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Report On

Specific Absorption Rate Testing of the
Cobham SOLO7 HD Nano Transmitter

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November 2014

TÜV SÜD Product Service, Octagon House, Concorde Way, Segensworth North,
Fareham, Hampshire, United Kingdom, PO15 5RL
Tel: +44 (0) 1489 558100. Website: www.tuv-sud.co.uk

REPORT ON

Specific Absorption Rate Testing of the
Cobham SOLO7 HD Nano Transmitter.

Document 75926941 Report 04 Issue 1

November 2014

PREPARED FOR

Cobham Tactical Communications and Surveillance
The Cobham Centre – Solent, Fusion 2
1100 Parkway
Solent Business Park
Whiteley, Fareham
Hampshire
PO15 7AB

PREPARED BY

Nigel Grigsby
Senior Engineer

APPROVED BY

Mark Jenkins
Authorised Signatory

DATED

05 November 2014

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CONTENTS

SECTION 1

REPORT SUMMARY

Specific Absorption Rate Testing of the
Cobham SOLO7 HD Nano Transmitter

1.1 INTRODUCTION

The information contained in this report is intended to show verification of the Specific Absorption Rate Testing of the Cobham SOLO7 HD Nano Transmitter to the requirements of KDB 447498 – D01 v05 General RF Exposure Guidance.

Objective	To perform Specific Absorption Rate Testing to determine the Equipment Under Test's (EUT's) compliance with the requirements specified of KDB 447498 – D01 v05 General RF Exposure Guidance, for the series of tests carried out.
Applicant	Cobham Tactical Communications and Surveillance
Manufacturer	Cobham Tactical Communications and Surveillance
Manufacturing Description	SOLO7 HD Nano Transmitter 1.98 – 2.70GHz
Model Number	SOL7HDNTX-198270
Serial/IMEI Number(s)	030119
Number of Samples Tested	1
Hardware Version	V4.0
Software Version	SN V1.2
Test Specification/Issue/Date	KDB 447498 – D01 v05r02 General RF Exposure Guidance
Start of Test	18 August 2014
Finish of Test	19 August 2014
Related Document(s)	FCC 47CFR 2.1093: 2012 KDB 865664 – D01 v01r03 KDB 865664 – D02 v01r01 IEEE 1528-2009
Name of Engineer(s)	Nigel Grigsby

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1.2 BRIEF SUMMARY OF RESULTS

The measurements shown in this report were made in accordance with the procedures specified KDB 865664 – D01 v05.

The maximum 1g volume averaged SAR found during this Assessment

Max 1g SAR (W/kg) Body	0.63 (Measured)	0.75 (Scaled)
The maximum 1g volume averaged SAR level measured for all the tests performed did not exceed the limits for General Population/Uncontrolled Exposure (W/kg) Partial Body of 1.6 W/kg.		

1.3 TEST RESULTS SUMMARY

1.3.1 System Performance / Validation Check Results

Prior to formal testing being performed a System Check was performed in accordance with KDB 865664 and the results were compared against published data in Standard IEEE 1528-2009. The following results were obtained: -

System performance / Validation results

Date	Dipole Used	Frequency (MHz)	Max 1g SAR (W/kg)*	Percentage Drift on Reference
19/08/2014	2450	2450	53.77	-0.26

*Normalised to a forward power of 1W

1.3.2 Results Summary Tables

2481MHz Body Specific Absorption Rate (Maximum SAR) 1g Results for the Cobham SOLO7 HD Nano Transmitter. Modulation Coding Scheme NB/UMVL.

Position		Channel Number	Frequency (MHz)	Measured Conducted Power (dBm)	Tune Up limit (dBm)	Measured 1g SAR (W/kg)	Scaled 1g SAR (W/kg)	Area scan (Figure number)
Spacing	Position							
5mm	Rear Face	Top	2481.0	20.20	21.0	0.53	0.64	Figure 06
Limit for General Population (Uncontrolled Exposure) 1.6 W/kg (1g) KDB 447498 D01 - Testing of other required channels within the operation mode of a frequency band is not required when the reported 1g SAR for mid-band or highest output power channel is: ≤ 0.8W/kg when the transmission band is ≤ 100MHz ≤ 0.6W/kg when the transmission band is between 100MHz and 200MHz ≤ 0.4W/kg when the transmission band is ≥ 200MHz								

2481MHz Body Specific Absorption Rate (Maximum SAR) 1g Results for the Cobham SOLO7 HD Nano Transmitter. Modulation Coding Scheme DVB-T.

Position		Channel Number	Frequency (MHz)	Measured Conducted Power (dBm)	Tune Up limit (dBm)	Measured 1g SAR (W/kg)	Scaled 1g SAR (W/kg)	Area scan (Figure number)
Spacing	Position							
5mm	Rear Face	Top	2481.0	20.25	21.0	0.63	**0.75**	Figure 07
Limit for General Population (Uncontrolled Exposure) 1.6 W/kg (1g) KDB 447498 D01 - Testing of other required channels within the operation mode of a frequency band is not required when the reported 1g SAR for mid-band or highest output power channel is: ≤ 0.8W/kg when the transmission band is ≤ 100MHz ≤ 0.6W/kg when the transmission band is between 100MHz and 200MHz ≤ 0.4W/kg when the transmission band is ≥ 200MHz								

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1.4 PRODUCT INFORMATION

1.4.1 Technical Description

The equipment under test (EUT) was a Cobham SOLO7 HD Nano Transmitter. A full technical description can be found in the manufacturer’s documentation.

1.4.2 Test Configuration and Modes of Operation

The testing was performed with an external connection to a power supply unit set to 12V. The SOLO7 Transmitter was also connected to a Blackmagic HD Video Streamer.

For body SAR assessment, testing was performed for the 2.4GHz frequency band at maximum power. The device was placed in its orientation of declared intended use at a distance of 5mm from the bottom of the flat phantom for all body testing. The Flat Phantom dimensions were 245mm x 195mm x 200mm with a sidewall thickness of 2.00mm. The phantom was filled to a minimum depth of 150mm with the appropriate Body simulant liquid. The dielectric properties were in accordance with the requirements specified in KDB 865665.

Testing was performed at the frequency that gave the highest output power. No SAR levels were found to be <0.80 W/kg (KDB 447498 D01) therefore no additional testing was required. The testing was achieved using the devices internal software, customer supplied software and settings supplied by the customer. The worse case configurations for testing were obtained from data provided by TUV. The worst case was deemed as configuration which produced the highest level of conducted average power for each modulation coding scheme.
These were as follows:

Modulation Coding Scheme NB/UMVL, Modulation BPSK, Bandwidth 6MHz.
Modulation Coding Scheme DVB-T, Modulation 16QAM, Bandwidth 6MHz

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 handset against the body as appropriate

1.5 FCC POWER MEASUREMENTS

1.5.1 Method

Conducted power measurements were made using a power meter.

1.5.2 Conducted Power Measurements

WLAN

Modulation Coding Scheme NB/UMVL, Modulation BPSK, Bandwidth 6MHz.

Bandwidth (MHz)	Modulation	Bottom Channel (2452.50 MHz)	Middle Channel (2466.75 MHz)	Top Channel (2481.00 MHz)
0.625	QPSK	19.78	19.98	20.07
	16-QAM	19.77	19.94	20.07
	BPSK	19.80	19.96	20.08
	8PSK	19.79	19.96	20.03
1.25	QPSK	19.76	20.13	20.01
	16-QAM	19.76	20.19	20.05
	BPSK	19.79	20.14	20.02
	8PSK	19.77	20.13	20.04
2.5	QPSK	19.72	20.05	20.14
	16-QAM	19.67	20.06	20.09
	BPSK	19.69	20.10	20.04
	8PSK	19.67	20.06	20.05
6	QPSK	19.57	19.95	20.19
	16-QAM	19.62	19.91	20.17
	BPSK	19.56	19.93	**20.20**
	8PSK	19.58	19.92	20.18
7	QPSK	19.51	19.80	20.05
	16-QAM	19.50	19.87	20.04
	BPSK	19.50	19.85	20.02
	8PSK	19.49	19.85	20.09
8	QPSK	19.70	19.76	19.95
	16-QAM	19.69	19.80	19.94
	BPSK	19.46	19.78	19.92
	8PSK	19.48	19.76	19.89

Modulation Coding Scheme DVB-T, Modulation 16QAM, Bandwidth 6MHz

Bandwidth (MHz)	Modulation	Bottom Channel (2452.50 MHz)	Middle Channel (2466.75 MHz)	Top Channel (2481.00 MHz)
6	QPSK	19.98	20.21	20.23
	16-QAM	20.00	20.19	**20.25**
	64-QAM	19.97	20.18	20.22
7	QPSK	1.99	20.17	20.15
	16-QAM	19.98	20.13	20.20
	64-QAM	20.01	20.16	20.16
8	QPSK	19.92	20.09	20.12
	16-QAM	19.94	20.10	20.15
	64-QAM	19.87	20.11	20.14

1.5.3 Standalone SAR Test Exclusion Considerations (KDB 447498 D01)

The 1g SAR Test exclusion thresholds for 100 MHz to 6 GHz *test separation distances* ≤ 50 mm are determined by:

[(*max power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] [√f ($_{GHz}$)]* ≤ 3.0, where

- f ($_{GHz}$) is the RF channel transmit frequency in GHz.
- Power and distance are rounded to the nearest mW and mm before calculation.
- The result is rounded to one decimal place for comparison.
- When the maximum test separation distance is < 5 mm, a distance of 5 mm is applied.

Band	Frequency (MHz)	Max Power		Test Position	Distance (mm)	Threshold	Test Exclusion
		(dBm)	(mW)				
2.4 GHz	2481	21	125.89	Body	5	39.7	No

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SECTION 2

TEST DETAILS

Specific Absorption Rate Testing of the
Cobham SOLO7 HD Nano Transmitter

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2.1 SARA-C SAR MEASUREMENT SYSTEM

2.1.1 Robot System Specification

The SAR measurement system being used is the IndexSAR SARA-C system, which consists of a cartestian 6-axis robot jig, a dedicated robot controller, a straight IndexSAR probe, an L-shaped Indexsar probe, a fast amplifier, and two phantoms: an upside-down SAM phantom, and a rectangular box phantom,

Figure 1. The L-probe is used in connection with measurements on DUTs held against the SAM phantom, while the straight probe is used exclusively in the box phantom. The robot is used to articulate the probe to programmed positions inside the phantom head to obtain SAR readings from the DUT.

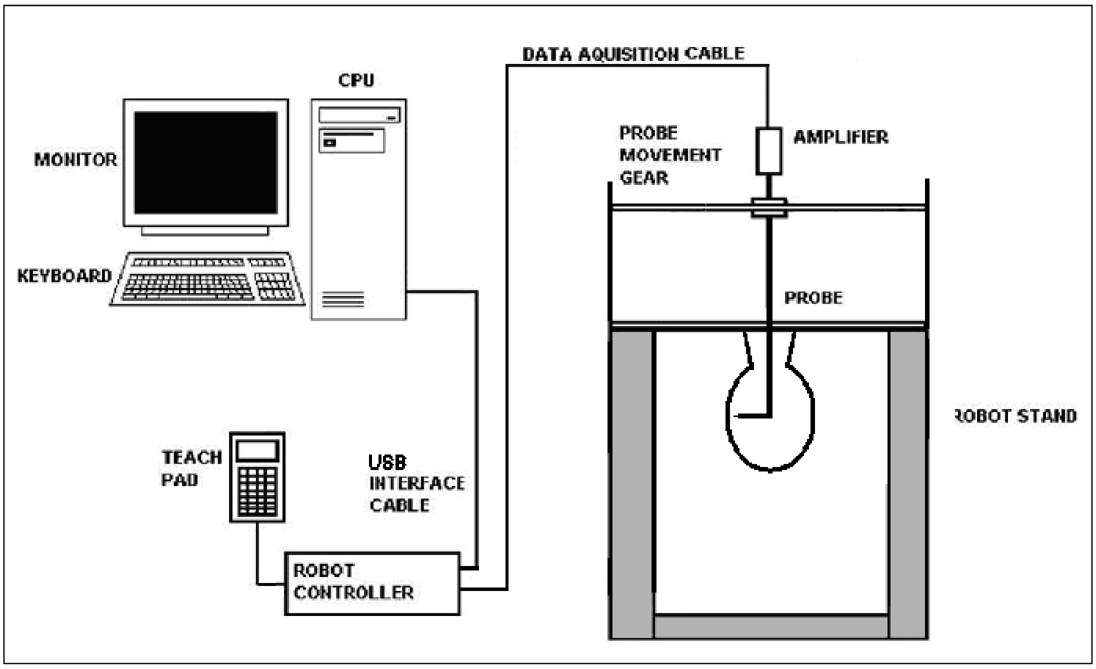

Figure 1 Schematic diagram of the SARA-C measurement system showing the L-probe and upside-down SAM phantom

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

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. Even with this accuracy, registration errors and deformation of the phantom when filled with 7 litres of fluid, can lead to probe placement errors of 1mm or more. For this reason, the L-probes house a 2-axis strain gauge unit, which allow the actual phantom wall position to be sensed to an accuracy of 0.3mm during probe movements.

In operation, the system first does an area (2D) scan within the liquid following the curve of the phantom wall at a fixed distance. 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.

2.1.2 Probe and Amplifier Specification

IndexSAR isotropic immersible straight SAR probes

Straight 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. The tips come in either 5mm (typically for use up to 3GHz) or 2.5mm (above 3GHz) versions, model types IXP-050 and IXP-025 respectively.

Straight probes are calibrated by NPL in the UK.

Straight probes are used exclusively in the box phantom, to measure SAR from DUTs placed against the phantom base. In SARA2, straight probes were also used in the SAM phantom, but this is forbidden in SARA-C, where L-probes are demanded. NB the reverse is not true: L-probes can be used in the box phantom.

IndexSAR L-probes

The L-shaped probe is so designed to ensure the probe tip can remain perpendicular to the SAM phantom wall during scans. To allow for greater probe articulation freedom, the SAM phantom head has been turned upside down and the probe is inserted through the throat aperture, rather than through a small hole at the top of the head in the old SARA2 SAR measurement system.

Like the straight probes, L-probes also come in the same two tip sizes: IXP-020 (5mm) and IXP-021 (2.5mm).

L-probes are calibrated to national standards in-house by IndexSAR.

L-probes can be used either in the SAM head, or against the side wall of the box phantom.

IFA-020 Fast Amplifier

A block diagram of the fast probe amplifier electronics is shown below.

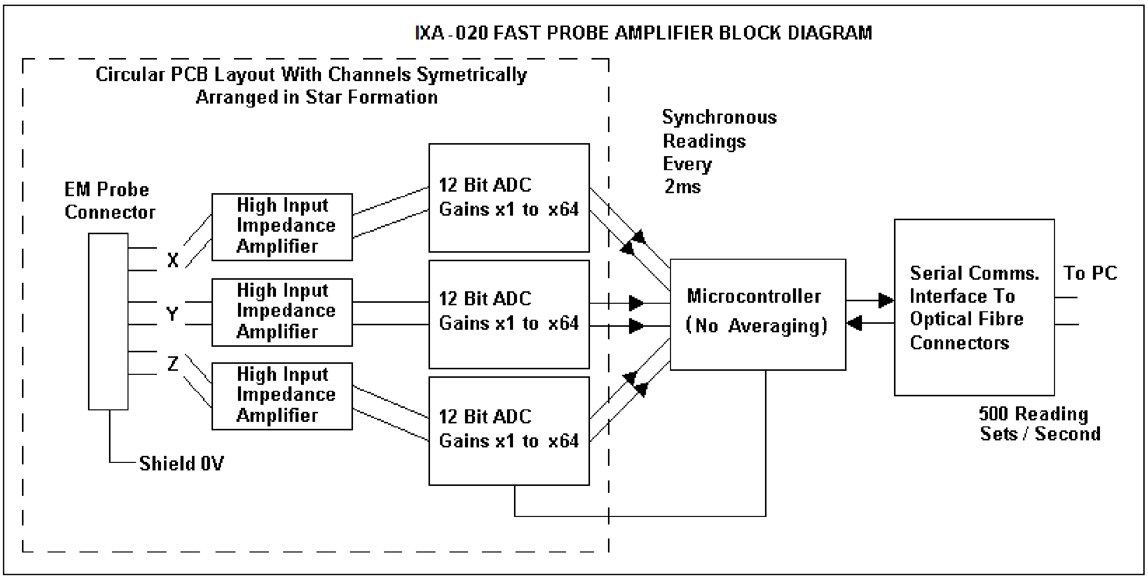

Figure 2 Schematic diagram of the fast amplifier

This amplifier has a time constant of approx. 50μs, which is much faster than the SAR probe response time. The overall system time constant is therefore that of the probe (<1ms) and a reading containing data for all three channels is returned to the PC every 2ms. The conversion period is approx. 1 μs at the start of each 2ms period. This enables the probe to follow pulse modulated signals of periods >>2ms. The PC software applies the linearisation procedure separately to each reading, so no linearisation corrections for the averaging of modulated signals are needed in this case.

The fast amplifier sampling rate can be adjusted via the SARA-C user interface from 1.7ms to 2.3ms. When not measuring CW signals, it is important to ensure that this probe reading rate and the modulated signal's pulse repetition rate are not unintentionally synchronised since this can lead to aliasing and a gross reduction in accuracy. For GSM signals, the default amplifier sampling rate of 2ms is entirely satisfactory, whereas changing it to 2.3ms (almost exactly half the GSM frame rate) could mean GSM bursts are always missed.

When aggregating 2ms samples to reduce the stochastic noise, it is equally important to match the number of samples with the longer-term timing structure of the modulation scheme. Taking GSM as an example again, since 120ms is the precise length of a GSM traffic channel multiframe, best practice would dictate that aggregated samples should cover exact multiples of this timescale. In this case, setting the number of samples to be aggregated to 120 (2 multiframes), or 240 samples (4 multiframes) should be ideal. Other signalling protocols would require changing these numbers as appropriate.

Phantoms

The Flat phantom used is a rectangular Perspex Box IndexSAR item IXB-2HF, dimensions 240 x 190 x 195mm (w x d x h). The base and one side wall are made of FR4 material which has specific dielectric properties and a tightly-controlled thickness. The base is used in tandem with straight probes, measuring either a DUT or a validation dipole, while the side wall is for performing validations with the L-probe. It is also feasible to perform measurements on body-worn devices with the L-probe against the side window, but only if the L-probe is suitably calibrated (ie if the measurement standard demands body and head fluids have the same dielectric properties).

The Specific Anthropomorphic Mannequin (SAM) Upright Phantom is fabricated using moulds generated from the CAD files as specified by CENELEC EN 62209-1: 2006.

2.1.3 SAR Measurement Procedure

Detailed measurement procedures for SARA-C are set out in a separate IndexSAR technical document ("SARA-C Operational Procedures"

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 the 110mm diameter penetration hole in the neck.

An area scan is performed inside the head at a fixed distance of 5mm from the curved surface on the source side. An algorithm presents the user with the location of any local hotspots and allows one to be selected for a follow-up 3D scan, looking at how the signal absorption varies with depth. A comparison between the start and end readings at a fixed distance from the DUT also enables the power drift during measurement to be assessed.

SARA-C Interpolation and Extrapolation schemes

SARA-C software contains support for both 2D cubic B-spline interpolation as well as 3D cubic B-spline interpolation. In addition, for extrapolation purposes, a proprietary curve-fitting routine is implemented as a weighted average of 3 different polynomial fits. The polynomial fitting procedures have been extensively tested by comparing the fitting coefficients generated by the SARA-C 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. 115mm 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.

Extrapolation of 3D scan

For the 3D scan, data are collected on a spatially regular, but conformal, 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). SARA-C enables full control over the selection of alternative step sizes in all directions.

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The overall accuracy of the 1g and 10g SAR volume average depends largely on the accuracy with which the probe can be re-positioned in the head. Although the digitised shape of the head is available to the SARA-C software, a better positioning solution is to use strain gauges attached to the L-probe to feel for the actual surface and to base all movements relative to this positive detection. An even more precise, but time-consuming, method is to place the probe tip in positive contact against the phantom wall, then step backwards 0.01mm at a time while monitoring the recorded SAR reading. At the exact moment that the probe detaches from contact, the SAR reading will suddenly fall.

After the data collection, the data are extrapolated up to the shell wall in the depth direction to assign values to points in the 3D array which cannot be measured in practice because of the finite size of the sensor tip. For automated measurements inside the head, the distance of the closest plane from the wall cannot be less than 2.7mm (for 5mm probes) and 1.39mm (for 2.5mm probes), this being the distance of the probe sensors behind the front edge of the probe tip.

Interpolation of 3D scan and volume averaging

The procedure used in SARA-C for defining the volumes used in SAR averaging 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 62209-1: 2006). This is called, here, the conformal scheme.

For each row of data in the depth direction, the data are extrapolated to the phantom wall, 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, one for 1g and the other for 10g masses, 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.

The default step size 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 EN 62209-1: 2006) is +/- 0.04mm.

2.1.4 Head Test Positions

This recommended practice specifies exactly two test positions for the handset against the head phantom, the “Cheek” position and the “tilted” position. The handset should be tested in both positions on the left and right sides of the SAM phantom. In each test position the centre of the earpiece of the device is placed directly at the entrance of the auditory canal. The angles mentioned in the test positions used are referenced to the line connecting both auditory canal openings. The plane this line is on is known as the reference plane. Testing is performed on the right and left-hand sides of the generic phantom head.

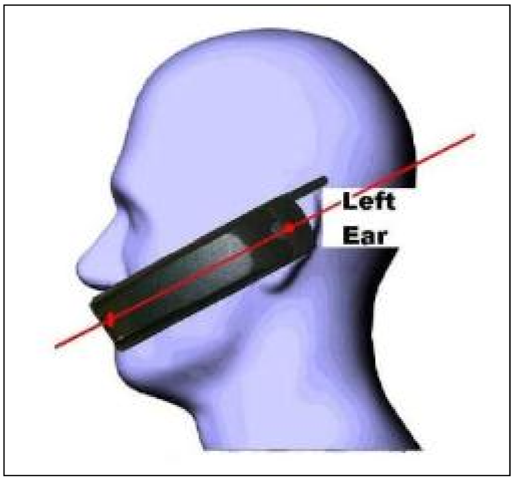

Figure 3 Side view of mobile next to head showing alignment

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The Cheek Position

The Cheek Position is where the mobile is in the reference plane and the line between the mobile and the line connecting both auditory canal openings is reduced until any part of the mobile touches any part of the generic twin phantom head.

The 15° Position

The 15° Position is where the mobile is in the reference Cheek position and the phone is kept in contact with the auditory canal at the earpiece; the bottom of the phone is then tilted away from the phantom mouth by 15°.

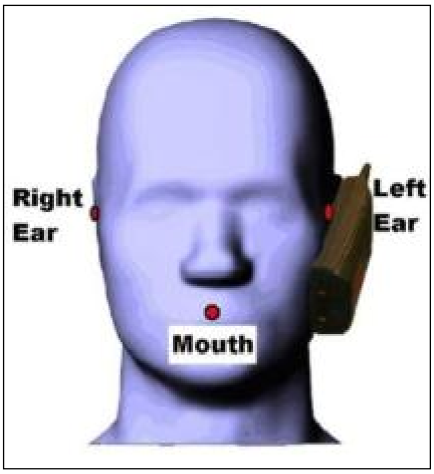

Figure 4 Cheek position

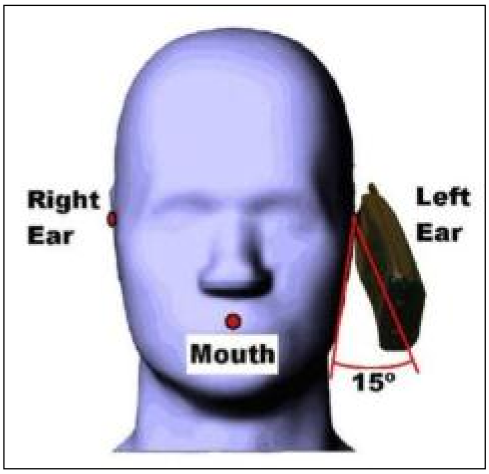

Figure 5 15º Tilt Position

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2.2 2481MHz BODY SAR TEST RESULTS AND COURSE AREA SCANS – 2D

SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	19/08/2014-11:05:26	DUT BATTERY MODEL/NO:	NA
AMBIENT TEMPERATURE:	22.80°C	LIQUID SIMULANT:	2450MHz
DEVICE UNDER TEST:	SOL7HDNTX-198270	RELATIVE PERMITTIVITY:	51.06
RELATIVE HUMIDITY:	31.80%	CONDUCTIVITY:	1.989
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	-39.20mm
DUT POSITION:	5mm-Rear Facing	MAX SAR Z-AXIS LOCATION:	-0.90mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	15.44
TEST FREQUENCY:	2481.0MHz	SAR 1g:	0.527 W/kg
TYPE OF MODULATION:	BPSK	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.549 W/kg
INPUT POWER LEVEL:	21dBm	SAR END:	0.526 W/kg
PROBE BATTERY LAST CHANGED:	19/08/2014	SAR DRIFT DURING SCAN:	-4.200 %

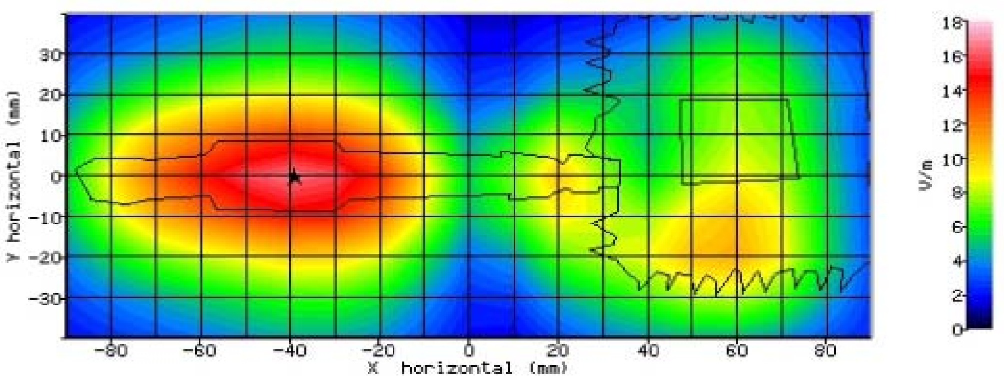

Figure 6: SAR Testing Results for the SOL7HDNTX-198270 Transmitter, Modulation Scheme NB/UMVL at 2481.0MHz.

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SYSTEM / SOFTWARE:	SARA-C / v6.09.08	INPUT POWER DRIFT:	0 dB
DATE / TIME:	19/08/2014-12:43:58	DUT BATTERY MODEL/NO:	NA
AMBIENT TEMPERATURE:	22.80°C	LIQUID SIMULANT:	2450MHz
DEVICE UNDER TEST:	SOL7HDNTX-198270	RELATIVE PERMITTIVITY:	51.06
RELATIVE HUMIDITY:	31.80%	CONDUCTIVITY:	1.989
PHANTOM S/NO:	IXB-2HF	LIQUID TEMPERATURE:	23.00°C
PHANTOM ROTATION:	N/A	MAX SAR Y-AXIS LOCATION:	-42.10mm
DUT POSITION:	5mm-Rear Facing	MAX SAR Z-AXIS LOCATION:	-0.10mm
ANTENNA CONFIGURATION:	N/A	MAX E FIELD:	16.68
TEST FREQUENCY:	2481.0MHz	SAR 1g:	0.630 W/kg
TYPE OF MODULATION:	16QAM	SAR 10g:	N/A
MODN. DUTY CYCLE:	100%	SAR START:	0.650 W/kg
INPUT POWER LEVEL:	21dBm	SAR END:	0.672 W/kg
PROBE BATTERY LAST CHANGED:	19/08/2014	SAR DRIFT DURING SCAN:	3.300 %

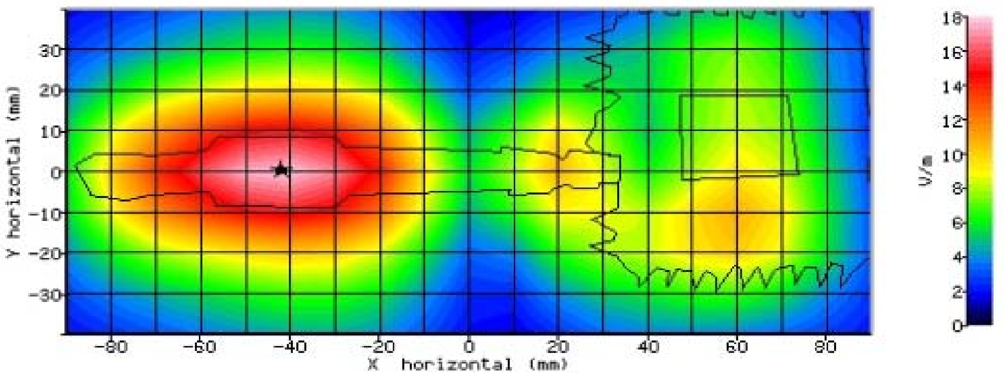

Figure 7: SAR Testing Results for the SOL7HDNTX-198270 Transmitter, Modulation Scheme DVB-T at 2481.0MHz.

SECTION 3

TEST EQUIPMENT USED

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3.1 TEST EQUIPMENT USED

The following test equipment was used at TÜV SÜD Product Service:

Instrument Description	Manufacturer	Model Type	TE Number	Cal Period (months)	Calibration Due Date
Power Sensor	Rohde & Schwarz	NRV-Z1	60	12	11-Jun-2015
Signal Generator	Hewlett Packard	ESG4000A	61	12	1-Jul-2015
Thermometer	Digitron	T208	64	12	29-Apr-2015
Amplifier (5GHz)	IndexSar Ltd	5GHz	157	-	TU
Directional Coupler	Hewlett Packard	11692D	452	-	TU
Attenuator (20dB, 10W)	Weinschel	37-20-34	482	12	17-Oct-2014
Dipole Positioner/Support (plastic)	IndexSar Ltd	IXH-020	1584	-	TU
Bi-directional Coupler	IndexSar Ltd	7401 (VDC0830-20)	2414	-	TU
Validation Amplifier (10MHz - 2.5GHz)	IndexSar Ltd	VBM2500-3	2415	-	TU
Hygromer	Rotronic	I-1000	2784	12	10-Apr-2015
Power Sensor	Rohde & Schwarz	NRV- Z5	2878	12	11-Jun-2015
Dual Channel Power Meter	Rohde & Schwarz	NRVD	3259	12	12-Jun-2015
SAR 835 MHz dipole	Speag	D835V2	3857	36	19-Feb-2017
Part of SARAC System	IndexSar Ltd	Cartesian Leg Extension	4078	-	TU
Cartesian 4-axis Robot	IndexSar Ltd	SARAC	4079	-	TU
Part of SARAC System	IndexSar Ltd	White Benchtop	4080	-	TU
Part of SARAC System	IndexSar Ltd	Wooden Bench	4081	-	TU
hold DUT to base of flat phantom.	IndexSar Ltd	Body Testing Platform	4262	-	TU
Immersible SAR Probe	IndexSar Ltd	IPX-050	4313	24	7-Mar-2015
Flat Phantom	IndexSar Ltd	IXB-2HF 700-6000MHz	4399	-	TU
Flat Phantom	IndexSar Ltd	IXB-2HF 700-6000MHz	4400	-	TU
Power Sensor	Rohde & Schwarz	NRV-Z1	60	12	11-Jun-2015
2450MHz Body Fluid	IndexSar Ltd	Batch 7	N/A	1	08-Sep-2014

TU – Traceability Unscheduled

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3.2 TEST SOFTWARE

The following software was used to control the TÜV SÜD Product Service SARAC System.

Instrument	Version Number	Date
SARA-C system	v.6.09.08	23 July 2014
Probe amplifier GLP2	Version 1	-

Product Service

3.3 DIELECTRIC PROPERTIES OF SIMULANT LIQUIDS

The fluid properties of the simulant fluids used during routine SAR evaluation meet the dielectric properties required KDB 865665.

IEEE 1528 Recipes

Frequency (MHz)	300	450		835	900			1450	1800				1900		1950	2000	2100		2450		3000
Recipe#	1	1	3	1	1	2	3	1	1	2	2	3	1	2	4	1	1	2	2	3	2
Ingredients (% by weight)																					
1, 2-Propanediol						64.81															
Bactericide	0.19	0.19	0.50	0.10	0.10		0.50													0.50	
Diacetin			48.90				49.20													49.45	
DGBE								45.41	47.00	13.84	44.92		44.94	13.84	45.00	50.00	50.00	7.99	7.99		7.99
HEC	0.98	0.96		1.00	1.00																
NaCl	5.95	3.95	1.70	1.45	1.48	0.79	1.10	0.67	0.36	0.35	0.18	0.64	0.18	0.35				0.16	0.16		0.16
Sucrose	55.32	56.32		57.00	56.50																
Triton X-100										30.45				30.45				19.97	19.97		19.97
Water	37.56	38.56	48.90	40.45	40.92	34.40	49.20	53.80	52.64	55.36	54.90	49.43	54.90	55.36	55.00	50.00	50.00	71.88	71.88	49.75	71.88
Measured dielectric parameters																					
ε_r'	46.00	43.40	44.30	41.60	41.20	41.80	42.70	40.9	39.3	41.00	40.40	39.20	39.90	41.00	40.10	37.00	36.80	41.10	40.30	39.20	37.90
σ (S/m)	0.86	0.85	0.90	0.90	0.98	0.97	0.99	1.21	1.39	1.38	1.40	1.40	1.42	1.38	1.41	1.40	1.51	1.55	1.88	1.82	2.46
Temp (ºC)	22	22	20	22	22	22	20	22	22	21	22	20	21	21	20	22	22	20	20	20	20
Target dielectric parameters (Table 2)																					
ε_r'	45.30	43.50		41.5	41.50			40.50	40.00								39.80		39.20		38.50
σ (S/m)	0.87	0.87		0.9	0.97			1.20	1.40								1.49		1.80		2.40

NOTE – Multiple columns for any single frequency are optional recipe #, reference: 1 (Kanda et al. [B185]), 2 (Vigneras [B143]), 3 (Peyman and Gabriel [B119]), 4 (Fukunaga et al [B50])

The dielectric properties of the tissue simulant liquids used for the SAR testing at TÜV SÜD Product Service are as follows:-

Fluid Type and Frequency	Relative Permittivity εR (ε') Target	Relative Permittivity εR (ε') Measured	Conductivity σ Target	Conductivity σ Measured
2450MHz Body	52.7	51.06	1.95	1.989

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3.4 TEST CONDITIONS

3.4.1 Test Laboratory Conditions

Ambient temperature: Within +15°C to +35°C.
The actual temperature during the testing ranged from 22.8°C to 22.8°C.
The actual humidity during the testing ranged from 31.8% to 31.8% RH.

3.4.2 Test Fluid Temperature Range

Frequency	Body / Head Fluid	Min Temperature °C	Max Temperature °C
2450MHz	Body	23.0	23.0

3.4.3 SAR Drift

The SAR Drift was within acceptable limits during scans. The maximum SAR Drift, drift due to the handset electronics, was recorded as 4.2% (1.043 dB). The measurement uncertainty budget for this assessment includes the maximum SAR Drift figures.

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3.5 MEASUREMENT UNCERTAINTY

Source of Uncertainty	IEEE P1528 Description	Tolerance / Uncertainty ± %	Probability distribution	Div	c_i (1g)	Standard Uncertainty ± % (1g)	v_i or v_{eff}
Measurement System							
Probe calibration	E.2.1	6.20	N	1	1	6.20	∞
Axial Isotropy	E.2.2	3.50	R	1.73	0.7071	1.43	∞
Hemispherical Isotropy	E.2.2	9.60	R	1.73	0.7071	3.92	∞
Boundary effect	E.2.3	0.49	R	1.73	1	0.28	∞
Linearity	E.2.4	1.60	R	1.73	1	0.92	∞
Detection limits	E.2.4	4.75	R	1.73	1	2.74	∞
Modulation response	E.2.5	1.20	R	1.73	1	0.69	∞
Readout electronics	E.2.6	0.05	N	1	1	0.05	∞
Response time	E.2.7	0.00	R	1.73	1	0.00	∞
Integration time	E.2.8	1.50	N	1.00	1	1.50	∞
RF ambient conditions - noise	E.6.1	3.00	R	1.73	1	1.73	∞
RF ambient conditions - reflections	E.6.1	3.00	R	1.73	1	1.73	∞
Probe positioner mech. restrictions	E.6.2	1.50	R	1.73	1	0.87	∞
Probe positioning with respect to phantom shell	E.6.3	0.34	R	1.73	1	0.20	∞
Post-processing	E.5	2.00	R	1.73	1	1.15	∞
Test sample related							
Device holder uncertainty	E.4.1	5.1	N	1	1	3.90	9.00
Test sample positioning	E.4.2	2.4	N	1	1	2.30	9.00
Input Power and SAR Drift	E.2.9	4.2	R	1.73	1	2.42	∞
Phantom and set-up							
Phantom uncertainty (shape, thickness & permittivity tolerances)	E.3.1	2.00	R	1.73	1	1.15	∞
							∞
Uncertainty in SAR correction for deviations in permittivity and conductivity	E.3.2	1.20	N	1.00	0.808	1.20	∞
Liquid conductivity measurement	E.3.3	1.31	N	1	0.71	1.02	∞
Liquid permittivity measurement	E.3.3	1.27	N	1	0.26	0.29	∞
Liquid conductivity - temperature uncertainty	E.3.4	0.00	R	1.73	0.71	0.00	∞
Liquid permittivity - temperature uncertainty	E.3.4	0.00	R	1.73	0.26	0.00	∞
Combined standard uncertainty			RSS			10.27	
Expanded uncertainty (95% confidence interval)			K=2			21.54	

SECTION 4

ACCREDITATION, DISCLAIMERS AND COPYRIGHT

4.1 ACCREDITATION, DISCLAIMERS AND COPYRIGHT

This report relates only to the actual item/items tested.

Our UKAS Accreditation does not cover opinions and interpretations and any expressed are outside the scope of our UKAS Accreditation.

Results of tests not covered by our UKAS Accreditation Schedule are marked NUA (Not UKAS Accredited).

ANNEX A

PROBE CALIBRATION REPORT

Product Service

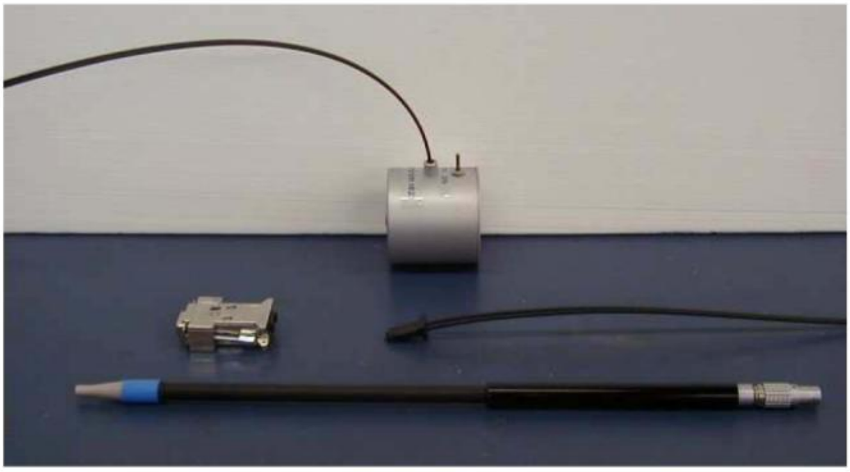
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 050

S/N 0204

April 2013



Indexsar Limited
Oakfield House
Cudworth Lane
Newdigate
Surrey RH5 5BG
Tel: +44 (0) 1306 632 870
Fax: +44 (0) 1306 631 834
e-mail: enquiries@indexsar.com

Product Service

Indexsar Limited
Oakfield House
Cudworth Lane
Newdigate
Surrey RH5 5BG
Tel: +44 (0) 1306 632 870
Fax: +44 (0) 1306 631 834
e-mail: enquiries@indexsar.com

Calibration Certificate 1304/0204
Date of Issue: 23rd April 2013
Immersible SAR Probe

Type:	IXP-050
Manufacturer:	IndexSAR, UK
Serial Number:	0204
Place of Calibration:	IndexSAR, UK
Date of Receipt of Probe:	N/A
Calibration Dates:	14th January – 7th March 2013
Customer:	TUV Sud

IndexSAR Ltd hereby declares that the IXP-050 Probe named above has been calibrated for conformity to the current versions of IEEE 1528, IEC 62209-1, IEC 62209-2, and FCC OET65 standards using the methods described in this calibration document. Where applicable, the standards used in the calibration process are traceable to the UK's National Physical Laboratory.

Calibrated by:	A. Brinklow	**Technical Manager**
Approved by:	[signature]	**Director**

Please keep this certificate with the calibration document. When the probe is sent for a calibration check, please include the calibration document.

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INTRODUCTION

Straight probes can work on either SARA-C (to measure SAR values in flat phantoms containing Body tissue simulant fluid) or on SARA2 (where they can measure either in a flat phantom with Body fluid, or in a SAM phantom containing Head fluid).

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N 0204) for use on SARA-C only. **The calibration factors do not apply to, and will not give correct readings on, the IndexSAR SARA2 system.**

Indexsar probes are characterised using procedures that, where applicable, follow the recommendations of IEC 62209-1 [Ref 1], IEEE 1528 [Ref 2], IEC 62209-2 [Ref 3] and FCC OET65 [Ref 4] standards. The procedures incorporate techniques for probe linearisation, isotropy assessment and determination of liquid factors (conversion factors). Calibrations are determined by comparing probe readings with analytical computations in canonical test geometries (waveguides) using normalised power inputs.

Each step of the calibration procedure and the equipment used is described in the sections below.

CALIBRATION PROCEDURE

1. Objectives

The calibration process comprises the following stages

1) Determination of the channel sensitivity factors which optimise the probe's overall axial isotropy in 900MHz brain fluid

2) Measure the incidental spherical isotropy using these derived channel sensitivity factors.

3) Since isotropy and channel sensitivity factors are frequency independent, these channel sensitivity factors can be applied to model the exponential decay of SAR in a waveguide fluid cell at each frequency of interest, and hence derive the liquid conversion factors at that frequency.

2. Probe output

The probe channel output signals are linearised in the manner set out in Refs [1] - [4]. The following equation is utilized for each channel:

$$U_{lin} = U_{o/p} + U_{o/p}{}^{2} / DCP \qquad (1)$$

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

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-020 probes with CW signals the DCP values are typically 100mV.

For this value of DCP, the typical linearity response of IXP-050 probes to CW and to GSM modulation is shown in Figure 7, along with departures of this same dataset from linearity.

In turn, measurements of E-field are determined using the following equation:

$$E_{liq}^2 \text{ (V/m)} = U_{linx} * \text{Air Factor}_x * \text{Liq Factor}_x + U_{liny} * \text{Air Factor}_y * \text{Liq Factor}_y + U_{linz} * \text{Air Factor}_z * \text{Liq Factor}_z \qquad (3)$$

Here, "Air Factor" represents each channel's sensitivity, while "Liq Factor" represents the enhancement in signal level when the probe is immersed in tissue-simulant liquids at each frequency of interest.

3. Selecting channel sensitivity factors to optimise isotropic response

Within SARA-C, an L-probe's predominant mode of operation is with the tip pointing directly towards the source of radiation. Consequently, optimising the probe's response to boresight signals ("axial isotropy") is far more important than optimising its spherical isotropy (where the direction, as well as the polarisation angle, of the incoming radiation must be taken into account).

The setup for measuring the probe's axial isotropy is shown in **Error! Reference source not found.**. Since isotropy is frequency-independent, measurements are normally made at a frequency of 900MHz as lower frequencies are more tolerant of positional inaccuracies.

A 900MHz waveguide containing head-fluid simulant is selected. Like all waveguides used during probe calibration, this particular waveguide contains two distinct sections: an air-filled launcher section, and a liquid cell section, separated by a dielectric matching window designed to minimise reflections at the air-liquid interface.

The waveguide stands in an upright position and the liquid cell section is filled with 900MHz brain fluid to within 10 mm of the open end. The depth of liquid ensures there is negligible radiation from the waveguide open top and that the probe calibration is not influenced by reflections from nearby objects.

During the measurement, a TE_{01} mode is launched into the waveguide by means of an N-type-to-waveguide adapter. The probe is then lowered vertically into the liquid until the tip is exactly 10mm above the centre of the dielectric window. This particular separation ensures that the probe is operating in a part of the waveguide where boundary corrections are not necessary.

Care must also be taken that the probe tip is centred while rotating.

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The exact power applied to the input of the waveguide during this stage of the probe calibration is immaterial since only relative values are of interest while the probe rotates. However, the power must be sufficiently above the noise floor and free from drift.

The dedicated Indexsar calibration software rotates the probe in 10 degree steps about its axis, and at each position, an Indexsar 'Fast' amplifier samples the probe channels 500 times per second for 0.4 s. The raw $U_{o/p}$ data from each sample are packed into 10 bytes and transmitted back to the PC controller via an optical cable. U_{linx}, U_{liny} and U_{linz} are derived from the raw $U_{o/p}$ values and written to an Excel template.

Once data have been collected from a full probe rotation, the Air Factors are adjusted using a special Excel Solver routine to equalise the output from each channel and hence minimise the axial isotropy. This automated approach to optimisation removes the effect of human bias.

Figure 2 represents the output from each diode sensor as a function of probe rotation angle.

4. Measurement of Spherical Isotropy

As mentioned earlier, in SARA-C a straight probe is always positioned so as to be end-on to the incoming signal source. The probe's axial isotropy response is therefore far more important than its spherical isotropy, which is included here for completeness only.

The setup for assessing the probe's spherical isotropy is shown in Figure 1.

A box phantom containing 900MHz head fluid is irradiated by a tuned dipole, mounted to the side of the phantom on the SARA2 robot's seventh axis. During calibration, the spherical response is generated by rotating the probe about its axis in 15 degree steps and changing the dipole polarisation in 10 degree steps.

The relative channel sensitivities are fixed by the earlier measurement of, and optimisation for, axial isotropy. The effect on spherical isotropy is shown in Figure 3.

5. Determination of Conversion ("Liquid") Factors at each frequency of interest

A lookup table of conversion factors for a probe allows a SAR value to be derived at the measured frequencies, and for either brain or body fluid-simulant.

The method by which the conversion factors are assessed is based on the comparison between measured and analytical rates of decay of SAR with height above a dielectric window. This way, not only can the conversion factors for that frequency/fluid combination be determined, but an allowance can also be made for the scale and range of boundary layer effects.

The theoretical relationship between the SAR at the cross-sectional centre of the lossy waveguide as a function of the longitudinal distance (z) from the

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dielectric separator is given by Equation 4:

$$SAR(z) = \frac{4(P_f - P_b)}{\rho ab\delta} e^{-2z/\delta} \quad (4)$$

Here, the density ρ is conventionally assumed to be 1000 kg/m^3, *ab* is the cross-sectional area of the waveguide, and P_f and P_b are the forward and reflected power inside the lossless section of the waveguide, respectively. The penetration depth δ (which is the reciprocal of the waveguide-mode attenuation coefficient) is a property of the lossy liquid and is given by Equation (5).

$$\delta = \left[\mathrm{Re}\left\{ \sqrt{(\pi / a)^2 + j\omega\mu_o(\sigma + j\omega\varepsilon_o\varepsilon_r)} \right\} \right]^{-1} \quad (5)$$

where σ is the conductivity of the tissue-simulant liquid in S/m, ε_r is its relative permittivity, and ω is the radial frequency (rad/s). Values for σ and ε_r are obtained prior to each waveguide test using an Indexsar DiLine measurement kit, which uses the TEM method as recommended in [2]. σ and ε_r are both temperature- and fluid-dependent, so are best measured using a sample of the tissue-simulant fluid immediately prior to the actual calibration.

Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at 22 $\pm$ 2.0°C; if this is not possible, the values of σ and ε_r should reflect the actual temperature. Values employed for calibration are listed in the tables below.

By ensuring the liquid height in the waveguide is at least three penetration depths, reflections at the upper surface of the liquid are negligible. The power absorbed in the liquid is therefore determined solely from the waveguide forward and reflected power.

Different waveguides are used for 700MHz, 835/900MHz, 1450MHz, 1800/1900MHz, 2100/2450/2600MHz and 5200/5800MHz measurements. Table A.1 of [1] can be used for designing calibration waveguides with a return loss greater than 20 dB at the most important frequencies used for personal wireless communications, and better than 15dB for frequencies greater than 5GHz. Values for the penetration depth for these specific fixtures and tissue-simulating mixtures are also listed in Table A.1.

According to [1], this calibration technique provides excellent accuracy, with standard uncertainty of less than 3.6% depending on the frequency and medium. The calibration itself is reduced to power measurements traceable to a standard calibration procedure. The practical limitation to the frequency band of 800 to 5800 MHz because of the waveguide size is not severe in the context of compliance testing.

During calibration, the probe is lowered carefully until it is just touching the cross-sectional centre of the dielectric window. 200 samples are then taken and written to an Excel template file before moving the probe vertically

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upwards. This cycle is repeated 150 times. The vertical separation between readings is determined from practical considerations of the expected SAR decay rate, and range from 0.2mm steps at low frequency, through 0.1mm at 2450MHz, down to 0.05mm at 5GHz.

Once the data collection is complete, a Solver routine is run which optimises the measured-theoretical fit by varying the conversion factor, and the boundary correction size and range.

For calibrations at 450MHz, where waveguide calibrations become unfeasible, a full 3D SAR scan over a tuned dipole is performed, and the conversion factor adjusted to make the measured 1g and 10g volume-averaged SAR values agree with published targets.

CALIBRATION FACTORS MEASURED FOR PROBE S/N 0204

The probe was calibrated at 450, 835, 900, 1800, 2100, 2450 and 2600MHz in liquid samples representing brain and body liquid at these frequencies.

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 axial isotropy of the probe was measured by rotating the probe about its axis in 10 degree steps through 360 degrees in this orientation.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 2.7 mm from the probe tip in the direction of the probe amplifier. A value of 2.7 mm should be used for the tip to sensor offset distance in the software. The distance of 2.7mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 8).

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.

CALIBRATION EQUIPMENT

The table on page 20 indicates the calibration status of all test equipment used during probe calibration.

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MEASUREMENT UNCERTAINTIES

A complete measurement uncertainty analysis for the SARA-C measurement system has been published in Reference [6]. Table 17 from that document is re-created below, and lists the uncertainty factors associated just with the calibration of probes.

Source of uncertainty	Uncertainty value ± %	Probability distribution	Divisor	c_i	Standard uncertainty ui ± %	v_i or v_{eff}
Forward power	3.92	N	1.00	1	3.92	∞
Reflected power	4.09	N	1.00	1	4.09	∞
Liquid conductivity	1.308	N	1.00	1	1.31	∞
Liquid permittivity	1.271	N	1.00	1	1.27	∞
Field homgeneity	3.0	R	1.73	1	1.73	∞
Probe positioning	0.22	R	1.73	1	0.13	∞
Field probe linearity	0.2	R	1.73	1	0.12	∞
Combined standard uncertainty		**RSS**			**6.20**	

At the 95% confidence level, therefore, the expanded uncertainty is ±12.4%

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SUMMARY OF CAL FACTORS FOR PROBE IXP-020 S/N 0204

Relative Channel Sensitivities (to optimise Axial Isotropy)				
	X	Y	Z	
Air Factors	91.78	66.90	81.32	$(V/m)^2/mV$
DCPs	100	100	100	mV

Measured Isotropy	(+/-) dB
Axial Isotropy	0.02
Spherical Isotropy	0.66

Additional Information	
Sensor offset (mm)	2.7
Elbow – Tip dimension (mm)	0.0

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SAR Conversion Factors/ Boundary Corrections							
	Head Fluid			Body Fluid			
Frequency* (MHz)	**SAR Conv Factor**	**Boundary Correction f(0)**	**Boundary Correction d(mm)**	**SAR Conv Factor**	**Boundary Correction f(0)**	**Boundary Correction d(mm)**	**Notes**
450	0.317	0	1	0.317	0	1	3
700	-	-	-	-	-	-	-
835	0.310	1.69	1.08	0.327	0.59	1.91	1,2
900	0.313	0.80	1.52	0.327	1.17	1.31	1,2
1450	-	-	-	-	-	-	-
1800	0.357	0.77	1.68	0.381	0.64	2.07	1,2
1900	0.366	0.71	1.83	0.388	0.64	2.12	1,2
2100	0.397	0.70	1.96	0.413	0.78	1.86	1,2
2450	0.397	1.09	1.44	0.440	1.09	1.51	1,2
2600	0.394	1.26	1.35	0.449	1.17	1.46	1,2
Notes							
1)	Calibrations done at 22°C +/-2°C						
2)	Waveguide calibration						
3)	By validation						

* The valid frequency of SARA-C probe calibrations are ±100MHz (F<300MHz) and ±200MHz (F>300MHz).

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PROBE SPECIFICATIONS

Indexsar probe 0204, along with its calibration, is compared with BSEN 62209-1 and IEEE standards recommendations (Refs [1] and [2]) in the Tables below. A listing of relevant specifications is contained in the tables below:

Dimensions	S/N 0204	BSEN [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 centers (mm)	2.7		

Typical Dynamic range	S/N 0204	BSEN [1]	IEEE [2]
Minimum (W/kg)	0.01	<0.02	0.01
Maximum (W/kg) N.B. only measured to > 100 W/kg on representative probes	>100	>100	100

Isotropy (measured at 900MHz)	S/N 0204	BSEN [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB)	0.02	0.5	0.25
Spherical isotropy covering all orientations to source (+/- dB)	0.66	N/A	N/A

NB Isotropy is frequency independent

Construction	Each probe contains three orthogonal dipole sensors arranged on a triangular prism core, protected against static charges by built-in shielding, and covered at the tip by PEEK cylindrical enclosure material. No adhesives are used in the immersed section. Outer case materials are PEEK and heat-shrink sleeving.
Chemical resistance	Tested to be resistant to TWEEN20 and sugar/salt-based simulant liquids but probes should be removed, cleaned and dried when not in use. NOT recommended for use with glycol or soluble oil-based liquids.

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REFERENCES

References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.

For a specific reference, subsequent revisions do not apply.

For a non-specific reference, the latest version applies.

[1] IEC 62209-1.
Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices — Human models, instrumentation, and procedures — Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)

[2] IEEE 1528
Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques

[3] IEC 62209-2
Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, Instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)

[4] FCC OET65
Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

[5] Indexsar Report IXS-0300, October 2007.
Measurement uncertainties for the SARA2 system assessed against the recommendations of BS EN 62209-1:2006

[6] SARA-C SAR Testing System: Measurement Uncertainty, v1.0.3. October 2011.

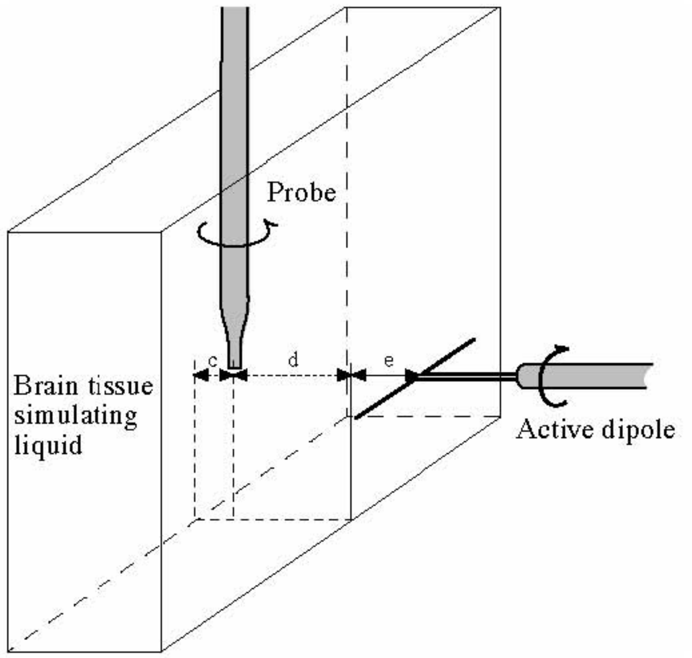

Figure 1. Spherical isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

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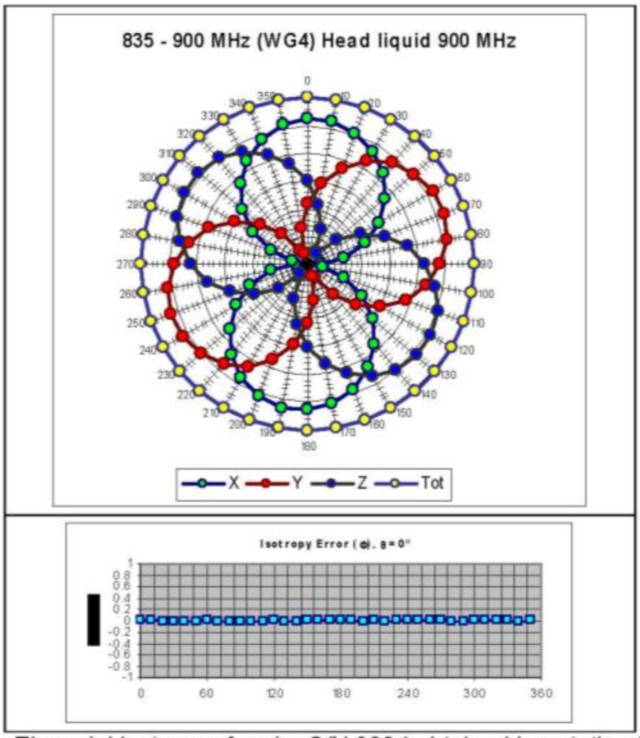

Figure 2. The axial isotropy of probe S/N 0204 obtained by rotating the probe in a liquid-filled waveguide at 900 MHz. (NB Axial Isotropy is frequency independent)

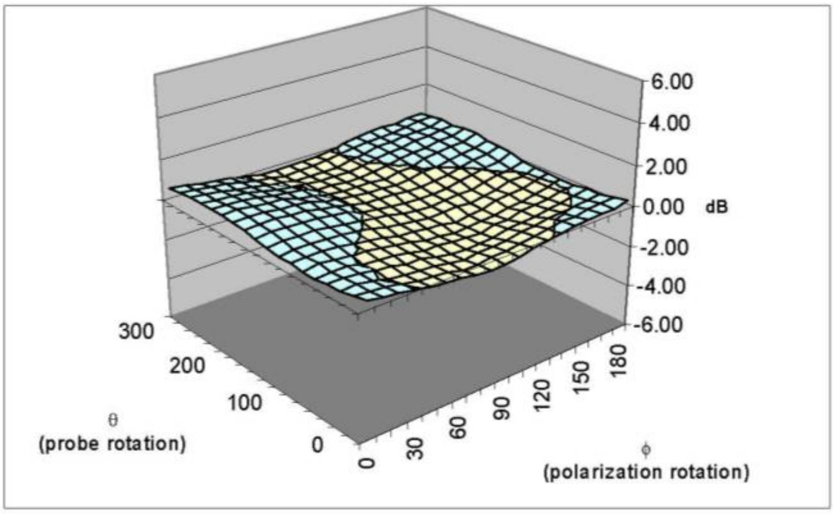

Figure 3 Spherical isotropy diagram after optimisation of relative channel sensitivities for axial isotropy

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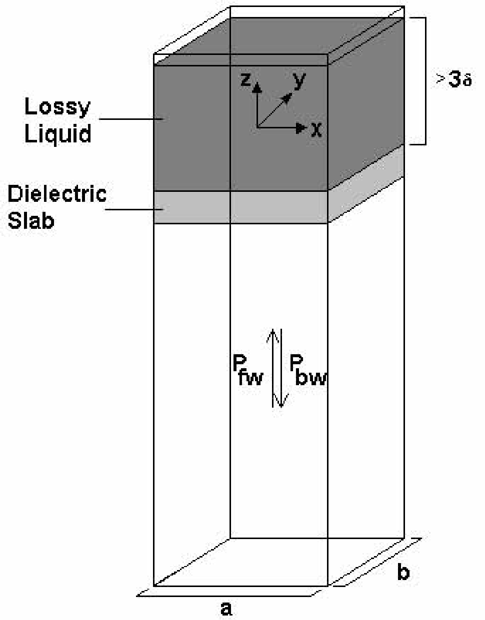

Figure 4. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

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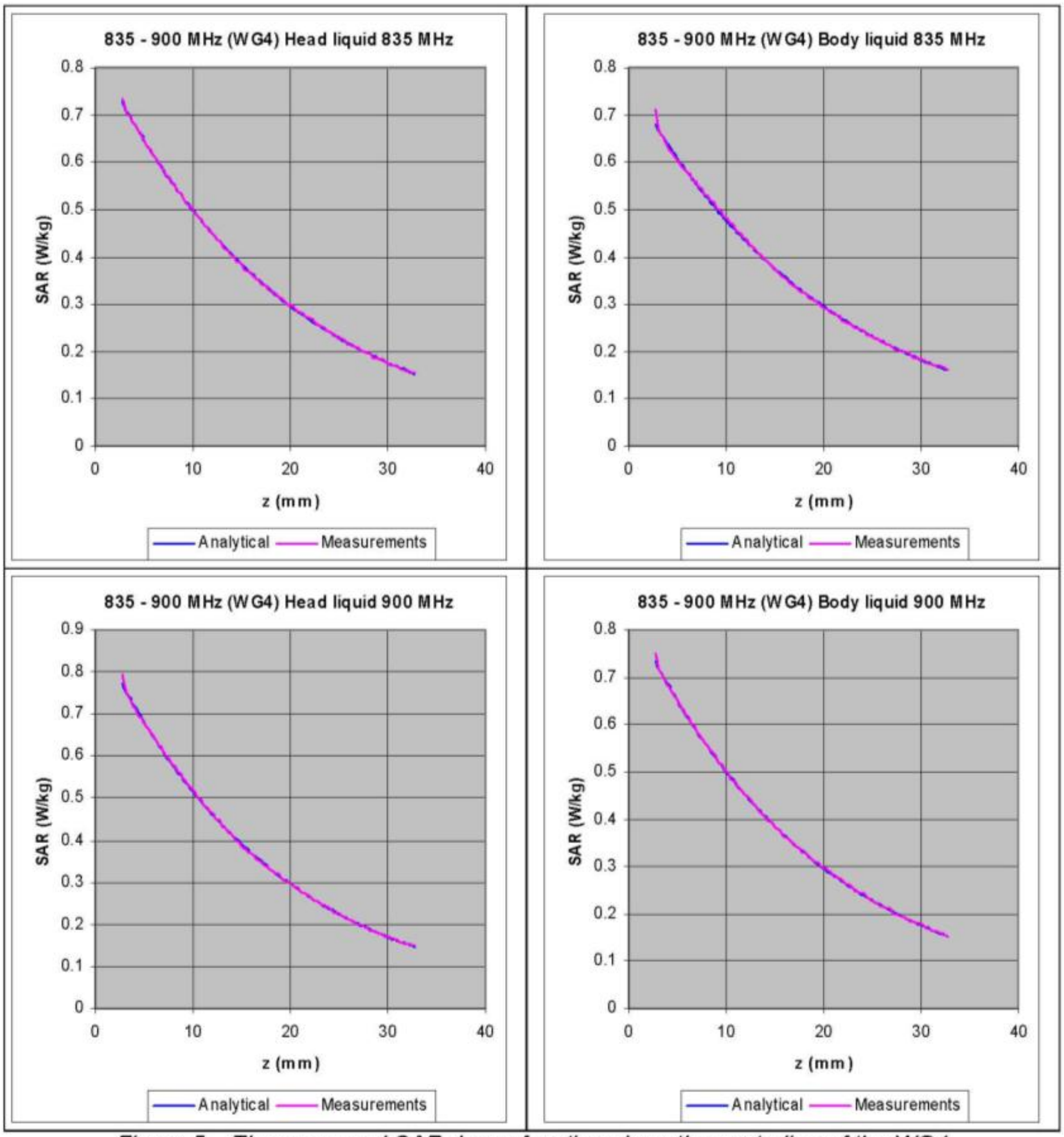

Figure 5 . The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

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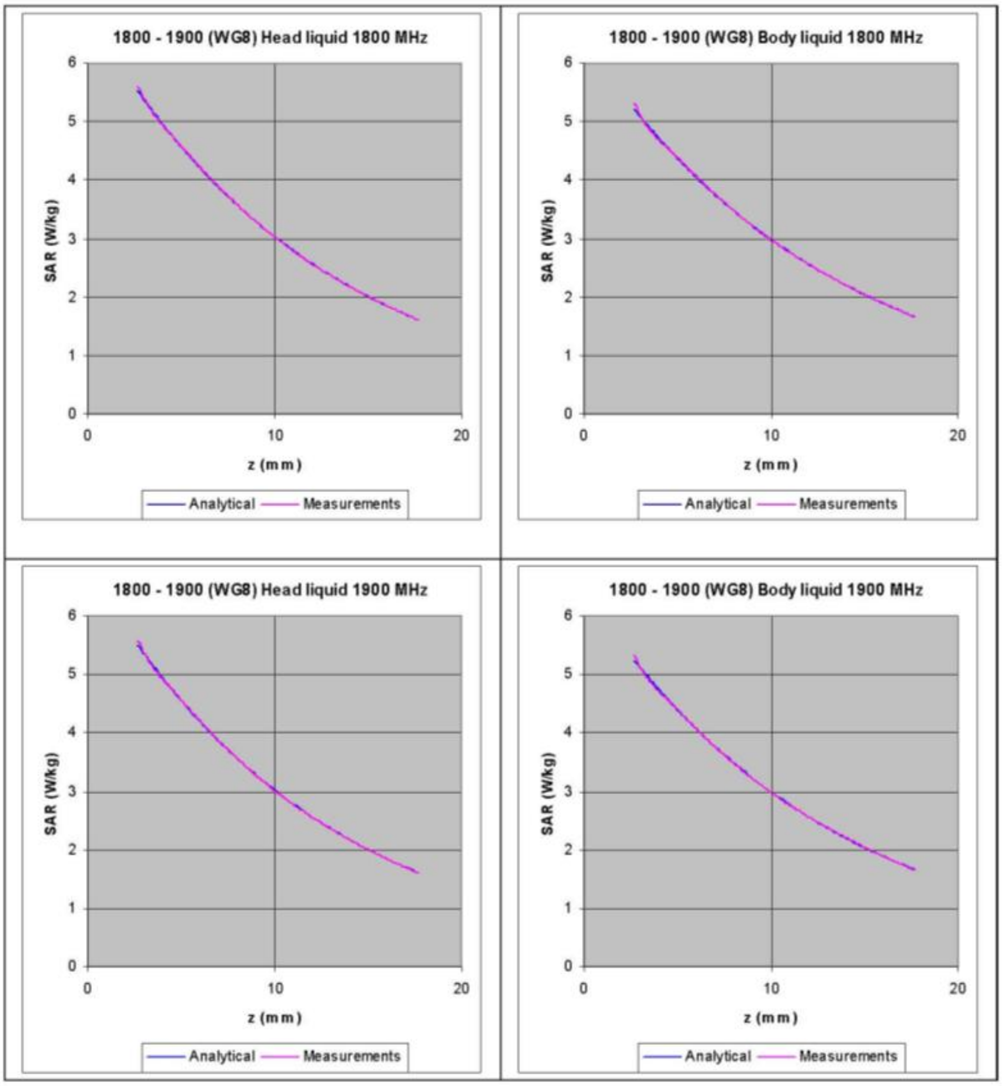

1800 - 1900 (WG8) Head liquid 1800 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements
1800 - 1900 (WG8) Body liquid 1800 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements
1800 - 1900 (WG8) Head liquid 1900 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements
1800 - 1900 (WG8) Body liquid 1900 MHz
SAR (W/kg)
z (mm)
Analytical
Measurements

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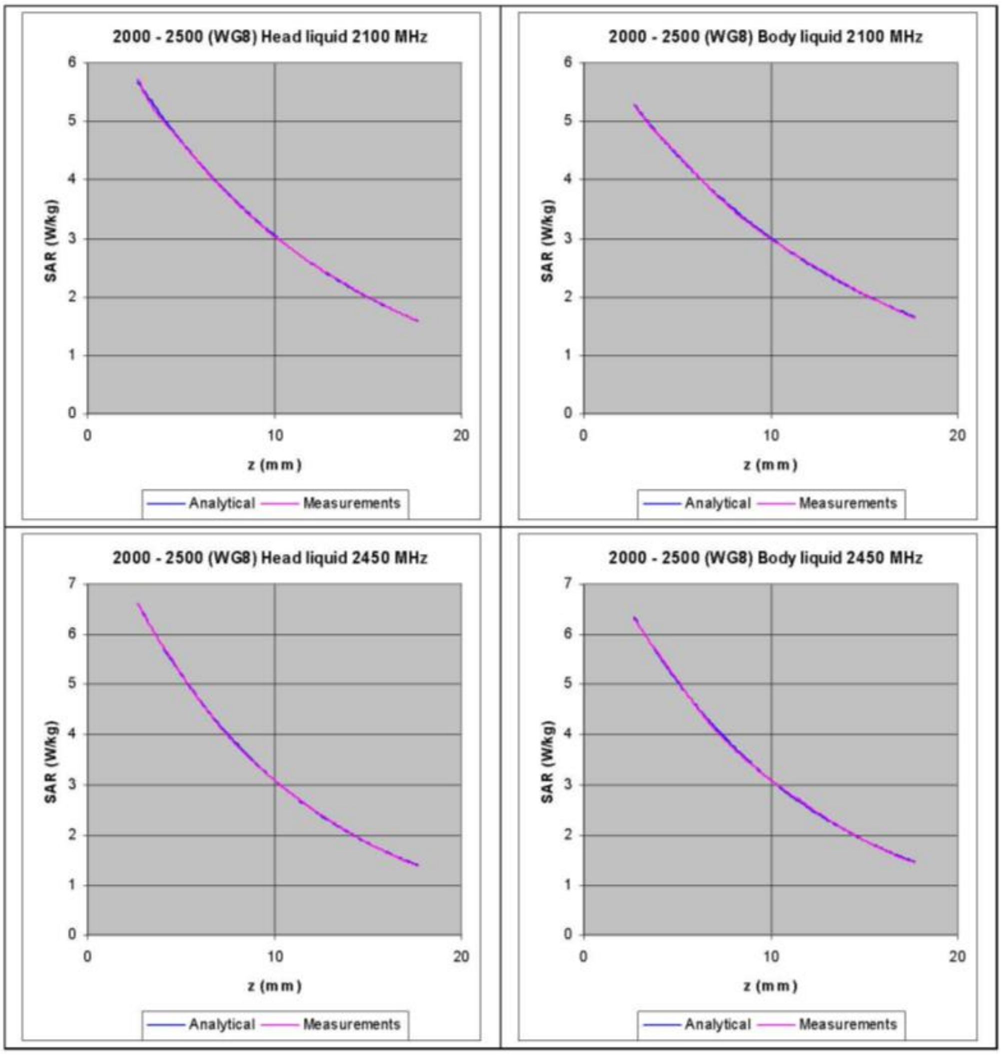

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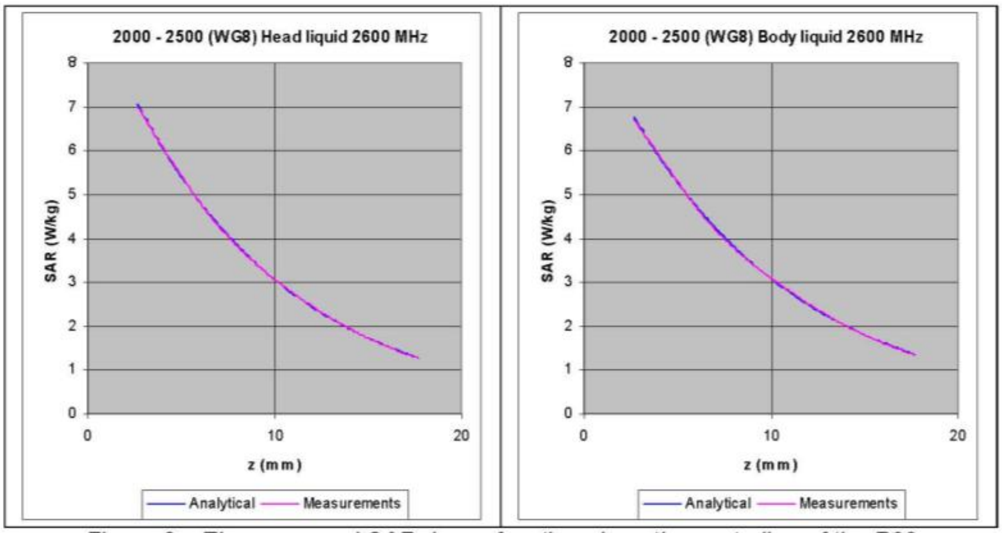

Figure 6 . The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

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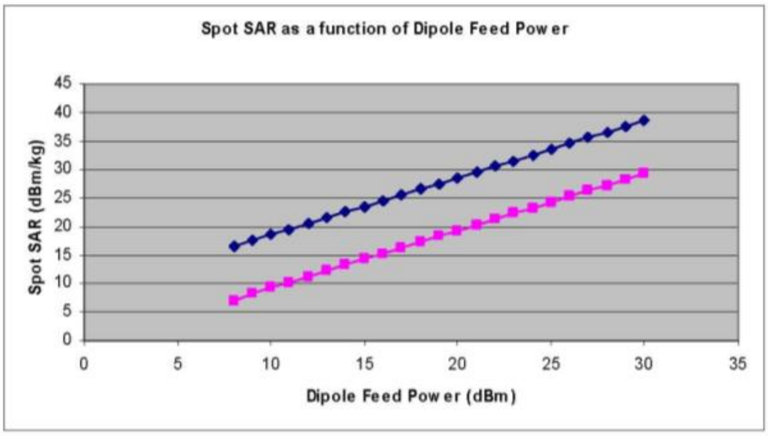

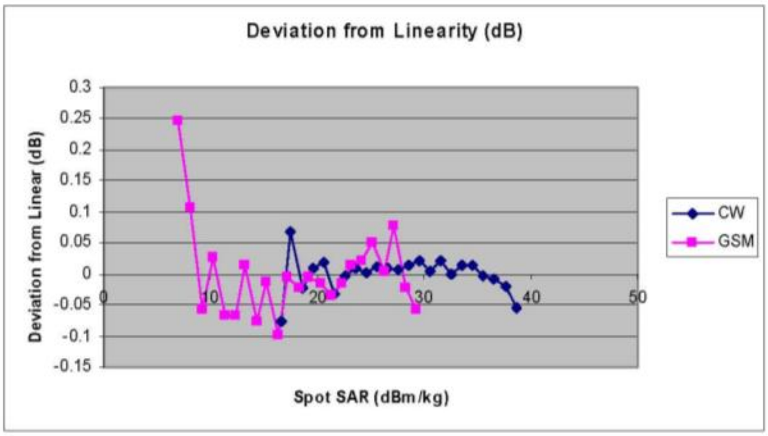

Figure 7 : The typical linearity response of IXP-050 probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of 8 (ie 9dB) lower than CW. The lower diagram shows the departure from linearity of the same two datasets.

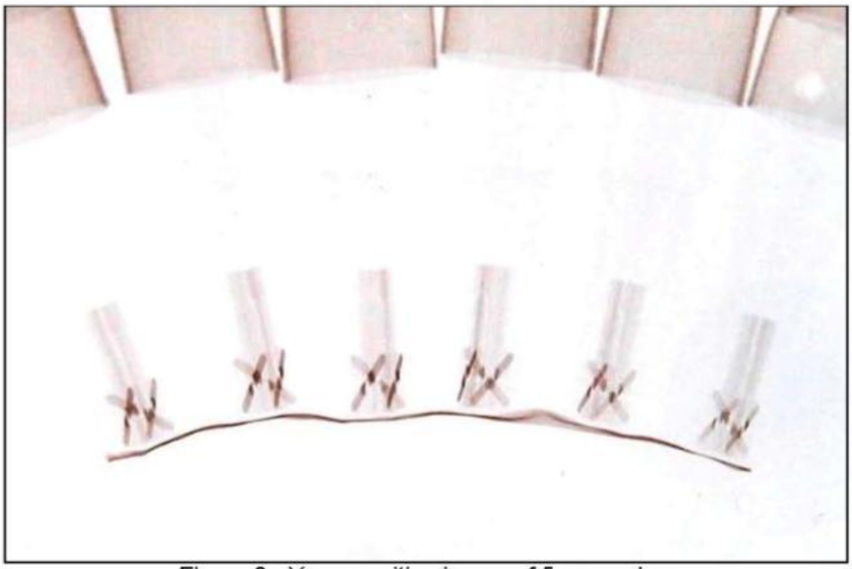

Figure 8 : X-ray positive image of 5mm probes

Product Service

Table indicating the dielectric parameters of the liquids used for calibrations at each frequency

Frequency (MHz)	Fluid Type	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity	Relative Permittivity	Conductivity
450	Head	44.33	0.835	43.5	0.87	1.9	-4.0	Pass	Pass
835		42.25	0.900	41.5	0.90	1.8	0.0	Pass	Pass
900		41.45	0.962	41.5	0.97	-0.1	-0.8	Pass	Pass
1800		39.92	1.395	40.0	1.40	-0.2	-0.4	Pass	Pass
1900		39.67	1.400	40.0	1.40	-0.8	0.0	Pass	Pass
2100		40.96	1.500	39.8	1.49	2.9	0.7	Pass	Pass
2450		39.81	1.821	39.2	1.80	1.6	1.2	Pass	Pass
2600		39.30	1.971	39.0	1.96	0.8	0.6	Pass	Pass
450	Body	57.53	0.902	56.7	0.94	1.5	-3.7	Pass	Pass
835		55.14	0.958	55.2	0.97	-0.1	-1.2	Pass	Pass
900		54.53	1.023	55	1.05	-0.9	-2.6	Pass	Pass
1800		53.07	1.521	53.3	1.52	-0.4	0.1	Pass	Pass
1900		52.85	1.533	53.3	1.52	-0.8	0.9	Pass	Pass
2100		53.92	1.568	53.2	1.62	1.4	-3.2	Pass	Pass
2450		52.90	1.957	52.7	1.95	0.4	0.4	Pass	Pass
2600		52.47	2.132	52.5	2.16	-0.1	-1.3	Pass	Pass

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ANNEX B

DIPOLE CALIBRATION REPORTS

Product Service

Test Equipment Number (TE): 3875

Calibration Class: A

TUV SUD Product Service

Internal Calibration Laboratory Report

Date of Calibration: 19/02/2014

Report Number: 26576

Calibration Expiry Date: 19/02/2017

Page 1 of 6

It is certified that the test(s) detailed in the above Calibration Report have been carried out to the requirement of the specification, unless otherwise stated above. The quality control arrangements adopted in respect of these tests have accorded with the conditions of our UKAS registration. The uncertainties are for an estimated confidence probability of not less than 95%.

Manufacturer: Speag

Item: Dipoles

Model: D2450V2

Serial No: 715

Calibration Procedure, as per: CP036/CAL

The results recorded, were taken after a warm up period of 1 Hour(s) in an ambient temperature of 22.6°C ±3°C @ 34.0% RH ±10% RH. The mains voltage was 240V ±10%.

Calibration Engineer:___________________ _________________

N. R. Grigsby

Product Service

Approved Signatory:__________________________________

A. T. Pearce

TUV SUD Product Service

Calibration Classification and Key to Results

(X) Class A: All results measured, lie within the specification limits, even when extended by their measurement uncertainties. The instrument therefore complies with the specification.

( ) Class B: Some/all results measured, lie INSIDE the specification limits, by a margin less than their measurement uncertainties. It is therefore not possible to state compliance of these results. However, these results indicate that compliance is more probable than non-compliance. (***)

( ) Class C: Some/all results measured, lie OUTSIDE the specification limits, by a margin less than their measurement uncertainties. It is therefore not possible to state compliance of these results. However, these results indicate that non-compliance is more probable than compliance. (**)

( ) Class D: Some/all results measured, lie OUTSIDE the specification limits, by a margin greater than their measurement uncertainties. Those results therefore, do not comply with the specification. (*)

( ) Class R: The instrument was repaired prior to calibration. Refer to enclosed repair report for details.

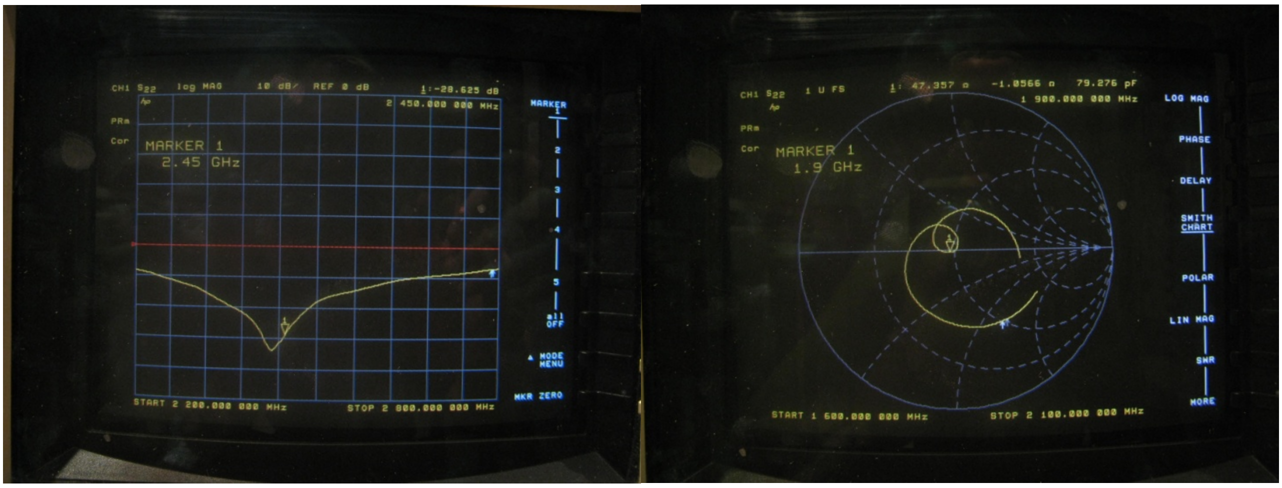
Test Equipment Used On This Calibration

Make & Model	Description	Calibration Due	TE ID
Rohde & Schwarz: NRV-Z1	Power Sensor	14/06/2014	TE0060
Hewlett Packard: ESG4000A	Signal Generator	22/05/2014	TE0061
Narda: 766F-20	Attenuator (20dB, 20W)	13/06/2014	TE0483
Hewlett Packard: 8753D	Network Analyser	23/04/2014	TE1149
Hewlett Packard: 85054A	'N' Calibration Kit	24/12/2014	TE1309
IndexSar Ltd: 7401 (VDC0830-20)	Bi-directional Coupler		TE2414
IndexSar Ltd: VBM2500-3	Validation Amplifier (10MHz - 2.5GHz)		TE2415
Rotronic: I-1000	Hygromer	03/04/2014	TE2784
Rohde & Schwarz: NRV- Z5	Power Sensor	14/06/2014	TE2878
Rohde & Schwarz: NRVD	Dual Channel Power Meter	14/06/2014	TE3259
R.S Components: Meter 615-8206 & Type K T/C	Meter & T/C	08/07/2014	TE3612
IndexSar Ltd: SARAC	Cartesian 4-axis Robot		TE4079
IndexSar Ltd: White Benchtop	Part of SARAC System		TE4080
IndexSar Ltd: Wooden Bench	Part of SARAC System		TE4081
IndexSar Ltd: IPX-050	Immersible SAR Probe	07/03/2015	TE4313
IndexSar Ltd: IXB-2HF 700- 6000MHz	Flat Phantom		TE4400

Dipole impedance and return loss

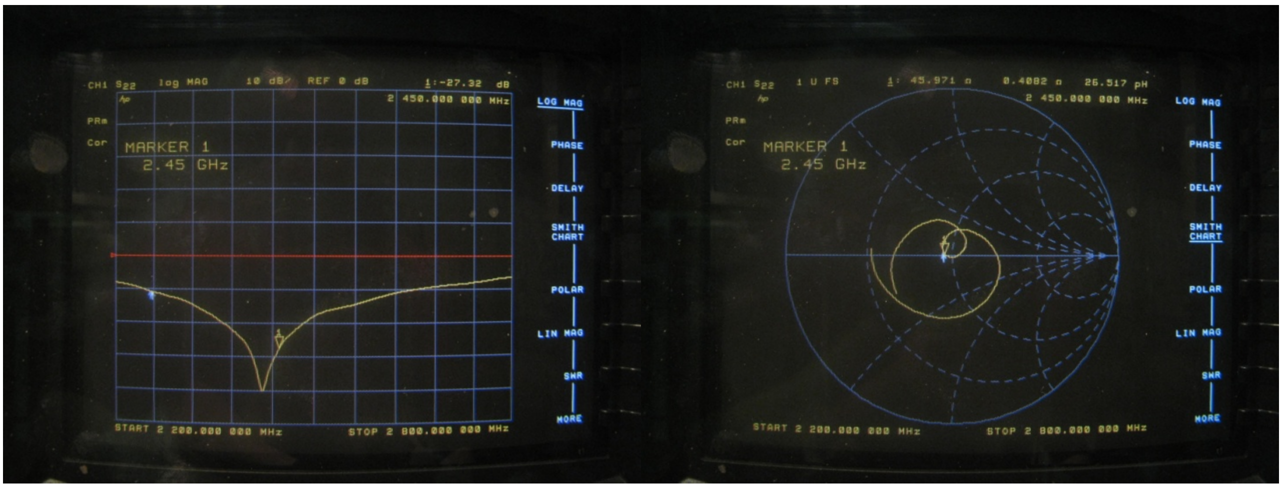
The dipoles are designed to have low return loss ONLY when presented against a lossy-phantom at the specified distance. A Vector Network Analyser (VNA) was used to perform a return loss measurement on the specific dipole when in the measurement-location against the box phantom. The distance was as specified in the standard i.e. 10mm from the liquid (for 2450MHz).

The impedance was measured at the SMA-connector with the network analyser.
The following parameters were measured against Head fluid:



Dipole impedance at 2450MHz	Re{Z} = 47.69 Ω
	Im{Z} = 2.827 Ω
Return loss at 2450MHz	**-28.63 dB**

Standards [1][2][3][4] call for dipoles to have a return loss better than 20dB
The measurements repeated against Body fluid:



Dipole impedance at 2450MHz	Re{Z} = 45.97 Ω
	Im{Z} = 0.41 Ω
Return loss at 2450MHz	**-27.32 dB**

Standards [1][2][3][4] call for dipoles to have a return loss better than 20dB

SAR Validation Measurement in Brain Fluid

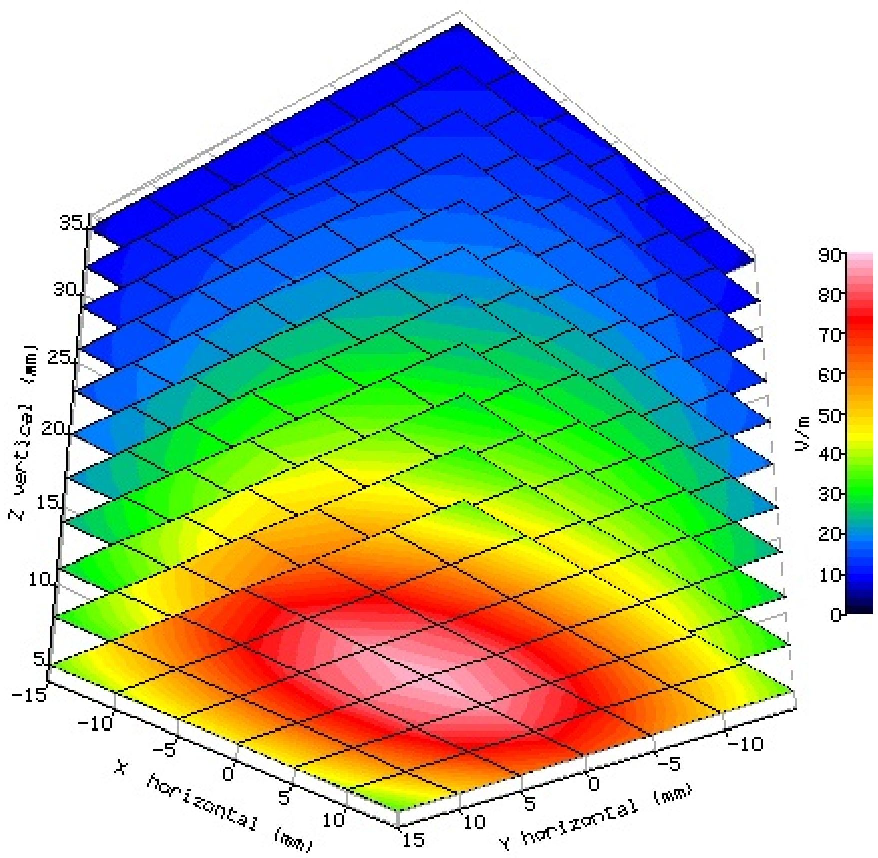
SAR validation checks have been performed using the 2450MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 22.6°C and the relative humidity was 34.0% during the measurements.

The phantom was filled with 2450MHz brain liquid using a recipe from [1], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 2450MHz at the measurement temperature:

Relative Permittivity	**39.11**
Conductivity	**1.797 S/m**
Fluid Temperature	22.6 °C

The SARA-C software version v6.08.11 was used with Indexsar IXP_050 probe Serial Number 204 previously calibrated using waveguides.

The 3D measurement made using the dipole at the bottom of the phantom box is shown below:



The validation results normalised to an input power of 1W (forward power) were:

	Measured SAR values (W/kg) (250mW input power)	Measured SAR values (W/kg) (Normalised to 1W feed power) and % Variance from target Value.		Target SAR values (W/kg) derived from system validation (Normalised to 1W feed power)
		Measured	% Variance	
1g SAR	13.64	54.30	2.50	52.98
10g SAR	6.39	25.45	2.48	24.83

All validation measurements are with ± 10% of Target values as required in standards [1][2][3][4]

SAR Measurement in Body Fluid

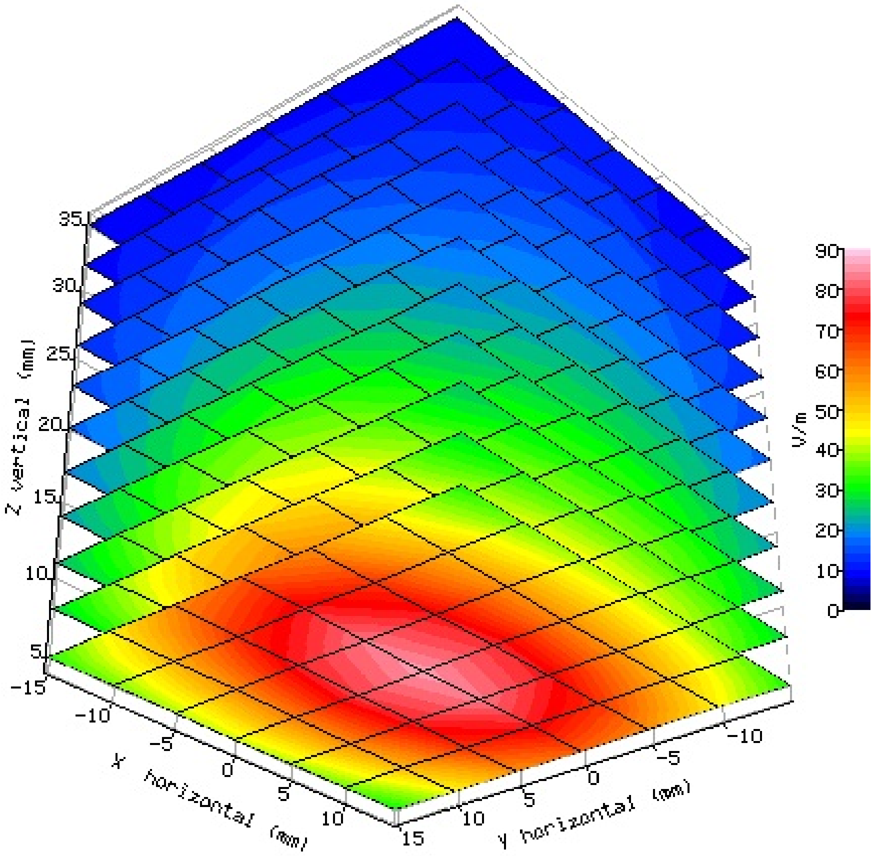
SAR validation checks have been performed using the 2450MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 22.8°C and the relative humidity was 30.2% during the measurements.

The phantom was filled with 2450MHz body liquid using a recipe from [1][4], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 2450MHz at the measurement temperature:

Relative Permittivity	**51.09**
Conductivity	**1.983 S/m**
Fluid Temperature	22.7 °C

The SARA-C software version v6.08.11 was used with Indexsar IXP_050 probe Serial Number 204 previously calibrated using waveguides.

The 3D measurement made using the dipole at the bottom of the phantom box is shown below:



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The validation results normalised to an input power of 1W (forward power) were:

	Measured SAR values (W/kg) (250mW input power)	Measured SAR values (W/kg) (Normalised to 1W feed power) and % Variance from target Value.		Target SAR values (W/kg) derived from system validation (Normalised to 1W feed power)
		Measured	% Variance	
1g SAR	13.47	53.64	1.25**	52.98*
10g SAR	6.37	25.36	2.13**	24.83*

* In the specifications, SAR validation target values are only define for standardised measurements in brain fluid. Using the target values (W/kg) derived from system validation with brain fluid the validation measurements are within ± 10% of Target values.
**Variance against target values (W/kg) derived from system validation with brain fluid.

References

[1] IEEE Std 1528-2013. IEEE recommended practice for determining the peak spatial-average specific absorption rate (SAR) in the human body due to wireless communications devices: Measurement Techniques – Description.

[2]BS EN 62209-1:2006 Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices — Human models, instrumentation, and procedures — Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz).

[3]BS EN 62209-2:2010 Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices — Human models, instrumentation, and procedures — Part 2: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the human body (frequency range of 300 MHz to 6 GHz) (IEC 62209-2:2010)

[4] FCC KDB 865664 D01 SAR Measurement 100MHz to 6GHz V01r03