TEST REPORT

In support of the Application for Grant of Equipment Authorisation of the SEMS Base Unit

FCC ID: PW9R8060 September 2002

TÜV PRODUCT SERVICE

BABT

TUV Product Service Ltd. Segensworth Road, Titchfield
Fareham, Hampshire, United Kingdom, PO15 5RH
Tel: +44(0)1329 443300, Fax: +44(0)1329 443331
www.tuvps.co.uk

REPORT ON:	Specific Absorption Rate Testing of the SEMS Base Unit. Report No: WS608900A
FCC ID:	PW9R8060
PREPARED FOR:	E2V Technologies 106 Waterhouse Lane Chelmsford Essex CM1 2QU United Kingdom
ATTESTATION:	The wireless portable devices described within this report have been shown to be capable of compliance for localised specific absorption rate (SAR) for Occupational/Controlled Exposure Limits as defined in Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01) of 8.0W/kg. The devices were tested in accordance with the measurement procedures specified in Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01) and IEEE1528-200x (Draft April 2002). I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements. A. Miller **SAR Test Engineer**
APPROVED BY:	M Jenkins **Wireless Group Leader**
DATED:	23rd September 2002

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Note: The test results reported herein relate only to the item tested as identified above and on the Status Page.

UKAS TESTING 0141 Group

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EXECUTIVE SUMMARY

Specific Absorption Rate Testing of the
SEMS Base Unit.

PROJECT MANAGER : M. OSBORNE

1.1 STATUS

MANUFACTURING DESCRIPTION	SEMS Base Unit
STATUS OF TEST	Specific Absorption Rate Testing
APPLICANT	E2V Technologies
CLASS	Licensed Radio Service Equipment, General Mobile Radio Services (except cellular)
MANUFACTURER	E2V Technologies
TYPE OR MODEL NUMBER	R0860
HARDWARE VERSION	Drawing Identity: DAS 548060AA
SOFTWARE VERSION	BU02527_V100_CT_TST
SERIAL NUMBER	B2

TEST SPECIFICATIONS:

Federal Communications Commission, Code of Federal Regulations, Title 47 (CFR47), Vol. 1, Chapter 1, Part 2 (§2.1091 and §2.1093).

Federal Communications Commission (FCC) OET Bulletin 65c, Edition 01-01, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields - Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions

REFERENCES:

IEEE 1528 –200X: DRAFT Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques

BABT REGISTRATION NUMBER:	WS608900.
RECEIPT OF TEST SAMPLES:	14^{th} June 2002.
START OF TEST:	10^{th} August 2002.
FINISH OF TEST:	11^{th} August 2002.

1.2 SUMMARY

The SEMS Base Unit is a wireless device, operating in the frequency range of 453.0375MHz to 465.6375MHz and was supplied for Specific Absorption Rate (SAR) testing to the requirements of Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01). They were found to be compliant with requirements for Occupational/Controlled Exposure for Mobile/Portable devices. The Partial-Body SAR limit of 1g volume averaged SAR is stated as 8.0W/kg.

SAR testing was performed using a Flat Phantom dimensions 300mmx300mmx200mm and 5.7mm thickness. The phantom was filled to a depth of 170mm with 450MHz Body simulant liquid. The dielectric properties were in accordance with the requirements for the dielectric properties specified in Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01).

SAR testing was performed with the device affixed to the base of the unit, with the rear of the device facing toward the flat phantom. Testing was performed with the device being set to transmit at the top, middle and the bottom frequencies. Transmission at maximum power was enabled via the REDS 2 Service centre software provided by the client. The transmission mode selected was "Transmit Pre-amble". In this mode the carrier was frequency modulated with a 1.2 kHz tone that deviated the carrier nominally 1.5 kHz peak. This transmission mode was declared as being frequency modulated, and that the total transmitted power is the same as an un-modulated carrier transmission.

A coarse scan of the whole device was performed to obtain the position giving maximum SAR. The scan parameters were redefined to perform a 3D scan to enable a volume averaged SAR reading to be obtained.

The SEMS Base Unit had a stub antenna, so that the requirement for testing with antenna extended and retracted was not applicable. The SEMS Base Unit was only tested with the rear of the device against the flat phantom, as this was stated to be the simulated worst case normal mode of operation.

No accessories were supplied with SEMS Base Unit.
Note: for Body worn operation, the SEMS Base Unit has been tested and meet FCC RF exposure guidelines when used with an accessory which contains no metal and that the positions these device’s a minimum of 1.5mm from the body. Use of other accessories may not ensure compliance with FCC RF guidelines.

Included in this report are descriptions of the test method; the equipment used and an analysis of the test uncertainties applicable and diagrams indicating the locations of maximum SAR for each test position along with photographs indicating the positioning of the device’s against the Flat Phantom.

SEMS Base Unit
The testing was performed with an external power source supplying 24.0 V dc to the Base Unit, The battery source supplied did not last the scan time for the test transmission mode used for SAR assessment.

TEST DETAILS

Specific Absorption Rate Testing of the
SEMS Base Unit.

TEST ENGINEERS: **A. MILLER**

2.1 TEST EQUIPMENT

The following test equipment was used at BABT:

INSTRUMENT DESCRIPTION	MANUFACTURER	MODEL TYPE	INVENTORY NO.	SERIAL NUMBER	CALIBRATION DATES
Bench-top Robot	Mitsubishi	RV-E2	4691	EA009006	N/A
Flat Phantom 300x300x200mm	BABT	450MHz	N/A	N/A	N/A
450 MHz Body Tissue Simulant	BABT	Batch 1	N/A	N/A	05/08/02*
450 MHz Dipole	IndexSAR	IEEE1528	N/A	N/A	N/A
RF Pre-Amplifier	Vectawave	10M-2.5G	4697	N/A	N/A
Bi-Directional Coupler	Narda	3020A	EMC209	02126	31/08/02 (due)
20dB Attenuator	Weinschel	46-20-34	4653	AT9195	23/08/02 (due)
Power Meter	Rohde and Schwarz	NRV	2472	860327/025	03/05/02 (due)
Power Sensor	Leistungsmesskopf	NRV-Z1	4617	N/A	21/05/03
Power Sensor	Leistungsmesskopf	NRV-Z1	4616	N/A	21/05/03
Hygrometer	Rotronic	A1	4167	N/A	16/04/02 (due)
Thermometer	Fluke	51 K/J	4221	73860001	09/12/02 (due)
SAR Probe	IndexSAR	65	N/A	65	24/01/03 (due)
DVM	Fluke	70	4159	N/A	04/01/03 (due)

* Verified at time of test.

2.2 TEST SOFTWARE

The following software was used to control the BABT SARA2 System:

INSTRUMENT	VERSION NO.	DATE
SARA2 system	v.0.281	23/07/2002
Mitsubishi robot controller firmware revision	RV-E2 Version C9a	-
IXA-10 Probe amplifier	Version 2.4	-

2.3 DIELECTRIC PROPERTIES OF SIMULANT LIQUIDS

The dielectric properties of the tissue simulant liquids used for the SAR testing at BABT are as follows:-

PARAMETER	450 MHz BODY FLUID (ACTUAL)	450 MHz BODY FLUID (REQUIRED)
Relative Permittivity, ε_r (ε')	58.851	58
Conductivity, σ	0.813 S/m	0.83 S/m
Mass Density, ρ	1000 kg/m^3	1000 kg/m^3

This fluid was calibrated and re-checked prior to any measurements being made against reference fluids stated in IEEE 1528-200X of 0.9% NaCl (Salt Solution) at 20ºC and also for Dimethylsulphoxide (DMS) at 20ºC.

The fluids were made at BABT under controlled conditions to the following Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01) formula:

450 MHZ SOLUTION
51.16% Water
1.49% Salt
46.78% Sugar
0.52% HEC
0.05% Bactericide

2.4 TEST CONDITIONS

Ambient Temperature: Within +15°C to +35°C at 20% RH to 75% RH.
The actual Temperature during the testing ranged from 19.6°C to 22.3°C.
The actual Humidity during the testing ranged from 43.5% to 51.8% RH.

Tissue simulating liquid temperature: +20°C to +23°C.
The actual tissue simulating liquid temperature was recorded to be between 20.0°C to 21.5°C

Drift in Mobile power during scans. The mobile power levels were monitored before and after each full 3D scan. The before and after power levels recorded were within +/-1dB of each other for all of the testing.

2.5 MEASUREMENT UNCERTAINTY

ERROR SOURCES	EN 50361 Description (Subclause)	Uncertainty (%)	Probability Distribution	Divisor	ci	Standard Uncertainty (%)
Measurement Equipment						
Calibration	7.2.1.1	10	Normal	2	1	5.00
Isotropy	7.2.1.2	10.9	Rectangular	1.73	1	6.29
Linearity	7.2.1.3	2.92	Rectangular	1.73	1	1.69
Probe Stability	-	2.46	Rectangular	1.73	1	1.42
Detection limits	7.2.1.4	0	Rectangular	1.73	1	0.00
Boundary effect	7.2.1.5	1.7	Rectangular	1.73	1	0.98
Measurement device	7.2.1.6	0	Normal	1	1	0.00
Response time	7.2.1.7	0	Normal	1	1	0.00
Noise	7.2.1.8	0	Normal	1	1	0.00
Integration time	7.2.1.9	2.3	Normal	1	1	2.30
Mechanical constraints						
Scanning system	7.2.2.1	0.57	Rectangular	1.73	1	0.33
Phantom shell	7.2.2.2	1.43	Rectangular	1.73	1	0.83
Matching between probe and phantom	7.2.2.3	2.86	Rectangular	1.73	1	1.65
Positioning of the phone	7.2.2.4	10	Normal	1	1	10.00
Physical Parameters						
Liquid conductivity (deviation from target)	7.2.3.2	0.3	Rectangular	1.73	0.5	0.17
Liquid conductivity (measurement error)	7.2.3.2	5	Rectangular	1.73	0.5	2.89
Liquid permittivity (deviation from target)	7.2.3.3	3.6	Rectangular	1.73	0.5	2.08
Liquid permittivity (measurement error)	7.2.3.3	5	Rectangular	1.73	0.5	2.89
Drifts in output power of the phone, probe, temperature and humidity	7.2.3.4	5	Rectangular	1.73	1	2.89
Perturbation by the environment	7.2.3.5	3	Rectangular	1.73	1	1.73
Post-Processing						
SAR interpolation and extrapolation	7.2.4.1	2.4	Rectangular	1.73	1	1.39
Maximum SAR evaluation	7.2.4.2	2.4	Rectangular	1.73	1	1.39

Expanded uncertainty = 28.26 % (Using a Coverage Factor of K=2) (confidence interval of 95 %)

2.6 SAR MEASUREMENT SYSTEM

ROBOT SYSTEM SPECIFICATION

The SAR measurement system being used is the IndexSAR SARA2 system, which consists of a Mitsubishi RV-E2 6-axis robot arm and controller, IndexSAR probe and amplifier and SAM phantom Head Shape. The robot is used to articulate the probe to programmed positions inside the phantom head to obtain the SAR readings from the DUT.

The system is controlled remotely from a PC, which contains the software to control the robot and data acquisition equipment. The software also displays the data obtained from test scans.

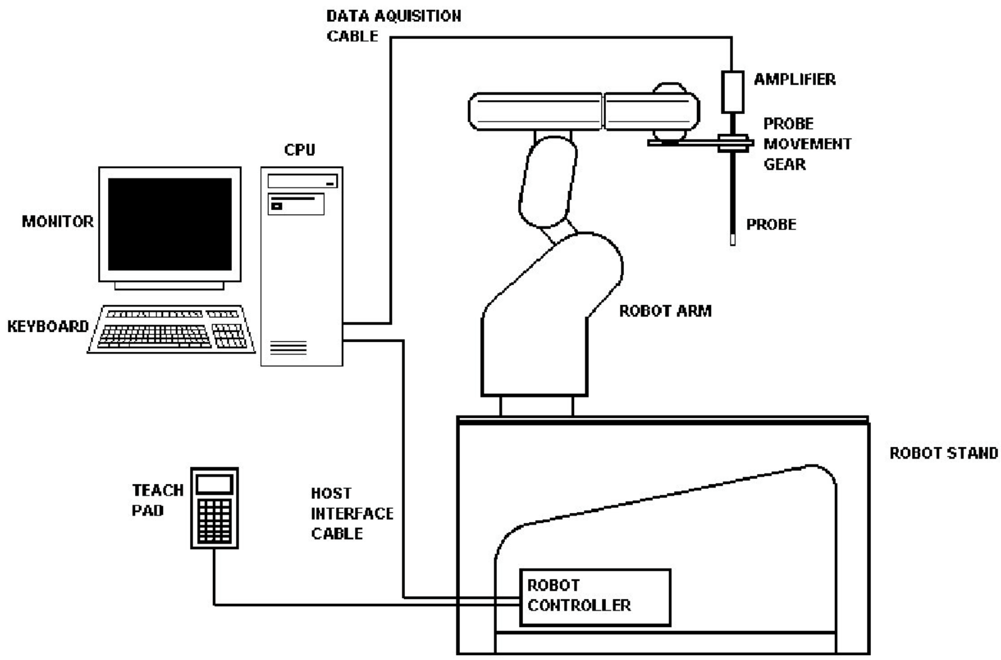


Figure 1: Schematic diagram of the SAR measurement system

The position and digitised shape of the phantom heads are made available to the software for accurate positioning of the probe and reduction of set-up time.
The SAM phantom heads are individually digitised 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 centred at that point to determine volume averaged SAR level.

2.6 SAR MEASUREMENT SYSTEM

PROBE AND AMPLIFIER SPECIFICATION

IXP-065 Indexsar isotropic immersible SAR probe
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 the following section.

IXP-039 Amplifier
The amplifier unit has 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.

Phantoms
The 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.

2.6 SAR MEASUREMENT SYSTEM

PROBE CALIBRATION PROCEDURE

Note: For the 450MHz-calibration procedures see Annex A.

Indexsar probes are characterised using procedures that, where applicable, follow the recommendations of CENELEC [1] and IEEE [2] standards. The procedures incorporate techniques for probe linearisation, isotropy assessment and determination of liquid factors. Calibrations are determined by comparing probe readings with theoretical computations in canonical test geometries, using normalised power inputs.

Calibrations are checked in a set-up where probe response can be accurately compared with probes previously calibrated at the National Physical Laboratory (NPL).

For the first part of the calibration procedure, the probe is placed in a calibration jig as pictured in Figure 1. In this position the probe can be rotated about its axis by a belt driven by a stepper motor.

A balanced dipole (900 or 1800 MHz) is inserted horizontally into the bracket attached to a second belt (Figure 1). The dipole also can be rotated about its axis. A cable connects the dipole to a signal generator, via a coupler and power meter. The signal generator is used to output a signal of 900 (or 1800) MHz at constant power, which is monitored on the power meter. The probe is positioned so that its sensors line up with the rotation center of the dipole. By recording E-field measurements as both the probe and the dipole are rotated, the spherical isotropy of the probe can be determined.

The calibration process requires E-field measurements to be taken in air, in 900 MHz simulated brain liquid and in 1800 MHz simulated brain liquid. A rectangular box made from PMMA (200mm internal width, 200mm internal height and 100mm internal depth; wall thickness 4mm) is filled with the appropriate liquid and positioned on the stand so that the probe tip is centered within the liquid (Figure 1). The box is positioned so that its outer surface is 2mm from the dipole.

The probe channel output signals are linearised in the manner set out in Refs [1] and [2].
The following equation is utilized for each channel:

$$U_{lin} = U_{o/p} + U_{o/p}{}^{2} / DCP$$

where U_{lin} is the linearised signal, $U_{o/p}$ is the raw output signal in voltage units and DCP is the diode compression potential in similar voltage units.

DCP is determined from fitting equation (1) to measurements of U_{lin} versus source feed power over the full dynamic range of the probe. The DCP is a characteristic of the schottky diodes used as the sensors. For the IXP-050 probes the DCP values are typically 0.10V (or 20 in the voltage units used by Indexsar software, which are V*200).

The first step of the calibration process is to calibrate the Indexsar probe to a W&G EMR300 E-field meter in air. The principal reasons for this are to balance the channels in air and to obtain air factors that are used in subsequent steps of the calibration procedure.

2.6 SAR MEASUREMENT SYSTEM

PROBE CALIBRATION PROCEDURE - Continued

The probe and a 900 MHz standard dipole are positioned in the calibration jig as outlined in the section above. With the Indexsar probe located in air, individual channel output voltages are recorded as probe and dipole are rotated. An ‘air factor’ is applied to each of the probe’s three channels in order to equilibrate the peak magnitudes of each channel. A multiplier is applied to factors to bring the magnitudes of the average E-field measurements as close as possible to those of the W&G probe.

The following equation is used (where output voltages are in units of V*200):

$$E_{air}^2\ (V/m) = U_{linx} * \text{Air Factor}_x + U_{liny} * \text{Air Factor}_y + U_{linz} * \text{Air Factor}_z$$

It should be noted that the IXP-050 probes are optimised for use in tissue simulating liquids and do not behave isotropically in air.

The second phase of calibration requires the channel output voltages of the Indexsar probe to be measured in a box filled with 900 MHz simulated brain liquid. Channel outputs for the different orientations of probe and dipole are recorded and entered into a spreadsheet. These measurements are multiplied by the previously determined air factors. Another factor, referred to as the ‘liquid factor’ is also applied to the measurements of each channel. The magnitude of the liquid factor for each channel is selected so as to optimise the isotropy of the probe (i.e. equilibrate the peak magnitudes of the three channels) in the liquid. The following equation is used (where output voltages are in units of V*200):

$$E_{liq}^2\ (V/m) = U_{linx} * \text{Air Factor}_x * \text{Liq Factor}_x + U_{liny} * \text{Air Factor}_y * \text{Liq Factor}_y + U_{linz} * \text{Air Factor}_z * \text{Liq Factor}_z$$

The rotational isotropy is also determined and the results are presented in the individual probe calibration documents.

The final step of the 900 MHz calibration requires the measurement of SAR decay in a generic, spherical phantom and fitting the measured data to one of the two following theoretical predictions of the decay profile:

a) SAR decay curve modelled using a 200mm diameter sphere energised by a balanced dipole in a ‘benchmark configuration’ or

b) SAR decay curve modelled by Flomerics [3] using a sphere and a balanced dipole in a similar test configuration.

To measure SAR decay the probe is inserted through the neck of a spherical phantom filled with 900 MHz simulant liquid, and the tip is positioned at the inside surface of the flask. A 900 MHz balanced dipole is aligned with the probe tip and placed a specific distance from the outer surface of the sphere. As the probe is progressively withdrawn along the centre line of the sphere, E-field measurements are taken. A multiplier is applied to the liquid factors so as to equilibrate the resultant decay function with the modelled results.

2.6 SAR MEASUREMENT SYSTEM

PROBE CALIBRATION PROCEDURE - Continued

The calibration process is then repeated for 1800 MHz. The test set up is modified slightly to use 1800 MHz simulant liquid and a standard 1800 MHz balanced dipole.

Probe calibration parameters are compared with CENELEC and IEEE standards recommendations (Refs [1] and [2]) in the Tables below.

A listing of relevant specifications are listed in the probe calibration document supplied with each probe.

Dimensions	**S/N 0065**	**CENELEC [1]**	**IEEE [2]**
Overall length (mm)	350		
Tip length (mm)	10		
Body diameter (mm)	12		
Tip diameter (mm)	5.2	8	8
Distance from probe tip to dipole centres (mm)	2.5		

Dynamic range	**S/N 0065**	**CENELEC [1]**	**IEEE [2]**
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg) N.B. only measured to 35 W/kg	>35	>100	100

Linearity of response	**S/N 0065**	**CENELEC [1]**	**IEEE [2]**
Over range 0.01 – 100 W/kg (+/- dB)	0.125	0.50	0.25

Isotropy (measured at 900MHz)	**S/N 0065**	**CENELEC [1]**	**IEEE [2]**
Axial rotation with probe normal to source (+/- dB)	0.25	0.5	0.25
Spherical isotropy covering all orientations to source (+/- dB)	0.50	1.0	0.50

2.6 SAR MEASUREMENT SYSTEM

SAR MEASUREMENT PROCEDURE

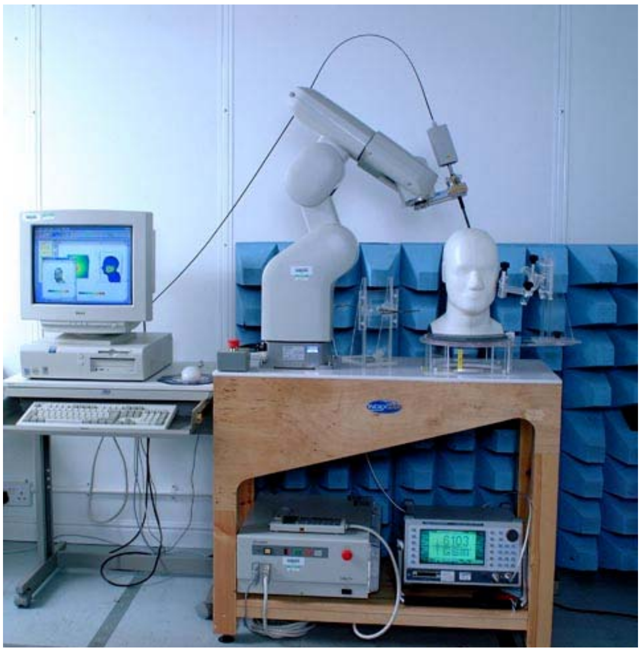


Figure 2: Principal components of the SAR measurement test bench

The major components of the test bench are shown in the picture above. A test set and dipole antenna control the handset via an air link and a low-mass phone holder can position the phone at either ear. Graduated scales are provided to set the phone in the 15 degree position. The upright phantom head holds approx. 7 litres of simulant liquid. The phantom is filled and emptied through a 45mm diameter penetration hole in the top of the head.

After an area scan has been done at a fixed distance of 8mm from the surface 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 drift during measurement to be assessed.

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.

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.

2.6 SAR MEASUREMENT SYSTEM

SAR MEASUREMENT PROCEDURE - Continued

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 digitised shape of the head 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.

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 curved inner 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 digitised 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.

2.6 SAR MEASUREMENT SYSTEM

SAR MEASUREMENT PROCEDURE - Continued

The 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 digitised 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.

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).

2.7 TEST POSITIONS

Figure 3: Normal Use - Defined Position

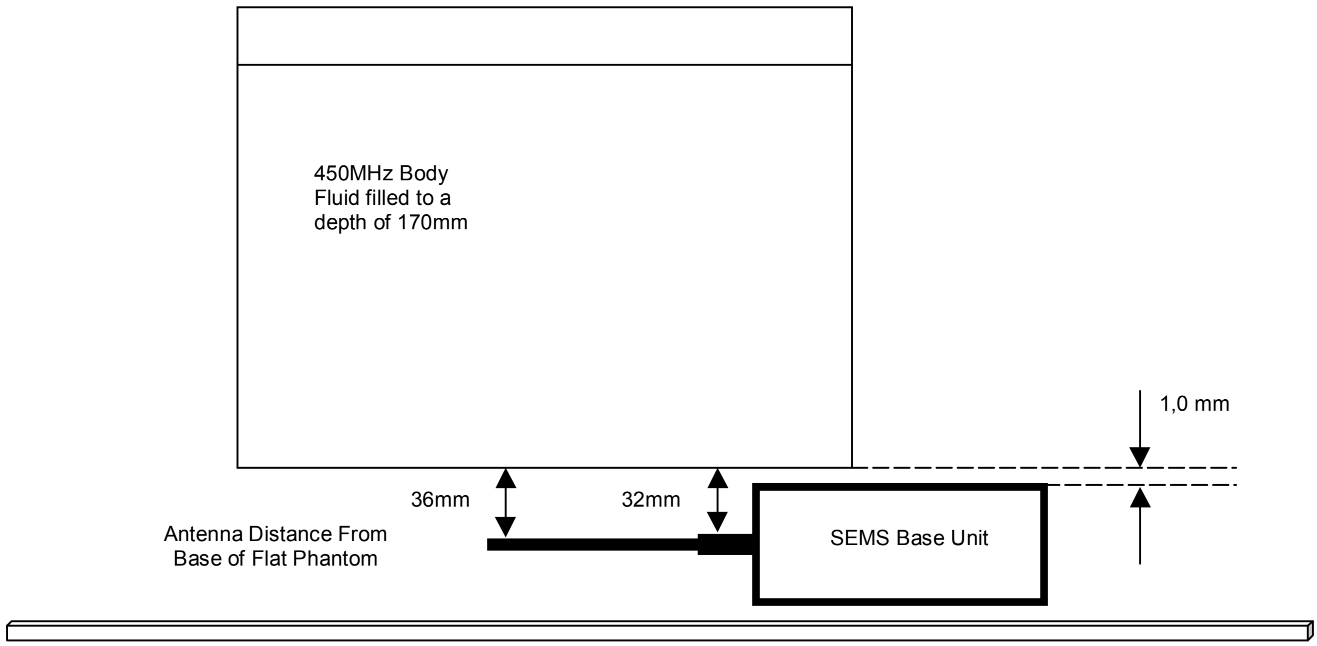
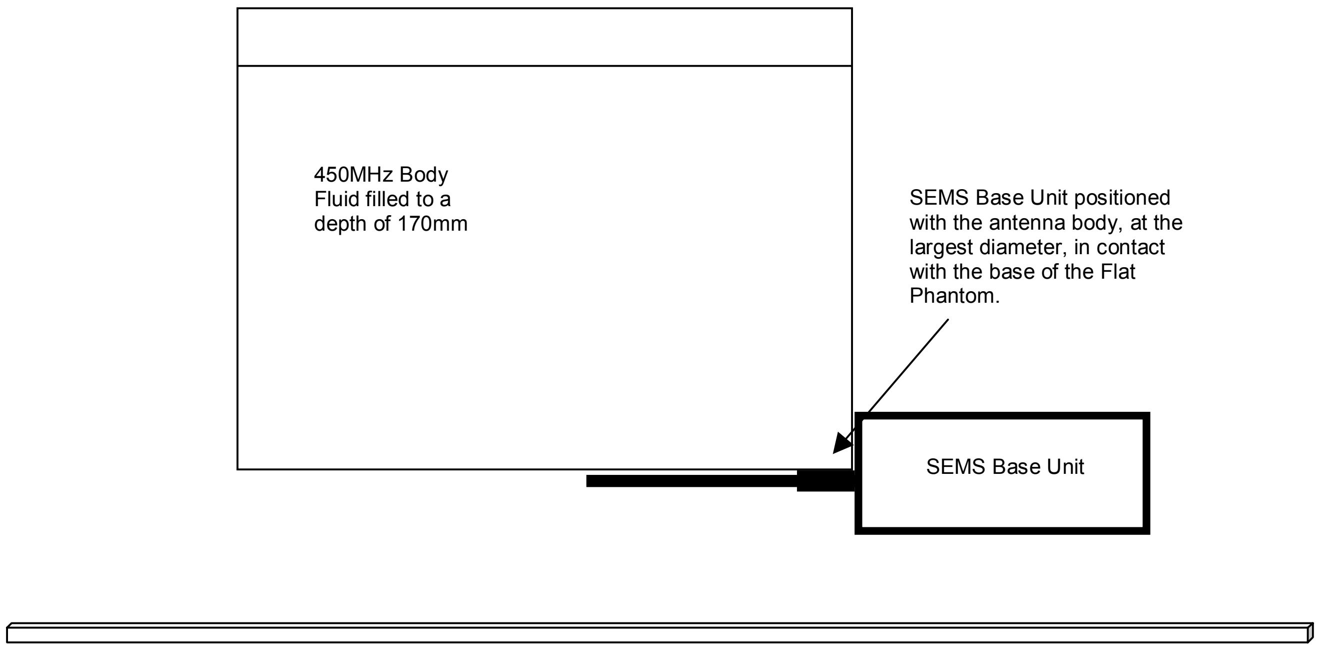


Figure 4: Worstcase Use - Defined Position



2.8 TEST RESULT SUMMARY

SYSTEM PERFORMANCE / VALIDATION CHECK RESULTS

Prior to formal testing being performed a system check was performed in accordance with Annex D of EN 50361. The following result was obtained:-

Dipole Used	Frequency (MHz)	Max 1g SAR (W/kg)	Percentage Drift on Reference
450 MHz	450	0.728	0.824%

Specific Absorption Rate (SAR) 10g & 1g Results for SEMS Base Unit.

Device / Position	Channel Number	Frequency (MHz)	Max spot SAR (W/Kg)	Max 1g SAR (W/kg	Max 10g SAR (W/kg)	Area scan (Figure number)
SEMS Base Unit with antenna positioned from 32mm at nearest and 36mm farthest from Flat Phantom Base	0	453.0375	0.16	0.188	0.143	Figure 6
SEMS Base Unit with antenna positioned from 32mm at nearest and 36mm farthest from Flat Phantom Base	604	460.5875	0.16	0.194	0.147	Figure 7
SEMS Base Unit with antenna positioned from 32mm at nearest and 36mm farthest from Flat Phantom Base	1008	465.6375	0.14	0.172	0.129	Figure 8
SEMS Base Unit with antenna positioned from 0.0mm at nearest and 2.0mm farthest from Flat Phantom Base	604	460.5875	0.81	0.972	0.677	Figure 9
Limit for Occupational/Controlled Exposure = 8.0W/kg						

2.9 SAR DISTRIBUTIONS (AREA SCANS – 2D)

Specific Absorption Rate (SAR) distributions for the SEMS Base Unit.

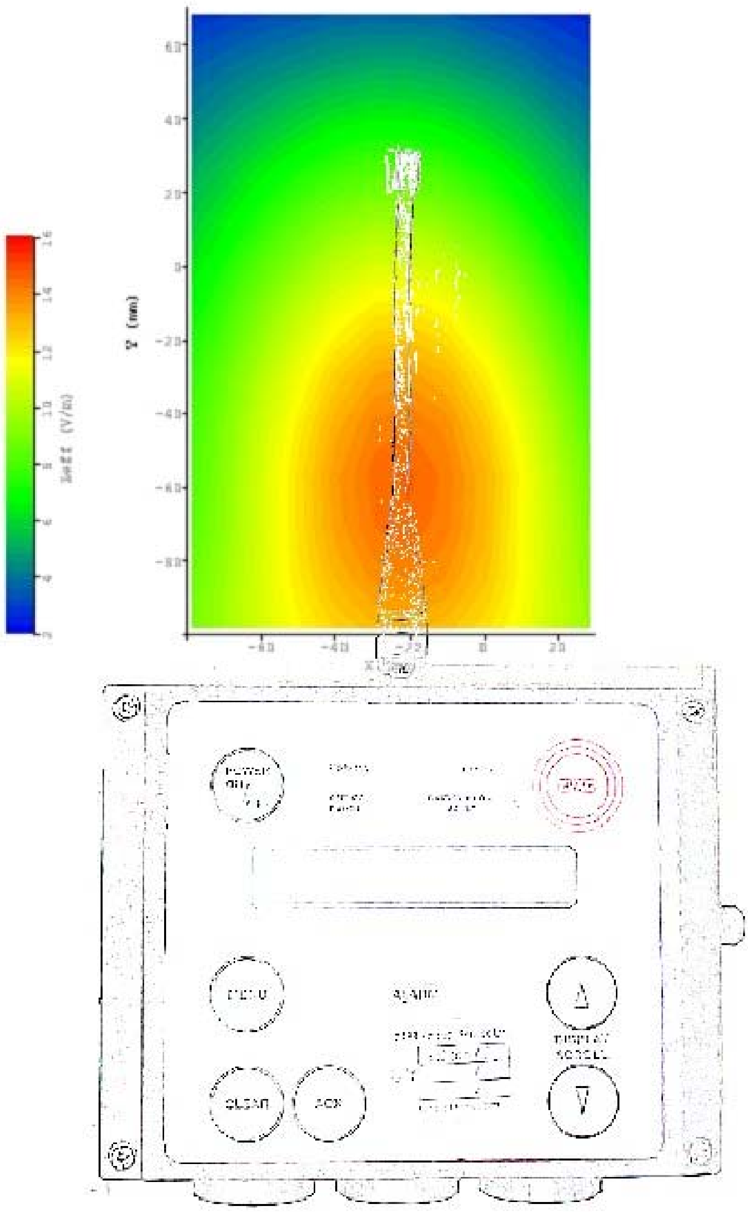


Figure 5. Device positioned 1.5mm from Bottom of Flat Phantom (Channel 0; 453.0375MHz)

2.9 SAR DISTRIBUTIONS (AREA SCANS – 2D)

Specific Absorption Rate (SAR) distributions for the SEMS Base Unit.

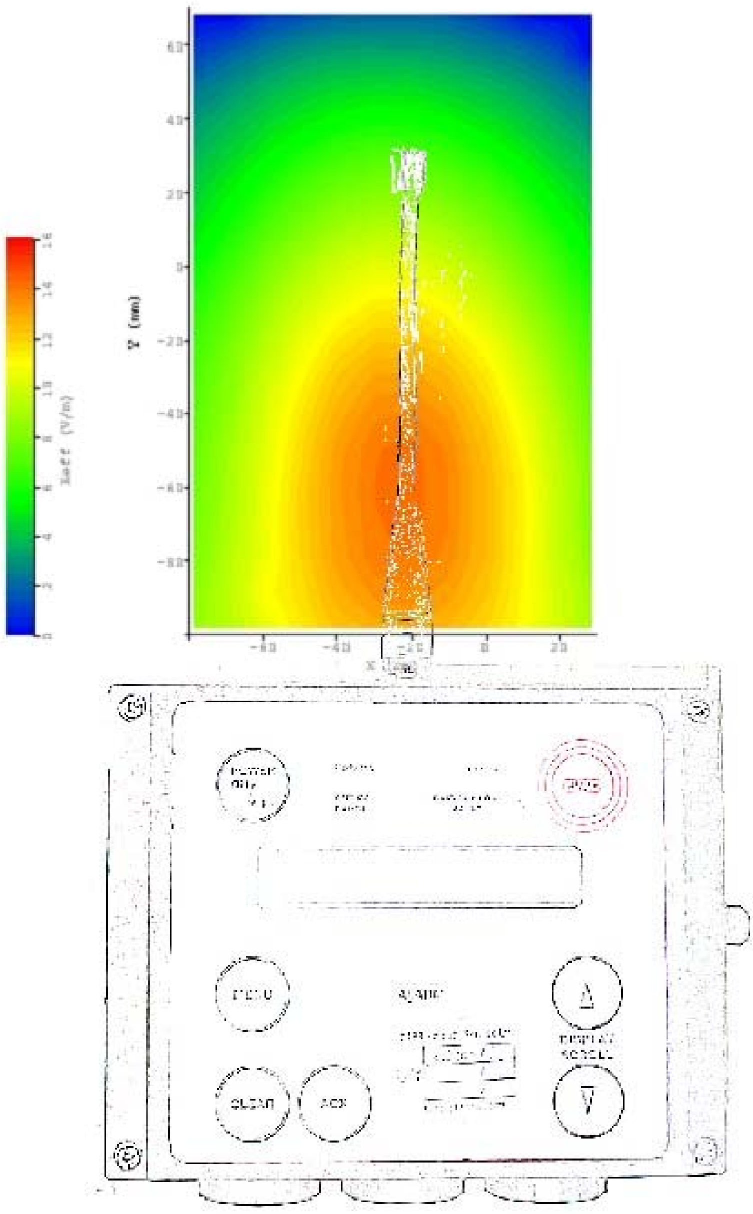


Figure 6. Device positioned 1.5mm from Bottom of Flat Phantom (Channel 604; 460.5875 MHz)

2.9 SAR DISTRIBUTIONS (AREA SCANS – 2D)

Specific Absorption Rate (SAR) distributions for the SEMS Base Unit.

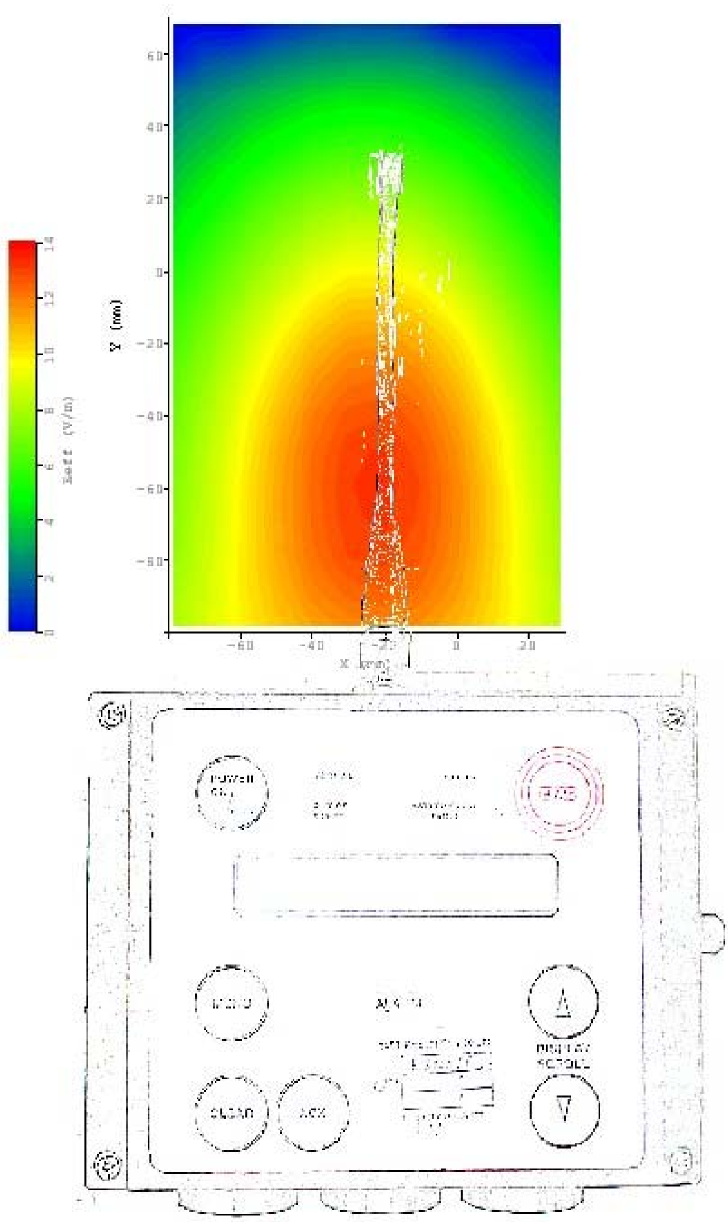


Figure 7. Device positioned 1.5mm from Bottom of Flat Phantom (Channel 1008; 465.6375MHz)

2.9 SAR DISTRIBUTIONS (AREA SCANS – 2D)

Specific Absorption Rate (SAR) distributions for the SEMS Base Unit.

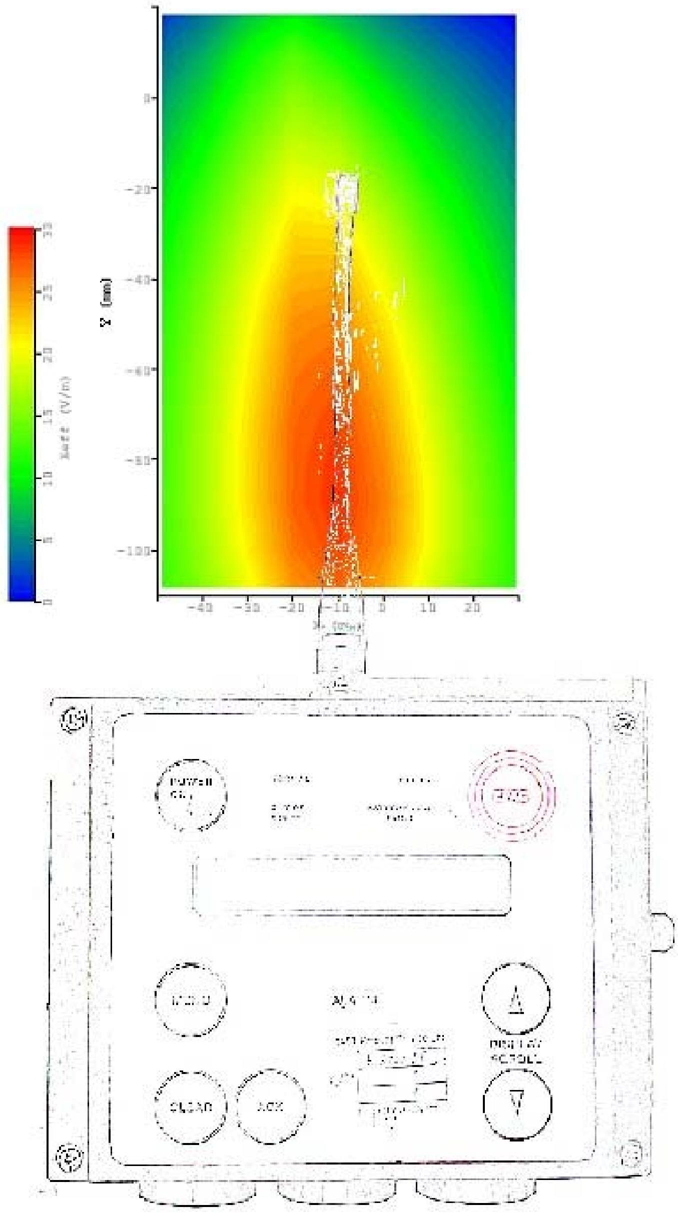


Figure 8. Device positioned with antenna against Bottom of Flat Phantom (Channel 604; 460.5875MHz).

2.10 TEST POSITIONAL PHOTOGRAPHS

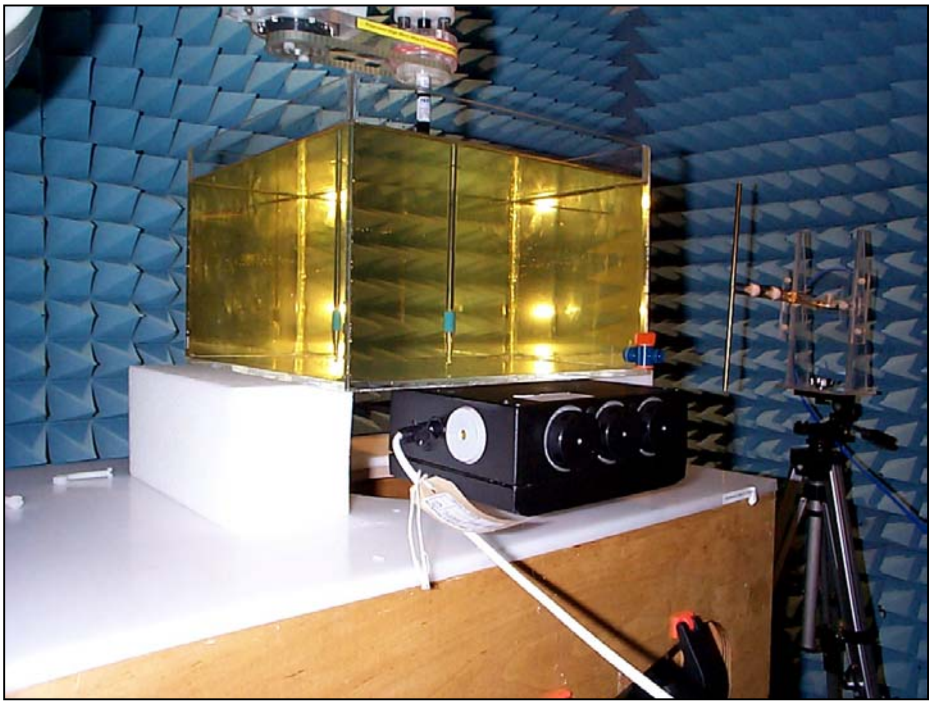


Figure 9. Positional photograph of SEMS Base Unit with Positoned 1.5mm from Base of Flat phantom. The antenna distance from base of flat phantom varied from 32mm-36mm, see figure 3.

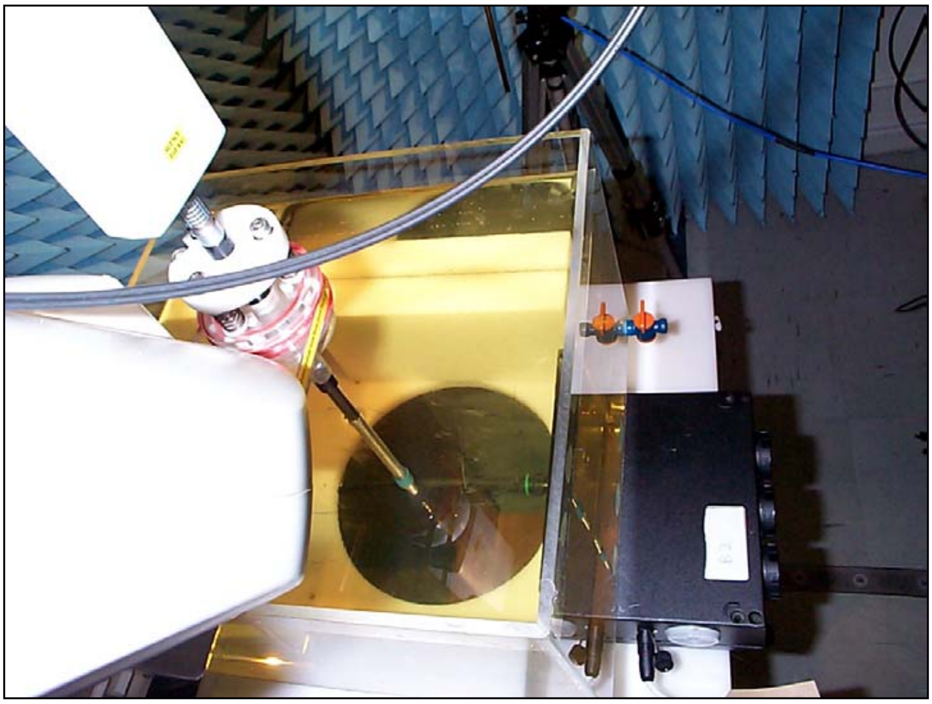


Figure 10. Positional photograph of SEMS Base Unit with Positoned 1.5mm from Base of Flat phantom. The antenna distance from base of flat phantom varied from 32mm-36mm, see figure 3.

2.10 TEST POSITIONAL PHOTOGRAPHS

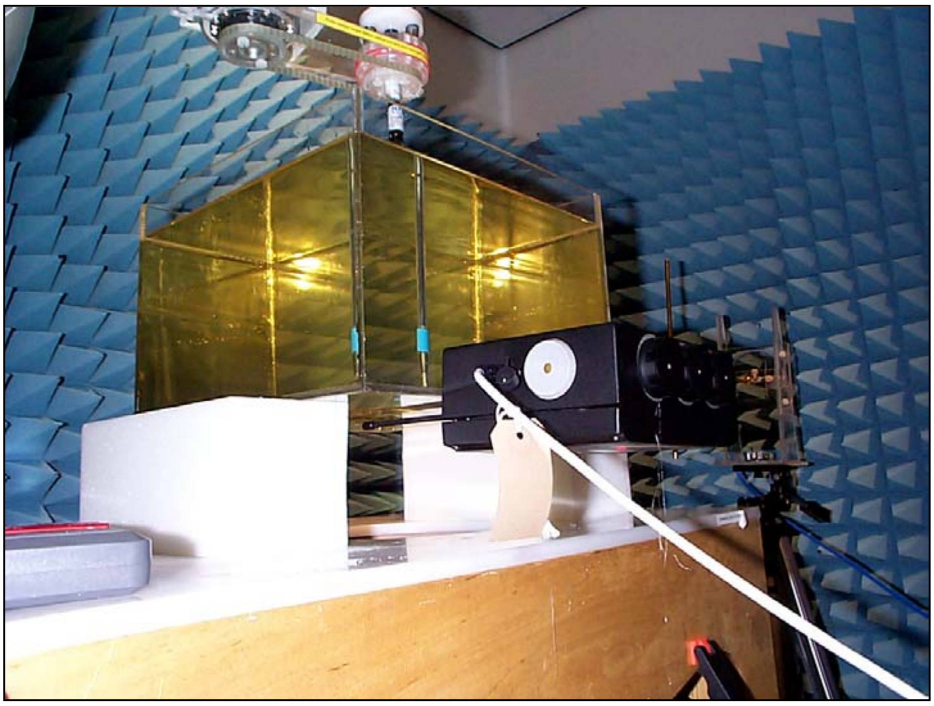


Figure 11. Positional photograph of SEMS Base Unit with Positoned 1.5mm from Base of Flat phantom.
The antenna distance from base of flat phantom varied from 32mm-36mm, see figure 3.

2.10 RECORD PHOTOGRAPHS

Figure 12. Front view of SEMS Base Unit.

Figure 13. Rear view of SEMS Base Unit.

Annex A - <u>450MHz Certificate of Calibration</u>

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Teddington Middlesex UK TW11 0LW Switchboard 020 8977 3222

Certificate of Calibration

SAR PROBE
Model: IndexSAR IXP-050
Serial number: 0065

FOR: BABT Product Service
Segensworth Road
Fareham
Hampshire
PO15 5RH.

For the attention of Alex Miller.

Order number: 51274

DESCRIPTION: An IndexSAR isotropic electric field probe for determining specific absorption rates (SAR) in dielectric liquids. The probe has three orthogonal sensors, and the output voltage of each sensor is converted to an optical signal by an analogue to digital (AD) converter. Probe readings are obtained using pc software via a digital to analogue (DA) converter connected to the RS232 port. The probe was calibrated with IndexSAR amplifier model IXA-010 s/n 039.

IDENTIFICATION: The probe is marked with the manufacturer's serial number 0065.

MEASUREMENTS COMPLETED ON: 31 July 2002

PREVIOUS NPL CERTIFICATE: EF07/2002/02/BABT

The reported uncertainty is based on a coverage factor k=2, providing a level of confidence of approximately 95%

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Date of Issue : 1 August 2002 **Signed :** R.N.Clarke **(Authorised Signatory)**

Checked by : kleef **Name : Mr R. Clarke** **for Managing Director**

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Annex A - 450MHz Certificate of Calibration - Continued

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MEASUREMENT PROCEDURE

The calibration method is based on setting up a calculable specific absorption rate (SAR) in a matched waveguide cell [1]. The cell has a feed section and a liquid filled section, and a matching window that is designed to minimise reflections at the interface separates these. A TE_{01} mode is launched into the waveguide by means of a N-type-to-waveguide adapter. The power delivered to the liquid section is calculated from the forward power and reflection coefficient measured at the input to the cell. At the centre of the cross-section of the waveguide cell, the volume specific absorption rate (SAR^V)in the liquid as a function of distance from the window is given by

$$SAR^V = \frac{4(P_w)}{ab\delta} e^{-2Z/\delta}$$

where

a = the larger cross-sectional dimension of the waveguide.
b = the smaller cross-sectional dimension of the waveguide.
δ = the skin depth for the fluid in the waveguide.
z = the distance from the liquid/matching window boundary to the probe sensor elements.
P_w = the power delivered to the waveguide.

The value of δ for the liquid is obtained by measuring the electric field (E) at a number of distances from the matching window.

The probe was calibrated at 450 MHz in 450 MHz tissue equivalent material to the CENELEC [2] and draft IEEE standard, having measured permittivity 42.8-33.5j. The calibration was for CW signals only, and the axis of the probe was parallel to the direction of propagation of the incident field i.e. end-on to the incident radiation. The probe was rotated about its axis to find the position for maximum and minimum isotropy and calibrated at these positions. The calibration factors quoted are for the mean sensitivity.

The probe software uses separate correction factors for each of the three sensors. The ratios of these correction factors have been determined by the manufacturer to reduce the spherical isotropy error. In the end-on calibration, these ratios have been preserved so as not to degrade the performance of the probe. Because of this, the calibration factors quoted are different for each of the sensors. However, the probe has been calibrated for SAR, which is dependent on the total electric field strength (E), and the sensitivities of the three sensors have not been

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Annex A - 450MHz Certificate of Calibration - Continued

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Continuation Sheet

calibrated individually. The spherical isotropy of the probe has not been measured as part of this calibration.

The probe was calibrated with the air correction factors, linearisation and isotropy corrections enabled. Comparing the measured values of E^2 in the liquid to those calculated for the waveguide cell allows the ratio of sensitivity for $(E^2_{liquid}) / (E^2_{air})$ to be determined, as required by the probe software.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 2.5 mm from the probe tip in the direction of the AD converter. A value of 2.5 mm should be used for the tip to sensor offset distance in the software.

It is important that the diode compression point and air factors used in the software are the same as those quoted in the results tables, as these are used to convert the diode output voltages to a SAR value.

ENVIRONMENT

Measurements were made in a temperature controlled laboratory at 21.8 ± 2°C. The temperature of the liquid used was measured at the beginning and end of the measurement.

UNCERTAINTIES

The estimated uncertainty in calibration for SAR (W/Kg) at 450 MHz is ± 12%. The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a level of confidence of approximately 95%.

This uncertainty is valid when the probe is used in a liquid with the same dielectric properties as those used for the calibration. For constant liquid permittivity and conductivity no significant changes in the probe calibration factors would be anticipated over the temperature range 20 to 24 °C. No estimate is made for the long term stability of the device calibrated or of the fluids used in the calibration.

When using the probe for SAR testing, additional uncertainties should be added to account for the spherical isotropy of the probe, proximity effects, linearity, and response to pulsed fields. There will be additional uncertainty if the probe is used in liquids having significantly different electrical properties to those used for the calibration. The electrical properties of the liquids may be related to temperature.

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Annex A - 450MHz Certificate of Calibration - Continued

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RESULTS

The results of the calibration are given in Table 1. The calibration factors given are for the mean sensitivity in the axial rotation.

These calibration factors are only correct when the probe tip offset, SAR factors, diode factors and linearisation factors are set in the probe software are the same as those given in Table 1. The gain level of the probe amplifier must be set to 2 (send command "G2").

The axial isotropy error for the probe is less than ± 0.25 dB at 450 MHz when used in the IEEE TEM 450 MHz tissue equivalent material. Estimates for the errors in SAR calibration factors when the probe is brought in close proximity to the fluid /air boundary, with the axis of the probe perpendicular to the boundary, are given in Table 2 . Proximity to the boundary causes the probe to read high. Note that distance in this table is measured from the probe tip, and not the position of the sensors.

REFERENCE:

[1] Pokovic et al 1997, Pokovic, KT, T.Schmid and N.Kuster, "Robust set-up for Precise Calibration of E-field probes in Tissue Simulating Liquids at Mobile Phone Frequencies.," Proceedings ICECOM 1997, pp 120 – 124, Dubrovnik, Croatia Oct 12-17, 1997.

[2] British Standard BS EN 503361:2001. "Basic standard for the measurement of specific absorption rate related to human exposure to electromagnetic fields from mobile phones (300 MHz – 3 GHz)".

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Annex A - 450MHz Certificate of Calibration - Continued

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Table 1
SAR probe: IndexSAR IXP-050, s/n 0065.

FREQUENCY 450 MHz			
Probe tip offset = 2.5 mm			
LIQUID PARAMETERS Permittivity = 42.76 –33.47j at 22.3 ^{0}C Conductivity = 0.84 S/m at 22.3 ^{0}C Temperature of liquid during probe calibration = 21.6 ^{0}C			
Approximate SAR levels used in calibration = 0.5 to 2 W/Kg Probe linearity over calibration range = ± 0.028 dB Axial isotropy = ± 0.25 dB			
	X	Y	Z
SAR factors E*E liq/air	**0.324**	**0.335**	**0.324**
Diode factor V*200[1]	20	20	20
Lin factor for (V*200) [1]	400	370	410

Table 2
Proximity errors at 450 MHz, for guidance
SAR probe: IndexSAR IXP-050, s/n 0065.

FREQUENCY 450 MHz	
Liquid: IEEE 450 MHz tissue equivalent material	
Distance from probe tip to fluid / air boundary (mm)	Error in SAR reading due to proximity effect (%)
0.0	+10.4
1.0	+5.8
2.0	+2.6
3.0	+1.3
4.0	+0.6
5.0	+0.4
6.0	+0.2
7.0	+0.1

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