



BSI Standards Publication

**Measurement procedure for the assessment
of specific absorption rate of human exposure
to radio frequency fields from hand-held
and body-mounted wireless communication
devices – Vector measurement-based systems
(Frequency range of 30 MHz to 6 GHz)**

National foreword

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PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD



Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Vector measurement-based systems (Frequency range of 30 MHz to 6 GHz)

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**MEASUREMENT PROCEDURE FOR THE ASSESSMENT OF
SPECIFIC ABSORPTION RATE OF HUMAN EXPOSURE TO RADIO
FREQUENCY FIELDS FROM HAND-HELD AND BODY-MOUNTED
WIRELESS COMMUNICATION DEVICES –****Vector measurement-based systems
(Frequency range of 30 MHz to 6 GHz)**

FOREWORD

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IEC PAS 63151 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document

Draft PAS	Report on voting
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Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned may transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of 3 years starting from the publication date. The validity may be extended for a single period up to a maximum of 3 years, at the end of which it shall be published as another type of normative document, or shall be withdrawn.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This Publicly Available Specification (PAS) specifies the requirements for vector measurement-based systems to measure the Specific Absorption Rate (SAR) of devices that are used in close proximity to the human body or head.

This PAS is published in order to make available the current state of the technology. It is planned to publish a standard as Part 3 of the IEC 62209 series. When IEC 62209-3 is published this PAS will be withdrawn.

This PAS acknowledges the need for fast and accurate systems to determine the human exposure to radio frequency fields from hand-held and body mounted wireless communication devices.

As SAR measurement systems are used for showing compliance with national and international exposure limits the test procedures have to be standardized. The standardization is necessary to achieve comparable results for the approval process.

Vector measurement-based systems and protocols can differ from traditional SAR measurement systems and protocols. These systems use more advanced field reconstruction methods, allowing the application of indirect measurement approaches in which the SAR is evaluated in three dimensions from a limited number of measurement points which may be located in a limited part of the volume of interest, or even outside this volume. Such new SAR assessment approaches result in significantly reduced SAR measurement times.

MEASUREMENT PROCEDURE FOR THE ASSESSMENT OF SPECIFIC ABSORPTION RATE OF HUMAN EXPOSURE TO RADIO FREQUENCY FIELDS FROM HAND-HELD AND BODY-MOUNTED WIRELESS COMMUNICATION DEVICES –

Vector measurement-based systems (Frequency range of 30 MHz to 6 GHz)

1 Scope

This Publicly Available Specification (PAS) specifies protocols and test procedures for the reproducible measurement of the peak spatial-average specific absorption rate (psSAR) induced inside a simplified model of the head or the body by radio-frequency (RF) transmitting devices, with a defined uncertainty. It provides requirements for systems using vector measurement-based systems. Such systems determine the psSAR by 3D field reconstruction within the volume of interest by specifying the requirements for the measurement system, calibration, uncertainty assessment and validation methods. The protocols and procedures apply for a significant majority of people including children during use of hand-held and body-worn wireless communication devices.

This PAS is applicable to any wireless communication device intended to be used at a position near the human head or body at distances up to and including 200 mm. This PAS can be employed to evaluate SAR compliance of different types of wireless communication devices used next to the ear, in front of the face, mounted on the body, combined with other RF-transmitting or non-transmitting devices or accessories (e.g. belt-clip), or embedded in garments. The overall applicable frequency range is from 30 MHz to 6 GHz.

The system validation procedures provided within this PAS cover frequencies from 600 MHz to 6 GHz.

NOTE Some specifications (e.g., validation antennas and other procedures or requirements) are not yet defined over the full frequency range within the scope of this document but will be included in a future revision.

The device categories covered include but are not limited to mobile telephones, cordless microphones, auxiliary broadcast devices and radio transmitters in personal computers, desktop, laptop devices, multi-band, multi-antenna, and push-to-talk devices.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

IEC 62209-1:2016, *Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Part 1: Devices used next to the ear (Frequency range of 300 MHz to 6 GHz)*

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)*

IEC 62479, *Assessment of the compliance of low-power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)*

IEC TR 62630:2010, *Guidance for evaluating exposure from multiple electromagnetic sources*

IEC/IEEE 62704 (all parts), *Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62209-1, IEC 62209-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

vector probe

probe which measures both the magnitude and phase of an electric or magnetic field

3.2

scalar probe

probe which measures only the amplitude of the electric or magnetic field

3.3

vector measurement-based system

system consisting of multiple sensors which together provide information about the amplitude distribution or the amplitude and phase distribution of the electric or magnetic fields over a specified volume

3.4

analysis bandwidth (of a signal analyser)

maximum frequency span of observation for a system capable of spectral analysis. The analysis bandwidth is generally characterized by a certain flatness ($\pm$ tolerance) of the responses of the system in the defined range of frequencies

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms in IEC 62209-1 and IEC 62209-2 apply.

5 Overview of the measurement procedure

The objective of this clause is to give the user of this PAS a quick overview about the test procedures in this PAS. The user of the PAS shall refer to the respective clauses for more details when using the flowchart.

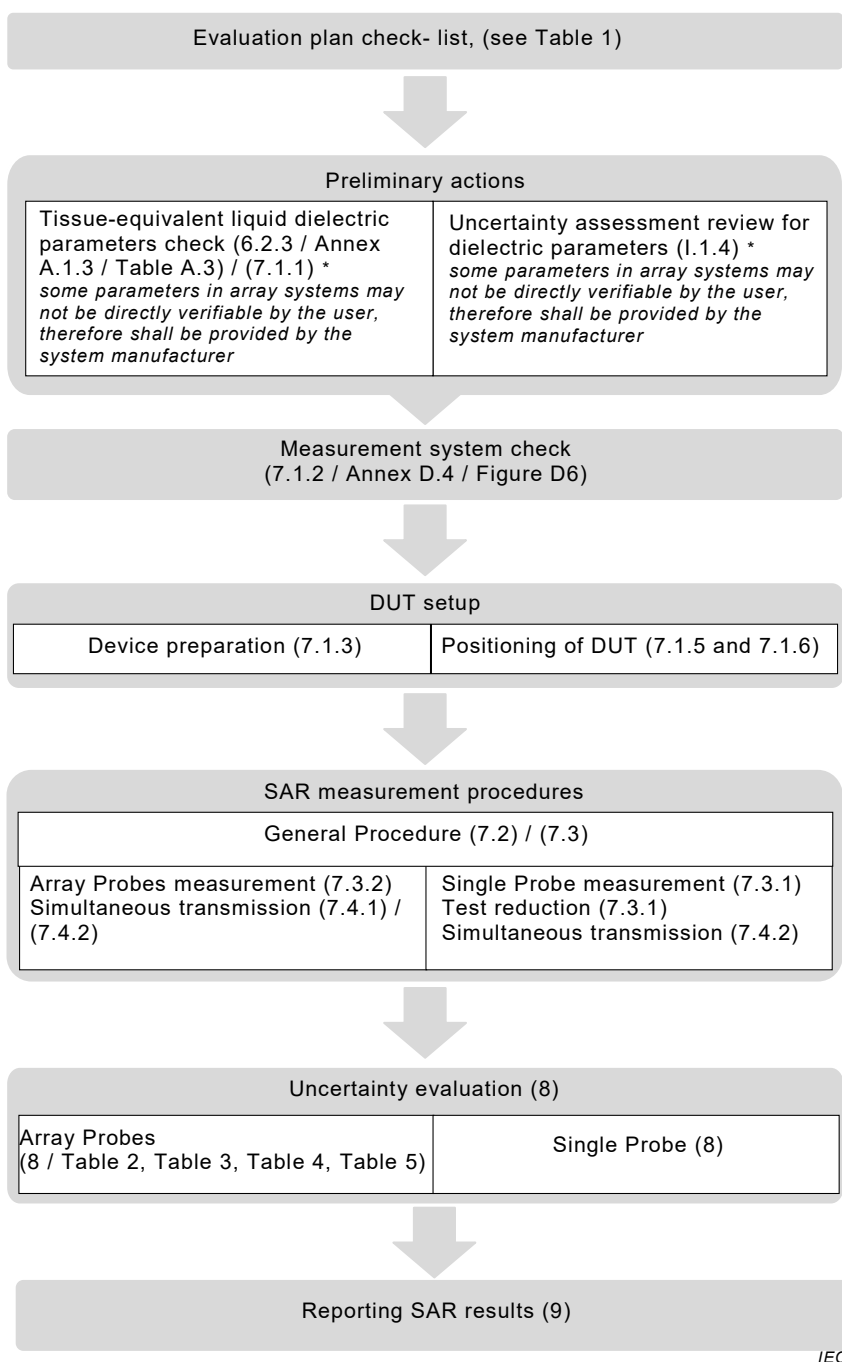


Figure 1 – Evaluation plan checklist

Table 1 – Evaluation plan checklist

Stage	Evaluation steps	Action
Evaluation plan check-list Planning of the measurement configurations	What type of device is being evaluated? Review of antenna contained and wireless technologies supported, singly or in combination. What are the test positions applicable? Working under laboratory conditions and following good laboratory practice and documentation, prepare to conduct the necessary evaluation.	Complete check-list based on evaluation plan (Table 1, Figure 1)
Preliminary actions and Measurement <i>system check</i>	A dielectric measurement of the tissue simulating medium shall be performed for systems with open phantoms, and the result shall be recorded. <i>System check</i> needs to be performed to verify the correct working of the system components (Annex D.3).	Shall be conducted before starting a project and repeated according to 7.1.2
DUT set-up Preparation of DUT	The protocol for SAR assessment defines all the permutations of operational conditions that should be tested. The essential steps include: Preparing the DUT by establishing a connection to a network simulator Configuring the DUT to operate on the appropriate test frequencies Positioning the DUT in relation to the phantom	Ensure the DUT is configured in the correct way and radiating appropriately when positioned against the phantom.
SAR measurements procedures General SAR procedure	This stage is the actual procedure of measurement of SAR. The procedure is iterative to ensure that the highest value of the peak spatial-average SAR of a DUT is captured. This is done by a systematic process looking at all device test positions, configurations and operating modes in all frequency bands accordingly (7.2). Systems can incorporate single probe (7.3.1) or array probes (7.3.2). Some accepted techniques that may be used to either reduce or accelerate the measurement process.	Determining highest SAR Ensure the rationale for test reduction is recorded and reported if used
Uncertainty evaluation	Guidelines and approximation formulas are provided (clause 8), enabling the estimation of each individual uncertainty component. The uncertainty budget shall cover the appropriate frequency range with regards to equipment used in the SAR system. For array systems, see (Table 2 to Table 5)	Determine uncertainty and complete the uncertainty table
Reporting SAR results	The final report describes the results of the evaluations, provides sufficient technical details to allow for repeatability of the evaluations performed and reports the results by comparison with the relevant limit (clause 9). The production of the test report will be the demonstration of compliance with this PAS.	Prepare the final report and consider the requirements listed in clause 9.

6 Measurement system specifications

6.1 General requirements

A vector measurement-based system consists of the phantom (a SAM phantom representing the human head and/or a flat phantom representing the human body) filled with tissue-equivalent medium, the electronic measurement instrumentation, one or multiple probes, a field reconstruction algorithm (Annex C) and DUT holder. The peak spatial-average SAR shall be assessed from the SAR distribution induced in the volume of the phantom from the electromagnetic fields produced by the DUT. The vector measurement-based system shall reconstruct the SAR in the volume of the phantom from the electric or magnetic fields measured by the probes. The vector measurement-based system may be a single probe system (scanning a single probe in the volume of the phantom) or an array system having multiple probes. The measurement system calibration shall be traceable to national standards and with quantified and documented measurement uncertainties. In addition, the systems shall meet the validation requirements specified in Annex D.

The information contained in the captured field shall be sufficient to determine the peak spatial-average SAR with an uncertainty meeting the requirements of this PAS. The manufacturer of the measurement system shall document the field reconstruction algorithms. The phantoms are filled with the required homogeneous tissue-equivalent medium. In the case of movable probes inside the phantom, the tissue-equivalent medium shall be a low-viscosity fluid to allow free movement of the probes within it. For a fixed probe-array no such constraint applies.

The tests shall be performed in a laboratory conforming to the following environmental conditions:

- The ambient temperature shall be within the range of 18 °C to 25 °C.
- In open systems where tissue-simulating material is in direct contact with air, tissue-equivalent medium dielectric properties shall be verified regularly following the procedures described in IEC 62209-1 and IEC 62209-2.
- In hermetic systems, the manufacturer shall provide either
 - a) a procedure for the accurate measurement of dielectric properties, or
 - b) documentation of the dielectric parameters and corresponding medium temperature and ambient temperature that were measured for the specific phantom when it was manufactured or during system recalibration.
- In hermetic systems, the manufacturer shall provide a demonstration of the stability of the dielectric properties of the tissue-simulating material over a period of time which is equal to or greater than the calibration interval of the SAR measurement system.
- Prior to tissue-equivalent medium dielectric properties measurement and SAR measurements, the DUT, test equipment, tissue simulating medium and phantom shall have been kept in the laboratory for their temperatures to have stabilized (i.e., they shall not have been recently moved from another area with a different ambient temperature, such as a refrigerator or storage area).
- Between the measurement of the dielectric parameters and the SAR measurement, the temperature of the tissue simulating medium shall not vary by more than 2 °C or by more than 5 %, in both ϵ and σ according to the temperature sensitivity measurement of the tissue simulating medium, whichever temperature range is less (both ϵ and σ shall stay within the tolerance of the targets), unless active temperature compensation is employed by the SAR measurement system. If active temperature compensation is used, the manufacturer of the measurement system shall provide documentation of the temperature measurement and compensation algorithms and the uncertainty of the temperature compensation. See Annex I.1.14.5 to determine the temperature sensitivity uncertainty of the tissue simulating medium.
- The effect of reflections from cables, test equipment, or other reflectors shall be determined using the SAR *system check* procedure with and without reflectors present or where necessary with the judicious placement of absorbing materials and/or the use of ferrite beads on cables.
- SAR measurements of DUT shall only be performed when the effects of reflections, secondary RF transmitters, etc., result in a peak spatial-average SAR (for 1 g or 10 g mass, whichever is applicable to the test) of less than 0,012 W/kg by measuring the peak spatial-average SAR at (approximately) 0,4 W/kg (used to establish the above 3 % limit) using the SAR *system check* procedure. When the effect of cables and reflectors is more than 0,012 W/kg, ferrite beads, RF absorbers and other mitigation techniques shall be applied to reduce the induced error. If the preceding limit cannot be achieved, a value higher than 3 % (0,012 W/kg) has to be considered in the uncertainty budget in the “RF ambient conditions – reflections” row, provided it can be demonstrated that the SAR contribution due to reflections determined by the *system check* procedure is less than 10 % of the SAR measured for the DUT. The requirement on reflections shall be verified at least every year or whenever the *system check* shows unexpected results.
- During testing the DUT shall not be connected to any wireless network except a base station simulator in the lab.

NOTE The terms *system validation* and *system check* are italicised because they refer to specific test protocols described for the purposes of this PAS.

System validation according to the protocol defined in Annex D shall be done at least once per year by the system manufacturer, including when a new system is put into operation and whenever modifications have been made to the system, such as a new software version with e.g., updated field reconstruction algorithms, different type or version of readout electronics or different types of probes. The full system validation defined in Annex D shall be performed the first time for a new measurement system. It may be unnecessary to perform a complete system validation each subsequent time. A reduced set of measurements may be performed if it can be demonstrated and documented by the system manufacturer that the set is sufficient to warrant acceptance according to the criteria (e.g., if the frequency dependent sensitivity of the sensors is constant due to reasons of sensor design, then the number of frequencies may be reduced). The antennas used for *system validation* shall be designed and validated to meet the requirements specified in this PAS (see Annex F).

NOTE System validation is normally performed by the system manufacturer, even though it is defined such that it can also be performed independently by any third party.

The measurement system shall be validated as a complete system (i.e., consisting of all parts, including the full sensor array, the dielectric medium, phantom shell, electronics, etc.). The measurement probe or probe array shall be calibrated in conditions equivalent to the final operating conditions meeting the requirements of this PAS. Probe or probe-array calibration shall be documented by the system manufacturer.

Where this PAS explicitly specifies performance characteristics for the measurement system or a part of the measurement system, the manufacturer of the system or of the part, or the system integrator shall document conformity with the provisions of this PAS.

6.2 Phantom specifications

6.2.1 Head Phantom specifications – shell

The SAM phantom shall be used as the head phantom. The rationale for the SAM phantom and the geometrical properties of the SAM phantom are provided in Annex A. The head SAR procedures in this PAS are applicable to the SAM phantom requirements in IEC 62209-1. For some system configurations, this may not be restricted to a sagittally-bisected horizontal SAM phantom. The phantom container may be open (i.e., the tissue-equivalent material is in direct contact with air) or hermetic.

6.2.2 Body Phantom specifications – shell

The flat phantom shall comply with requirements specified in Annex A. The phantom container may be open (i.e., the tissue-equivalent material is in direct contact with air) or hermetic.

6.2.3 Tissue-equivalent medium material properties

The phantom shall be filled with tissue-equivalent medium with the required dielectric properties. The dielectric parameters shall be evaluated and compared with the values given in Table A.3 using linear interpolation. This measurement can be performed using the equipment and procedures described in IEC 62209-1:2016, Annex J. The measured dielectric properties, not the values of Table A.3, shall be used in the SAR calculations.

To minimize reflections from the tissue-equivalent medium surface that is distal from the measurement (phantom) surface, the depth of the medium should be at least 15 cm from the flat body phantom inner surface or from the SAM inner surface above the ear reference point. In such case, the uncertainty due to such reflections does not need to be added to the budget. A medium depth of less than 15 cm may be used if it is demonstrated (e.g., using numerical simulations) that the effect on peak spatial-average SAR is less than 1 % under worst-case conditions. If it is more than 1, detailed evaluation of the maximum uncertainty shall be documented and added to the uncertainty budget. For the case of systems with hermetic phantoms, the depth of tissue-equivalent medium for the individual phantom shall be reported by the manufacturer.

6.3 Hand and Device holder considerations

The requirements of IEC 62209-1 and IEC 62209-2 apply.

6.4 Measurement system requirements

6.4.1 General

The vector measurement-based system may be a scanning system (moving a single probe in the volume of the phantom) or an array system with multiple probes. The requirements for scanning systems are provided in subclause 6.4.2, and the requirements for array systems are provided in subclause 6.4.3.

6.4.2 Single probe measurement system specifications

The single probe measurement system shall comply with the following:

- The probe and scanning system and reconstruction algorithm shall allow the determination of the spatial SAR distribution in the required regions of the phantom with known uncertainty for a near-field antenna placed outside the phantom. The requirements on the uncertainty are provided in 8.2.
- The manufacturer of the measurement system shall provide documentation to the user defining the measurement region and frequency range where the requirements of this PAS are met.
- The spatial resolution of the measurement grid and the reconstruction algorithm shall allow the fields to be reconstructed anywhere within the defined measurement region and to the boundary between the tissue-equivalent medium and the phantom shell.
- The accuracy of the probe tip positioning at a measurement point shall be documented and the related uncertainty shall be evaluated according to Annex I.1.10.
- All relevant uncertainty contributions as defined in clause 8 shall be assessed and documented.
- The dynamic range of the measurement system shall be such that the measurement uncertainty budget is valid for 1 g average SAR values from 0,1 W/kg to 10 W/kg for all modulations. The peak spatial-average SAR cube can be located anywhere in the region of the phantom in which the uncertainty is defined by the system manufacturer.
- Probe calibration shall be performed in conditions equivalent to its final operating condition meeting the requirements of this PAS. Calibration of the probe separately from the system is allowed, provided that the electrical interface characteristics between the probe and readout electronics are specified and implemented during measurements. The probe shall be calibrated together with the identical type of equipment (amplifier, filtering, data acquisition, etc.). The probe shall be calibrated at the appropriate operating frequency and temperature range, according to the methodology described in IEC 62209-1.

6.4.3 Array measurement system specifications

The array measurement system shall comply with the following:

- The probe array shall allow the measurement of the electric or magnetic field that is used as an input to the reconstruction algorithms that enable the determination of the spatial SAR distribution in the required regions of the phantom with known uncertainty for a near-field antenna placed outside the phantom. The requirements on the uncertainty are provided in 8.2.
- The manufacturer of the measurement system shall mark the extent of the measurement region on the flat phantom and document this region as well as the frequency range where the requirements of this PAS are met. At the head phantoms, the marking is not required as the DUT position and orientations are specified in the test procedure. Markings shall be such that phantom shell requirements of this PAS are still respected.

- For the head phantom, the SAR evaluation region of the system after field reconstruction shall include all points within the projection of the outline of the wireless device.
- The deviation of the locations of the probes in the array from their specified locations shall be documented and the related uncertainty shall be evaluated according to Annex I.1.2. These positions shall not vary by more than $\pm 0,1$ mm as a function of temperature and pressure. If the displacement is larger, the probe displacement shall be documented and the uncertainty shall be assessed by the system manufacturer.
- The spatial resolution of the measurement grid and the reconstruction algorithm shall allow the reconstruction of the fields anywhere within the defined measurement region and to the boundary between the tissue-equivalent medium and the phantom shell. The manufacturer shall document the types and spatial distribution of probes in the array. In particular, it shall be specified for each probe in the array:
 - 1) its location within the phantom;
 - 2) whether it is sensitive to incident magnetic or electric field;
 - 3) which polarizations of the incident field it is designed to receive;
 - 4) if they measure magnitude of the field only or magnitude and phase.
- All relevant uncertainty contributions as defined in clause 8 shall be assessed and documented.
- The dynamic range of the measurement system shall be such that the measurement uncertainty budget is valid for 1 g average SAR values from 0,1 W/kg to 10 W/kg for all modulations. 1 g and 10 g SAR cubes can be located anywhere in the region of the phantom in which the uncertainty is guaranteed by the manufacturer.
- Probe-array shall be calibrated at the considered operating frequency range and temperature range in conditions equivalent to its final operating condition meeting the requirements of this PAS. The probe-array sub-system shall be calibrated in the final phantom assembly, with the same or electrically equivalent read-out electronics used for the system and identical type of equipment (amplifiers, filtering, data acquisition etc.), at the appropriate operating frequencies and temperature range, with one of the methods described in the Annex B.

6.5 Device holder specification

The requirements for the device holder in IEC 62209-1 and IEC 62209-2 apply respectively for measurements at the head and flat phantoms. The DUT is preferably mounted on a piece of low relative permittivity ($< 1,2$) and low loss foam before being mounted into the device holder to avoid any direct contact between the device holder and the DUT. If this is not possible, the device holder shall provide the minimum amount of contact to the DUT to give a secure hold and maintain the required position during the measurement.

When the highest reported SAR is greater than 75 % of the compliance limit and the DUT has been measured in contact with the device holder, the highest SAR test condition among all frequency bands and positions shall be tested again for each single transmitter, without using the holder. In this case, the DUT position shall be realized by using low-loss foam material and non-conductive adhesive (e.g., tape or elastic bands). The peak spatial-average SAR both with and without holder conditions shall be reported. If the difference between these values is greater than the expanded ($k = 2$) uncertainty for measurement repeatability, then all SAR test conditions that are within the expanded ($k = 2$) uncertainty (see Clause 8) of the compliance limit shall be measured without the holder.

The effect of the hand on the exposure of the head phantom is not considered in this PAS. Refer to IEC 62209-1 for a rationale.

With array systems using closed flat phantom, a holder may not be needed in certain test positions. The DUT may for example be disposed over the flat phantom, in direct contact with the phantom or using a low-loss and low-permittivity high density foam spacer providing a separation distance.

6.6 Reconstruction algorithm and peak spatial-averaging specifications

Unlike SAR measurement systems defined in IEC 62209-1 and IEC 62209-2, a vector measurement-based system does not determine the peak spatial-average SAR directly from measurement points on a 3D grid covering the peak spatial averaging volume. Therefore, the purpose of the reconstruction algorithm is to determine the distribution of the SAR in the volume of interest such that the peak spatial-average SAR can be evaluated with known uncertainty using the electric and/or magnetic fields measured by the vector measurement-based system.

The following requirements on reconstruction and peak spatial-average SAR shall be met:

- The reconstruction algorithm shall determine the SAR distribution in the phantom from the measured electric and/or magnetic field from the sensors. The SAR distribution shall be determined within a volume containing all peak spatial-average SAR volumes (primary and secondary).
- The averaging volume shall be in the shape of a cube, except that the front face of the volume shall conform to the phantom shell and the back face shall be equally distorted. The four side walls of the cube shall be parallel to the line normal to the phantom at the centre of the front face of the averaging volume (Figure 2).
- The software of the measurement equipment shall provide error messages to the user if the peak spatial-average SAR is outside the spatial region for which the uncertainty requirements of this PAS are met.

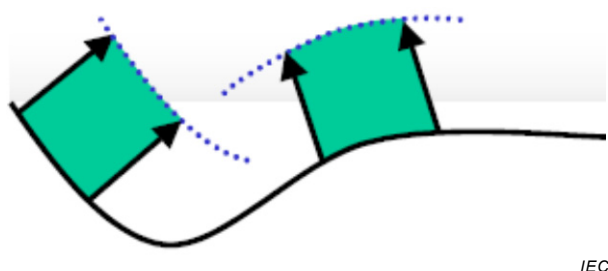


Figure 2 – Illustration of the shape and orientation relative to a curved phantom surface of the distorted cubic volume for computing peak spatial-average SAR

7 Protocol for SAR assessment

7.1 Measurement preparation

All measurements should be carried out with good laboratory practice, e.g., in accordance with ISO/IEC 17025, or any other local and national requirements for device certification. This PAS does not contain detailed information needed to configure devices for specific wireless technologies, such as transmission mode or data rate settings for satisfying national requirements to ensure that the maximum SAR is obtained.

7.1.1 Preparation of tissue-equivalent medium

Tissue equivalent medium shall yield relative permittivity and conductivity values within $\pm 10\%$ of the target values at the frequencies at which the SAR is measured. Annex I.1.14 shall be used to correct the measured SAR for the deviations in permittivity and conductivity. If the correction ΔSAR has a negative sign, the measured SAR results shall not be corrected.

For systems using open phantom, the dielectric properties of the tissue-equivalent medium shall be measured within 24 h before the SAR measurements and every two days of continuous use. The dielectric properties of the tissue-equivalent medium may be measured less frequently (but not less than once per week) if the laboratory can document compliance

with dielectric properties of the tissue-equivalent medium material as specified in IEC 62209-1 and in IEC 62209-2.

If the tissue simulating medium is in a hermetically sealed phantom the test laboratory may not be able to directly measure the dielectric properties of the tissue-equivalent medium. In this case, the manufacturer of the measurement system shall document compliance with dielectric properties of the tissue-equivalent medium during production, as specified in IEC 62209-1 and in IEC 62209-2, as well as the recommended procedure and measurement interval only if the latter is longer than the validity period of the system calibration. The compliance certificate shall be valid for the intervals between the measurements of dielectric properties of the tissue-equivalent medium.

7.1.2 System check

A *system check* according to the procedures of Annex D shall be completed within 24 hours before performing SAR measurements for the DUT. The purpose of the *system check* is to verify that the system operates within its specifications. The *system check* is a test of repeatability with a calibrated antenna to ensure that the system works correctly during the compliance test. The *system check* shall be performed in order to detect possible drift over short time periods and other uncertainties in the system, such as:

- unacceptable changes in the parameters of the tissue simulating medium, e.g. due to water evaporation or temperature changes;
- component failures;
- component drift;
- operator errors in the set-up or the software parameters;
- adverse conditions in the system, e.g., RF interference.

NOTE 1 The terms *system validation* and *system check* are italicised because they refer to specific test protocols described for the purposes of this PAS.

The *system check* procedure shall be performed on the same SAR measurement system, using the same SAR probe(s) and tissue-equivalent medium as the SAR evaluation of the DUT for each frequency band tested.

7.1.3 Preparation of the device under test

The requirements for the preparation of the DUT as specified in IEC 62209-1 and IEC 62209-2 apply.

7.1.4 Operating modes

For DUT operating modes, the requirements of IEC 62209-1 and IEC 62209-2 apply.

7.1.5 Position of the DUT in relation to the phantom

For the positioning of the DUT, the requirements of IEC 62209-1 and IEC 62209-2 apply.

7.1.6 Positions of the DUT in relation to the flat phantom for large DUT

If the DUT is equal to or larger than the measurement area supported by the phantom, the scan shall be divided into smaller regions. The DUT shall be shifted such that multiple scans can be combined to encompass at least the projection of the DUT over the flat phantom. When the DUT is shifted over the measurement area, the coupling between the DUT and phantom may be affected and differ from that with a larger phantom. Therefore, this procedure may not apply if there is a significant change in the shape of the SAR distribution between scans; otherwise, this effect shall be taken into account in the uncertainty evaluation.

To limit the measurement errors due to coupling variations, the scanned areas of the DUT from two successive tests shall overlap by at least one third in the shift direction as shown in Figure 3. The formula below provides the minimum number of tests to perform for a DUT equal to or larger than the measurement area, when successive SAR evaluations with one third overlapping section are combined:

$$NB_{\text{tests}} = NB_{\text{sublength}} \times NB_{\text{subwidth}} \quad (1)$$

$$NB_{\text{tests}} = \text{roundup}\left(\left(\left(\frac{L'}{L}\right) \times \left(1 + \frac{1}{3}\right)\right) \times \text{roundup}\left(\left(\frac{W'}{W}\right) \times \left(1 + \frac{1}{3}\right)\right)\right) \quad (2)$$

Where:

L' is the length of the DUT

W' is the width of the DUT

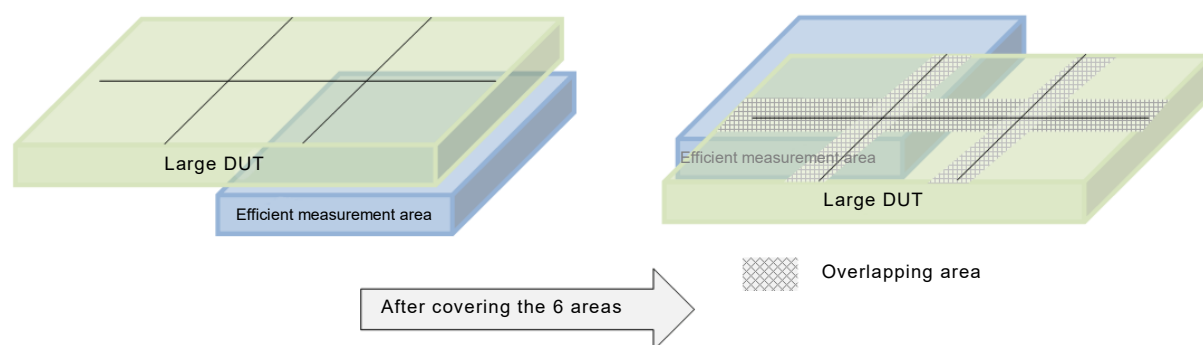
L is the length of the measurement area recommended by the manufacturer

W is the width of the measurement area recommended by the manufacturer

NB_{tests} is the number of tests performed on DUT sub-divisions for a complete SAR evaluation of the DUT

$NB_{\text{sublength}}$ is the number of sub-divisions of the DUT length

NB_{subwidth} is the number of sub-divisions of the DUT width



IEC

Figure 3 – Measurements performed by shifting a large device over the efficient measurement area of the system including overlapping areas – in this case: 6 tests performed

7.1.7 Test frequencies for DUT

A DUT shall be compliant with applicable exposure standards at all transmitting frequencies. However, testing at every channel is impractical and unnecessary. The purpose of this subclause is to define a practical subset of channels where SAR measurements are to be performed. This subset of channels is chosen so as to give a characterization of a DUT with any applicable exposure standards.

NOTE In some cases of Wi-Fi technology and other wide band systems such as WiMAX, the maximum output power of a channel may vary across the frequency band. The required test channels may not include the channel with the highest RF transmit power. For example, for Wi-Fi based technologies, the channels operating at the band edge may produce lower power in order to comply with specific out-of-band limits, therefore it may be necessary to perform the testing on the channel adjacent to the band edge channel. For other devices, the maximum output power of different channels may be optimized differently. Therefore, before performing testing using the specific channels required by this standard, the maximum output power of the channels need to be verified to determine the chosen channels are indeed producing the highest rated output of the device. The process used to establish the channels for testing purposes shall be documented in the test report.

For each operating mode of a wireless technology used by the DUT, tests shall be performed at the channel closest to the centre of each transmit frequency band. If the width of the transmit frequency band ($\Delta f = f_{\text{high}} - f_{\text{low}}$) exceeds 1 % of its centre frequency f_c , then the channels at the lowest and highest frequencies of the transmit band shall also be tested. Furthermore, if the width of the transmit band exceeds 10 % of its centre frequency, the following formula shall be used to determine the number of channels, N_c , to be tested:

$$N_c = 2 \times \text{roundup} \left[\left[10 \times \frac{(f_{\text{high}} - f_{\text{low}})}{f_c} \right] \right] + 1 \quad (3)$$

Where:

- f_c is the centre frequency channel of the transmission band in Hz
- f_{high} is the highest frequency channel of the transmission band in Hz
- f_{low} is the lowest frequency channel of the transmission band in Hz
- N_c is the number of channels

NOTE 1 The function roundup(x) rounds its argument x to the next highest integer. Thus, the number of channels, N_c , will always be an odd number. The channels tested shall be equally spaced apart in frequency (as much as possible) and shall include the channels at the lowest and highest frequencies. Probe calibrations shall be valid for all test frequencies and liquid dielectric parameters at those frequencies. Substantially large transmission bands may require multiple probe calibration points and different tissue-equivalent liquids to cover the entire frequency band.

NOTE 2 Regulatory agencies may have different requirements on the number of channels to be tested per transmission band, according to frequency allocations and other wireless technology requirements.

NOTE 3 If the test frequency yielding the highest output power does not correspond to the middle channel, the test requirements may vary among different national regulatory authorities.

7.2 Tests to be performed

In order to determine the highest value of the peak spatial-average SAR of a device, all device positions, configurations and operational modes shall be tested for each frequency band according to step 1 to step 3 below.

Step 1:

The tests shall be performed at the channel that is closest to the centre of the transmit frequency band (f_c) for:

- a) all device positions on the body phantom (if testing of DUT against body phantom is required);
- b) all cheek and tilt positions on the left and right head phantoms (if testing of DUT against head phantom is required);
- c) all configurations for each device position in a), e.g., with device slide or cover open and closed or antenna extended and retracted;
- d) all operational modes, e.g., different resource block allocations in LTE or modulations, for each device position in Step 1 a) and configuration in Step 1 b) in each frequency band;
- e) all antennas used.

Step 2:

For the test condition providing the highest peak spatial-average SAR determined in step 1, perform the tests at all other test frequencies as required by 7.1.7 (e.g., lowest and highest channels). In addition, for each device position, configuration and operating mode where the peak spatial-average SAR value determined in step 1a), step 1b) and step 1c) is greater than or equal to half of the applicable SAR limit, testing of other channels of 7.1.7 is required as well, otherwise it is not required.

Step 3:

Examine all data to determine the highest value of the peak spatial-average SAR found in step 1 to step 2 for each operation mode in each frequency band.

7.3 General measurement procedure

This clause documents the procedure to be performed for each of the test conditions described in 7.2. For single probe systems, the measurement procedure of 7.3.1 shall be applied. For array systems, the measurement procedure of 7.3.2 shall be applied.

7.3.1 Measurement procedure for single probe systems

If a single probe measurement system is used, the general measurement procedure of IEC 62209-1 or IEC 62209-2 (as appropriate) shall be applied, except that the zoom scan described in the procedure may not be required due to the use of the field reconstruction algorithm. Additionally, reference and drift measurements IEC 62209-1 or IEC 62209-2 may be replaced by the following procedure:

- If the DUT power drifts by more than 2 % during the SAR measurement period, the SAR shall be measured at a fixed reference point immediately before and after the SAR evaluation. The reference point shall be within 10 mm of the inner surface of the phantom where the measured local field exceeds the lower detection limit of the measurement system. The SAR drift of the DUT is estimated as the difference between the two measured single-point SAR values.
- If the SAR drift exceeds 5 % then the provisions of Annex I.4.3 shall apply

7.3.2 Measurement procedure for array systems

If an array system is used, the following procedure and requirements shall be applied:

- a) Measure the electric or magnetic field over the measurement region.
- b) Apply the reconstruction algorithm to reconstruct the SAR distribution in the applicable volume of the phantom.
- c) Apply the averaging algorithm to determine the peak spatial-average SAR.

Commercial devices typically have output power drifts within ± 5 %. Some devices could have significant fluctuations in output power that are not classifiable as undesirable power drift but rather are a characteristic of the normal operating behaviour of the device. In these cases, methods such as power scaling shall be applied with the aim of ensuring that an accurate and conservative SAR is obtained.

7.4 SAR measurements for simultaneous transmission

DUTs with multiple antennas or multiple transmitters (with single or multiple antennas) transmitting simultaneously require special test considerations. The methods to combine the fields in order to determine the combined SAR distribution differ depending on whether the corresponding RF transmitters emit waveforms that are correlated or uncorrelated in time (IEC TR 62630).

7.4.1 SAR measurements for non-correlated signals

When two or more signals are non-correlated (e.g., transmission at different frequencies, modulations, or data streams), the combined SAR at each location, r , in the phantom is calculated from simple summation of the SAR values of the individual transmitters:

$$SAR_T(r) = \sum_{k=1}^N SAR_k(r)$$

(4)



Prior to averaging and search of the peak spatial-average SAR, each SAR distribution shall be assessed separately. After field reconstruction and determination of the individual SAR distributions, $SAR_k(r)$, the summation given in the above equation is performed. The averaging and search of the peak-spatial average SAR are then conducted.

The above procedure applies regardless of whether the N non-correlated signals are turned on separately or transmitting simultaneously. SAR measurement while signals are transmitting simultaneously is possible only if the measurement system is capable of distinguishing the signals so that they can be processed separately.

For measurement equipment, capable of distinguishing between various signals and frequency contributions, direct SAR assessment for simultaneous transmission, including carrier aggregation technologies (with contiguous or non-contiguous transmitting channels), can be performed providing that all the transmission frequencies fall within a valid range of both the probe calibration and the tissue equivalent medium. In such a case, the following procedure applies:

- a) The DUT is set to transmit simultaneously at frequencies $f_1, f_2, f_N \dots$ in the considered supported transmission mode.
- b) The DUT is positioned to the phantom according to 7.1.5.
- c) Measurement system is set to measure SAR at frequency f_1 , so that frequency contributions falling within the $f_1 \pm B_a/2$ range are assessed. B_a is the analysis bandwidth of the probe or probe-array readout electronics. The procedure described here supposes B_a is larger than the signal bandwidth B_s .
- d) If $f_i \pm B_{si}/2$, for any transmitter i between 2 and N , is contained in the $f_1 \pm B_a/2$ range, then the SAR is measured directly as in the case of single-frequency transmission mode. This is equally applied to the case where more than two signal bands fall within B_a .
- e) If there is no overlap between $f_i \pm B_{si}/2$, for any index transmitter index i , and $f_1 \pm B_a/2$ range, then measure SAR for the f_1 transmission mode.
- f) If there is overlap between $f_i \pm B_{si}/2$ and $f_1 \pm B_a/2$ range, then (i) reduce the analysis bandwidth to match a bandwidth as small as possible but no lower than B_{s1} and avoid overlap, then apply step g); (ii) enlarge and/or move the analysis bandwidth so that the span from the minimum frequency to the maximum frequency of the two signals falls within the analysis bandwidth, then apply step d).

NOTE Depending on measurement system technology, the analysis bandwidth can be in the radiofrequency range or DC centred using downconverting techniques.

- g) Set the measurement system to measure SAR at frequency f_2 , so that frequency contributions falling within the $f_2 \pm B_a/2$ range are assessed. Apply step d), step e) and step f) for transmitter 2 as appropriate.
- h) Repeat step d), step e), step f) and step g) for all other transmission modes.
- i) Use one of the four alternatives defined in clause 6.4.3.2 of IEC 62209-1:2016 to obtain the combined SAR.

7.4.2 SAR measurements for correlated signals

DUTs with multiple antennas transmitting correlated signals simultaneously represent a particular case of devices such as MIMO transmitters with digital beam-forming capabilities and require special test considerations. Signals of such DUTs can be classified based on the change of relative phases of signal in a normal communication. In general, there are two types of signals that can be found in most of recent generation multi-antenna transmitters. The first, referred to as type 1, is signals with relative phases unchanged during a relatively long duration compared with symbol duration. This type of signals can be found in phased array antenna systems where the relative phases of signals fed to the antennas are controlled to form the radiation pattern of the array antenna toward a certain direction. In different operating environments, the relative phases may change to obtain different desired radiation patterns. Yet, as soon as transmitting direction is determined and the pattern is formed, the relative phases will be fixed during certain duration, and will only change when the radiation

pattern is configured to another form. In fact, the duration that relative phases are kept unchanged is relatively long, compared with the duration of a symbol in normal communication. The second type, referred to as type 2, on the other hand, is signals with relative phases changed quickly in a relatively short duration. Such signals can be found in the systems utilizing MIMO techniques. Relative phases of signals will be changed from symbols to symbols due to the function of space-time block code (STBC) in the MIMO schemes. The relative phases of signals are changed from symbol to symbol according to the STBC coding, and no specified direction is formed during a normal communication.

As explained in IEC TR 62630, the correlated signals can only be transmitted at the same carrier frequency and SAR depends on the relative phase(s) between the signals.

For type 1 correlated signals, the peak spatial-average SAR is evaluated by one of the methods described in IEC TR 62630. Prior to averaging and search of the peak spatial-average SAR, each field distribution shall be assessed separately. After field reconstruction of each signal contribution, the combined SAR distribution is determined at each point either by summation of the E-field magnitudes, summation of the E-field components or summation of the complex E-field vectors (IEC TR 62630). The averaging and search of the peak-spatial average SAR are then conducted. Summation of the E-field magnitudes or E-field components provides a conservative overestimation compared to the summation of the E-field vectors. If both amplitude and phase of the electric field are known, it is possible to accurately evaluate peak spatial-average SAR under simultaneous transmission condition by combining the vector fields of each individual transmitter, transmitting separately at the highest time-averaged output power with single SAR measurements, in such case, clause 6.5.1 of IEC TR 62630:2010 applies to characterize the combined fields from correlated signals.

For type 1 correlated signals, the phase combination providing the highest peak spatial-average SAR shall be determined from among the set of phase combinations that the device is capable of. If summation of the complex E-field vectors is used, post-processing may be used to vary the phases prior to summation (i.e., for two signals, add a constant phase shift to the induced E-fields from the second signal, then add the SAR distributions from the first and second signals). Otherwise, other techniques can be used, such as measurement of all phase combinations or estimation from fewer phase combinations.

For type 2 correlated signals, the SAR shall be measured with all signals transmitting simultaneously. The signal integration time shall be sufficient to ensure that enough symbols are transmitted.

8 Uncertainty estimation

8.1 General

The uncertainty budget is applicable to either head or body SAR measurements. The estimate of the measurement repeatability, as verified by the *system check* measurement, is obtained by omitting the Type B contributions from the uncertainty budget. The uncertainty budget calculated in Table 2 to Table 5 is an example for the 1 g or 10 g SAR measurement of a DUT or a validation antenna.

Each input quantity is described together with an example of how the associated standard uncertainty is evaluated. These are general examples that may not be applicable to all measuring systems, and additional quantities may be required in a specific case as determined by the system manufacturer.

Further information for system manufacturers and calibration laboratories to assess the measurement system uncertainty is given in ISO/IEC Guide 98-3.

8.2 Requirements on the uncertainty evaluation

The expanded uncertainty is the result of an uncertainty evaluation, specific details of which are recorded in an uncertainty budget. Separate uncertainty budgets shall be evaluated for SAR measurements according to the following:

- The expanded uncertainty in the measured value of mass-averaged SAR (1 g or 10 g) shall be assessed in accordance with the guidance and explanation given in ISO/IEC Guide 98-3 and requirements specified in this PAS.
- The frequency range for which the uncertainty analysis is valid shall be specified.
- The reported uncertainty shall represent the maximum expanded uncertainty within this range.
- The expanded uncertainty in the *system check* and *system validation* measurements shall also be evaluated. The uncertainty shall be quoted at the 95 % confidence level, and the expanded uncertainty shall not exceed 30 % of the peak spatial-average SAR value in the range of 0,4 W/kg to 10 W/kg for SAR averaged over 1 g.
- If the expanded uncertainty for DUT testing is greater than 30 % and it is not related to errors due to incorrect test setup of the test equipment or device, reported data needs to take into account the percentage difference between the actual uncertainty and the 30 % target value (ISO/IEC Guide 98–3). The formula for reducing the applicable SAR limit by the excess uncertainty shall be as described in IEC 62479.

8.3 Description of uncertainty models

The combined standard uncertainty of the 1 g or 10 g SAR consists of uncertainty contributions from the following influences.

- 1) **Measuring system uncertainties to be specified by the manufacturer**, *MM* (Annex I.1 and top section of Table 2): The standard uncertainty for calibration of the vector measurement-based system is determined by the system calibration laboratory or manufacturer.
- 2) **Uncertainties in post-processing and corrections**, *MN* (Annex I.2 and bottom section of Table 2): applied to the measurand (i.e. SAR scaling, etc.).
- 3) **Measuring system uncertainties which are dependent on the device under test (DUT)** (Annex I.3 and Table 3): These uncertainties include those relating to device position (I.4.2), device holder (I.4.1), integration time (I.3.4), signal modulation (I.3.3), coupling between the antenna and the sensor array (I.3.2). The corresponding uncertainty may include a Type A uncertainty analysis based on a set of sources which shall be documented and demonstrated to be sufficient for ensuring a conservative assessment of the related uncertainty contribution. The analytical approach described in Annex H.5 may also be used.
- 4) **Environmental factors** (Annex I.4 and Table 3): The uncertainties caused by the laboratory environment in which the measuring system will be used. These uncertainties include those relating to temperature, ambient signals and reflections.
- 5) **DUT-related uncertainties** (Annex I.4 and Table 3): including drift in RF output, device holder effects, positional errors and modulation (if different from those in 2).

The types of devices under test for which the combined uncertainty estimate is valid shall be stated. For all other devices, additional tests may be required to establish the measurement uncertainty. The uncertainty analysis shall be performed at a set of frequencies which is sufficient to ensure that the uncertainty between the frequencies of characterization is not higher than at the frequencies of evaluation.

The measuring system uncertainties shall be assessed separately for head or body measurements and for 1 g or 10 g averaged SAR as required. All error terms are given as fractions or percentages. The measurement uncertainty shall be a realistic estimate of the uncertainty in the measured SAR of the device under test, and this will be multiplied by a coverage factor to provide a 95 % confidence level.

According to ISO/IEC Guide 98-3 the uncertainty is defined as the root-sum-squared of the uncertainty contributions. The following uncertainty components are defined that are described in Annex I:

Measuring system uncertainties to be specified by the manufacturer:

$$MS = \sqrt{MM^2 + MN^2} \quad (5)$$

where MM and MN are the errors in the measurement system and errors in the corrections and post-processing, respectively:

$$MM = \sqrt{CF^2 + ISO^2 + MSC^2 + AS^2 + LIN^2 + SL^2 + BE^2 + RE^2 + RT^2 + PP^2 + SE^2 + AB^2 + PS^2 + MAT^2 + HOM^2} \quad (6)$$

$$MN = \sqrt{REC^2 + POL^2 + SAV^2 + SARS^2 + SC^2} \quad (7)$$

SAR measurement of a DUT:

$$\Delta SAR = \sqrt{MS^2 + PAC^2 + MOD^2 + IT^2 + DN^2 + DP^2 + DH^2 + SD^2 + AC^2 + MSI^2} \quad (8)$$

For *system validation* measurement:

$$\Delta SAR = \sqrt{MS^2 + PAC^2 + MOD^2 + IT^2 + DN^2 + DP^2 + DH^2 + AC^2 + MSI^2 + DEX^2 + OVS^2} \quad (9)$$

For *system check* measurement:

$$\Delta SAR = \sqrt{MS^2 + PAC^2 + MOD^2 + IT^2 + DN^2 + DP^2 + DH^2 + AC^2 + MSI^2 + DEX^2 + OVS^2} \quad (10)$$

Table 2 to Table 5 show the templates for the uncertainty budgets of the above equations.

Table 2 – Uncertainty budget template for the evaluation of the measurement system uncertainty of the 1 g or 10 g psSAR to be carried out by the system manufacturer (N = normal, R = rectangular)

Symbol /notes	Quantity x_i (source of uncertainty)	Reference	Prob. Dist.*	Uncertainty	Divisor $^*q$	$u(x_i)$	c_i	$u_i(y)$	v_i
Uncertainty in the measurement system to be specified by the manufacturer (<i>MM</i>)									
<i>CF</i>	Calibration	I.1.1							n
<i>ISO</i>	Vector probe or vector probe-array isotropy	I.1.2							n
<i>MSC</i>	Mutual sensor coupling	I.1.3							n
<i>AS</i>	Scattering within the array	I.1.4							n
<i>LIN</i>	System linearity	I.1.5							n
<i>SL</i>	Sensitivity limit	I.1.6							n
<i>BE</i>	Boundary Effect	I.1.7							n
<i>RE</i>	Readout Electronics	I.1.8							n
<i>RT</i>	Response Time	I.1.9							n
<i>PP</i>	Probe Positioning	I.1.10							n
<i>SE</i>	Sampling error	I.1.11							n
<i>AB</i>	Array Boundaries	I.1.12							n
<i>PS</i>	Phantom shell	I.1.13							n
<i>MAT</i>	Tissue-equivalent material parameters	I.1.14							n
<i>HOM</i>	Phantom Homogeneity	I.1.15							n
Uncertainty in corrections and post processing to be specified by the manufacturer (<i>MN</i>)									
<i>REC</i>	Reconstruction	I.2.2							n
<i>POL</i>	Impact of noise on interpolation and extrapolation	I.2.3							n
<i>SAV</i>	SAR averaging	I.2.4							n
<i>SARS</i>	SAR scaling	I.2.5							n
<i>SC</i>	SAR correction for deviations in permittivity and conductivity	I.2.6							n
<i>MS</i>	Uncertainty ($k=1$) and effective degrees of freedom						$U=$		$v_{\text{eff}}=$
* Probability distributions and divisors are chosen to best represent available knowledge of the quantities concerned. n = number of repeated measurements used in the Type A evaluation. Some uncertainty components may be evaluated in combination with other uncertainty components.									

Table 3 – Uncertainty budget template for evaluating the uncertainty in the measured value of 1 g SAR or 10 g SAR from a DUT (N = normal, R = rectangular)

Symbol /notes	Quantity x_i (source of uncertainty)	Reference	Prob. Dist.*	Uncertainty	Divisor $^*q$	$u(x_i)$	c_i	$u_i(y)$	v_i
Measuring system uncertainties to be specified by the manufacturer									
<i>MS</i>	Measuring system uncertainties to be specified by the manufacturer	Table 2							n
Measuring system uncertainties which are dependent on the DUT									
<i>PAC</i>	Probe or probe-array coupling with DUT	I.3.2							n
<i>MOD</i>	Modulation response	I.3.3							n
<i>IT</i>	Integration time	I.3.4							n
<i>DN</i>	Drift and noise	I.3.5							n
DUT-related uncertainties related uncertainties and environmental factors									
<i>DP</i>	Device positioning	I.4.2							n
<i>DH</i>	Device holder	I.4.1							n
<i>SD</i>	Measured SAR drift	I.4.3							n
<i>AC</i>	RF ambient conditions	I.4.4							n
<i>MSI</i>	Measurement system immunity/secondary reception	I.4.5							n
<i>U</i>	Expanded uncertainty and effective degrees of freedom						$U=$		$v_{\text{eff}}=$
* Probability distributions and divisors are chosen to best represent available knowledge of the quantities concerned. n = number of repeated measurements used in the Type A evaluation. Some uncertainty components may be evaluated in combination with other uncertainty components.									

Table 4 – Uncertainty budget template for evaluating the uncertainty in the measured value of 1 g SAR or 10 g SAR from a validation antenna (N = normal, R = rectangular)

Symbol / notes	Quantity x_i (source of uncertainty)	Reference	Prob. Dist.*	Uncertainty	Divisor $^*q$	$u(x_i)$	c_i	$u_i(y)$	v_i
Measuring system uncertainties to be specified by the manufacturer									
<i>MS</i>	Measuring system uncertainties to be specified by the manufacturer	Table 2							n
Measuring system uncertainties which are dependent on the DUT									
<i>PAC</i>	Probe or probe-array coupling with DUT	I.3.2							n
<i>MOD</i>	Modulation response	I.3.3							n
<i>IT</i>	Integration time	I.3.4							n
<i>DN</i>	Drift and noise	I.3.5							n
Validation antenna related uncertainties and environmental factors									
<i>DP</i>	Device positioning	I.4.2							n
<i>DH</i>	Device holder	I.4.1							n
<i>AC</i>	RF ambient conditions	I.4.4							n
<i>MSI</i>	Measurement system immunity/secondary reception	I.4.5							n
<i>DEX</i>	Deviation of experimental antennas	I.4.6							n
<i>OVS</i>	Other uncertainty contributions when using validation antennas	I.4.7							n
<i>U</i>	Expanded uncertainty and effective degrees of freedom						$U=$		$v_{\text{eff}}=$
* Probability distributions and divisors are chosen to best represent available knowledge of the quantities concerned. n = number of repeated measurements used in the Type A evaluation. Some uncertainty components may be evaluated in combination with other uncertainty components.									

Table 5 – Uncertainty budget template for evaluating the uncertainty in the measured value of 1 g SAR or 10 g SAR from the *system check* (N = normal, R = rectangular)

Symbol / notes	Quantity x_i (source of uncertainty)	Reference	Prob. Dist.*	Uncertainty	Divisor $^*q$	$u(x_i)$	c_i	$u_i(y)$	v_i
Measuring system uncertainties to be specified by the manufacturer									
<i>MS</i>	Measuring system uncertainties to be specified by the manufacturer	Table 2					1		∞
Measuring system uncertainties which are dependent on the DUT									
<i>PAC</i>	Probe or probe-array coupling with DUT	I.3.2					1		∞
<i>MOD</i>	Modulation response	I.3.3					0		∞
<i>IT</i>	Integration time	I.3.4					0		∞
<i>DN</i>	Drift and noise	I.3.5					1		∞
DUT-related uncertainties or system check antenna related uncertainties and environmental factors									
<i>AC</i>	RF ambient conditions	I.4.4					1		∞
<i>MSI</i>	Measurement system immunity/secondary reception	I.4.5					1		∞
<i>DEX</i>	Deviation of experimental antennas	I.4.6					1		∞
<i>OVS</i>	Other uncertainty contributions when using system check antennas	I.4.7					1		∞
<i>U</i>	Expanded uncertainty and effective degrees of freedom						$U=$		$v_{\text{eff}} =$
* Probability distributions and divisors are chosen to best represent available knowledge of the quantities concerned. n = number of repeated measurements used in the Type A evaluation. Some uncertainty components may be evaluated in combination with other uncertainty components.									

9 Measurement report

The requirements of IEC 62209-1 and IEC 62209-2 apply, as well as the reporting requirements specified in other clauses of this PAS.

Annex A (normative)

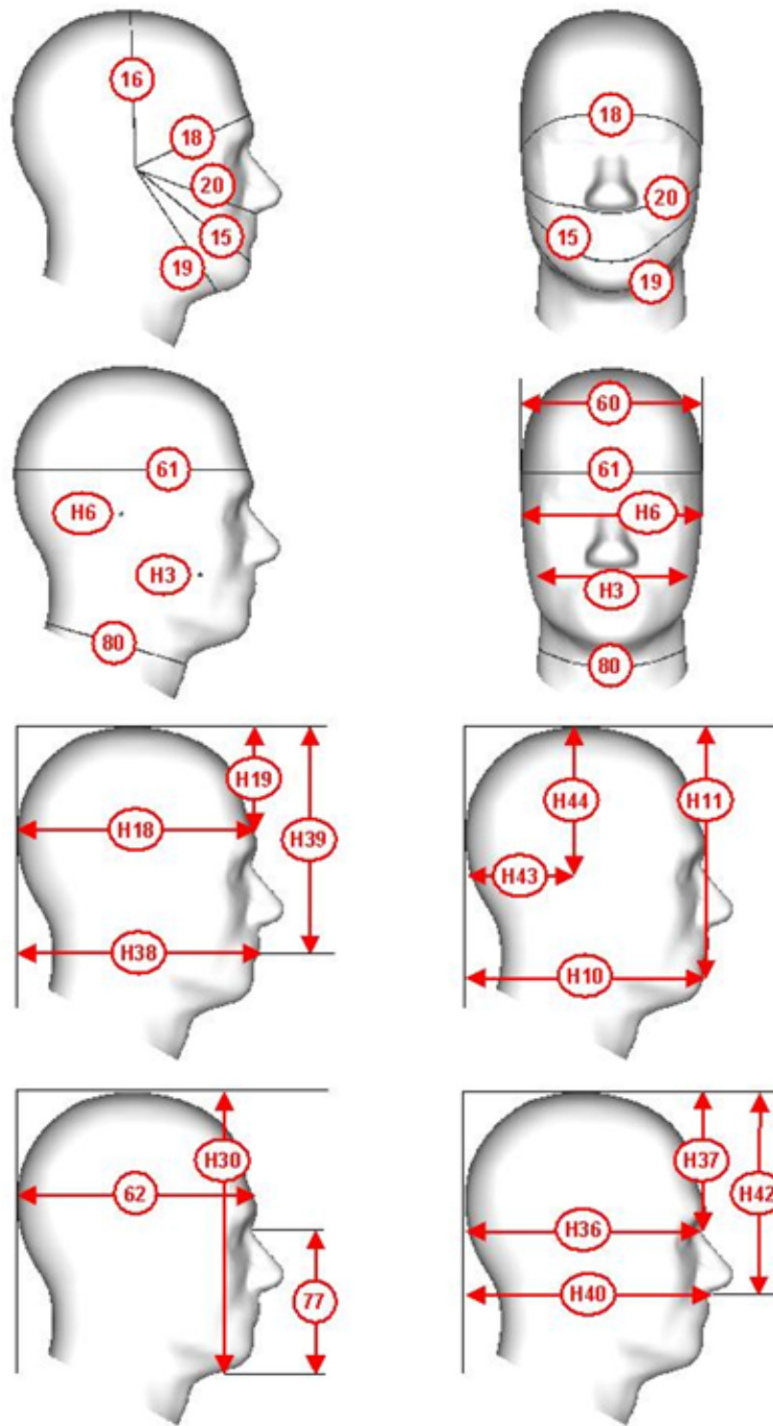
Phantom specifications

A.1 SAM phantom specifications

The justification for the SAM phantom is provided in IEC 62209-1.

A.1.1 SAM phantom geometry

The dimensions of the SAM phantom have been derived from selected 90th percentile male head data reported by Gordon et al. [61], and are listed in Table A.1 and shown in Figure A.1. Table A.2 shows other pertinent dimensions for comparison. At the ear reference point (ERP), a thickness of 6 mm including the 2 mm shell is selected to model the external ear (pinna). This thin ear spacer also simulates users with small ears, and gives a conservative SAR representation. A system of reference points and reference lines is used to correlate the device positioning with the phantom (Figure A.2 and Figure A.3). The point “M” is the mouth reference point, “LE” is the left ear reference point (ERP), and “RE” is the right ERP. The ERPs are 15 mm posterior to the entrance to ear canal (EEC) along the B-M Line (back-mouth) (Figure A.2).



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NOTE The dimensions in Table A.1 are used to define the SAM phantom. The dimensions in Table A.2 are measured on the SAM phantom and compared with the ARMY data

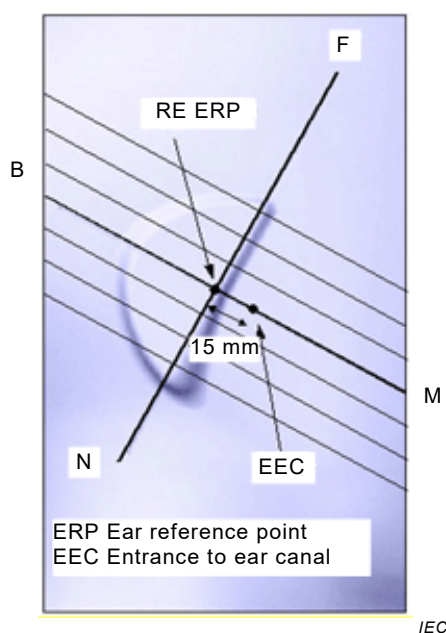
Figure A.1 – Illustration of dimensions in Table A.1 and Table A.2

Table A.1 – Dimensions used in deriving SAM phantom from the ARMY 90th percentile male head data (Gordon et al.[61])

Ref.	Anatomy	Gordon report [mm]			SAM [mm]	Deviation [%]
		Mean value	Std deviation	90 th Percentile		
H15	Bitragion Chin Arc	325,8	13,4	343,1	329,3	-4,0
H16	Bitragion Coronal Arc	353,3	12,9	369,7	367,3	-0,6
H18	Bitragion Frontal Arc	304,3	10,6	318,2	314,1	-1,3
H19	Bitragion Submandibular Arc	304,2	14,5	323,2	333,5	3,2
H20	Bitragion Subnasale Arc	292	11,1	306,3	305,3	-0,3
H60	Head Breadth	151,7	5,4	158,6	158,4	-0,1
H61	Head Circumference	567,7	15,4	587,3	594,8	1,3
H62	Head Length	197,1	7,1	206	206,0	0,0
H77	Menton-Sellion Length	121,9	6,5	130,4	125,0	-4,1
H80	Neck Circumference	379,6	19,7	405,3	395,4	-2,5

Table A.2 – Additional SAM dimensions compared with selected dimensions from the ARMY 90th-percentile male head data (Gordon et al. [61]) – Specialist head measurement section

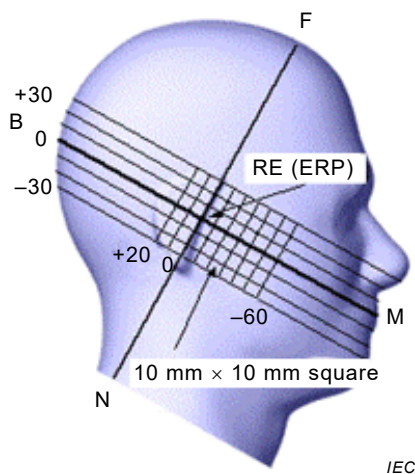
Ref.	Anatomy	Gordon report [mm]			SAM [mm]	Deviation [%]
		Mean value	Std deviation	90 th Percentile		
H3	Bigonial Breadth	118,9	7,9	129,2	130,0	0,6
H6	Bitragion Breadth	144,8	6	152,3	152,7	0,2
H10	Chin-Back of Head	194,2	10,3	207,3	206,5	-0,4
H11	Chin-Top of Head	216,8	8,9	228,3	220,4	-3,5
H18	Glabella-Back of Head	199,7	7,2	208,5	209,2	0,3
H19	Glabella-Top of Head	96,2	7,3	105,6	104,4	-1,1
H30	Menton-Top of Head	232,0	8,8	243,3	246,7	1,4
H36	Sellion-Back of Head	197	7,1	205,9	205,3	-0,3
H37	Sellion-Top of Head	112	6,9	120,9	121,7	0,7
H38	Stomion-Back of Head	199,4	9,6	211,9	211,4	-0,2
H39	Stomion-Top of Head	186,3	7,8	196,3	196,3	0,0
H40	Subnasale-Back of Head	203,5	8,3	213,6	213,0	-0,3
H42	Subnasale-Top of Head	161,9	7,7	171,8	177,6	3,4
H43	Tragion-Back of Head	98,9	8,5	106,4	106,4	0,0
H44	Tragion-Top of Head	131	5,7	138,2	138,2	0,0



Key

- B Direction of B-M line back endpoint
- F Direction of N-F line front endpoint
- N Direction of N-F line neck endpoint
- M Mouth reference point
- RE Right ear reference point (ERP)

Figure A.2 – Close up side view of phantom showing the ear region



Key

- B Line B-M back endpoint
- M Line B-M front endpoint
- N Line N-F neck endpoint
- F Line N-F front endpoint
- RE Right ear reference point (ERP)

Figure A.3 – Side view of the phantom showing relevant markings, dimensions are in mm

NOTE The full-head model is shown for illustration purposes only. The procedures in this PAS are derived primarily for the phantom set-up shown in Figure A.3.

The plane passing through the two ear reference points and M is defined as the reference plane. The line N-F (neck-front), also called the reference pivoting line, is along the front truncated edge of the ear. Both N-F and B-M lines shall be marked on the external phantom shell to facilitate handset positioning. Posterior to the N-F line, the thickness of the phantom shell with the shape of an ear is a flat surface 6 mm thick at the ERPs. Anterior to the N-F line, the ear is truncated as illustrated in Figure A.2. The ear truncation is introduced to preclude unstable handset positioning at the cheek.

The projection of the reference line B-M and reference line N-F shall be marked on the phantom. Additional lines may be chosen for convenience, but the additional lines are optional. The optional markings in Figure A.3 may be etched into the external surface of the phantom without affecting the compliance with phantom shell thickness and dielectric parameter requirements.

A.1.2 SAM Phantom shell

The phantom shell with integral solid ear spacer, as specified in the SAM CAD model, shall be constructed from chemical-resistant, non-hygroscopic, low-permittivity and low-loss material, with relative permittivity between 2 and 5; however, less than 2 is acceptable for frequencies up to 3 GHz. The loss tangent of the phantom shell shall be less than or equal to 0,05. It has been shown that at higher frequencies, particularly above 3 GHz, the permittivity of the phantom shell, has an increasing impact on SAR measurement uncertainty (ISO/IEC Guide 98-3). According to ISO/IEC Guide 98-3, the SAR is affected by the shell even though the shell is thin and has dielectric properties much lower than the tissue-equivalent medium. Specifically, they showed that the variation in the SAR depends not only on the frequency, but also on the relative permittivity of the shell and the distance between the antenna and the material. It was recommended that the effects of the shell shall be taken into account in the higher frequency range. Therefore, uncertainty evaluation shall be conducted above 3 GHz according to Annex I.1.13. The shape of the phantom shell shall have a tolerance of less than $\pm 0,2$ mm with respect to the SAM CAD file. In any area within the projection of the handset, the shell thickness shall be $2 \text{ mm} \pm 0,2 \text{ mm}$. The phantom shell shall be made of materials resistive to compounds used for making tissue-equivalent media (e.g., those listed in Annex I of IEC 62209-1:2016), to avoid damage and preserve the $\pm 0,2$ mm tolerances. For non-critical areas, i.e., the central strip containing the nose, as shown in Figure A.5, the thickness tolerance is allowed to be within ± 1 mm.

The CAD file cross section for the reference plane is given in Figure A.4.

NOTE The CAD model is for use in the basic manufacture of the SAM phantom standard test fixture by groups having the necessary expertise and resources. Four *.IGES files of inner and outer surfaces for the left and right halves extracted from the CAD model of the SAM phantom are available on the support document folder of <http://www.iec.ch/tc106>. The four file names are:

- 1) sam_lft_in_6_11.igs
- 2) sam_lft_out_6_11.igs
- 3) sam_rt_in_6_11.igs
- 4) sam_rt_out_6_11.igs

Dimensions in millimetres

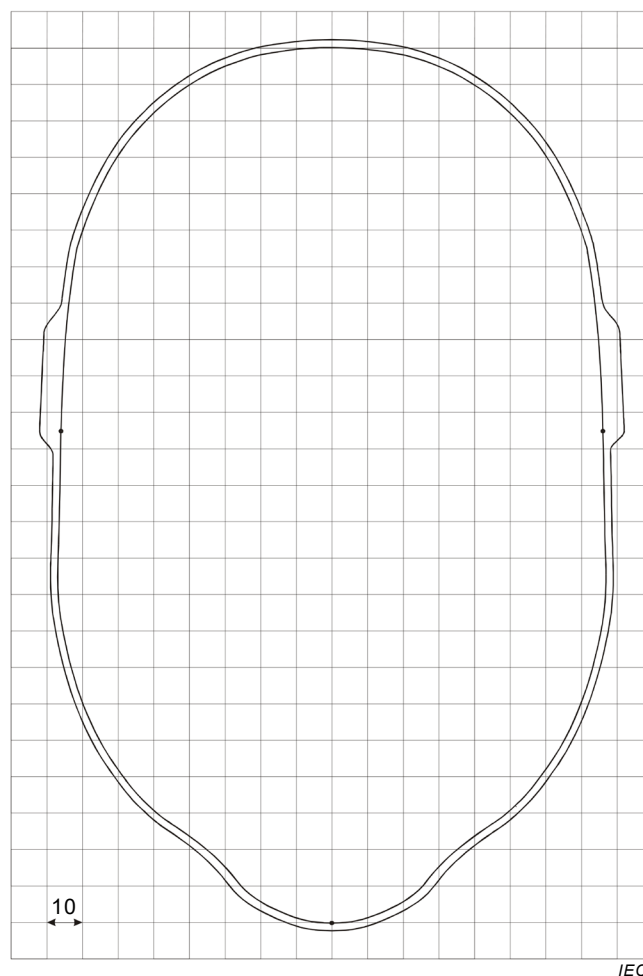


Figure A.4 – Cross-sectional view of SAM at the reference plane

A.1.3 Tissue Equivalent Medium

The phantom shall be filled with a homogeneous tissue-equivalent medium. The dielectric parameters of the tissue-equivalent medium are provided in A.4.

If the vector measurement-based system is a single probe measurement system, the phantom shall be an open container and the tissue-equivalent medium shall be a liquid, so as to allow the scanning system to move the probe. The sagittally-bisected phantom is recommended for devices having the peak spatial-average SAR near the ear (see Figure A.5). Other phantom orientations may be used if the peak spatial-average SAR is in another region of the head. Different phantom orientations may also be necessary for enabling probe access to certain regions of the SAM phantom for SAR measurement. For single probe systems, the orientation of the phantom should be chosen to minimize the measurement uncertainties (e.g., from probe isotropy and boundary effects). If the vector measurement-based system is an array system with fixed sensor locations, the phantom can be a closed container and the tissue-equivalent medium can be either solid or liquid. The orientation of the SAM phantom is irrelevant if a closed container is used.

To minimize reflections within the phantom, the depth of the homogeneous medium should be chosen such that the effect of reflections on peak spatial-average SAR is less than 1 %. If the effect of reflections on peak spatial-average SAR is more than 1 % but less than 3 %, the maximum uncertainty shall be added to the uncertainty budget.

For hermetic phantoms, the presence of air voids beneath the measurement surface will result in large measurement. Great care must be taken when designing and filling the phantoms to avoid this situation occurring.

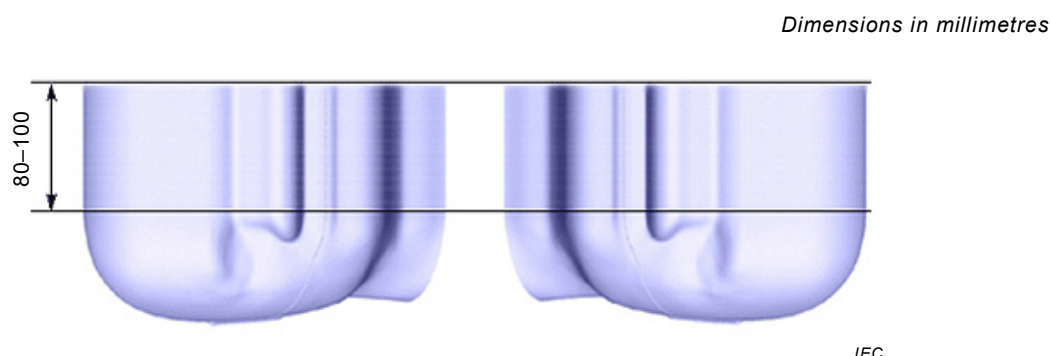


Figure A.5 – Sagittally bisected phantom with extended perimeter, used for single probe systems

Figure A.5 illustrates a sagittally bisected phantom with extended perimeter, used for single probe systems (shown placed on its side as used for device SAR tests). Other phantom orientations may be used if the peak spatial-average SAR is in another region of the head or to enable probe access to certain regions of the SAM phantom for SAR measurement. The orientation of the SAM phantom is irrelevant if a sealed phantom is used.

A.2 Flat phantom specifications

The shell of the flat phantom shall be constructed in the form of a container with a flat side that is in contact with the DUT.

Any flat phantoms used shall be large enough to allow SAR to be measured accurately using the *system validation* and *system check* antennas for 1 g and 10 g peak spatial-average SAR with less than 1 % influence from the phantom shape and dimensions.

For open containers, the flat phantom shall have the following shape and dimensions:

- a) Unless specified in Step b), the shape of the phantom shall be an ellipse with a length of $600 \text{ mm} \pm 5 \text{ mm}$ and a width of $400 \text{ mm} \pm 5 \text{ mm}$ (Figure A.6).
- b) For frequencies above 300 MHz, phantoms with other shapes and smaller dimensions are allowed as follows:
 - between 300 MHz and 800 MHz, the phantom flat phantom side that makes contact with the DUT may have any shape that encompasses an ellipse with a length of $0,6 \lambda_0$ and a width of $0,4 \lambda_0$, where λ_0 is the wavelength in air.
 - between 800 MHz and 6 GHz, the phantom side that makes contact with the DUT may have any shape that encompasses an ellipse with a length of 225 mm and a width of 150 mm.