

CONSOLIDATED VERSION

VERSION CONSOLIDÉE



**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)**

**Exposition humaine aux champs radiofréquence produits par les dispositifs de communications sans fils tenus à la main ou portés près du corps –
Modèles de corps humain, instrumentation et procédures –
Partie 2: Procédure de détermination du débit d'absorption spécifique produit par les appareils de communications sans fil utilisés très près du corps humain (gamme de fréquences de 30 MHz à 6 GHz)**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2019 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

67 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

CONSOLIDATED VERSION

VERSION CONSOLIDÉE



**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)**

**Exposition humaine aux champs radiofréquence produits par les dispositifs de communications sans fils tenus à la main ou portés près du corps –
Modèles de corps humain, instrumentation et procédures –
Partie 2: Procédure de détermination du débit d'absorption spécifique produit par les appareils de communications sans fil utilisés très près du corps humain (gamme de fréquences de 30 MHz à 6 GHz)**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.050.10

ISBN 978-2-8322-6980-0

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

This document is a preview generated by EVS

REDLINE VERSION**VERSION REDLINE**

**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)**

**Exposition humaine aux champs radiofréquence produits par les dispositifs de communications sans fils tenus à la main ou portés près du corps –
Modèles de corps humain, instrumentation et procédures –
Partie 2: Procédure de détermination du débit d'absorption spécifique produit par les appareils de communications sans fil utilisés très près du corps humain (gamme de fréquences de 30 MHz à 6 GHz)**

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	9
4 Symbols and abbreviated terms.....	12
4.1 Physical quantities	12
4.2 Constants.....	12
4.3 Abbreviations	12
5 Measurement system specifications	13
5.1 General requirements.....	13
5.2 Phantom specifications – shell and liquid	14
5.2.1 General requirements.....	14
5.2.2 Phantom material, shape and size	14
5.2.3 Tissue-equivalent liquid material properties	15
5.3 Measurement instrumentation system specifications	17
5.3.1 General requirements.....	17
5.3.2 Scanning system	17
5.3.3 Probes.....	17
5.3.4 Probe calibration	17
5.3.5 Specifications for fixture(s) to hold the DUT in the test position	17
6 Protocol for SAR evaluation.....	18
6.1 Measurement preparation.....	18
6.1.1 General preparation.....	18
6.1.2 System check	18
6.1.3 Preparation of the device under test	18
6.1.4 Position of the device under test in relation to the phantom	20
6.1.5 Test frequencies	30
6.2 Tests to be performed	30
6.2.1 General requirements.....	30
6.2.2 Test reductions.....	30
6.2.3 General test procedure	31
6.2.4 Fast SAR evaluations	32
6.3 Measurement procedure.....	34
6.3.1 General procedure.....	34
6.3.2 Procedures for testing of DUTs with simultaneous multi-band transmission	37
6.4 Post-processing	39
6.4.1 Interpolation	39
6.4.2 Probe offset extrapolation.....	39
6.4.3 Definition of averaging volume.....	39
6.4.4 Searching for the maxima	40
7 Uncertainty estimation.....	40
7.1 General considerations.....	40
7.1.1 Concept of uncertainty estimation.....	40
7.1.2 Type A and type B evaluations	40

7.1.3	Degrees of freedom and coverage factor	41
7.2	Components contributing to uncertainty	41
7.2.1	General	41
7.2.2	Contribution of the measurement system (probe and associated electronics).....	42
7.2.3	Contribution of mechanical constraints	47
7.2.4	Contribution of physical parameters	51
7.2.5	Contribution of post-processing	54
7.2.6	Standard source offset and tolerance	59
7.3	Uncertainty estimation	59
7.3.1	Combined and expanded uncertainties	59
7.3.2	Maximum expanded uncertainty	60
8	Measurement report	66
8.1	General	66
8.2	Items to be recorded in the measurement report.....	66
Annex A (informative)	Phantom rationale	68
Annex B (normative)	SAR measurement system verification	71
Annex C (informative)	Fast SAR testing	80
Annex D (informative)	Standard sources and phantoms for system validation	82
Annex E (informative)	Example recipes for phantom tissue-equivalent liquids	88
Annex F (normative)	SAR correction for deviations of complex permittivity from targets	91
Annex G (informative)	Hands-free kit testing	93
Annex H (informative)	Skin enhancement factor	96
Annex I (informative)	Tissue-equivalent liquid dielectric property measurements and measurement uncertainty estimation	100
Annex J (informative)	Testing compliance for the exposure of the hand	102
Annex K (informative)	Test reduction	104
Annex L (normative)	Power scaling procedure	106
Annex M (informative)	Rationale for probe parameters	108
Bibliography	110
Figure 1	– Dimensions of the elliptical phantom	15
Figure 2	– Definition of reference points	21
Figure 3	– Measurements by shifting of the device at the phantom	22
Figure 4	– Test positions for a generic device	23
Figure 5	– Test positions for body-worn devices	24
Figure 6	– Device with swivel antenna (example of desktop device).....	24
Figure 7	– Test positions for body supported devices.....	26
Figure 8	– Test positions for desktop devices	27
Figure 9	– Test positions for front-of-face devices.....	28
Figure 10	– Test position for limb-worn devices	29
Figure 11	– Test position for clothing-integrated wireless devices	30
Figure 12	– Block diagram of the tests to be performed	33
Figure 13	– Orientation of the probe with respect to the normal of the phantom surface.....	37
Figure 14	– Orientation of the probe with respect to the line normal to the phantom surface, shown at two different locations	35

Figure B.1 – Set-up for the system check.....	73
Figure D.1 – Mechanical details of the reference dipole	84
Figure D.2 – Dimensions of the flat phantom set-up used for deriving the minimal dimensions for W and L	85
Figure D.3 – FDTD predicted uncertainty in the 10 g peak spatial-average SAR as a function of the dimensions of the flat phantom compared with an infinite flat phantom	86
Figure D.4 – Standard waveguide source.....	87
Figure G.1 – Configuration of a wired personal hands-free headset	93
Figure G.2 – Configuration without a wired personal hands-free headset	94
Figure H.1 – SAR and temperature increase (ΔT) distributions simulated for a three-layer (skin, fat, muscle) planar torso model.....	96
Figure H.2 –Statistical approach to protect 90 % of the population.....	97
Figure H.3 – Spatial-average SAR skin enhancement factors.....	98
Figure J.1 – Test position for hand-held devices, not used at the head or torso	102
Table 1 – Dielectric properties of the tissue-equivalent liquid material	16
Table 2 – Example uncertainty template and example numerical values for relative permittivity (ϵ'_r) and conductivity (σ) measurement; separate tables may be needed for each ϵ'_r and σ	52
Table 3 – Parameters for reference function f_1	56
Table 4 – Reference SAR values in watts per kilogram used for estimating post-processing uncertainties	57
Table 5 – Measurement uncertainty evaluation template for DUT SAR test.....	61
Table 6 – Measurement uncertainty evaluation template for system validation	63
Table 7 – Measurement uncertainty evaluation template for system repeatability.....	65
Table 8 – Zoom scan parameters.....	36
Table B.1 – Numerical reference SAR values for reference dipoles and flat phantom – All values are normalized to a forward power of 1 W.....	78
Table B.2 – Numerical reference SAR values for reference matched waveguides in contact with flat phantom (from reference [53])	79
Table D.1 – Mechanical dimensions of the reference dipoles	83
Table D.2 – Parameters used for calculation of reference SAR values in Table B.1	86
Table D.3 – Mechanical dimensions of the standard waveguide	87
Table E.1 – Suggested recipes for achieving target dielectric parameters.....	89
Table F.1 – Root-mean-squared error of Equations (F.1) to (F.3) as a function of the maximum change in permittivity or conductivity [13].....	92
Table H.1 – Spatial-average SAR correction factors.....	98
Table I.1 – Parameters for calculating the dielectric properties of various reference liquids.....	100
Table I.2 – Dielectric properties of reference liquids at 20 °C	101
Table M.1 – Minimum probe requirements as a function of frequency and parameters of the tissue equivalent liquid.....	108
Table M.2 – Extrapolation and integration uncertainty of the 10 g peak spatial average SAR ($k=2$) for homogeneous and graded meshes	109

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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)

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

DISCLAIMER

This Consolidated version is not an official IEC Standard and has been prepared for user convenience. Only the current versions of the standard and its amendment(s) are to be considered the official documents.

This Consolidated version of IEC 62209-2 bears the edition number 1.1. It consists of the first edition (2010-03) [documents 106/195/FDIS and 106/200/RVD] and its corrigendum (2010-06), and its amendment 1 (2019-05) [documents 106/484/FDIS and 106/492/RVD]. The technical content is identical to the base edition and its amendment.

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough

red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 62209-2 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

The French version of this standard has not been voted upon.

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

A list of all parts of the IEC 62209 series, published under the general title *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures*, can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site 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.

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

The IEC work item “Evaluation of the Human Exposure to Radio Fields from Hand-Held and Body-Mounted Wireless Communication Devices in the Frequency range 30 MHz to 6 GHz (Human Models, Instrumentation, Procedures),” has the objective to measure the human exposure from devices intended to be used at a position near the human body. This standard was developed to provide procedures to evaluate exposures due to any electromagnetic field (EMF) transmitting device when held in the hand or in front of the face, mounted on the body, combined with other transmitters within a product, or embedded in garments. The types of devices dealt with include but are not limited to mobile telephones, cordless telephones, cordless microphones, auxiliary broadcast devices and radio transmitters in personal computers. For transmitters used in close proximity to the human ear, specific absorption rate (SAR) measurements should be performed using the procedures of IEC 62209-1:2005.

TC 106 has the scope to prepare international standards on measurement and calculation methods used to assess human exposure to electric, magnetic and electromagnetic fields. The task includes assessment methods for the exposure produced by specific sources. It applies to basic restrictions and reference levels. Although the establishment of exposure limits is not within the scope of TC 106, the results of assessments performed in accordance with TC 106 standards can be compared with the basic restrictions of relevant standards and guidelines. Conformity assessment depends on the policy of national regulatory bodies.

A Category D liaison in IEC involves organizations that can make an effective technical contribution and participate at the working group level or specific project level of the IEC technical committees or subcommittees. Obvious goals are standards harmonization and minimizing duplication of effort. The work of IEC technical committee 106 (TC 106) and IEEE International Committee on Electromagnetic Safety (ICES SCC39), technical committee 34 (TC 34), is an example where two international committees worked together informally through common membership to achieve the goal of harmonization, specifically between IEC Project Team 62209 (PT 62209) on the “Procedure to Measure the Specific Absorption Rate (SAR) for Hand-Held Mobile Telephones” and IEEE/SCC39-ICES/TC34 on IEEE Std 1528-2003 “IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques” [32].¹

IEEE/SCC39-ICES/TC34 has a similar project. Because the project is more advanced in IEC, a Category D liaison was sought in order to avoid divergence of standards and duplication of work. Thus, rather than developing two separate standards (IEC and IEEE), the IEEE committee felt it would be more efficient to develop a single IEC standard with direct input from the members of IEEE/SCC39-ICES/TC34, many of whom are also members of PT 62209 or are from the same organizations that send delegates to participate in the work of PT 62209. The Category D liaison is limited only to this project (Part 2 of IEC 62209 series).

¹ Figures in square brackets refer to the Bibliography.

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)

1 Scope

This part of IEC 62209 series is applicable to any wireless communication device capable of transmitting electromagnetic fields (EMF) intended to be used at a position near the human body, in the manner described by the manufacturer, with the radiating part(s) of the device at distances up to and including 200 mm from a human body, i.e. when held in the hand or in front of the face, mounted on the body, combined with other transmitting or non-transmitting devices or accessories (e.g. belt-clip, camera or Bluetooth add-on), or embedded in garments. For transmitters used in close proximity to the human ear, the procedures of IEC 62209-1:2005 are applicable.

This standard is applicable for radio frequency exposure in the frequency range of 30 MHz to 6 GHz, and may be used to measure simultaneous exposures from multiple radio sources used in close proximity to human body. Definitions and evaluation procedures are provided for the following general categories of device types: body-mounted, body-supported, desktop, front-of-face, hand-held, laptop, limb-mounted, multi-band, push-to-talk, clothing-integrated. The types of devices considered include but are not limited to mobile telephones, cordless microphones, auxiliary broadcast devices and radio transmitters in personal computers.

This International Standard gives guidelines for a reproducible and conservative measurement methodology for determining the compliance of wireless devices with the SAR limits.

Because studies suggest that exclusion of features to represent a hand in human models constitutes a conservative case scenario for SAR in the trunk and the head, a representation of a hand is not included if the device is intended to be used next to the head or supported on or near the torso [73], [80]. This standard does not apply for exposures from transmitting or non-transmitting implanted medical devices. This standard does not apply for exposure from devices at distances greater than 200 mm away from the human body.

IEC 62209-2 makes cross-reference to IEC 62209-1:2005 where complete clauses or subclauses apply, along with any changes specified.

2 Normative references

The following referenced documents are indispensable for the application 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 62209-1:2005, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the IEC 62209-1:2005, as well the following apply.

3.1

accessory

optional component that can be used in conjunction with a transmitting device

EXAMPLES

Accessories for mobile phones, wireless transmitting devices, wireless receiving devices or wireless transceiving devices, or two-way radios include the following:

- a) accessories for holding, affixing, or otherwise carrying, wearing or attaching the device, as well as providing spacing from the body (e.g. a belt-clip, wrist-strap or any other body strap, or lanyard for wearing the device as necklace);
- b) electronic accessories for performing tasks or which provide features (e.g., GPS modules, outboard printers, MP3 players, cameras or viewing devices);
- c) electronic accessories providing audio or video input or output (e.g., headsets, microphones, cameras);
- d) accessories providing enhanced RF capability to the device (e.g., replacement or auxiliary antennas);
- e) batteries and related d.c. power components;
- f) combinations of accessories, where two or more of the above are combined within one component (e.g., belt clip with built-in Bluetooth and "pigtail" audio cable to device).

3.2

body-mounted device²

body-worn device

portable device containing a wireless transmitter or transceiver which is positioned in close proximity to a person's torso or limbs (excluding the head) by means of a carry accessory during its intended use or operation of its radio functions

3.3

body-supported device

a device whose intended use includes transmitting with any portion of the device being held directly against a user's body

NOTE This differs from a body-mounted device in that it is not attached to a user's body by means of a carry accessory

3.4

cable

wire that is necessary for the functionality in the intended operational configuration

3.5

conservative exposure

estimate of the peak spatial-average SAR, including uncertainties as defined in this standard, representative of and slightly higher than expected to occur in the bodies of a significant majority of persons during intended use of hand-held devices

NOTE Conservative estimate does not mean the absolute maximum SAR value that could possibly occur under every conceivable combination of body size, body shape, wireless device orientation, and spacing relative to the body. In order to ensure that the results are not overly restrictive, and thereby unnecessarily inhibit the

² Both terms are used. Colloquially the term "body-worn" is preferred over "body-mounted".