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PUBLICLY AVAILABLE SPECIFICATION

Conversion method of specific absorption rate to absorbed power density for the assessment of human exposure to radio frequency electromagnetic fields from wireless devices in close proximity to the head and body – Frequency range of 6 GHz to 10 GHz

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The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
106/572/DPAS	106/580/RVDPAS

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This document contains supplemental files that are detailed in Annex D. These files can be downloaded from https://www.iec.ch/tc106/supportingdocuments.

INTRODUCTION

This document provides the method to conservatively evaluate the area averaged electromagnetic (EM) power density entering the human body, i.e. the absorbed power density (APD), for communication devices intended to be used at a position near the human head or body, or mounted on the body, combined with other transmitters within a product, or embedded in garments. The device categories covered include but are not limited to mobile telephones, radio transmitters in personal computers, and desktop and laptop devices. The applicable frequency range is from 6 GHz to 10 GHz.

This document specifies:

- conversion of the psSAR to the psAPD (Clause 6);
- uncertainty estimation (Clause 7);
- reporting requirements (Clause 8);
- methods of validation and system check (Annex C)

The measurement and computational standards IEC/IEEE 63195-1:2022 [1][1] and IEC/IEEE 63195-2:2022 [2] for incident power density (IPD) cover the frequency range from 6 GHz to 300 GHz. Hence there is a frequency overlap from 6 GHz to 10 GHz between this document on APD and the IEC/IEEE standards addressing IPD. The committee was aware of this fact and opted for enhanced flexibility by providing methods for basic restriction metric APD in addition to reference level metric IPD.

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

CONVERSION METHOD OF SPECIFIC ABSORPTION RATE TO ABSORBED POWER DENSITY FOR THE ASSESSMENT OF HUMAN EXPOSURE TO RADIO FREQUENCY ELECTROMAGNETIC FIELDS FROM WIRELESS DEVICES IN CLOSE PROXIMITY TO THE HEAD AND BODY – FREQUENCY RANGE OF 6 GHZ TO 10 GHZ

1 Scope

This document specifies a conversion method for the assessment of the peak spatial-average absorbed power density ($psAPD$) in the human head and body due to exposure to radio frequency (RF) electromagnetic fields (EMF) from wireless communication devices, with a specified conversion uncertainty. This conversion method is based on specific absorption rate (SAR) values and is specified with the objective to yield conservative and reproducible absorbed power density values of the exposure for a significant majority of the population during the use of hand-held, body-worn or any other RF transmitting communication devices that can operate in close proximity to a human head or body. This conversion method applies for devices that can feature single or multiple transmitters and/or antennas and can be operated with their radiating structure(s) at distances up to 200 mm from a human head or body.

The conversion method of this document can be employed to determine conformity with applicable absorbed power density or epithelial power density limits, such as those defined in ICNIRP guidelines 2020 [3] and IEEE Std C95.1™-2019 [4], of different types of RF transmitting communication devices being used in close proximity to the head and body. The assessment of $psAPD$ is based on the conversion of the peak spatial-average specific absorption rate (psSAR) values assessed according to applicable international standards. The applicable frequency range of the conversion method of this document is 6 GHz to 10 GHz.

NOTE Applicable international standards for the assessment of the psSAR are those accepted by the local regulatory body or specified in the CENELEC product standards. Such international standards include, e.g. IEC/IEEE 62209-1528 and IEC 62209-3 [5] for measurement methods, and IEC/IEEE 62704-1 [6] and IEC/IEEE 62704-4 [7] for computational methods. The frequency range of [5], [6] and [7] is limited up to 6 GHz. While the applicability of the methods of [5] for the frequency range of this document may need further verification, the numerical standards [6] and [7].may be applied for frequencies up to 10 GHz.

The categories of RF transmitting communication devices covered in this document include but are not limited to mobile telephones, radio transmitters in personal computers, and desktop and laptop devices or devices embedded in garments, using single or multiple transmitters and/or antennas, when operating within the frequency range indicated above.

The conversion method of this document does not apply for EMF evaluation of exposure from the devices or objects intended to be implanted in the body, such as active or passive implanted medical devices.

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/IEEE 62209-1528:2020, *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 1528: Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 GHz)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
absorbed power density
locally absorbed power density
APD
power per skin surface unit area that is absorbed in the body

Note 1 to entry: APD is determined using Formula (1) and Formula (2):

$$APD = \frac{1}{A_{\mathrm{av}}} \iint_{A_{\mathrm{av}}} dxdy \int_{0+}^{z_{\max}} \rho(x,y,z)\, SAR(x,y,z)\, dz = PD_0\big|_{\delta \ll z_{\max}} \tag{1}$$

and

$$SAR(x,y,z) = SAR(x,y,0)\,\mathrm{e}^{-2z/\delta} \tag{2}$$

where

PD_0 is the specific absorbed power density averaged over the area A_{av} at the phantom bottom (z = 0);

A_{av} is the averaging area;

δ is the penetration depth of the tissue equivalent medium (< 6 mm), which is much smaller than the medium liquid depth $z_{\max}$ at any location of the phantom;

$\rho(x,y,z)$ is the mass density of the tissue equivalent medium;

$SAR(x,y,z)$ is the local specific absorption rate.

Note 2 to entry: The quantity APD is equivalent to the quantity S_{ab} of Formula (23) of [3].

Note 3 to entry: In IEEE Std C95.1 [4] the identical metric is called epithelial power density. Identical term transmitted power density is used in some scientific publications.

Note 4 to entry: Power density is also referred to as power flux density.

Note 5 to entry: Further details can be found in Annex A and Annex B.

Note 6 to entry: Definition is valid for any surface and not limited to the flat phantom surface.

3.2
incident power density
power per unit area that impinges on the body surface

Note 1 to entry: The incident power density just outside the body surface is used to establish local exposure reference levels, which apply at frequencies above 6 GHz in some jurisdictions.

3.3
spatial-average absorbed power density
$sAPD(A_{av})$
APD averaged over a surface of an averaging area A_{av}

Note 1 to entry: The $sAPD$ is a function of the location vector $\boldsymbol{r}$. It is defined on the evaluation surface, except for the edges where no averaging area can be constructed.

Note 2 to entry: For the frequency range from 6 GHz to 10 GHz the averaging area size specified in exposure limits is 4 cm^2.

3.4
peak spatial-average absorbed power density
$psAPD(A_{av})$
global maximum value of $sAPD$ (3.3) on the interface of the entire inner phantom surface and the tissue equivalent medium

Note 1 to entry: $psAPD$ is given by Formula (3):

$$psAPD = \max\{sAPD(r)\} \tag{3}$$

where $\boldsymbol{r}$ is a point on the evaluation surface as defined in IEC/IEEE 63195-1:2022 [1].

Note 3 to entry: Other local maxima (i.e. secondary peak spatial-average power density values) can exist (see 3.5).

3.5
secondary peak spatial-average absorbed power density
other local maxima of the spatial-average power density ($sAPD$) values that are smaller than the peak spatial-average power density ($psAPD$)

3.6
maximized peak spatial-average absorbed power density
$mpsAPD$

global maximum value of $psAPD$ for all combinations of phasors that represent the input signal to an antenna array

3.7
Poynting vector
S
vector product of the electric field strength $\boldsymbol{E}$ and the magnetic field strength $\boldsymbol{H}$ of the electromagnetic field at a given point

Note 1 to entry: The flux of the Poynting vector through a closed surface is equal to the electromagnetic power passing through this surface.

Note 2 to entry: For a periodic electromagnetic field, the time average of the Poynting vector is a vector, the direction of which, with certain reservations, can be considered as the direction of the propagation of electromagnetic energy and the magnitude can be considered as the average power flux density.

Note 3 to entry: For a sinusoidal wave of angular frequency ω, the complex Poynting vector is expressed by Formula (4):

$$\boldsymbol{S} = \frac{1}{2}\boldsymbol{E} \times \boldsymbol{H}^* \tag{4}$$

where $\boldsymbol{E}$ and $\boldsymbol{H}$ are phasors and the asterisk denotes the complex conjugate.

Note 4 to entry: The Poynting vector has units of watt per square metre (W/m^2).

[SOURCE: IEC 60050-121:2019, 121-11-66, modified – excerpts combined and rearranged, Note 4 added.]

3.8
averaging area
A_{av}
nominal size of the area used for calculating $sAPD$ (3.3)

Note 1 to entry: The shape of the averaging area is the cross section of a sphere ($r = (A_{av}/\pi)^{1/2}$) with the centre on the surface (circular in case of a planar surface) or the cross-section of a cube with side length of $(A_{av})^{1/2}$ determined according to IEC/IEEE 63195-2:2022 [2].

3.9
specific absorption rate
SAR
measure of the rate at which energy is absorbed per unit mass in a human body when exposed to a radio frequency electromagnetic field

Note 1 to entry: This quantity is equal to specific energy absorption rate defined in ICNIRP 2020 guidelines [3].

3.10
spatial-average SAR
$sSAR$
SAR averaged within a local region based on a specific averaging mass

Note 1 to entry: Averaging masses 1 g and 10 g of tissue in the shape of a cube are considered for example in IEC/IEEE 62209-1528:2020. In this document, 8 g of tissue in the shape of a cube is considered for determining $sAPD$ over a square 4 cm^2 surface area of the body.

3.11
peak spatial-average SAR
$psSAR$
maximum SAR averaged within a local region based on a specific averaging mass

Note 1 to entry: Averaging masses 1 g and 10 g of tissue in the shape of a cube are considered for example in IEC/IEEE 62209-1528:2020. In this document, 8 g of tissue in the shape of a cube is considered for determining $sAPD$ over a square 4 cm^2 surface area of the body.

3.12
evaluation surface
interface at the inner surface of the phantom shell and the tissue equivalent medium where the spatial-average power density ($sAPD$) is evaluated

4 Symbols and abbreviated terms

4.1 Physical quantities

The internationally accepted SI units are used throughout the document.

Symbol	Quantity	Unit	Dimensions
A_{av}	area	square metre	m^2
APD	absorbed power density	watt per square metre	W/m^2
F_{APD}	conversion factor	kilogram per square metre	kg/m^2
δ	penetration depth of the tissue equivalent medium	metre	m
$\boldsymbol{E}$	electric field vector	volt per metre	V/m
η	wave impedance of the tissue equivalent medium	ohm	Ω
ε_r	relative permittivity (real part)	1	1
$\boldsymbol{H}$	magnetic field vector	ampere per metre	A/m
$\boldsymbol{k}$	wave vector	1 per metre	1/m