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MEASUREMENT UNCERTAINTIES

A complete measurement uncertainty analysis for the SARA-C measurement system has been published in Reference [3]. 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 L0006

Relative Channel Sensitivities (to optimise Axial Isotropy)				
	X	Y	Z	
Air Factors	72.81	90.02	77.16	$(V/m)^2/mV$
CW DCPs	100	100	100	mV

Measured Isotropy at 900MHz	Probe orientation range relative to dipole	(+/-) dB
Axial Isotropy	0°(end-on to dipole)	0.01
Spherical Isotropy	±20°	0.17
	±30°	0.28
	±60°	0.58
	±90°	0.63

SAR Conversion Factors/ Boundary Corrections (Head Fluid)				
Frequency* (MHz)	**SAR Conv Factor**	**Boundary Correction f(0)**	**Boundary Correction d(mm)**	**Notes**
450	0.298	0.0	1.0	3
835	0.304	0.8	1.5	1,2
900	0.305	1.0	1.4	1,2
1800	0.373	0.9	1.5	1,2
1900	0.382	0.5	2.3	1,2
2100	0.396	0.6	2.0	1,2
2450	0.423	0.9	1.5	1,2
2600	0.427	1.1	1.4	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).

Physical Information	
Sensor offset (mm)	2.7
Elbow – Tip dimension (mm)	84.55

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PROBE SPECIFICATIONS

Indexsar probe L0006, 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 L0006	BSEN [1]	IEEE [2]
Vertical shaft (mm)	510		
Horizontal shaft (mm)	90		
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		

Dynamic range	S/N L0006	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 L0006	BSEN [1]	IEEE [2]
Axial	Probe at 0°	0.01	0.5	0.25
Spherical	Probe at ±20°	0.17	N/A	N/A
	Probe at ±30°	0.28		
	Probe at ±60°	0.58		
	Probe at ±90°	0.63		

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. Outer case materials are PEEK and heat-shrink sleeving.
Chemical resistance	Tested to be resistant to TWEEN 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.

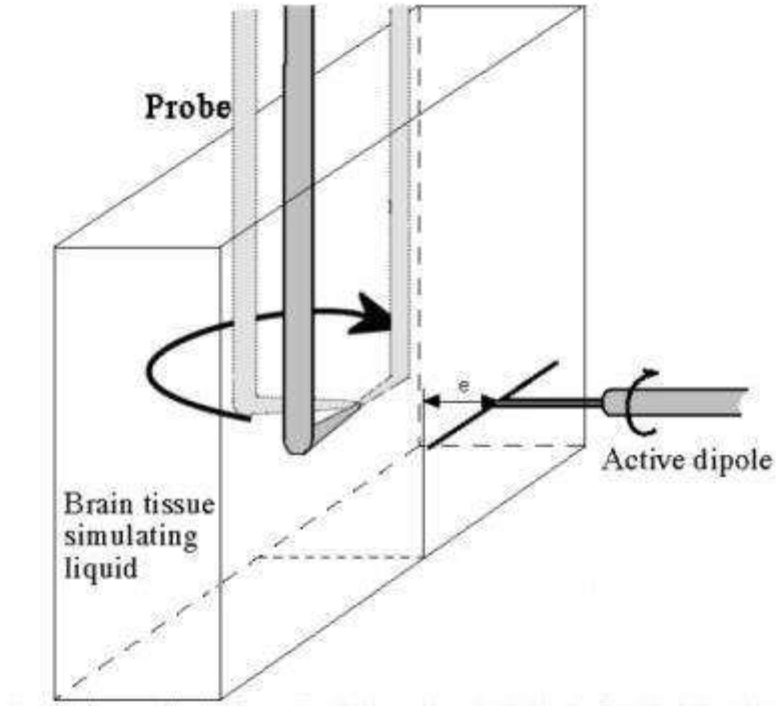

Figure 1 Isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

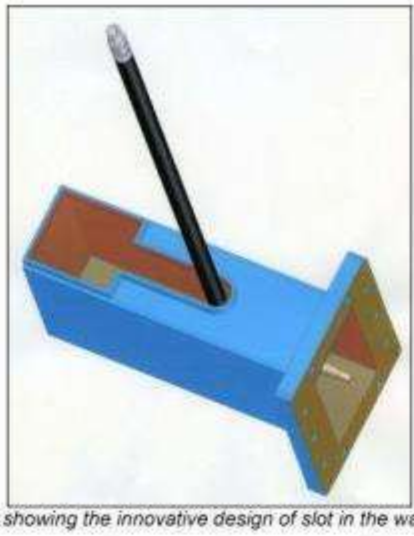

Figure 2 Schematic showing the innovative design of slot in the waveguide termination

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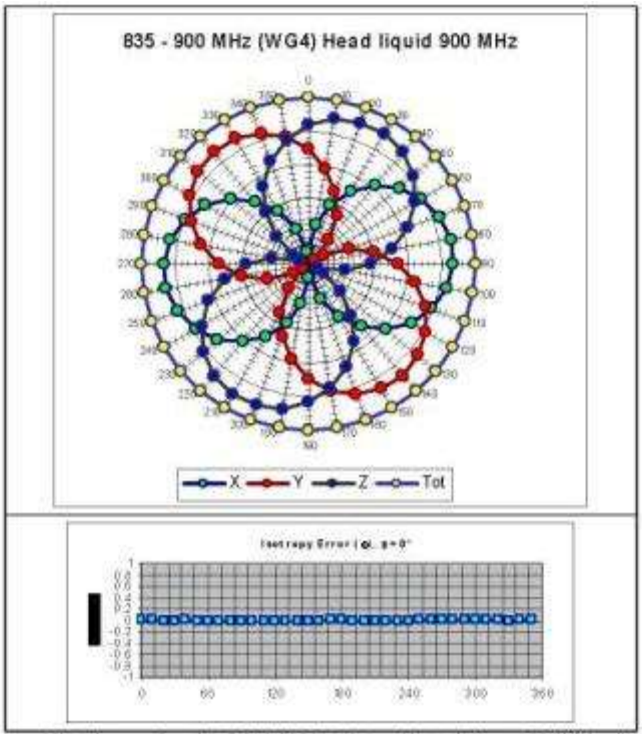

Figure 3 The axial isotropy of probe S/N L0006 obtained by rotating a 900MHz dipole with probe tip aligned with dipole boresight (NB Axial Isotropy is frequency independent)

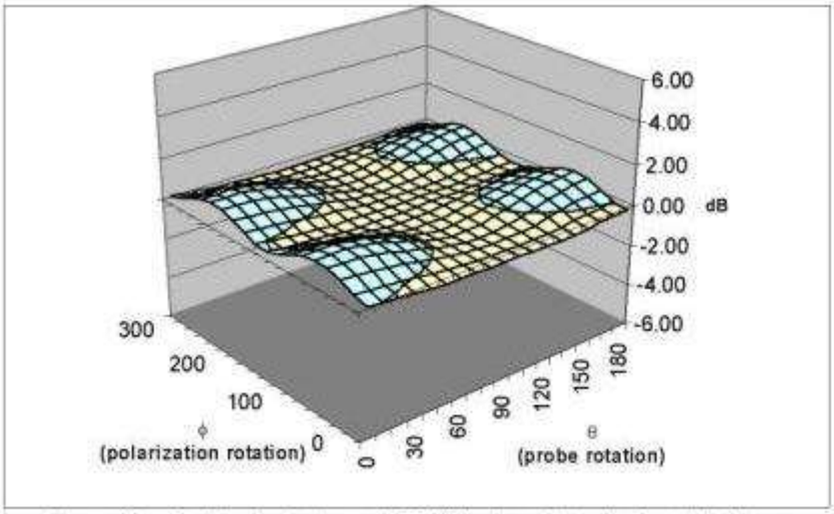

Figure 4 Residual Surface Isotropy at 900 MHz after optimisation for axial isotropy

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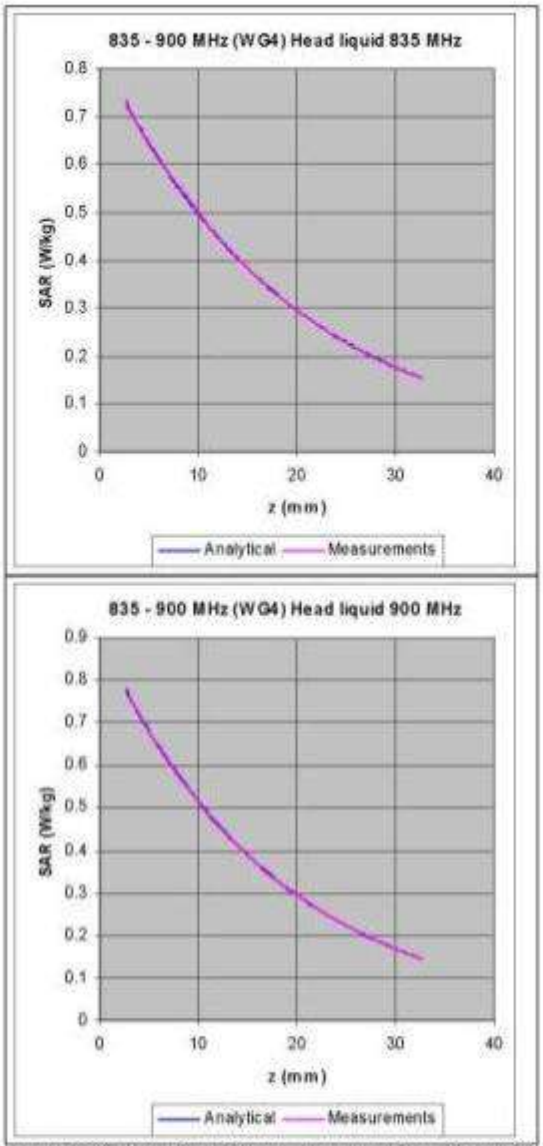
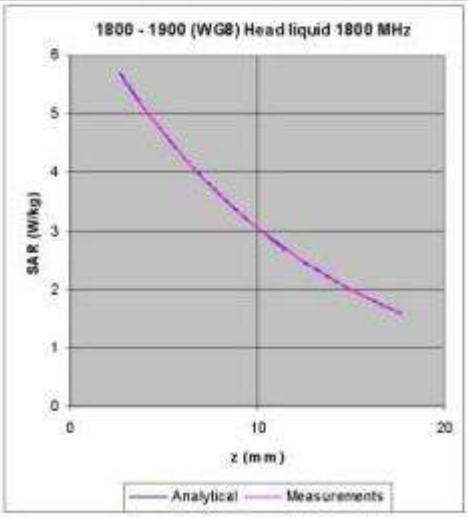
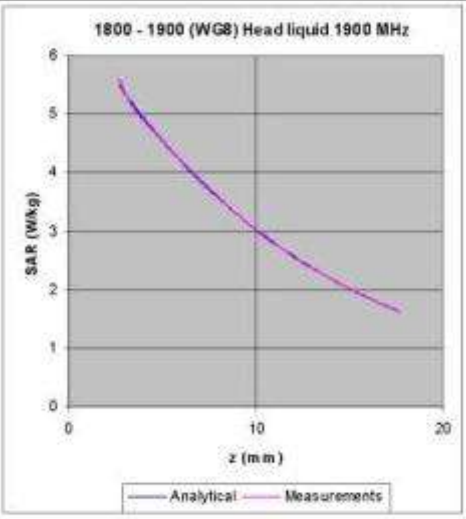


Figure 5 The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.


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


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

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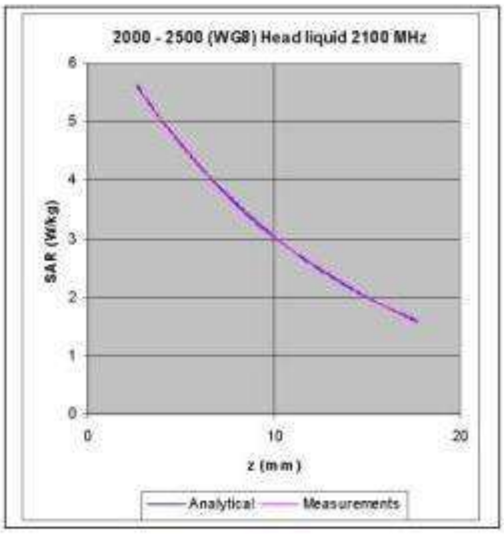

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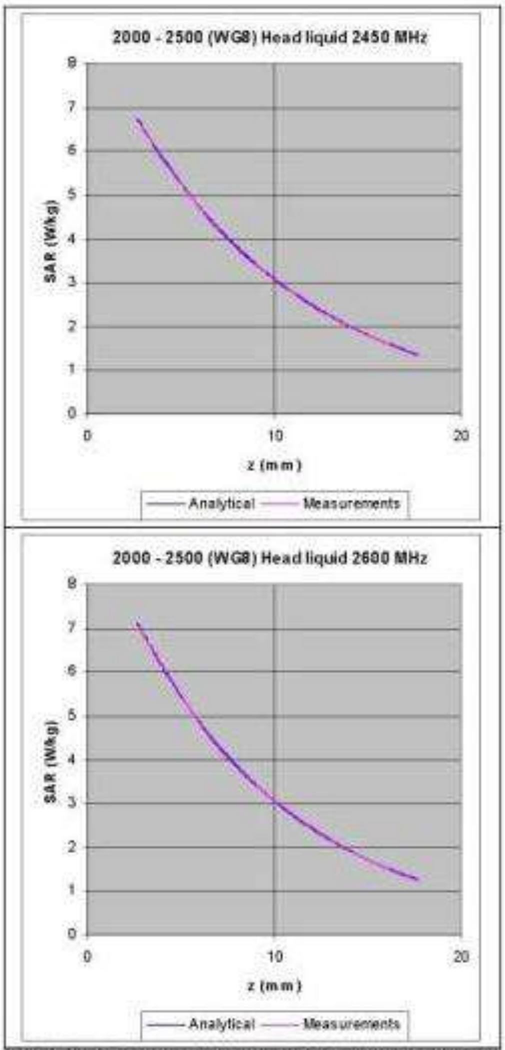

Figure 6: The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

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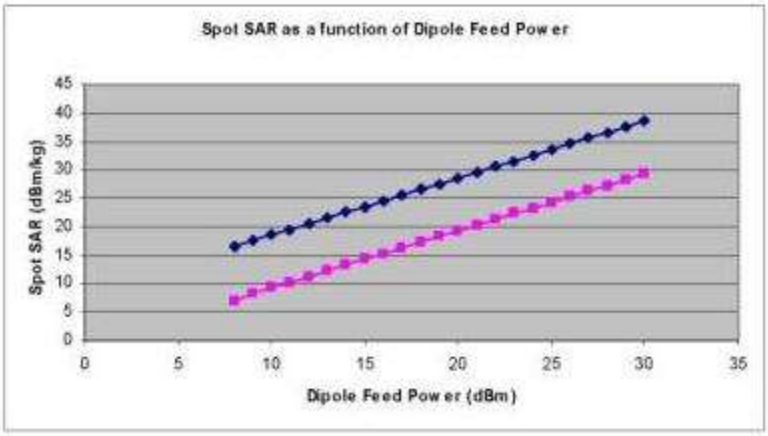

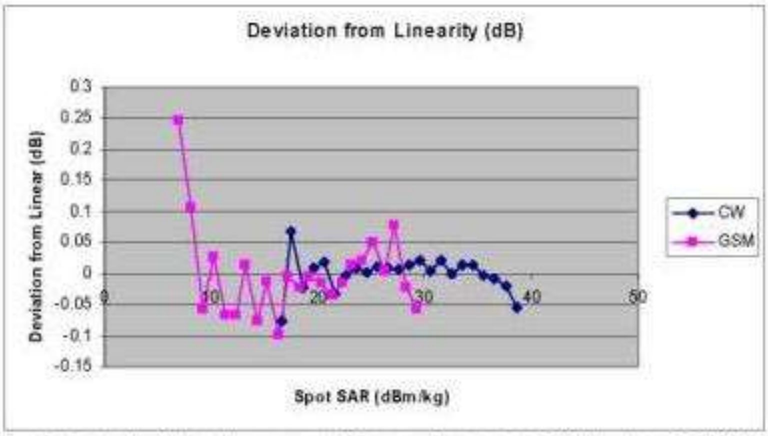

Figure 7: The typical linearity response of 5mm probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of of 8 (ie 9dB) lower than CW. The lower diagram shows the departure from linearity of the same two datasets.

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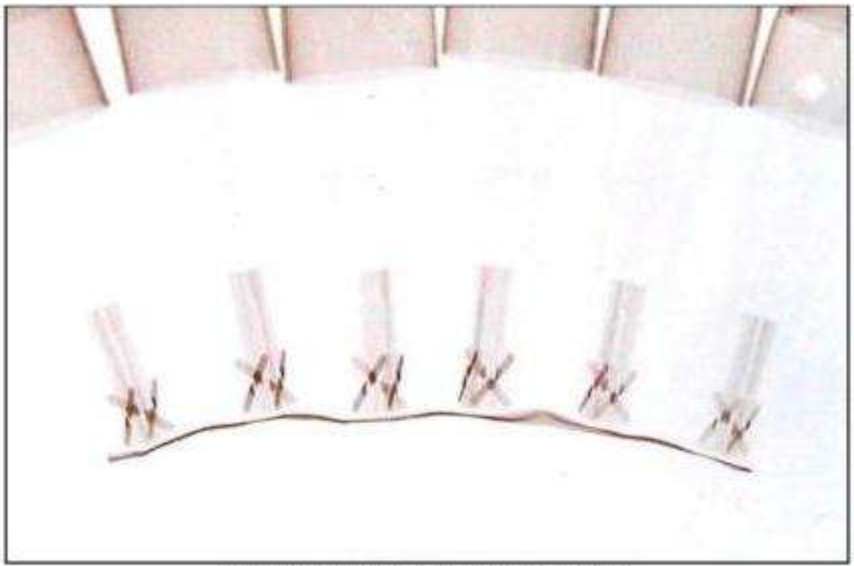
Figure 8 X-ray positive image of 5mm probes

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

Frequency (MHz)	Fluid Type	Measured		Target		% Deviation		Verdict	
		Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity	Relative Permittivity	Conductivity
450	Head	44.142	0.845	43.5	0.87	1.5	-2.9	Pass	Pass
835		42.114	0.901	41.5	0.90	1.5	0.1	Pass	Pass
900		41.13	0.961	41.5	0.97	-0.9	-0.9	Pass	Pass
1800		39.719	1.428	40.0	1.40	-0.7	2.0	Pass	Pass
1900		39.744	1.396	40.0	1.40	-0.6	-0.3	Pass	Pass
2100		40.541	1.463	39.8	1.49	1.9	-1.8	Pass	Pass
2450		39.265	1.815	39.2	1.80	0.2	0.8	Pass	Pass
2600		38.715	1.975	39.0	1.96	-0.7	0.8	Pass	Pass

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IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP–021

S/N LG0018

March 2014

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TÜV SÜD Product Service

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Calibration Certificate 1403/LG0018
Date of Issue: 24th March 2014
Immersible SAR Probe

Type:	IXP-021
Manufacturer:	IndexSAR, UK
Serial Number:	LG0018
Place of Calibration:	IndexSAR, UK
Date of Receipt of Probe:	30 January 2014
Calibration Dates:	11-21 March 2014
Customer:	TUV Sud

IndexSAR Ltd hereby declares that the IXP-025 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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Product Service

INTRODUCTION

This Report presents measured calibration data for a particular Indexsar SAR probe (S/N LG0018) only and describes the procedures used for characterisation and calibration.

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

2) Use of these channel sensitivity factors to compare the SAR decay curve in a waveguide fluid cell with an analytical curve 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] and [2]. 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-021 probes with CW signals the DCP values are typically 100mV.

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

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

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$$+ U_{liny} * \text{Air Factor}_y * \text{Liq Factor}_y$$
$$+ U_{linz} * \text{Air Factor}_z * \text{Liq Factor}_z \quad (3)$$

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, a 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).

A 5-6GHz 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 on a turntable and the liquid cell section is filled with 5-6GHz brain fluid to within 1 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 held by the robot in a dedicated jig with the probe's long shaft horizontal and the short shaft pointing vertically down over the centre of the waveguide opening, Figure 1. In this position, the short shaft lies directly along the waveguide's main axis in the direction of signal travel. The probe is then lowered along the waveguide axis directly into the liquid until the tip is exactly 5mm 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.

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 during the assessment of axial isotropy. However, the power must be sufficiently above the noise floor and free from drift.

With the probe's short shaft lying directly along the waveguide axis, the probe's axial isotropy can be measured by changing their relative position angle. This can be done by either spinning the probe while the waveguide remains stationery (usual procedure for straight probes) or, as is the case for L-probes, the waveguide is turned by hand while the probe does not move. The dedicated Indexsar calibration software requests that the user rotates the waveguide 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 3 represents the output from each diode sensor as a function of probe rotation angle.

4. 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 perpendicular distance from 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 dielectric separator is given by Equation 4:

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

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).

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

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.

There are two ways of accommodating the geometry of an L-shaped probe as it traces out the decay profile. Above 3GHz, as here, the waveguide's fluid cell is short enough that the probe's short shaft can be lowered vertically down into the waveguide without the long shaft fouling on the waveguide edge, Figure 1. By contrast, at lower frequencies, the measurement geometry has to be changed, and the waveguide now lies horizontally and the fluid cell has to be capped with a metal plate at least three penetration depths away from the dielectric window (see Figure 2). A slot is cut in the top ("b") face through which tissue simulant fluid can be poured, and through which the probe can enter the guide and be offered up to the now vertical waveguide window.

During high frequency calibration, the probe is lowered carefully until the flat face of the tip 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 away from the waveguide window. This cycle is repeated 150 times, with a different separation each time, in steps of 0.35mm.

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.

Different waveguides are used for 835/900MHz, 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.

For 450 MHz calibrations, a slightly different technique must be used — the equatorial response of the probe-under-test is compared with the equivalent response of a probe whose 450MHz characteristics have already been determined by NPL. The conversion factor of the probe-under-test can then be deduced.

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.

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CALIBRATION FACTORS MEASURED FOR PROBE S/N LG0018

The probe was calibrated at 5200, 5500 and 5800 MHz in liquid samples representing brain tissue at these frequencies.

The calibration was for CW signals only, and the horizontal axis of the probe was parallel to the direction of propagation of the incident field i.e. end-on to the incident radiation.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 1.39 mm from the probe tip in the direction of the probe amplifier. A value of 1.39 mm should be used for the tip to sensor offset distance in the software. The distance of 1.39 mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 9).

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 18 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 [3]. 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%

SUMMARY OF CAL FACTORS FOR PROBE IXP-021 S/N LG0018

SAR Calibration Factors / Boundary Corrections*								
Freq (MHz)	Tissue Type	Air Factor X $((V/m)^2/mV)$	Air Factor Y $((V/m)^2/mV)$	Air Factor Z $((V/m)^2/mV)$	Rotational Isotropy (± dB)	SAR Conv Factor	Boundary Correction f(0)	Boundary Correction d(mm)
5200	Head	289.0	322.7	348.3	0.10	0.788	0.55	1.1
5500						0.800	0.50	1.5
5800						0.800	0.66	1.0

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PROBE SPECIFICATIONS

Indexsar probe LG0018, 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 LG0018	BSEN [1]	IEEE [2]
Vertical shaft (mm)	510		
Horizontal shaft (mm)	84.15		
Tip length (mm)	10		
Body diameter (mm)	12		
Tip diameter (mm)	2.55	8	8
Distance from probe tip to dipole centers (mm)	1.39		

Dynamic range	S/N LG0018	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

Rotational Isotropy (at 5.2GHz)	S/N LG0018	BSEN [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB)	0.10	0.5	0.25

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. Outer case materials are PEEK and heat-shrink sleeving.
Chemical resistance	Tested to be resistant to TWEEN 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.

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
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[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.

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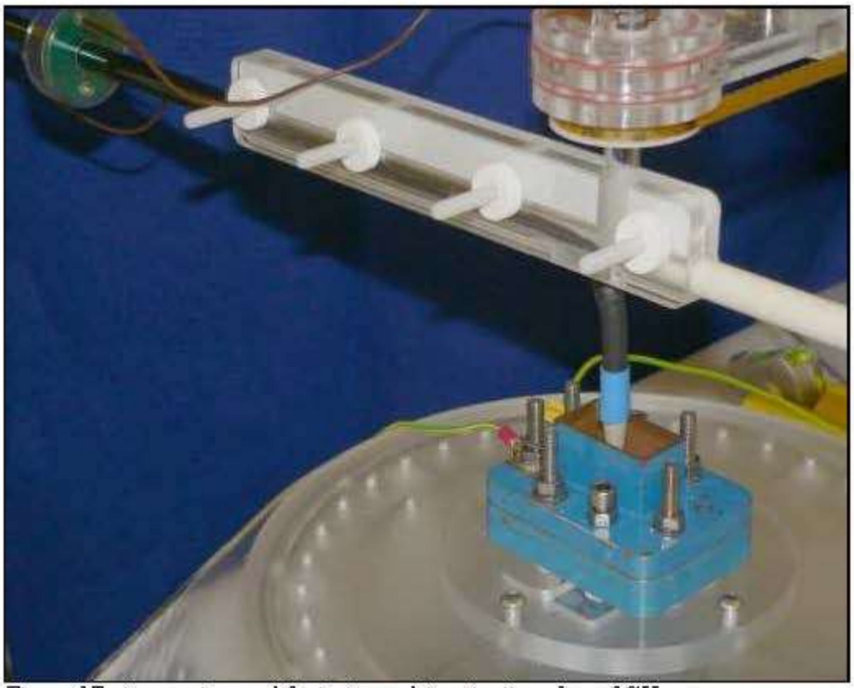

Figure 1 Test geometry used for isotropy determination above 3GHz

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Figure 2. Schematic showing the innovative design of slot in the waveguide termination

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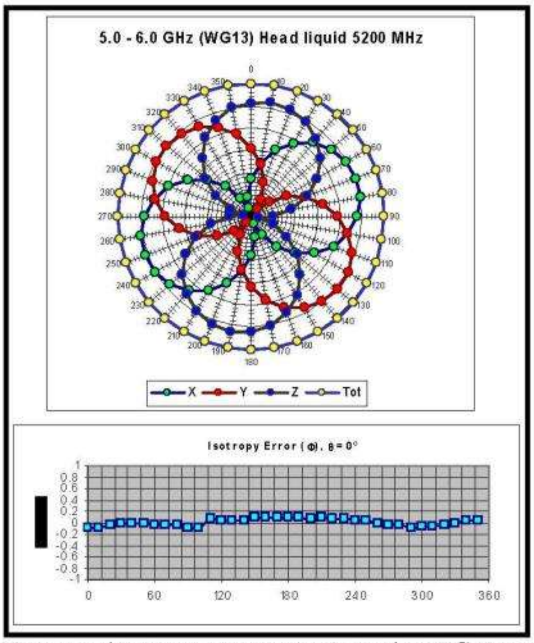
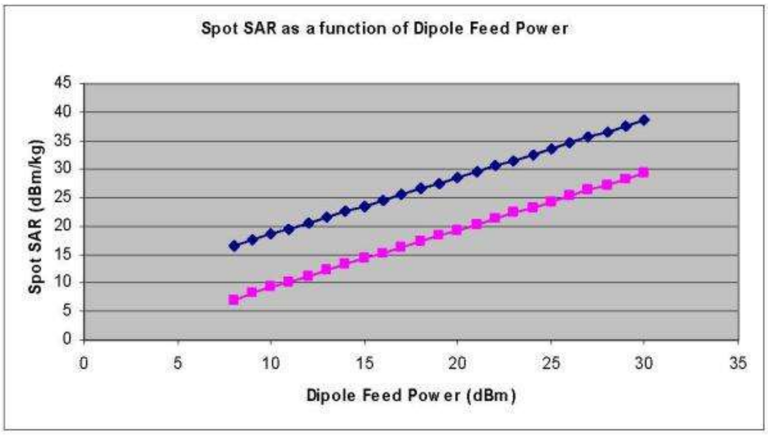


Figure 3Rotational isotropy measurements inside a WG13 waveguide.

Product Service



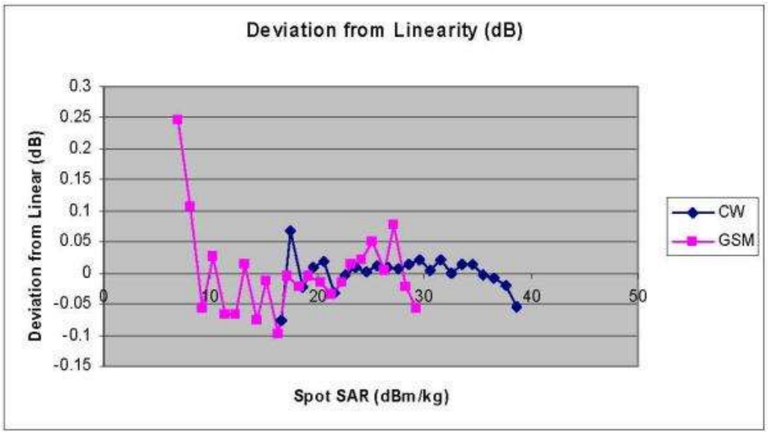


Figure 4 The typical linearity response of IXP-021 probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of 8

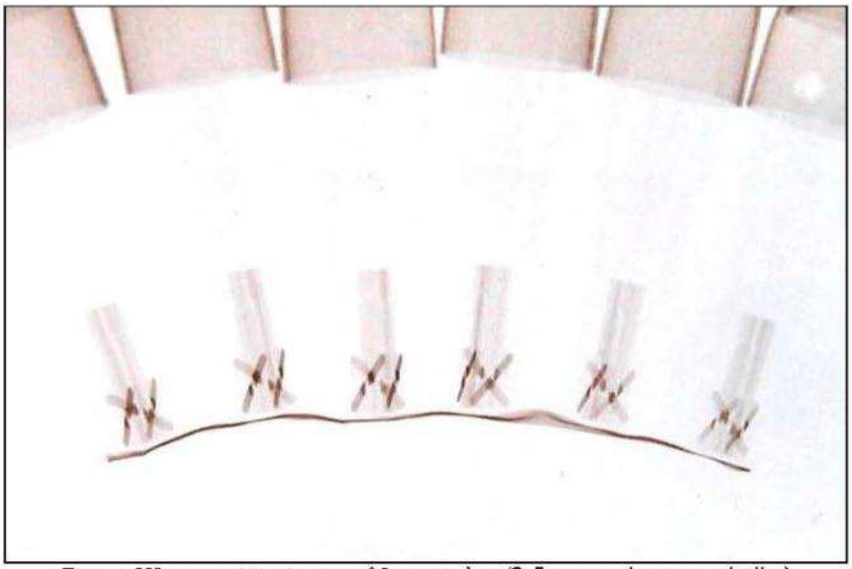


Figure 5X-ray positive image of 5mm probes (2.5mm probes are similar)

Product Service

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

Frequency (MHz)	Fluid Type	Measured		Target		% Deviation		Verdict	
		Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity	Relative Permittivity	Conductivity
5200	Head	37.39	4.72	36.0	4.66	3.9	1.3	Pass	Pass
5500		36.36	5.12	35.7	4.97	2.0	3.2	Pass	Pass
5800		35.51	5.49	35.3	5.27	0.6	4.2	Pass	Pass

Product Service

Table of test equipment calibration status as at time of probe calibration

Instrument description	Supplier / Manufacturer	Model	Serial No.	Last calibration date	Calibration due date
Power sensor	Rohde & Schwarz	NRP-Z23	100063	09/08/2012	09/08/2014
Dielectric property measurement	Indexsar	DiLine (sensor lengths: 160mm, 80mm and 60mm)	N/A	(absolute) – checked against NPL values using reference liquids	N/A
Vector network analyser	Anritsu	MS6423B	003102	21/01/2014	21/01/2015
SMA autocalibration module	Anritsu	36581KKF/1	001902	21/01/2014	21/01/2015

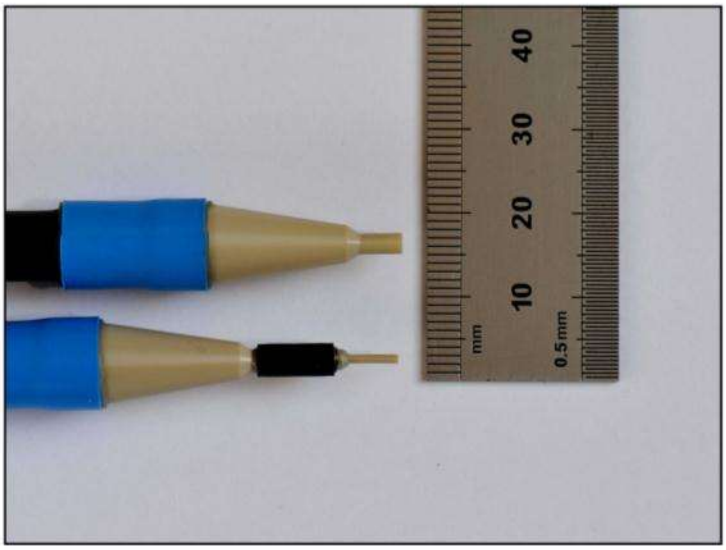
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 025

S/N G0006

March 2014



Indexsar Limited
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Calibration Certificate 1403/G0006
Date of Issue: 24 March 2014
Immersible SAR Probe

Type:	IXP-025
Manufacturer:	IndexSAR, UK
Serial Number:	G0006
Place of Calibration:	IndexSAR, UK
Date of Receipt of Probe:	30 January 2014
Calibration Dates:	11-21 March 2014
Customer:	TUV Sud

IndexSAR Ltd hereby declares that the IXP-025 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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Product Service

INTRODUCTION

Straight probes work on either SARA-C (to measure SAR values in flat phantoms containing Body tissue simulant fluid), or on SARA2 (where they, too, can measure 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 G0006) 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
2) Use of these channel sensitivity factors to compare the SAR decay curve in a waveguide fluid cell with an analytical curve 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.

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For this value of DCP, the typical linearity response of IXP-025 probes to CW and to GSM modulation is shown in Figure 3, along with departures of this same dataset from linearity.

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

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

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, a 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).

A 5-6GHz 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 5-6GHz brain fluid to within 1 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 5mm 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.

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

Product Service

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

4. 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 dielectric separator is given by Equation 4:

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

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).

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

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.

Product Service

Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at 22 ± 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 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 G0006

The probe was calibrated at 5.2, 5.5 and 5.8GHz 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

Product Service

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 1.39 mm from the probe tip in the direction of the probe amplifier. A value of 1.39 mm should be used for the tip to sensor offset distance in the software. The distance of 1.39mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 4).

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.

Product Service

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 homogeneity	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-025 S/N G0006

Relative Channel Sensitivities (to optimise Axial Isotropy)				
	X	Y	Z	
Air Factors*	366.37	427.51	166.12	$(V/m)^2/mV$
DCPs	100	100	100	mV

Measured Isotropy	(+/-) dB
Axial Isotropy*	0.08

Physical Information	
Sensor offset (mm)	1.39
Elbow – Tip dimension (mm)	0.0

Product Service

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
5200	0.90	0.32	1.6	0.93	0.58	1.0	1,2
5500	0.94	0.33	1.9	0.99	0.62	1.0	1,2
5800	0.92	0.28	1.8	1.07	0.61	1.1	1,2
Notes							
1)	Calibrations done at 22°C +/-2°C						
2)	Waveguide calibration						
3)	By interpolation						

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

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Product Service

PROBE SPECIFICATIONS

Indexsar probe G0006, 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 G0006	BSEN [1]	IEEE [2]
Overall length (mm)	350		
Tip length (mm)	10		
Body diameter (mm)	12		
Tip diameter (mm)	2.55	8	8
Distance from probe tip to dipole centers (mm)	1.39		

Typical Dynamic range	S/N G0006	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 5200MHz)	S/N G0006	BSEN [1]	IEEE [2]
Axial rotation with probe normal to source (+/- dB)	<0.08	0.5	0.25

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.

Product Service

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.

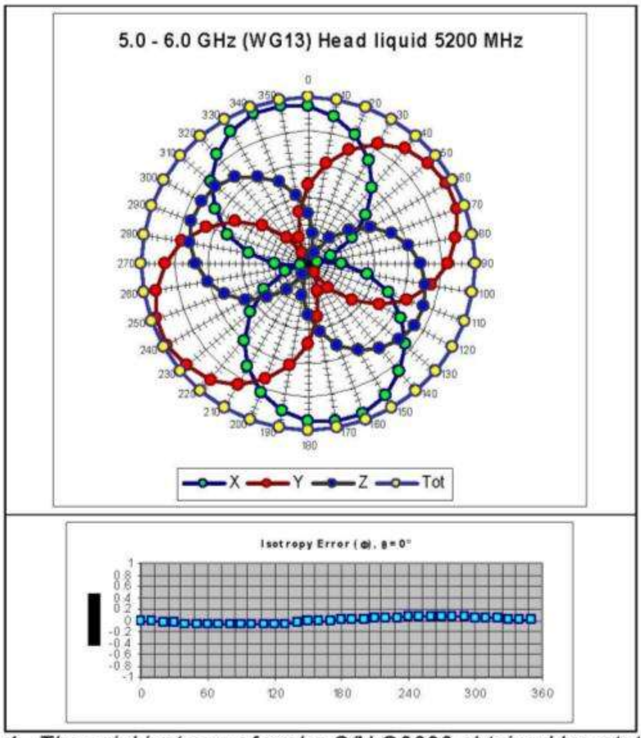

Figure 1. The axial isotropy of probe S/N G0006 obtained by rotating the probe in a liquid-filled waveguide at 5200 MHz. (NB Axial Isotropy is largely independent of frequency)

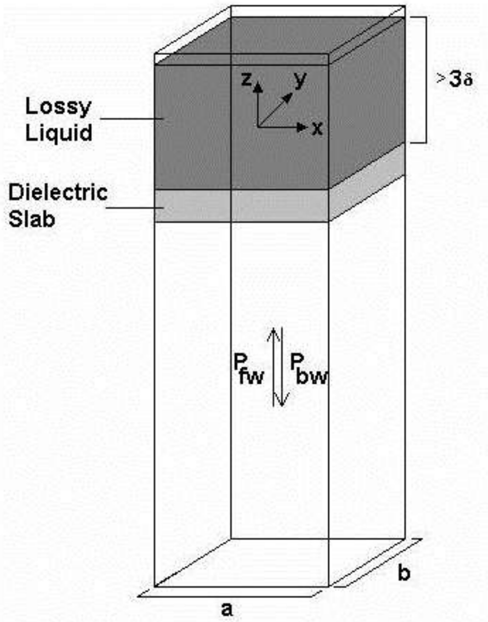

Figure 2. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

Product Service

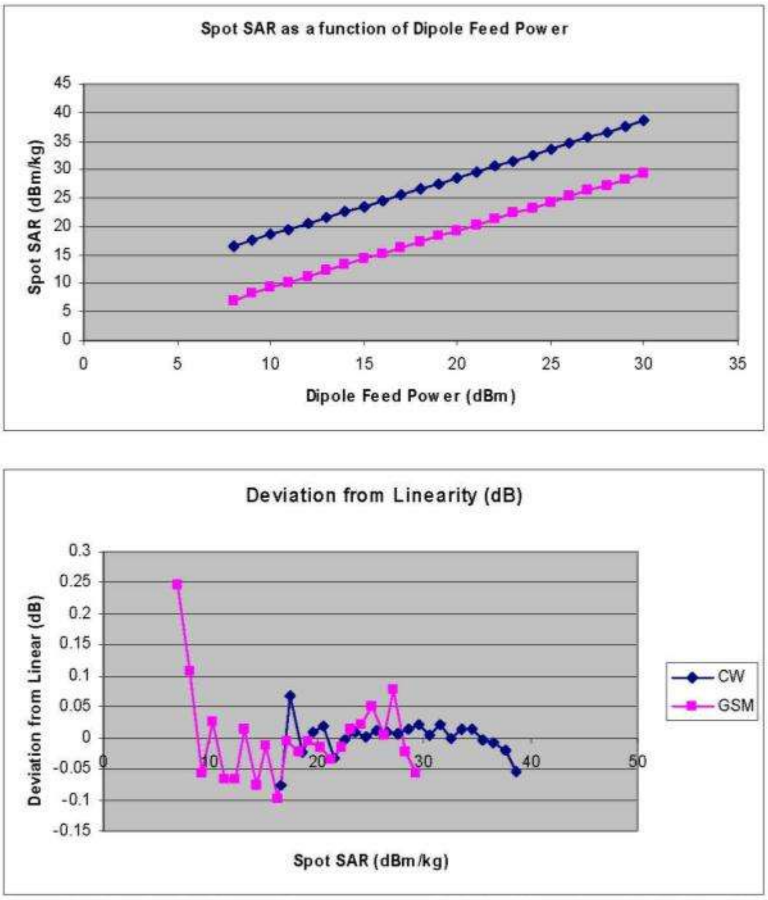

Figure 3 : The typical linearity response of IXP-025 probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of 8 (ie 9dB) lower than CW. The lower diagram shows the departure from linearity of the same two datasets.

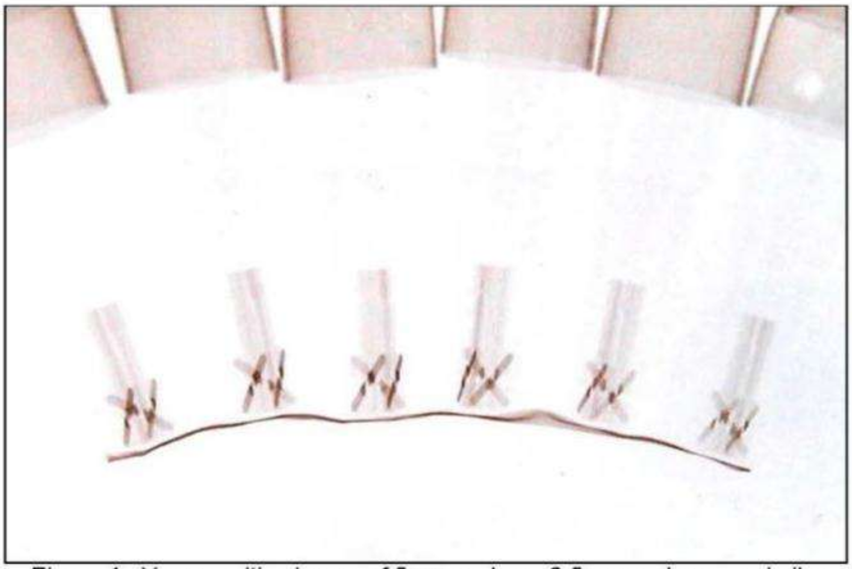

Figure 4 : X-ray positive image of 5mm probes. 2.5mm probes are similar

Product Service

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

Frequency (MHz)	Fluid Type	Measured		Target		% Deviation		Verdict	
		Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity (S/m)	Relative Permittivity	Conductivity	Relative Permittivity	Conductivity
5200	Head	36.82	4.87	36.0	4.66	2.3	4.5	Pass	Pass
5500		36.08	5.19	35.7	4.97	1.2	4.5	Pass	Pass
5800		35.87	5.41	35.3	5.27	1.6	2.6	Pass	Pass
5200	Body	49.12	5.34	49.0	5.30	0.2	0.7	Pass	Pass
5500		48.38	5.62	48.6	5.65	-0.5	-0.5	Pass	Pass
5800		47.49	6.02	48.2	6.00	-1.5	0.3	Pass	Pass

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Product Service

Table of test equipment calibration status

Instrument description	Supplier / Manufacturer	Model	Serial No.	Last calibration date	Calibration due date
Power sensor	Rohde & Schwarz	NRP-Z23	100063	09/08/2012	09/08/2014
Dielectric property measurement	Indexsar	DiLine (sensor lengths: 160mm, 80mm and 60mm)	N/A	(absolute) – checked against NPL values using reference liquids	N/A
Vector network analyser	Anritsu	MS6423B	003102	21/01/2014	21/01/2015
SMA autocalibration module	Anritsu	36581KKF/1	001902	21/01/2014	21/01/2015

1.

ANNEX B

DIPOLE CALIBRATION REPORTS

COMMERCIAL-IN-CONFIDENCE

Product Service

Test Equipment Number (TE): 3857

Calibration Class: A

TUV SUD Product Service

Internal Calibration Laboratory Report

Date of Calibration: 19/02/2014 **Report Number:** 26553

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:	D835V2
Serial No:	447

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 @ 43.9% RH ±10% RH. The mains voltage was 240V ±10%.

Calibration Engineer:__________

N. R. Grigsby

Approved Signatory:__________

A. T. Pearce

Product Service

CALIBRATION LABORATORY REPORT

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: Cartesian Leg Extension	Part of SARAC System		TE4078
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

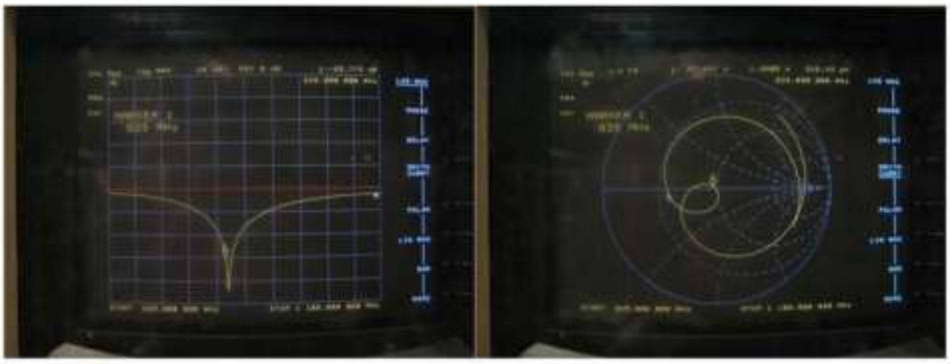
Product Service

CALIBRATION LABORATORY REPORT

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. 15mm from the liquid (for 835MHz).

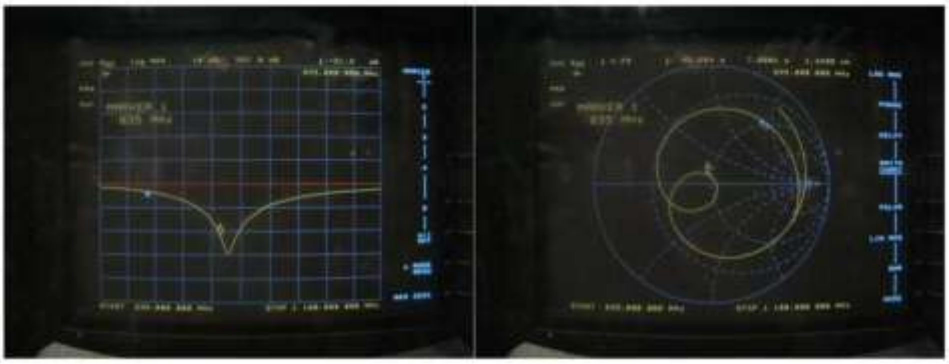
The impedance was measured at the SMA-connector with the network analyser.
The following parameters were measured against Head fluid:



Dipole impedance at 835MHz	Re{Z} = 47.30 Ω
	Im{Z} = 1.56 Ω
Return loss at 835MHz	**-29.77 dB**

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

The measurements repeated against Body fluid:



Product Service

Report № 26553
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CALIBRATION LABORATORY REPORT

Dipole impedance at 835MHz	Re{Z} = 46.68 Ω Im{Z} = 7.08 Ω
Return loss at 835MHz	**-21.90 dB**

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

SAR Validation Measurement in Brain Fluid

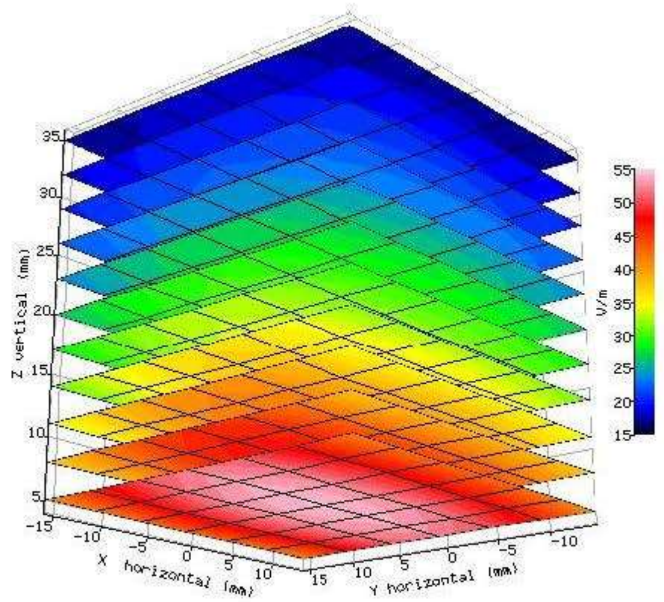
SAR validation checks have been performed using the 835MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 22.6°C and the relative humidity was 43.9% during the measurements.

The phantom was filled with 835MHz brain liquid using a recipe from [1], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 835MHz at the measurement temperature:

Relative Permittivity	**41.67**
Conductivity	**0.895 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:



Product Service

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CALIBRATION LABORATORY REPORT

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	2.65	10.55	1.93	10.35
10g SAR	1.73	6.88	2.12	6.74

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

SAR Measurement in Body Fluid

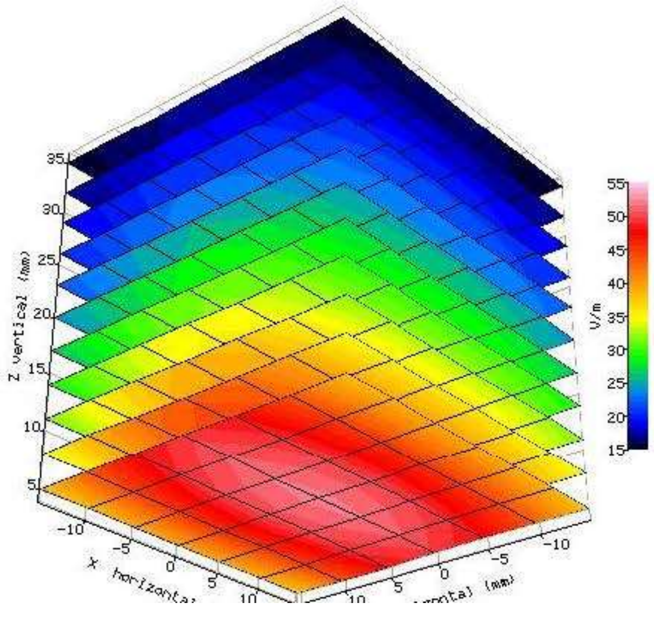
SAR validation checks have been performed using the 835MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 22.9°C and the relative humidity was 35.4% during the measurements.

The phantom was filled with 835MHz body liquid using a recipe from [1][4], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 835MHz at the measurement temperature:

Relative Permittivity	**56.6**
Conductivity	**1.006 S/m**
Fluid Temperature	22.5 °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:



Product Service

Report № 26553
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CALIBRATION LABORATORY REPORT

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	2.65	10.56	2.01**	10.35*
10g SAR	1.77	7.05	4.60**	6.74*

* 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

Product Service

Test Equipment Number (TE): 4413

Calibration Class: A

TUV SUD Product Service

Internal Calibration Laboratory Report

Date of Calibration: 18/03/2014 **Report Number:** 26602

Calibration Expiry Date: 18/03/2017 **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: IndexSar Ltd

Item: Dipoles

Model: 700

Serial No: 0279

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 23.2°C ±3°C @ 29.3% RH ±10% RH. The mains voltage was 240V ±10%.

Calibration Engineer:________________ ________________

N. R. Grigsby

Approved Signatory:____________ ____________________

A. T. Pearce

Product Service

Report №
Page 2 of 6

CALIBRATION LABORATORY REPORT

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		

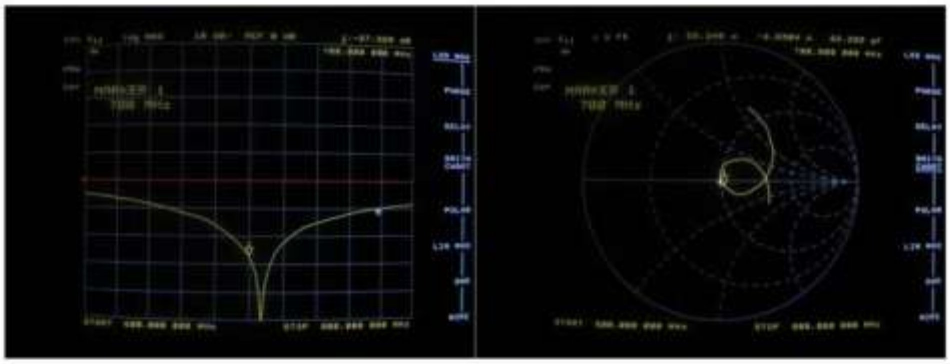
Product Service

CALIBRATION LABORATORY REPORT

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. 15mm from the liquid (for 700MHz).

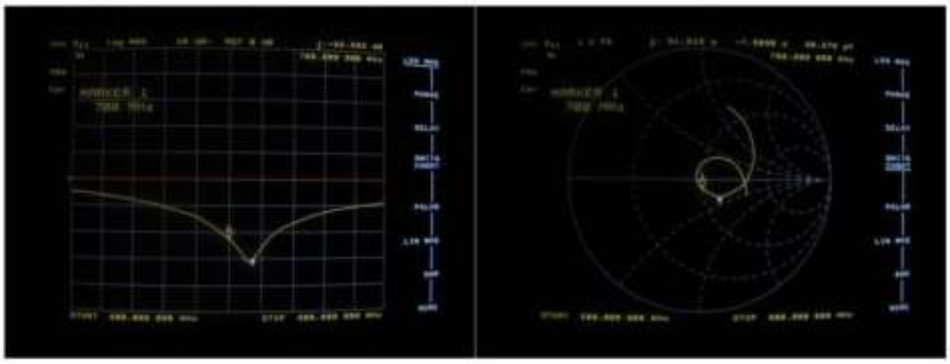
The impedance was measured at the SMA-connector with the network analyser.
The following parameters were measured against Head fluid:



Dipole impedance at 700MHz	Re{Z} = 52.35 Ω
	Im{Z} = -3.65 Ω
Return loss at 700MHz	**-27.29 dB**

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

The measurements repeated against Body fluid:



CALIBRATION LABORATORY REPORT

Dipole impedance at 700MHz	Re{Z} = 51.215 Ω
	Im{Z} = -7.51 Ω
Return loss at 700MHz	**-22.58 dB**

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

SAR Validation Measurement in Brain Fluid

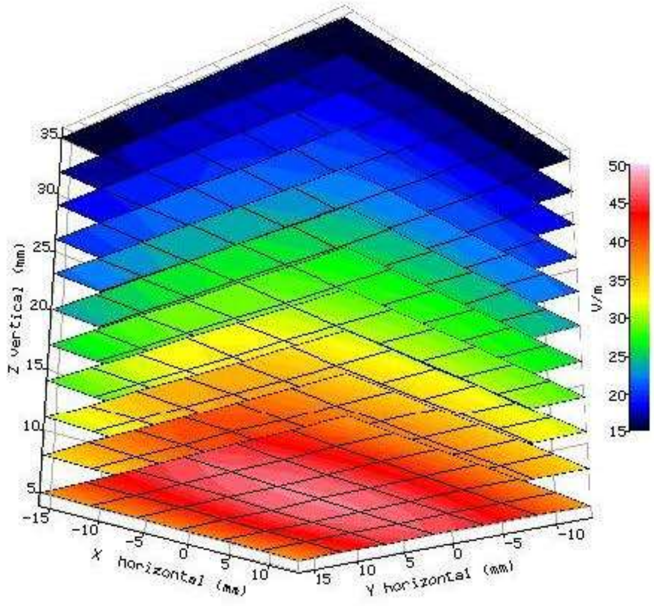
SAR validation checks have been performed using the 700MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 23.2°C and the relative humidity was 29.3% during the measurements.

The phantom was filled with 700MHz brain liquid using a recipe from [1], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 700MHz at the measurement temperature:

Relative Permittivity	**42.6**
Conductivity	**0.896 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:



Report №
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CALIBRATION LABORATORY REPORT

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	1.94	7.72	0.64	7.67
10g SAR	1.30	5.16	0.97	5.11

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

SAR Measurement in Body Fluid

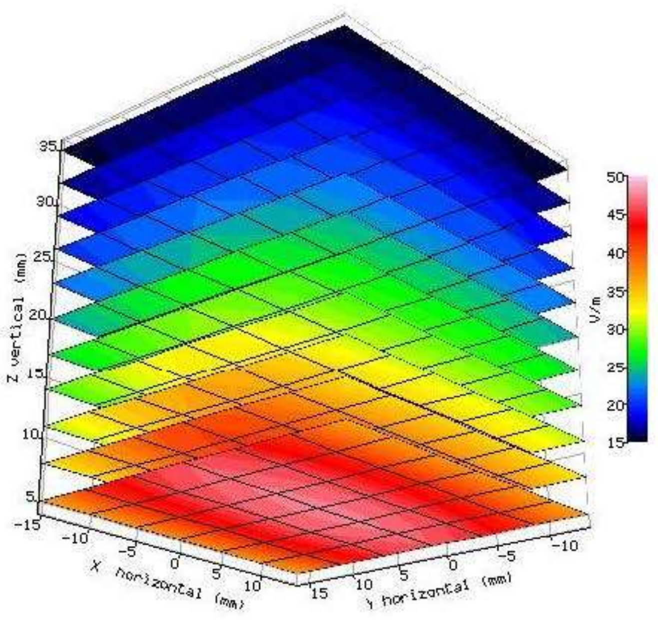
SAR validation checks have been performed using the 700MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 23.3°C and the relative humidity was 30.9% during the measurements.

The phantom was filled with 700MHz body liquid using a recipe from [1][4], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 700MHz at the measurement temperature:

Relative Permittivity	**55.4**
Conductivity	**0.988 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:



Product Service

CALIBRATION LABORATORY REPORT

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	2.061	8.20	6.97**	7.67*
10g SAR	1.40	5.57	8.91**	5.11*

* 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

Product Service

Test Equipment Number (TE): 3876

Calibration Class: A

TUV SUD Product Service

Internal Calibration Laboratory Report

Date of Calibration: 19/02/2014 **Report Number:** 26575

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: D1900V2

Serial No: 546

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 22.4°C ±3°C @ 43.4% RH ±10% RH. The mains voltage was 240V ±10%.

Calibration Engineer:

N. R. Grigsby

Approved Signatory:

A. T. Pearce

Product Service

CALIBRATION LABORATORY REPORT

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

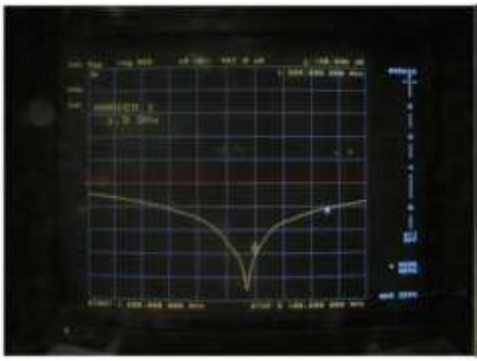
Product Service

CALIBRATION LABORATORY REPORT

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 1900MHz).

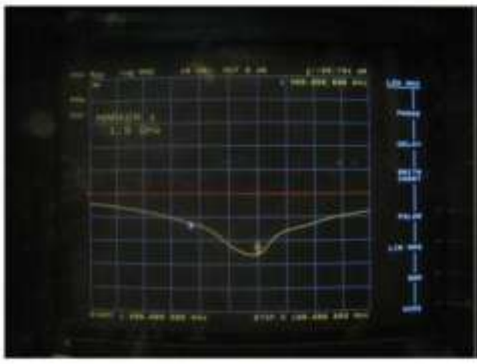
The impedance was measured at the SMA-connector with the network analyser.
The following parameters were measured against Head fluid:



Dipole impedance at 1900MHz	Re{Z} = 47.36 Ω Im{Z} = -1.06 Ω
Return loss at 1900MHz	**-30.59 dB**

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

The measurements repeated against Body fluid:



Product Service

CALIBRATION LABORATORY REPORT

Dipole impedance at 1900MHz	Re{Z} = 49.46 Ω Im{Z} = -5.06 Ω
Return loss at 1900MHz	**-25.73 dB**

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

SAR Validation Measurement in Brain Fluid

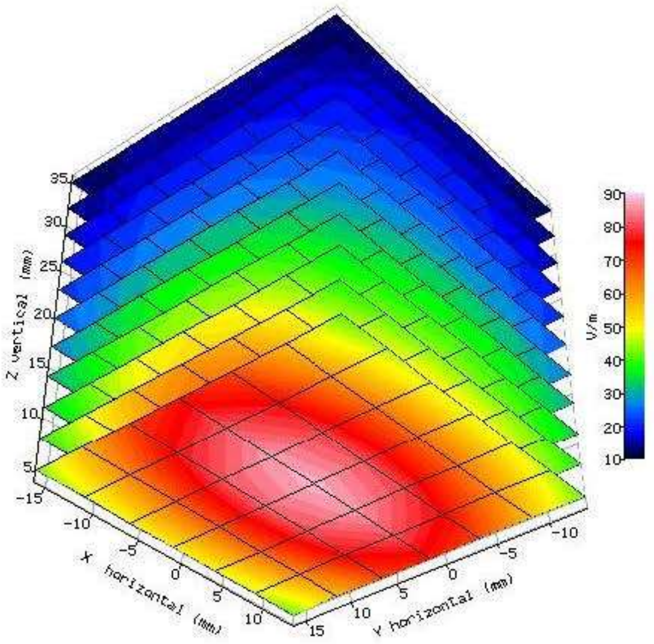
SAR validation checks have been performed using the 1900MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 22.4°C and the relative humidity was 43.4% during the measurements.

The phantom was filled with 1900MHz brain liquid using a recipe from [1], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 1900MHz at the measurement temperature:

Relative Permittivity	**39.28**
Conductivity	**1.433 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:



Product Service

CALIBRATION LABORATORY REPORT

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	10.37	41.28	3.10	40.04
10g SAR	5.464	21.75	2.17	21.29

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

SAR Measurement in Body Fluid

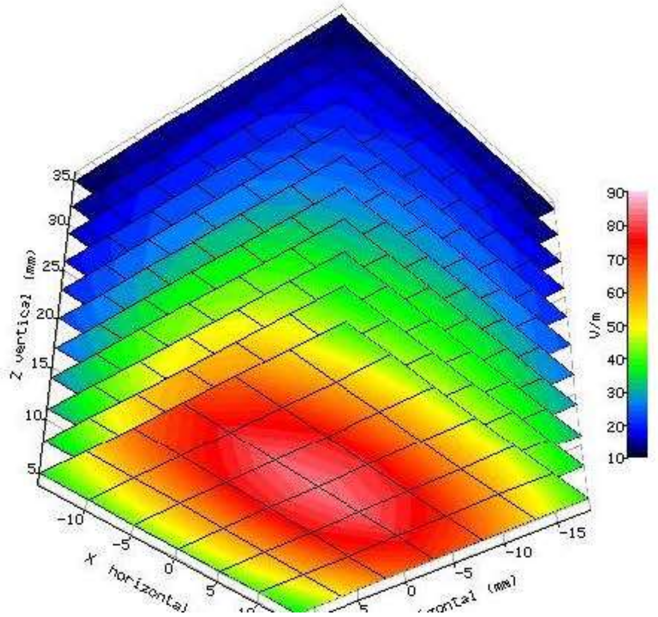
SAR validation checks have been performed using the 1900MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained to the standard input power conditions of 1W (forward power). The ambient temperature was 22.2°C and the relative humidity was 49.1% during the measurements.

The phantom was filled with 1900MHz body liquid using a recipe from [1][4], which has the following electrical parameters (measured using an Indexsar DiLine kit) at 1900MHz at the measurement temperature:

Relative Permittivity	**53.21**
Conductivity	**1.596 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:



Product Service

CALIBRATION LABORATORY REPORT

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	10.12	40.29	0.63**	40.04*
10g SAR	5.38	21.41	0.54**	21.29*

* 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

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

Approved Signatory:

A. T. Pearce

Product Service

CALIBRATION LABORATORY REPORT

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

Product Service

Report № 26576
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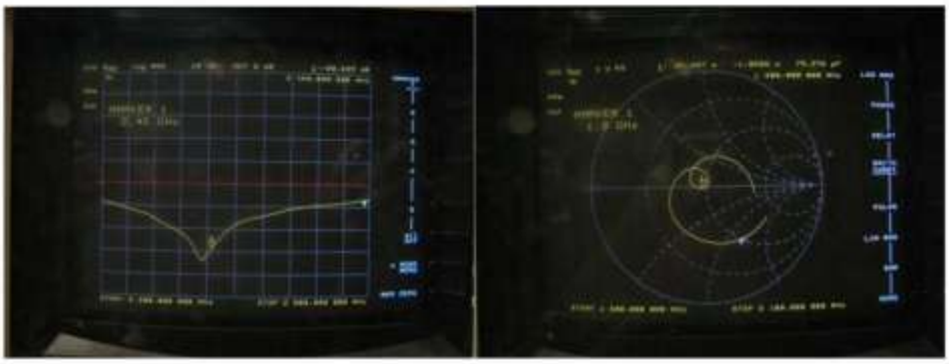
CALIBRATION LABORATORY REPORT

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).

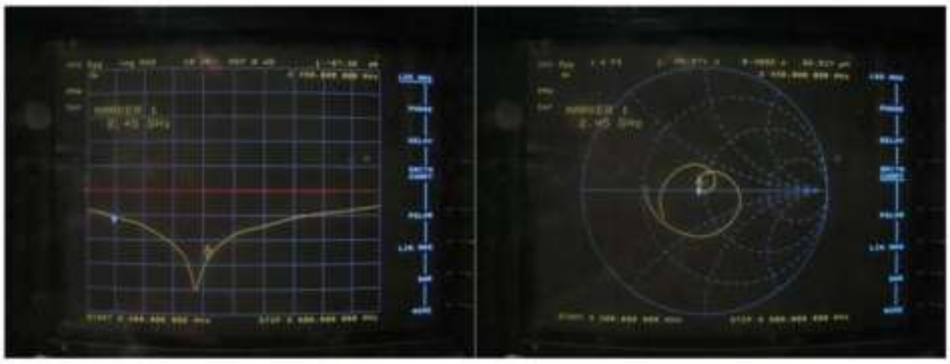
The impedance was measured at the SMA-connector with the network analyser.
The following parameters were measured against Head fluid:



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:



Product Service

CALIBRATION LABORATORY REPORT

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

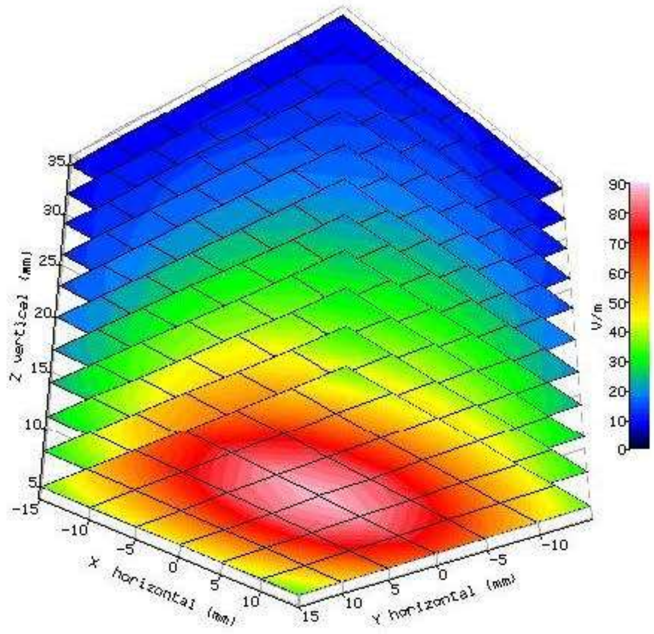
SAR validation checks have been performed using the 2450MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained 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:



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Report № 26576
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CALIBRATION LABORATORY REPORT

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

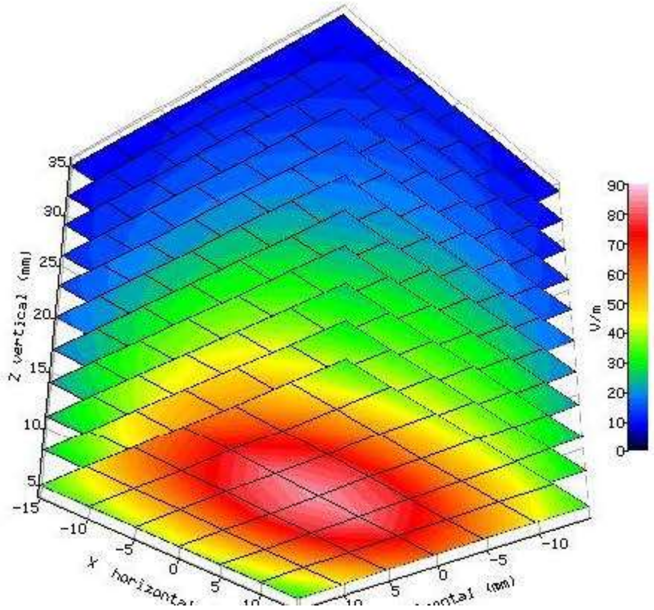
SAR validation checks have been performed using the 2450MHz dipole and the box-phantom located on the SARA-C phantom support base on the SARA-C robot system. Tests were then conducted at a feed power level of approx. 0.25W. The actual power level was recorded and used to normalise the results obtained 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:



Product Service

CALIBRATION LABORATORY REPORT

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

TÜV SÜD Product Service

Calibration Laboratory of
Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland

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Accreditation No.: **SCS 108**

Client **TÜV Product Service Ltd**

Certificate No: **D5GHzV2-1100_Mar11**

CALIBRATION CERTIFICATE

Object	D5GHzV2 - SN: 1100
Calibration procedure(s)	QA CAL-22.v1 Calibration procedure for dipole validation kits between 3-6 GHz
Calibration date:	March 14, 2011

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Power meter EPM-442A	GB37480704	06-Oct-10 (No. 217-01266)	Oct-11
Power sensor HP 8481A	US37292783	06-Oct-10 (No. 217-01266)	Oct-11
Reference 20 dB Attenuator	SN: 5086 (20g)	30-Mar-10 (No. 217-01158)	Mar-11
Type-N mismatch combination	SN: 5047.2 / 06327	30-Mar-10 (No. 217-01162)	Mar-11
Reference Probe EX3DV4	SN: 3503	04-Mar-11 (No. EX3-3503_Mar11)	Mar-12
DAE4	SN: 601	10-Jun-10 (No. DAE4-601_Jun10)	Jun-11

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Power sensor HP 8481A	MY41092317	18-Oct-02 (in house check Oct-09)	In house check: Oct-11
RF generator R&S SMT-06	100005	4-Aug-99 (in house check Oct-09)	In house check: Oct-11
Network Analyzer HP 8753E	US37390585 S4206	18-Oct-01 (in house check Oct-10)	In house check: Oct-11

	Name	Function	Signature
Calibrated by:	Dimce Iliev	Laboratory Technician	D. Iliev
Approved by:	Katja Pokovic	Technical Manager	[signature]

Issued: March 16, 2011

Product Service

Calibration Laboratory of
Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland

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Swiss Calibration Service

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The Swiss Accreditation Service is one of the signatories to the EA
Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 108**

Glossary:

TSL	tissue simulating liquid
ConvF	sensitivity in TSL / NORM x,y,z
N/A	not applicable or not measured

Calibration is Performed According to the Following Standards:

a) IEC 62209-2, "Evaluation of Human Exposure to Radio Frequency Fields from Handheld and Body-Mounted Wireless Communication Devices in the Frequency Range of 30 MHz to 6 GHz: Human models, Instrumentation, and Procedures"; Part 2: "Procedure to determine the Specific Absorption Rate (SAR) for including accessories and multiple transmitters", March 2010

b) Federal Communications Commission Office of Engineering & Technology (FCC OET), "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", Supplement C (Edition 01-01) to Bulletin 65

Additional Documentation:

c) DASY4/5 System Handbook

Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

Measurement Conditions

DASY system configuration, as far as not given on page 1.

DASY Version	DASY5	V52.6.2
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom V5.0	
Distance Dipole Center - TSL	10 mm	with Spacer
Area Scan resolution	dx, dy = 10 mm	
Zoom Scan Resolution	dx, dy = 4.0 mm, dz = 1.4 mm	
Frequency	5200 MHz ± 1 MHz 5500 MHz ± 1 MHz 5800 MHz ± 1 MHz	

Head TSL parameters at 5200 MHz

The following parameters and calculations were applied.

	Temperature	**Permittivity**	**Conductivity**
Nominal Head TSL parameters	22.0 °C	36.0	4.66 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	36.4 ± 6 %	4.51 mho/m ± 6 %
Head TSL temperature during test	(22.0 ± 0.2) °C	----	----

SAR result with Head TSL at 5200 MHz

SAR averaged over 1 cm³ (1 g) of Head TSL	condition	
SAR measured	100 mW input power	8.31 mW / g
SAR normalized	normalized to 1W	83.1 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**83.2 mW / g ± 19.9 % (k=2)**

SAR averaged over 10 cm³ (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.36 mW / g
SAR normalized	normalized to 1W	23.6 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**23.6 mW / g ± 19.5 % (k=2)**

Product Service

Head TSL parameters at 5500 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.6	4.96 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	35.9 ± 6 %	4.80 mho/m ± 6 %
Head TSL temperature during test	(22.0 ± 0.2) °C	----	----

SAR result with Head TSL at 5500 MHz

SAR averaged over 1 cm^3 (1 g) of Head TSL	condition	
SAR measured	100 mW input power	8.98 mW / g
SAR normalized	normalized to 1W	89.8 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**89.8 mW / g ± 19.9 % (k=2)**

SAR averaged over 10 cm^3 (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.54 mW / g
SAR normalized	normalized to 1W	25.4 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**25.4 mW / g ± 19.5 % (k=2)**

Head TSL parameters at 5800 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.3	5.27 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	35.5 ± 6 %	5.10 mho/m ± 6 %
Head TSL temperature during test	(22.0 ± 0.2) °C	----	----

SAR result with Head TSL at 5800 MHz

SAR averaged over 1 cm^3 (1 g) of Head TSL	condition	
SAR measured	100 mW input power	8.39 mW / g
SAR normalized	normalized to 1W	83.9 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**83.9 mW / g ± 19.9 % (k=2)**

SAR averaged over 10 cm^3 (10 g) of Head TSL	condition	
SAR measured	100 mW input power	2.37 mW / g
SAR normalized	normalized to 1W	23.7 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**23.7 mW / g ± 19.5 % (k=2)**

Product Service

Body TSL parameters at 5200 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	49.0	5.30 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.4 ± 6 %	5.48 mho/m ± 6 %
Body TSL temperature during test	(21.0 ± 0.2) °C	----	----

SAR result with Body TSL at 5200 MHz

SAR averaged over 1 cm^3 (1 g) of Body TSL	condition	
SAR measured	100 mW input power	7.70 mW / g
SAR normalized	normalized to 1W	77.0 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**76.8 mW / g ± 19.9 % (k=2)**

SAR averaged over 10 cm^3 (10 g) of Body TSL	condition	
SAR measured	100 mW input power	2.14 mW / g
SAR normalized	normalized to 1W	21.4 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**21.4 mW / g ± 19.5 % (k=2)**

Body TSL parameters at 5500 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.6	5.65 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	47.8 ± 6 %	5.85 mho/m ± 6 %
Body TSL temperature during test	(21.0 ± 0.2) °C	----	----

SAR result with Body TSL at 5500 MHz

SAR averaged over 1 cm^3 (1 g) of Body TSL	condition	
SAR measured	100 mW input power	8.22 mW / g
SAR normalized	normalized to 1W	82.2 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**82.0 mW / g ± 19.9 % (k=2)**

SAR averaged over 10 cm^3 (10 g) of Body TSL	condition	
SAR measured	100 mW input power	2.27 mW / g
SAR normalized	normalized to 1W	22.7 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**22.7 mW / g ± 19.5 % (k=2)**

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Body TSL parameters at 5800 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.2	6.00 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	47.1 ± 6 %	6.22 mho/m ± 6 %
Body TSL temperature during test	(21.0 ± 0.2) °C	----	----

SAR result with Body TSL at 5800 MHz

SAR averaged over 1 cm³ (1 g) of Body TSL	condition	
SAR measured	100 mW input power	7.61 mW / g
SAR normalized	normalized to 1W	76.1 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**75.8 mW / g ± 19.9 % (k=2)**

SAR averaged over 10 cm³ (10 g) of Body TSL	condition	
SAR measured	100 mW input power	2.10 mW / g
SAR normalized	normalized to 1W	21.0 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**20.9 mW / g ± 19.5 % (k=2)**

Product Service

Appendix

Antenna Parameters with Head TSL at 5200 MHz

Impedance, transformed to feed point	52.5 Ω - 7.5 jΩ
Return Loss	-22.3 dB

Antenna Parameters with Head TSL at 5500 MHz

Impedance, transformed to feed point	48.9 Ω - 1.7 jΩ
Return Loss	-33.8 dB

Antenna Parameters with Head TSL at 5800 MHz

Impedance, transformed to feed point	51.7 Ω + 4.3 jΩ
Return Loss	-26.9 dB

Antenna Parameters with Body TSL at 5200 MHz

Impedance, transformed to feed point	53.0 Ω - 6.6 jΩ
Return Loss	-23.1 dB

Antenna Parameters with Body TSL at 5500 MHz

Impedance, transformed to feed point	49.4 Ω - 1.4 jΩ
Return Loss	-36.4 dB

Antenna Parameters with Body TSL at 5800 MHz

Impedance, transformed to feed point	52.2 Ω + 3.8 jΩ
Return Loss	-27.3 dB

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Product Service

General Antenna Parameters and Design

Electrical Delay (one direction)	1.207 ns

After long term use with 40 W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

Additional EUT Data

Manufactured by	SPEAG
Manufactured on	September 24, 2010

Product Service

DASY5 Validation Report for Head TSL

Date/Time: 11.03.2011 14:54:17

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 5GHz; Type: D5GHz; Serial: D5GHzV2 - SN:1100

Communication System: CW; Frequency: 5200 MHz, Frequency: 5500 MHz, Frequency: 5800 MHz; Duty Cycle: 1:1
Medium: HSL 5000
Medium parameters used: f = 5200 MHz; σ = 4.51 mho/m; ε_r = 36.4; ρ = 1000 kg/m^3 ,
Medium parameters used: f = 5500 MHz; σ = 4.8 mho/m; ε_r = 35.9; ρ = 1000 kg/m^3 ,
Medium parameters used: f = 5800 MHz; σ = 5.1 mho/m; ε_r = 35.5; ρ = 1000 kg/m^3
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY5 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.41, 5.41, 5.41), ConvF(4.91, 4.91, 4.91), ConvF(4.81, 4.81, 4.81); Calibrated: 04.03.2011
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 10.06.2010
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- Measurement SW: DASY52, V52.6.2 Build (424)
- Postprocessing SW: SEMCAD X, V14.4.4 Build (2829)

Pin=100mW, f=5200 MHz/Zoom Scan (4x4x1.4mm), dist=1.4mm (8x8x7)/Cube 0:
Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 60.701 V/m; Power Drift = 0.06 dB
Peak SAR (extrapolated) = 31.049 W/kg
SAR(1 g) = 8.31 mW/g; SAR(10 g) = 2.36 mW/g
Maximum value of SAR (measured) = 18.802 mW/g

Pin=100mW, f=5500 MHz/Zoom Scan (4x4x1.4mm), dist=1.4mm (8x8x7)/Cube 0:
Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 60.450 V/m; Power Drift = 0.07 dB
Peak SAR (extrapolated) = 35.828 W/kg
SAR(1 g) = 8.98 mW/g; SAR(10 g) = 2.54 mW/g
Maximum value of SAR (measured) = 21.257 mW/g

Pin=100mW, f=5800 MHz/Zoom Scan (4x4x1.4mm), dist=1.4mm (8x8x7)/Cube 0:
Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 57.226 V/m; Power Drift = 0.04 dB
Peak SAR (extrapolated) = 35.431 W/kg
SAR(1 g) = 8.39 mW/g; SAR(10 g) = 2.37 mW/g
Maximum value of SAR (measured) = 20.329 mW/g

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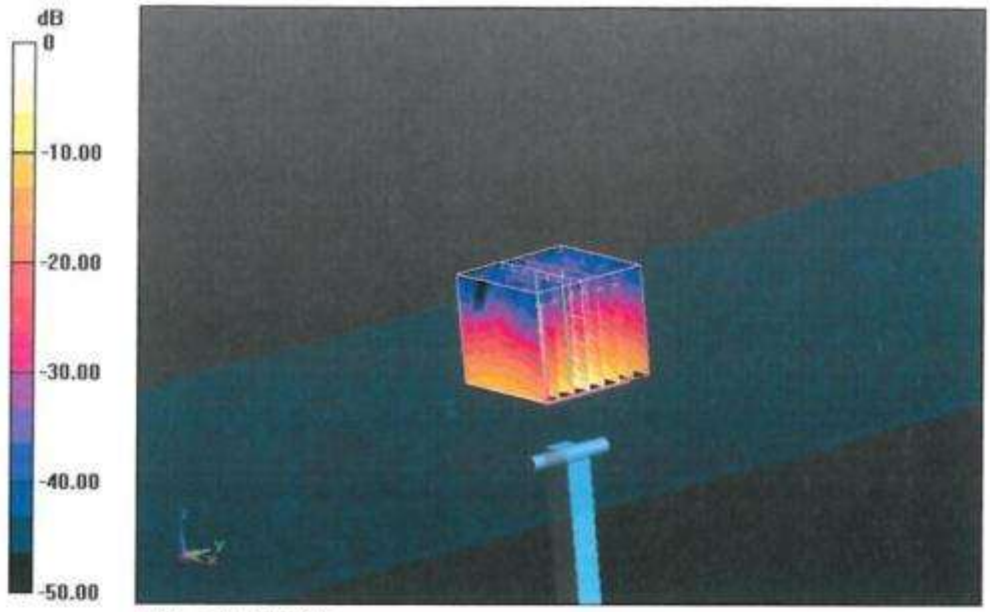
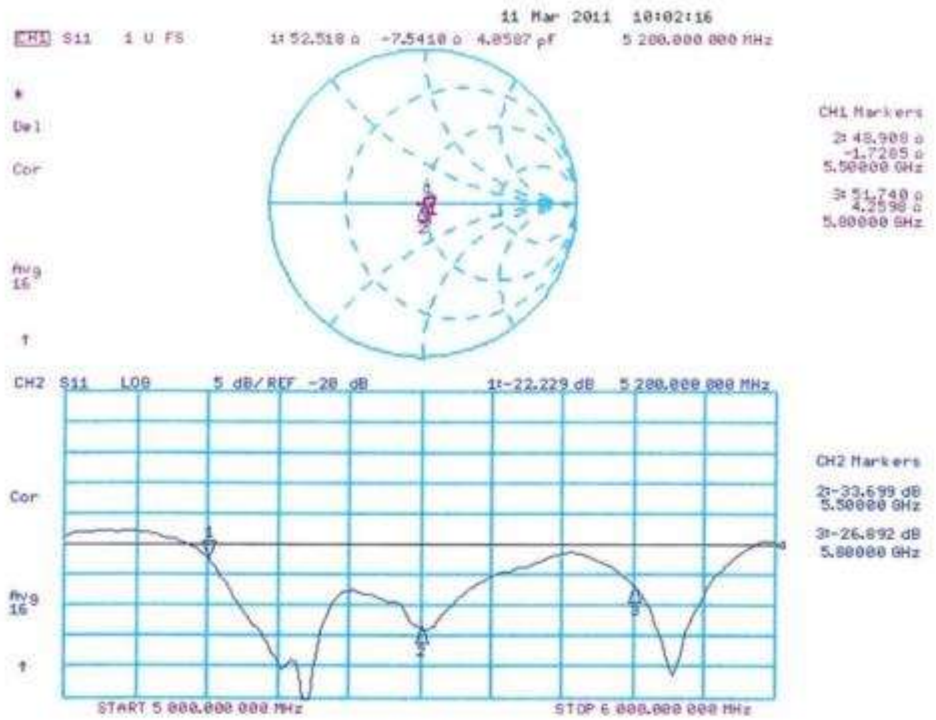
Product Service



0 dB = 20.330mW/g

Product Service

Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date/Time: 14.03.2011 15:25:41

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 5GHz; Type: D5GHz; Serial: D5GHzV2 - SN:1100

Communication System: CW; Frequency: 5200 MHz, Frequency: 5500 MHz, Frequency: 5800 MHz; Duty Cycle: 1:1
Medium: MSL 5000 MHz
Medium parameters used: f = 5200 MHz; σ = 5.54 mho/m; ε_r = 48.3; ρ = 1000 kg/m^3 ,
Medium parameters used: f = 5500 MHz; σ = 5.92 mho/m; ε_r = 47.7; ρ = 1000 kg/m^3 ,
Medium parameters used: f = 5800 MHz; σ = 6.3 mho/m; ε_r = 47; ρ = 1000 kg/m^3
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY5 Configuration:

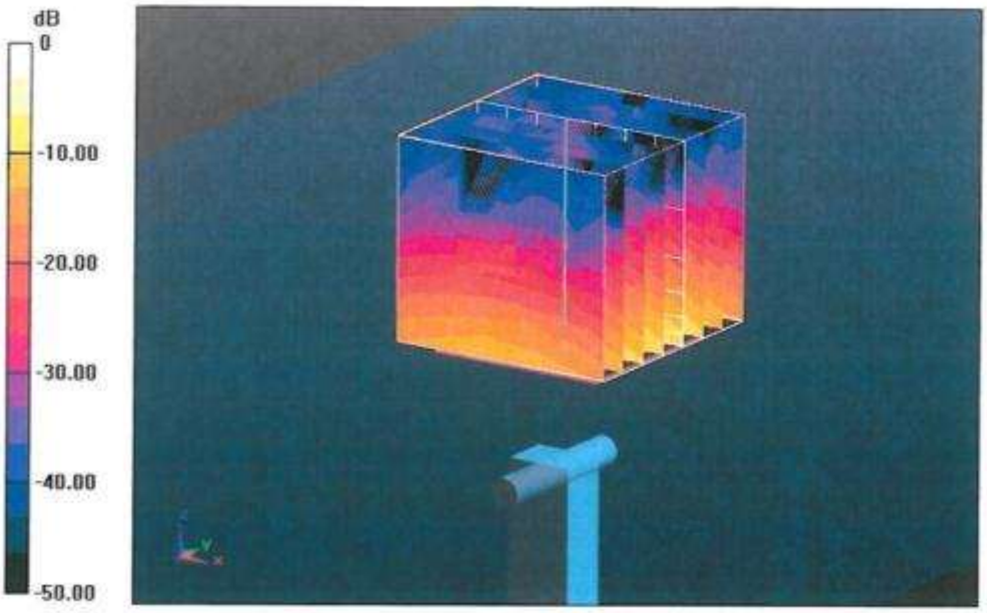
- Probe: EX3DV4 - SN3503; ConvF(4.91, 4.91, 4.91), ConvF(4.43, 4.43, 4.43), ConvF(4.38, 4.38, 4.38); Calibrated: 04.03.2011
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 10.06.2010
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- Measurement SW: DASY52, V52.6.2 Build (424)
- Postprocessing SW: SEMCAD X, V14.4.4 Build (2829)

Pin=100mW, f=5200 MHz/Zoom Scan (4x4x1.4mm), dist=1.4mm (8x8x7)/Cube 0:
Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.462 V/m; Power Drift = -0.0014 dB
Peak SAR (extrapolated) = 30.321 W/kg
SAR(1 g) = 7.7 mW/g; SAR(10 g) = 2.14 mW/g
Maximum value of SAR (measured) = 17.819 mW/g

Pin=100mW, f=5500 MHz/Zoom Scan (4x4x1.4mm), dist=1.4mm (8x8x7)/Cube 0:
Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.851 V/m; Power Drift = -0.03 dB
Peak SAR (extrapolated) = 35.000 W/kg
SAR(1 g) = 8.22 mW/g; SAR(10 g) = 2.27 mW/g
Maximum value of SAR (measured) = 19.554 mW/g

Pin=100mW, f=5800 MHz/Zoom Scan (4x4x1.4mm), dist=1.4mm (8x8x7)/Cube 0:
Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 55.021 V/m; Power Drift = -0.03 dB
Peak SAR (extrapolated) = 35.337 W/kg
SAR(1 g) = 7.61 mW/g; SAR(10 g) = 2.1 mW/g
Maximum value of SAR (measured) = 18.772 mW/g

Product Service



0 dB = 18.770mW/g

Impedance Measurement Plot for Body TSL