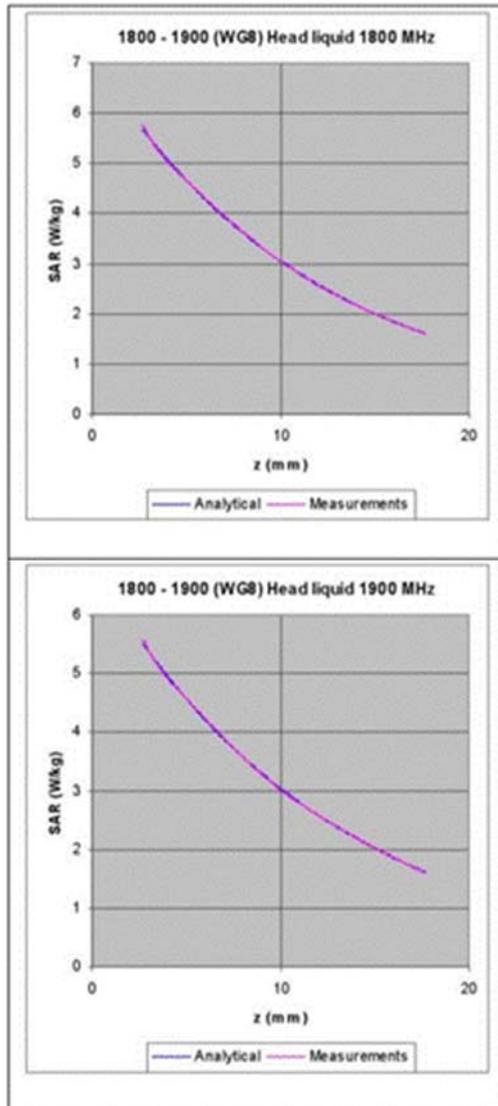


Figure 5 The measured SAR decay function along the centreline of the WG4 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.



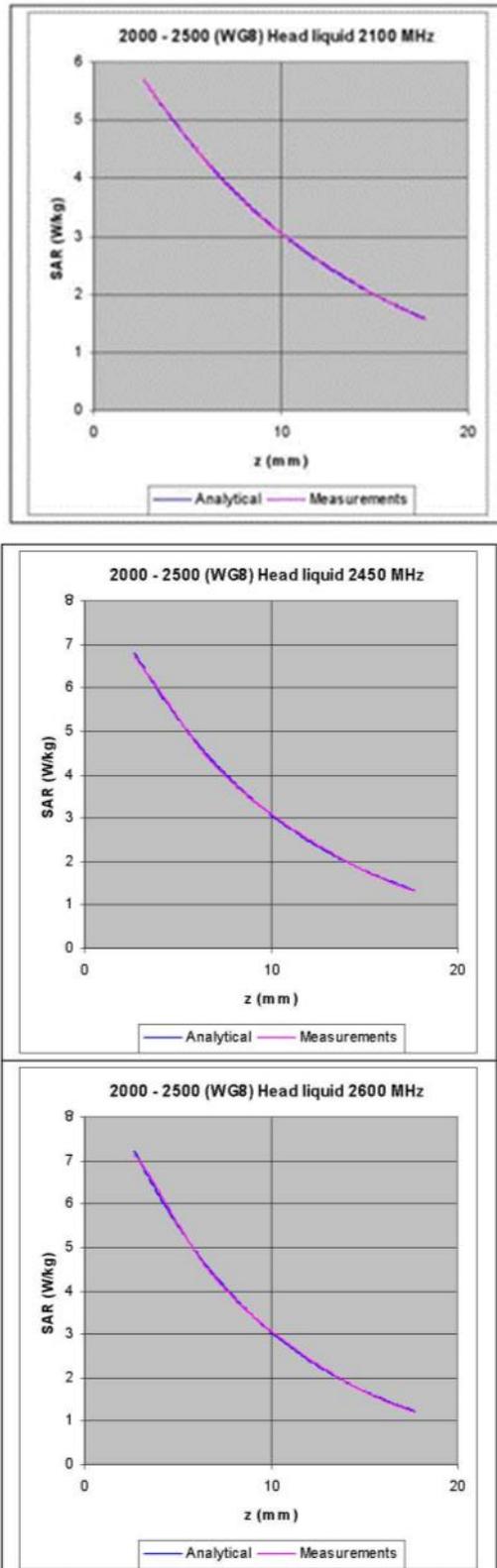


Figure 6. The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

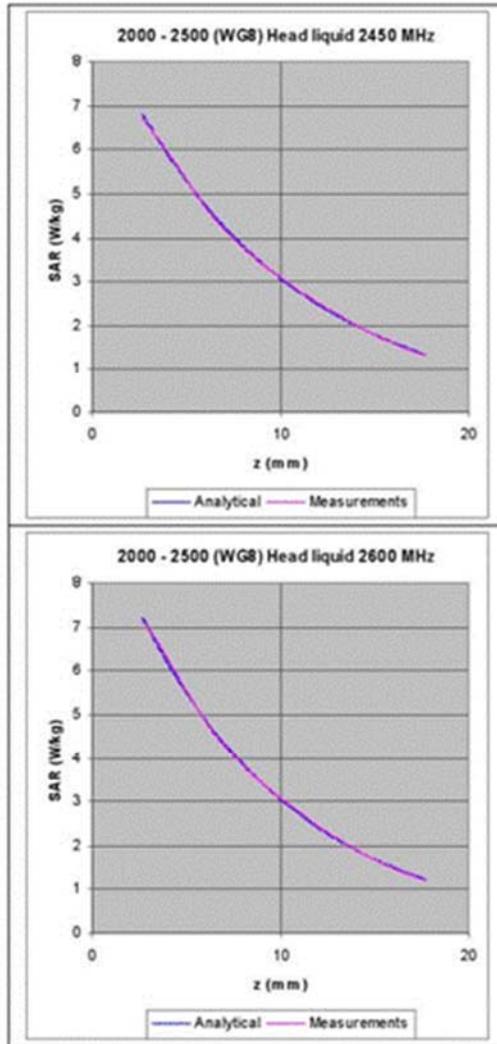


Figure 6. The measured SAR decay function along the centreline of the R22 waveguide with conversion factors adjusted to fit to the theoretical function for the particular dimension, frequency, power and liquid properties employed.

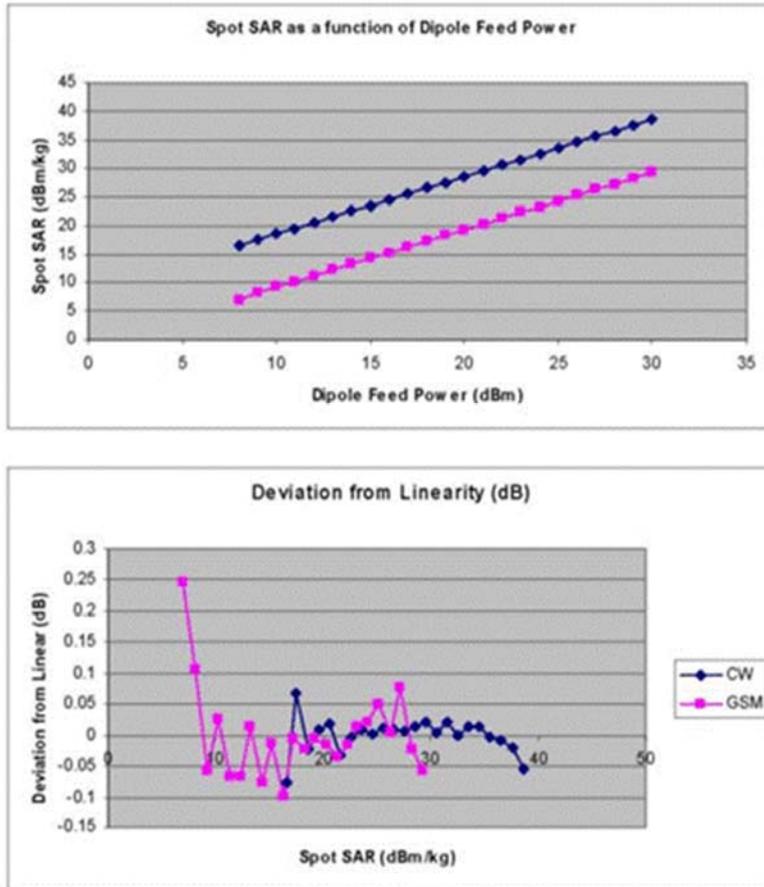


Figure 7: The typical linearity response of 5mm probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of 8 (ie 9dB) lower than CW. The lower diagram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

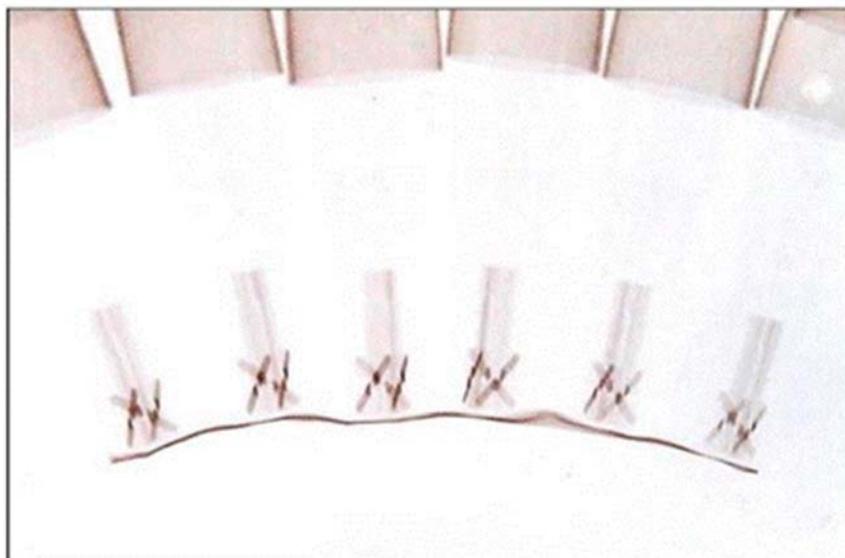


Figure 8 X-ray positive image of 5mm probes



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 | 44.09 | 0.84 | 43.5 | 0.87 | 1.4 | -3.3 | Pass | Pass |
| 835 | | 42.14 | 0.90 | 41.5 | 0.90 | 1.5 | 0.1 | Pass | Pass |
| 900 | | 41.13 | 0.96 | 41.5 | 0.97 | -0.9 | -0.9 | Pass | Pass |
| 1800 | | 39.72 | 1.43 | 40.0 | 1.40 | -0.7 | 2.0 | Pass | Pass |
| 1900 | | 39.71 | 1.41 | 40.0 | 1.40 | -0.7 | 0.6 | Pass | Pass |
| 2100 | | 40.50 | 1.48 | 39.8 | 1.49 | 1.8 | -0.6 | Pass | Pass |
| 2450 | | 39.17 | 1.85 | 39.2 | 1.80 | -0.1 | 2.8 | Pass | Pass |
| 2600 | | 38.60 | 2.01 | 39.0 | 1.96 | -1.0 | 2.7 | Pass | Pass |

Table of test equipment calibration status

| Instrument description | Supplier / Manufacturer | Model | Serial No. | Last calibration date | Cal certificate number | See Annex | Calibration due date |
|---------------------------------|-------------------------|---|------------|---|------------------------|-----------|----------------------|
| Power sensor | Rohde & Schwarz | NRP-Z23 | 100063 | 14/08/2013 | 10-300287035 | 1 | 14/08/2015 |
| Power sensor | Rohde & Schwarz | NRP-Z23 | 100169 | 06/08/2014 | 1400-46811 | 2 | 06/08/2016 |
| Dielectric property measurement | Indexsar | DILine (sensor lengths: 160mm, 80mm and 60mm) | N/A | (absolute) – checked against NFL values using reference liquids | N/A | | N/A |
| Vector network analyser | Anritsu | MS6423B | 003102 | 17/02/2015 | RMA20027002 | 3 | 17/02/2016 |
| SMA autocalibration module | Anritsu | 36581KKF/1 | 001902 | 22/01/2015 | RMA20021769 | 4 | 22/01/2016 |



Product Service

Annex 1

Calibration Certificate of NRP-Z23 power sensor, S/N 100063

| | | | |
|---|---|---------------------------------|---|
| | | Calibration Certificate | Certificate Number 10-300287035 |
| Kalibrierschein | | Zertifikatsnummer | |
| Unit Data | | | |
| Item / Gegenstand | Average power sensor | | <p>This calibration certificate documents, that the named item is tested and measured against defined specifications.</p> <p>Measurement results are located usually in the corresponding interval with a probability of approx. 95% (coverage factor $k = 2$).</p> <p>Calibration is performed with test equipment and standards directly or indirectly traceable by means of approved calibration techniques to the PTB/CNKD or other national / international standards, which realize the physical units of measurement according to the International System of Units (SI).</p> <p>In all cases where no standards are available, measurements are referenced to standards of the R&S laboratories.</p> <p>Principles and methods of calibration correspond with EN ISO/IEC 17025. The applied quality system is certified to EN ISO 9001.</p> <p>This calibration certificate may not be reproduced other than in full. Calibration certificates without signatures are not valid. The user is obliged to have the object recalibrated at appropriate intervals.</p> |
| Manufacturer / Hersteller | ROHDE & SCHWARZ | | |
| Type / Typ | NRP-Z23 | | |
| Material Number / Materialnummer | 1137.8002.02 | Serial Number / Seriennummer | |
| Asset Number / Inventarnummer | | | |
| Order Data | | | |
| Customer / Auftraggeber | IndexSAR Ltd | | |
| | Oakfield House, RH5 5BG Newdigate GB | | |
| Order Number / Bestellnummer | | | |
| Date of Receipt / Eingangsdatum | 2013-08-08 | | |
| Performance | | | |
| Place and Date of Calibration / Ort und Datum der Kalibrierung | Memmingen, 2013-08-14 | | |
| Scope of Calibration / Umfang der Kalibrierung | Standard Calibration | | |
| Statement of Compliance (Steuerung) / Konformitätsaussage (Anlieferung) | Measurement results within specifications | | |
| Statement of Compliance (Schlingung) / Konformitätsaussage (Auslieferung) | Measurement results within specifications | | |
| Extent of Calibration Documents / Umfang des Kalibrierdokuments | 2 Pages Calibration Certificate 17 Pages Outgoing Results 17 Pages Incoming Results | | |
| Rohde & Schwarz GmbH & Co. KG; Service Operations West | | | |
| Date of Issue / Ausstellungsdatum | Head of Laboratory / Laborleitung | Person Responsible / Bearbeiter | |
| | | | |
| 2013-08-14 | Courage | Ruprecht Schmid | Page 1/2 w/01515K0005 |
| ROHDE & SCHWARZ GmbH & Co. KG · Münchenerstraße 10 · D-81671 München, Federal Republic of Germany · Telefon (089) 41 29-0 · Telefax (089) 41 29-132 70 Geschäftsführung: Manfred Passmann (Vorsitzsänder), Christian Lechner, Gerhard Deier Sitz München · Registerkennz. HRB 18 270 · Personlich haftender Gesellschafter: RUGES Verwaltungs-GmbH · Sitz München · Registerkennz. AG München HRB 7 534 | | | |



Product Service

Material Number 1137.8052.82 Serial Number 100643 **Certificate Number 10-300287035**

Calibration Method **NRVC-1109.0930.32** Relative Humidity **20%-60%**
 Kalibrieranweisung Relative Luftfeuchte
 Ambient Temperature **(23 ± 1) °C**
 Umgebungstemperatur

| Working standards used (having a significant effect on the accuracy) Verwendete Gebrauchsnormale (mit signifikantem Einfluss auf die Genauigkeit) | | | | |
|--|-------------|-------------------------------|---|-------------------------|
| Item Gegenstand | Type Typ | Serial Number Seriennummer | Calibration Certificate Number Kalibrierscheinnummer | Cal. Due Kalibr. bis |
| Dual Channel Powermeter | NRVD | 100962 | 0114 D.K.15195-01-00 2013-08 | 2014-11-30 |
| Dual Channel Power Meter | NRVD | 828583-0023 | 0113 D.K.15195-01-00 2013-08 | 2014-11-30 |
| Vector Network Analyzer | ZVM | 835228-0020 | 0102 CRD-K.16101-2011-08 | 2013-09-30 |
| Accura Set for Lin. Measurement | NRVC-B2 | 840867-0026 | 0085 D.K.15195-01-00 2013-01 | 2014-04-30 |
| Calibration Kit Type-N /50 Ohm | 80548 | 2705A00188 | 217-04723 (METAS) | 2015-03-31 |
| Power Standard | NRVC | 836497-0005 | 0082 D.K.15195-01-00 2013-01 | 2014-04-30 |

Conformity statements take the measurement uncertainties into account.
 Die Konformitätsaussagen berücksichtigen die Messunsicherheiten.

Notes
 Anmerkungen

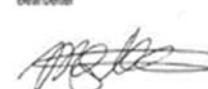
Installed options are included in calibration. Depending on installed options, numbers of pages of the record are not consecutive.



Product Service

Annex 2

Calibration Certificate of NRP-Z23 power sensor, S/N 100169

|  ROHDE & SCHWARZ | | | |
|--|---|---|---|
| Calibration Certificate | | Certificate Number | |
| Kalibrierschein | | Zertifikatsnummer | |
| Unit data | | <p>This calibration certificate documents, that the named item is tested and measured against defined specifications. Measurement results are located usually in the corresponding interval with a probability of approx. 95% (coverage factor $k = 2$). Calibration is performed with test equipment and standards directly or indirectly traceable by means of approved calibration techniques to the PTB/DKD or other national / international standards, which realize the physical units of measurement according to the International System of Units (SI). In all cases where no standards are available, measurements are referenced to standards of the R&S laboratories.</p> <p>Principles and methods of calibration correspond essentially with the technical requirements of EN ISO/IEC 17025. The applied quality system is certified to EN ISO 9001. This calibration certificate may not be reproduced other than in full. Calibration certificates without signatures are not valid. The user is obliged to have the object recalibrated at appropriate intervals.</p> <p>Dieser Kalibrierschein dokumentiert, dass der genannte Gegenstand nach festgelegten Vorgaben geprüft und gemessen wurde. Die Messwerte liegen im Regelfall mit einer Wahrscheinlichkeit von annähernd 95% im zugehörigen Messbereich.</p> <p>(Erwartete Messunsicherheit mit $k = 2$).</p> <p>Die Kalibrierung erfolgte mit Messmitteln und Normen, die direkt oder indirekt durch Ableitung mittel anerkannter Kalibriertechniken rückgeführt sind auf Normale der PTB/DKD oder anderer national/internationaler Standards zur Darstellung der physikalischen Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI). Wenn keine Normale existieren, erfolgt die Rückführung auf Bezugsnormale der R&S-Laboratorien. Grundsätze und Verfahren der Kalibrierung entsprechen im Wesentlichen den technischen Anforderungen der EN ISO/IEC 17025. Das angewendete Qualitätsmanagementsystem ist zertifiziert nach EN ISO 9001. Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Kalibrierscheine ohne Unterschriften sind ungültig. Für die Erhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.</p> | |
| Item Gegenstand | AVERAGE POWER SENSOR | | |
| Manufacturer Hersteller | Rohde & Schwarz | | |
| Type Typ | NRP-Z23 | | |
| Material number Materialnummer | 1137.8002.02 | | Serial number ID: 1137.8002.02-100169-aj Seriennummer Ser.: 100169 |
| Asset number Anlagennummer | Recommended Calibration Interval 24 Months | | |
| Order data | | | |
| Customer Auftraggeber | IndexSAR Ltd Oakfield House, Newdigate RH16 6BG Great Britain | | |
| On behalf of (where applicable) In namen von (Wenn gewünscht) | | | |
| Order number Bestellungsnummer | 1024R&S | | |
| Date of receipt Empfangsdatum | 2014-08-06 (yyyy-mm-dd) | | |
| Performance | | | |
| Place and date of calibration Ort u. Datum d. Kalibrierung | Fleet; | 2014-08-06 (yyyy-mm-dd) | |
| Scope of calibration Umfang der Kalibrierung | Factory Standard Calibration | | |
| Statement of Compliance (Incoming) Konformitätsaussage (Anlieferung) | All measured values are <u>within the data sheet specifications</u> . | | |
| Statement of Compliance (Outgoing) Konformitätsaussage (Auslieferung) | All measured values are <u>within the data sheet specifications</u> . | | |
| Extent of calibration documents Umfang der Kalibrierdokumentation | 2 | Pages Calibration Certificate | |
| | 40 | Pages Calibration Results | |
| | 2 | Pages Incoming Report | |
| Rohde & Schwarz UK | | | |
| Date of issue Ausstellungsdatum | Head of laboratory Laborleitung | Person responsible Bearbeiter | |
| |  |  | |
| 2014-08-06 (yyyy-mm-dd) | Carol McKenzie | Martin Gil | |
| Page (Seite) 1 of 2 | | | |

ROHDE & SCHWARZ UK Ltd, Ancoats Business Park, Fleet Hanger Lane, GUS1 2UZ, United Kingdom
Registered in England No. 539607



Product Service

| | | | |
|--|--|--|------------|
| Material number Materialnummer | 1137.8002.02 | Certificate Number Zertifikatsnummer | 1400-48811 |
| Serial number Seriennummer | ID: 1137.8002.02-100169-aj Ser.: 100169 | | |

| | | | |
|--|---------------------------------------|--|--------------------------|
| Calibration instruction Kalibrieranweisung | See first page of calibration results | Date of receipt Eingangdatum | 2014-08-06 (mm-dd-yy) |
| Ambient temperature Umgebungstemperatur | (23 ± 2) °C | Relative humidity Relative Luftfeuchte | 20 % - 60 % |

This calibration fulfils the requirements of the standard / guideline
Diese Kalibrierung entspricht den Forderungen der Norm / Richtlinie

| Working standards used (having a significant effect on the accuracy) Verwendete Gebrauchsnormale (mit signifikantem Einfluss auf die Genauigkeit) | | | | |
|--|-------------|-------------------------------|--|-------------------------|
| Item Gegenstand | Type Typ | Serial number Seriennummer | Calibration certificate number Kalibrierschein Nummer | Cal. due Kalibr. bis |
| See page 2 of calibration results | | | | |

UGB (Uncertainty guard Band): Measurement uncertainty violates the datasheet limit

UGB1 A compliance statement may be possible where a confidence level of less than 95 % is acceptable.
Die Bestätigung der Konformität ist möglich, sofern ein Grad des Vertrauens von weniger als 95% akzeptabel ist.

UGB2 A non-compliance statement may be possible where a confidence level of less than 95 % is acceptable.
Die Bestätigung der Nicht-Konformität ist möglich, sofern ein Grad des Vertrauens von weniger als 95% akzeptabel ist.

Conformity statements take the measurement uncertainties into account.
Die Konformitätsaussagen berücksichtigen die Messunsicherheiten.

Ref.: ILAC-G8 1996 'Guidelines on Assessment and Reporting of Compliance with Specification (based on measurements and tests in a laboratory)'

Notes
Anmerkungen



Product Service

Annex 3

Calibration certificate of Anritsu MS4623B VNA

| Certificate of Calibration | | Anritsu Discover What's Possible™ | |
|---|-----------------|---|-------------|
| Customer: INDEXSAR LTD INDEXSAR LTD, OAKFIELD HOUSE NEWDIGATE SURREY RH15 5BG UNITED KINGDOM | | ANRITSU EMEA LIMITED 200 CAPABILITY GREEN LUTON LU1 3LU UNITED KINGDOM Tel: +44 (0) 1582 433285 Fax: +44 (0) 1582 455875 Email: service_emea@eu.anritsu.com | |
| Date of Issue: | 17/02/2015 | Certificate N°: | RMA20027002 |
| Customer: | INDEXSAR LTD | Order No: | Contract |
| Manufacturer: | Anritsu Company | | |
| Model | Serial Number | Description | |
| MS4623B | 003102 | VNA,10 MHZ-6 GHZ,ACTIVE | |
| <p>Anritsu EMEA Limited does hereby certify the above listed equipment complies to published or stated specifications at the measured parameters, and has been calibrated to the general requirements of ISO 17025 against instruments whose accuracies are traceable to National or International Standards, where such standards are applicable.</p> | | | |
| Repair required before calibration | (yes) |  Murray Coleman Head of Customer Services (EMEA) | |
| Electrical Safety | (yes) | | |
| Laser safety class | () | | |
| <p>Note: Original calibration results are attached and copies held on file at Anritsu EMEA Limited. The attached results relate only to the instrument under calibration. Anritsu EMEA Limited Quality system is certified to ISO9001:2000 (Cert. No. FQA 0363176) This Certificate comprises of: Certificate of Calibration Call Report 25 Page(s) of test results</p> | | | |



Product Service

Annex 3

Calibration certificate of Anritsu MS4623B VNA

| Certificate of Calibration | | Anritsu Discover What's Possible™ | |
|---|-----------------|---|-------------|
| Customer: INDEXSAR LTD INDEXSAR LTD, OAKFIELD HOUSE NEWGATE SURREY Road 550 UNITED KINGDOM | | ANRITSU EMEA LIMITED 200 CAPABILITY GREEN LUTON LU1 3LU UNITED KINGDOM Tel: +44 (0) 1582 433285 Fax: +44 (0) 1582 455675 Email: service_emea@eu.anritsu.com | |
| Date of Issue: | 17/02/2015 | Certificate N°: | RMA20027002 |
| Customer: | INDEXSAR LTD | Order No: | Contract |
| Manufacturer: | Anritsu Company | | |
| Model | Serial Number | Description | |
| MS4623B | 003102 | VNA, 10 MHz-6 GHz, ACTIVE | |
| <p>Anritsu EMEA Limited does hereby certify the above listed equipment complies to published or stated specifications at the measured parameters, and has been calibrated to the general requirements of ISO 17025 against instruments whose accuracies are traceable to National or International Standards, where such standards are applicable.</p> | | | |
| Repair required before calibration | (yes) |  Murray Coleman Head of Customer Services (EMEA) | |
| Electrical Safety | (yes) | | |
| Laser safety class | () | | |
| <p>Note: Original calibration results are attached and copies held on file at Anritsu EMEA Limited. The attached results relate only to the instrument under calibration. Anritsu EMEA Limited Quality system is certified to ISO9001:2000 (Cert. No. FQA 0353176) This Certificate comprises of: Certificate of Calibration Call Report 25 Page(s) of test results</p> | | | |



Product Service

Annex 4

Calibration certificate of Anritsu 36581KKF/1 auto-cal kit

| Certificate of Calibration | | Anritsu Discover What's Possible™ |
|---|-------------------------------------|--|
| Customer: INDEXSAR LTD INDEXSAR LTD, OAKFIELD HOUSE NEWGATE SURREY RH5 5BG UNITED KINGDOM | | ANRITSU EMEA LIMITED 200 CAPABILITY GREEN LUTON LU1 3LU UNITED KINGDOM Tel: +44 (0) 1582 433285 Fax: +44 (0) 1582 455575 Email: service_esc@eu.anritsu.com |
| Date of Issue: | 22/01/2015 | Certificate N°: RMA20026648 |
| Customer: | INDEXSAR LTD | Order No: 1045ANR |
| Manufacturer: | Anritsu Company | |
| Model | Serial Number | Description |
| MS4623B 36581KKF/1 | 003102 001902 | VNA,10 MHZ-6 GHZ,ACTIVE TESTED & CHARACTERIZED TO 6 GHZ |
| <p>Anritsu EMEA Limited does hereby certify the above listed equipment complies to published or stated specifications at the measured parameters, and has been calibrated to the general requirements of ISO 17025 against instruments whose accuracies are traceable to National or International Standards, where such standards are applicable.</p> | | |
| Within specification before calibration Repair required before calibration Electrical Safety Laser safety class | (yes) (no) (yes) () |  Murray Coleman Head of Customer Services (EMEA) |
| <p>Note: Original calibration results are attached and copies held on file at Anritsu EMEA Limited. The attached results relate only to the instrument under calibration. Anritsu EMEA Limited Quality system is certified to ISO9001:2000 (Cert. No. FQA 0353176) This Certificate comprises of: Certificate of Calibration Call Report 13 Page(s) of test results</p> | | |



Product Service



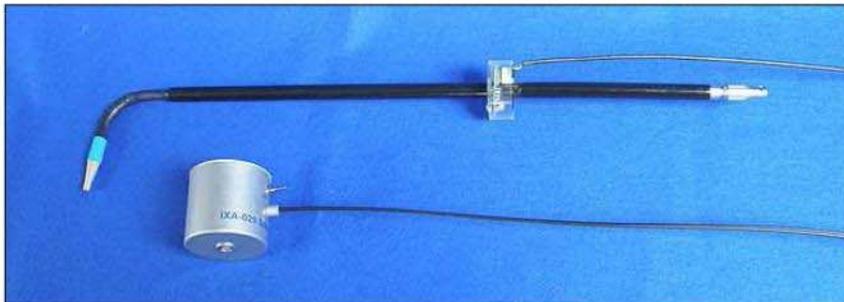
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP-021

S/N LG0018

March 2014



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

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Product Service



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

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.

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:

$$U_{lin} = U_{op} + U_{op}^2 / DCP \quad (1)$$

where U_{lin} is the linearised signal, U_{op} 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:

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



$$\begin{aligned}
 &+ U_{\text{liny}} * \text{Air Factor}_y * \text{Liq Factor}_y \\
 &+ U_{\text{linz}} * \text{Air Factor}_z * \text{Liq Factor}_z
 \end{aligned}
 \tag{3}$$

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 TE₀₁ 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 stationary (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_{op} 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_{op} 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:

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

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).

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

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.

Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at $22 \pm 2.0^{\circ}\text{C}$; 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.



Product Service

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.



Product Service

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 \pm % | Probability distribution | Divisor | c_i | Standard uncertainty $u_i \pm$ % | 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 $\pm 12.4\%$

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 (\pm dB) | SAR Conv Factor | Boundary Correction f(θ) | 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 |



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
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.

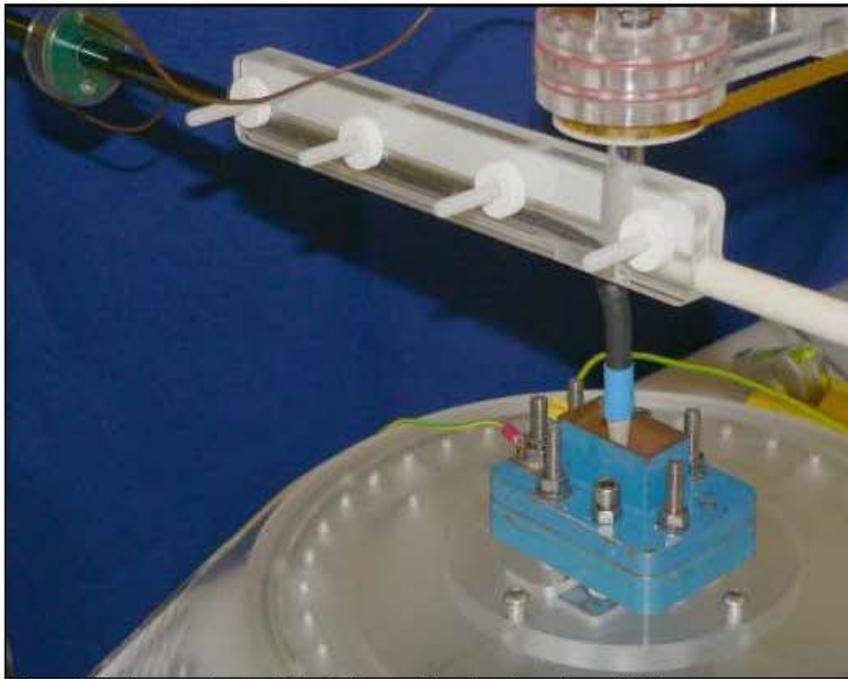


Figure 1 Test geometry used for isotropy determination above 3GHz



Product Service

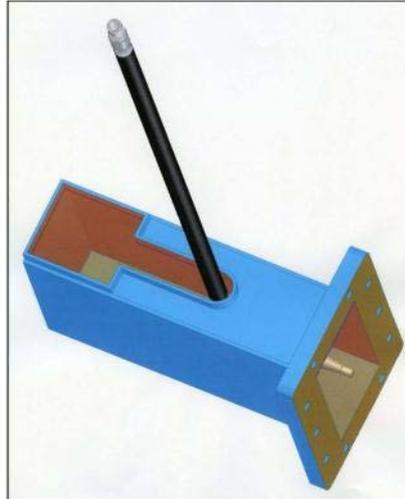


Figure 2. Schematic showing the innovative design of slot in the waveguide termination

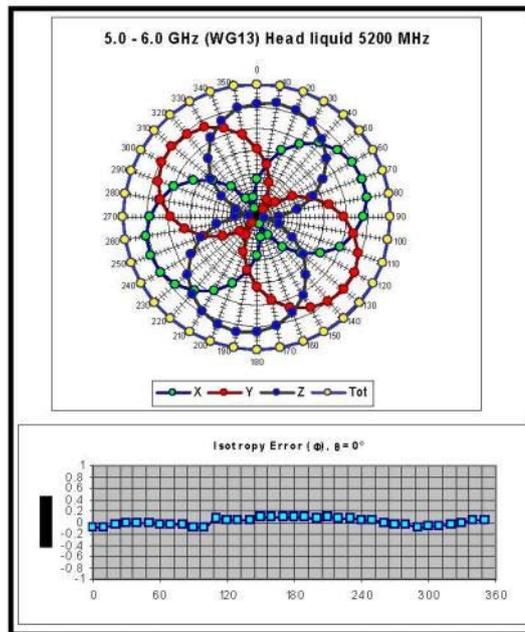


Figure 3 Rotational isotropy measurements inside a WG13 waveguide.

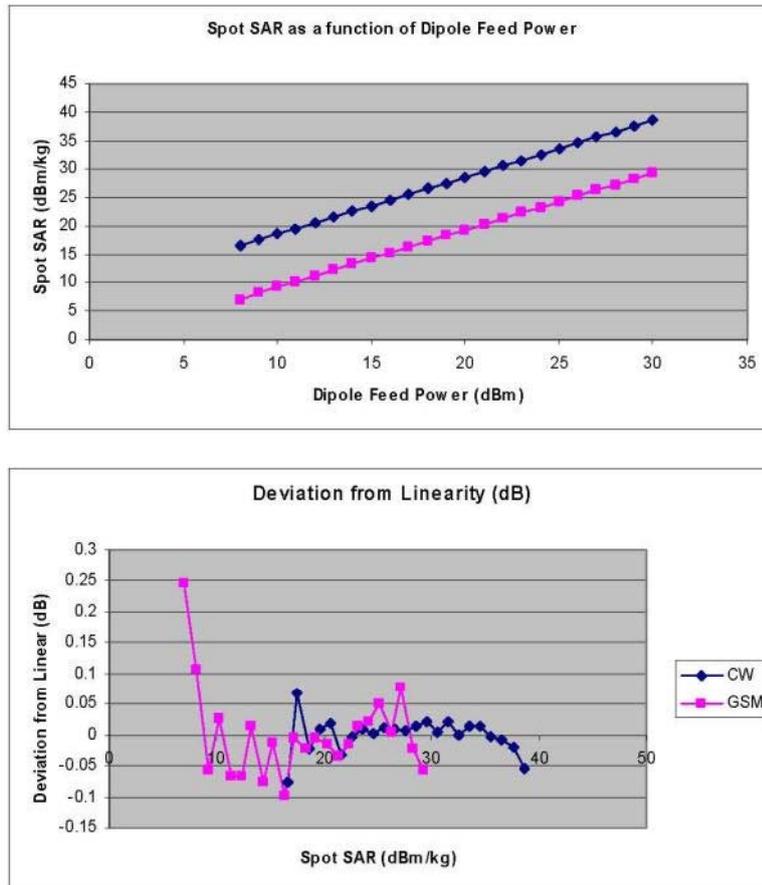


Figure 4 The typical linearity response of IXP-021 probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of 8

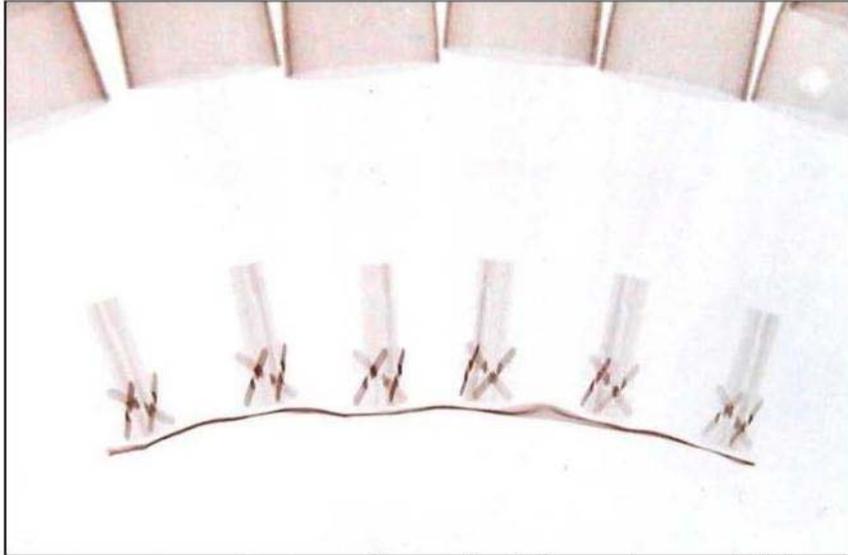


Figure 5X-ray positive image of 5mm probes (2.5mm probes are similar)



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 |

**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 |



Product Service



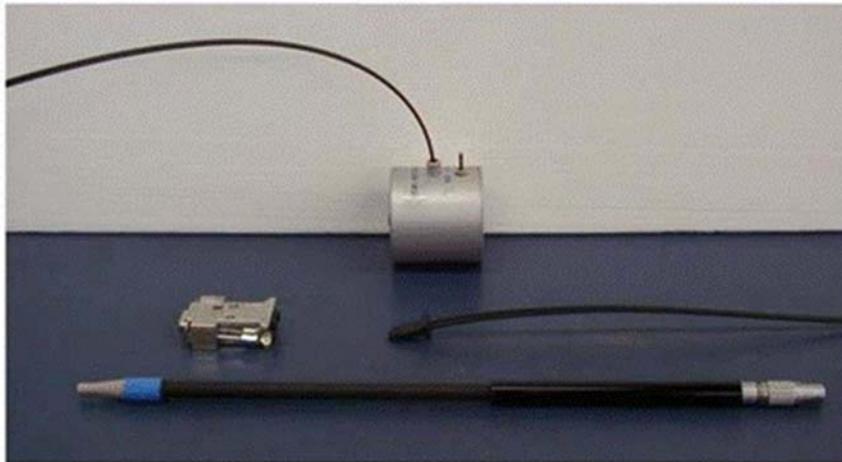
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 050

S/N 0204

March 2015



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Calibration Certificate 1503/0204
Date of Issue: 31 March 2015
Immersible SAR Probe

| | |
|---------------------------|----------------------------|
| Type: | IXP-050 |
| Manufacturer: | IndexSAR, UK |
| Serial Number: | 0204 |
| Place of Calibration: | IndexSAR, UK |
| Date of Receipt of Probe: | 10 February 2015 |
| Calibration Dates: | 25 February– 13 March 2015 |
| Customer: | TUV Sud |

IndexSAR Ltd hereby declares that the IXP-050 Probe named above has been calibrated for conformity to the current versions of IEEE 1528, IEC 62209-1, IEC 62209-2, and FCC SAR 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:  Engineer

Approved by:  Director

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



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 0204) for use on SARA-C only. **The calibration factors do not apply to, and will not give correct readings on, the IndexSAR SARA2 system.**

Indexsar probes are characterised using procedures that, where applicable, follow the recommendations of IEC 62209-1 [Ref 1], IEEE 1528 [Ref 2], IEC 62209-2 [Ref 3] and FCC [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) Channel sensitivity factors are largely frequency independent. Consequently, they can be combined to model the exponential decay of SAR in a waveguide fluid cell at each frequency of interest, and hence derive the liquid conversion factors at that frequency.

2. Probe output

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

$$U_{lin} = U_{op} + U_{op}^2 / DCP \quad (1)$$

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

DCP is determined from fitting equation (1) to measurements of U_{lin} versus source feed power over the full dynamic range of the probe. The DCP is a characteristic of the Schottky diodes used as the sensors. For the IXP-020 probes with CW signals the DCP values are typically 100mV.



For this value of DCP, the typical linearity response of IXP-050 probes to CW and to GSM modulation is shown in Figure 4, 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, an L-probe's predominant mode of operation is with the tip pointing directly towards the source of radiation. Consequently, optimising the probe's response to boresight signals ("axial isotropy") is far more important than optimising its spherical isotropy (where the direction, as well as the polarisation angle, of the incoming radiation must be taken into account).

The setup for measuring the probe's axial isotropy is shown in Figure 1. Since isotropy is frequency-independent, measurements are normally made at a frequency of 900MHz as lower frequencies are more tolerant of positional inaccuracies.

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

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

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

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

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_{op} 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_{op} values and written to an Excel template.

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

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

4. 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:

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

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).

$$\delta = \left[\text{Re} \left\{ \sqrt{(\pi/a)^2 + j\omega\mu_0(\sigma + j\omega\epsilon_0\epsilon_r)} \right\} \right]^{-1} \tag{5}$$

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.

Wherever possible, all DiLine and calibration measurements should be made in the open laboratory at $22 \pm 2.0^\circ\text{C}$; 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. 240 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 0.35mm steps below 3GHz, down to 0.05mm at 5GHz.

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

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

CALIBRATION FACTORS MEASURED FOR PROBE S/N 0204

The probe was calibrated at 700, 835, 900, 1800, 1900, 2100, 2450 and 2600 MHz in liquid samples representing brain and body liquid at these frequencies.



The calibration was for CW signals only, and the axis of the probe was parallel to the direction of propagation of the incident field i.e. end-on to the incident radiation. The axial isotropy of the probe was measured by rotating the probe about its axis in 10 degree steps through 360 degrees in this orientation.

The reference point for the calibration is in the centre of the probe's cross-section at a distance of 2.7 mm from the probe tip in the direction of the probe amplifier. A value of 2.7 mm should be used for the tip to sensor offset distance in the software. The distance of 2.7mm for assembled probes has been confirmed by taking X-ray images of the probe tips (see Figure 5).

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 19 indicates the calibration status of all test equipment used during probe calibration.

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 u _i ± % | 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 | | | 6.29 | |

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

SUMMARY OF CAL FACTORS FOR PROBE IXP-050 S/N 0204

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

| Measured Isotropy | (+/-) dB |
|-------------------|-----------|
| Axial Isotropy* | 0.05±0.01 |

| Physical Information | |
|----------------------------|-----|
| Sensor offset (mm) | 2.7 |
| Elbow – Tip dimension (mm) | 0.0 |



| SAR Conversion Factors/ Boundary Corrections | | | | | | | |
|--|----------------------------------|--------------------------|---------------------------|-----------------|--------------------------|---------------------------|-------|
| Frequency* (MHz) | Head Fluid | | | Body Fluid | | | Notes |
| | SAR Conv Factor | Boundary Correction f(θ) | Boundary Correction d(mm) | SAR Conv Factor | Boundary Correction f(θ) | Boundary Correction d(mm) | |
| 450 | 0.311 | 0.90 | 1.7 | 0.317 | 1.00 | 1.6 | 3 |
| 700 | 0.313 | 0.89 | 1.7 | 0.312 | 0.58 | 1.8 | 1,2 |
| 835 | 0.307 | 1.78 | 1.1 | 0.309 | 0.53 | 1.5 | 1,2 |
| 900 | 0.311 | 0.81 | 1.6 | 0.318 | 0.94 | 1.4 | 1,2 |
| 1800 | 0.357 | 0.70 | 1.5 | 0.382 | 0.51 | 1.9 | 1,2 |
| 1900 | 0.392 | 0.76 | 1.8 | 0.398 | 0.58 | 1.8 | 1,2 |
| 2100 | 0.395 | 0.70 | 2.0 | 0.434 | 0.62 | 1.5 | 1,2 |
| 2450 | 0.397 | 1.09 | 1.4 | 0.440 | 1.04 | 1.2 | 1,2 |
| 2600 | 0.382 | 1.30 | 1.5 | 0.446 | 1.11 | 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).



PROBE SPECIFICATIONS

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

| Dimensions | S/N 0204 | BSEN [1] | IEEE [2] |
|--|----------|----------|----------|
| Overall length (mm) | 350 | | |
| Tip length (mm) | 10 | | |
| Body diameter (mm) | 12 | | |
| Tip diameter (mm) | 5.2 | 8 | 8 |
| Distance from probe tip to dipole centers (mm) | 2.7 | | |

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

| Isotropy (measured at 900MHz) | S/N 0204 | BSEN [1] | IEEE [2] |
|---|----------|----------|----------|
| Axial rotation with probe normal to source (+/- dB) | 0.05 | 0.5 | 0.25 |

NB Isotropy is frequency independent

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



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 KDB865664
- [5] Indexsar Report IXS-0300, October 2007.
Measurement uncertainties for the SARA2 system assessed against the recommendations of BS EN 62209-1:2006
- [6] SARA-C SAR Testing System: Measurement Uncertainty, v1.0.3. October 2011.

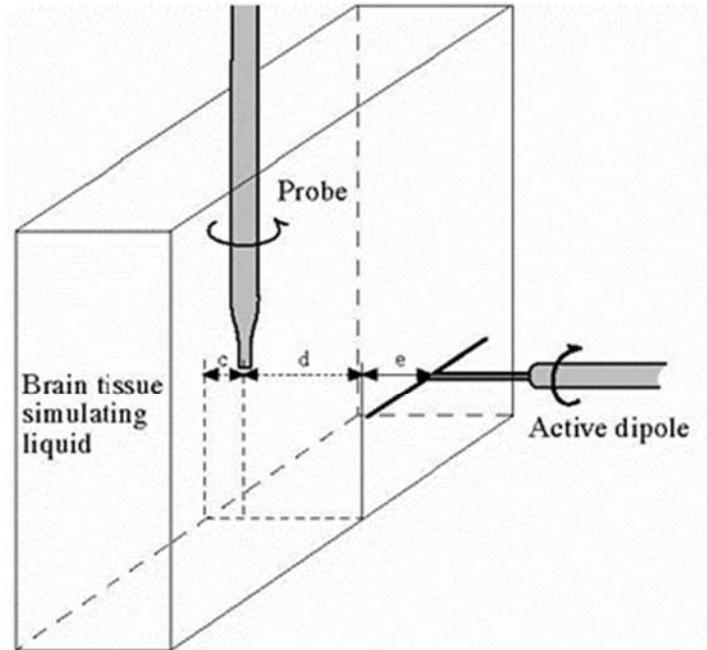


Figure 1. Spherical isotropy jig showing probe, dipole and box filled with simulated brain liquid (see Ref [2], Section A.5.2.1)

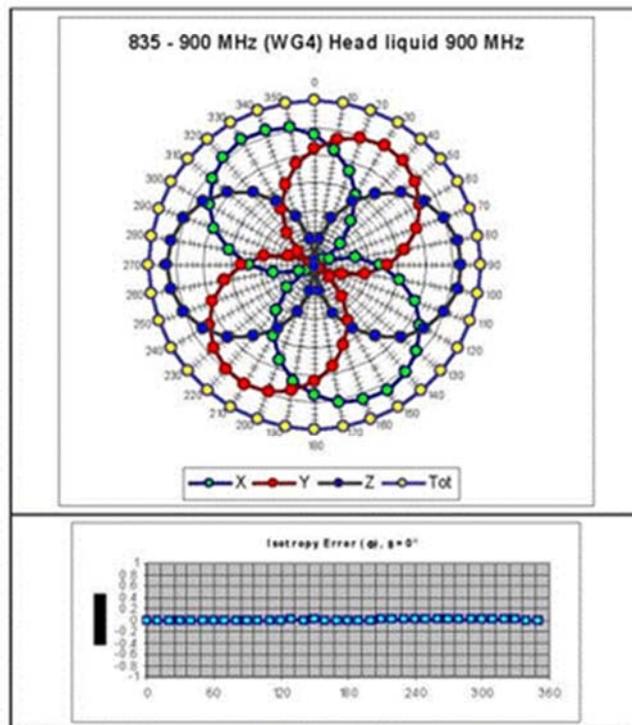


Figure 2. The axial isotropy of a typical IXP-050 probe obtained by rotating the probe in a liquid-filled waveguide at 900 MHz. (NB Axial Isotropy is largely frequency- independent)

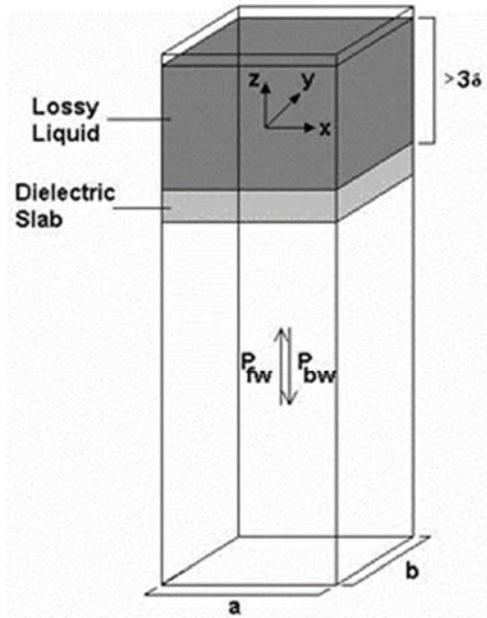


Figure 3. Geometry used for waveguide calibration (after Ref [2]. Section A.3.2.2)

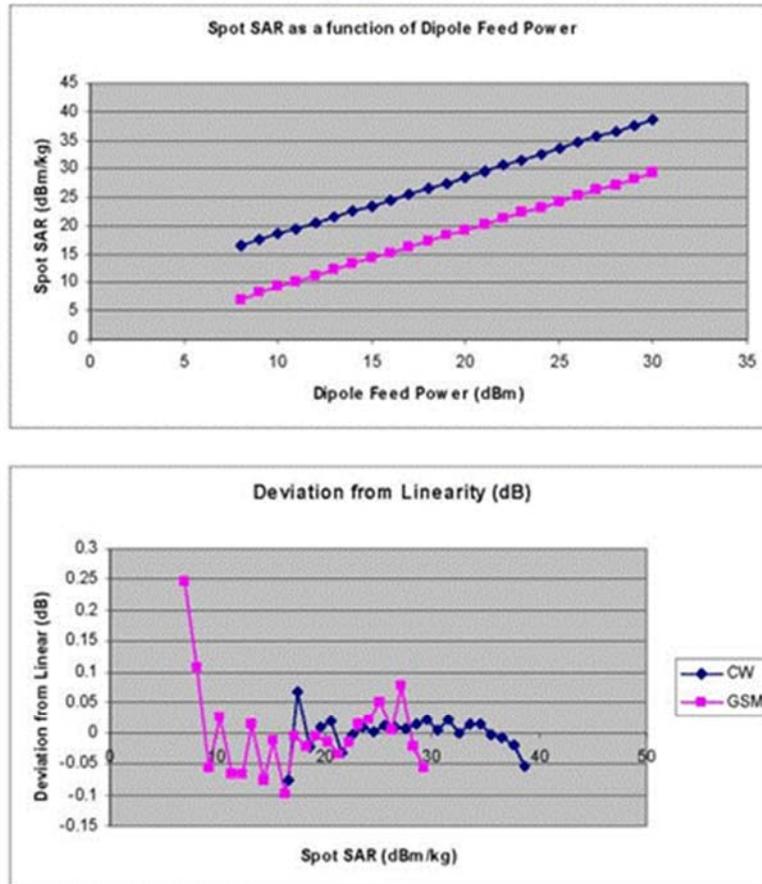


Figure 4 : The typical linearity response of IXP-050 probes to both CW (blue) and GSM (pink) modulation in close proximity to a source dipole. The top diagram shows the SAR reading as a function of dipole feed power, with GSM modulation being approx a factor of 8 (ie 9dB) lower than CW. The lower diagram shows the departure from linearity of the same two datasets.

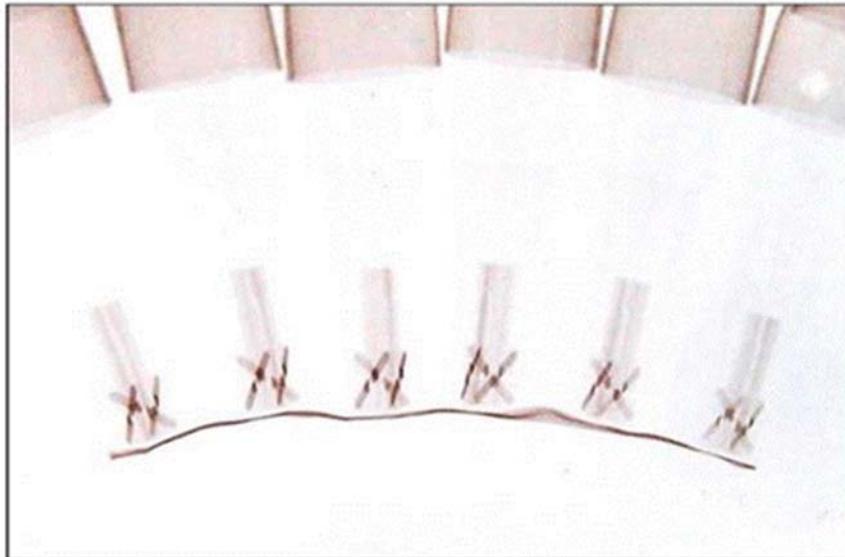


Figure 5 : X-ray positive image of 5mm probes

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 | 43.52 | 0.864 | 43.5 | 0.87 | 0.0 | -0.7 | Pass | Pass |
| 700 | | 43.349 | 0.888 | 42.2 | 0.89 | 2.8 | 0.1 | Pass | Pass |
| 835 | | 41.55 | 0.898 | 41.5 | 0.90 | 0.1 | -0.2 | Pass | Pass |
| 900 | | 41.139 | 0.957 | 41.5 | 0.97 | -0.9 | -1.3 | Pass | Pass |
| 1800 | | 39.632 | 1.401 | 40.0 | 1.40 | -0.9 | 0.1 | Pass | Pass |
| 1900 | | 40.057 | 1.396 | 40.0 | 1.40 | 0.1 | -0.3 | Pass | Pass |
| 2100 | | 40.32 | 1.51 | 39.8 | 1.49 | 1.3 | 1.3 | Pass | Pass |
| 2450 | | 39.03 | 1.849 | 39.2 | 1.80 | -0.4 | 2.7 | Pass | Pass |
| 2600 | | 38.587 | 1.972 | 39.0 | 1.96 | -1.1 | 0.6 | Pass | Pass |
| 450 | | Body | 56.86 | 0.938 | 56.7 | 0.94 | 0.3 | -0.2 | Pass |
| 700 | 55.954 | | 0.964 | 55.73 | 0.96 | 0.4 | 0.5 | Pass | Pass |
| 835 | 55.587 | | 0.977 | 55.2 | 0.97 | 0.7 | 0.7 | Pass | Pass |
| 900 | 54.857 | | 1.045 | 55 | 1.05 | -0.3 | -0.5 | Pass | Pass |
| 1800 | 52.958 | | 1.531 | 53.3 | 1.52 | -0.6 | 0.7 | Pass | Pass |
| 1900 | 52.965 | | 1.524 | 53.3 | 1.52 | -0.6 | 0.3 | Pass | Pass |
| 2100 | 53.886 | | 1.618 | 53.2 | 1.62 | 1.3 | -0.1 | Pass | Pass |
| 2450 | 52.768 | | 1.965 | 52.7 | 1.95 | 0.1 | 0.8 | Pass | Pass |
| 2600 | 52.354 | | 2.179 | 52.5 | 2.16 | -0.3 | 0.9 | Pass | Pass |

Table of test equipment calibration status

| Instrument description | Supplier / Manufacturer | Model | Serial No. | Last calibration date | Cal certificate number | See Annex | Calibration due date |
|---------------------------------|-------------------------|---|------------|---|------------------------|-----------|----------------------|
| Power sensor | Rohde & Schwarz | NRP-Z23 | 100063 | 14/08/2013 | 10-300287035 | 1 | 14/08/2015 |
| Power sensor | Rohde & Schwarz | NRP-Z23 | 100169 | 06/08/2014 | 1400-48811 | 2 | 06/08/2016 |
| Dielectric property measurement | Indexsar | DiLine (sensor lengths: 160mm, 80mm and 60mm) | N/A | (absolute) – checked against NPL values using reference liquids | N/A | | N/A |
| Vector network analyser | Anritsu | MS6423B | 003102 | 17/02/2015 | RMA20027002 | 3 | 17/02/2016 |
| SMA autocalibration module | Anritsu | 36581KXF/r1 | 001902 | 22/01/2015 | RMA20021769 | 4 | 22/01/2016 |



Product Service

Annex 1

Calibration Certificate of NRP-Z23 power sensor, S/N 100063

| | | |
|---|---|---|
| | | Calibration Certificate Certificate Number 10-300287035 |
| Kalibrierschein | | Zertifikatsnummer |
| Unit Data | | |
| Item / Gegenstand | Average power sensor | |
| Manufacturer / Hersteller | ROHDE & SCHWARZ | |
| Type / Typ | NRP-Z23 | |
| Material Number / Materialnummer | 1137.8002.02 | Serial Number / Seriennummer: 100063 |
| Asset Number / Inventurnummer | | |
| Order Data | | |
| Customer / Auftraggeber | IndexSAR Ltd | |
| | Oakfield House, RH5 5BG Newdigate GB | |
| Order Number / Bestellnummer | | |
| Date of Receipt / Eingangsdatum | 2013-08-08 | |
| Performance | | |
| Place and Date of Calibration / Ort und Datum der Kalibrierung | Memmingen, 2013-08-14 | |
| Scope of Calibration / Umfang der Kalibrierung | Standard Calibration | |
| Statement of Compliance (Decision) / Konformitätsaussage (Auslieferung) | Measurement results within specifications | |
| Statement of Compliance (Outgoing) / Konformitätsaussage (Auslieferung) | Measurement results within specifications | |
| Extent of Calibration Documents / Umfang des Kalibrierdokuments | 2 Pages Calibration Certificate 17 Pages Outgoing Results 17 Pages Incoming Results | |
| This calibration certificate documents, that the named item is tested and measured against defined specifications. Measurement results are located usually in the corresponding interval with a probability of approx. 90% (coverage factor k = 2). Calibration is performed with test equipment and standards directly or indirectly traceable by means of approved calibration techniques to the PTB/DKD or other national / international standards, which realize the physical units of measurement according to the International System of Units (SI). In all cases where no standards are available, measurements are referenced to standards of the R&S laboratories. Principles and methods of calibration correspond with EN ISO/IEC 17025. The applied quality system is certified to EN ISO 9001. This calibration certificate may not be reproduced other than in full. Calibration certificates without signature are not valid. The user is obliged to have the object recalibrated at appropriate intervals. | | |
| Dieser Kalibrierschein dokumentiert, dass der genannte Gegenstand nach festgelegten Vorgaben geprüft und gemessen wurde. Die Messwerte liegen im Regelfall mit einer Wahrscheinlichkeit von annähernd 90% im zugeordneten Intervall (Erweiterte Messunsicherheit mit k = 2). Die Kalibrierung erfolgte mit Messmitteln und Normale, die direkt oder indirekt durch Ableitung mittels anerkannter Kalibriertechniken rückgeführt sind auf Normale der PTB/DKD oder anderer national/internationaler Standards zur Darstellung der physikalischen Einheiten in Übereinstimmung mit dem internationalen Einheitensystem (SI). Wenn keine Normale existieren, erfolgt die Rückführung auf Bezugnormale der R&S-Laboratorien. Grundsätze und Verfahren der Kalibrierung entsprechen EN ISO/IEC 17025. Das angewandte Qualitätsmanagement-System ist zertifiziert nach EN ISO 9001. Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Kalibrierscheine ohne Signifizierungen sind ungültig. Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich. | | |
| Rohde & Schwarz GmbH & Co. KG: Service Operations West | | |
| Date of Issue / Ausfertigungsdatum | Head of Laboratory / Laborleitung | Person Responsible / Bearbeiter |
| 2013-08-14 | Courage | Ruprecht Schmid |
| Page 12 ver513R0002 | | |
| ROHDE & SCHWARZ GmbH & Co. KG, Minibühlstraße 15, D-81871 München, Federal Republic of Germany · Telefon (089) 41 29-0 · Telefax (089) 41 29-132 78 Geschäftsführung: Manfred Fleischmann (Vorstandsvorsitz), Christian Lechner, Gerhard Sauer Sitz München · Registeramt: HRB 19 270 · Persönlich haftendee Geschäftsführer: RUSSE Verwaltungs-GmbH · Sitz München · Registeramt: AG München HRB 1 534 | | |



Product Service

Material Number 1137.8032.02 Serial Number 100043 **Certificate Number 10-300287035**

Calibration Method **NRVC-1109.0930.32** Relative Humidity **20%-60%**
 Kalibrieranweisung Relative Luftfeuchte
 Ambient Temperature **(23 ± 0.1) °C**
 Umgebungstemperatur

Working standards used (having a significant effect on the accuracy)
 Verwendete Gebrauchsnormale (mit signifikanten Einfluss auf die Genauigkeit)

| Item Gegenstand | Type Typ | Serial Number Seriennummer | Calibration Certificate Number Kalibrierscheinnummer | Cal. Due Kalibr. bis |
|---------------------------------|-------------|-------------------------------|---|-------------------------|
| Dual Channel Powermeter | NRVD | 100862 | 0114 D.K.15195-01-00 2013-08 | 2014-11-30 |
| Dual Channel Power Meter | NRVD | 838583/0023 | 0113 D.K.15195-01-00 2013-08 | 2014-11-30 |
| Vector Network Analyzer | ZVM | 835228/0029 | 0102 CKD-K-16101-2011-08 | 2013-10-31 |
| Access Set for Lin. Measurement | NRVC-R2 | 848957/0028 | 0085 D.K.15195-01-00 2013-01 | 2014-04-30 |
| Calibration Kit Type-N (50 Ohm) | ES0540 | 2705A00100 | 217-01723 (METAS) | 2010-03-31 |
| Power Standard | NRVC | 836487/0005 | 0082 D.K.15195-01-00 2013-01 | 2014-04-30 |

Conformity statements take the measurement uncertainties into account.
 Die Konformitätsaussagen berücksichtigen die Messunsicherheiten.

Notes
 Anmerkungen

Installed options are included in calibration. Depending on installed options, numbers of pages of the record are not consecutive.



Annex 2

Calibration Certificate of NRP-Z23 power sensor, S/N 100169

| | | | | | | | | |
|--|-------------------------------|---|---|-------------------------------|----|---------------------------|---|-----------------------|
| | | | | | | | | |
| Calibration Certificate Kalibrierschein | | Certificate Number 1400-48811 Zertifikatsnummer | | | | | | |
| <p>Unit data</p> <p>Item / Gegenstand: AVERAGE POWER SENSOR</p> <p>Manufacturer / Hersteller: Rohde & Schwarz</p> <p>Type / Typ: NRP-Z23</p> <p>Material number / Materialnummer: 1137.8002.02 Serial number ID: 1137.8002.02-100169-aj Seriennummer Ser.: 100169</p> <p>Asset number / Anlagennummer: Recommended Calibration Interval: 24 Months</p> | | | | | | | | |
| <p>Order data</p> <p>Customer / Auftraggeber: IndexSAR Ltd Oakfield House, Newdigate RM16 6BG Great Britain</p> <p>On behalf of (where applicable) / In namen von (Wenn gewünscht):</p> <p>Order number / Bestellnummer: 1024R&S</p> <p>Date of receipt / Eingangsdatum: 2014-08-06 (YYYY-MM-DD)</p> | | | | | | | | |
| <p>Performance</p> <p>Place and date of calibration / Ort u. Datum d. Kalibrierung: Fleet; 2014-08-06 (YYYY-MM-DD)</p> <p>Scope of calibration / Umfang der Kalibrierung: Factory Standard Calibration</p> <p>Statement of Compliance (incoming) / Konformitätsaussage (Anlieferung): All measured values are within the data sheet specifications.</p> <p>Statement of Compliance (outgoing) / Konformitätsaussage (Auslieferung): All measured values are within the data sheet specifications.</p> <p>Extent of calibration documents / Umfang der Kalibrierdokumentation:</p> <table border="0"> <tr> <td style="width: 100px;">2</td> <td>Pages Calibration Certificate</td> </tr> <tr> <td>40</td> <td>Pages Calibration Results</td> </tr> <tr> <td>2</td> <td>Pages Incoming Report</td> </tr> </table> | | | 2 | Pages Calibration Certificate | 40 | Pages Calibration Results | 2 | Pages Incoming Report |
| 2 | Pages Calibration Certificate | | | | | | | |
| 40 | Pages Calibration Results | | | | | | | |
| 2 | Pages Incoming Report | | | | | | | |
| <p>Rohde & Schwarz UK</p> <p>Date of issue / Ausstellungsdatum: Head of laboratory / Labordirektion: Person responsible / Bearbeiter:</p> <p style="text-align: center;"> </p> <p>2014-08-06 (YYYY-MM-DD) Carol McKenzie Martin Gill Page (Seite) 1 of 2</p> | | | | | | | | |
| <small>ROHDE & SCHWARZ UK Ltd, Ancoats Business Park, Fleet Hampshire GU51 2UZ, United Kingdom Registered in England No. 539607</small> | | | | | | | | |



Product Service

| | |
|---|--|
| Material number 1137.8002.02 | Certificate Number 1400-48811 |
| Serial number ID: 1137.8002.02-100169-aj | Zertifikatsnummer |
| <small>Materialnummer</small> | <small>Seriennummer</small> Ser.: 100169 |

| | |
|--|---|
| Calibration instruction See first page of calibration results | Date of receipt 2014-08-06 |
| <small>Kalibrieranweisung</small> | <small>Eingangsdatum</small> (YYYY-MM-DD) |
| Ambient temperature (23 ± 2) °C | Relative humidity 20 % - 60 % |
| <small>Umgebungstemperatur</small> | <small>Relative Luftfeuchte</small> |

This calibration fulfils the requirements of the standard / guideline
 Diese Kalibrierung entspricht den Forderungen der Norm / Richtlinie

| Working standards used (having a significant effect on the accuracy) <small>Verwendete Gebrauchsnormale (mit signifikantem Einfluss auf die Genauigkeit)</small> | | | | |
|---|----------------------------|--|---|---------------------------------------|
| Item <small>Gegenstand</small> | Type <small>Typ</small> | Serial number <small>Seriennummer</small> | Calibration certificate number <small>Kalibrierschein Nummer</small> | Cal. due <small>Kalibr bis</small> |
| See page 2 of calibration results | | | | |

UGB (Uncertainty guard Band): Measurement uncertainty violates the datasheet limit

UGB1 A compliance statement may be possible where a confidence level of less than 95 % is acceptable
 Die Bestätigung der Konformität ist möglich, sofern ein Grad des Vertrauens von weniger als 95% akzeptabel ist.

UGB2 A non-compliance statement may be possible where a confidence level of less than 95 % is acceptable.
 Die Bestätigung der Nicht-Konformität ist möglich, sofern ein Grad des Vertrauens von weniger als 95% akzeptabel ist.

Conformity statements take the measurement uncertainties into account.
 Die Konformitätsaussagen berücksichtigen die Messunsicherheiten.

Ref.: ILAC-G8:1996 Guidelines on Assessment and Reporting of Compliance with Specification (based on measurements and tests in a laboratory)

Notes
 Anmerkungen

Page (Seite) 2 of 2



Product Service

Annex 3

Calibration certificate of Anritsu MS4623B VNA

| Certificate of Calibration | | Anritsu |
|---|---|--|
| | | Discover What's Possible™ |
| Customer: INDEXSAR LTD INDEXSAR LTD, OAKFIELD HOUSE NEWDIGATE SURREY RH5 5BG UNITED KINGDOM | ANRITSU EMEA LIMITED 200 CAPABILITY GREEN LUTON LU1 3LU UNITED KINGDOM Tel: +44 (0) 1582 433285 Fax: +44 (0) 1582 455675 Email: service.emea@eu.anritsu.com | |
| Date of Issue: 17/02/2015 | Certificate N°: RMA20027002 | |
| Customer: INDEXSAR LTD | Order No: Contract | |
| Manufacturer: Anritsu Company | | |
| Model | Serial Number | Description |
| MS4623B | 003102 | VNA, 10 MHz-6 GHz, ACTIVE |
| <p>Anritsu EMEA Limited does hereby certify the above listed equipment complies to published or stated specifications at the measured parameters, and has been calibrated to the general requirements of ISO 17025 against instruments whose accuracies are traceable to National or International Standards, where such standards are applicable.</p> | | |
| Repair required before calibration | (yes) |  Authorised Signature Murray Coleman Head of Customer Services (EMEA) |
| Electrical Safety | (yes) | |
| Laser safety class | () | |
| <p>Note: Original calibration results are attached and copies held on file at Anritsu EMEA Limited. The attached results relate only to the instrument under calibration. Anritsu EMEA Limited Quality system is certified to ISO9001:2000 (Cert. No. FQA 0353176) This Certificate comprises of: Certificate of Calibration Call Report 25 Page(s) of test results</p> | | |



Product Service

Annex 4

Calibration certificate of Anritsu 36581KKF/1 auto-cal kit

| Certificate of Calibration | | Anritsu Discover What's Possible™ |
|--|-------------------------------------|--|
| Customer: INDEXSAR LTD INDEXSAR LTD, OAKFIELD HOUSE NEWGATE SURREY RH5 5BQ UNITED KINGDOM | | ANRITSU EMEA LIMITED 200 CAPABILITY GREEN LUTON LU1 3LU UNITED KINGDOM Tel: +44 (0) 1562 433295 Fax: +44 (0) 1562 455575 Email: service_esc@eu.anritsu.com |
| Date of Issue: | 22/01/2015 | Certificate N°: RMA20026648 |
| Customer: | INDEXSAR LTD | Order No: 1045ANR |
| Manufacturer: | Anritsu Company | |
| Model | Serial Number | Description |
| MS4623B 36581KKF/1 | 003102 001902 | VNA,10 MHZ-6 GHZ,ACTIVE TESTED & CHARACTERIZED TO 6 GHZ |
| <p>Anritsu EMEA Limited does hereby certify the above listed equipment complies to published or stated specifications at the measured parameters, and has been calibrated to the general requirements of ISO 17025 against instruments whose accuracies are traceable to National or International Standards, where such standards are applicable.</p> | | |
| Within specification before calibration Repair required before calibration Electrical Safety Laser safety class | (yes) (no) (yes) () |  Authorised Signature Murray Coleman Head of Customer Services (EMEA) |
| <p>Note: Original calibration results are attached and copies held on file at Anritsu EMEA Limited. The attached results relate only to the instrument under calibration. Anritsu EMEA Limited Quality system is certified to ISO9001:2000 (Cert. No. FQA 0353176) This Certificate comprises of: Certificate of Calibration Call Report 13 Page(s) of test results</p> | | |



Product Service



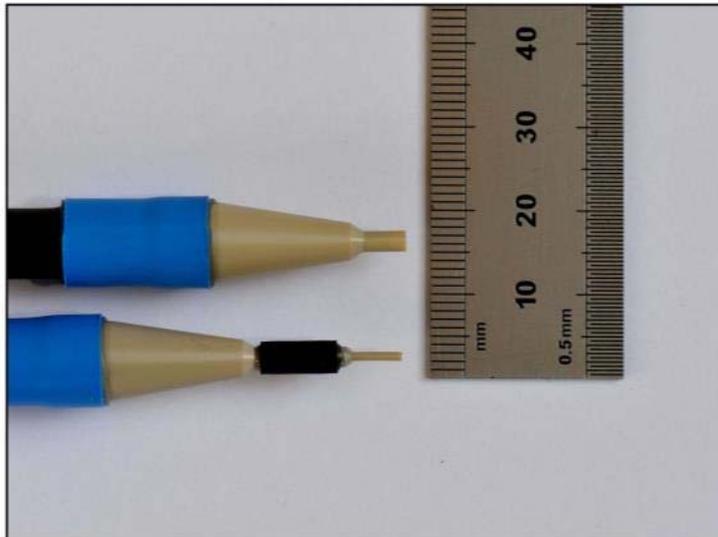
IMMERSIBLE SAR PROBE

CALIBRATION REPORT

Part Number: IXP – 025

S/N G0014

August 2014



**Indexsar Limited
Oakfield House
Cudworth Lane
Newdigate
Surrey RH5 5BG**

Tel: +44 (0) 1306 632 870

Fax: +44 (0) 1306 631 834

e-mail: enquiries@indexsar.com

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Product Service



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 Fax: +44 (0) 1306 631 834
 e-mail: enquiries@indexsar.com

Calibration Certificate 1408/G0014
Date of Issue: 26 August 2014
Immersible SAR Probe

| | |
|---------------------------|------------------|
| Type: | IXP-025 |
| Manufacturer: | IndexSAR, UK |
| Serial Number: | G0014 |
| Place of Calibration: | IndexSAR, UK |
| Date of Receipt of Probe: | N/A |
| 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, or equivalent, 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.



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 G0014) 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, or equivalent. 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. Where applicable, all test equipment is calibrated by the manufacturers themselves, ensuring traceability to national standards.

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, thereby ensuring independence of probe reading from incident polarisation.
- 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:

$$U_{lin} = U_{op} + U_{op}^2 / DCP \quad (1)$$

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



DCP is determined from fitting equation (1) to measurements of U_{lin} versus source feed power over the full dynamic range of the probe. The DCP is a characteristic of the Schottky diodes used as the sensors. For the IXP-020 probes with CW signals the DCP values are typically 100mV.

For this value of DCP, the typical linearity response of IXP-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, equivalent to at least 4 penetration depths, ensures both that there is negligible radiation from the waveguide open top, and that the probe calibration is not influenced by reflections either from nearby objects or the liquid/air interface.

During the measurement, a TE_{10} 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 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:

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

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).

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

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