessments", IEEE Transactions on Microwave Theory and Techniques, vol. 44, pp. 105{113, Jan. 1996.

[4] Niels Kuster, Ralph K.astle, and Thomas Schmid, \Dosimetric evaluation of mobile communications equipment with known precision", IEICE Transactions on Communications, vol. E80-B, no. 5, pp. 645{652, May 1997.

[5] CENELEC, \Considerations for evaluating of human exposure to electromagnetic fields (EMFs) from mobile telecommunication equipment (MTE) in the frequency range 30MHz - 6GHz", Tech. Rep., CENELEC, European Committee for Electrotechnical Standardization, Brussels, 1997.

[6] ANSI, ANSI/IEEE C95.1-1992: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, The Institute of Electrical and Electronics Engineers, Inc., New York, NY 10017, 1992.

[7] Katja Pokovic, Thomas Schmid, and Niels Kuster, \Robust setup for precise calibration of E-field probes in tissue simulating liquids at mobile communications frequencies", in ICECOM _ 97, Dubrovnik, October 15{17, 1997, pp. 120-24.

[8] Katja Pokovic, Thomas Schmid, and Niels Kuster, \E-_eld probe with improved isotropy in brain simulating liquids", in Proceedings of the ELMAR, Zadar, Croatia, 23{25 June, 1996, pp. 172-175.

[9] Volker Hombach, Klaus Meier, Michael Burkhardt, Eberhard K. uhn, and Niels Kuster, \The depen-dence of EM energy absorption upon human head modeling at 900 MHz", IEEE Transactions on Microwave Theory and Techniques, vol. 44, no. 10, pp. 1865-1873, Oct. 1996.

[10] Klaus Meier, Ralf Kastle, Volker Hombach, Roger Tay, and Niels Kuster, \The dependence of EM energy absorption upon human head modeling at 1800 MHz", IEEE Transactions on Microwave Theory and Techniques, Oct. 1997, in press.

[11] W. Gander, Computermathematik, Birkhaeuser, Basel, 1992.

[12] W. H. Press, S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, Numerical Recepies in C, The Art of Scientific Computing, Second Edition, Cambridge University Press, 1992.Dosimetric Evaluation of Sample device, month 1998 9

[13] NIS81 NAMAS, \The treatment of uncertainity in EMC measurement", Tech. Rep., NAMAS Executive, National Physical Laboratory, Teddington, Middlesex, England, 1994.

[14] Barry N. Taylor and Christ E. Kuyatt, \Guidelines for evaluating and expressing the uncertainty of NIST measurement results", Tech. Rep., National Institute of Standards and Technology, 1994. Dosimetric Evaluation of Sample device, month 1998 10

2 - TESTING EQUIPMENT

2.1 Equipments List & Calibration Info

Type / Model	Cal. Date	S/N:
DASY3 Professional Dosimetric System	N/A	N/A
Robot RX60L	N/A	F00/5H31A1/A/01
Robot Controller	N/A	F01/5J72A1/A/01
Dell Computer Optiplex GX110	N/A	N/A
Pentium III, Windows NT	N/A	N/A
SPEAG EDC3	N/A	N/A
SPEAG DAE3	6/02	456
SPEAG E-Field Probe ET3DV6	9/7/02	1604
SPEAG Dummy Probe	N/A	N/A
SPEAG Generic Twin Phantom	N/A	N/A
SPEAG Light Alignment Sensor	N/A	278
Apprel Validation Dipole D-1800-S-2	11/6/01	BCL-049
SPEAG Validation Dipole D900V2	9/3/02	122
Brain Equivalent Matter (800MHz)	Daily	N/A
Brain Equivalent Matter (1900MHz)	Daily	N/A
Brain Equivalent Matter (2450MHz)	Daily	N/A
Muscle Equivalent Matter (800MHz)	Daily	N/A
Muscle Equivalent Matter (1900MHz)	Daily	N/A
Muscle Equivalent Matter (2450MHz)	Daily	N/A
Robot Table	N/A	N/A
Phone Holder	N/A	N/A
Phantom Cover	N/A	N/A
HP Spectrum Analyzer HP8593GM	6/20/02	3009A00791
Microwave Amp. 8349B	N/A	2644A02662
Power Meter HP436A	4/2/02	2709A29209
Power Sensor HP8482A	4/2/02	2349A08568
Signal Generator RS SMIQ O3	2/10/02	1084800403
Network Analyzer HP-8753ES	7/30/02	820079
Dielectric Probe Kit HP85070A	N/A	N/A
Apprel Validation Dipole D-2450-S-1	10/1/02	BCL-141

2.2 Equipment Calibration Certificate

Please see the attached file.

Engineering

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

Additional Conversion Factors
for Dosimetric E-Field Probe

Type	ET3DV6
Serial Number:	1604
Place of Assessment	Zurich
Date of Assessment:	October 4, 2002
Probe Calibration Date:	August 26, 2002
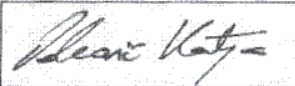
Schmid & Partner Engineering AG hereby certifies that conversion factor(s) of this probe have been evaluated on the date indicated above. The assessment was performed using the FDTD numerical code SEMCAD of Schmid & Partner Engineering AG. Since the evaluation is coupled with measured conversion factors, it has to be recalculated yearly, i.e., following the re-calibration schedule of the probe. The uncertainty of the numerical assessment is based on the extrapolation from measured value at 900 MHz or at 1800 MHz.

Assessed by:

Conversion Factor ($\pm$ standard deviation)

150 MHz	ConvF	$9.2 \pm 8\%$	$\varepsilon_r = 52.3$ $\sigma = 0.76$ mho/m (head tissue)
300 MHz	ConvF	$8.0 \pm 8\%$	$\varepsilon_r = 45.3$ $\sigma = 0.87$ mho/m (head tissue)
450 MHz	ConvF	$7.3 \pm 8\%$	$\varepsilon_r = 43.5$ $\sigma = 0.87$ mho/m (head tissue)
2450 MHz	ConvF	$4.7 \pm 8\%$	$\varepsilon_r = 39.2$ $\sigma = 1.80$ mho/m (head tissue)
150 MHz	ConvF	$8.8 \pm 8\%$	$\varepsilon_r = 61.9$ $\sigma = 0.80$ mho/m (body tissue)
450 MHz	ConvF	$7.7 \pm 8\%$	$\varepsilon_r = 56.7$ $\sigma = 0.94$ mho/m (body tissue)
2450 MHz	ConvF	$4.3 \pm 8\%$	$\varepsilon_r = 52.7$ $\sigma = 1.95$ mho/m (body tissue)

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:	ET3DV6
Serial Number:	1604
Place of Calibration:	Zurich
Date of Calibration:	August 26, 2002
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: N. Vetter

Approved by:

DASY3 - Parameters of Probe: ET3DV6 SN:1604

Sensitivity in Free Space

NormX	1.73	$\mu V/(V/m)^2$
NormY	1.68	$\mu V/(V/m)^2$
NormZ	1.72	$\mu V/(V/m)^2$

Diode Compression

DCP X	93	mV
DCP Y	93	mV
DCP Z	93	mV

Sensitivity in Tissue Simulating Liquid

Head	900 MHz	$\varepsilon_r = 41.5 \pm 5\%$	$\sigma = 0.97 \pm 5\%$ mho/m
Head	835 MHz	$\varepsilon_r = 41.5 \pm 5\%$	$\sigma = 0.90 \pm 5\%$ mho/m

			Boundary effect:	
ConvF X	6.5	$\pm 9.5\%$ (k=2)		
ConvF Y	6.5	$\pm 9.5\%$ (k=2)	Alpha	0.36
ConvF Z	6.5	$\pm 9.5\%$ (k=2)	Depth	2.82

Head	1800 MHz	$\varepsilon_r = 40.0 \pm 5\%$	$\sigma = 1.40 \pm 5\%$ mho/m
Head	1900 MHz	$\varepsilon_r = 40.0 \pm 5\%$	$\sigma = 1.40 \pm 5\%$ mho/m

			Boundary effect:	
ConvF X	5.5	$\pm 9.5\%$ (k=2)		
ConvF Y	5.5	$\pm 9.5\%$ (k=2)	Alpha	0.50
ConvF Z	5.5	$\pm 9.5\%$ (k=2)	Depth	2.46

Boundary Effect

Head	900 MHz	Typical SAR gradient: 5 % per mm

Probe Tip to Boundary		1 mm	2 mm
SAR_{be} [%]	Without Correction Algorithm	11.1	6.6
SAR_{be} [%]	With Correction Algorithm	0.4	0.6

Head	1800 MHz	Typical SAR gradient: 10 % per mm

Probe Tip to Boundary		1 mm	2 mm
SAR_{be} [%]	Without Correction Algorithm	12.3	8.1
SAR_{be} [%]	With Correction Algorithm	0.1	0.1

Sensor Offset

Probe Tip to Sensor Center	2.7	mm
Optical Surface Detection	1.3 ± 0.2	mm

Body 2450 Mhz Liquid Measurement, 2/19/03

frequency	e'	e"
2300000000.0000	52.4366	13.7143
2306000000.0000	52.3577	13.6945
2312000000.0000	52.2640	13.7276
2318000000.0000	52.1476	13.7359
2324000000.0000	52.0221	13.7303
2330000000.0000	51.8907	13.7539
2336000000.0000	51.7097	13.7816
2342000000.0000	51.5776	13.7994
2348000000.0000	51.4797	13.8238
2354000000.0000	51.4099	13.8679
2360000000.0000	51.3626	13.9040
2366000000.0000	51.3428	13.9458
2372000000.0000	51.3467	14.0164
2378000000.0000	51.4003	14.0546
2384000000.0000	51.4732	14.0965
2390000000.0000	51.5568	14.1357
2396000000.0000	51.6834	14.1611
2402000000.0000	51.7481	14.1878
2408000000.0000	51.8035	14.2049
2414000000.0000	51.8586	14.2074
2420000000.0000	51.8952	14.2059
2426000000.0000	51.8661	14.1936
2432000000.0000	51.8625	14.1964
2438000000.0000	51.7914	14.2041
2444000000.0000	51.6654	14.1879
2450000000.0000	51.5398	14.1827
2456000000.0000	51.4363	14.2115
2462000000.0000	51.2764	14.2520
2468000000.0000	51.1117	14.2943
2474000000.0000	50.9685	14.2780
2480000000.0000	50.8460	14.2728
2486000000.0000	50.7424	14.2978
2492000000.0000	50.6473	14.3041
2498000000.0000	50.5971	14.3161
2504000000.0000	50.6019	14.3361
2510000000.0000	50.5562	14.3655
2516000000.0000	50.5702	14.4021
2522000000.0000	50.6130	14.4240
2528000000.0000	50.6564	14.4345
2534000000.0000	50.6887	14.4776
2540000000.0000	50.7214	14.5204
2546000000.0000	50.7300	14.5416
2552000000.0000	50.7684	14.5724
2558000000.0000	50.7774	14.5996
2564000000.0000	50.7906	14.6392
2570000000.0000	50.7728	14.6791
2576000000.0000	50.7250	14.6955
2582000000.0000	50.7178	14.7168
2588000000.0000	50.6677	14.7628
2594000000.0000	50.6085	14.7826
2600000000.0000	50.5185	14.8032

$$\boldsymbol{s} = \boldsymbol{w}\boldsymbol{e}_o\, \boldsymbol{e}" = 2\,\boldsymbol{p}\, f\, \boldsymbol{e}_o\, \boldsymbol{e}" = 1.93$$
$$\text{where} \quad f = 2450$$
$$\boldsymbol{e}_o = 8.854 \times 10^{-12}$$
$$\boldsymbol{e}" = 14.1827$$

3 - EUT DESCRIPTION

Applicant: AMBIT Microsystems Corporation
Product Description: 802.11b Wireless PC Card
                              (This EUT is a portable device of identical prototype, which is within 20cm
                              from human body.)
Product Name: T60H677
FCC ID: MCLT60H677
Serial Number: None
Transmitter Frequency: 2.4-2.4835GHz
Maximum Output Power: 0.046W (for 802.11b)
Dimension: 2.4"L x 1.7"W x 0.1"H
RF Exposure environment: General Population/Uncontrolled
Power Supply: ASTEC AC Adapter, M/N: SA80-3115
Applicable Standard   FCC CFR 47, Part 15 Subpart C
Application Type: Certification

1 Specific Absorption Rate (SAR) is a measure of the rate of energy absorption due to exposure to an RF transmitting source (wireless portable device).
2 IEEE/ANSI Std. C95.1-1992 limits are used to determine compliance with FCC ET Docket 93-62.

Note: The test data was good for test sample only. It may have deviation for other test samples.

4 - SYSTEM TEST CONFIGURATION

4.1 Justification

The system was configured for testing in a typical fashion (as normally used by a typical user).

4.2 EUT Exercise Software and Procedure

The EUT exercising program used during SAR testing was designed to exercise the various system components in a manner similar to a typical use. The software, PRISM utilities, contained on the hard drive, is auto starting on power-up. Once loaded, the program sequentially exercises each system component.

The testing procedure is as follows:

1. Click PRISM test utilities on Window
2. Select wireless LAN Adapter under adapters list
3. Select low, mid and high channels under Radio Channels
4. Select Tx Rate of 11MB
5. Click on "continuous Tx" bottom

4.3 Special Accessories

All interface cables used for compliance testing are shielded as normally supplied by INMAC, Monster Cable and their respective support equipment manufacturer. The EUT is featured shielded metal connectors.
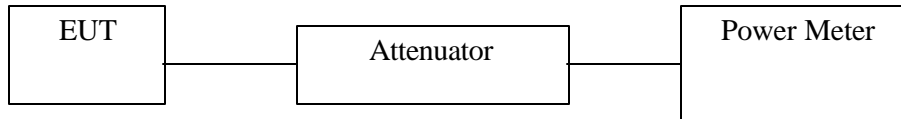
4.4 Equipment Modifications

No modification(s) were made to ensure that the EUT complies with the applicable limits.

5 - CONDUCTED OUTPUT POWER MEASUREMENT

5.1 Measurement Procedure

1. Place the EUT on a bench and set it in transmitting mode.
2. Remove the antenna from the EUT and then connect a low loss RF cable from the antenna port to a spectrum analyzer.
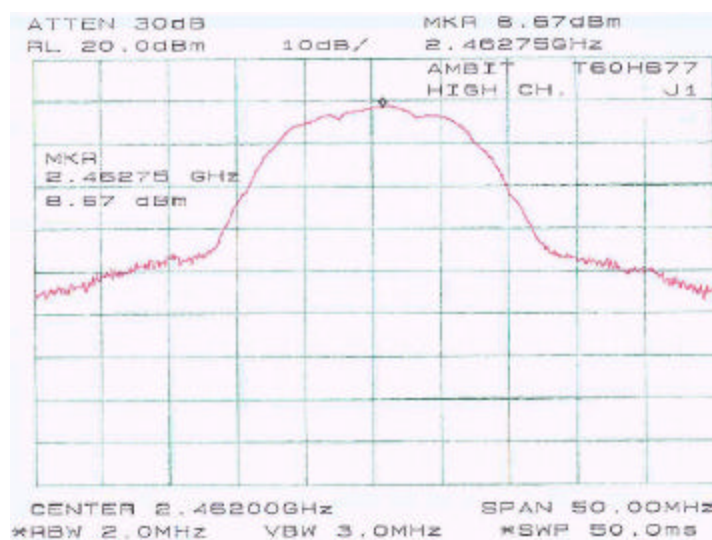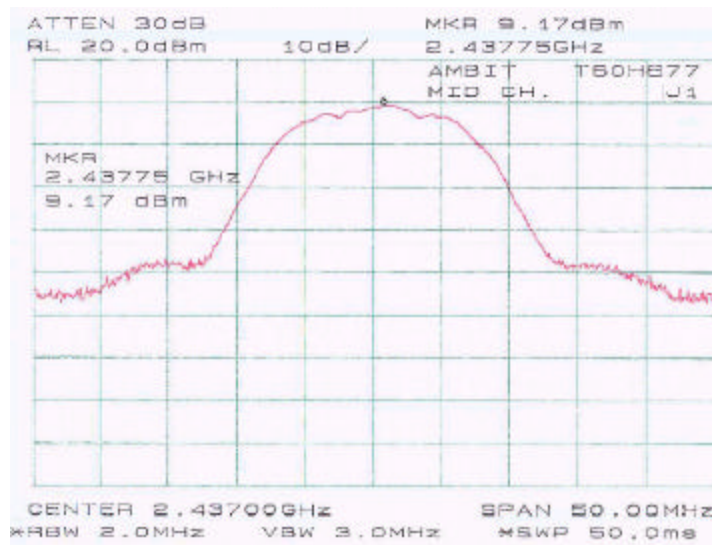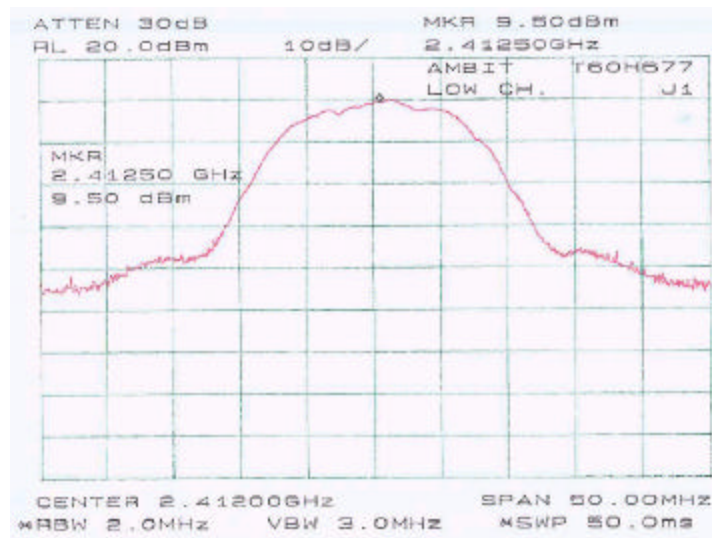3. Add a correction factor to the display.

```
┌─────────┐      ┌──────────────┐      ┌──────────────┐
│   EUT   │──────│  Attenuator  │──────│ Power Meter  │
└─────────┘      └──────────────┘      └──────────────┘
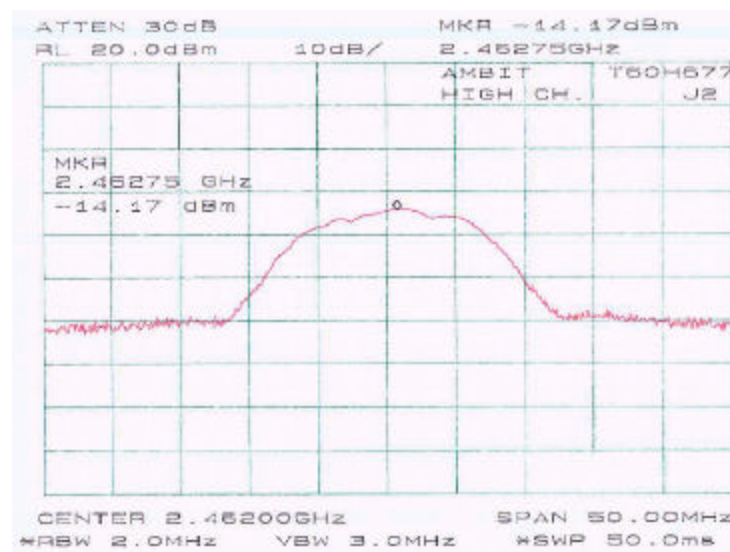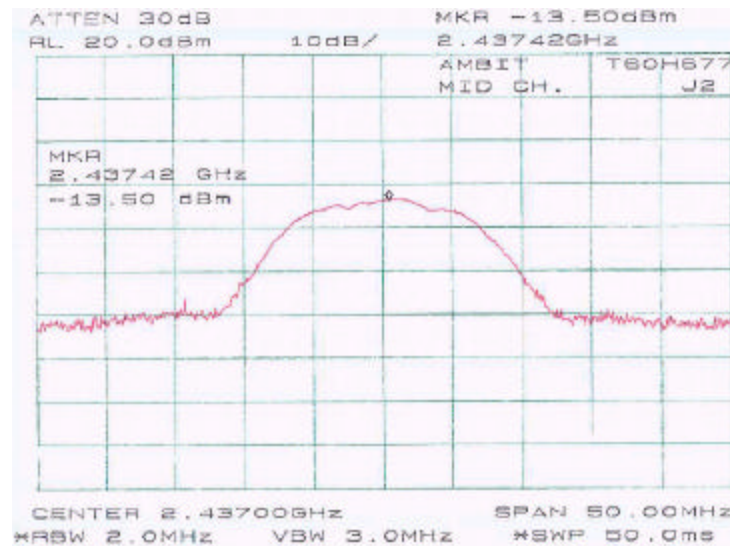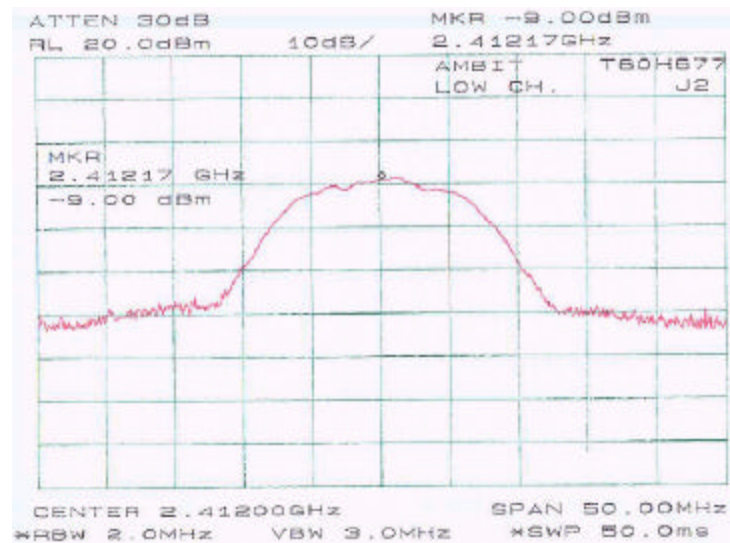```

## 5.2 Test Results

| Port | Channel | Frequency (MHz) | Output Power (dBm) | Correction Factor (dB) | Corrected Output Power (dBm) | Corrected Output Power (mW) | Standard (W) | Result |
|------|---------|-----------------|--------------------|------------------------|-------------------------------|------------------------------|--------------|-----------|
|      | Low     | 2412            | 9.5                | 7.2                    | 28.71                         | 46.8                         | ≤ 1W         | Compliant |
| J1   | Mid     | 2437            | 9.17               | 7.2                    | 27.29                         | 43.4                         | ≤ 1W         | Compliant |
|      | High    | 3462            | 8.67               | 7.2                    | 25.82                         | 38.6                         | ≤ 1W         | Compliant |
|      | Low     | 2412            | -9.00              | 7.2                    | 3.83                          | 0.66                         | ≤ 1W         | Compliant |
| J2   | Mid     | 2437            | -13.50             | 7.2                    | 3.64                          | 0.23                         | ≤ 1W         | Compliant |
|      | High    | 2462            | -14.17             | 7.2                    | 3.38                          | 0.21                         | ≤ 1W         | Compliant |

Note: The power output may depend on the intended use of the EUT. For all tests, the EUT was set to maximum conditions.

## 5.3 Measurement Plots

Please refer to the plots hereinafter.

ATTEN 30dB                    MKR  -9.00dBm
RL 20.0dBm        10dB/      2.41217GHz
                             AMBIT      T60H677
                             LOW CH.        J2

MKR
2.41217 GHz
-9.00 dBm

CENTER 2.41200GHz              SPAN 50.00MHz
*RBW 2.0MHz      VBW 3.0MHz    *SWP 50.0ms

ATTEN 30dB                    MKR -13.50dBm
RL 20.0dBm        10dB/      2.43742GHz
                             AMBIT      T60H677
                             MID CH.        J2

MKR
2.43742 GHz
-13.50 dBm

CENTER 2.43700GHz              SPAN 50.00MHz
*RBW 2.0MHz      VBW 3.0MHz    *SWP 50.0ms

ATTEN 30dB                    MKR -14.17dBm
RL 20.0dBm        10dB/      2.45275GHz
                             AMBIT      T60H677
                             HIGH CH.       J2

MKR
2.45275 GHz
-14.17 dBm

CENTER 2.45200GHz              SPAN 50.00MHz
*RBW 2.0MHz      VBW 3.0MHz    *SWP 50.0ms

# 6 - DOSIMETRIC ASSESSMENT SETUP

These measurements were performed with the automated near-field scanning system DASY3 from Schmid & Partner Engineering AG (SPEAG). The system is based on a high precision robot (working range greater than 0.9m) which positions the probes with a positional repeatability of better than ±0.02mm. Special E- and H-field probes have been developed for measurements close to material discontinuity, the sensors of which are directly loaded with a Schottky diode and connected via highly resistive lines to the data acquisition unit. The system is described in detail in [3].

The SAR measurements were conducted with the dosimetric probe ET3DV6 SN: 1604 (manufactured by SPEAG), designed in the classical triangular configuration [3] and optimized for dosimetric evaluation. The probe has been calibrated according to the procedure described in [7] with accuracy of better than ±10%. The spherical isotropy was evaluated with the procedure described in [8] and found to be better than ±0.25dB.

The phantom used was the \Generic Twin Phantom" described in [4]. The ear was simulated as a spacer of 4 mm thickness between the earpiece of the phone and the tissue simulating liquid. The Tissue simulation liquid used for each test is in according with the FCC OET65 supplement C as listed below.

| Ingredients | Frequency (MHz) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (% by weight) | 450 | | 835 | | 915 | | 1900 | | 2450 | |
| Tissue Type | Head | Body | Head | Body | Head | Body | Head | Body | Head | Body |
| Water | 38.56 | 51.16 | 41.45 | 52.4 | 41.05 | 56.0 | 54.9 | 40.4 | 62.7 | 73.2 |
| Salt (Nacl) | 3.95 | 1.49 | 1.45 | 1.4 | 1.35 | 0.76 | 0.18 | 0.5 | 0.5 | 0.04 |
| Sugar | 56.32 | 46.78 | 56.0 | 45.0 | 56.5 | 41.76 | 0.0 | 58.0 | 0.0 | 0.0 |
| HEC | 0.98 | 0.52 | 1.0 | 1.0 | 1.0 | 1.21 | 0.0 | 1.0 | 0.0 | 0.0 |
| Bactericide | 0.19 | 0.05 | 0.1 | 0.1 | 0.1 | 0.27 | 0.0 | 0.1 | 0.0 | 0.0 |
| Triton x-100 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 36.8 | 0.0 |
| DGBE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 44.92 | 0.0 | 0.0 | 26.7 |
| Dielectric Constant | 43.42 | 58.0 | 42.54 | 55.2 | 42.0 | 55.9 | 39.9 | 53.3 | 39.8 | 52.7 |
| Conductivity (s/m) | 0.85 | 0.83 | 0.91 | 0.97 | 1.0 | 0.98 | 1.42 | 1.52 | 1.88 | 1.95 |

## 6.1 Measurement System Diagram
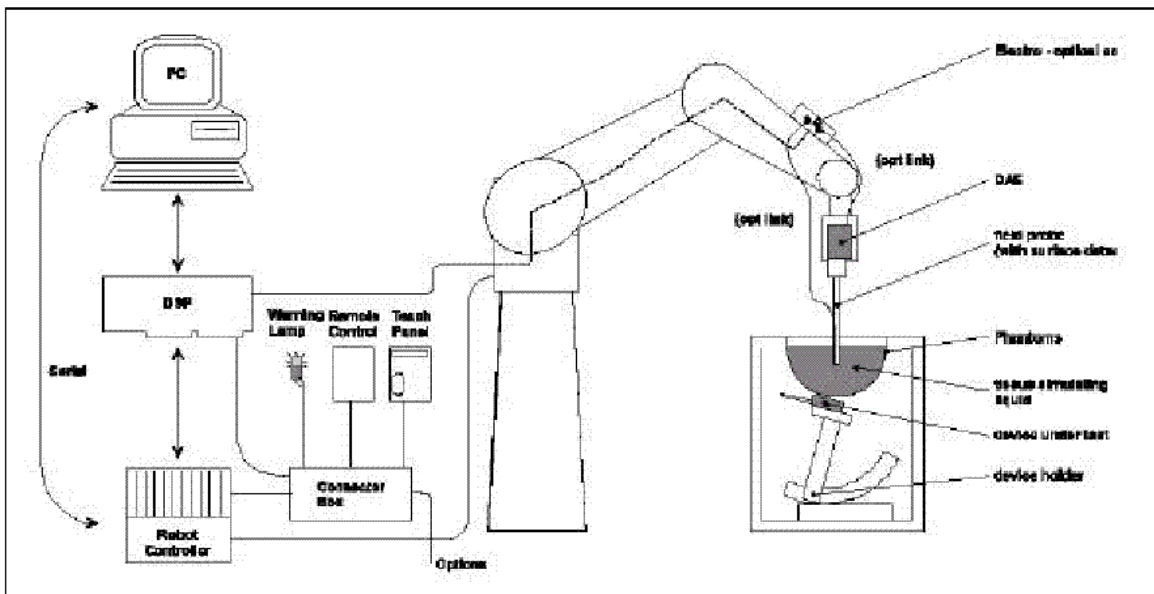


The DASY3 system for performing compliance tests consist of the following items:

1.  A standard high precision 6-axis robot (Stäubli RX family) with controller and software.
2.  An arm extension for accommodating the data acquisition electronics (DAE).
3.  A dosimetric probe, i.e., an isotropic E-field probe optimized and calibrated for usage in tissue simulating liquid. The probe is equipped with an optical surface detector system.
4.  A data acquisition electronic (DAE), which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
5.  A unit to operate the optical surface detector, which is connected to the EOC. The Electro-optical coupler (EOC) performs the conversion from the optical into a digital electric signal of the DAE. The EOC is connected to the PC plug-in card. The functions of the PC plug-in card based on a DSP is to perform the time critical task such as signal filtering, surveillance of the robot operation fast movement interrupts.
6.  A computer operating Windows 95 or larger
7.  DASY3 software
8.  Remote control with teaches pendant and additional circuitry for robot safety such as warning lamps, etc.
9.  The generic twin phantom enabling testing left-hand and right-hand usage.
10. The device holder for handheld EUT.
11. Tissue simulating liquid mixed according to the given recipes (see Application Note).
12. System validation dipoles to validate the proper functioning of the system.

## 6.2 System Components

**ET3DV6 Probe Specification**
Construction Symmetrical design with triangular core
Built-in optical fiber for surface detection System
Built-in shielding against static charges
Calibration In air from 10 MHz to 2.5 GHz
In brain and muscle simulating tissue at
Frequencies of 450 MHz, 900 MHz and
1.8 GHz (accuracy ± 8%)
Frequency 10 MHz to > 6 GHz; Linearity: ± 0.2 dB
(30 MHz to 3 GHz)
Directivity ± 0.2 dB in brain tissue (rotation around
probe axis)
± 0.4 dB in brain tissue (rotation normal probe axis)
Dynamic 5 mW/g to > 100 mW/g;
Range Linearity: ± 0.2 dB
Surface ± 0.2 mm repeatability in air and clear liquids
Detection over diffuse reflecting surfaces.
Dimensions Overall length: 330 mm
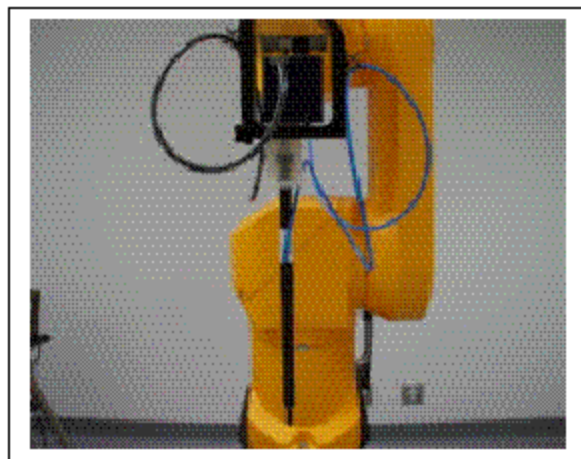Tip length: 16 mm
Body diameter: 12 mm
Tip diameter: 6.8 mm
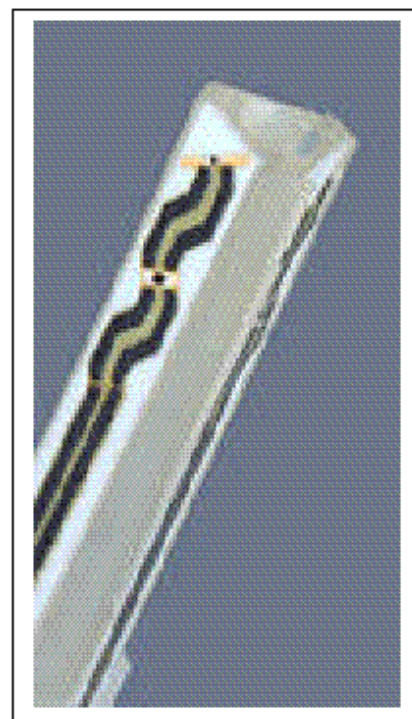Distance from probe tip to dipole centers: 2.7 mm
Application General dosimetric up to 3 GHz
Compliance tests of mobile phones
Fast automatic scanning in arbitrary phantoms



**Photograph of the probe**

The SAR measurements were conducted with the dosimetric probe
ET3DV6 designed in the classical triangular configuration and
optimized for dosimetric evaluation. The probe is constructed using
the thick film technique; with printed resistive lines on ceramic
substrates. The probe is equipped with an optical multi-fiber 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. As 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 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 2 nd
order fitting. The approach is stopped when reaching the maximum.



**Inside view of
ET3DV6 E-field Probe**

**E-Field Probe Calibration Process**

Each probe is calibrated according to a dosimetric assessment procedure described in [6] with accuracy better than +/- 10%. The spherical isotropy was evaluated with the procedure described in [7] and found to be better than +/-0.25dB. The sensitivity parameters (NormX, NormY, NormZ), the diode compression parameter (DCP) and the conversion factor (ConvF) of the probe are tested.

The free space E-field from amplified probe outputs is determined in a test chamber. This is performed in a TEM cell for frequencies bellow 1 GHz, and in a waveguide above 1 GHz for free space. For the free space calibration, the probe is placed in the volumetric center of the cavity and at the proper orientation with the field. The probe is then rotated 360 degrees.

E-field temperature correlation calibration is performed in a flat phantom filled with the appropriate simulated brain tissue. The measured free space E-field in the medium correlates to temperature rise in dielectric medium. For temperature correlation calibration a RF transparent thermistor-based temperature probe is used in conjunction with the E-field probe.

**Data Evaluation**

The DASY3 software automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. The parameters used in the evaluation are stored in the configuration modules of the software:

| Probe Parameter: | -Sensitivity | $Norm_i$, $a_{i0}$, $a_{i1}$, $a_{i2}$ |
| --- | --- | --- |
| | -Conversion Factor | ConvFi |
| | -Diode compression point | $Dcp_i$ |
| Device parameter: | -Frequency | f |
| | -Crest Factor | cf |
| Media parameter: | -Conductivity | ó |
| | -Density | ñ |

These parameters must be set correctly in the software. They can either be found in the component documents or be imported into the software from the configuration files issued for the DASY3 components. In the direct measuring mode of the multi-meter option, the parameters of the actual system setup are used. In the scan visualization and export modes, the parameters stored in the corresponding document files are used.

The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC-transmission factor from the diode to the evaluation electronics. If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given as:

$$Vi = Ui + (Ui)^2 \, cf \, / \, dcp_i$$

With  $Vi$  = compensated signal of channel i (i =x, y, z)
       $Ui$   = input signal of channel i (i =x, y, z)
       cf    = crest factor of exciting field (DASY parameter)
      $dcp_i$ = diode compression point (DASY parameter)

From the compensated input signals the primary field data for each channel can be evaluated:

E-field probes:
$$E_i = \sqrt{\frac{V_i}{Norm_i \cdot ConvF}}$$

H-field probes:
$$H_i = \sqrt{Vi} \cdot \frac{a_{i0} + a_{i1}f + a_{i2}f^2}{f}$$

With   Vi     = compensated signal of channel i (i =x, y, z)
       $Norm_i$ = sensor sensitivity of channel i (i =x, y, z)
              ìV/ (V/m)$^2$ for E-field probes
       ConF   = sensitivity enhancement in solution
       $a_{ij}$   = sensor sensitivity factors for H-field probes
       f      = carrier frequency [GHz]
       Ei     = electric field strenggy of channel i in V/m
       $H_i$    =  diode compression point (DASY parameter)

The RSS value of the field components gives the total field strength (Hermitian magnitude):

$$E_{tot} = \text{Square Root } [(E_x)^2 + (E_y)^2 + (E_z)^2]$$

The primary field data are used to calculate the derived field units.

$$SAR = (E_{tot})^2 \quad ó/(ñ \quad 1000)$$

With   SAR =  local specific absorption rate in mW/g
       $E_{tot}$  = total field strength in V/m
       ó     = conductivity in [mho/m] or [Siemens/m]
       ñ     = equivalent tissue density in g/cm$^3$

Note that the density is normally set to 1 (or 1.06), to account for actual brain density rather than the density of the simulation liquid.

The power flow density is calculated assuming the excitation field as a free space field.

$$P_{pwe} = (E_{tot})^2 / 3770 \text{ or } P_{pwe} = (H_{tot})2 \quad 37.7$$

With   $P_{pwe}$ = equivalent power density of a plane wave in mW/cm3
       $E_{tot}$ = total electric filed strength in V/m
       $H_{tot}$ = total magnetic filed strength in V/m

**Generic Twin Phantom**

The Generic Twin Phantom is constructed of a fiberglass shell integrated in a wooden table. The shape of the shell is based on data from an anatomical study designed to determine the maximum exposure in at least 90% of all users [9][10]. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. A cover prevents the evaporation of the liquid. Reference markings on the Phantom allows the complete setup of all predefined phantom positions and measurement grids by manually teaching three points in the robot.
Shell Thickness 2 ± 0.1 mm
Filling Volume Approx. 20 liters
Dimensions 810 x 1000 x 500 mm (H x L x W)
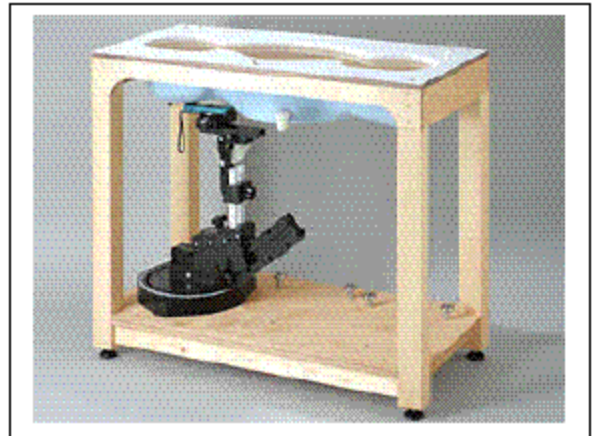


**Generic Twin Phantom**

**Device Holder**

In combination with the Generic Twin Phantom V3.0, the Mounting Device enables the rotation of the mounted transmitter in spherical coordinates whereby the rotation points is the ear opening. The devices can be easily, accurately, and repeatedly positioned according to the FCC and CENELEC specifications. The device holder can be locked at different phantom locations (left head, right head, flat phantom).

\* Note: A simulating human hand is not used due to the complex anatomical and geometrical structure of the hand that may produced infinite number of configurations [10]. To produce the worst-case condition (the hand absorbs antenna output power), the hand is omitted during the tests.
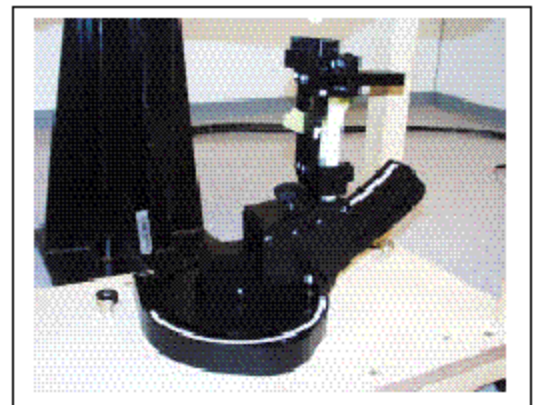


**Device Holder**

## 6.3 Measurement Uncertainty

The uncertainty budget has been determined for the DASY3 measurement system according to the NIS81 [13] and the NIST1297 [14] documents and is given in the following Table.

| Uncertainty Description | Error | Distrib. | Weight | Std. Dev. | Offset |
|---|---|---|---|---|---|
| Probe Uncertainty | | | | | |
| Axial isotropy | ± 0.2 dB | U-shape | 0.5 | ±2.4 % | / |
| Spherical isotropy | ±0.4 dB | U-shape | 0.5 | ±4.8 % | / |
| Isotropy from gradient | ±0.5 dB | U-shape | 0 | / | / |
| Spatial resolution | ±0.5 % | Normal | 1 | ±0.5 % | / |
| Linearity error | ±0.2 dB | Rectangle | 1 | ±2.7 % | / |
| Calibration error | ±3.3 % | Normal | 1 | ± 3.3 % | / |
| SAR Evaluation Uncertainty | | | | | |
| Data acquisition error | ±1% | Rectangle | 1 | ±0.6 % | / |
| ELF and RF disturbances | ±0.25 % | Normal | 1 | ±0.25 % | / |
| Conductivity assessment | ±10 % | Rectangle | 1 | ± 5.8 % | / |
| Spatial Peak SAR Evaluation Uncertainty | | | | | |
| Extrapol boundary effect | ±3% | Normal | 1 | ±3% | ± 5% |
| Probe positioning error | ±0.1 mm | Normal | 1 | ± 1% | / |
| Integrat. and cube orient | ±3% | Normal | 1 | ±3% | / |
| Cube shape inaccuracies | ±2% | Rectangle | 1 | ±1.2 % | / |
| Device positioning | ±6% | Normal | 1 | ± 6% | / |
| Combined Uncertainties | / | / | 1 | ±11.7 % | ± 5% |
| Extended uncertainty (K = 2) | / | / | / | ± 23.5 %. | / |

# 7 - SYSTEM EVALUATION

## 7.1 Simulated Tissue Liquid Parameter Confirmation

The dielectric parameters were checked prior to assessment using the HP85070A dielectric probe kit. The dielectric parameters measured are reported in each correspondent section:

## 7.2 Evaluation Procedures

### Maximum Search

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.

### Extrapolation

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 and the grid offset. The extrapolation is based on fourth order polynomal functions. The extrapolation is only available for SAR values.

### Boundary Corrections

The correction of the probe boundary effect in the vicinity of the phantom surface can be done in two different ways. In the standard (worse 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 of probes with specifications on the boundary effect.

### Peak Search for 1g and 10g cube averaged SAR

The 1g and 10g peak evaluations are only available for the predefined cube 4x4x7 and cube 5x5x7 scans. The routine 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 get all points within the measured volume in a 1mm grid (35000 points). In the last step, a 1g cube is place 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.

## 7.3 System Accuracy Verification

Prior to the assessment, the system validation kit was used to test whether the system was operating within its specifications of ±10%. The validation results are tabulated below. And also the corresponding SAR plot is attached as well in the SAR plots files.

IEEE P1528 recommended reference value

| Frequency (MHz) | 1 g SAR | 10 g SAR | Local SAR at surface (above feed point) | Local SAR at surface (v=2cm offset from feed point) |
|---|---|---|---|---|
| 300 | 3.0 | 2.0 | 4.4 | 2.1 |
| 450 | 4.9 | 3.3 | 7.2 | 3.2 |
| 835 | 9.5 | 6.2 | 14.1 | 4.9 |
| 900 | 10.8 | 6.9 | 16.4 | 5.4 |
| 1450 | 29.0 | 16.0 | 50.2 | 6.5 |
| 1800 | 38.1 | 19.8 | 69.5 | 6.8 |
| 1900 | 39.7 | 20.5 | 72.1 | 6.6 |
| 2000 | 41.1 | 21.1 | 74.6 | 6.5 |
| 2450 | 52.4 | 24.0 | 104.2 | 7.7 |
| 3000 | 63.8 | 25.7 | 140.2 | 9.5 |

**Validation Dipole SAR Reference Test Result for Body (2450 MHz)**

| Validation Measurement | SAR @ 0.025W Input averaged over 1g | SAR @ 1W Input averaged over 1g | SAR @ 0.025W Input averaged over 10g | SAR @ 1W Input averaged over 10g |
|---|---|---|---|---|
| Test 1 | 14.2 | 56.80 | 6.33 | 25.32 |
| Test 2 | 14.3 | 57.20 | 6.34 | 25.36 |
| Test 3 | 14.2 | 56.80 | 6.33 | 25.32 |
| Test 4 | 14.1 | 56.40 | 6.32 | 25.28 |
| Test 5 | 14.3 | 57.20 | 6.33 | 25.32 |
| Test 6 | 14.0 | 56.00 | 6.31 | 25.24 |
| Test 7 | 14.2 | 56.80 | 6.33 | 25.32 |
| Test 8 | 14.2 | 56.80 | 6.33 | 25.32 |
| Test 9 | 14.4 | 57.60 | 6.34 | 25.36 |
| Test 10 | 14.2 | 56.80 | 6.32 | 25.28 |
| Average | 14.21 | 56.84 | 6.32 | 25.31 |

System validation result

2/18/03:

| Simulant | Freq [MHz] | Parameters | Liquid Temp [ºC] | Target Value | Measured Value | Deviation [%] | Limits [%] |
|---|---|---|---|---|---|---|---|
| Body | 2450 | ε | 22 | 52.7 | 51.5 | -2.28 | ±5 |
| | | σ | 22 | 1.95 | 1.93 | -1.03 | ±5 |
| | | 1g SAR | 22 | 56.84 | 61.89 | 8.88 | ±10 |

2/19/03:

| Simulant | Freq [MHz] | Parameters | Liquid Temp [ºC] | Target Value | Measured Value | Deviation [%] | Limits [%] |
|---|---|---|---|---|---|---|---|
| Body | 2450 | ε | 22 | 52.7 | 51.5 | -2.28 | ±5 |
| | | σ | 22 | 1.95 | 1.93 | -1.03 | ±5 |
| | | 1g SAR | 22 | 56.84 | 61.89 | 8.88 | ±10 |

$\varepsilon$ = relative permittivity, $\sigma$ = conductivity and $\rho$=1000kg/m$^3$
Note: Forward power = 56.23mW

System Validation 2450 MHz ( Ambient Temp = 23 Deg C, Liquid Temp = 22 Deg C,
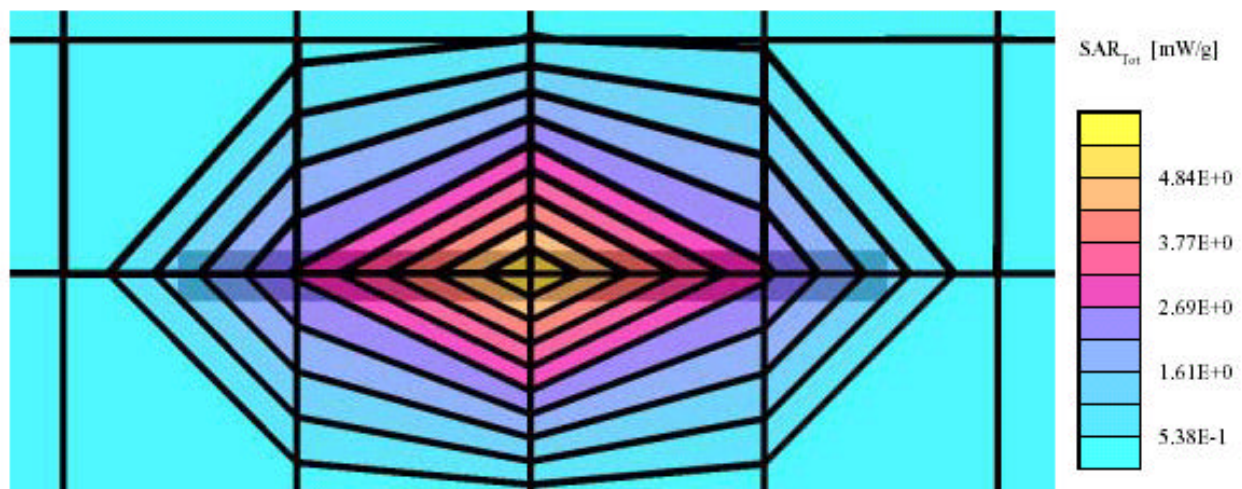2/18/2003) Forward Power = 17.5 dBm

SAM Phantom; Flat Section; Position: (90°,90°); Frequency: 2450 MHz
Probe: ET3DV6 - SN1604; ConvF(4.30,4.30,4.30); Crest factor: 1.0; Flat (Body) 2450 MHz: $\sigma = 1.93$ mho/m $\varepsilon_r = 51.5$) $\rho = 1.00$ g/cm³
Cube 5x5x7: SAR (1g): 3.48   mW/g, SAR (10g): 1.58   mW/g, (Worst-case extrapolation)
Coarse: Dx = 17.0, Dy = 17.0, Dz = 14.0
Powerdrift: -0.08 dB

System Validation 2450 MHz (Body, Ambient Temp. = 23 Deg. C, liquid Temp. = 22 Deg. C, 2/19/03) Forward power = 17.5 dBm
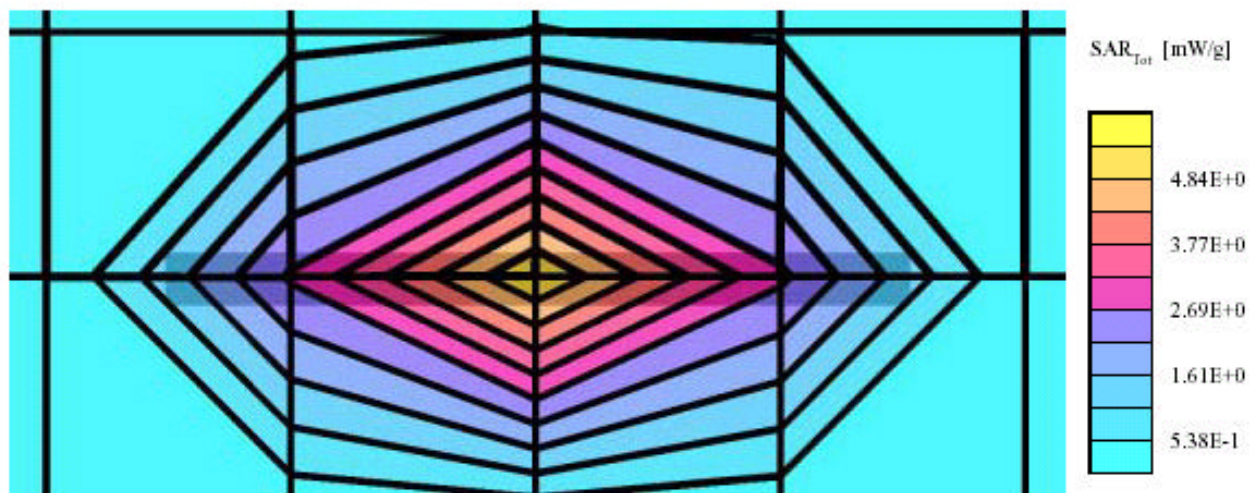
SAM Phantom; Flat Section; Position: (90°,90°); Frequency: 2450 MHz
Probe: ET3DV6 - SN1604; ConvF(4.30,4.30,4.30); Crest factor: 1.0; Flat (Body) 2450 MHz: $\sigma = 1.93$ mho/m $\varepsilon_r = 51.5$ $\rho = 1.00$ g/cm³
Cube 5x5x7: SAR (1g): 3.48   mW/g, SAR (10g): 1.58   mW/g, (Worst-case extrapolation)
Coarse: Dx = 17.0, Dy = 17.0, Dz = 14.0
Powerdrift: -0.08 dB

## 7.4 SAR Evaluation Procedure

    a.   The evaluation was performed in the applicable area of the phantom depending on the type of device being tested. For device held to the dear during normal operation, both the left and right ear positions were evaluated in accordance with FCC OET Bulletin 65, Supplement C (Edition 01-01) using the SAM phantom. For body-worn and face-held devices a planar phantom was used. The EUT in the test setup for body-worn and face-held devices was placed in three different positions (relative to the phantom): parallel, bystand (perpendicular) and 1.5cm separation.

    b.   The SAR was determined by a pre-defined procedure within the DASY3 software. Upon completion of a reference and optical surface check, the exposed region of the phantom was scanned near the inner surface with a grid spacing of 20mm x 20mm.

    c.   A 5x5x7 matrix was performed around the greatest special SAR distribution found during the area scan of the applicable exposed region. SAR values were then calculated using a 3-D spline interpolation algorithm and averaged over spatial volumes of 1 and 10 grams.

    d.   The depth of the simulating tissue in the planar used for the SAR evaluation and system validation was no less than 15.0cm.

    e.   For this particular evaluation, a stack of low-density, low-loss dielectric foamed polystyrene was used in place of the device holder.

    f.   Re-measurement of the SAR value at the same location as in a. If the value changed by more than 5%, the evaluation was repeated.

## 7.5 Exposure Limits

Table 1: Limits for Occupational/Controlled Exposure (W/kg)

| Whole-Body | Partial-Body | Hands. Wrists. Feet and Ankles |
|------------|--------------|--------------------------------|
| 0.4        | 8.0          | 20.0                           |

Table 2: Limits for General Population/Uncontrolled Exposure (W/kg)

| Whole-Body | Partial-Body | Hands. Wrists. Feet and Ankles |
|------------|--------------|--------------------------------|
| 0.08       | 1.6          | 4.0                            |

*Note: Whole-body SAR is averaged over the entire body, partial-body SAR is averaged over any 1 gram of tissue defined as a tissue volume in the shape of a cube SAR for hands, writs, feet and ankles is averaged over any 10 grams of tissue defined as a tissue volume in the shape of a cube.*

Population/Uncontrolled Environments are defined as locations where there is the exposure of individual who have no knowledge or control of their exposure.

*Occupational/Controlled Environments are defined as locations where there is exposure that may be incurred by people who are aware of the potential for exposure (i.e. as a result of employment or occupation).*

*Population/uncontrolled environments Partial-body limit 1.6W/kg applied to the EUT.*