0371

SAR Evaluation Report
for
FCC OET Bulletin 65 Supplement C

Report No.: ET94S-09-023

Client:	Suncorp Communications Limited
Product:	2.4GHz WDCT Color Display
Model:	WDCT45-AS
Manufacturer/supplier:	Shenzhen Guo Wei Electronics Co. Ltd

Date test item received:	2005/08/29
Date test campaign completed:	2005/10/11
Date of issue:	2005/10/12

Test Result: ■ Compliance ☐ Not Compliance

Statement of Compliance:
The SAR values measured for the test sample are below the maximum recommended level of 1.6 mW/g averaged over any 1g tissue according to FCC OET Bulletin 65 Supplement C (Edition 01-01).

The test result only corresponds to the tested sample. It is not permitted to copy this report, in part or in full, without the permission of the test laboratory.

Total number of pages of this test report: 30 pages
Total number of pages of annex: 48 pages

Test Engineer	Checked by	Approved by
Mark Chang	Joe Hsieh	Win-Po Tsai
Justin Ma	Joe Hsieh	Win-Po Tsai

The testing described in this report has been carried out to the best of our knowledge and ability, and our responsibility is limited to the exercise of reasonable care. This certification is not intended to believe the sellers from their legal and/or contractual obligations.

Applicant Information

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Title	:	Head of Engineering Department
Manufacturer	:	Shenzhen Guo Wei Electronics Co. Ltd
Address	:	No. 68 Guowei Road, Liantang Industrial District, Shenzhen, P.R.C.
EUT	:	2.4GHz WDCT Color Display
Trade Name	:	SunCorp
Model No.	:	WDCT45-AS
Standard Applied	:	FCC OET 65 Supplement C (Edition 01-01, June 2001)

The Suncorp DECT handset WDCT45-AS is in compliance with the FCC Report and Order 93-326 and the tests were performed according to the FCC OET65c.

Laboratory Introduction:

Electronics Testing Center, Taiwan is recognized, filed and mutual recognition arrangement as following:

❶ *ISO9001: TüV Product Service*

❷ *ISO/IEC 17025: BSMI, CNLA, DGT, NVLAP, CCIBLAC, UL, Compliance*

❸ *Filing: FCC, Industry Canada, VCCI*

❹ *MRA: Australia, Hong Kong, New Zealand, Singapore, USA, Japan, Korea, China, APLAC through CNLA*

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Table of Contents

EXECUTIVE SUMMARY **5**

1. GENERAL INFORMATION **6**

1.1 Description of Equipment Under Test 6
1.2 Photograph of EUT 6
1.3 Environment Conditions 7
1.4 FCC Requirements for SAR Compliance Testing 7
1.4.1 RF Exposure Limits 7
1.5 The SAR Measurement Procudure for Mobile 8
1.5.1 General Requirements 8
1.5.2 Phantom Requirements 8
1.5.3 Test Positions 8
1.5.4 Test Procedures 9
1.5.4 Test Procedures 10

2 DESCRIPTION OF THE TEST EQUIPMENT **10**

2.1 Test Equipment List 10
2.2 DASY4 Measurement System Diagram: 12
2.3 DASY4 Measurement Server 13
2.4 DAE (Data Acquisition Electronics) 14
2.5 Phantom 14
2.6 Device Holder 15
2.7 Specifications of Probes 16
2.8 SAR Measurement Procedures in DASY4 16
2.9 Simulating Liquids 17
2.10 System Performance Check 18
2.10.1 Purpose： 18
2.10.2 System Performance Check Procedure 18
2.10.3 System Performance Check Setup： 19
2.10.4 Result of System Performance Check: Valid Result 19

3 RESULTS **20**

3.1 Summary of Test Results 20
3.2 Head 20
3.3 Body 20
3.4 Measurement Position (IncludingLC, LT,RC, RT) 21
3.4.1 Left-Cheek (LC) 21
3.4.2 Left-Tilt (LT) 21
3.4.3 Right-Cheek (RC) 21

3.4.4 Right-Tilt (RT) 22
3.4.5 Body-Flat (Side view) 23
3.4.6 Body-Flat (Top view) 23

4 DESCRIPTION OF THE TEST PROCEDURE FOR FCC 24

4.1 Scan Procedure 24
4.2 SAR Averaging Methods 24
4.3 Data Storage 24
4.4 Data Evaluation 25
4.5 Spatial Peak SAR Evaluation 27

5 MEASUREMENT UNCERTAINTY 28

5.1 Measurement Uncertainty I (According to IEEE 1528) 28
5.2 Measurement Uncertainty II (According to IEC 62209) 29

6 REFERENCES 30

Executive Summary

The product WDCT45-AS is a new DECT handset from Suncorp Communications Limited operating in the 2400 MHz frequency range. The measurements was conducted by ETC and carried out with the dosimetric assessment system – DASY4.

The measurements of handset were conducted according to FCC OET 65 Supplement C [Reference 5] for evaluating compliance with requirements of FCC Report and Order 96-326 [Reference 3].

The handset under test is controlled by an external personal computer (hereafter called the Test Host) via RS-232 connection and a control software running on it. The specific control software can setup the handset under test into RE Test Mode and then user can select different carrier, time-slot as well as continuous transmittion mode to keep handset transmitting in maximum output power and in a continuous way.

Another important factor is the Crest Factor when applying SAR testing to DECT. It is normally to get such information directly by asking customer or to use a spectrum to scan the duty cycle in time domain when transmitting.

1. General Information

1.1 Description of Equipment Under Test

EUT Type	2.4GHz WDCT Color Display, DECT PP
Trade Name	SunCorp
Model Name	WDCT45-AS
Hardware version	V1.2
Software version	N/A
Tx Frequency	2401.056 ~ 2480.544 MHz
Rx Frequency	2401.056 ~ 2480.544 MHz
Antenna Type	Internal Type
Max. conducted output power	24.06 dBm (measured in CH01)
Device Category	Portable Part
RF Exposure Environment	General Population / Uncontrolled
Power supply	Battery: Two Alkaline Batteries of AAA LR03 DC 1.5 V
Crest Factor	12
Test Host	ASUS L7245; ETC Inventory S/N: 13081501-001 Function: Providing external control to EUT

1.2 Photograph of EUT

Front	Back

1.3 Environment Conditions

Item	Target	Measured
Ambient Temperature (°C)	15 ~ 30	22 ± 1
Temperature of Simulant	20 ~ 24	22 ± 1
Relative Humidity(% RH)	30 ~ 70	45 ~ 65

Note: Reference ANNEX F to get the monitor of continuous variation in ambient temperature

1.4 FCC Requirements for SAR Compliance Testing

According to the FCC order "Guidelines for Evaluating the Environmental Effects of RF Radiation", for consumer products, the SAR limit is **1.6mW/g** for an uncontrolled environment and **8.0 mW/g** for an occupational/controlled environment. Pursuant to the Supplement C of OET Bulletin 65 "Evaluating Compliance with FCC Guide-lines for Human Exposure to Radio frequency Electromagnetic Fields", released on June 29, 2001 by FCC, the equipment under test should be evaluated at maximum output power (radiated from the antenna) under "worst-case" conditions for intended or normal operation, incorporating normal antenna operating positions, equipment undet test peak performance frequencies and positions for maximum RF power coupling.

1.4.1 RF Exposure Limits

	Whole-Body	Partial-Body	Arms and Legs
Population/Uncontrolled Environments (mW/g)	0.08	1.6	4.0
Occupational/Controlled Environments (mW/g)	0.4	8.0	2.0

Notes:
1. Population/Uncontrolled Environments: Locations where there is the exposure of individuals who have no sense or control of their exposure.
2. Occupational/Controlled Environments: Locations where there is exposure that may be incurred by people who have knowledge of the potential for exposure.
3. Whole-Body: SAR is averaged over the entire body.
4. Partial-Body: SAR is averaged over any 1g of tissue volume as defined in specification.
5. Arms and Legs: SAR is averaged over 10g of tissue volume as defined in specification.

1.5 The SAR Measurement Procudure for Mobile

1.5.1 General Requirements

The test should be performance in a laboratory without influence on SAR measurements by ambient RF sources and any reflection from the environment inside. The ambient temperature should be kept in the range of 15°C to 30°C with a maximum variation within ± 2°C during the test.

1.5.2 Phantom Requirements

The phantoms used in test are simplified representations of the human head and body as a specific shaped container for the head or body simulating liquids. The physical characteristics of the phantom models should resemble the head and the body of a mobile user sice the shape is a dominant parameter for exposure. The shell of the phantom should be made of low loss and low permittivity material and the thickness tolerance should be less than 0.2 mm. In addition, the phantoms should provide simulations of both right and left hand operations.

1.5.3 Test Positions

Due to a fact of that it cannot be expected that all mobile user will hold the moble exactly in one well-defined position, different operational conditions should be conducted. EN 50361 requires two test positions: the cheek and tilted positons. In each test position the acoustic output should be placed directly at the entrance of the auditory canal in phantom.
The acoustic output is defined in Fig. 1. There are two imaginary lines defined on the handset: the vertical center line and the horizontal line and the cross of these two lines is the acoustic output. The human head position is given by means of a reference plane defined by the following three reference points: RE (Right-Ear), LE (Left-Ear) and M (Mouth) and shown in Fig. 2 and 3.
The Cheek Position: the vertical center line should lie in the reference plane and the acoustic output meets the reference points RE or LE. The vertical center line should align to the line connecting the point M to points RE or LE and the angle between these two lines should be reduced to minimum by touching the cheek of the phantom with handset.
The Tilted Position: same as Cheek Potion but only change the angle by 15º between vertical center line and the line connecting the point M to points RE or LE.

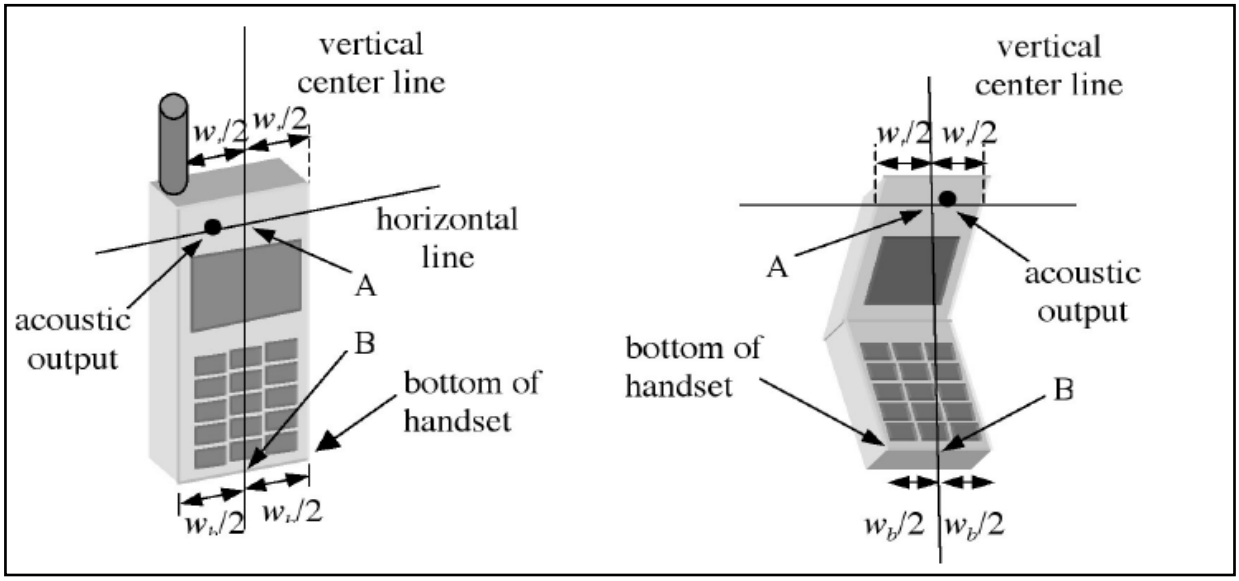


Fig.1 Test reference points on handset

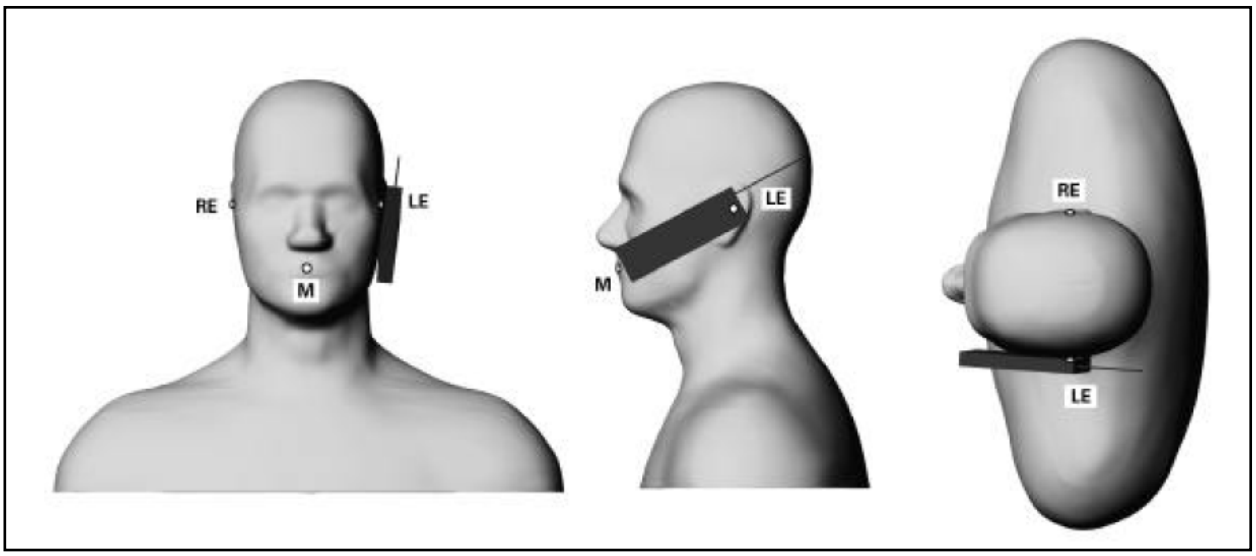


Fig. 2 Cheek Position

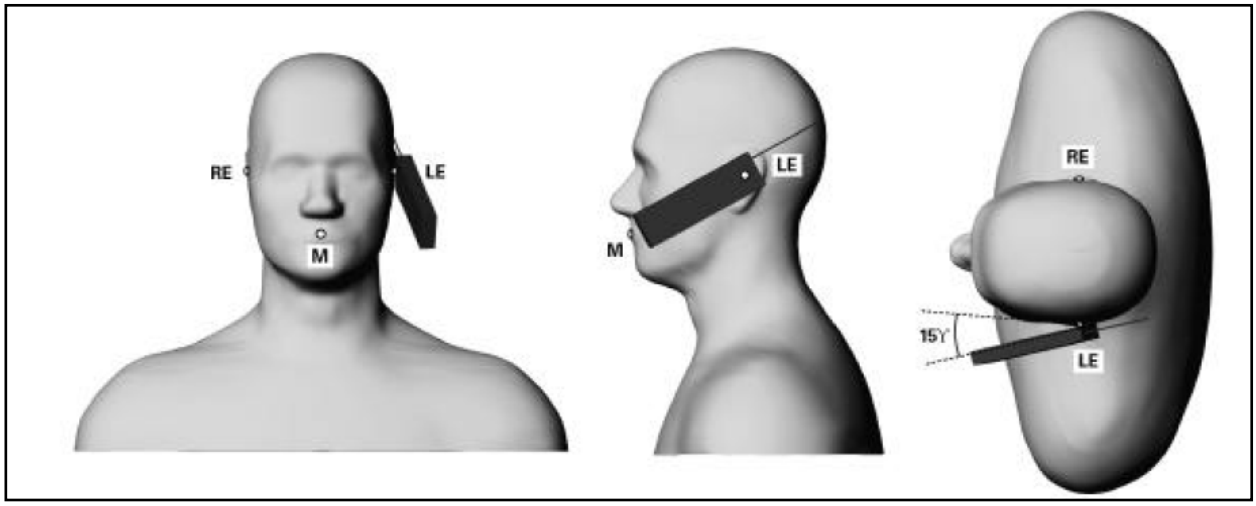


Fig. 3 Tilted Position

1.5.4 Test Procedures

The SAR test should be performed with both Cheek Position and Tilted Position mentioned above. At first, to use the center frequency of each available operating band to apply SAR measurements on four modes: Right-Cheek, Right-Tilted, Left-Cheek and Left-Titled. And the second step, to apply the low-end and high-end frequencies of SAR measurements respectively to the mode which the maximum mass-averaged SAR happens. For handsets with extendable antenna, all of the tests mentioned above should be performed with the antenna in fully extended and fully retracted modes.

2 Description of the Test Equipment

The measurements were performed using an automated near-field scanning system, DASY4 software, manufactured by Schmid & Partner Engineering AG (SPEAG) in Switzerland.
The SAR extrapolation algorithm used in all measurements on the test device was the 'worstcase extrapolation' algorithm.

2.1 Test Equipment List

Notation:□ means this item is not used in this report; ■ means this item is used.; the above excepted, other items are used for each test.

Equipment of SAR Measurement	S/N	Calibration Interval	Calibration Expiry
Staubli Robot - RX90B L	F03/5W16A1/A/01	(not necessary)	
Staubli Robot Controller – CS7MB	F03/5W16A1/C/01	(not necessary)	
Staubli Teach Pendant	D221340061	(not necessary)	
DAE4	629	12 Months	2005-10-12
■ E-field Probe ET3DV6	1791	12 Months	2005-11-26
□ E-field Probe EX3DV4	3555	12 Months	2005-11-05
□ Dipole Validation Kit D900V2	1d010	24 Months	2006-11-11
□ Dipole Validation Kit D1800V2	2d103	24 Months	2006-11-12
□ Dipole Validation Kit D1900V2	5d054	24 Months	2006-11-12
■ Dipole Validation Kit D2450V2	764	24 Months	2006-11-15
□ Dipole Validation Kit D5GHzV2	1030	24 Months	2006-10-21
□ Rohde & Schwarz CMU200	101006	12 Months	2005-10-11
□ Agilent 8960	GB45070291	12 Months	2006-02-26
Software	**Version**	**Note**	

DASY4 Software	Version 4.5B19	To automatically control the robot and perform the SAR measurement	
SEMCAD Software	Version 1.8B146	Post-processing and report management	
Equipment of System Performance Check	**Brand/Model**	**S/N**	**Calibration Expiry**
Signal Generator	☐ Agilent 8648C	3623A01662	2006-05-16
	■ Agilent 83640B	3844A01143	2006-09-21
Amplifier	Mini-Circuits	D111704-01-02	2006-01-30
Spectrum	Agilent 8564EC	13052007-001	2006-09-23
Power Meter	BOONTON 4532	136601	2006-06-14
Power Sensor	■ BOONTON 51011-EMC	32861	2006-06-13
	■ BOONTON 56518	3233	2006-06-13
Equipment of Simulant Measurement	**Brand/Model**	**S/N**	**Calibration Expiry**
S-Parameter Netaork Analyzer	Agilent 8753ES	MY40001340	2006-10-20
Calibration Kit	Agilent 85033C	2920A03287	(not necessary)
Dielectric Probe Kit	Agilent 85070E	MY44300101	(not necessary)
Simulant	**ETC Inventory S/N**		**Validation Expiry**
Head-2450NHz	M00-SAR-HSL2450L30-200507		2005-10
Body-2450NHz	M00-SAR-BSL2450L30-200507		2005-10

2.2 DASY4 Measurement System Diagram:

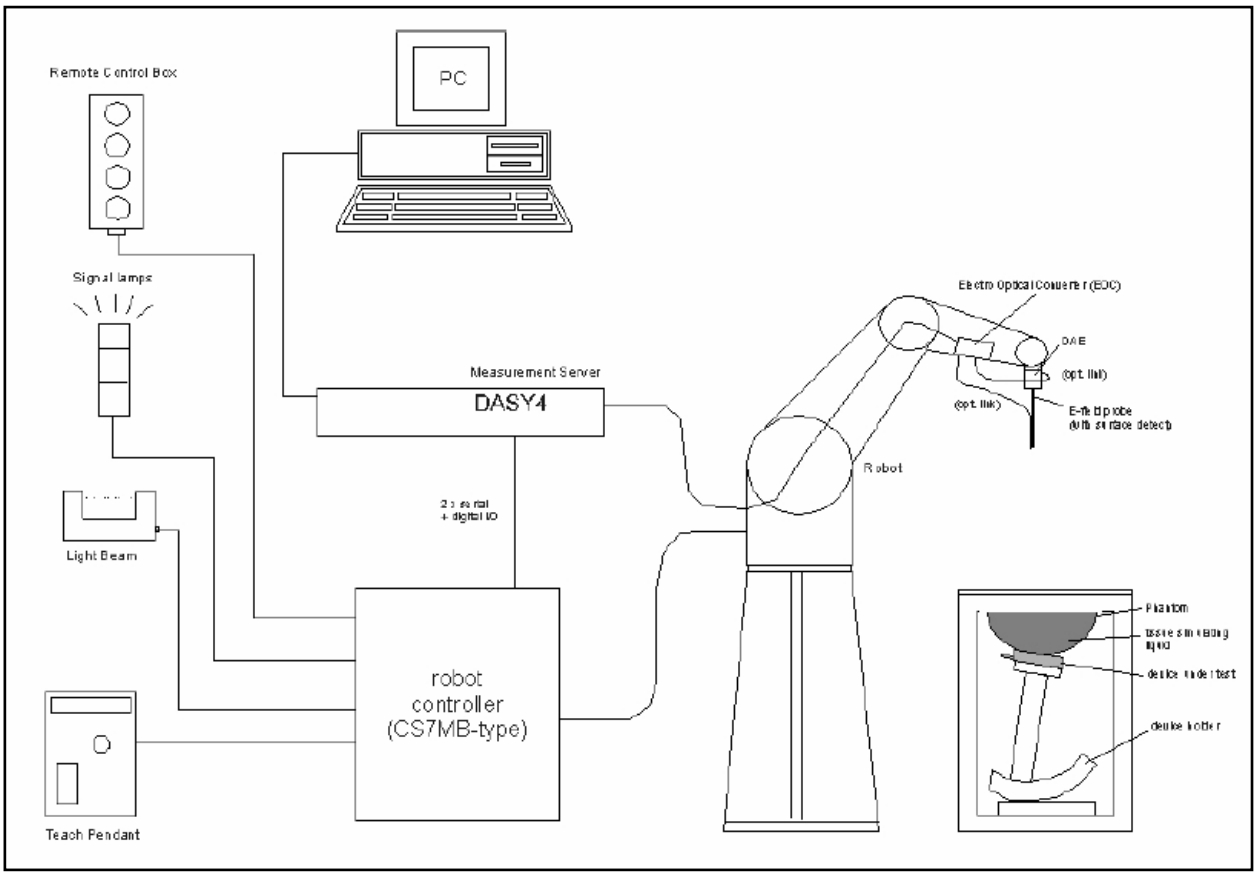


Fig. 4 The DASY4 Measurement System

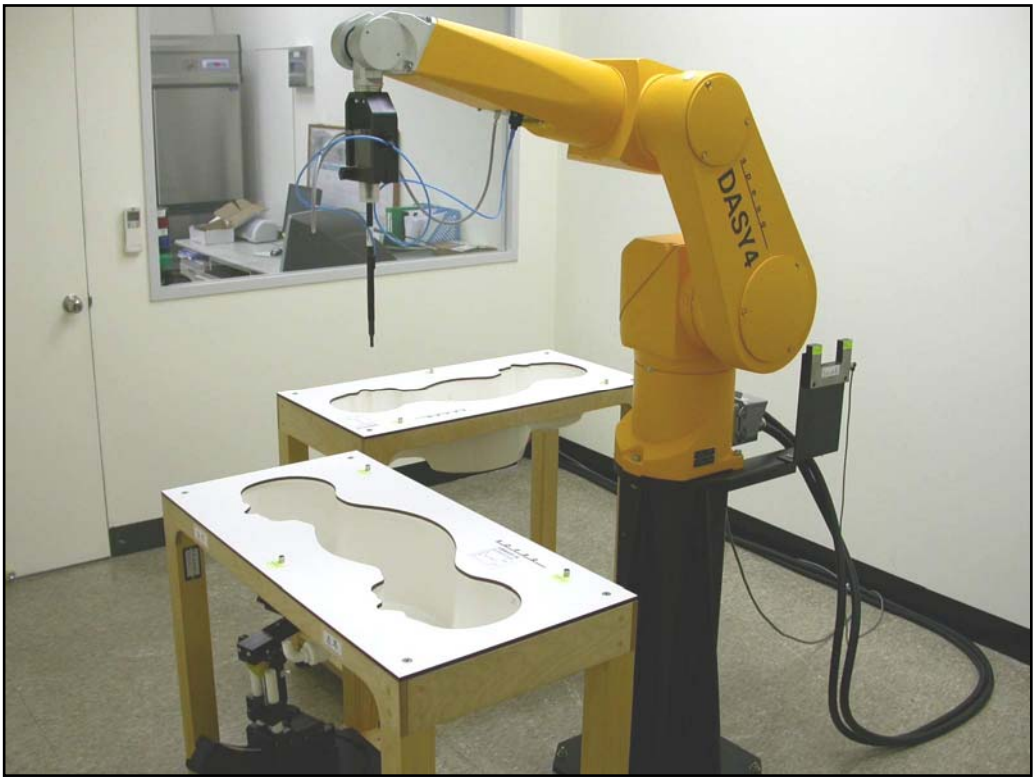


Fig. 5 The DASY4 System used in ETC set-up with two phantoms

The DASY4 system consists of the following items:

- A fixed-on-ground high precision 6-axis robot with controller and software and an arm extension for moving the Data Acquisition Electronics (DAE) and Probe.
- A dosimetric probe, an isotropic E-field probe optimized and calibrated for usage in head or body tissue simulating liquids. Some of the probes are equipped with an optical surface detector system.
- A Data Acquisition Electronic (DAE) performing the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. DAE is powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
- A unit to operate the optical surface detector which is connected to Electro-Optical Coupler (EOC).
- The EOC performs the conversion from the optical into a digital electric signal of the DAE. The EOC is connected to the DASY4 measurement server.
- The DASY4 measurement server performing all real-time data evaluation for field measurements and surface detection, controling robot movements and handling safety operation. A computer with operating Windows 2000 is used for server.
- DASY4 software and SEMCAD data evaluation software are installed in PC.
- Remote control with teach panel and additional circuitry for robot safety such as warning lamps, etc.
- The generic twin phantom enabling the testing of left-hand and right-hand usage.
- The device holder for handheld mobile phones.
- Tissue simulating liquid mixed well according to the given recipes.
- System validation dipoles is used to validate the proper functioning of the system

2.3 DASY4 Measurement Server

Fig. 6 DASY4 Measurement Server

The DASY4 measurement server is based on a PC/104 CPU board with a 166MHz low-power pentium, 32MB chipdisk and 64MB RAM. The necessary circuits for communication with either the DAE4 (or DAE3) electronic box as well as the 16-bit AD-converter system for optical detection and digital I/O interface are contained on the DASY4 I/O-board, which is directly connected to the PC/104 bus of the CPU board.
The measurement server performs all real-time data evaluation for field measurements and surface detection, controls robot movements and handles safety operation. The PC-operating system cannot interfere with these time critical processes. All connections are supervised by a

watchdog, and disconnection of any of the cables to the measurement server will automatically disarm the robot and disable all program-controlled robot movements. Furthermore, the measurement server is equipped with two expansion slots which are reserved for future applications. Please note that the expansion slots do not have a standardized pinout and therefore only the expansion cards provided by SPEAG can be inserted. Expansion cards from any other supplier could seriously damage the measurement server.

2.4 DAE (Data Acquisition Electronics)

Fig. 7 DAE used in ETC

Some probes are equipped with an optical multifiber line, ending at the front of the probe tip. This line is connected to the EOC box on the robot arm and provides 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 during the approach, reaches a maximum and then decreases. If the probe perpendicularly touches 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 DASY4 software reads the reflection during a software approach and looks for the maximum using a 2nd order fitting. The approach is stopped upon reaching the maximum.
The optical surface detection works in transparent liquids and on di_use 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 1.0mm to 2.0mm in tissue simulating mixtures. The distance can be measured with the surface check job (described in the reference guide).

2.5 Phantom

The phantom used for all tests i.e. for both system performance checking and device testing, was the twinheaded "SAM Twin Phantom V4.0", manufactured by SPEAG. The phantom conforms to the requirements of IEEE 1528 - 2003.

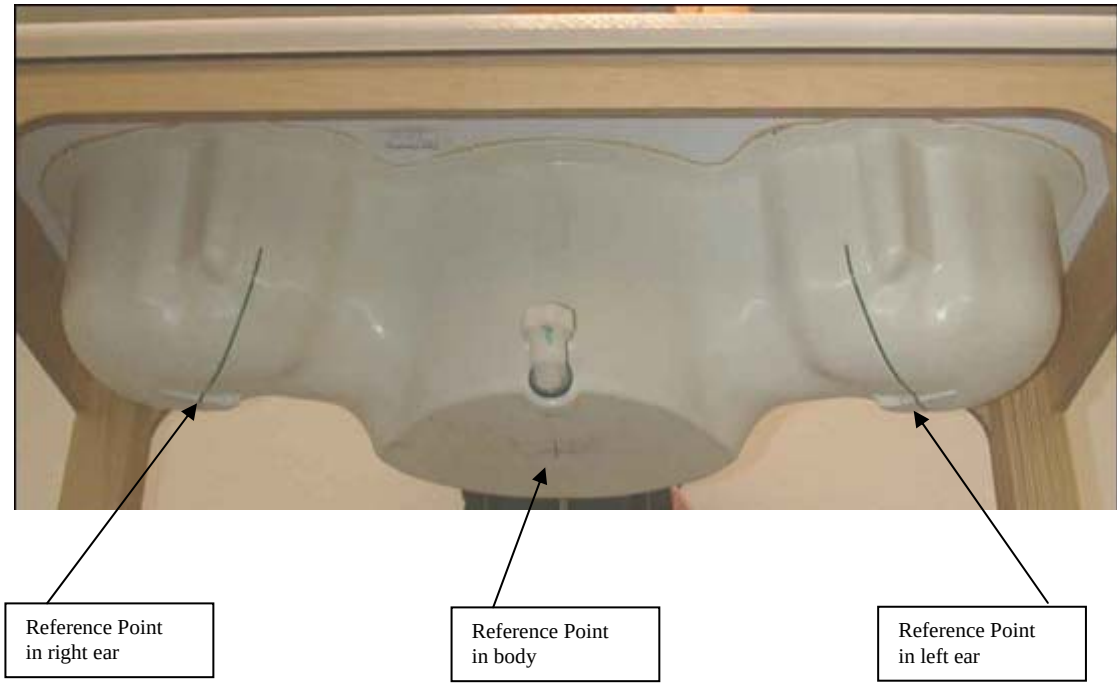


Fig. 8 SAM Twin Phantom and the definition points

2.6 Device Holder

The device was placed in the device holder (illustrated below) that is supplied by SPEAG as an integrated part of the Dasy system.

Fig. 9 Device holder supplied by SPEAG

2.7 Specifications of Probes

The E-Field Probes ET3DV6 or EX3DV4, manufactured and calibrated annually by Schmid & Partner Engineering AG with following specification are used for the dosimetric measurements.

ET3DV6:

- Dynamic range: 5 μ W/g ~ 100 mW/g
- Tip diameter: 6.8 mm
- Probe linearity: ± 0.2 dB (30MHz to 3 GHz)
- Axial isotropy: ± 0.2 dB
- Spherical isotropy: ± 0.4 dB
- Distance from probe tip to dipole centers: 2.7 mm
- Calibration range: 900MHz/1750MHz/1900MHz/ /2450MHz for head and body simulating liquids.

EX3DV4:

- Dynamic range: 10 μ W/g ~ 100 mW/g
- Tip diameter: 2.5 mm
- Probe linearity: ± 0.2 dB (30MHz to 3 GHz)
- Axial isotropy: ± 0.2 dB
- Spherical isotropy: ± 0.4 dB
- Distance from probe tip to dipole centers: 1.0 mm
- Calibration range: 900MHz/1810MHz for head simulating liquid and

2.8 SAR Measurement Procedures in DASY4

Step 1 Setup a Call Connection

Establish a call in handset at the maximum power level with a base station simulator via air interface.

Step 2 Power Reference Measurement

To measure the local E-field value at a fixed location which value will be taken as a reference value for calculating a possible power drift.

Step 3 Area Scan

To measure the SAR distribution with a grid with spacing of 15 mm x 15 mm and kept with a constant distance to the inner surface of the phantom. Additional all peaks within 3 dB of the maximum SAR are searched.

Step 4 Zoom Scan

At these points (maximum number of SAR peaks is two), a cube of 32 mm x 32 mm x 30 mm is applied to and measured with 5 x 5 x 7 points. With these measured data, a peak spatial-average SAR value can be calculated by SEMCAD software.

Step 5 Power Drift Measurement

Repetition of the E-field measurement at the fixed location mentioned in Step 1 to make sure the two results differ by less than ± 0.2 dB.

2.9 Simulating Liquids

Liquid Recipes for this test report are as following:

HSL 2450MHz band (Head)

Ingredient	% by weight
Water	55
DGBE	45
Salt	0.0

BSL 2450MHz band (Body)

Ingredient	% by weight
Water	68.64
DGBE	31.36
Salt	0.0

2.10 System Performance Check

2.10.1 Purpose：

1. To verify the simulating liquids are valid for testing.
2. To verify the performance of testing system is valid for testing.

2.10.2 System Performance Check Procedure

The DASY4 installation includes predefined files with recommended procedures for measurements and the system performance check. They are read-only document files and destined as fully defined but unmeasured masks, so the finished system performance check must be saved under a different name. The system performance check document requires the SAM Twin Phantom, so this phantom must be properly installed in your system. (User defined measurement procedures can be created by opening a new document or editing an existing document file). Before you start the system performance check, you need only to tell the system with which components (probe, medium, and device) you are performing the system performance check; the system will take care of all parameters.

• **The Power Reference Measurement and Power Drift Measurement** jobs are located at the beginning and end of the batch process. They measure the field drift at one single point in the liquid over the complete procedure. The indicated drift is mainly the variation of the amplifier output power. If it is too high (above ±0.1 dB), the system performance check should be repeated; some amplifiers have very high drift during warm-up. A stable amplifier gives drift results in the DASY system below ±0.02 dB.

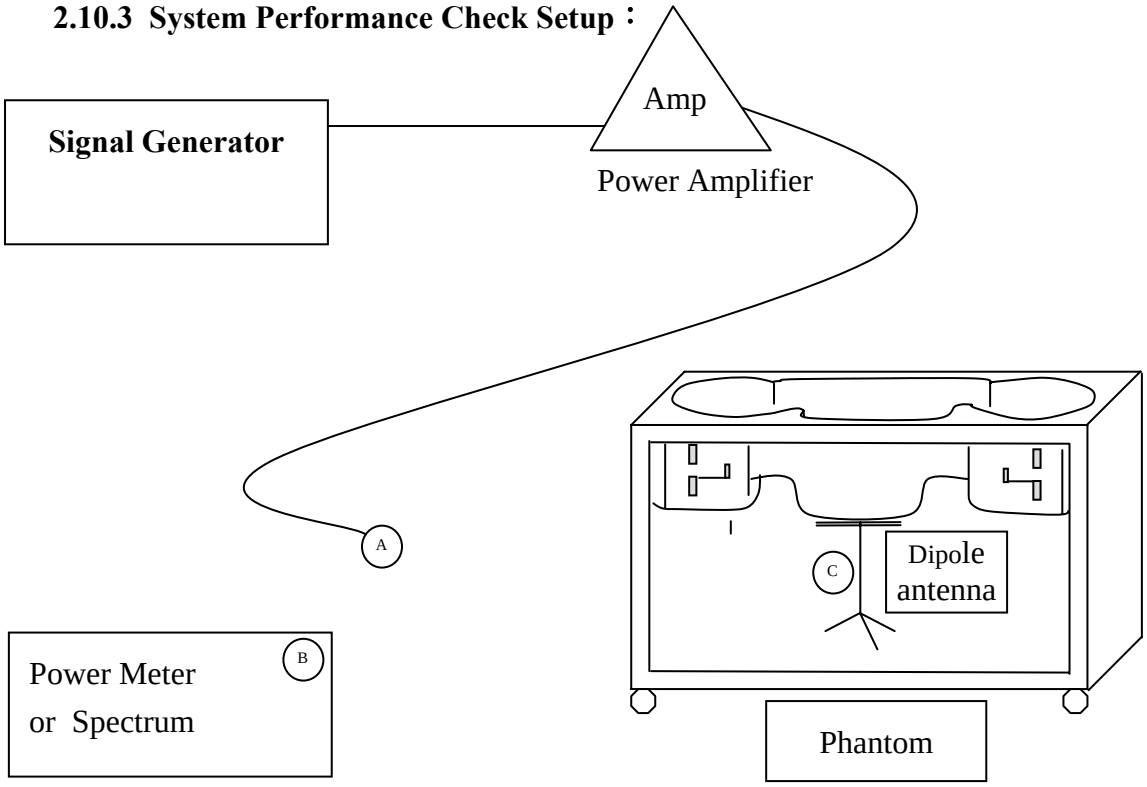
• **The Surface Check** job tests the optical surface detection system of the DASY system by repeatedly detecting the surface with the optical and mechanical surface detector and comparing the results. The output gives the detecting heights of both systems, the di_erence between the two systems and the standard deviation of the detection repeatability. Air bubbles or refraction in the liquid due to separation of the sugar-water mixture gives poor repeatability (above ±0.1mm). In that case it is better to abort the system performance check and stir the liquid.

• **The Area Scan** job measures the SAR above the dipole on a plane parallel to the surface. It is used to locate the approximate location of the peak SAR. The proposed scan uses large grid
spacing for faster measurement; due to the symmetric field, the peak detection is reliable.
Schmid & Partner Engineering AG, DASY4 Manual, February 2005 16-2
System Performance Check Application Notes
If a finer graphic is desired, the grid spacing can be reduced. Grid spacing and orientation have no influence on the SAR result.

• **The Zoom Scan** job measures the field in a volume around the peak SAR value assessed in the previous Area Scan job (for more information see the application note on SAR evaluation).

If the system performance check gives reasonable results, the SAR peak, 1 g and 10 g spatial average SAR values normalized to 1W dipole input power give reference data for comparisons. The next sections analyze the expected uncertainties of these values, as well as additional checks for further information or troubleshooting.

2.10.3 System Performance Check Setup：



Note：

1. A connected to B is used to make sure whether the input power is 250mW for target frequency..
2. A connected to C is used to input the measured power to dipole antenna

2.10.4 Result of System Performance Check: Valid Result

Diepole Antenna: D2450V2 SN:764

Date of Measurement And Reference Value	SAR@1g [mW/kg]	Dielectric Parameters)		Tem-perature [℃]
		ε r	σ [S/m]	
Head 2450 MHz Reference Value	13.8 ±10% [12.42 ~ 15.18]	39.2 ± 5% [37.24 ~ 41.16]	1.8 ± 5% [1.71 ~ 1.89]	22.0 ± 2 [20 ~ 24]
2005-09-02	12.9	38.2	1.82	21.8
2005-10-11	12.9	38.2	1.82	20.4
Body 2450 MHz Reference Value	13.6 ±10% [12.24 ~ 14.96]	52.7 ± 5% [50.1 ~ 55.3]	1.95 ± 5% [1.85 ~ 2.05]	22.0 ± 2 [20 ~ 24]
2005-09-05	13.0	50.8	1.98	22.6

3 Results

3.1 Summary of Test Results

No deviations from the technical specification(s) were ascertained in the course of the tests performed.	■
The deviations as specified in this chapter were ascertained in the course of the tests Performed.	□

3.2 Head

Frequency		Mode	Conducted Power (dBm)		Conducted Power Drift	SAR@1g [mW/g]	Power Drift (dB)	Note
CH	MHz		Before	After				
01	2402	LC-Low	23.96	23.56	-0.016	0.219	-0.344	
46	2441	LC-Mid	23.25	22.82	-0.018	0.21	-0.201	
92	2480	LC-High	22.44	22.11	-0.015	0.168	0.016	
01	2402	LT-Low	23.85	23.23	-0.02	0.184	-0.218	
46	2441	LT-Mid	23.02	22.89	-0.005	**0.241**	-0.197	worse
92	2480	LT-High	22.24	22.09	-0.007	0.194	-0.058	
01	2402	RC-Low	24.06	23.51	-0.023	0.197	-0.387	
46	2441	RC-Mid	23.32	22.85	-0.02	0.194	-0.251	
92	2480	RC-High	22.5	22.25	-0.01	0.154	0.01	
01	2402	RT-Low	23.86	23.35	-0.02	0.198	-0.361	
46	2441	RT-Mid	23.17	22.85	-0.014	0.212	-0.292	
92	2480	RT-High	22.37	22.06	-0.014	0.169	-0.026	

The Max Head SAR@2402MHz@1g is 0.241 mW/g, less than limitation of 1.6 mW/g.

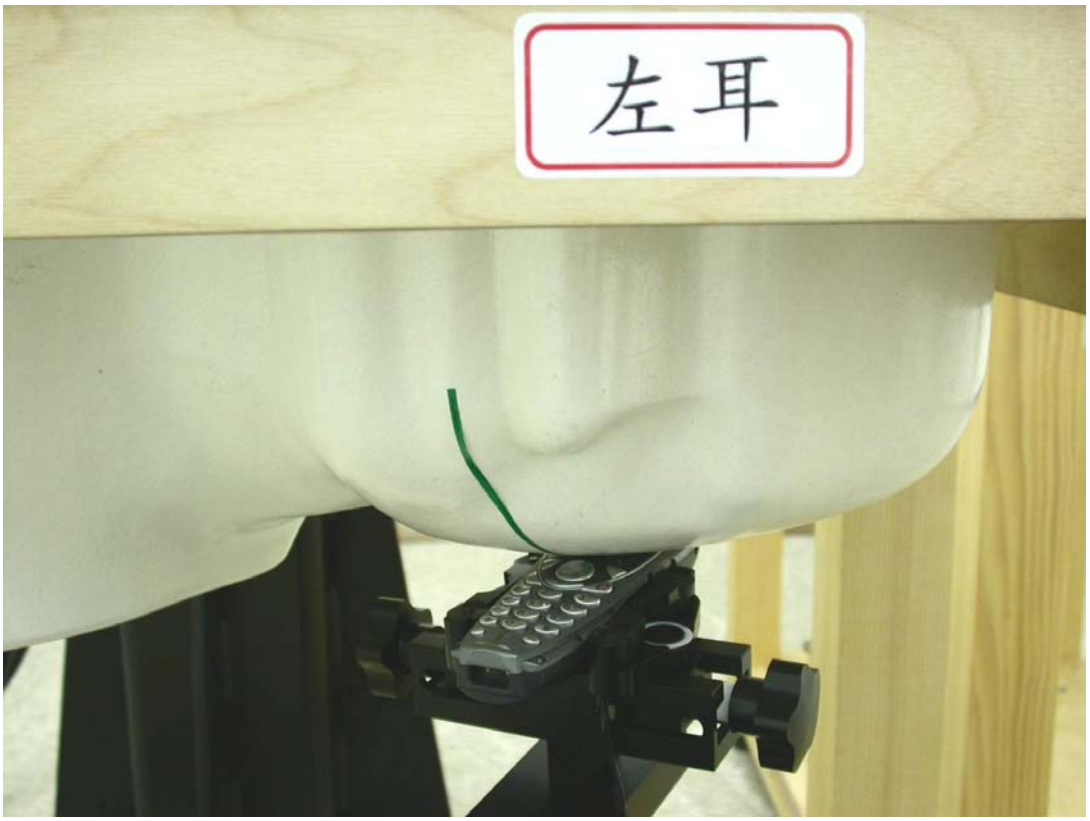
3.3 Body

Frequency		Mode	Conducted Power (dBm)		Conducted Power Drift	SAR@1g [mW/g]	Power Drift (dB)	Note
CH	MHz		Before	After				
01	2402	B-Low	23.76	23.29	-0.02	**0.220**	-0.256	worse
46	2441	B-Mid	23.09	22.59	-0.02	0.206	-0.171	
92	2480	B-High	22.3	21.84	-0.02	0.155	0.051	

The Max Body SAR@2402MHz@1g is 0.220 mW/g, less than limitation of 1.6 mW/g.

3.4 Measurement Position (IncludingLC, LT,RC, RT)

3.4.1 Left-Cheek (LC)



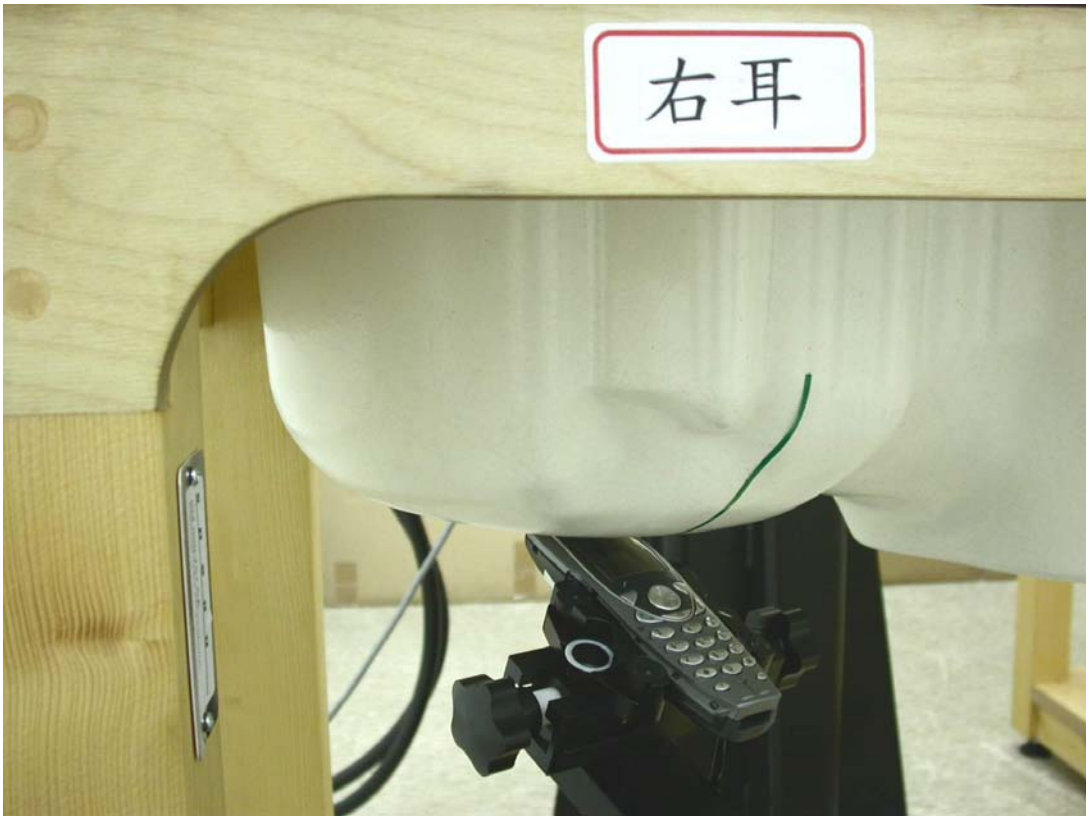
Measurement Position of Left-Cheek (LC) with Handset

3.4.2 Left-Tilt (LT)

Measurement Position of Left-Tilt (LT) with Handset

Measurement Position of Right-Cheek (RC) with Handset

3.4.4 Right-Tilt (RT)



Measurement Position of Right-Tilt (RT) with Handset

3.4.5 Body-Flat (Side view)

Measurement Position of Body with Handset and earphone

3.4.6 Body-Flat (Top view)

Measurement Position of Body with Handset and earphone

4 Description of the Test Procedure for FCC

4.1 Scan Procedure

First coarse scans were used for determination of the field distribution. Next a cube scan, 5x5x7 points covering a volume of 32x32x30mm was performed around the highest E-field value to determine the averaged SAR value. Drift was determined by measuring the same point at the start of the coarse scan and again at the end of the cube scan.

4.2 SAR Averaging Methods

The maximum SAR value was averaged over a cube of tissue using interpolation and extrapolation. The interpolation, extrapolation and maximum search routines within Dasy4 are all based on the modified Quadratic Shepard's method (Robert J. Renka, "Multivariate Interpolation Of Lagre Sets Of Scattered Data", University of North Texas ACM Transactions on Mathematical Software, vol. 14, no. 2, June 1988, pp. 139-148).

The interpolation scheme combines a least-square fitted function method with a weighted average method. A trivariate 3-D / bivariate 2-D quadratic function is computed for each measurement point and fitted to neighbouring points by a least-square method. For the cube scan, inverse distance weighting is incorporated to fit distant points more accurately. The interpolating function is finally calculated as a weighted average of the quadratics.
In the cube scan, the interpolation function is used to extrapolate the Peak SAR from the deepest measurement points to the inner surface of the phantom.

4.3 Data Storage

The DASY4 software stores the assessed data from the data acquisition electronics as raw data (in microvolt readings from the probe sensors), together with all the necessary software parameters for the data evaluation (probe calibration data, liquid parameters and device frequency and modulation data) in measurement files with the extension .DA4. The postprocessing software evaluates the desired unit and format for output each time the data is visualized or exported. This allows verification of the complete software setup even after the measurement and allows correction of erroneous parameter settings.

The measured data can be visualized or exported in different units or formats, depending on the selected probe type (e.g., [V/m], [A/m] or [mW/g]). Some of these units are not available in certain situations or give meaningless results, e.g., a SAR-output in a lossless media will always be zero. Raw data can also be exported to perform the evaluation with other software packages.

4.4 Data Evaluation

The DASY4 postprocessing software (SEMCAD) 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 parameters:	- Sensitivity	$Norm_i$, a_{i0}, a_{i1}, a_{i2}
	- Conversion factor	$ConvF_i$
	- Diode compression point	dcp_i
Device parameters:	- Frequency	f
	- Crest factor	cf
Media parameters:	- Conductivity	σ
	- Density	ρ

These parameters must be set correctly in the software. They can be found in the component documents or they can be imported into the software from the configuration files issued for the DASY components. In the direct measuring mode of the multimeter 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:

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

with	V_i	= compensated signal of channel i	(i = x, y, z)
	U_i	= 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:

$$\text{E} - \text{fieldprobes}: \qquad E_i = \sqrt{\frac{V_i}{Norm_i \cdot ConvF}}$$

$$\text{H} - \text{fieldprobes}: \qquad H_i = \sqrt{V_i} \cdot \frac{a_{i0} + a_{i1} f + a_{i2} f^2}{f}$$

with	V_i	= compensated signal of channel i	(i = x, y, z)
	$Norm_i$	= sensor sensitivity of channel i μV/(V/m)^2 for E-field Probes	(i = x, y, z)
	$ConvF$	= sensitivity enhancement in solution	
	a_{ij}	= sensor sensitivity factors for H-field probes	
	f	= carrier frequency [GHz]	
	E_i	= electric field strength of channel i in V/m	
	H_i	= magnetic field strength of channel i in A/m	

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

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

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

$$SAR = E_{tot}^2 \cdot \frac{\sigma}{\rho \cdot 1'000}$$

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

Note that the density is set to 1, to account for actual head tissue density rather than the density of the tissue simulating liquid.

4.5 Spatial Peak SAR Evaluation

The procedure for spatial peak SAR evaluation has been implemented according to the IEEE1529 standard. It can be conducted for 1 g and 10 g, as well as for user-specific masses. The DASY4 system allows evaluations that combine measured data and robot positions, such as:

- maximum search
- boundary correction
- extrapolation
- peak search for averaged SAR

During a maximum search, global and local maxima searches are automatically performed in 2-D after each Area Scan measurement with at least 6 measurement points. It is based on the evaluation of the local SAR gradient calculated by the Quadratic Shepard's method. The algorithm will find the global maximum and all local maxima within -2 dB of the global maxima for all SAR distributions.

Extrapolation

Extrapolation routines are used to obtain 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 o_set. Several measurements at di_erent distances are necessary for the extrapolation. Extrapolation routines require at least 10 measurement points in 3-D space. They are used in the Zoom Scan to obtain SAR values between the lowest measurement points and the inner phantom surface. The routine uses the modified Quadratic Shepard's method for extrapolation. For a grid using 5x5x7 measurement points with 5mm resolution amounting to 343 measurement points, the uncertainty of the extrapolation routines is less than 1% for 1 g and 10 g cubes.

Boundary effect

For measurements in the immediate vicinity of a phantom surface, the field coupling e_ects between the probe and the boundary influence the probe characteristics. Boundary e_ect errors of
di_erent dosimetric probe types have been analyzed by measurements and using a numerical probe model. As expected, both methods showed an enhanced sensitivity in the immediate vicinity of the boundary. The e_ect strongly depends on the probe dimensions and disappears with increasing distance from the boundary. The sensitivity can be approximately given as:

$$S \approx S_o + S_b exp(-\frac{z}{a}) cos(\pi \frac{z}{\lambda})$$

Since the decay of the boundary e_ect dominates for small probes (a <<_), the cos-term can be omitted. Factors Sb (parameter Alpha in the DASY4 software) and a (parameter Delta in the DASY4 software) are assessed during probe calibration and used for numerical compensation of the boundary e_ect. Several simulations and measurements have confirmed that the compensation is valid for di_erent field and boundary configurations.
This simple compensation procedure can largely reduce the probe uncertainty near boundaries. It works well as long as:
- the boundary curvature is small
- the probe axis is angled less than 30_ to the boundary normal
- the distance between probe and boundary is larger than 25% of the probe diameter
- the probe is symmetric (all sensors have the same o_set from the probe tip)

Since all of these requirements are fulfilled in a DASY4 system, the correction of the probe boundary effect in the vicinity of the phantom surface is performed in a fully automated manner via the measurement data extraction during postprocessing.

5 Measurement Uncertainty

5.1 Measurement Uncertainty I (According to IEEE 1528)

DASY4 Uncertainty Budget
According to IEEE 1528 [2]

Error Description	Uncertainty value	Prob. Dist.	Div.	(c_i) 1g	(c_i) 10g	Std. Unc. (1g)	Std. Unc. (10g)	(v_i) v_{eff}
Measurement System								
Probe Calibration	±5.9 %	N	1	1	1	±5.9 %	±5.9 %	∞
Axial Isotropy	±4.7 %	R	$\sqrt{3}$	0.7	0.7	±1.9 %	±1.9 %	∞
Hemispherical Isotropy	±9.6 %	R	$\sqrt{3}$	0.7	0.7	±3.9 %	±3.9 %	∞
Boundary Effects	±1.0 %	R	$\sqrt{3}$	1	1	±0.6 %	±0.6 %	∞
Linearity	±4.7 %	R	$\sqrt{3}$	1	1	±2.7 %	±2.7 %	∞
System Detection Limits	±1.0 %	R	$\sqrt{3}$	1	1	±0.6 %	±0.6 %	∞
Readout Electronics	±0.3 %	N	1	1	1	±0.3 %	±0.3 %	∞
Response Time	±0.8 %	R	$\sqrt{3}$	1	1	±0.5 %	±0.5 %	∞
Integration Time	±2.6 %	R	$\sqrt{3}$	1	1	±1.5 %	±1.5 %	∞
RF Ambient Conditions	±3.0 %	R	$\sqrt{3}$	1	1	±1.7 %	±1.7 %	∞
Probe Positioner	±0.4 %	R	$\sqrt{3}$	1	1	±0.2 %	±0.2 %	∞
Probe Positioning	±2.9 %	R	$\sqrt{3}$	1	1	±1.7 %	±1.7 %	∞
Max. SAR Eval.	±1.0 %	R	$\sqrt{3}$	1	1	±0.6 %	±0.6 %	∞
Test Sample Related								
Device Positioning	±2.9 %	N	1	1	1	±2.9 %	±2.9 %	145
Device Holder	±3.6 %	N	1	1	1	±3.6 %	±3.6 %	5
Power Drift	±5.0 %	R	$\sqrt{3}$	1	1	±2.9 %	±2.9 %	∞
Phantom and Setup								
Phantom Uncertainty	±4.0 %	R	$\sqrt{3}$	1	1	±2.3 %	±2.3 %	∞
Liquid Conductivity (target)	±5.0 %	R	$\sqrt{3}$	0.64	0.43	±1.8 %	±1.2 %	∞
Liquid Conductivity (meas.)	±2.5 %	N	1	0.64	0.43	±1.6 %	±1.1 %	∞
Liquid Permittivity (target)	±5.0 %	R	$\sqrt{3}$	0.6	0.49	±1.7 %	±1.4 %	∞
Liquid Permittivity (meas.)	±2.5 %	N	1	0.6	0.49	±1.5 %	±1.2 %	∞
Combined Std. Uncertainty						±10.8 %	±10.6 %	330
Expanded STD Uncertainty						**±21.6 %**	**±21.1 %**	

5.2 Measurement Uncertainty II (According to IEC 62209)

DASY4 Uncertainty Budget
According to IEC 62209 [3]

Error Description	Uncertainty value	Prob. Dist.	Div.	(c_i) 1g	(c_i) 10g	Std. Unc. (1g)	Std. Unc. (10g)	(v_i) v_{eff}
Measurement System								
Probe Calibration	±5.9 %	N	1	1	1	±5.9 %	±5.9 %	∞
Axial Isotropy	±4.7 %	R	$\sqrt{3}$	0.7	0.7	±1.9 %	±1.9 %	∞
Spherical Isotropy	±9.6 %	R	$\sqrt{3}$	0.7	0.7	±3.9 %	±3.9 %	∞
Boundary Effects	±1.0 %	R	$\sqrt{3}$	1	1	±0.6 %	±0.6 %	∞
Linearity	±4.7 %	R	$\sqrt{3}$	1	1	±2.7 %	±2.7 %	∞
Detection Limits	±1.0 %	R	$\sqrt{3}$	1	1	±0.6 %	±0.6 %	∞
Readout Electronics	±0.3 %	N	1	1	1	±0.3 %	±0.3 %	∞
Response Time	±0.8 %	R	$\sqrt{3}$	1	1	±0.5 %	±0.5 %	∞
Integration Time	±2.6 %	R	$\sqrt{3}$	1	1	±1.5 %	±1.5 %	∞
Perturbation of the Environment	±3.0 %	R	$\sqrt{3}$	1	1	±1.7 %	±1.7 %	∞
Probe Positioner Mech. Restr.	±0.4 %	R	$\sqrt{3}$	1	1	±0.2 %	±0.2 %	∞
Probe Positioning	±2.9 %	R	$\sqrt{3}$	1	1	±1.7 %	±1.7 %	∞
Post-Processing	±1.0 %	R	$\sqrt{3}$	1	1	±0.6 %	±0.6 %	∞
Test Sample Related								
Test Sample Positioning	±2.9 %	N	1	1	1	±2.9 %	±2.9,%	145
Device Holder Uncertainty	±3.6 %	N	1	1	1	±3.6 %	±3.6 %	5
Drift of Output Power	±5.0 %	R	$\sqrt{3}$	1	1	±2.9 %	±2.9 %	∞
Phantom and Setup								
Phantom Uncertainty	±4.0 %	R	$\sqrt{3}$	1	1	±2.3 %	±2.3 %	∞
Liquid Conductivity (target)	±5.0 %	R	$\sqrt{3}$	0.7	0.5	±2.0 %	±1.4 %	∞
Liquid Conductivity (meas.)	±4.3 %	R	$\sqrt{3}$	0.7	0.5	±1.7,%	±1.2 %	∞
Liquid Permittivity (target)	±5.0 %	R	$\sqrt{3}$	0.6	0.5	±1.7 %	±1.4 %	∞
Liquid Permittivity (meas.)	±4.3 %	R	$\sqrt{3}$	0.6	0.5	±1.5 %	±1.2 %	∞
Combined Std. Uncertainty						±10.5 %	±10.2 %	330
Expanded Uncertainty						**±21.0 %**	**±20.5 %**	

6 References

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