BS EN IEC 62209-3:2019

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

Part 3: Vector measurement-based systems
(Frequency range of 600 MHz to 6 GHz)

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Full document details: BS EN IEC 62209-3:2019

National foreword

This British Standard is the UK implementation of EN IEC 62209-3:2019. It is identical to IEC 62209-3:2019.

The UK participation in its preparation was entrusted to Technical Committee GEL/106, Human exposure to low frequency and high frequency electromagnetic radiation.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2019

ISBN 978 0 580 97329 1

ICS 17.220.20; 33.050.10; 33.060.20

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2019.

Amendments/corrigenda issued since publication

Date	Text affected

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN IEC 62209-3

November 2019

ICS 33.060.20

English Version

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 3: Vector measurement-based systems (Frequency range of 600 MHz to 6 GHz) (IEC 62209-3:2019)

Procédure de mesure pour l'évaluation du débit d'absorption spécifique de l'exposition humaine aux champs radiofréquence produits par les dispositifs de communications sans fil tenus à la main ou portes près du corps - Partie 3: Systèmes basés sur la mesure vectorielle (plage de fréquences comprise entre 600 MHz et 6 GHz) (IEC 62209-3:2019)

Messverfahren für die Beurteilung der spezifischen Absorptionsrate bei der Exposition von Personen gegenüber hochfrequenten Feldern von handgehaltenen und am Körper getragenen schnurlosen Kommunikationsgeräten - Teil 3: Auf Vektormessungen basierende Systeme (Frequenzbereich von 600 MHz bis 6 GHz) (IEC 62209-3:2019)

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European foreword

The text of document 106/494/FDIS, future edition 1 of IEC 62209-3, prepared by IEC/TC 106 "Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62209-3:2019.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2020-07-29
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2022-10-29

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In the official version, for Bibliography, the following notes have to be added for the standards indicated:

ISO/IEC 17025	NOTE	Harmonized as EN ISO/IEC 17025
ISO 3611:2010	NOTE	Harmonized as EN ISO 3611:2010 (not modified)
ISO/IEC 17043	NOTE	Harmonized as EN ISO/IEC 17043

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
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)	EN 62209-1	2016
IEC 62209-2	2010	Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)	EN 62209-2	2010
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)	EN 62479	-
IEC TR 62630	2010	Guidance for evaluating exposure from multiple electromagnetic sources	-	-
ISO/IEC Guide 98-1	2009	Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement	-	-
ISO/IEC Guide 98-3	-	Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-
IEC/IEEE 62704-1	-	Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz - Part 1: General requirements for using the finite difference time-domain (FDTD) method for SAR calculations	-	-

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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 –

Part 3: Vector measurement-based systems (Frequency range of 600 MHz to 6 GHz)

FOREWORD

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IEC 62209-3 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 International Standard is based on the following documents:

FDIS	Report on voting
106/494/FDIS	106/497/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

In this standard, the following print types are used:

– specific test protocols: in *italic* type.

This standard contains attached files in the form of four *.IGS files of inner and outer surfaces for the left and right halves extracted from the CAD model of the SAM phantom (see A.1.2). These files are available in the supporting documents folder at www.iec.ch/tc106/supportingdocuments.

This standard contains attached files for the analytical functions that are to be used for the evaluation of the reconstruction algorithm uncertainty in Table H.1. These files are available in the supporting documents folder at www.iec.ch/tc106/supportingdocuments.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

This document 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.

Because SAR measurement systems are used for showing compliance with national and international exposure limits, the test procedures have to be standardized. This standardization aims at achieving comparable results for the equipment approval process.

Vector measurement-based systems and the associated 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 that 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.

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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 3: Vector measurement-based systems (Frequency range of 600 MHz to 6 GHz)

1 Scope

This part of IEC 62209 specifies measurement protocols and test procedures for the reproducible measurement of peak spatial-average specific absorption rate (psSAR) induced inside a simplified model of a human head or body by radio-frequency (RF) transmitting devices, with a specified measurement uncertainty. Requirements are provided for psSAR assessment using vector measurement-based systems. Such systems determine the psSAR by three-dimensional (3D) field reconstruction within the volume of interest in accordance with the requirements herein for the measurement system, calibration, uncertainty assessment and validation methods. The protocols and procedures apply for the psSAR assessments covering a significant majority of people including children during use of wireless communication devices operated in close proximity to the head or body.

This document is applicable to wireless communication devices intended to be used at a position near the human head or body at distances up to and including 200 mm. This document may 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 600 MHz to 6 GHz.

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

With a vector measurement-based system this document can be employed to evaluate SAR compliance of different types of wireless communication devices.

The wireless communication device categories covered include but are not limited to mobile telephones, cordless microphones, auxiliary broadcast devices and radio transmitters in personal computers, desktop and 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.

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)*

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IEC 62209-2:2010, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for 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*

ISO/IEC Guide 98-1:2009, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*

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

IEC/IEEE 62704-1, *Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz – Part 1: General requirements for using the finite difference time-domain (FDTD) method for SAR calculations*

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 that measures both the amplitude and phase of an electric field or a magnetic field

3.2
scalar probe
probe that measures only the amplitude of an electric field or a magnetic field

3.3
vector measurement-based system
system consisting of multiple sensors that together provide information about the amplitude distribution or the amplitude and phase distribution of an electric field or a magnetic fields to reconstruct SAR over a specified volume

Note 1 to entry: Throughout this document the term “measurement system” generally refers to vector measurement-based system.

3.4
analysis bandwidth
<of a signal analyser> maximum frequency span of observation for a system capable of spectral analysis

Note 1 to entry: The analysis bandwidth is generally characterized by a specific flatness (+/- a tolerance) of the responses of the system in the specified range of frequencies.

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3.5
array system
array measurement system
vector measurement-based system comprised of multiple vector probe or scalar probe elements that are located at fixed positions on a two-dimensional or three-dimensional regular or irregular grid to obtain the measurement data needed to reconstruct the field within and outside the scanned area and in the region of interest

3.6
scanning system
scanning measurement system
vector measurement-based system comprised of one or more vector probe or scalar probe elements that are physically scanned on a two-dimensional or three-dimensional regular or irregular grid to obtain the measurement data needed to reconstruct the field within and outside the scanned area and in the region of interest with an automatic positioning system capable of placing the measurement probe at specified positions

3.7
volume of interest
volume described by the specified measurement area on the phantom surface having side walls that are normal to the phantom surface with a height of at least 22 mm, and having a back side parallel to the surface of the phantom

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 Clause 5 is to give the user of this document a quick overview of the test procedures in this document. The user of the document shall refer to the respective clauses for more details when using the flowchart presented in Figure 1 and the evaluation plan checklist for the the device under test (DUT) in Table 1.

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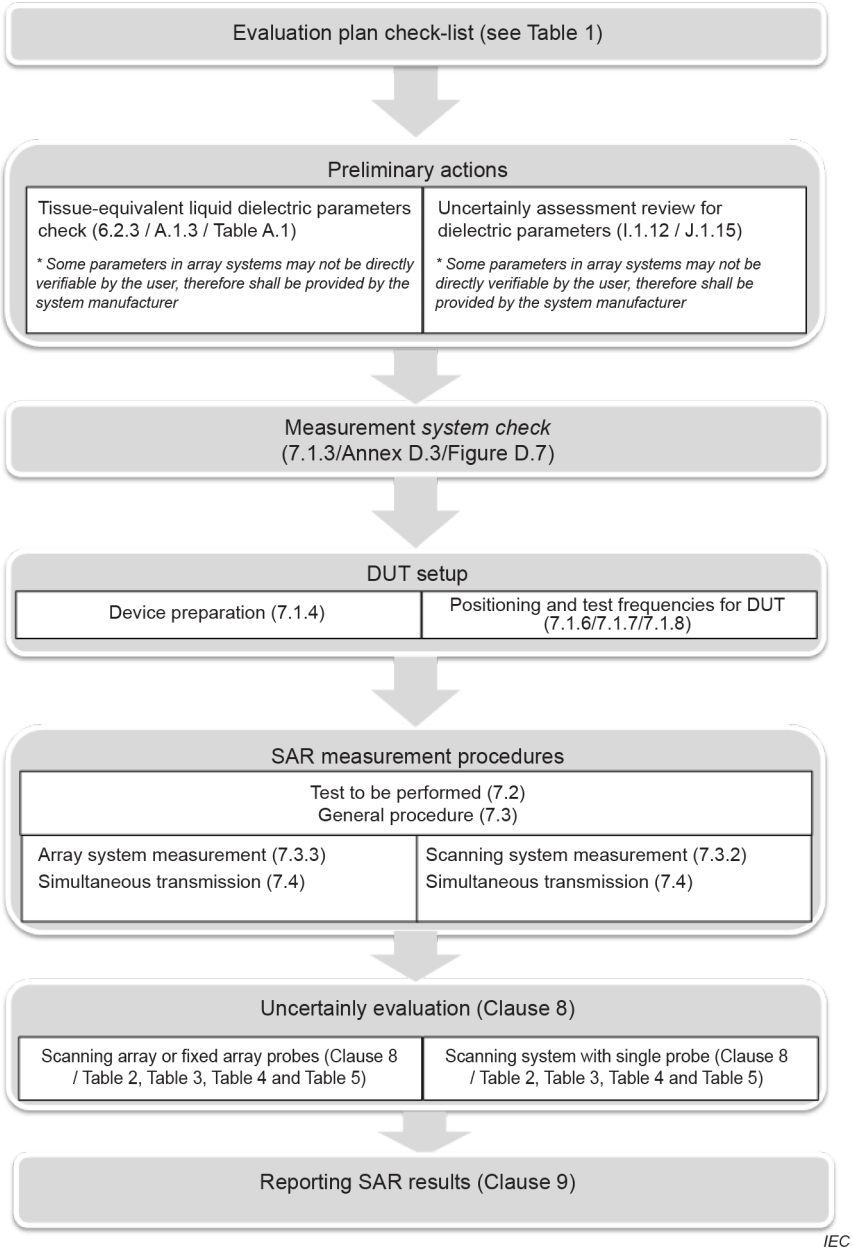

Figure 1 – Evaluation plan checklist

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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(s) 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 perform the necessary evaluation. • There should be a check that the measurement system meets the system requirements, including validation, reporting of the reconstruction algorithm and reporting of the measurement uncertainty.	Complete check-list based on evaluation plan (Table 1, Figure 1).
• Preliminary actions and measurement system check	• A measurement of the tissue-equivalent medium dielectric properties shall be performed for systems with open phantoms, and the result shall be recorded. • Follow individual system protocol and requirements for sealed phantoms. • *System check* shall be performed to verify that system components are working correctly (Clause D.3).	Perform dielectric measurements of tissue-equivalent medium as well as perform *system check* before starting a project and repeat according to 7.1.3.
• DUT set-up • Preparation of DUT	• The protocol for SAR assessment specifies all the configurations 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 measurement procedures • General SAR procedure	• This stage is the actual SAR measurement procedure. • The procedure is sequential to ensure that the highest value of the psSAR 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). • Scanning systems (7.3.2) or array systems (7.3.3) are used. Specific system or implementation techniques are often used to either reduce or accelerate the measurement process.	Determine highest SAR and ensure the rationale for test reduction is recorded and reported when used.
• Measurement 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 (8.3.3).	Evaluate uncertainty contributions and complete the uncertainty analysis.
• 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 results in the test report can serve as demonstration of conformity with this document.	Prepare the final report and consider the requirements listed in Clause 9.

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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 vector probes and/or scalar probes, a field reconstruction algorithm (Annex C) and DUT holder. The vector measurement-based system may be a scanning system or an array system, and shall meet the following requirements:

a) The phantoms are filled with the required homogeneous tissue-equivalent medium (6.2.3 and Annex A, also IEC 62209-1 and IEC 62209-2). When scanning probes are used, the tissue-equivalent medium shall be a low-viscosity fluid to allow free movement of the probes in the phantom. For systems using a fixed probe-array specific considerations to ensure long term stability of the tissue-equivalent medium apply (7.1.2).

b) The psSAR shall be assessed from the SAR distribution induced in the volume of interest from the electromagnetic fields produced by the DUT.

c) The vector measurement-based system shall reconstruct the SAR in the volume of interest from the electric field (E-field) or magnetic field (H-field) components (amplitude and/or phase) that may be obtained from their direct measurement or through phase retrieval procedures or through other techniques.

d) The information obtained from the measured fields shall be used to reconstruct the SAR distribution and to determine psSAR with an uncertainty meeting the requirements of this document.

e) The manufacturer of the measurement system shall validate and document the field reconstruction algorithms.

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

a) The ambient temperature shall be within the range of 18 °C to 25 °C.

b) In open phantom systems where tissue-equivalent medium is in direct contact with air, the tissue-equivalent medium dielectric properties shall be verified regularly following the procedures described in IEC 62209-1 and IEC 62209-2.

c) In hermetically sealed systems, the measurement system manufacturer shall provide either

   1) a procedure for the accurate measurement of dielectric properties, or

   2) documentation of the dielectric properties and corresponding medium temperature and ambient temperature that were measured for the specific phantom when it was manufactured or during system recalibration.

d) In hermetically sealed systems, the measurement system manufacturer shall document and make available the information on the stability of the dielectric properties of the tissue-equivalent medium over a period of time that is equal to or greater than the calibration interval of the SAR measurement system.

e) Prior to measuring tissue-equivalent medium dielectric properties and SAR measurements, the DUT, test equipment, tissue equivalent 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).

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f) The temperature of the tissue-equivalent medium at the time of the dielectric properties measurement and during the SAR measurement shall not vary by more than 2 °C or by more than 5 %, in both relative permittivity ε_r and conductivity σ according to the temperature sensitivity measurement of the tissue-equivalent medium, whichever temperature range is less (both relative permittivity ε_r and conductivity 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 I.1.12.5 and J.1.15.5 to determine the temperature sensitivity uncertainty contributions of the tissue-equivalent medium.

g) 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.

h) SAR measurements of the DUT shall be performed only when the effects of reflections, secondary RF transmitters, etc., result in a psSAR (for 1 g or 10 g mass, whichever is applicable to the test) of less than 0,012 W/kg by measuring the psSAR 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 SAR error. If the preceding requirement cannot be achieved, and 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, then a value higher than 3 % (0,012 W/kg) shall be considered in the uncertainty budget in the “RF ambient conditions” row. The requirement on reflections shall be verified at least every year or whenever the system check shows unexpected results.

i) During testing the DUT shall not be connected to any wireless network other than a base station simulator in the lab.

System validation according to the full protocol specified in Annex D shall be performed when a new system is put into operation and whenever hardware or software modifications have been made to the system (e.g. updated field reconstruction algorithms, update electronics or updated probe types used in a scanning system). The same validation requirements apply to both scanning systems and array systems. After routine calibration of the system, *system validation* per Annex D is required. A reduced set of measurements may be performed if the system manufacturer has demonstrated that the reduced set is sufficient to warrant acceptance according to the criteria for the full test. For example, if the frequency dependent sensitivity of the sensors is constant due to reasons of sensor design, then the number of frequencies may be reduced. Any reduced validation set shall include measurements in each of the phantoms. The antennas used for *system validation* shall be designed and validated to meet the requirements specified in this document (see Annex F).

NOTE 1 *System validation* is normally performed by the system manufacturer, even though it is specified such that it can also be performed independently by any third party on the manufacturer site or at the user facilities.

NOTE 2 A reduced validation set can be specified by the system manufacturer for users to perform.

Each phantom of the measurement system shall be validated as a complete system (i.e. consisting of all parts, including the sensors, the dielectric medium, phantom shell, electronics, and algorithms) according to Annex D. Probe or probe-array calibration shall be documented by the system manufacturer.

Where this document 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 document.

Measurement uncertainties and associated parameters are specified in 8.2.

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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 document 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 medium is in direct contact with air) or hermetically sealed.

6.2.2 Body phantom specifications – shell

The flat phantom for representing a human body shall comply with requirements specified in Annex A. The phantom container may be open (i.e. the tissue-equivalent medium is in direct contact with air) or hermetically sealed.

6.2.3 Tissue-equivalent medium properties

The phantom shall be filled with tissue-equivalent medium with the required dielectric properties. The dielectric properties shall be evaluated and compared with the values given in Table A.1 using linear interpolation. Regardless of the type of system, the measured dielectric properties, not the values of Table A.1, shall be used in the SAR calculations. For an open phantom, the equipment and procedures in Annex J of IEC 62209-1:2016 shall be used.

To minimize reflections from the tissue-equivalent medium surface that is distal from the measurement (phantom) surface in an open phantom, the depth of the medium should be at least 15 cm from the flat phantom inner surface or from the SAM phantom inner surface above the ear reference point. In such case, the uncertainty due to such reflections may be neglected in the uncertainty 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 psSAR 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. Hermetically sealed phantoms shall comply with the requirements in Annex A.

6.3 Measurement system requirements

6.3.1 General

The vector measurement-based system may be a scanning system or an array system. The requirements for scanning systems are provided in 6.3.2, and the requirements for array systems are provided in 6.3.3.

6.3.2 Scanning measurement system specifications

Scanning measurement system uses a single scalar probe or vector probe or an array of probes on a robot to scan the field inside the phantom on a two-dimensional or three-dimensional regular or irregular grid. It uses the measured field points to reconstruct the field according to the requirement of 6.5, in order to assess the psSAR values. The grid resolution may be selected according to system knowledge (e.g. frequency), or according to information gained during the scan process (e.g. peak search).

The scanning measurement system shall comply with the following:

a) The probe and scanning system and the reconstruction algorithm shall allow the determination of the spatial SAR distribution in the required regions of the phantom with known uncertainty with the phantom in the near-field of a source antenna that is placed outside the phantom. The requirements on the measurement uncertainty are provided in 8.2.

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b) The measurement system manufacturer shall provide documentation to the user specifying the measurement region and frequency range where the requirements of this document are met.

c) The spatial resolution of the measurement grid and the reconstruction algorithm shall allow the fields to be reconstructed within the manufacturer-specified measurement region and to the boundary between the tissue-equivalent medium and the phantom shell.

d) The accuracy of the probe positioning and orientation at measurement points shall be documented by the system manufacturer and the related uncertainty shall be evaluated according to I.1.9 or J.1.11.

e) All uncertainty contributions as specified in Clause 8 shall be assessed and documented.

f) The uncertainty budget shall be valid and the maximum measurement uncertainty within the specified tolerance for a measurement system dynamic range covering average SAR values from 0,1 W/kg to 100 W/kg for CW and from 0,1 W/kg to 10 W/kg for all modulations. This requirement applies to the psSAR within the specified measurement region.

g) The probe shall be calibrated for the applicable use conditions (i.e. complex permittivity of the phantom, frequency, temperature, etc.) according to the requirements of Annex B. 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.

h) The scanning method shall be documented, including whether it performs two-dimensional or three-dimensional scans within the phantom volume, and the algorithm for determining the measurement grid if it does not measure a fixed grid.

i) Any boundary-effect corrections shall be documented. The document shall include the method and the verification that the applied corrections are valid for any scanning position (distance to the boundary and orientation of the sensors with respect to the surface) and consistent with the boundary-effect uncertainty. The extent of the measurement region shall be indicated in the software, including the region where the angle of the probe axis with respect to the normal of the phantom surface is within the above requirement.

j) The scan region shall find the primary and all secondary SAR peaks covering the area projected by the DUT onto the phantom.

k) The linearity for local SAR shall be evaluated in the range of 0,12 W/kg to 100 W/kg (RMS for CW signals).

6.3.3 Array measurement system specifications

Array measurement systems consist of a fixed array of sensors to measure the field inside the phantom. Unlike a scanning system, the sensors in an array system are at fixed locations. It uses the measured field points to reconstruct the field in order to assess the psSAR values.

The array measurement system shall comply with the following:

– The probe array shall allow the measurement of the electric field or magnetic field that is used as an input to the reconstruction algorithms that enable the determination of the spatial SAR distribution with known uncertainty in the required regions of the phantom in the near-field of a source antenna outside the phantom. The requirements on the measurement uncertainty are provided in 8.2.

– The measurement system manufacturer 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 document are met. The marking is not required for the head phantoms because the DUT position and orientations are specified in the test procedure. Markings shall be such that phantom shell requirements of this document are still respected.

– For head phantoms, the SAR evaluation region of the system after field reconstruction shall include all points within the projection of the outline of the wireless device.

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– 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 J.1.11. These positions shall not vary by more than ± 0,1 mm as a function of temperature and pressure.
– The spatial resolution of the measurement grid and the reconstruction algorithm shall allow the reconstruction of the fields anywhere to the boundary between the tissue-equivalent medium and the phantom shell within the specified measurement region. The manufacturer shall document the types and spatial distribution of probes in the array. In particular, for each probe in the array, it shall be specified:
  1) its location within the phantom;
  2) whether it is sensitive to incident magnetic field or electric field;
  3) which polarizations of the incident field it is designed to receive;
  4) whether they measure amplitude of the field only or amplitude and phase.
– All relevant uncertainty contributions as specified in Clause 8 shall be assessed and documented.
– The uncertainty budget shall be valid and the maximum measurement uncertainty within the specified tolerance for a measurement system dynamic range covering average SAR values from 0,1 W/kg to 100 W/kg for all modulations. 1 g and 10 g SAR cubes can be located anywhere in the specified measurement region.
– The probe-array shall be calibrated at the operating frequency range and temperature range specified for the system in test configurations equivalent to the use conditions (i.e., complex permittivity of the phantom, frequency, temperature, etc.) according to the requirements of Annex B. The probe-array 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 operating frequencies and temperature range, with one of the methods described in Annex B.
– The linearity for local SAR shall be evaluated in the range of 0,12 W/kg to 100 W/kg (RMS for CW signals).

6.4 Device holder specification

The device holder shall permit the DUT to be positioned according to the specifications given in 7.1.6. It shall be made of low loss and low permittivity material(s): loss tangent tan δ ≤ 0,05 and relative permittivity ε_r ≤ 5.

With array systems using a sealed flat phantom that is oriented upward (open phantoms face downward to hold the tissue-equivalent medium), 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 spacer providing a separation distance.

If spacers are used between the DUT and the phantom to provide the required position or separation distance, they shall not contain metal and shall be made of low loss and low permittivity material(s): loss tangent tan δ ≤ 0,005 and relative permittivity ε_r ≤ 1,1.

When the highest 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 psSAR 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 document. Refer to IEC 62209-1 and IEC 62209-2 for rationales.

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6.5 Reconstruction algorithm and peak spatial-averaging specifications

Unlike SAR measurement systems specified in IEC 62209-1 and IEC 62209-2, a vector measurement-based system does not determine the psSAR directly from measurement results at 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 values in the volume of interest such that the psSAR can be evaluated with known uncertainty using the electric fields and/or magnetic fields measured by the vector measurement-based system.

Reconstruction methods are described in Annex C and are applicable to both scanning systems and array systems.

The following requirements on reconstruction and psSAR shall be met:

– The reconstruction algorithm shall determine the SAR distribution in the phantom from the measured electric field and/or magnetic field measured by the sensors.
– The SAR distribution shall be determined within the volume of interest containing all SAR peaks (primary and secondary).
– The averaging volume shall be in the shape of a cube, except that the front face of the averaging volume shall conform to the phantom shell and the back face shall be equally distorted (Figure 2). 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.
– The software of the measurement system shall provide error messages to the user if the psSAR is outside the spatial region for which the measurement uncertainty requirements of this document are not met.

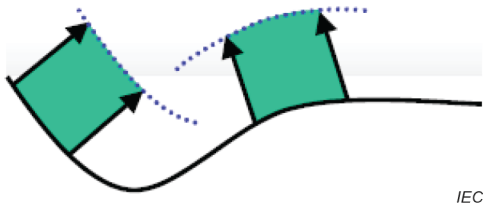

Figure 2 – Illustration of the shape and orientation relative to a curved phantom surface of the distorted cubic volume for computing psSAR

7 Protocol for SAR assessments

7.1 Measurement preparation

7.1.1 General

All measurements should be carried out using good laboratory practice, e.g. in accordance with ISO/IEC 17025, or any other local and national requirements for device certification. Interlaboratory comparisons can be used to compare the results from several laboratories in order to evaluate the performance of SAR measurement systems (Annex E).

7.1.2 Preparation of tissue-equivalent medium

The tissue-equivalent medium shall yield relative permittivity ε_r and conductivity σ values within ± 10 % of the target values at the frequencies at which the SAR is measured. The methods of I.2.6 or J.2.6 shall be used to correct the measured SAR for the deviations in permittivity and conductivity.

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

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

If the tissue-equivalent 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 procedure and measurement interval when it is longer than the validity period of the system calibration.

7.1.3 System check

A *system check* according to the procedures of Annex D shall be completed 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-equivalent 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.

The *system check* procedure shall be performed on the same SAR measurement system, using the same SAR probe, tissue-equivalent medium and software version as the SAR evaluation of the DUT. The measurement shall include each frequency band tested according to the procedures of Annex D.

7.1.4 Preparation of the device under test (DUT)

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

7.1.5 Operating modes

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

7.1.6 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.

7.1.7 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.

To limit the measurement uncertainties 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. Formula (1) and Formula (2) provide the minimum number of tests to perform for a DUT with dimensions greater than or equal to the dimensions of the

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measurement area, when successive SAR evaluations with one third overlapping section are combined:

$$N_{\text{tests}} = N_{\text{sublength}} \times N_{\text{subwidth}} \tag{1}$$

$$N_{\text{tests}} = \text{roundup}\left(\left(\left(\frac{L'}{L}\right)\right)\times\left(1+\frac{1}{3}\right)\right)\times\text{roundup}\left(\left(\frac{w'}{w}\right)\right)\times\left(1+\frac{1}{3}\right)\right) \tag{2}$$

where

L'	is the length of the DUT;
W'	is the width of the DUT;
L	is the length of the measurement area specified by the system manufacturer;
W	is the width of the measurement area specified by the system manufacturer ;
N_{tests}	is the number of tests performed on DUT sub-divisions for a complete SAR evaluation of the DUT;
$N_{\text{sublength}}$	is the number of sub-divisions of the DUT length;
N_{subwidth}	is the number of sub-divisions of the DUT width.

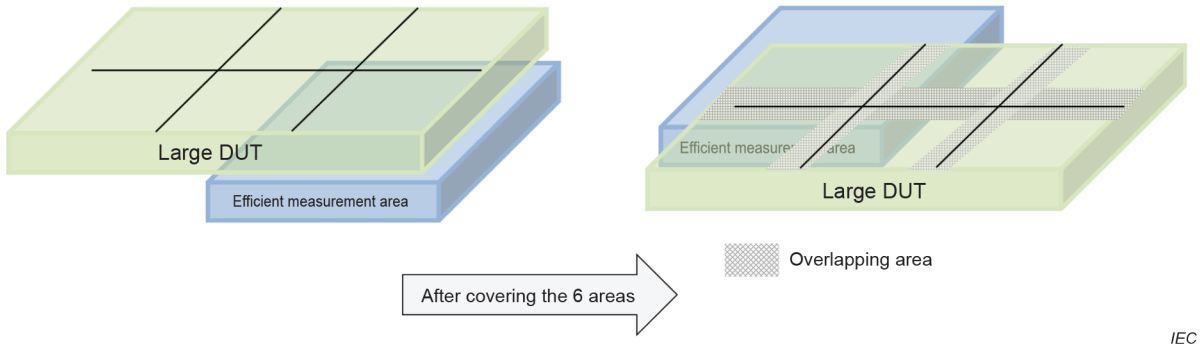

Figure 3 – Measurements performed by shifting a large device over the efficient measurement area of the system including overlapping areas – in this case: six tests performed

7.1.8 Test frequencies for DUT

The requirements of 6.2.5 of IEC 62209-1:2016 and 6.1.5 of IEC 62209-2:2010 shall apply.

NOTE Subclause 6.1.5 of IEC 62209-2:2010 refers to IEC 62209-1:2005.

7.2 Tests to be performed

In order to determine the highest value of the psSAR of a device, all device positions, configurations and operational modes shall be tested for each frequency band according to step 1 to step 4 as follows.

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) the following positions

1) all device positions on the body phantom (if testing of DUT against body phantom is required);

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2) all cheek and tilt positions on the left and right head phantoms (if testing of DUT against head phantom is required);

b) all physical configurations of the DUT for each device position per Step 1a),

NOTE Examples of physical configurations are device slide or cover open and closed or antenna extended and retracted.

c) all operational modes, e.g. modulations and multiplexing modes, for each device position in step 1 a) and configuration(s) of Step 1 b) in each frequency band;

d) all antennas used.

Step 2: For the test condition providing the highest psSAR determined in step 1, perform the tests at all other test frequencies as required by 7.1.8 (e.g. lowest and highest channels). In addition, for each device position, configuration and operating mode where the psSAR value determined in Step 1 a), step to Step 1 d) is greater than or equal to half of the applicable SAR limit, testing of other channels of 7.1.8 is required as well;.

Step 3: When the highest 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).

Step 4: Examine all data to determine the highest value of the psSAR found in Step 1 to Step 3 for each operation mode in each frequency band.

7.3 General measurement procedure

7.3.1 General

Subclause 7.3 provides the procedure to be performed for each of the test conditions described in 7.2. For scanning systems, the measurement procedure of 7.3.2 shall be applied. For array systems, the measurement procedure of 7.3.3 shall be applied.

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.

Because of the differences in the array systems versus scanning systems the drift requirements are different.

7.3.2 Measurement procedure for scanning systems

If a scanning measurement system is used, the following procedure and requirements shall be applied:

a) Take a reference measurement with a fully charged battery at a specific location within the phantom.

b) Measure the electric field or magnetic field within the volume of interest.

c) If applicable to the method, refine the scanning with higher spatial resolution at the location of interest.

d) Apply the reconstruction algorithm to reconstruct the field for determining the psSAR distributions.

e) Apply the averaging algorithm as described in 6.5 to determine the psSAR.

f) The reference measurement in step a) shall be repeated at the end of each measurement. The relative difference between the first and each subsequent reference measurement should be within 5 %. Otherwise, the measurements shall be repeated, o all SAR values

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shall be increased by the absolute percentage difference between the first and last reference measurement.

g) Add the upper-bound percentage allowed (i.e. otherwise full re-test needed).

7.3.3 Measurement procedure for array systems

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

a) Measure the electric field or magnetic field over the measurement region.

b) Apply the reconstruction algorithm to reconstruct the SAR distribution in the volume of interest.

c) Apply the averaging algorithm as described in 6.5 to determine the psSAR.

d) If a sequence of different configurations is evaluated without recharging the battery, then the first measurement shall be repeated at the end of each measurement and the relative difference between the first and last measurement shall be within the repeatability tolerance of the system (see 8.2) but not larger than 5 %. If the SAR difference exceeds 5 % then the measurements shall be repeated with full charged battery or all SAR values shall be increased by the absolute percentage difference between the first and last measurement.

7.4 SAR measurements for simultaneous transmission

7.4.1 General

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).

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7.4.2 SAR measurements for uncorrelated signals

7.4.2.1 General

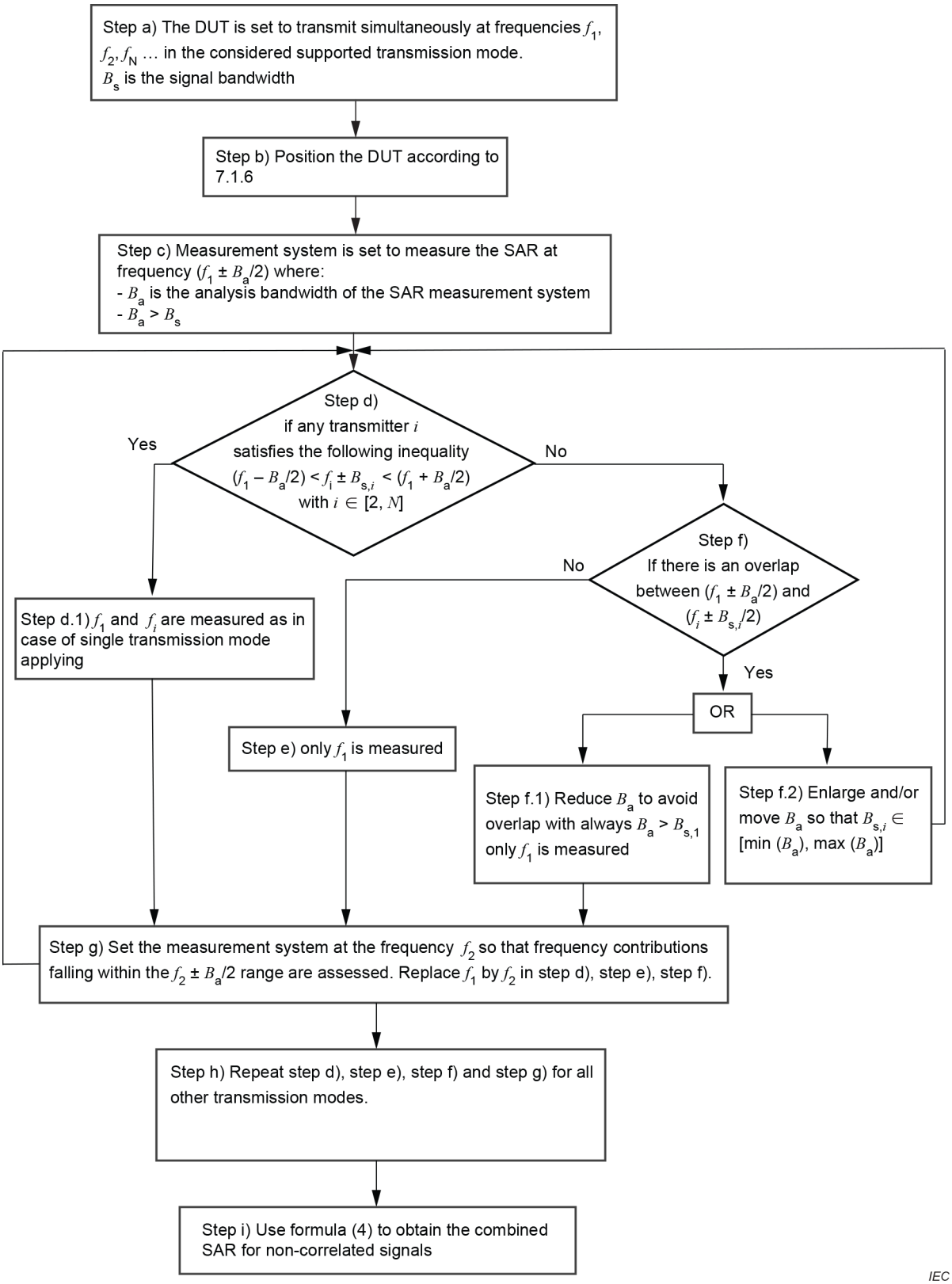

Figure 4 – Flow chart for SAR measurements of uncorrelated signals at different frequencies using a measurement system able to distinguish between different frequency components (Method 2)

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Subclause 7.4.2 describes two methods (7.4.2.2 and 7.4.2.3) for the measurement of SAR from non-correlated signals. The summation of the SAR distributions is described in 7.4.2.4.

7.4.2.2 Method 1

For measurement of uncorrelated signals that are transmitting separately, the following procedure applies:

a) Set the DUT to transmit in one of the N frequency bands at frequencies f_k for $f_1, f_2, \ldots, f_N$.

b) Measure the SAR distribution, $SAR_k(r)$, as described in 7.3.

c) Repeat steps a) and b) for the other frequency bands.

d) Perform the summation of the N SAR distributions as described in 7.4.2.4.

7.4.2.3 Method 2

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), may be performed provided that all the transmission frequencies fall within a valid range of both the probe calibration and the tissue-equivalent medium. Figure 4 illustrates the individual steps of Method 2.

In such a case, the following procedure applies:

a) The DUT is set to transmit simultaneously at frequencies f_1, f_i, f_N, … in the considered supported transmission mode (Figure 5).

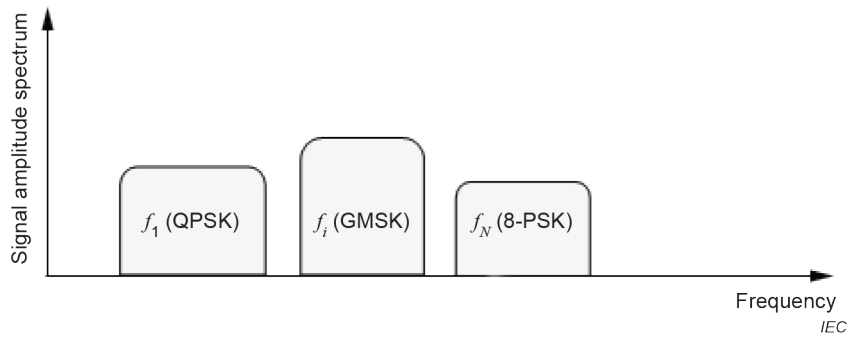

Figure 5 – Illustration of the amplitude spectrum, as function of frequency, for simultaneously transmitted signals of multiple frequency bands emitted by a DUT

b) The DUT is positioned in relation to the phantom according to 7.1.6. at a single position such that SAR summation or aggregation is applicable.

c) The measurement system is set to measure SAR at frequency f_1, so that frequency contributions falling within the analysis bandwidth B_a of the measurement system readout electronics are assessed. B_a shall be larger than the signal bandwidth B_s as illustrated in Figure 6.

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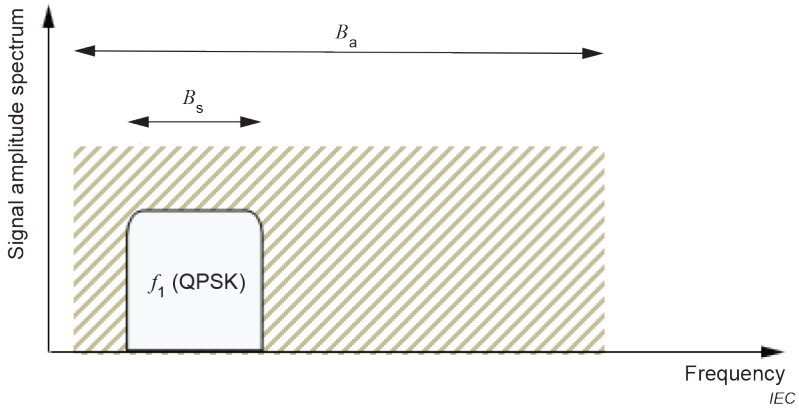

Figure 6 – Illustration of a completely covered signal bandwidth B_s by the measurement system analysis bandwidth B_a at single transmission mode

d) If all B_{si} are contained in B_a range, for any transmitter i between 2 and N, as illustrated in Figure 7, 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.

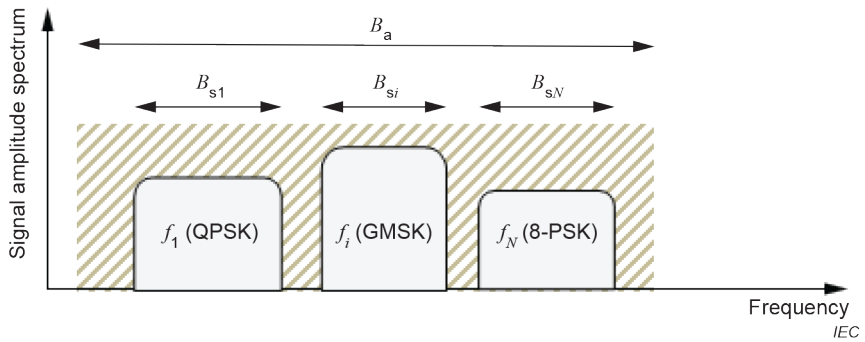

Figure 7 – Illustration of a completely covered signal bandwidths B_{si} (for i = 2 to N) by the measurement system analysis bandwidth B_a for simultaneous multiple-frequency transmission mode

e) If B_{si}, of any transmitter (index i = 1 to N), does not fully overlap B_a then only the B_{si} that are strictly fully covered by B_a shall be measured simultaneously and according to step d) (Figure 8).

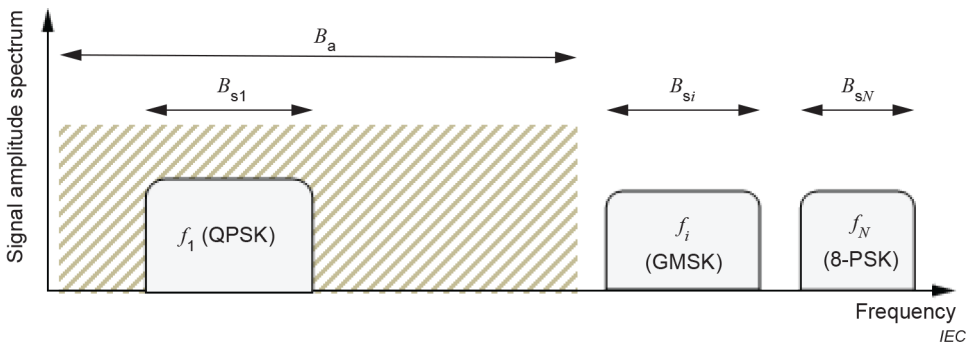

Figure 8 – Illustration of a non-coverage of the signal bandwidths B_{si} (for i = 2 to N) by the measurement system analysis bandwidth B_a for simultaneous multiple-frequency transmission mode

f) If there is an overlap between B_a and B_{si}, of any transmitter index i = 2 to N, as shown in Figure 9, then one of the two steps f)1) or f)2) shall be applied.

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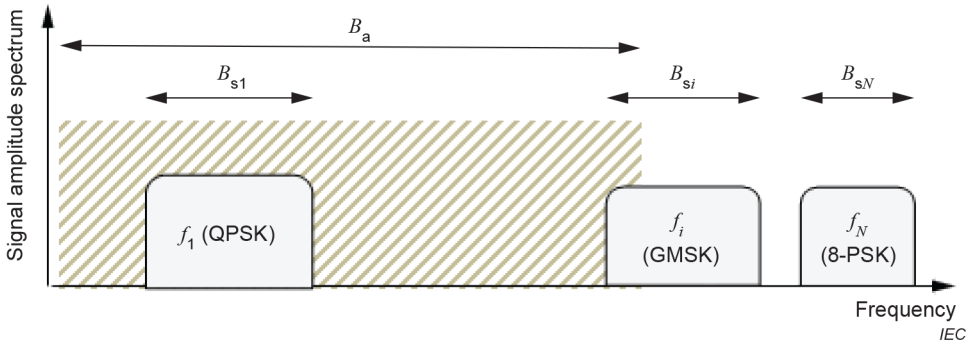

Figure 9 – Illustration of a partial-coverage of the signal bandwidths B_{si} (for i = 2 to N) by the measurement system analysis bandwidth B_a for simultaneous multiple-frequency transmission mode

1) The analysis bandwidth shall be reduced to match a bandwidth as small as possible but no lower than B_{s1} and avoid overlap, then apply step g) (Figure 10).

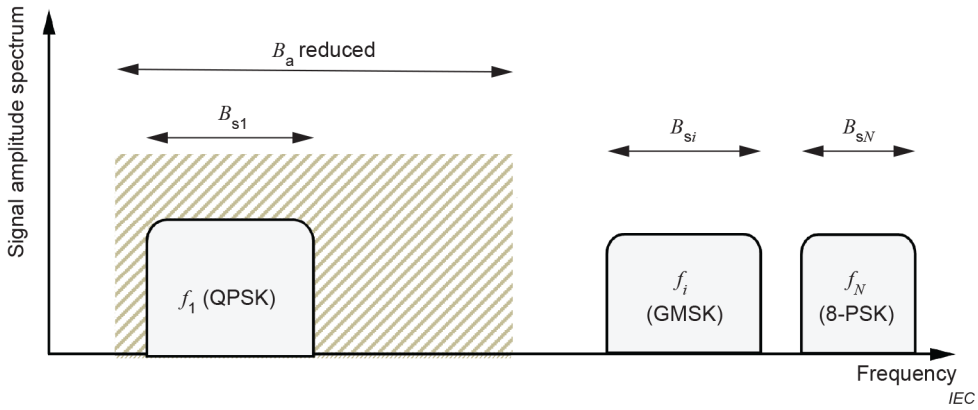

Figure 10 – Illustration of reduction of the measurement system analysis bandwidth B_a to cover only one signal bandwidth B_{si} (for i = 1 to N) for simultaneous multiple-frequency transmission mode

2) The analysis bandwidth B_a shall be enlarged or moved or both 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) (Figure 11).

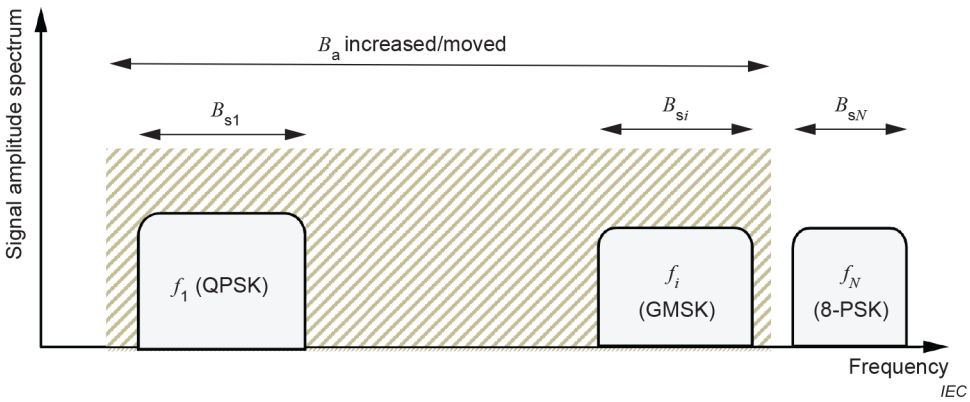

Figure 11 – Illustration of increasing or moving the measurement system analysis bandwidth B_a to cover one or more signal bandwidth B_{si} (for i = 1 to N) for simultaneous multiple-frequency transmission mode

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

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g) The measurement system shall be set to measure SAR at frequency f_2, so that frequency contributions fall within the analysis bandwidth B_a. 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) The summation of the N SAR distributions shall be performed as described in 7.4.2.4.

7.4.2.4 Procedure for summation of SAR distributions

When two or more signals are uncorrelated (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 (Formula (3)):

$$SAR_T(r) = \sum_{k=1}^{N} SAR_k(r) \tag{3}$$

Prior to averaging and search of the psSAR, each SAR distribution shall be assessed separately. After field reconstruction and determination of the individual SAR distributions, $SAR_k(r)$, the summation given in Formula (3) is performed. The averaging and search procedures for the peak-spatial average SAR are then performed.

7.4.3 SAR measurements for correlated signals

DUTs with multiple antennas transmitting correlated signals simultaneously represent a particular class 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 amplitude and 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, are signals with relative phases unchanged during a relatively long duration compared with symbol duration. These types 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 towards a specific direction. In different operating environments, the relative phases may change to obtain different desired radiation patterns. However, as soon as the transmitting direction is determined and the pattern is formed, the relative phases will be fixed for a specific 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, are signals with relative phases changed quickly in a relatively short time period. Such signals can be found in systems utilizing MIMO techniques. The relative phases of signals will be changed from symbols to symbols due to the function of space-time block codes (STBC) in 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 normal communications.

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

For type 1 correlated signals, the psSAR is evaluated by one of the methods described in IEC TR 62630. Prior to averaging and search of the psSAR, 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 amplitudes, summation of the E-field components or summation of the complex E-field vectors (IEC TR 62630). The averaging and search of the psSAR procedure steps are then performed. Summation of the E-field amplitudes 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 psSAR under simultaneous transmission conditions by combining the vector fields of each individual transmitter as

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transmitting separately at the highest time-averaged output power with single SAR measurements, in that case, 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 psSAR 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 (e.g. space-time block code (STBC)). The signal integration time of the measurement system shall be determined according to I.3.4 and J.3.4 to ensure convergence of the acquisition of the modulated signal spectrum.

8 Measurement uncertainty estimation

8.1 General

The concepts of uncertainty estimation in the measurement of the SAR from wireless devices are based on the general rules provided by ISO/IEC Guide 98-3 and the guidelines provided in Annex H.

Clause 8 provides guidance on how the uncertainty budget shall be assessed for scanning systems and array systems. At a minimum, the uncertainty components listed in Table 2 to Table 5 shall be determined and documented. These tables provide the generic uncertainty terms that are applicable to both head and body SAR measurement. Because this document allows for different implementations of measurement systems, additional uncertainty components may be required that are not sufficiently covered by these generic tables.

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.

The measurement uncertainty of 1 g and 10 g SAR assessment results shall be estimated using established procedures (e.g. ISO/IEC Guide 98-3) and documented following the uncertainty model in 8.3. In addition, the measurement uncertainty for the *system check* results shall be provided using the same procedure.

8.2 Requirements on the measurement uncertainty evaluation

The expanded measurement 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 measurement results according to the following:

– The expanded measurement uncertainty of the measured value of psSAR (1 g or 10 g) measured values shall be assessed in accordance with the guidance and explanation given in ISO/IEC Guide 98-3 and the requirements specified in this document following the uncertainty model in 8.3.
– The range for which the measurement uncertainty is applicable shall be clearly stated by documented and valid analysis, e.g. measurement region on the phantom, frequency range and power range.
– For the *system validation* acceptance criteria, the measurement uncertainty estimate used shall be the maximum for any DUT type to be measured on the system, i.e. it is comprehensive for any DUT type to be measured with the system.

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– The measurement uncertainty quoted on the test report shall provide a realistic uncertainty estimate for the measurement result at the 95 % confidence level.

– The reported measurement uncertainty shall represent the maximum expanded uncertainty within this range.

– The expanded measurement uncertainty of the *system check* and *system validation* measurement results shall also be evaluated. The uncertainty shall be quoted at the 95 % confidence level, and the expanded uncertainty shall not exceed 30 % of the psSAR value in range of 0,4 W/kg to 20 W/kg for SAR averaged over 1 g and 10 g. Accordingly, for psSAR values below 0,4 W/kg, the expanded uncertainty shall not exceed 0,12 W/kg. If the expanded uncertainty for DUT testing is greater than 30 %, when acceptable by national requirements, the reported data shall take into account the percentage difference between the actual uncertainty and the 30 % target value (ISO/IEC Guide 98–3). The formula used for scaling the measured SAR by the excess uncertainty shall be as described in IEC 62479.

8.3 Description of measurement uncertainty models

8.3.1 General

The combined standard measurement uncertainty of the 1 g or 10 g SAR consists of uncertainty contributions from the following influences, as described in Annex I for single probe scanning systems and Annex J for fixed or scanning array systems.

a) Measurement system uncertainties to be specified by the manufacturer, MM (Clauses I.1 and J.1). The standard uncertainty for calibration of the vector measurement-based system is determined by the system calibration laboratory or system manufacturer.

b) Uncertainties in reconstruction, post-processing and corrections, MN (Clauses I.2 and J.2).

c) Measurement system uncertainties that are dependent on the DUT, MD (Clauses I.3 and J.3), including probe coupling with the DUT, modulation response, integration time and SAR drift. The corresponding uncertainty may include a Type A uncertainty analysis based on a set of sources that shall be documented and demonstrated to be sufficient for ensuring a conservative assessment of the related uncertainty contribution. The analytical approach described in Clause H.5 may also be used.

d) Uncertainties related to the measurement environment, ME (Clauses I.4 and J.4). The uncertainties caused by the user handling or the laboratory environment in which the measurement system will be used. These uncertainties include those relating to the setup, ambient signals and reflections.

e) Uncertainties of the validation antennas, MV (Clauses I.5 and J.5).

The types of DUTs for which the combined uncertainty estimate is valid shall be stated.

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

According to ISO/IEC Guide 98-3 the measurement uncertainty is defined as the result of root-sum-squares of the uncertainty contributions. The following uncertainty components are specified which are described in Annex I and Annex J.

Table 2 to Table 5 list all of the measurement uncertainty components. For a particular measurement case, the relevant uncertainty terms are summed according to the uncertainty models (Formulas (4) to (12)) for that measurement.

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8.3.2 Uncertainty models for array measurement system and scanning measurement systems

For the result of a DUT SAR measurement, the measurement uncertainty ΔSAR is per Formula (4):

$$\Delta SAR = \sqrt{MS^2 + MD^2 + ME^2} \tag{4}$$

For *system check*, the measurement uncertainty is per Formula (5):

$$\Delta SAR = \sqrt{MS^2 + MD^2 + ME^2 + MV^2} \tag{5}$$

In the above formulas, MS is the total measurement system uncertainty that shall be specified by the system manufacturer, given by Formula (6):

$$MS = \sqrt{MM^2 + MN^2} \tag{6}$$

where MM and MN are the uncertainty contributions from the measurement system and from the corrections and post-processing, respectively. MM depends on the type of measurement system. For scanning systems with a single probe (Annex I), Formula (7) applies:

$$MM = \sqrt{CF^2 + ISO^2 + LIN^2 + SL^2 + BE^2 + RE^2 + RT^2 + PP^2 + SE^2 + PS^2 + MAT^2 + MSI^2} \tag{7}$$

For fixed or scanning array systems (Annex J), Formula (8) applies:

$$MM = \sqrt{CF^2 + ISO^2 + MSC^2 + AS^2 + LIN^2 + SL^2 + BE^2 + RE^2 + RT^2 + PP^2 + SE^2 + AB^2 + PS^2 + MAT^2 + HOM^2 + MSI^2} \tag{8}$$

The other terms are given by Formulas (9) to (12):

$$MN = \sqrt{REC^2 + POL^2 + SAV^2 + SARS^2 + SC^2} \tag{9}$$

$$MD = \sqrt{PC^2 + MOD^2 + IT^2 + SD^2} \tag{10}$$

$$ME = \sqrt{DH^2 + DP^2 + AC^2 + DN^2} \tag{11}$$

$$MV = \sqrt{DEX^2 + PMU^2 + OVS^2} \tag{12}$$

The uncertainty contributors that are not involved during the repeatability of the SAR measurement of a DUT are set to zero. The total uncertainty for this case is provided in Formula (13):

$$\Delta SAR = \sqrt{AS^2 + PP^2 + POL^2 + SC^2 + PC^2 + DN^2 + DP^2 + DH^2 + SD^2 + AC^2 + MSI^2} \tag{13}$$

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8.3.3 Example uncertainty budget templates

Table 2 to Table 5 show the templates for the uncertainty budgets of the formulas in 8.3.2.

– Table 2 shows an example measurement system uncertainty budget template, which shall be completed by the SAR system manufacturer.
– Table 3 shows an example uncertainty budget template for a DUT measurement.
– Table 4 shows an example uncertainty budget template for a *system validation* measurement.
– Table 5 shows an example uncertainty budget template for a *system check* measurement.

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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

Symbol /notes	Quantity x_i (source of uncertainty)	Reference	Prob. Dist.[a]	Uncertainty	Divisor[a] q	$u(x_i)$	c_i	$u_i(y)$	v_i
Uncertainty in the measurement system to be specified by the manufacturer (*MM*)									
CF	Calibration	I.1.2, J.1.2							n
ISO	Isotropy	I.1.3, J.1.3							n
MSC	Mutual sensor coupling	J.1.4							n
AS	Scattering due to the presence of the array	J.1.5							n
LIN	System linearity	I.1.4, J.1.6							n
SL	Sensitivity limit	I.1.5, J.1.7							n
BE	Boundary effect	I.1.6, J.1.8							n
RE	Readout electronics	I.1.7, J.1.9							n
RT	Response time	I.1.8, J.1.10							n
PP	Probe positioning	I.1.9, J.1.11							n
SE	Sampling error	I.1.10, J.1.12							n
AB	Array boundaries	J.1.13							n
PS	Phantom shell	I.1.11, J.1.14							n
MAT	Tissue-equivalent medium parameters	I.1.12, J.1.15							n
HOM	Phantom homogeneity	J.1.16							n
MSI	Measurement system immunity/secondary reception	I.1.13, J.1.17							n
Uncertainty in corrections and post processing to be specified by the manufacturer (*MN*)									
REC	Uncertainty due to reconstruction	I.2.2, J.2.2							n
POL	Impact of noise on the reconstruction	I.2.3, J.2.3							n
SAV	SAR averaging	I.2.4, J.2.4							n
SARS	SAR scaling	I.2.5, J.2.5							n
SC	SAR correction for deviations in permittivity and conductivity	I.2.6, J.2.6							n
Total uncertainty to be determined by the manufacturer									
MS	Uncertainty (k = 1) and effective degrees of freedom						U =		v_{eff} =

[a] 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.

NOTE Some uncertainty components can be evaluated in combination with other uncertainty components.

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Table 3 – Uncertainty budget template for evaluating the uncertainty in the measured value of 1 g SAR or 10 g SAR from a DUT

Symbol/ notes	Quantity x_i (source of uncertainty)	Reference	Prob. Dist. [a]	Unc	Divisor [a] q	$u(x_i)$	c_i	$u_i(y)$	v_i
Measurement system uncertainties to be specified by the manufacturer , *MS*									
MS	Measurement system uncertainties to be specified by the manufacturer	Table 2							*n*
Measurement system uncertainties that are dependent on the DUT, *MD*									
PC	Probe or probe-array coupling with DUT	I.3.2, J.3.2							*n*
MOD	Modulation response	I.3.3, J.3.3							*n*
IT	Integration time	I.3.4, J.3.4							*n*
SD	Measured SAR drift	I.3.5, J.3.5							*n*
DUT-related uncertainties and environmental factors, *ME*									
DH	Device holder	I.4.2, J.4.2							*n*
DP	Device positioning	I.4.3, J.4.3							*n*
AC	RF ambient conditions	I.4.4, J.4.4							*n*
DN	Drift and noise	I.4.5, J.4.5							*n*
ΔSAR	Expanded uncertainty and effective degrees of freedom							U =	v_{eff} =

[a] 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.

NOTE Some uncertainty components can be evaluated in combination with other uncertainty components.

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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

Symbol/notes	Quantity x_i (source of uncertainty)	Reference	Prob. Dist.[a]	Uncer-tainty	Divisor[a] q	$u(x_i)$	c_i	$u_i(y)$	v_i
Measurement system uncertainties to be specified by the manufacturer, *MS*									
MS	Measurement system uncertainties to be specified by the manufacturer	Table 2							*n*
Measurement system uncertainties that are dependent on the DUT, *MD*									
PC	Probe or probe-array coupling with DUT	I.3.2, J.3.2							*n*
MOD	Modulation response	I.3.3, J.3.3							*n*
IT	Integration time	I.3.4, J.3.4							*n*
Uncertainty related to source or noise, *ME*									
DP	Device positioning	I.4.3, J.4.3							*n*
DH	Device holder	I.4.2, J.4.2							*n*
AC	RF ambient conditions	I.4.4, J.4.4							*n*
DN	Drift and noise	I.4.5, J.4.5							*n*
MSI	Measurement system immunity/secondary reception	I.1.13, J.1.17							*n*
Uncertainties of validation antennas, *MV*									
DEX	Deviation of experimental antennas	I.5.2, J.5.2							*n*
PMU	Power measurement uncertainty	I.5.3 J.5.3							
OVS	Other uncertainty contributions when using validation antennas	I.5.4, J.5.4							*n*
ΔSAR	Expanded uncertainty and effective degrees of freedom							U =	v_{eff} =

[a] 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.

NOTE Some uncertainty components may be evaluated in combination with other uncertainty components.

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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*

Symbol /notes	Quantity x_i (source of uncertainty)	Reference	Prob. Dist. [a]	Uncer-tainty	Divisor [a] q	$u(x_i)$	c_i	$u_i(y)$	v_i
Measurement system uncertainties to be specified by the manufacturer, *MS*									
MS	Measurement system uncertainties to be specified by the manufacturer	Table 2					1		n
Measurement system uncertainties that are dependent on the DUT, *MD*									
PC	Probe or probe-array coupling with DUT	I.3.2, J.3.2					1		n
MOD	Modulation response	I.3.3, J.3.3					0		n
IT	Integration time	I.3.4, J.3.4					0		n
Uncertainties related to the source or noise, *ME*									
DH	Device holder	I.4.2, J.4.2					1		n
DP	Device positioning	I.4.3, J.4.3					1		n
AC	RF ambient conditions	I.4.4, J.4.4					1		n
DN	Drift and noise	I.4.5, J.4.5					1		n
Uncertainties of *system check* antennas, *MV*									
MSI	Measurement system immunity/secondary reception	I.1.13, J.1.17					1		n
DEX	Deviation of experimental antennas	I.5.2, J.5.2					1		n
PMU	Power measurement uncertainty	I.5.3 J.5.3					1		∞
OVS	Other uncertainty contributions when using *system check* antennas	I.5.4, J.5.4					1		n
ΔSAR	Expanded uncertainty and effective degrees of freedom							$U=$	v_{eff} =

[a] 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.

NOTE Some uncertainty components can be evaluated in combination with other uncertainty components.

9 Measurement report

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

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