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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)

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

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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.

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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

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[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.

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.

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]

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[2] Numbers in square brackets refer to the Bibliography.

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

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

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 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.

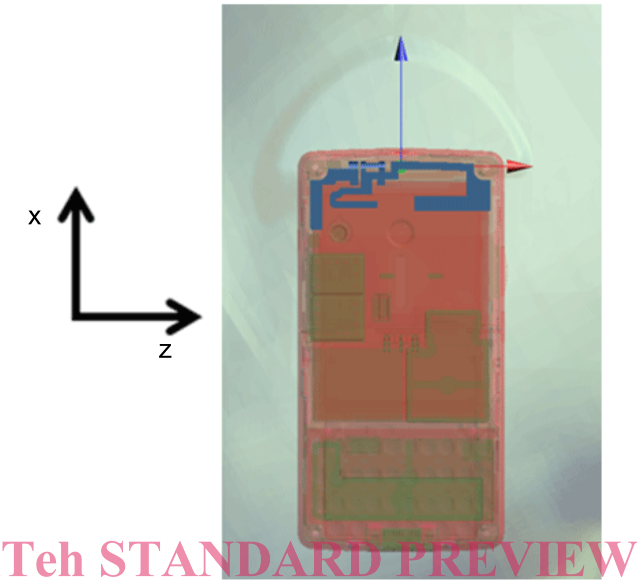
In order to optimize the computational resources, the components in the DUT model, for instance components located inside shielded cans, that are not expected to have noticeable impact to SAR distributions may be removed [6]. Consequently, such metallic components shall be given meshing priority over 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.

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.

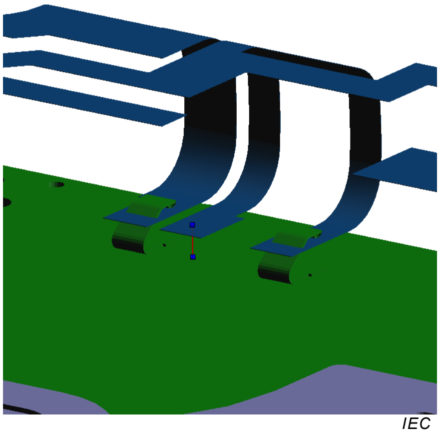


Figure 2 – An example of a source gap position that is inserted in replacement of a real-life feeding spring pin

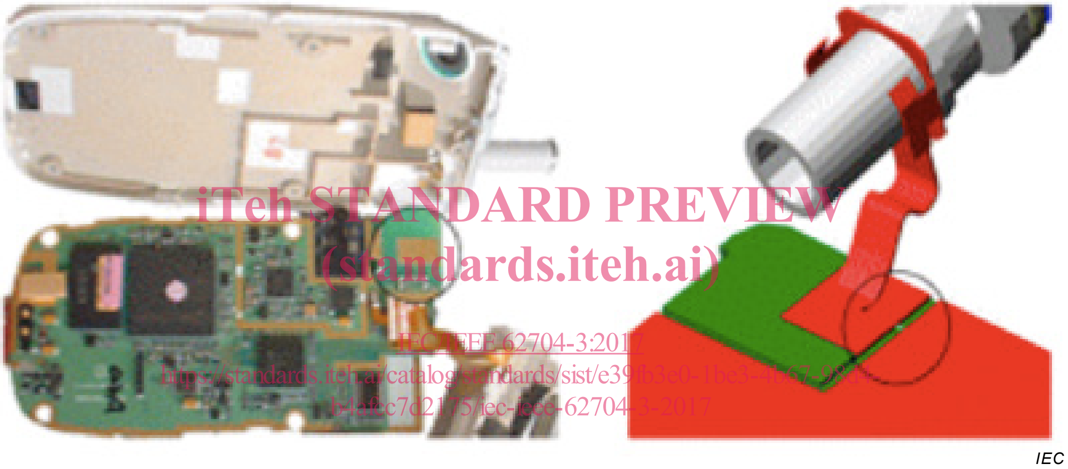


Figure 3 – An example of a microstrip feed line

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.