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# 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](#)

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## 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

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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](http://www.iec.ch/dyn/www/f?p=103:227:0:::FSP_ORG_ID,FSP_LANG_ID:1303,25).

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## 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.

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# 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].

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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>)

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- 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**

$\bar{P}$   
time-averaged rate of energy transfer

$$\bar{P} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P(t) dt \quad (1)$$

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**

$\sigma$   
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,  $k \times (\text{combined uncertainty}) = (\text{expanded uncertainty})$ . When  $k = 1$ ,  $P \approx 0,68$ ;  $k = 2$ ,  $P \approx 0,95$ ;  $k = 3$ ,  $P \approx 0,999$ .

### 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  $2\pi$  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  $\mu$ , 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**

$\varepsilon_r$

ratio of the complex permittivity to the permittivity of free space

Note 1 to entry: The complex relative permittivity,  $\varepsilon_r = \varepsilon/\varepsilon_0$ , of an isotropic, linear, lossy dielectric medium is given

by  $\varepsilon_r = \varepsilon_r' - j\varepsilon_r'' = \varepsilon_r' - j\frac{\sigma}{\omega\varepsilon_0} = \varepsilon_r' \left( 1 - j\frac{\varepsilon_r''}{\varepsilon_r'} \right) = \varepsilon_r'(1 - j\tan\delta)$

where

- $\varepsilon_0$  is the free space permittivity ( $8,854 \times 10^{-12}$  F/m);
- $\varepsilon_r'$  is the relative permittivity or dielectric constant;
- $\sigma$  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  $\delta$  is given in Formula (2):

$$\delta = \frac{1}{\omega} \left[ \frac{\mu_0 \epsilon_r' \epsilon_0}{2} \left( \sqrt{1 + \left( \frac{\sigma}{\omega \epsilon_r' \epsilon_0} \right)^2} - 1 \right) \right]^{-1/2} \quad (2)$$

### 3.26 permeability

$\mu$

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

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

where

$Y_{\text{rms}}$  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