IEC/IEEE 62704-3

Edition 1.0 2017-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz – Part 3: Specific requirements for using the finite difference time domain (FDTD) method for SAR calculations of mobile phones

Détermination du débit d'absorption spécifique (DAS) maximal moyenné dans le corps humain, produit par les dispositifs de communication sans fil, 30 MHz à 6 GHz – Partie 3: Exigences spécifiques pour l'utilisation de la méthode des différences finies dans le domaine temporel (FDTD) pour les calculs de DAS des téléphones mobiles

IEC/IEEE 62704-3:2017-10(en-fr)

Documents
Document Sharing Hub

Full document details: IEC/IEEE 62704-3-2017

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2017 IEC, Geneva, Switzerland
Copyright © 2017 IEEE

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 being secured. Requests for permission to reproduce should be addressed to either IEC at the address below or IEC's member National Committee in the country of the requester or from IEEE.

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.

AVA Documents
Document Sharing Hub

Full document details: IEC/IEEE 62704-3-2017

IEC/IEEE 62704-3

Edition 1.0 2017-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz – Part 3: Specific requirements for using the finite difference time domain (FDTD) method for SAR calculations of mobile phones

Détermination du débit d'absorption spécifique (DAS) maximal moyenné dans le corps humain, produit par les dispositifs de communication sans fil, 30 MHz à 6 GHz – Partie 3: Exigences spécifiques pour l'utilisation de la méthode des différences finies dans le domaine temporel (FDTD) pour les calculs de DAS des téléphones mobiles

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 17.220.20

ISBN 978-2-8322-4772-3

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.

AVA Documents
Document Sharing Hub

® Registered trademark of the International Electrotechnical Commission
Marque déposée de la Commission Electrotechnique Internationale

Full document details: IEC/IEEE 62704-3-2017

CONTENTS

FOREWORD 5
INTRODUCTION 7
1 Scope 8
2 Normative references 8
3 Terms and definitions 9
4 Abbreviated terms 9
5 Simulation procedure 10
5.1 General 10
5.2 General considerations 10
5.3 General mesh settings 10
5.4 Simulation parameters 10
5.5 DUT model 10
5.5.1 General 10
5.5.2 Antenna 12
5.5.3 RF source 12
5.5.4 PCB 13
5.5.5 Screen 13
5.5.6 Battery and other larger metallic components 14
5.5.7 Casing 14
5.6 SAR calculation using phantom models 14
5.6.1 General 14
5.6.2 Head phantom model 15
5.6.3 Body phantom model 18
5.6.4 Phantom mesh generation 18
5.7 Recording of results 18
5.8 Peak spatial-average SAR calculation 19
6 Benchmark models 19
6.1 General 19
6.2 Generic metallic box phone for 835 MHz and 1 900 MHz 19
6.3 GSM/UMTS mobile phone 21
6.4 Generic multi-band patch antenna mobile phone 22
6.5 Neo Free Runner mobile phone 24
7 Computational uncertainty 25
7.1 General considerations 25
7.2 Uncertainty of the test setup with respect to simulation parameters 26
7.3 Uncertainty of the developed numerical model of the DUT 26
7.4 Validation of the developed numerical model of the DUT 26
7.5 Uncertainty budget 26
8 Reporting simulation results 27
8.1 General considerations 27
8.2 DUT 27
8.3 Simulated configurations 27
8.4 Numerical simulation tool 28
8.5 Results of the benchmark models 28
8.6 Uncertainties 28
8.7 SAR results 28

AVA Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

Annex A (informative) Additional results for the generic mobile phone with integrated multiband antenna 29

Annex B (informative) Additional results for the Neo Free Runner mobile phone 31

Bibliography 35

Figure 1 – An example of a multi-band antenna consisting of two metallic elements for the GSM and UMTS frequency bands 12

Figure 2 – An example of a source gap position that is inserted in replacement of a real-life feeding spring pin 13

Figure 3 – An example of a microstrip feed line 13

Figure 4 – Orientation of the mobile phone model prior to positioning against the head or the body phantom 15

Figure 5 – Orientation of the SAM phantom prior to positioning against the DUT shown in Figure 4 16

Figure 6 – Suggested steps for the cheek position of the DUT against the SAM phantom 16

Figure 7 – Tilt position of the DUT against the SAM phantom 17

Figure 8 – Example of the full model space that includes the DUT and the SAM phantom for the numerical simulations for the right cheek position 17

Figure 9 – Example of the model space for the DUT/body phantom calculation setup 18

Figure 10 – The SAM head phantom and the generic metallic box phone 19

Figure 11 – Physical dimensions of the generic metallic box phone 20

Figure 12 – Generic GSM/UMTS mobile phone 21

Figure 13 – Generic mobile phone with integrated multiband patch antenna 23

Figure 14 – CAD model of the Neo Free Runner mobile phone 24

Figure A.1 – Real part of the input impedance of the antenna obtained with three different commercially available software products 29

Figure A.2 – Imaginary part of the input impedance of the antenna obtained with three different commercially available software products 30

Figure B.1 – Basic version of the Neo Free Runner CAD model 31

Figure B.2 – Intermediate version of the Neo Free Runner CAD model 31

Figure B.3 – Full version of the Neo Free Runner CAD model 32

Figure B.4 – Interlaboratory comparison results of the free space reflection coefficient for the basic CAD model 32

Figure B.5 – Interlaboratory comparison results of the free space reflection coefficient for the intermediate CAD model 33

Figure B.6 – Interlaboratory comparison results of the free space reflection coefficient for the full CAD model 33

Table 1 – Dielectric parameters of the materials of the generic phone 20

Table 2 – Peak spatial-average SAR for 1 g and 10 g of the benchmark 21

Table 3 – Dielectric properties of the materials of the generic GSM/UMTS mobile phone 22

Table 4 – Peak 1 g and 10 g SAR results of the GSM/UMTS mobile phone 22

Table 5 – Limits of the output parameters for the generic multi-band mobile phone 23

Table 6 – Peak 1 g and 10 g SAR results of the GSM/UMTS mobile phone 24

Table 7 – Dielectric properties of the materials of the Neo Free Runner mobile phone 25

AVA Documents
Document Sharing Hub

Full document details: IEC/IEEE 62704-3-2017

Table 8 – Peak 1 g and 10 g SAR results of the Neo Free Runner mobile phone 25
Table 9 – Overall uncertainty budget..... 27
Table B.1 – Frequency limits of the −6 dB reflection coefficient for the three different versions of the Neo Free Runner mobile phone..... 34

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

© IEC/IEEE 2017

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 3: Specific requirements for using the finite difference time domain (FDTD) method for SAR calculations of mobile phones

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.

Documents
Document Sharing Hub

Full document details: IEC/IEEE 62704-3-2017

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 IEC/IEEE 62704-3 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 International Committee on Electromagnetic Safety of the IEEE Standards Association[1], under the IEC/IEEE Dual Logo Agreement between IEC and IEEE.

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

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

FDIS	Report on voting
106/404/FDIS	106/414/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.

This standard contains attached files in the form of CAD models described in Clause 6. These files are available at:
http://www.iec.ch/dyn/www/f?p=103:227:0::::FSP_ORG_ID,FSP_LANG_ID:1303,25

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 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.

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.

[1] A list of IEEE participants can be found at the following URL:
http://standards.ieee.org/downloads/62704/62704-3-2017/62704-3-2017_wg-participants.pdf.

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

© IEC/IEEE 2017

INTRODUCTION

The increasing complexity of assessing product compliance with exposure standards according to specific absorption rate (SAR) limits calls for new compliance or pre-compliance techniques. Currently standardized experimental SAR compliance assessments of wireless communication devices are time-consuming and costly. Computational techniques have reached a level of maturity which allows their use in the pre-compliance assessments of wireless communication devices such as mobile phones. For example, pre-compliance testing is important for mobile phone manufacturers in their product development phase where this document may be applied. The benefits to the users and manufacturers include standardized and accepted protocols, validation techniques, benchmark results, reporting format and means for estimating the overall uncertainty in order to produce valid, repeatable, and reproducible data.

The results obtained by following the protocols specified in this document represent a conservative estimate of the peak spatial-average SAR induced in the standard human body models due to mobile phones. The protocols set forth herein produce results subject to modelling, simulations and other uncertainties that are defined in this document.

It is not the intent of this document to provide a result representative of the absolute maximum SAR value possible under every conceivable combination of human body and mobile phone usage. The following items are described in detail: simulation concepts, simulation techniques, finite difference time domain (FDTD) numerical method, benchmark results, standardized numerical models of the human body. Procedures for validating the numerical tools used for SAR simulations and assessing the SAR simulation uncertainties are provided. This document is intended primarily for use by engineers and other specialists who are familiar with electromagnetic (EM) theory, numerical methods, and, in particular, FDTD techniques. This document does not recommend specific SAR limit values since these are found in other documents.

Documents
Document Sharing Hub

Full document details: IEC/IEEE 62704-3-2017

DETERMINING THE PEAK SPATIAL-AVERAGE SPECIFIC ABSORPTION RATE (SAR) IN THE HUMAN BODY FROM WIRELESS COMMUNICATIONS DEVICES, 30 MHz TO 6 GHz –

Part 3: Specific requirements for using the finite difference time domain (FDTD) method for SAR calculations of mobile phones

1 Scope

This part of IEC/IEEE 62704 defines the concepts, techniques, benchmark phone models, validation procedures, uncertainties and limitations of the finite difference time domain (FDTD) technique when used for determining the peak spatial-average specific absorption rate (SAR) in standardized head and body phantoms exposed to the electromagnetic fields generated by wireless communication devices, in particular pre-compliance assessment of mobile phones, in the frequency range from 30 MHz to 6 GHz. It recommends and provides guidance on the numerical modelling of mobile phones and benchmark results to verify the general approach for the numerical simulations of such devices. It defines acceptable modelling requirements, guidance on meshing and test positions of the mobile phone and the phantom models. This document does not recommend specific SAR limits since these are found in other documents, e.g. IEEE C95.1-2005[1][2] and ICNIRP[2].

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

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

IEC 62209-2, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)*

IEC/IEEE 62704-1:2017, *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*

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*

IEEE Standards Dictionary Online[3]

---

2 Numbers in square brackets refer to the Bibliography.

3 Subscription available at: http://dictionary.ieee.org.

Documents
Document Sharing Hub

Full document details: IEC/IEEE 62704-3-2017

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC/IEEE 62704-1, 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
cell
discretization step along a given axis of the Cartesian coordinates

3.2
component
part present in the mobile phone

EXAMPLE Antenna, battery, etc.

3.3
handset
hand-held device intended to be operated close to the body, consisting of an acoustic output or earphone and a microphone, and containing a radio transmitter and a receiver

3.4
object
solid identified by computer-aided design (CAD) criteria

4 Abbreviated terms

ACIS	3-D file format derived from its authors' names (Alan Charles, Ian's System)
CAD	computer-aided design; commonly used file formats are IGES, DXF and SAT
DCS	digital communication system
DUT	device under test
DXF	digital exchange file
ERP	ear reference point
FDTD	finite difference time domain
GSM	global system for mobile communication
IGES	international graphics exchange standard
LCD	liquid crystal display
PCB	printed circuit board
PEC	perfect electric conductor
PML	perfectly matched layers
RF	radio frequency
SAM	specific anthropomorphic mannequin
SAR	specific absorption rate
SAT	standard ACIS text
UMTS	universal mobile telecommunication system

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

5 Simulation procedure

5.1 General

Clause 5 presents the steps that shall be followed to compute SAR from a mobile phone placed against a head or a body phantom. The procedure requires voxel models derived from the CAD data files of the DUT and of either the SAM head phantom or the body phantom.

5.2 General considerations

The practical considerations for the application of the FDTD method are provided in Annex C of IEC/IEEE 62704-1:2017. Since the standard FDTD method relies on the Cartesian Yee cell, stair casing of curved surfaces is a problem that needs special consideration, particularly for the case of the DUT and the SAM head phantom. To limit stair casing, the positioning of the DUT against the SAM phantom shall be achieved by performing transformations such as translations and rotations on the SAM phantom only. The body phantom should preferably be reconstructed using the built-in drawing features of the numerical simulation tool when available. It can be easily aligned with both the handset and the FDTD axes.

5.3 General mesh settings

For the FDTD method, the intrinsic problem of choosing a sufficiently small cell or grid size yet limit the memory requirements can be challenging. The wavelength in the material with the highest relative permittivity generally dictates the required minimum grid step. To mesh the free-space surrounding the phone and the phantom, a cell size corresponding to about $\lambda/30$ to $\lambda/10$ may be sufficient, where λ is the smallest wavelength corresponding to the wave propagation in the material with the highest relative permittivity. Since the relative permittivities of the materials present in a mobile phone are usually low – typically in the range 2 to 10 – the tissue equivalent liquid is expected to have the highest relative permittivity. Since this is generally insufficient for modelling the smaller components in a mobile phone, it may be necessary to further decrease the cell size to fully account for fine details such as slots or gaps or small components. The cell size may then be much smaller than the minimum cell size imposed by the highest relative permittivity of the materials present in the computational domain.

5.4 Simulation parameters

Practical considerations for the application of the FDTD such as voxel size, stability, absorbing boundaries are described in IEC/IEEE 62704-1:2017, Annex C.

5.5 DUT model

5.5.1 General

Prior to performing the SAR calculation using the head or the body phantom, the numerical simulation shall first be undertaken considering the DUT alone, i.e. free space configuration. The validity of the numerical model of the DUT shall be verified as described in Clause 7.

A DUT model normally contains many different solids, typically more than one hundred, making this model a very complex structure to handle. Given the complexity of recent generation wireless handsets used by consumers and the extensive time required for device modelling, the only practical approach for producing the FDTD mesh is by importing the mechanical CAD file of the DUT, and to automatically generate the FDTD model for the handset. The file with the model shall be exported from the mechanical engineering CAD tool in a format that can be easily imported into the FDTD simulation tool (usually SAT or IGES file format). Prior to the export of the CAD model, all parts shall be assembled and correctly aligned with respect to each other.

When the mechanical CAD file is not available, it may be acceptable to reconstruct the numerical model based on information such as the geometrical dimensions and positions of

AVA Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

the different components of the DUT [3]. In this document, the numerical model of the DUT is considered as a CAD model whether it is obtained following a numerical reconstruction or available as an export of a mechanical CAD file. The validity of the numerical model shall be demonstrated according to 7.4.

It is most important that the components present in the DUT model are assigned the correct material dielectric parameters. After import of the CAD file into the FDTD simulation tool, the correct material shall be assigned to each object to be meshed. The components and dielectric properties should be verified by a CAD engineer familiar with the physical and mechanical construction of the mobile phone.

Prior to meshing, the cell size requirements shall be established. This can be done in several ways, including automatic mesh generation, by a CAD object or group of objects, or manually. In order to provide an accurate mesh that will require minimal computer memory and run times, it is common practice to use a graded mesh, also called non-uniform mesh [4]. A graded mesh allows the FDTD mesh cell sizes to vary with position in one dimension. This approach allows smaller cells to be used where needed in order to accurately describe small but important CAD objects. A typical application for smaller mesh cells is in the antenna region which usually consists of slots.

While the above basic approach is a good start, there are exceptions that shall be considered. For example, the CAD objects may not have continuous surfaces. This can happen when the surface of the object is formed by the combination of separate facets and these facets may not join precisely at their intersections, leaving unintended gaps. This problem can be mitigated by "healing" the object manually to close the gaps (the healing feature is usually available in most commercially available FDTD simulation tools to fix connection problems among CAD objects to be fixed). However, for CAD objects with large gaps it may be impossible to develop an accurate FDTD mesh without manual intervention.

It is recommended that the larger metallic components or parts should be made into separate objects for which specific grid settings can be applied. In particular, the antenna model shall be a separate object so that this structure can be meshed as accurately as possible. The metallic parts of the model shall be aligned and connected so that artificial floating of electrically connected objects does not occur. Usually the printed circuit board (PCB) is not well represented in the CAD model. It is typically modelled as a few thin metallic layers interleaved with dielectric material [5]. However, it is acceptable to model the PCB as one thick solid metallic object. It is important to note that if the PCB is not correctly modelled, it will be seen as an invalid CAD model according to 7.4.

In order to optimize the computational resources, the components in the DUT model, for instance components located inside shielded cans, that are not expected to have noticeable impact to SAR distributions may be removed [6]. Consequently, such metallic components shall be given meshing priority over a component of lesser impact on SAR distribution. Components with the same material dielectric property that are in physical contact shall be united to form one solid. As a minimum requirement, essential parts such as antenna, chassis, PCB, display or screen, battery, other relatively large metallic components and the dielectric material supporting the antenna shall be modelled accurately. The meshing order of the objects or groups of objects shall be specified so that objects that touch, or perhaps even overlap, are correctly represented in the FDTD model.

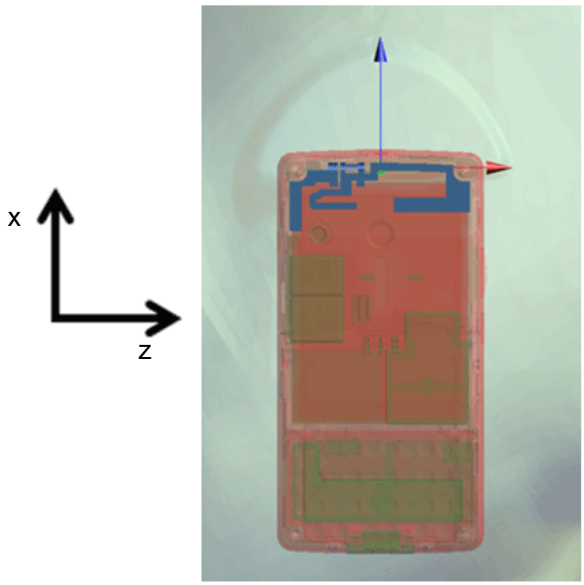
Once the meshing has been completed, the resulting FDTD model of the handset shall be viewed and verified for accuracy. Critical areas such as the antenna region and other conductive components shall be carefully examined since the most important objects of the DUT model are the metallic components because they have the biggest impact on the SAR distribution.

As a guideline for the mesh generation, the components of the mobile phone that are expected to have the relatively highest impact on the SAR distribution are provided in 5.5.2 to 5.5.7.

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

5.5.2 Antenna

The antenna of the DUT is the most important component to be modelled and the grid step shall be chosen so as to resolve all details such as slots and gaps contained in it. Figure 1 shows the typical appearance of a top-mounted multi-band patch antenna for the GSM and UMTS frequency bands of operation.



IEC

NOTE The two separate metallic elements constituting the antenna are highlighted.

Figure 1 – An example of a multi-band antenna consisting of two metallic elements for the GSM and UMTS frequency bands

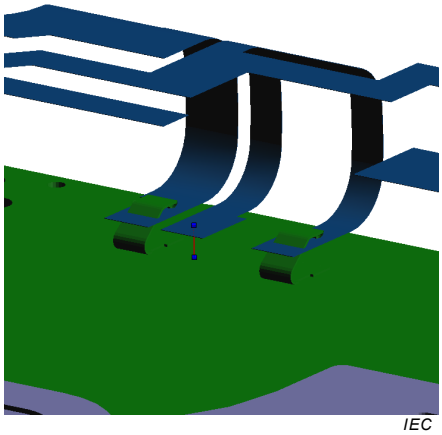
The shape of this particular antenna is rather complex and the cell size shall be chosen such that all details are resolved. In particular, if the antenna consists of separate metallic elements, most often used for operations at higher and/or multiple frequency bands, it is important to use a cell size that is less than half the separation between the elements. In the example shown in Figure 1, a cell size of 0,25 mm or less is necessary along the z-axis because the gap between the left and the middle branches of the antenna is only 0,5 mm. In the actual meshing, at least three cells are required to model the separations; otherwise, the tangential field in the gap to the parasitic element will not be simulated correctly. Furthermore, to correctly model the slot on the right metallic element of this antenna, a similar cell size is required along the x-axis.

5.5.3 RF source

The antenna feed model shall be constructed according to the feed used in the actual device. Usually a coaxial feed is connected to a feeding pin, in which case a classic FDTD feed gap source model shall be used. The actual feeding pin shall be replaced with the FDTD source excitation gap, as shown in Figure 2, and there shall be a gap of at least one cell corresponding to the actual gap dimension in the DUT model.

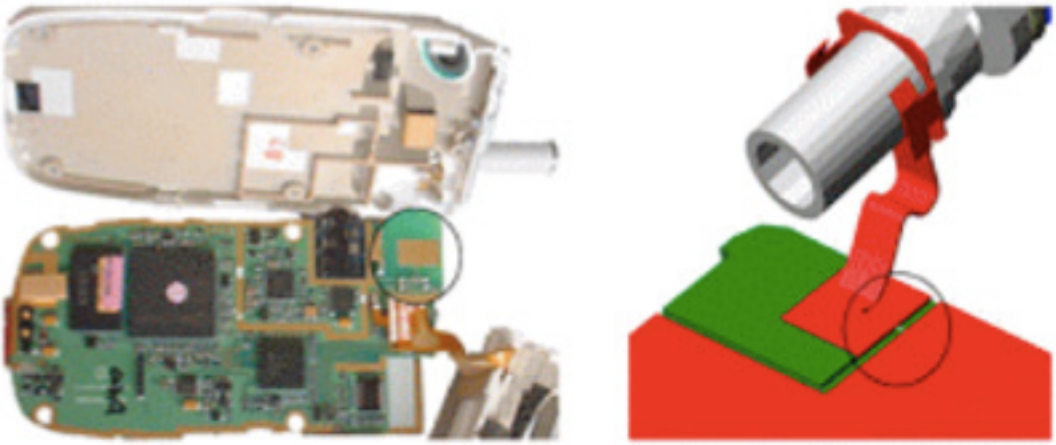
When the antenna is fed by a different means (e.g. a microstrip line as shown in Figure 3), the excitation source shall be modelled accordingly so that it is representative of the feed.

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017



IEC

Figure 2 – An example of a source gap position that is inserted in replacement of a real-life feeding spring pin



IEC

Figure 3 – An example of a microstrip feed line

5.5.4 PCB

The PCB is a sandwich structure that typically consists of several metallic sheets interleaved with dielectric layers. Modelling the PCB as a sandwiched structure has been found to be important in order to compute the losses in the PCB properly [5], but it requires a very fine cell size, usually 0,1 mm or less. Furthermore, it is usually difficult to model the interconnections between the different layers of the PCB. To alleviate this difficulty, the PCB should rather be modelled as a metallic solid since doing so is very unlikely to lead to under-estimation of the SAR.

5.5.5 Screen

The screen normally consists of several glass layers that may be merged into one solid object for simplicity, in which case an effective relative permittivity, typically an average of the different dielectric properties of the different materials, shall be used. If the screen contains metallic parts or conductive components, those parts shall be modelled as separate objects embedded in the display. For example, a metallic frame is sometimes placed around the screen.

The screen display is attached to the PCB at several points and there is sometimes a narrow gap between them. The cell size shall be small enough to resolve this gap properly and it can be necessary to increase the resolution around the screen to resolve the air gaps around it. This is important since high surface currents will flow on the metallic parts. If the screen is not correctly and properly connected to the PCB, a completely different SAR distribution may result.

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

5.5.6 Battery and other larger metallic components

The outer surface of the battery pack is typically covered with a thin metallic foil, which enables the battery to be treated as a solid metallic object.

Other metallic components in the phone include camera housing, vibrator rotor, external antenna connector, etc. The cells representing these components shall be examined carefully before the FDTD simulation can be started. It is important to investigate the final grid for artificial gaps between larger metallic components. When objects in the CAD model are not perfectly aligned, sub-millimetre gaps can introduce artificial breaks or discontinuity and lead to computational errors. In such situations, it is necessary to manually adjust such objects or replace the components with a metallic structure of the same outer dimensions. Also, thin metallization on the DUT front-side or inside the DUT shall be checked for artificial gaps in the CAD and FDTD models. This is also important for flex films that run between components, for instance between a keypad flip, or the screen, and the PCB.

5.5.7 Casing

The casing or outer housing is usually made of plastic but it may also be made of metallic elements or contain conductive additives such as paint or dye. The cell size for the casing is more or less dictated by the cell size adopted for the components inside the housing and therefore little concern is required for this grid. It is, however, necessary to ensure that the separation distance between the DUT and the head or body phantom is accurately represented by grid steps chosen for modelling the casing of the DUT in this region. For example, if the mesh is too coarse the mobile phone will be positioned at the wrong distance from the tissue simulating material in the phantom.

5.6 SAR calculation using phantom models

5.6.1 General

The SAR calculations using the head phantom shall be performed for all the measurement configurations described in IEEE Std 1528 and the SAR calculations using the body phantom shall be performed for all the measurement configurations described in IEC 62209-2. After validation of the numerical model of the DUT according to 7.4, the mesh density should be optimized to enable relatively rapid SAR calculation within the required SAR simulation accuracy using the head or the body phantom as described herein.

However, the mesh density applied to validate the mobile phone model alone, i.e. in free space configuration, shall be enforced for the SAR calculation using the head or the body phantom. If the automatic mesh generation feature of the numerical simulation tool was used to generate the mesh which validated the DUT model, it shall be de-activated when the results of the numerical model of the DUT are considered acceptable for the SAR calculations as described in 7.4. Depending on the amount of available computer memory, the same mesh density should preferably be applied to the head or the body phantom.

For the head SAR calculation, the CAD file of SAM head phantom provided in SAT format with IEC/IEEE 62704-1 shall be used. Further details about the SAM phantom are provided in IEEE Std 1528 and IEC 62209-1. For the body SAR calculation, the flat phantom defined in IEC 62209-2 shall be reconstructed according to the frequency of operation and size of the DUT. The positioning of the DUT against the phantom shall follow the procedures described in IEEE Std 1528.

A positioning error of the DUT against the SAM head phantom may lead to an important contribution to the uncertainty budget [7]. In numerical modelling, a positioning uncertainty of 1 degree may lead to 5 % to 10 % deviation (depending on frequency) in the SAR value. When a device is incorrectly positioned, the SAR error should not be treated as contributions of modelling uncertainty. The procedure is briefly outlined in 5.6.2 and 5.6.3 for the positioning against the SAM head phantom as well as the flat phantom. It is assumed that the DUT is positioned in the FDTD computational domain space as shown in Figure 4 wherein a

AVA Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

local coordinate system (u,v,w) is preferably used. The DUT shall be aligned such that the earpiece is located at the origin (0,0,0) of the transformed FDTD computational domain. When the local coordinate system feature is unavailable, the global coordinate system (x,y,z) shall be used and the earpiece shall be located at the origin of this global coordinate system, i.e. replace u by x, v by y and w by z.

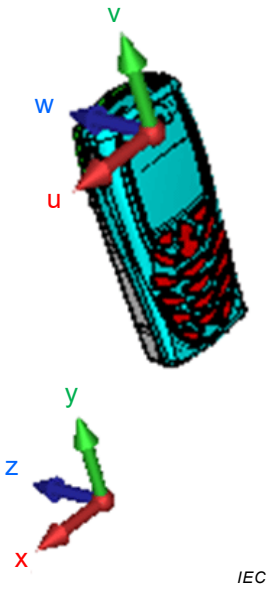


Figure 4 – Orientation of the mobile phone model prior to positioning against the head or the body phantom

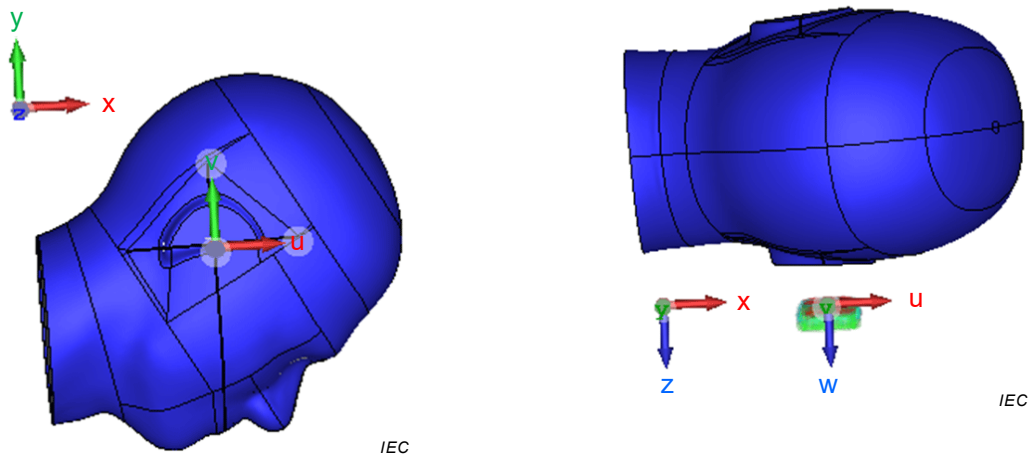
5.6.2 Head phantom model

The CAD file of the SAM head phantom contains two objects: one object represents the 2 mm thick phantom and the other object represents the tissue simulating material contained within the shell. The dielectric properties of the phantom shell and of the tissue simulating material shall be those given in IEEE Std 1528. The exact values for these properties shall be used, i.e. the allowed tolerance for the fabrication of the phantom shall not be taken into account.

Three reference points corresponding to the mouth, left and right ear reference points are defined in the CAD file for positioning handsets against the SAM head phantom, according to the same procedures required for the SAR measurements.

As a first step, and after importing the SAM CAD file into the previous simulation setup that contains only the DUT CAD model, the SAM head phantom shall be rotated so that the ear reference point is located at the grid origin (0, 0, 0). Secondly, the SAM head phantom shall be rotated so that the BM line, which connects between the ear and the mouth, is parallel to one of the principal coordinate planes prior to positioning the head model close to the device. Referring to the axes shown in Figure 5 a), if the head model is initially oriented vertically, i.e. upright along the v-axis or y-axis, a first rotation shall then be conducted around a line connecting both ear reference points until the edge of the truncated ear spacer is aligned with the horizontal axis of the DUT (u-axis or x-axis in Figure 5 a)). Additional rotations around the u-axis or x-axis and the v-axis or y-axis (as shown in Figure 5 b)) may then be necessary to align the handset front surface to the SAM head phantom according to the touch and tilt positioning requirements in IEEE Std 1528. These additional rotations shall be performed around the ear reference point.

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

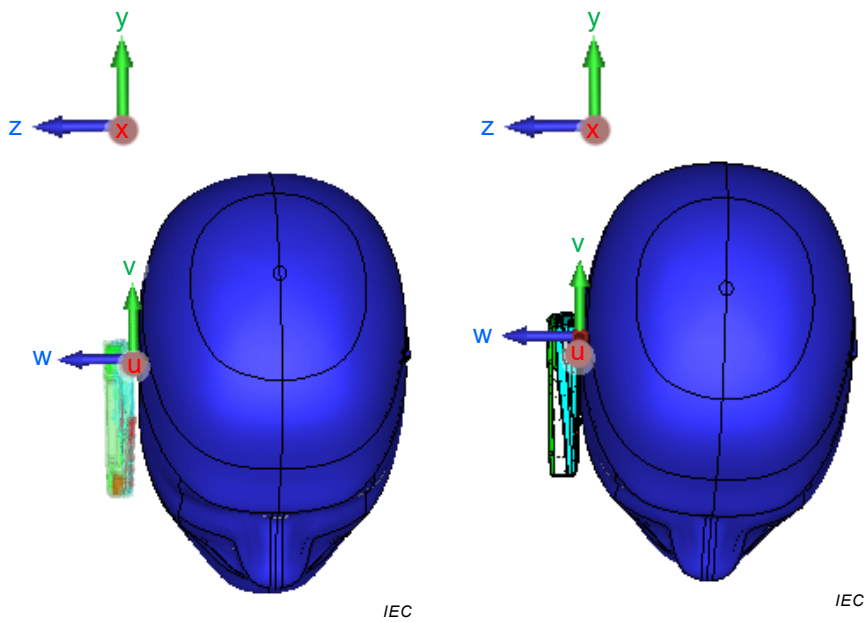


a) Rotation of SAM phantom until the edge of the truncated ear spacer is aligned with the u-axis or x-axis

b) Additional rotations around the u-axis or x-axis and the v-axis or y-axis to align the handset

Figure 5 – Orientation of the SAM phantom prior to positioning against the DUT shown in Figure 4

Following the above steps, the SAM head phantom is translated towards or away from the DUT (along the w-axis or z-axis) until it begins to touch the closest object of the DUT. Since both models have been positioned previously such that the ear reference point and the intersecting point of the vertical centre line and the horizontal line passing though the speaker output are located at the origin, they will resemble the initial state in the phone positioning procedure in the current SAR measurement standards in use as shown in Figure 6 a). Depending on the design of the DUT, the phone and phantom models might overlap such that, for example, part of the phone close to the speaker extends into the phantom model. In that case, the DUT shall be moved in the direction away from the SAM phantom until no part of the phone model overlaps the head model.



a) DUT is placed at the ear reference point of the SAM phantom

b) SAM phantom is rotated until the bottom part of the DUT begins to touch the cheek of the SAM phantom

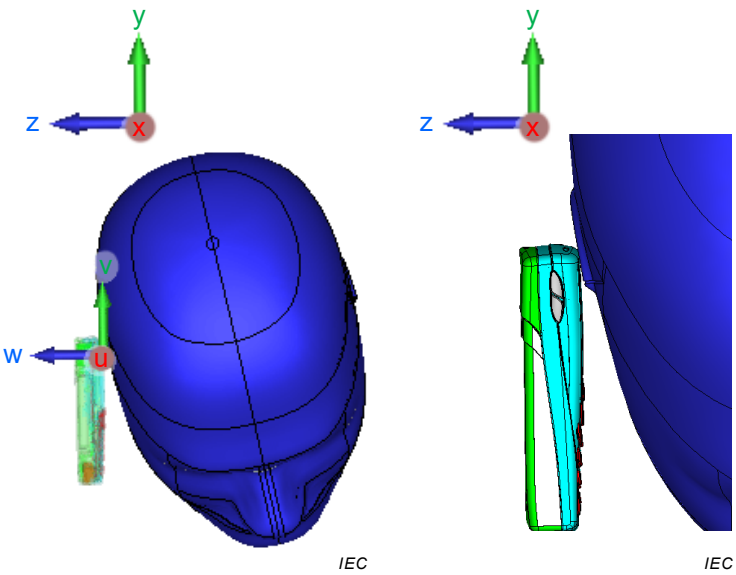
Figure 6 – Suggested steps for the cheek position of the DUT against the SAM phantom

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

Then, for the standardized cheek phone position, the head model shall be rotated around the ear reference point (here with the u-axis or x-axis as the rotation axis) so that the DUT begins to touch the SAM head phantom surface as shown in Figure 6 b). It is often quite difficult to see the point of contact and the rotation operation may need to be conducted in steps of 0,5 degrees.

For the standardized +15 degrees tilted position, the following two steps shall be carried out:

1) Rotate the SAM head phantom around the ear reference point (with the u-axis or x-axis as rotation axis) 15 degrees as shown in Figure 7 a).
2) The DUT model will then most probably protrude into the ear part of the SAM head phantom; in which case translate the DUT until they are in surface-contact again as shown in Figure 7 b).



a) The SAM phantom is rotated 15 degrees away from the DUT **b) Enlarged view showing the ear and DUT**

Figure 7 – Tilt position of the DUT against the SAM phantom

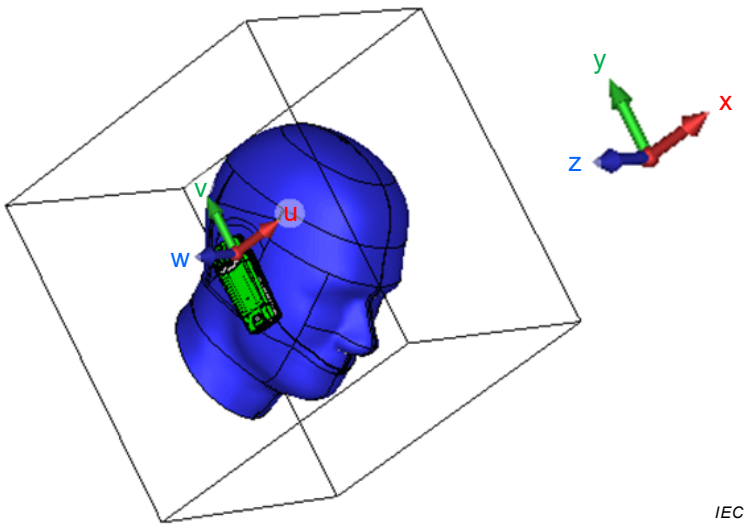


Figure 8 – Example of the full model space that includes the DUT and the SAM phantom for the numerical simulations for the right cheek position

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

Once the SAM head phantom is aligned with the DUT model as shown in Figure 8 for the example of the right cheek position, the complete FDTD grid shall be generated according to the coordinate system (x,y,z) of the phone model. However, the initial grid applied for the DUT model shall not be altered.

5.6.3 Body phantom model

The body phantom model and the dielectric properties of the phantom shell and of the tissue simulating material used for the simulations shall be the flat phantom specified in IEC 62209-2. The depth of the tissue-simulating material in the phantom shall be at least 150 mm and the values shall be those provided in IEC 62209-2. The exact values for these properties shall be used, i.e. the allowed tolerance for the fabrication of the phantom shall not be taken into account.

Figure 9 shows an example of a model space for a given separation distance between the DUT and the flat phantom.

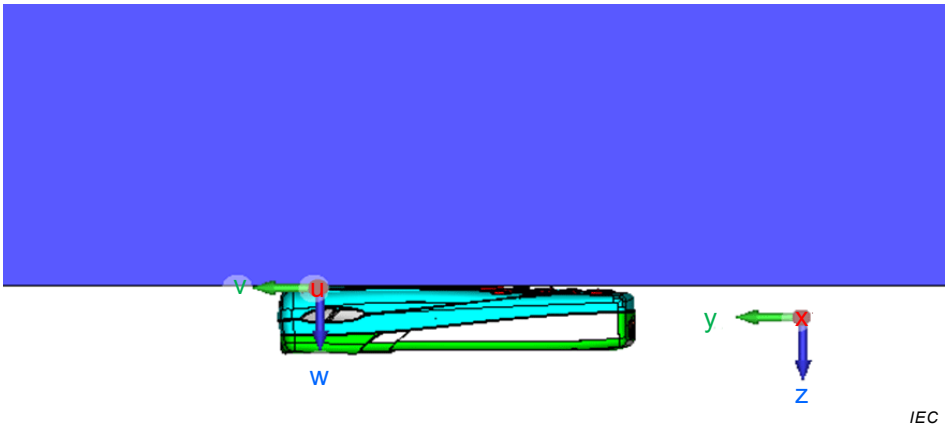


Figure 9 – Example of the model space for the DUT/body phantom calculation setup

5.6.4 Phantom mesh generation

Stair casing effect is expected to be negligible for the flat phantom. In order to reduce stair casing effects for the region of the SAM head phantom closest to the DUT, the grid size for the field calculation points that surrounds the ear and the phone should be 0,5 mm to 1 mm in all directions to a depth of 50 mm in the tissue simulating material. For the other regions of the SAM phantom, i.e. at the opposite ear, larger steps can be used, for example in the range 3 mm to 5 mm for frequencies up to 2 GHz. A grid step smaller than one fifth of the wavelength in the tissue simulating material is usually sufficient.

5.7 Recording of results

The recording of the calculation results will depend on the amount of memory space available, but some results are essential for the ultimate peak spatial-average SAR calculation. The S11 parameter is usually the default output in most commercial software. The SAR value computed at each voxel inside the phantom should be saved. It is also useful to compute the losses in the different materials. The calculation of the peak spatial-average SAR, either over 1 g or 10 g, usually requires a rather lengthy post-processing of the SAR data over each voxel. This post-processing algorithm can be launched over a sub-volume, in which case this sub-volume shall cover at least half the depth of the phantom. For example, only the half-head of the SAM phantom nearest to the DUT may be considered for the peak spatial-average SAR calculation.

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

5.8 Peak spatial-average SAR calculation

The peak spatial-average SAR calculation shall be evaluated according to the procedure described in 6.2 of IEC/IEEE 62704-1:2017. All values shall be normalized to the maximum power accepted by the antenna, i.e. the return loss is not taken into account thereby providing a conservative value of the peak spatial-average SAR value. It is important to note that the normalization to the maximum power accepted by the antenna shall not be applied for the purpose of evaluation of the computational uncertainty described in Clause 7.

6 Benchmark models

6.1 General

Clause 6 describes benchmark mobile phone models that shall be used for the validation of the numerical FDTD simulation tool prior to undertaking any numerical simulation using the CAD model of the DUT which is to be assessed for SAR pre-compliance. The desired target values for the given parameters of each benchmark shall be met within the stated limits (resonance frequency band or impedance) or deviations (peak spatial-average SAR).

6.2 Generic metallic box phone for 835 MHz and 1 900 MHz

This benchmark phone model was previously used in the SAM head phantom interlaboratory comparison project that was initiated by IEEE SCC-34, SC-2, WG2, in 2003 [8]. The generic metallic box phone consists of a PEC metallic box with a 1 mm plastic layer and a wire monopole antenna at the top surface. For the SAR calculation, it is positioned at the right ear of the SAM phantom as shown in Figure 10. The dimensions of the phone are shown in Figure 11. The antenna length, designated as L_A in Figure 11 is specified for two test frequencies: 71 mm at 835 MHz and 36 mm at 1 900 MHz. The length of the antenna includes the 1 mm source gap and the 1 mm of rubber coating of the antenna. The speaker output is located 10 mm below the top side of the chassis.

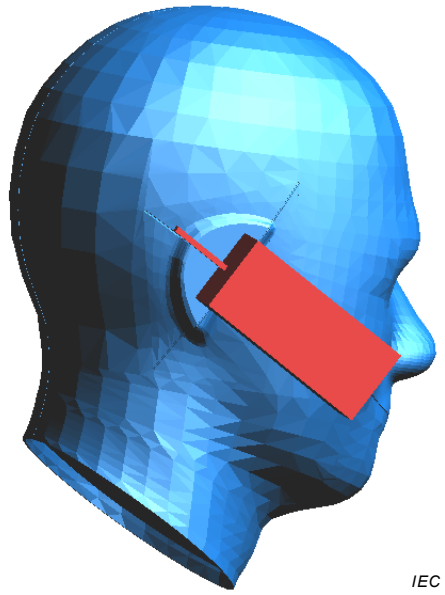


Figure 10 – The SAM head phantom and the generic metallic box phone

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

Dimensions in millimetres

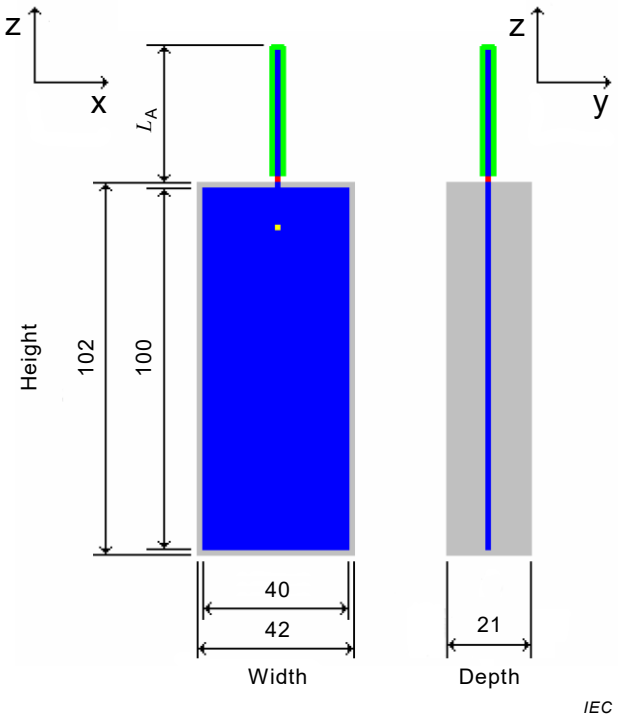


Figure 11 – Physical dimensions of the generic metallic box phone

The dielectric properties of the materials for this benchmark mobile phone model are provided in Table 1.

The SAR results for the specified simulations are shown in Table 2. All SAR results are normalized to 1 W power accepted by the antenna. Note that the presented data are the mean values of the results obtained from the participating laboratories in the interlaboratory comparison and they should not be considered as analytically obtained reference values. A deviation of less than 30 % from the mean value is considered to be indicative of an acceptable numerical simulation result.

Table 1 – Dielectric parameters of the materials of the generic phone

Material	835 MHz		1 900 MHz	
	ε_r	σ (S/m)	ε_r	σ (S/m)
Plastic (chassis)	4,0	0,04	4,0	0,04
Rubber (antenna cover)	2,5	0,005	2,5	0,005
SAM plastic shell	5,0	0,0016	5,0	0,0016
SAM tissue simulating material	41,5	0,90	40,0	1,40

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017

Table 2 – Peak spatial-average SAR for 1 g and 10 g of the benchmark

Frequency (MHz)	Ear side	Position	SAR 1 g (W/kg/W)	SAR 10 g (W/kg/W)
835	Right	Cheek	7,5	5,3
		Tilt	4,9	3,4
1 900		Cheek	8,3	4,8
		Tilt	12,0	6,8

6.3 GSM/UMTS mobile phone

This benchmark phone model is based on a CAD file that is provided with this document. The purpose of the benchmark is to test the handling of complicated models of the chosen FDTD-based tool. The model consists of a number of solids that are similar to the structures used in real mobile phones. The benchmark mobile phone model is shown in Figure 12. The model consists of both metallic and plastic solids with dielectric properties of the materials given in Table 3.

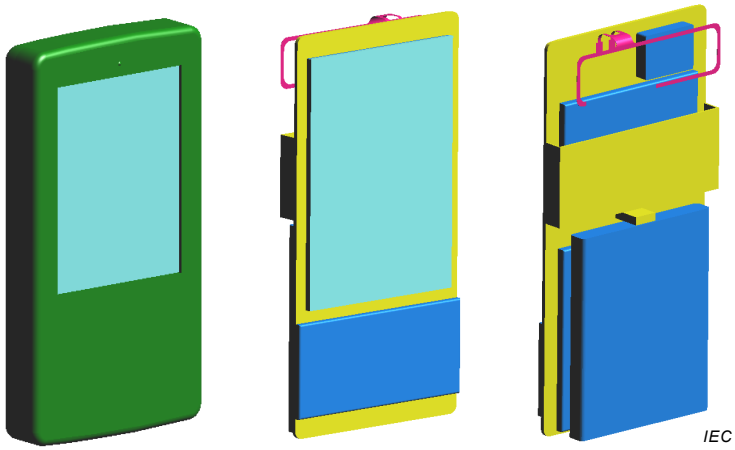


Figure 12 – Generic GSM/UMTS mobile phone

Documents
Document Sharing Hub
Full document details: IEC/IEEE 62704-3-2017