TEST REPORT CONCERNING RF EXPOSURE ASSESSMENT OF A TABLET PC WITH INTEGRAL IEEE 802.11b/g WLAN, BRAND ADS-TEC, MODEL COMPACT3 TO DEMONSTRATE COMPLIANCE WITH BASIC RESTRICTIONS RELATED TO EXPOSURE OF THE GENERAL PUBLIC TO ELECTROMAGNETIC FIELDS

FCC listed : 90828
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VCCI registered : R-1518, C-1598

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Description of test item

Test item	:	2.4 GHz IEEE 802.11b/g WLAN tablet PC
Manufacturer	:	ADS-tec
Brand	:	ADS-tec
Model	:	Compact3
Serial numbers	:	n.a.
Revision	:	n.a.
Received number of samples	:	1
Receipt date	:	14-11-2005

Applicant information

Applicant's representative	:	Th. Moegerle
Company	:	ADS-tec Gmbh
Address	:	Raiffeisenstr. 14
Postal code	:	70771
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Test(s) performed

Location	:	Niekerk
Test(s) started	:	November 17, 2005
Test(s) completed	:	November 18, 2005
Purpose of test(s)	:	To verify compliance with Federal regulated SAR requirements in the USA
Test specification(s)		IEEE 1528: 2003, FCC OET Bulletin 65 (including Supplement C)
Test engineer	:	J. Schuurmans, B.Sc.E.E.
Report written by	:	J. Schuurmans, B.Sc.E.E.
Report approved by	:	P.A.J.M Robben
Report date	:	January 13, 2006

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The test results relate only to the item(s) tested.

Table of contents

1 General.

1.1 Purpose of tests.

Tests were conducted to demonstrate compliance with the basic restrictions with respect to exposure of humans to electromagnetic fields.

1.2 Applied standards/publications.

was tested in conformity with the described test method(s) in the following standards and/or publications:

Publications	Year	Title
IEEE Std. 1528	2003	Recommended Practice for Determining the Peak Spatial-Average Specific Absorption rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques.
FCC OET Bulletin 65, Edition 97-01	1997	Evaluating Compliance with FCC Guidelines for Human Exposure to radio Frequency Fields
ANSI/IEEE C95.3	2002	IEEE Recommended Practice for the Measurement and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100kHz-300GHz

2 Summary and conclusion.

2.1 Exposure category.

The EUT is a portable device, intended for use near the body.

According to the characteristics of the EUT and the typical application and usage in accordance with the relevant product specifications of the manufacturer, the applicable exposure category is:

General population/Uncontrolled exposure

2.2 Summary of results.

The maximum peak spatial-average SAR measured was 0.153 W/Kg averaged over 1g with the EUT transmitting on 2437 MHz (channel 6) at a power level of 19 dBm (conducted average including 3 dBi antenna gain) while the EUT was positioned in lapheld fashion.

2.3 Compliance.

The equipment was found to be compliant with requirements of standards as indicated in the table below:

Exposure category and SAR limits	Compliance (Yes/No)
Limit value for General population / Uncontrolled exposure as per 47 CFR 2.1093 (d)(2): Spatial Peak SAR shall not exceed 1.6 W/kg, averaged over 1 g of tissue	**YES**

3 Identification of Equipment Under Test (EUT).

The following is the information provided by the applicant.

3.1 Equipment under Test (EUT) details.

Description	Model number	Serial number	FCC ID	Cable descriptions
Tabl;et PC	Compact3	n.a.	DoC	(none)

3.2 EUT test operating configurations.

Modulation type/ operating modes	:	According to IEEE 802.11 b and IEEE 802.11 g
Operating frequency range	:	2412-2464 MHz (11 channels)
Maximum indicated power	:	21.38 dBm incl. antenna gain of 0 dBi @ 2412 MHz – 2464 MHz
Duty cycle during testing	:	100%
Antenna type(s) and gain	:	Integral, gain 0.1 dBi @ 2.4 GHz.
Power supply/ power source	:	Internal battery
EUT Accessories	:	See section 3.1
Hardware/software changes applied for testing	:	EUT is made to transmit with 100% duty cycle, by means of specific test software supplied by applicant.

3.3 Additional operating configurations.

Power and signal distribution, grounding, interconnecting cabling and physical placement of the EUT under circumstances of testing at the test system are in accordance with the typical application and usage in so far as is practicable, and is in accordance with the relevant product specifications of the manufacturer.

The configuration of the EUT and its position are fully detailed and documented in the test report.

4 Test conditions.

4.1 Environmental conditions.

Requirement for	Specification	Determined value
Ambient temperature	+18°C to +25°C Temperature shall not exceed ±2 °C during the test	+19.5°C to 20.5°C
Ambient humidity	20% to 75%	45%-60%
Electro Magnetic environment	the ambient interference power shall be less than 0,012 W/kg	below the required lower detection limit of 0,010 W/kg, checked before and after test

4.2 System performance check 2.4 GHz.

The purpose of the system performance check (*system check*) is to verify that the system operates within its specifications at the device test frequency. The system check is to make sure that the system works correctly at the time of the compliance test. The system check has been performed using the specified tissue-equivalent liquid and at a chosen fixed frequency that is within ± 10% of the compliance test mid-band frequency. The system check is performed prior to compliance tests and the result must always be within ±10% of the target value corresponding to the test frequency, liquid and the source used. In section 10.3 a description of this check is given. Below photographs of the 2.4 check instrument setup and validation dipoles.

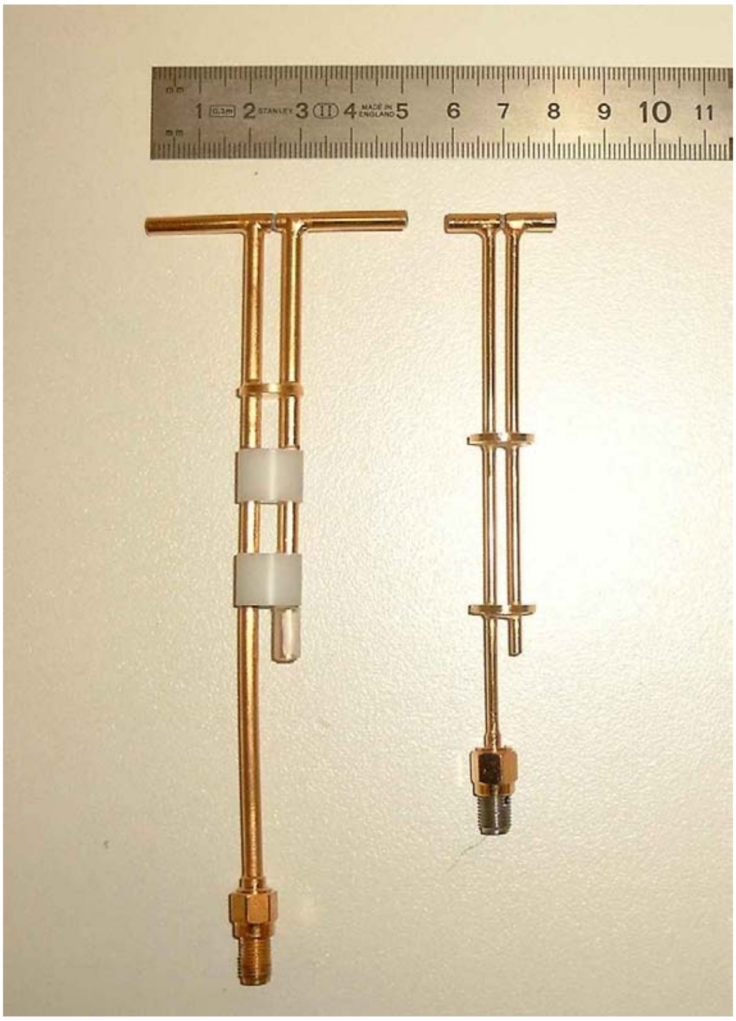
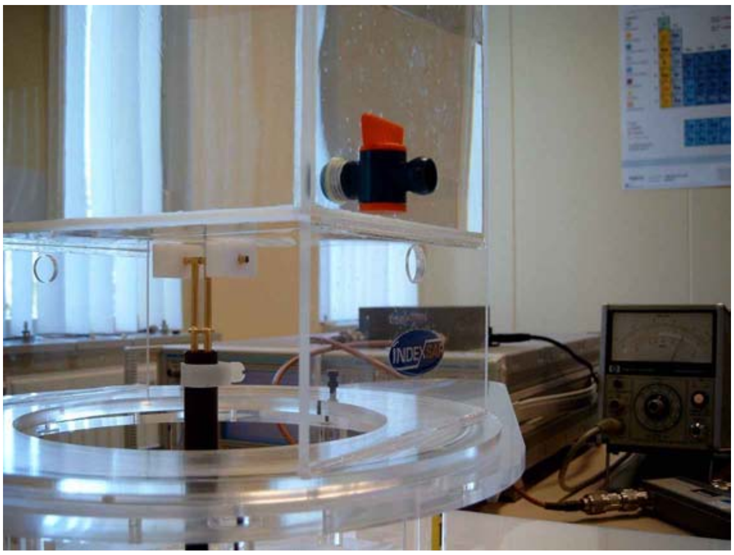


Photo 1: Validation dipoles (left dipole: 2.4 GHz)



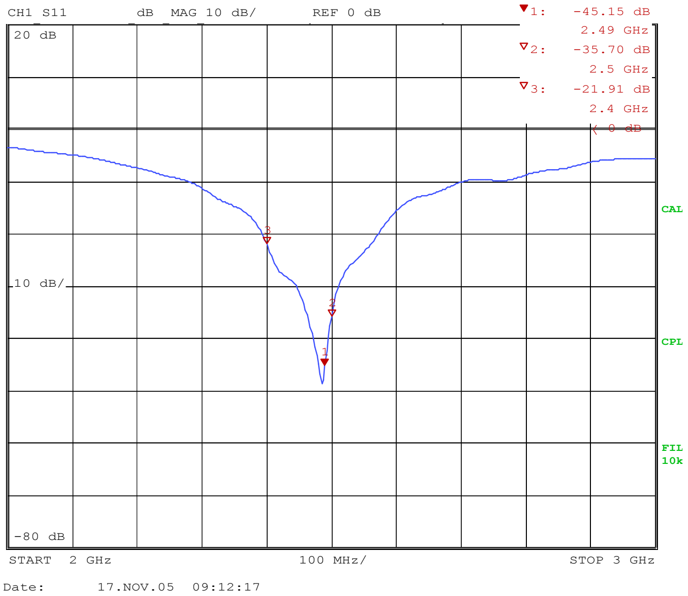


Figure 1: |S11| of the 2.4 GHz dipole placed underneath the filled phantom

4.2.1 2450 MHz validation parameters.

At 2450 MHz a system validation check was performed in accordance with section 8 of IEEE Std. 1528: 2003. Please refer to Photo 1 for a photograph of the dipole which has been used during this system validation check.

Frequency = 2450 MHz		Target value (W/kg)	Measured value (W/kg)	Deviation[1] (%)
Date: November 17, 2005	Peak Spatial-Average SAR 1g	52.00	56.00	+7.7%
	Peak Spatial-Average SAR 10g	24.00	26.00	+8.3%

Detailed validation results may be found in section 8 of this test report.

4.3 Measured maximum output power of EUT.

The EUT has been set to the maximum output power level that is defined by the manufacturer and/or the operating requirements of the system (see section 3.3 EUT test operating configurations).

The results of tests on the EUT are depicted in table below. Listed is the higher of the conducted average power and EIRP.

[1] Deviation is calulated: 100% *((measured value)/(reference value) –1)

4.3.1 Measured Average power on 2.4 GHz.

Mode	speed	Channel 1 2412 MHz	correction	result	Channel 6 2437 MHz	correction	result	Channel 11 2462 MHz	correction	result
IEEE 802.11 b	1 long	20.15	1.00	21.15	20.25	1.01	21.26	20.12	1.02	21.14
	1 short	20.19	1.00	21.19	20.29	1.01	21.30	20.11	1.02	21.13
	2 long	20.14	1.00	21.14	20.29	1.01	21.30	20.09	1.02	21.11
	2 short	20.14	1.00	21.14	19.78	1.01	20.79	20.11	1.02	21.13
	5.5 long	20.24	1.00	**21.24**	20.35	1.01	**21.36**	20.20	1.02	**21.22**
	5.5 short	19.98	1.00	20.98	19.84	1.01	20.85	20.18	1.02	21.2
	11 long	20.18	1.00	21.18	20.31	1.01	21.32	20.13	1.02	21.15
	11 short	19.88	1.00	20.88	19.78	1.01	20.79	20.12	1.02	21.14
IEEE 802.11 g	1 long	19.40	1.00	20.40	19.31	1.01	20.32	20.22	1.02	21.24
	2 long	19.38	1.00	20.38	19.32	1.01	20.33	20.19	1.02	21.21
	2 short	19.40	1.00	20.40	19.30	1.01	20.31	19.73	1.02	20.75
	5.5 long	19.44	1.00	20.44	19.38	1.01	**20.39**	20.22	1.02	**21.24**
	5.5 short	19.47	1.00	**20.47**	19.02	1.01	20.03	19.76	1.02	20.78
	11 long	19.43	1.00	20.43	19.33	1.01	20.34	20.13	1.02	21.15
	11 short	19.42	1.00	20.42	19.01	1.01	20.02	20.10	1.02	21.12
	6	19.10	1.00	20.10	19.49	1.01	20.50	19.82	1.02	20.84
	9	19.10	1.00	20.10	19.50	1.01	20.51	19.82	1.02	20.84
	12	19.10	1.00	20.10	19.50	1.01	20.51	19.82	1.02	20.84
	18	19.10	1.00	20.10	19.50	1.01	20.51	19.82	1.02	20.84
	24	19.12	1.00	20.12	19.47	1.01	20.48	19.81	1.02	20.83
	36	17.34	1.00	18.34	17.66	1.01	18.67	17.68	1.02	18.7
	48	16.09	1.00	17.09	16.94	1.01	17.95	16.75	1.02	17.77
	54	15.57	1.00	16.57	15.73	1.01	16.74	15.24	1.02	16.26
TURBO	12	n.a.	n.a.	n.a.	19.92	1.01	20.93	n.a.	n.a.	n.a.
	24	n.a.	n.a.	n.a.	19.90	1.01	20.91	n.a.	n.a.	n.a.
	36	n.a.	n.a.	n.a.	19.90	1.01	20.91	n.a.	n.a.	n.a.
	48	n.a.	n.a.	n.a.	19.88	1.01	**20.89**	n.a.	n.a.	n.a.
	72	n.a.	n.a.	n.a.	18.51	1.01	19.52	n.a.	n.a.	n.a.
	96	n.a.	n.a.	n.a.	17.64	1.01	18.65	n.a.	n.a.	n.a.
	108	n.a.	n.a.	n.a.	16.90	1.01	17.91	n.a.	n.a.	n.a.

Table 1: Average output power including antenna gain

From table 1 it can be seen that in channel 6 the highest power is found. First SAR scan will therefore be performed at channel 6, using 5.5 Mb/s (long) (See also section 7.1).

Transmission bit rate (Mbit/s)	Average transmit output power drift [dB]
	Channel 6 (2437 MHz)
OFDM 9	Less than 0.2 dB

Table 3: Average output power drift

4.4 Tissue simulating liquid dielectric parameters.

For the purpose of the tests as described in this report the following tissue dielectric parameters have been determined
The tables indicate the dielectric parameters of the liquids used during the tests. The indicated required values are derived from IEEE Std. 1528-2003 and OET Bulletin 65 supplement C. At frequencies other than reference frequencies, for which tissue parameters are given in the standards, the parameters have been determined by the linear interpolation. Depending the intended use of the EUT the interpolated values will refer to the mid-band frequency of each operating mode.

Deviation of the actual parameters vs. the prescribed parameters is calculated according: D=(A/T –1)*100% where D is deviation in %, A is the actual value and T is the Target value.

4.4.1 Mixing procedures.

All Tissue Equivalent Liquids are obtained from Bristol University.
Contact details:
Medical Physics Department
University of Bristol, Bristol Haemotology & Oncology Centre
Horfield road, Bristol BS2 8 ED, United Kingdom
Tel. 44 117 928 2469.

4.4.2 Dielectric parameters for 2.4 GHz

Freq (MHz)	ε	σ	ε		σ		Measured (19.0 ºC)			
			Min	Max	Min	Max	ε	Δ	σ	Δ
2412	52.75	1.91	47.78	58.03	1.72	2.11	**52.72**	**-0.05%**	**1.96**	**2.62%**
2437	52.72	1.94	47.45	57.99	1.74	2.13	**52.67**	**-0.09%**	**1.99**	**2.57%**
2462	52.68	1.97	47.42	57.95	1.77	2.16	**52.57**	**-0.21%**	**2.02**	**2.54%**

Table 2: Dielectric parameters for the 2.4 GHz, body liquid.

Freq (MHz)	ε	σ	ε		σ		Measured (19.0)			
			Min	Max	Min	Max	ε	Δ	σ	Δ
2412	39.27	1.77	35.34	43.10	1.63	1.99	**39.54**	**0.68%**	**1.79**	**1.12%**
2437	39.22	1.79	35.30	43.15	1.61	1.97	**39.48**	**0.66%**	**1.82**	**1.68%**
2462	39.18	1.81	35.27	35.27	43.10	1.99	**39.33**	**0.38%**	**1.84**	**1.66%**

Table 3: Dielectric parameters for 2.4 GHz, head liquid.

4.4.3 Tissue simulating liquid temperature requirements.

The variation of the liquid temperature shall not exceed ±2° C during the test; The actual tissue simulating liquid temperature was recorded to be between 19.0° C).

5 Photographs of EUT in host.

Photo 5 : EUT.

6 Identification of EUT-Phantom positions.

6.1 Portable Device operating near the body.

Following the guidelines from FCC OET bulletin 65 C and the TCB RF exposure training notes, 1 positions were investigated. The ‘lapheld’ position reflects the situation where the laptop is placed on the users lap. The laptop containing the EUT is placed underneath the flat phantom with the EUT placed in the bottom slot, thus minimizing the distance of the EUT and the users body.

6.1.1 Position lapheld.

This position follows the directions from FCC TCB training notes dated April 2002. This position reflects the situation where the user had the laptop on his or her lap, with the card inserted in the lower slot.
The separation distance, *d* was determined to be 13 mm, and reflects the position where the host would be positioned on the lap.

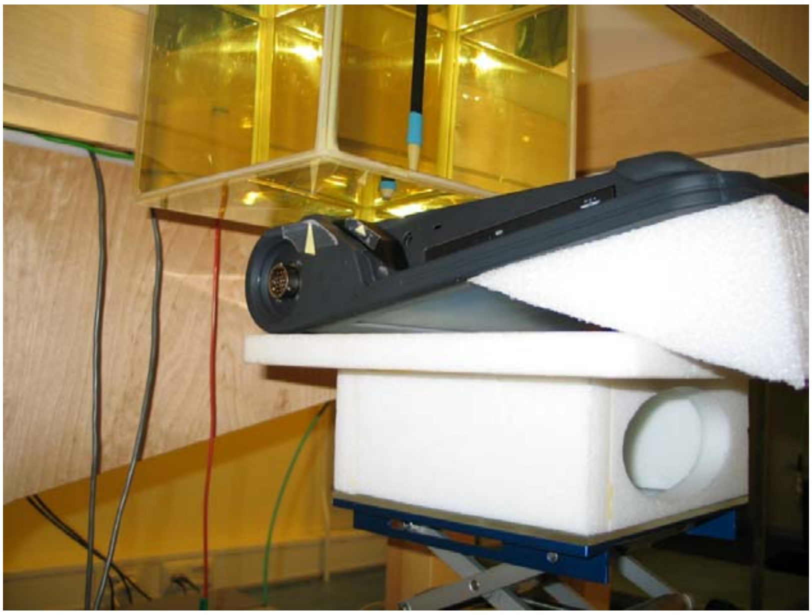


Photo 7 Position lapheld

7 Test Results.

7.1 Test methodology.

SAR evaluation starts with determining at which channels/modulation/bitrate combination SAR scans have to be performed. To do this, average conducted power is measured for all modulations and bitrates. From these measurements, in a given channel the modulation/bitrate is found by looking at the highest power found in that channel. In that channel, SAR is measured at that bitrate and modulation type. Should it appear that SAR tests in that channel show higher SAR than half the limit, SAR is also measured in the highest and lowest channel is that band. After testing, the channel with highest SAR found is rechecked by measureing Spot SAR in that channel while setting all modulation and bitrates. Should a higher value be found, a full SAR scan is performed for that particular bitrate/modulation. The highest value found is be reported.

7.2 Results.

Channel / modulation	Lapheld contact PSA[2] SAR 1g (W/kg)
1 (2412) OFDM 6 Mbit/s	n.a.
6 (2437) OFDM 6 MBit/s	0.105
11 (2462) OFDM 6 MBit/s	n.a.

Note: n.a. means that SAR measured in the channel with highest power is lower than 3 dB below the SAR limit, testing of the indicated channels is optional [ref: OET bull 65 suppl C p. 40). The channels n.a. have not been measured.

7.3 Step size and scan information.

Measurements on 2.4 GHz: A 32x32 mm area is scanned centered around the hotspot using 6 steps in the x-y plane and 10 steps of 3.5 mm in the z plane. The first area scan is performed with the probe tip 5 mm above the phantom bottom shell

The location of the hotspot is determined prior to each 3D scan by means of an area scan.

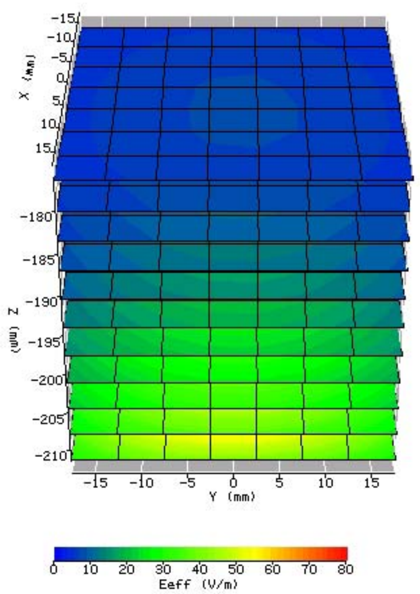
[2] PSA SAR is Peak Spatial-Average SAR.

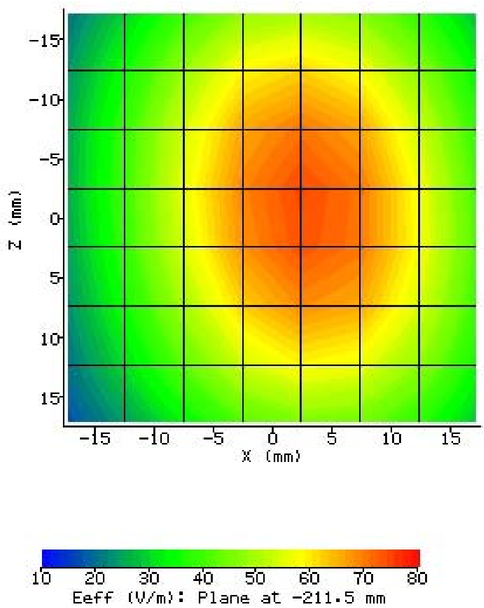
8 Plots of measurement data.

section	Ch	EUT position
01	-	Validation 2.4 GHz
02	6	Lapheld
03	6	Lapheld 2nd peak.

8.1 Validation 2.4 GHz.

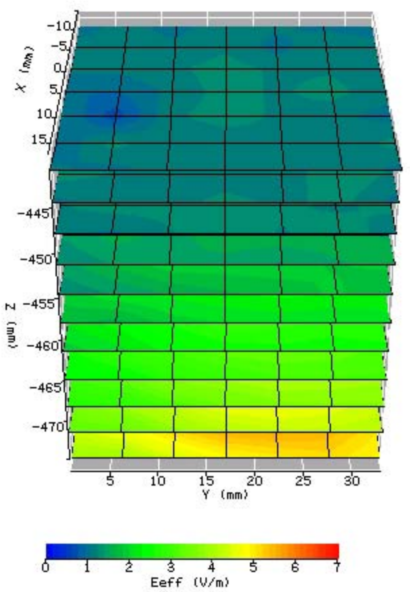
Device Under Test:		**Validation dipole**	
HOST		**n.a.**	
Position / Channel		**n.a.**	
DATE [dd/mm/yyyy]		**17-11-2005**	
System / software:		SARA v2.3	
Phantom S/No:	Box phantom.	No. of steps x and y	6
Test Frequency [MHz]	2447	Stepsize x and y [mm]	5.3
Antenna Configuration:	Dipole	No of steps z	10
Power / (setting(s) [dBm]	24	Stepsize z [mm]	3.5
Type of Modulation:	CW	Dist probe tip – phantom shell [mm]	5
Modn. Duty Cycle [%]	100	Prove conversion factor …..	0.534
Probe Serial Number:	105	Probe battery check [d/m/y]:	17-11-2005
Liquid Simulant:	Head	Max E-field [V/m in liquid]	71.10
Permittivity / Conductivity [S/m]	39.2 / 1.8	Location of max. X= [mm]	2
Liquid Temperature [C]	19.5	Location of max Y= [mm]	3
Ambient Temperature [C]	20.7	Location of max Z= [mm]	-225.0
Relative Humidity [%]	52	SAR Drift: [dB]	0.1
Results:			
SAR 1g [W/kg]:	**13.003**		
SAR 10g [W/kg]:	**5.996**		

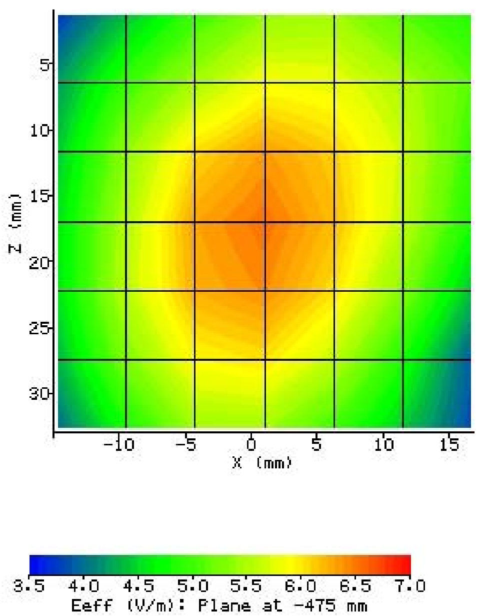




8.1.1 Host ADS-TEC, Lapheld channel 6.

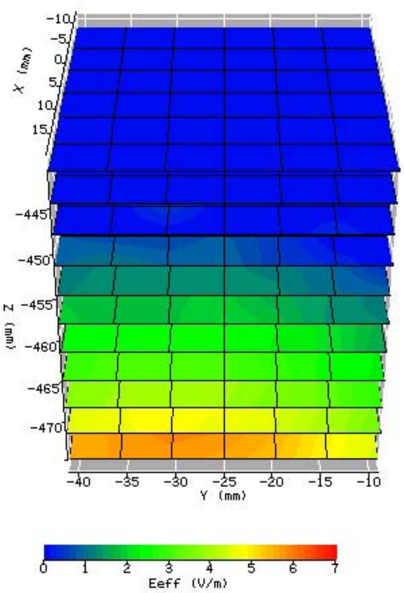
Device Under Test:		**Ads-tec Tablet PC**	
HOST		**Ads-tec Tablet PC**	
Position / Channel		**lapheld**	
DATE [dd/mm/yyyy]		**17-11-2005**	
System / software:		SARA v2.3	
Phantom S/No:	Box phantom.	No. of steps x and y	6
Test Frequency [MHz]	2437	Stepsize x and y [mm]	5.33
Antenna Configuration:	Integral	No. of steps z	10
Power / (setting(s) [dBm]	default	Stepsize z [mm]	3.5
Type of Modulation, datarate [Mb/s]:	OFDM, 6	Dist probe tip – phantom shell [mm]	5
Modn. Duty Cycle [%]	100	Prove conversion factor …..	0.540
Probe Serial Number:	105	Probe battery check [dd/mm/yyyy]:	17-11-2005
Liquid Simulant:	Body	Max E-field [V/m in liquid]	6.41
Permittivity / Conductivity [S/m]	52.7 / 1.8	Location of max. X= [mm]	0.1
Liquid Temperature [C]	19.7	Location of max Y= [mm]	15.9
Ambient Temperature [C]	20.5	Location of max Z= [mm]	-475.0
Relative Humidity [%]	41.0	SAR Drift: [dB]	0.1
Results:			
SAR 1g [W/kg]:			**0.098**
SAR 10g [W/kg]:			**0.056**

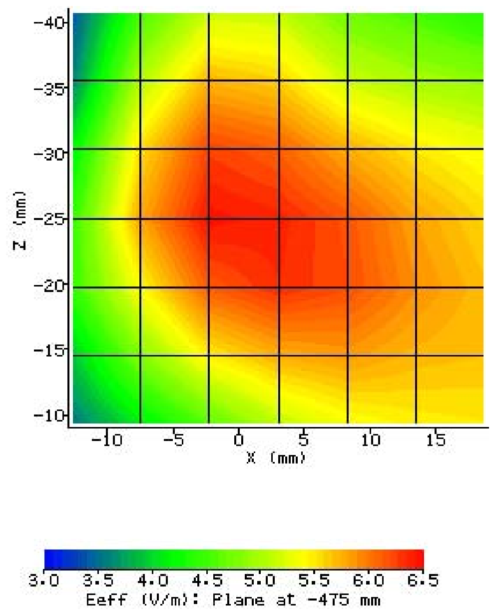




8.1.2 Host ADS-TEC, Lapheld channel 6.2nd peak

Device Under Test:		**Ads-tec Tablet PC**	
HOST		**Ads-tec Tablet PC**	
Position / Channel		**lapheld**	
DATE [dd/mm/yyyy]		**17-11-2005**	
System / software:		SARA v2.3	
Phantom S/No:	Box phantom.	No. of steps x and y	6
Test Frequency [MHz]	2437	Stepsize x and y [mm]	5.33
Antenna Configuration:	Integral	No. of steps z	10
Power / (setting(s) [dBm]	default	Stepsize z [mm]	3.5
Type of Modulation, datarate [Mb/s]:	OFDM, 6	Dist probe tip – phantom shell [mm]	5
Modn. Duty Cycle [%]	100	Prove conversion factor …..	0.540
Probe Serial Number:	105	Probe battery check [dd/mm/yyyy]:	17-11-2005
Liquid Simulant:	Body	Max E-field [V/m in liquid]	6.34
Permittivity / Conductivity [S/m]	52.7 / 1.8	Location of max. X= [mm]	0.9
Liquid Temperature [C]	19.7	Location of max Y= [mm]	-25.53
Ambient Temperature [C]	20.5	Location of max Z= [mm]	-475.0
Relative Humidity [%]	41.0	SAR Drift: [dB]	0.1
Results:			
SAR 1g [W/kg]:			**0.105**
SAR 10g [W/kg]:			**0.061**





8.2 Hotspot identification[3]

By means of an overlay of the 2d scan and a EUT photograph the location and orientation of the hotspot is given.

Photo 6: A 2d scan overlay giving the field strength in the first scanned plane, overlaid on a bottom side view photo of the laptop. 2d scan is that of the worst case lapheld value in channel 6.

Note: It can be seen that 2 peaks exist. Both peaks were investigated with a zoom scan. (see section 8.1)

[3] The hotspot location is indicated with approximate values.

9 Description of test configuration.

9.1 SAR measurement system.

9.1.1 Robot System description.

The SAR measurement system used by TNO EPS is the IndexSAR SARA2 system, which consists of a Mitsubishi RV-2A six-axis robot-arm and controller, IndexSAR probe and amplifier and an appropriate phantom as required and considered appropriate for the applied test. The robot is used to move and manipulate the probe to programmed positions inside the phantom to obtain the SAR readings from the EUT.

The system is remote controlled by a PC, which contains the software to control the robot and data acquisition equipment. The software also displays the data obtained from test scans by calculating the measured values into corresponding SAR values based on the currently acceptable calculation methods.

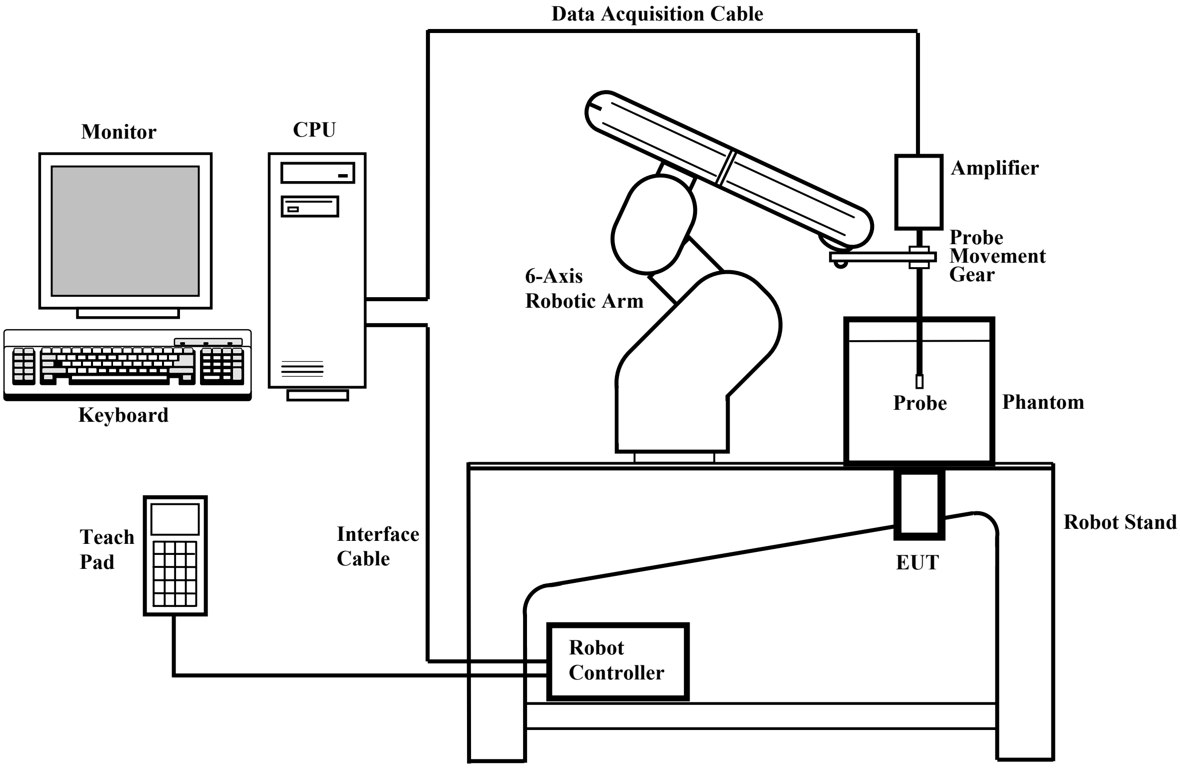


Figure 1: Overview of the SARA2 measurement system

The position and digitized shape of the phantom are made available to the software for accurate positioning of the probe and reduction of set-up time.

E.g. the SAM phantom heads are individually digitized using a Mitutoyo CMM machine to a precision of 0.001mm. The data is then converted into a shape format for the software, providing an accurate description of the phantom shell.

In operation, the system first does an area (2D) scan at a fixed depth within the liquid from the inside wall of the phantom. When the maximum SAR point has been found, the system will then carry out a 3D scan centered at that point to determine volume averaged SAR level.

9.1.2 Probe description.

The probes are constructed using three orthogonal dipole sensors arranged on an interlocking, triangular prism core. The probes have built-in shielding against static charges and are contained within a PEEK cylindrical enclosure material at the tip.

Probe calibration is described in section 10.1.

9.1.3 Amplifier description.

The amplifier unit has a multi-pole connector to connect to the probe and a multiplexer selects between the 3-channel single-ended inputs. A 16-bit AtoD converter with programmable gain is used along with an on-board micro-controller with non-volatile firmware. Battery life is around 150 hours and data are transferred to the PC via 3m of duplex optical fibre and a self-powered RS232 to optical converter.

9.1.4 Phantom description.

Body-worn operating configurations are tested using a flat phantom. The body phantom shell is made of a low-loss dielectric material with dielectric constant and loss tangent less than 5.0 and 0.05 respectively. The shell thickness for all regions coupled to the test device and its antenna are within 2.0 ± 0.2 mm. The phantom was filled with the required head or body equivalent tissue medium to a depth of 15.0 ± 0.5 cm.

For body mounted and frontal held push-to-talk devices, a flat phantom of dimensions 20x20x20cm with a base plate thickness of 2mm is used.

For Head mounted devices placed next to the ear, the phantom used in the evaluation of the RF exposure of the user of the wireless device is a IEEE P1528/CENELEC EN50361 compliant phantom, shaped like a human head and filled with a mixture simulating the dielectric characteristics of the brain.

The for SARA2 measurement system used Specific Anthropomorphic Mannequin (SAM) Upright Phantom is fabricated using moulds generated from the CAD files as specified by CENELEC EN50361. It is mounted via a rotation base to a supporting table, which also holds the robotic positioner. The phantom and robot alignment is assured by both mechanical and laser registration systems.

9.2 Measurement Procedure.

During the SAR measurement, the positioning of the probe is performed with sufficient accuracy to obtain repeatable measurements in the presence of rapid spatial attenuation phenomena. The accurate positioning of the E-field probe is accomplished by using the high precision robot. The robot can be taught to position the probe sensor following a specific pattern of points.

After an area scan has been done at a fixed distance of 8mm from the side of the phantom on the source side, a 3D scan is set up around the location of the maximum spot SAR. First, a point within the scan area is visited by the probe and a SAR reading taken at the start of testing. At the end of testing, the probe is returned to the same point and a second reading is taken. Comparison between these start and end readings enables the power (SAR) drift during measurement to be assessed.

9.2.1 SARA2 Interpolation and Extrapolation schemes.

SARA2 software contains support for both 2D cubic B-spline interpolation as well as 3D cubic B-spline interpolation. In addition, for extrapolation purposes, a general n^{-th} order polynomial fitting routine is implemented following a singular value decomposition algorithm presented in [4]. A 4^{th} order polynomial fit is used by default for data extrapolation, but a linear-logarithmic fitting function can be selected as an option. The polynomial fitting procedures have been tested by comparing the fitting coefficients generated by the SARA2 procedures with those obtained using the polynomial fit functions of Microsoft Excel when applied to the same test input data.

9.2.2 Interpolation of 2D area scan.

The 2D cubic B-spline interpolation is used after the initial area scan at fixed distance from the phantom shell wall. The initial scan data are collected with approx. 10mm spatial resolution and spline interpolation is used to find the location of the local maximum to within a 1mm resolution for positioning the subsequent 3D scanning.

9.2.3 Extrapolation of 3D scan.

For the 3D scan, data are collected on a spatially regular 3D grid having (by default) 6.4 mm steps in the lateral dimensions and 3.5 mm steps in the depth direction (away from the source). SARA2 enables full control over the selection of alternative step sizes in all directions. The digitized shape of the Flat Phantom is available to the SARA2 software, which decides which points in the 3D array are sufficiently well within the shell wall to be ‘visited’ by the SAR probe. After the data collection, the data are extrapolated in the depth direction to assign values to points in the 3D array closer to the shell wall. A notional extrapolation value is also assigned to the first point outside the shell wall so that subsequent interpolation schemes will be applicable right up to the shell wall boundary.

9.2.4 Interpolation of 3D scan and volume averaging.

The procedure used for defining the shape of the volumes used for SAR averaging in the SARA2 software follow the method of adapting the surface of the ‘cube’ to conform with the surface of the phantom (see Appendix C.2.2.1 in EN 50361). This is called, here, the conformal scheme.

For each row of data in the depth direction, the data are extrapolated and interpolated to less than 1mm spacing and average values are calculated from the phantom surface for the row of data over distances corresponding to the requisite depth for 10g and 1g cubes. This results in two 2D arrays of data, which are then cubic B-spline interpolated to sub mm lateral resolution. A search routine then moves an averaging square around through the 2D array and records the maximum value of the corresponding 1g and 10g volume averages. For the definition of the surface in this procedure, the digitized position of the headshell surface is used for measurement in head-shaped phantoms. For measurements in rectangular, box phantoms, the distance between the phantom wall and the closest set of gridded data points is entered into the software.

For measurements in box-shaped phantoms, this distance is under the control of the user. The effective distance must be greater than 2.5mm as this is the tip-sensor distance and to avoid interface proximity effects, it should be at least 5mm. A value of 6 or 8mm is recommended. This distance is called **dbe** in EN 50361.

For automated measurements inside the head, the distance cannot be less than 2.5mm, which is the radius of the probe tip and to avoid interface proximity effects, a minimum clearance distance of x mm is retained. The actual value of dbe will vary from point to point depending upon how the spatially-regular 3D grid points fit within the shell. The greatest separation is when a grid point is just not visited due to the probe tip dimensions. In this case the distance could be as large as the step-size plus the minimum clearance distance (i.e with x=5 and a step size of 3.5, **dbe** will be between 3.5 and 8.5mm).

The default step size (**dstep** in EN 50361) used is 3.5mm, but this is under user-control. The compromise is with time of scan, so it is not practical to make it much smaller or scan times become long and power-drop influences become larger.

The robot positioning system specification for the repeatability of the positioning (**dss** in EN50361) is +/- 0.04mm.

The Specific Anthropomorphic Mannequin (SAM) Upright Phantom shell is made by an industrial moulding process from the CAD files of the SAM shape, with both internal and external moulds. For the upright phantoms, the external shape is subsequently digitized on a Mitutoyo CMM machine (Euro C574) to a precision of 0.001mm. Wall thickness measurements made non-destructively with an ultrasonic sensor indicate that the shell thickness (**dph**) away from the ear is 2.0 +/- 0.1mm. The ultrasonic measurements were calibrated using additional mechanical measurements on available cut surfaces of the phantom shells.

The flat phantom is made from Polymethylmethacrylate (PMMA), a low-loss dielectric material with dielectric constant and loss tangent less than 5.0 and 0.05 respectively. The shell thickness for all regions coupled to the test device and its antenna are within 2.0 ± 0.2 mm.

For the upright phantom, the alignment is based upon registration of the rotation axis of the phantom on its 253mm-diameter baseplate bearing and the position of the probe axis when commanded to go to the axial position. A laser alignment tool is provided (procedure detailed elsewhere). This enables the registration of the phantom tip (**dmis**) to be assured to within approx. 0.2mm. This alignment is done with reference to the actual probe tip after installation and probe alignment. The rotational positioning of the phantom is variable – offering advantages for special studies, but locating pins ensure accurate repositioning at the principal positions (LH and RH ears).

10 Additional information supplementary to the test report.

10.1 Probe information.

To this report the probe test report and calibration document of the probe used are added. In the electronic version of this report, the pages are inserted after the last page of this report.

10.2 SAR system check.

The purpose of the SAR System check is to verify that the system operates within its specifications at the device test frequency. The SAR system check is a simple check of repeatability to make sure that the system works correctly at the time of the compliance test. It is not a verification of the system with respect to external standards. The SAR system check should detect possible short term drift and errors in the system.

The SAR system check is a complete 1 g or 10 g averaged SAR measurement in a simplified test system with a standard source. The instrumentation and procedures are the same as those used for the compliance tests. The SAR system check has been performed using the specified tissue-equivalent liquid and at a chosen fixed frequency that is within ± 10% of the compliance test mid-band frequency. The system check is performed prior to compliance tests and the result have been checked against the requirements (IEEE1528 and CENELEC Standards) and must always be within ±10% of the target value corresponding to the test frequency, liquid and the source used mentioned in these standards.

The following measurement setup has been used for performing SAR system checks using a box phantoms is based on the procedures fully described in IEEE1528. This SAR System Check is performed at the start of each measurement at a specific frequency range , with appropriate simulant liquids.

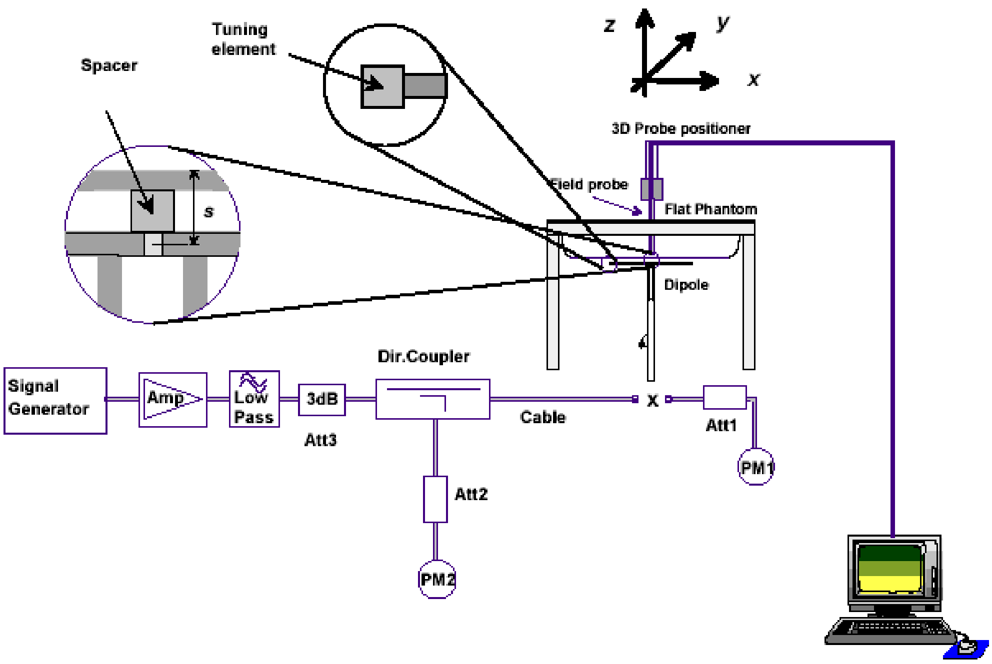


Fig. 10.2.1

With the Signal Generator, Amplifier and directional coupler in place, the source signal has been set up at the relevant frequency and a power meter has been used to measure the power at the end of the SMA cable which is going to be connected to the balanced dipole. The low noise and distortion Signal Generator is adjusted so, that including all cable losses and other losses, the power at the connector X (to be connected to the balanced dipole) is 0.25W (24 dBm) (Reading on PM1 in figure 10.2.1).A calibrated attenuator (Att 1. 20 dB) is used to protect overloading of the Power meter.

No tuning of the balanced dipole was required because fixed tuned and calibrated balanced dipoles for the appropriate test frequencies were used.

10.3 5.8 GHz system check.

For 5.8 GHz validation, a waveguide method as proposed by Li, Ghandi and Kang, ‘An open ended waveguide system validation and/or probe calibration for frequencies above 3 GHz, submitted to the IEEE transactions on Microwave Theory and Techniques, June 2003.
The description of this method is taken from ‘SARA2 system validation at 5.2 and 5.8 GHz, MI Manning, Indexsar Ltd., 17 October 2003.

SARA2 SYSTEM VALIDATION AT 5.2 AND 5.8GHz

MI Manning, Indexsar Ltd.
17th October 2003.

10.3.1 Introduction.

Whilst international standards recommend techniques for performing system validations of SAR test systems for frequencies between 300MHz and 3GHz, proposals for validation testing at higher frequencies are only at an early-draft stage of discussion.

However, 5 GHz devices are on the market and need to be tested now. IEC62209 has circulated two drafts of proposed procedures for 5-6GHz SAR testing (Annex X), but the procedures are, as yet, ill-defined. The Annex X validation defines a small dipole as a source. Dimensions were incompletely specified in the first draft and are only more fully-defined in the second draft. No recommended separation distance for the dipole beneath the phantom is given in either draft to correspond with the computed reference values suggested.

Indexsar built some dipoles based on the first draft dimensions, but has found that use of these dipoles at the expected 10mm spacing from the liquid do not give results that match the reference values. 5.8GHz validation results for max. 1g SAR with our prototype dipoles were 30% low at a spacing of 10mm and 50% high at a spacing of 7.5mm.

Since then, two useful contributions on 5 GHz validation testing have been circulated. A paper by Li, Gandhi and Kang [1] observes that “It is very difficult to develop half-wave dipole antennas for use in the 5.1 to 5.8 GHz band . . . .”. They propose an alternative procedure using an open-ended waveguide placed close to the bottom of the phantom. They propose that the open end of a WR187 waveguide is placed 10mm from the phantom liquid and they present FDTD computation results for use as reference values.

This particular waveguide has different internal dimensions to one recommended for probe calibration purposes in Annex X (WG13), which is unfortunate as otherwise the same waveguide could be recommended for both purposes.

The Utah paper [1] used liquids with the following properties for validations at 5.25 and 5.8 GHz:

Frequency (GHz)	Relative permittivity	Conductivity (S/m)
5.25	48.8	6.82
5.8	46.9	7.83

These property values are not very close to those recommended for compliance evaluations in Annex X, which are:

Frequency (GHz)	Relative permittivity	Conductivity (S/m)
5.25	36.0	4.7
5.8	35.3	5.3

In a separate paper [2], Utah authors argue that results of 1g SAR measurements are not very sensitive to liquid properties at 5-6GHz and use this contention to justify the use of liquids with different properties.

Another paper recently circulated from Motorola personnel makes recommendations for SAR zoom scan measurement grids at 5-6GHz [3]. The authors conclude that noise due to low measured values will compromise 10g volume average calculations and they recommend a restricted size zoom volume for 1g SAR determinations. They also conclude that 4th order polynomial extrapolations are not the best for these frequencies and suggest 3rd order polynomials or fitting to the logarithm of the SAR data.

10.3.2 Validation results using WR187 waveguide.

It would seem that an open-ended waveguide has some advantages in use as a source and we have performed validations based on the recommendations in [1]. The scanning parameters were set as per the recommendations in [3] and 3rd-order polynomial extrapolations were used instead of 4th order. The liquids have rather different property values to those employed in [1], but [2] suggests that this may not affect the max. 1g SAR results by much.

Using these conditions and with use of a WR187 waveguide, validation testing with the following liquid properties resulted in 1g SAR measurements close to the reference values given in [1]. The results are summarized below:

Frequency (GHz)	Relative permittivity	Conductivity (S/m)
5.2	37.12	5.01
5.8	35.41	5.79

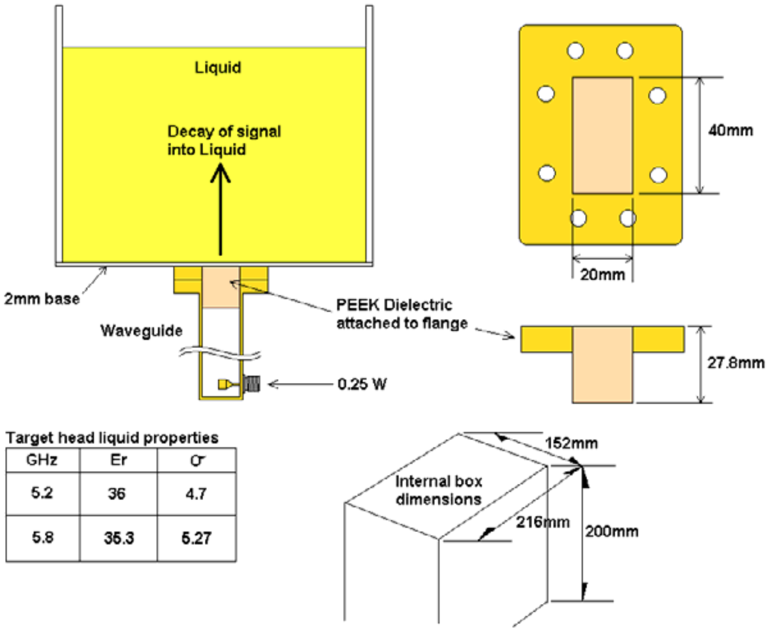
Frequency (GHz)	Reference 1g SAR value (W/kg) from [1] normalized to 1W	Measured 1g SAR value (W/kg) / error (%)
5.25	35.80	34.82 (-3%)
5.8	39.46	43.08 (+9%)

Based on the testing performed, it is recommended that SARA2 systems are validated using the open-ended WR187 waveguide technique until improved procedures become available or specific methods become adopted in the relevant standards.

10.3.3 An alternative open-ended waveguide geometry.

It is not clear why [1] recommends a spacing of 10mm from the liquid from a waveguide, when contact with the phantom would seem to be more appropriate and offer more accurate positioning. Also, a matching window with permittivity similar to that of the phantom wall material could minimize reflective losses. Lastly, a waveguide of the same dimensions as that recommended for probe calibration would be a useful reduction in the required equipment budget.

For these reasons, we are commissioning FDTD computations of reference values expected with a WG13 waveguide with a matching window as per Annex X in contact with a 2mm wall phantom filled with a liquid with the properties proposed in Annex X. In this way, we hope to have an optimized validation solution for 5-6GHz testing.



GHz	Er	σ
5.2	36	4.7
5.8	35.3	5.27

Figure 1: Proposed validation configuration with waveguide in contact with phantom for which reference values will be calculated

References

[1] Q Li, OP Gandhi, G Kang, 'An open-ended waveguide system validation and/or probe calibration for frequencies above 3GHz', submitted to IEEE Transactions on Microwave Theory and Techniques, June 2003.

[2] G Kang & OP Gandhi, 'Effect of dielectric properties on the peak 1- and 10g SAR for 802.11 a/b/g frequencies of 2.45 and 5.15 to 5.85 GHz', to be published in IEEE Transactions on Electromagnetic Compatibility.

[3] Recommendations for SAR zoom scan measurement grids at 5-6GHz.

10.4 Dielectric property measurement of tissue-simulant liquids for SAR testing.

10.4.1 Introduction.

This section describes the measurement of the dielectric properties of tissue-equivalent material as part of the SAR characterization procedure and the method used.

The measurement method is based on a published technique *(Toropainen et al , 'Method for accurate measurement of complex permittivity of tissue equivalent liquids', Electronics Letters 36 (1) 2000 pp32-34)* and uses a fixture with 2 parallel planes with a conductor in between. Liquid filling the space between the planes immerses the inner conductor wholly. Measurements of S_{21} with an empty fixture and that of a filled fixture are conducted so that the complex dielectric properties of the fluid can be deduced. The fixture is also referred to as *TEM line.*

10.4.2 TEM-cell construction.

The TEM cell construction is shown in Figure 10.3.1 and consists of a central cylindrical transmission line sandwiched between two ground planes

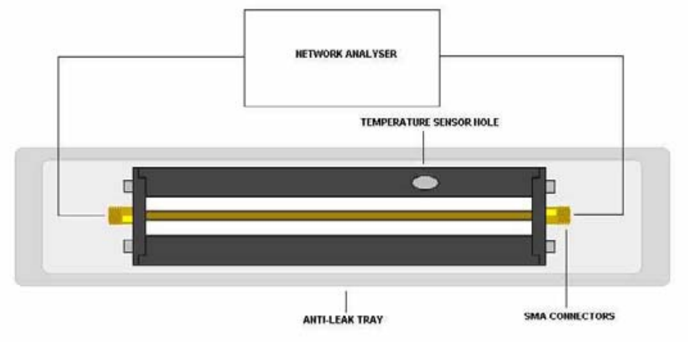


Figure 10.3.1. TEM Cell Construction.

Four different sensors can be used with transmission line lengths of 30mm, 60mm, 80mm and 160mm. The transmission line is terminated with SMA connectors at either end using short 50 ohm launcher sections. The assembly is held firmly against a plastic base with a clamping arrangement providing a seal to retain the liquid. The liquid under test is introduced with a pipette to fill the space between the ground planes. Care has been taken to prevent air bubbles and this is particularly important with viscous liquids. A hole is provided in one of the ground planes so that a thermometer probe has been be inserted to monitor the temperature. The cell is washed out and thoroughly dried before further use.

A vector network analyser (VNA) is used to measure the performance of the cell. A good impedance match will be found when air filled indicating that the transmission line impedance is close to 50 ohm. The transmission loss and phase are measured with and without the liquid to enable the electrical properties to be deduced.

10.4.3 Calculation of dielectric properties from VNA measurements.

The complex permittivity of the simulant liquids were measured using a TEM line sensor as recommended in the EN50361 and draft IEEE1528 standards. The method [1] is based on the measurement of complex transmission coefficient of a TEM-line filled with the liquid. Transmission measurement is done using a VNA, recording the magnitude and phase of scattering coefficient S_{21}. The complex permittivity of the liquid is calculated from the magnitude and phase of S_{21} by numerical solution of the equation of transmission coefficient derived by signal flow graph technique

$$S_{21} = \frac{\left(1-\Gamma^2\right)\exp\left(-\mathrm{j}(k-k_0)d\right)}{1-\Gamma^2\exp\left(-\mathrm{j}2kd\right)},$$

$$\Gamma = \frac{1-\sqrt{\varepsilon_r}}{1+\sqrt{\varepsilon_r}},$$

$$k = \frac{2\pi f}{c_0}\sqrt{\varepsilon_r},$$

where Γ is the reflection coefficient at liquid surfaces, k the propagation factor in the liquid, k_0 the vacuum propagation factor, d the length of the sample, f the frequency and $\varepsilon_r = \varepsilon_r' - \mathrm{j}\varepsilon_r''$ the relative complex permittivity of the sample.

10.5 Measurement uncertainty.

10.5.1 Introduction.

A measurement uncertainty assessment has been undertaken following guidance given in EN50361 and IEEE1528. IndexSAR Ltd has supplied a generic uncertainty analysis for the SARA2 system in the form of a spreadsheet and the supporting assessments are documented in an IndexSAR document IXS-2028. Additionally, uncertainties resulting from the probe positioning system and the upright phantom geometry are discussed in additional documents.

Some of the uncertainty contributions are site-specific and, for these, TNO Electronic Products & Services (EPS) has assessed the uncertainty contributions arising from local environmental and procedural factors.

The resultant uncertainty budget is shown on the next pages.

10.5.2 Uncertainty calculated for IEEE1528 : standard measurements (2450 MHz).

a	*b*	*c*	*d*	*e= f(d,k)*	*f*	*g*	*h= cxg/e*	*i= cxg/e*	*k*
Uncertainty Component	Section	Tol. (± %)	Prob. Dist.	Div.	ci (1-g)	ci (10-g)	1-g ui (±%)	10-g ui (±%)	vt
Measurement System									
Probe Calibration	E2.1	10.0	N	1or k	1	1	5.0	5.0	∞
Axial Isotropy	E2.2	5.93	R	√3	0.7	0.7	2.4	2.4	∞
Hemispherical Isotropy	E2.2	10.92	R	√3	1	1	6.3	6.3	∞
Boundary Effect	E2.3	4.0	R	√3	1	1	2.3	2.3	∞
Linearity	E2.4	0.93	R	√3	1	1	0.5	0.5	∞
System Detection Limits	E2.5	1.0	R	√3	1	1	0.6	0.6	∞
Readout Electronics	E2.6	1.0	N	1or k	1	1	1.0	1.0	∞
Response Time	E2.7	0.0	R	√3	1	1	0.0	0.0	∞
Integration Time	E2.8	1.8	R	√3	1	1	1.0	1.0	∞
RF Ambient Conditions	E6.1	3.0	R	√3	1	1	1.7	1.7	∞
Probe Positioner Mechanical Tolerance	E6.2	0.6	R	√3	1	1	0.3	0.3	∞
Probe Positioning wrt Phantom Shell	E6.3	5.0	R	√3	1	1	2.9	2.9	∞
SAR Evaluation Algoritms	E5.2	8.0	R	√3	1	1	4.6	4.6	∞
Test sample Related									∞
Test Sample Positioning	E4.2	5.0	R	√3	1	1	2.9	2.9	∞
Device Holder Uncertainty	E4.1	3	R	√3	1	1	1.7	1.7	∞
Output Power Variation	6.6.2	5.0	R	√3	1	1	2.9	2.9	∞
Phantom and Tissue Parameters									∞
Phantom Uncertainty (shape and thickness)	E3.1	4.0	R	√3	1	1	2.3	2.3	∞
Liquid Conductivity Target - tolerance	E3.2	1.0	R	√3	0.7	0.5	0.4	0.3	∞
Liquid Conductivity - measurement uncert.	E3.3	4.7	R	√3	0.7	0.5	1.9	1.4	∞
Liquid Permittivity Target tolerance	E3.2	4.4	R	√3	0.6	0.5	1.5	1.3	∞
Liquid Permittivity - measurement uncert.	E3.3	3.3	R	√3	0.6	0.5	1.1	1.0	∞
Combined Standard Uncertainty		$u_c = \sqrt{\sum_{i=1}^{m} c_i^2 \cdot u_i^2}$					11.7	11.6	
Expanded Uncertainty (95% confidence interval)		Normal k=1.96 **ue=k* u_c**					**22.9%**	**22.7%**	

10.5.3 Uncertainty calculated for IEEE1528 : standard measurements (5800 MHz).

a	*b*	*c*	*d*	*e= f(d,k)*	*f*	*g*	*h= cxg/e*	*i= cxg/e*	*k*
Uncertainty Component	Section	Tol. (± %)	Prob. Dist.	Div.	ci (1-g)	ci (10-g)	1-g ui (±%)	10-g ui (±%)	vt
Measurement System									
Probe Calibration	E2.1	12.0	N	1or k	1	1	6.0	6.0	∞
Axial Isotropy	E2.2	5.93	R	√3	0.7	0.7	2.4	2.4	∞
Hemispherical Isotropy	E2.2	10.92	R	√3	1	1	6.3	6.3	∞
Boundary Effect	E2.3	4.0	R	√3	1	1	2.3	2.3	∞
Linearity	E2.4	0.93	R	√3	1	1	0.5	0.5	∞
System Detection Limits	E2.5	1.0	R	√3	1	1	0.6	0.6	∞
Readout Electronics	E2.6	1.0	N	1or k	1	1	1.0	1.0	∞
Response Time	E2.7	0.0	R	√3	1	1	0.0	0.0	∞
Integration Time	E2.8	1.8	R	√3	1	1	1.0	1.0	∞
RF Ambient Conditions	E6.1	3.0	R	√3	1	1	1.7	1.7	∞
Probe Positioner Mechanical Tolerance	E6.2	0.6	R	√3	1	1	0.3	0.3	∞
Probe Positioning wrt Phantom Shell	E6.3	5.0	R	√3	1	1	2.9	2.9	∞
SAR Evaluation Algoritms	E5.2	8.0	R	√3	1	1	4.6	4.6	∞
Test sample Related									∞
Test Sample Positioning	E4.2	10.0	R	√3	1	1	5.8	5.8	∞
Device Holder Uncertainty	E4.1	5.0	R	√3	1	1	2.9	2.9	∞
Output Power Variation	6.6.2	5.0	R	√3	1	1	2.9	2.9	∞
Phantom and Tissue Parameters									∞
Phantom Uncertainty (shape and thickness)	E3.1	4.0	R	√3	1	1	2.3	2. 3	∞
Liquid Conductivity Target - tolerance	E3.2	7.5	R	√3	0.7	0.5	3.0	2.2	∞
Liquid Conductivity - measurement uncert.	E3.3	5.0	R	√3	0.7	0.5	2.0	1.4	∞
Liquid Permittivity Target tolerance	E3.2	1.0	R	√3	0.7	0.5	0.4	0.3	∞
Liquid Permittivity - measurement uncert.	E3.3	3.3	R	√3	0.7	0.5	1.3	1.0	∞
Combined Standard Uncertainty		$u_c = \sqrt{\sum_{i=1}^{m} c_i^2 \cdot u_i^2}$					13.5	13.3	
Expanded Uncertainty (95% confidence interval)	Normal k=1.96 **ue=k* u_c**						**26.5%**	**26.1%**	

10.5.4 Uncertainty calculated for IEEE1528 : System performance check (2450 MHz).

a	*b*	*c*	*d*	*e= f(d,k)*	*f*	*g*	*h= cxg/e*	*i= cxg/e*	*k*
Uncertainty Component	Section	Tol. (± %)	Prob. Dist.	Div.	ci (1-g)	ci (10-g)	1-g ui (±%)	10-g ui (±%)	vt
Measurement System									
Probe Calibration	E2.1	10.0	N	1or k	1	1	5.0	5.0	∞
Axial Isotropy	E2.2	5.93	R	√3	0.7	0.7	2.4	2.4	∞
Hemispherical Isotropy	E2.2	10.92	R	√3	1	1	6.3	6.3	∞
Boundary Effect	E2.3	4.0	R	√3	1	1	2.3	2.3	∞
Linearity	E2.4	0.93	R	√3	1	1	0.5	0.5	∞
System Detection Limits	E2.5	1.0	R	√3	1	1	0.6	0.6	∞
Readout Electronics	E2.6	1.0	N	1or k	1	1	1.0	1.0	∞
Response Time	E2.7	0.0	R	√3	1	1	0.0	0.0	∞
Integration Time	E2.8	1.8	R	√3	1	1	1.0	1.0	∞
RF Ambient Conditions	E6.1	3.0	R	√3	1	1	1.7	1.7	∞
Probe Positioner Mechanical Tolerance	E6.2	0.6	R	√3	1	1	0.3	0.3	∞
Probe Positioning wrt Phantom Shell	E6.3	5.0	R	√3	1	1	2.9	2.9	∞
SAR Evaluation Algoritms	E5.2	8.0	R	√3	1	1	4.6	4.6	∞
Dipole Related									∞
Dipole axis to liquid distance	8, E4.2	1.0	R	√3	1	1	0.6	0.6	∞
Input Power & SAR Drift measurments	8, 6.6.2	1.5	R	√3	1	1	0.9	0.9	∞
Phantom and Tissue Parameters									∞
Phantom Uncertainty (shape and thickness)	E3.1	4.0	R	√3	1	1	2.7	2. 7	∞
Liquid Conductivity Target - tolerance	E3.2	1.0	R	√3	0.7	0.5	0.4	0.3	∞
Liquid Conductivity - measurement uncert.	E3.3	4.7	R	√3	0.7	0.5	1.9	1.4	∞
Liquid Permittivity Target tolerance	E3.2	4.4	R	√3	0.6	0.5	1.5	1.3	∞
Liquid Permittivity - measurement uncert.	E3.3	3.3	R	√3	0.6	0.5	1.1	1.0	∞
Combined Standard Uncertainty		$u_c = \sqrt{\sum_{i=1}^{m} c_i^2 \cdot u_i^2}$					10.9	10.8	
Expanded Uncertainty (95% confidence interval)		Normal k=1.96 **ue=k* u_c**					**21.3%**	**21.1%**	

10.5.5 Uncertainty calculated for IEEE1528 : System performance check (5800 MHz).

a	*b*	*c*	*d*	*e= f(d,k)*	*f*	*g*	*h= cxg/e*	*i= cxg/e*	*k*
Uncertainty Component	Section	Tol. (± %)	Prob. Dist.	Div.	ci (1-g)	ci (10-g)	1-g ui (±%)	10-g ui (±%)	vt
Measurement System									
Probe Calibration	E2.1	12.0	N	1or k	1	6.0	6.0	6.0	∞
Axial Isotropy	E2.2	5.93	R	√3	0.7	2.4	2.4	2.4	∞
Hemispherical Isotropy	E2.2	10.92	R	√3	1	6.3	6.3	6.3	∞
Boundary Effect	E2.3	4.0	R	√3	1	2.3	2.3	2.3	∞
Linearity	E2.4	0.93	R	√3	1	0.5	0.5	0.5	∞
System Detection Limits	E2.5	1.0	R	√3	1	0.6	0.6	0.6	∞
Readout Electronics	E2.6	1.0	N	1or k	1	1.0	1.0	1.0	∞
Response Time	E2.7	0.0	R	√3	1	0.0	0.0	0.0	∞
Integration Time	E2.8	1.8	R	√3	1	1.0	1.0	1.0	∞
RF Ambient Conditions	E6.1	3.0	R	√3	1	1.7	1.7	1.7	∞
Probe Positioner Mechanical Tolerance	E6.2	0.6	R	√3	1	0.3	0.3	0.3	∞
Probe Positioning wrt Phantom Shell	E6.3	5.0	R	√3	1	2.9	2.9	2.9	∞
SAR Evaluation Algorithms	E5.2	8.0	R	√3	1	4.6	4.6	4.6	∞
Dipole Related									∞
Dipole axis to liquid distance	8, E4.2	1.0	R	√3	1	1	7.5	7.5	∞
Input Power & SAR Drift measurements	8, 6.6.2	2.0	R	√3	1	1	2.89	2.89	∞
Phantom and Tissue Parameters									∞
Phantom Uncertainty (shape and thickness)	E2.1	4.0	R	√3	1	1	2.3	2. 3	∞
Liquid Conductivity Target - tolerance	E2.2	7.5	R	√3	0.7	0.5	3.0	2.2	∞
Liquid Conductivity - measurement uncert.	E2.2	5.0	R	√3	0.7	0.5	2.0	1.4	∞
Liquid Permittivity Target tolerance	E2.2	1.0	R	√3	0.7	0.5	0.4	0.3	5
Liquid Permittivity - measurement uncert.	E2.2	3.3	R	√3	0.7	0.5	1.3	1.0	∞
Combined Standard Uncertainty		$u_c = \sqrt{\sum_{i=1}^{m} c_i^2 \cdot u_i^2}$					11.0	10.9	
Expanded Uncertainty (95% confidence interval)		Normal k=1.96 **ue=k* u_c**					**21.5%**	**21.3%**	

11 List of utilized test equipment.

Inventory number	Description	Brand	Model
03012	Network Analyzer (VNA)	Rohde & Schwarz	ZVC
03013	VNA Calibration Kit	Rohde & Schwarz	
12483	Guidehorn	EMCO	3115
12484	Guidehorn	EMCO	3115
12488	Guidehorn 18 - 26.5 GHz	EMCO	RA42-K-F-4B-C
12533	Signalgenerator	MARCONI	2032
12559	Digital storage oscilloscope	Le Croy	9310M
12561	DC Power Supply 20A/70V	DELTA	SM7020D
12605	calibrated dipole 28MHz-1GHz	Emco	3121c
12608	HF milliwattmeter	Hewlett Packard	HP435a
12609	Power sensor 10MHz-18GHz	Hewlett Packard	HP8481A
3664	Spectrum analyzer	HP	HP8593E
13078	Preamplifier 0.1 GHz - 12 GHz	Miteq	AMF-3D-001120-35-4p
13526	Signalgenerator 20 GHz	Hewlett & Packard	83620A
13594	Preamplifier 10 GHz - 25 GHz	Miteq	AMF-6D-100250-10p
14450	2.4 GHz bandrejectfilter	BSC	XN-1783
99068	Detector N-F/BNC-F	Radiall	R451576000
99076	Bandpassfilter 4 - 10 GHz	Reactel	7AS-7G-6G-511
99112	Tripod	Chase	--
99136	Bandpassfilter 10 - 26.5 GHz	Reactel	9HS-10G/26.5G-S11
03011	RF Amplifier (1 Watt)	IndexSAR	
03010	Bench-top Robot	Mitsubishi	RV-E2
03009	Calibration dipole 2450	IndexSAR	IXD 0022
03008	Calibration dipole 5800	IndexSAR	
03007	Directional Coupler	Hewlett & Packard	779D
03006	Attenuator (3 dB)	Hewlett & Packard	
03005	Hygrometer/room temperature meter		
03004	SAR Probe	IndexSAR	S/N 0131
03003	Phantom box	IndexSAR	N.A.
03002	TEM line liquid measurement	IndexSAR	N.A.
03012	Waveguide W-137	IndexSAR	N.A.
03013	Calibrated mercury thermometers	NMI	15-30 C

12 Test software.

During the tests as indicated in this test report the TNO EPS SARA2 system was operated with:

SARA2 system v2.3VPM
Mitsubishi robot controller firmware revision RV-E2 Version C9a
IXA-10 Probe amplifier Version 2.4
DiLine Dielectric Kit Software v 0.109 (12/6/2003)