IEC/IEEE 62704-1

Edition 1.0 2017-10

INTERNATIONAL STANDARD

**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**

IEC/IEEE 62704-1:2017-10(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue
New York, NY 10016-5997
United States of America
stds.ipr@ieee.org
www.ieee.org

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 the IEEE
IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities.

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

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
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 It also gives information on projects, replaced and withdrawn publications.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 also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions 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
65 000 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.

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: csc@iec.ch.

IEC/IEEE 62704-1

Edition 1.0 2017-10

INTERNATIONAL STANDARD

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 17.220.20; 33.060.20

ISBN 978-2-8322-4769-3

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

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

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.

   IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards. Use of IEEE Standards documents is wholly voluntary. *IEEE documents are made available for use subject to important notices and legal disclaimers (see* http://standards.ieee.org/IPR/disclaimers.html *for more information).*

   IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations. This Dual Logo International Standard was jointly developed by the IEC and IEEE under the terms of that agreement.

2) The formal decisions 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. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.

3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE 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 (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are 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 IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, 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/IEEE Publication or any other IEC or IEEE 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 implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

International Standard IEEE/IEC 62704-1 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure, in cooperation with the International Committee on Electromagnetic Safety of the IEEE Standards Association[1], under the IEC/IEEE Dual Logo Agreement.

This publication is published as an IEC/IEEE Dual Logo standard.

This standard contains attached files in the form of CAD models and reference results described in Annexes B and D. These files are available at: http://www.iec.ch/dyn/www/f?p=103:227:0::::FSP_ORG_ID,FSP_LANG_ID:1303,25.

The text of this standard is based on the following IEC documents:

FDIS	Report on voting
106/401A/FDIS	106/413/RVD

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

A list of all parts in the IEC/IEEE 62704 series, published under the general title *Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz*, can be found on the IEC website.

The IEC technical committee and IEEE technical committee have decided that the contents of this publication 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.

1 A list of IEEE participants can be found at the following URL: http://standards.ieee.org/downloads/62704/62704-1-2017/62704-1-2017_wg-participants.pdf.

INTRODUCTION

Computational techniques have reached a level of maturity which allows their use in specific absorption rate (SAR) assessment of wireless communication devices. Some wireless communication devices are used in situations where experimental SAR assessment is extremely complex or not possible at all. National regulatory bodies (e.g. US Federal Communications Commission) encourage the development of consensus standards and encouraged the establishment of the ICES Technical Committee 34 Subcommittee 2. The benefits to the users and the regulators include standardized and accepted protocols, anatomically correct body models, validation techniques, benchmark data, reporting format and means for estimating the computational uncertainty in order to produce valid, accurate, repeatable, and reproducible data.

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

1 Scope

This part of IEC/IEEE 62704 defines the methodology for the application of the finite-difference time domain (FDTD) technique when used for determining the peak spatial-average specific absorption rate (SAR) in the human body exposed to wireless communication devices with known uncertainty. It defines methods to validate the numerical model of the device under test (DUT) and to assess its uncertainty when used in SAR simulations. Moreover, it defines procedures to determine the peak spatial-average SAR in a cubical volume and to validate the correct implementation of the FDTD simulation software. The applicable frequency range is 30 MHz to 6 GHz.

NOTE Cubical averaging volumes are applied in all current experimental standards for the assessment of the peak spatial-average SAR (psSAR) and recommended by [1], [2] and [3]. Other averaging volumes have been proposed, for example, in [1], and may be included in future revisions of this document.

This document does not recommend specific SAR limits since these are found elsewhere, for example, in the guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [1] or in IEEE Std C95.1 [3].

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.

NOTE The experimental standards that define the SAM phantom and the testing positions are IEEE Std 1528 and IEC 62209-1.

IEEE Std 1528, *IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques*

IEC 62209-1, *Human Exposure to Radio Frequency Fields from Hand Held and Body Mounted Wireless Communication Devices – Human Models, Instrumentation and Procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for devices used next to the ear (frequency range of 300 MHz to 6 GHz)*

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)* (available at: http://www.electropedia.org)

IEEE Standards Dictionary Online (subscription available at: http://dictionary.ieee.org)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the IEEE Standards Dictionary Online, IEC 60050 (all parts) and the following apply.

ISO, IEC and IEEE 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
- IEEE Dictionary Online: available at http://dictionary.ieee.org

3.1
excitation source
source with an associated signal which feeds electric or magnetic energy to one or more edges of the mesh

Note 1 to entry: The amplitude of the signal is proportional to an arbitrary function of time.

3.1.1
added source
source whose amplitude is added to the present value of an E-field component on a mesh edge at each time step of the FDTD algorithm

3.1.2
hard source
source whose amplitude replaces the present value of an E-field component on a mesh edge at each time step of the FDTD algorithm

3.1.3
voltage source
source whose amplitude updates the present value of an E-field component on a mesh edge at each time step of the FDTD algorithm considering the current through the mesh edge represented by its surrounding H-fields and an internal resistance

3.2
antenna
part of a transmitting or receiving system that is designed to radiate or to receive electromagnetic waves

3.3
feed-point
<antenna> part of the radiating structure where the radio-frequency currents start to support the electromagnetic fields that carry energy away from the antenna

Note 1 to entry: Often the feed-point of the antenna is not accessible because of mechanical support requirements; in this case a connection point is available to inject radio-frequency energy into the antenna. Normally, the connection point is a simple connector or a waveguide flange. If not collocated, the connection and the feed-point of an antenna are interconnected by one or more sections of transmission line. By measuring the antenna impedance at the connection point, if the electrical characteristics of the transmission lines between the connection and the feed-point are known, it is possible to calculate the driving point or feed-point impedance of an antenna.

3.4
antenna feed-point impedance
terminal or driving-point impedance
ratio of complex voltage to complex current at the terminals of a transmitting antenna, or the ratio of the open-circuit voltage to the short-circuit current at the terminals of a receiving antenna

3.5
attenuation
decrease in magnitude of a field quantity in the transmission from one point to another

Note 1 to entry: Attenuation is expressed as a ratio.

3.6
average power
$\overline{P}$
time-averaged rate of energy transfer

$$\overline{P} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P(t)\,\mathrm{d}t \qquad (1)$$

where $P(t)$ is the instantaneous power

Note 1 to entry: The time duration could be source related (for example, the source repetition period, duty cycle) or use related.

3.7
background material
material or tissue which is not considered for the averaging volume

Note 1 to entry: Most typically, a background material will be any lossless material, such as the free-space or air surrounding the anatomical model. It also includes air enclosures or other lumina inside the body and tissues that have been excluded from averaging, for example, by user selection.

3.8
benchmark simulation
simulation test specifically defined to validate simulation results based on comparison with a reference

3.9
body
geometrical distribution of the dielectric properties and the mass densities of all live body tissues including body fluids

Note 1 to entry: The contents of body lumina or foreign matter, such as medical implants or jewellery, are not considered as part of the body.

3.10
conductivity
σ
ratio of the magnitude of the conduction-current density in a medium to the electric field strength

Note 1 to entry: Conductivity is expressed in units of siemens per metre (S/m).

3.11
conservative estimate
estimate of the peak spatial-average SAR and whole-body average SAR as defined in this document that is representative of what is expected to occur in the body of a significant majority of population during normal operating conditions of wireless communication devices

Note 1 to entry: Conservative estimate does not mean the absolute maximum SAR value that could possibly occur under every conceivable combination in the human body size, shape separation from the antenna and/or vehicle.

3.12
coverage factor
k
factor that is used to obtain the expanded uncertainty from the combined uncertainty with a known probability (P) of containing the true value of the measurand

Note 1 to entry: Specifically, k × (combined uncertainty) = (expanded uncertainty). When $k = 1$, $P \approx 0,68$; $k = 2$, $P \approx 0,95$; $k = 3$, $P \sim 0,999$.

3.13
electric field
E-field
vector field of electric field strength

3.14
electric field strength
E
at a given point, the magnitude (modulus) of the vector limit of the quotient of the force that a small stationary charge at that point will experience, by virtue of its charge, to the charge as the charge approaches zero in a macroscopic sense

Note 1 to entry: This may be measured either in newtons per coulomb or in volts per metre. This term is sometimes called the E-field intensity, but such use of the word intensity is deprecated, since intensity connotes power in optics and radiation.

3.14.1
electric field strength
<signal-transmission system> magnitude of the potential gradient in an E-field expressed in units of potential difference per unit length in the direction of the gradient

3.14.2
electric field strength
<radio wave propagation> magnitude of the E-field vector

Note 1 to entry: The electric field strength is expressed in volts per metre (V/m)

3.15
electrical length
length of a transmission medium or a transmission line, such as an antenna or a waveguide in any medium including air

Note 1 to entry: Electrical length is expressed in wavelengths, radians, or degrees. When expressed in angular units, it is a distance in wavelengths multiplied by 2π to yield radians, or by 360 to yield degrees.

3.16
electromagnetic field
EM field
electromagnetic phenomenon expressed in scalar or vector functions of space and time, for example, a time-varying field associated with electric and magnetic forces and described by Maxwell's equations

3.17
far-field region
region of the field of an antenna where the angular field distribution is essentially, independent of the distance from the antenna

Note 1 to entry: In this region (also called the free-space region), the field has predominantly plane wave characteristics, i.e. the electric field strength and magnetic field strength distributions are locally uniform in planes transverse to the direction of propagation.

Note 2 to entry: For larger antennas especially, the far-field region is also referred to as the Fraunhofer region.

3.18
incident wave
wave, travelling through a medium, in a specific direction, which impinges on a discontinuity or a medium of different propagation characteristics

3.19
magnetic field
H-field
vector field of magnetic field strength

3.20
magnetic field strength
H
magnitude of the magnetic field vector

Note 1 to entry: The magnetic field strength is expressed in amperes per metre (A/m).

Note 2 to entry: For time harmonic fields in a medium with linear and isotropic magnetic properties, H is equal to the ratio of the magnetic flux density B to the magnetic permeability of the medium μ, i.e., $H = B/\mu$.

3.21
mesh
discrete representation of the simulation model as a set of voxels in a regular three-dimensional Cartesian arrangement

Note 1 to entry: In the scientific literature, the mesh is often referred to as "grid".

3.22
near-field region
region in the field of an antenna, located near the antenna, in which the electric and magnetic fields do not have substantial plane-wave characteristics, but vary considerably from point to point

Note 1 to entry: The term near-field region is often vaguely defined and has different meanings for large and small antennas. The near-field region is further subdivided into the reactive near-field region, which is closest to the antenna and contains most or nearly all of the stored energy associated with the field of the antenna, and the radiating near-field region. If the antenna has a maximum overall dimension that is not large compared to the wavelength, the radiating near-field region may not exist. For antennas large in terms of wavelength, the radiating near-field region is sometimes referred to as the Fresnel region.

Note 2 to entry: For most antennas, the outer boundary of the reactive near-field region is commonly taken to exist at a distance of $\lambda/2\pi$ from the antenna surface.

3.23
perfect electric conductor
PEC
material with infinite electrical conductivity which does not dissipate any energy

3.24
relative permittivity
ε_r
ratio of the complex permittivity to the permittivity of free space

Note 1 to entry: The complex relative permittivity, $\varepsilon_r = \varepsilon/\varepsilon_o$, of an isotropic, linear, lossy dielectric medium is given by $\varepsilon_r = \varepsilon_r' - j\varepsilon_r'' = \varepsilon_r' - j\dfrac{\sigma}{\omega\varepsilon_0} = \varepsilon_r'\left(1 - j\dfrac{\varepsilon_r''}{\varepsilon_r'}\right) = \varepsilon_r'(1 - j\tan\delta)$

where

ε_0	is the free space permittivity (8,854 × 10^{-12} F/m);
ε_r'	is the relative permittivity or dielectric constant;
σ	is the conductivity in siemens per metre (S/m);
$\tan\delta$	is the loss tangent.

Note 2 to entry: For purposes of this document, the convention $e^{j\omega t}$ is used to describe time-varying electric fields.

Note 3 to entry: The permittivity of biological tissues is frequency dependent and may be a complex tensor quantity.

3.25
penetration depth
for a given frequency, the depth at which the electric field (E-field) strength of an incident plane wave, penetrating into a lossy medium, is reduced to 1/e of its value just beneath the surface of the lossy medium

Note 1 to entry: For a plane-wave incident normally on a planar half-space, the penetration depth δ is given in Formula (2):

$$\delta = \frac{1}{\omega}\left[\frac{\mu_0 \varepsilon_r' \varepsilon_0}{2}\left(\sqrt{1+\left(\frac{\sigma}{\omega \varepsilon_r' \varepsilon_0}\right)^2}-1\right)\right]^{-1/2} \tag{2}$$

3.26
permeability
μ
ratio of the magnetic flux density to the magnetic field strength at a point

Note 1 to entry: The permeability is expressed in units of henry per metre (H/m).

3.27
reactive field
electric and magnetic fields surrounding an antenna or other electromagnetic devices that result in storage rather than propagation of electromagnetic energy

3.28
root-mean-square value
rms
<of a periodic function> positive square root of the mean value of the square of the function taken over a given period

Note 1 to entry: For a periodic function y of t, the positive square root of y is

$$Y_{\text{rms}} = \left[\frac{1}{T}\int y(t)^2\,dt\right]^{1/2} \tag{3}$$

where

Y_{rms} is the rms value of y;
t is any value of time;
T is the period.

3.29
root-sum-square value
rss
positive square root of the sum of the squares of the elements of a set of numbers

3.30
scattering
process that causes waves incident on discontinuities or boundaries of media to be changed in direction, phase, or polarization