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TECHNICAL REPORT

Evaluation of absorbed power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 300 GHz

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Evaluation of absorbed power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 300 GHz

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INTRODUCTION

This document describes computational and measurement methods for the evaluation of absorbed (epithelial) power density related to human exposures due to electromagnetic field (EMF) transmitting devices operating in close proximity to the user at frequencies between 6 GHz and 300 GHz. The types of devices include but are not limited to mobile telephones, tablets, laptops, etc.

For portable devices, the specific absorption rate (SAR) assessment standard for wireless devices used in close proximity to the user IEC/IEEE 62209-1528:2020 [1] is specified up to 10 GHz. The IEC/IEEE 63195-1 and IEC/IEEE 63195-2 standards on the assessment of the incident power density (IPD) for wireless devices used in close proximity to the user are valid from 6 GHz to 300 GHz. For exposure to EMF emitted from base stations, IEC 62232:2022 [2] specifies methods to assess the compliance boundaries based on reference levels and basic restrictions for a frequency range from 110 MHz to 300 GHz.

The absorbed power density (APD) is considered as the relevant local basic restriction and exposure metric above 6 GHz in the ICNIRP 2020 guidelines [3] and in the Health Canada Notice [4]. Similarly, IEEE Std C95.1™-2019 [5] requires equivalent assessment of epithelial power density above 6 GHz. IEC PAS 63446 [6] describes methods to convert SAR results into APD in frequency range of 6 GHz to 10 GHz.

IEC TC 106 and IEEE ICES TC 34 (IEC/IEEE) have previously noted the necessity to extend compliance assessment standards for portable devices to cover the basic restrictions on APD. To ensure timely publication of the available knowledge on the computational and measurement technologies on APD assessment, IEC TC 106 and IEEE ICES TC 34 decided on a two-step strategy to ensure that the fundamental approaches are available.

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In 2023 and 2024, the focus was on the development of a Technical Report (this document), specifying the state of the art of computational and measurement techniques and test approaches for evaluating portable devices based on absorbed power density measurements from 6 GHz to 300 GHz.

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Upon drafting this document, a Technical Report, a new work item proposal has been initiated to develop a Dual Logo International Standard (IS) jointly among IEEE and IEC on the computational and measurement procedures based on leveraging the content of this document.

This document is an informative document that serves as the starting point for the International Standards on computational and measurement assessment procedures of the APD. The methodologies and approaches described in this document can be useful for the assessment of APD in the early phase of computational and measurement technology development. It also contains recommendations for future standardization work and highlights areas that require additional investigation or consideration.

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1 Scope

This document describes the computation and measurement techniques and test approaches for evaluating the local peak absorbed power density (pAPD) and peak spatial average absorbed (epithelial) power density (psAPD) induced in a human body from a wireless device transmitting in close proximity to the user at frequencies between 6 GHz and 300 GHz.

This document provides information on the testing of portable devices transmitting at distances close to the human body, such as mobile phones, tablets, wearable devices, etc. The information in this document is also relevant to exposure in the close proximity of base stations.

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 63195-1, *Assessment of power density of human exposure to radio frequency fields from wireless devices in close proximity to the head and body (frequency range of 6 GHz to 300 GHz) - Part 1: Measurement procedure*

IEC/IEEE 63195-2, *Assessment of power density of human exposure to radio frequency fields from wireless devices in close proximity to the head and body (frequency range of 6 GHz to 300 GHz) - Part 2: Computational procedure*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC/IEEE 63195-1, IEC/IEEE 63195-2, and the following apply.

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– ISO Online browsing platform: available at https://www.iso.org/obp
– IEEE Dictionary Online: available at http://dictionary.ieee.org

3.1
incident power density
IPD
function of the complex Poynting vector S at the location r

Note 1 to entry: The formula to compute IPD from S depends on the applicable exposure guidelines or national regulations.

Note 2 to entry: IEC/IEEE 63195-1:2022 and IEC/IEEE 63195-2:2022 refer to the incident power density and all derived quantities as power density.

3.2
absorbed power density
APD
epithelial power density
function of the Poynting vector ($\mathrm{Re}\{S\}$) that is transmitted into a phantom or a human body and integrated over a surface to compute the sAPD (3.6)

Note 1 to entry: See Clause 5 for details and formulae for the APD.

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3.3
body model
phantom
mock-up that represents the exposed human body or a part of it in a measurement set-up or in a simulation

3.4
spatial-average incident power density
sIPD
IPD (3.1) averaged over an averaging area

Note 1 to entry: sIPD is a function of the location. It is determined on the evaluation surface (3.13).

Note 2 to entry: Example averaging area sizes specified in exposure guidelines are 1 cm^2 and/or 4 cm^2.

Note 3 to entry: IEC/IEEE 63195-1:2022 and IEC/IEEE 63195-2:2022 refer to the spatial-average incident power density as spatial-average power density.

3.5
peak absorbed power density
pAPD
local maximum of the APD (3.2)

3.6
spatial-average absorbed power density
sAPD
APD (3.2) averaged over an averaging area (3.12)

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Note 1 to entry: sAPD is a function of the location. It is determined on the evaluation surface (3.13).

Note 2 to entry: Example averaging area sizes specified in exposure guidelines are 1 cm^2 and/or 4 cm^2.

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3.7
peak spatial-average incident power density
psIPD
global maximum value of the sIPD (3.4) on the evaluation surface (3.13)

Note 1 to entry: Other local maxima (i.e. secondary peak spatial-average power density values) can exist.

Note 2 to entry: IEC/IEEE 63195-1:2022 and IEC/IEEE 63195-2:2022 refer to the spatial-average incident power density as spatial-average power density.

3.8
peak spatial-average absorbed power density
psAPD
global maximum value of the sAPD (3.6) on the evaluation surface (3.13)

Note 1 to entry: Other local maxima (i.e. secondary peak spatial-average absorbed power density values) can exist.

3.9
maximized peak spatial-average incident power density
mpsIPD
maximum psIPD (3.7) over the entire steering range of the antenna beam

Note 1 to entry: IEC/IEEE 63195-1:2022 and IEC/IEEE 63195-2:2022 refer to the maximized spatial-average incident power density as maximized spatial-average power density.

3.10
maximized peak spatial-average absorbed power density
mpsAPD
maximum psAPD (3.8) over the entire steering range of the antenna beam

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3.11
Poynting vector
S
vector product of the electric field strength E and the magnetic field strength 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 sinusoidal wave of angular frequency ω, the complex Poynting vector is expressed by Formula (1)

$$S = \frac{1}{2} E \times H^* \qquad (1)$$

where E and H are complex vectors, and the asterisk denotes the complex conjugate.

[SOURCE: IEC 60050-121:2019 [7], 121-11-66, modified – Note 2 to entry has been modified.]

3.12
averaging area
A_{av}
contiguous region of the evaluation surface used for averaging the APD (3.2)

Note 1 to entry: On a planar evaluation surface (3.13), the sAPD is computed as the APD (3.2) integrated over a square area of size A_{av} divided by A_{av}. On a non-planar evaluation surface, the averaging area indicates the dimensions of the projection of the integration area of the APD onto a planar surface.

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3.13
evaluation surface
surface where the local absorbed power density (sAPD, 3.2) is assessed, i.e. the outer surface of the body model, which reproduces the reflection of human skin

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Note 1 to entry: In practice, the APD evaluation surface can be different from a measurement surface (e.g. field probe position).

3.14
near-field
region encompassed by the reactive near-field and the radiative near-field

Note 1 to entry: See also 3.15 and 3.16 for definitions of reactive near-field and radiative near-field, respectively.

3.15
radiative near-field
region of space between the reactive near-field and the far-field, wherein the predominant components of the electromagnetic field are those that represent the propagation of energy, and wherein the angular field distribution is dependent upon the distance from the antenna

Note 1 to entry: In the radiative near-field, the out-of-phase (i.e. evanescent) component of the electromagnetic field decays, and the in-phase (i.e. propagating) component of the electromagnetic field emerges.

[SOURCE: IEC 60050-712:1992 [8], 712-02-04, modified – In the term, "radiating" has been replaced by "radiative". In the definition, "region" has been deleted after "near-field" and "far-field". The note has been replaced by a new note to entry.]

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3.16
reactive near-field
region of space immediately surrounding an antenna, where the predominant components of the electromagnetic field are those which represent the exchange of reactive energy between the antenna and the surrounding medium

[SOURCE: IEC 60050-712:1992 [8], 712-02-01, modified – The admitted and deprecated terms have been omitted.]

3.17
far-field
region of the electromagnetic field of an antenna wherein the predominant components of the field are those which represent a propagation of energy and wherein the angular field distribution is essentially independent of the distance from the geometrical centre of the antenna, and the ratio of predominant electric field and magnetic field components is constant and is equal to the wave impedance of 377 Ω

Note 1 to entry: For the purposes of this document, the boundary of the near-field and far-field is as specified in 7.4.2.1 of IEC/IEEE 63195-1:2022.

[SOURCE: IEC 60050-712:1992 [8], 712-02-02, modified – The word “region” has been omitted from the term. In the definition, the distance to the geometrical centre of the antenna has been clarified, and the ratio of the electric and magnetic components has been added. The notes have been replaced by a new note to entry.]

3.18
pseudo-Brewster angle
angle at which the reflection coefficient of an incident TM-polarized wave on a lossy dielectric half space is minimized

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Note 1 to entry: For lossless media, this angle corresponds to the Brewster angle, at which the reflection coefficient of an incident TM-polarized wave is zero.

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3.19
backward propagation
inversion of the propagation direction of the electromagnetic waves in a medium with the purpose of calculating the electromagnetic field at a distance between the source and the measurement location

3.20
basic restriction
human exposure limits for compliance with time-varying electric, magnetic, and electromagnetic fields measured inside the body that are based on established adverse health effects

Note 1 to entry: Within the scope of this document, the physical quantity used as a basic restriction is the absorbed power density (APD).

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