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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 Coordinating Committee 39

Sponsored by the
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USA

IEEE Std 1528™-2013
(Revision of
IEEE Std 1528-2003)

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Abstract: Protocols and test procedures are specified for the measurement of the peak spatial-average SAR induced inside a simplified model of the head of users of certain handheld radio transceivers. These transceivers are intended to be used for personal wireless communications services, operate in the 300 MHz to 6 GHz frequency range, and are intended to be operated while held against the ear. The results obtained by following the protocols specified in this recommended practice represent a conservative estimate of the peak spatial-average SAR induced in the head of a significant majority of persons, subject to measurement and other uncertainties that are defined in this recommended practice. The results are representative of those expected during conditions of intended use of a handheld wireless device. It is not the intent of this recommended practice to provide a result representative of the absolute maximum SAR value possible under every conceivable combination of head size, head shape, handset orientation, and spacing relative to the head. The measurement of SAR induced in the external tissues of the head, e.g., the external ear (pinna), is not addressed in this document. This recommended practice also does not address the body SAR measurements typically required for wireless handsets. The following items are described in detail: measurement concepts, measurement techniques, instruments, calibration techniques, simulated-tissue (phantom) models, including homogeneous anatomically equivalent models of the human head and simple phantoms for validation of the SAR measurement system, and the limitations of these systems when used for measuring the spatial-peak mass-averaged SAR. Procedures for calibrating electric field (E-field) probes used for SAR measurements and assessing the SAR measurement and system uncertainties are provided in the annexes. This recommended practice is intended primarily for use by engineers and other specialists who are familiar with electromagnetic (EM) theory and SAR measurement techniques; it does not recommend specific SAR limit values since these are found in other documents. The benefits to the users include standardized and accepted protocols, validation techniques, and means for estimating the overall measurement uncertainty in order to produce valid and repeatable data.
Keywords: handheld wireless transceivers, IEEE 1528™, miniature E-field probes, non-ionizing radiation, RF dosimetry, RF/microwave exposure assessment, RF/microwave hazard assessment, SAR measurement systems, SAR measurement uncertainty, specific absorption rate (SAR) measurements, wireless handsets

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Introduction

This introduction is not part of IEEE Std 1528-2013, IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques.

In June 1995, the IEEE Standards Board approved the establishment of Standards Coordinating Committee 34 (SCC34) as a collaborating effort with the Electromagnetic Energy Association.[a] Prior to 1995, assessment of exposure to various products was based on the procedures found in IEEE Std C95.3™-1991 [B100] that addresses exposure assessment in general but does not provide detailed procedures that could be applied to specific products.[b] In accordance with policies of the IEEE, SCC34 standards were issued and developed as IEEE standards, as well as being submitted to ANSI for recognition.

Subcommittee 2 (SC2) of SCC34 was established in February 1997 to develop standard protocols for evaluating certain wireless devices, such as handheld radio transceivers, wireless LANs, and similar devices, to meet specific SAR measurement criteria. The first version of IEEE Std 1528 was released in December 2003; an amendment was issued in 2005.

In March 2005, the integration of IEEE SCC34 into the IEEE International Committee on Electromagnetic Safety (ICES) was approved. Specifically, two former Standards Coordinating Committees, IEEE SCC28 and SCC34 were combined into a single Type 2 Standards Coordinating Committee (SCC39), called ICES. IEEE SCC34 is now ICES Technical Committee 34 (TC34), and it consists of two subcommittees: Subcommittee 1 (SC1) for measurement techniques, and Subcommittee 2 (SC2) for numerical techniques. Due to the joint meetings and common interests of the two Subcommittees, they share the same membership.

The scope of ICES TC34 is "The development of product performance standards relative to the safe use of electromagnetic energy for specific products that emit EM energy at frequencies between 0 and 300 GHz, i.e., the frequency range covered by the basic restrictions and maximum permissible exposure (MPE) values developed by the IEEE International Committee on Electromagnetic Safety (ICES)." ICES TC34 is responsible for this recommended practice. Although the scope of ICES TC34 covers a variety of devices, this recommended practice is devoted exclusively to handsets used for personal wireless communication services.

Standards developed by ICES TC34 are expressed in terms of easily measured parameters, e.g., output power, current, voltage, which are related to the basic restrictions and MPE values found in the latest revisions of standards such as IEEE Std C95.1™ and IEEE Std C95.6™ [B101].[c] Included in the scope are standards, guides, and recommended practices that describe measurement and computational protocols for evaluating the basic restrictions and derived limits found in the IEEE C95™ standards and in other relevant national and international standards and guidelines.

The SAR determined by following the procedures specified in this recommended practice is subject to measurement uncertainty and other uncertainties that are discussed in this document. This recommended practice does not address the measurement of SAR induced in the external tissues of the head, e.g., the external ear (pinna) and other parts of the body.

The purpose of this recommended practice is to provide a protocol for the measurement of the peak spatial-average SAR in an anatomically equivalent model of the human head of users of wireless handsets intended to be operated while held next to the ear. It provides the users with standardized and accepted protocols, measurement and validation techniques, and the means for estimating the overall measurement uncertainty in order to produce valid and repeatable data. Specific SAR limit values are not included since these are

[a] The Electromagnetic Energy Association was dissolved in 2000.
[b] The numbers in brackets correspond to those of the bibliography in Annex K.
[c] Information on references can be found in Clause 2.

found in other documents, e.g., the latest published versions of IEEE Std C95.1 and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines.[d]

This revision extends the frequency range of IEEE Std 1528-2003 from 300 MHz to 3000 MHz to 300 MHz to 6000 MHz. Recently, there has been an increase in the development of personal wireless communication services in the 3 GHz to 6 GHz frequency range. Some of the technologies can be implemented in handsets and therefore SAR measurement protocols are needed to evaluate SAR according to exposure limits defined in international standards. IEEE Std C95.1-2005 states that for frequencies in the range 100 kHz to 6 GHz the evaluation of SAR may be used to demonstrate compliance with its specifications. SAR is the basic restriction for frequencies up to 3 GHz, and a transition frequency range of 3 GHz to 6 GHz allows compliance with the standard by evaluation of either incident power density or local SAR. Therefore, 6 GHz is the upper end of the frequency spectrum for which SAR evaluation is needed. While basic restrictions on SAR in the ICNIRP Guidelines go up to 10 GHz, the recommended practice in this revised IEEE standard was limited to an upper end frequency of 6 GHz since current wireless handsets operate below this frequency value.

An existing IEC standard has a scope that covers SAR measurements of devices held to the ear in the 300 MHz to 3000 MHz frequency range [IEC 62209-1, Human exposure to radio frequency fields from handheld and body-mounted wireless communication devices—Human models, instrumentation, and procedures—Part 1: Procedure to determine the specific absorption rate (SAR) for handheld devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz), published in 2005]. That standard was developed by the IEC, Technical Committee 106, Project Team 62209 (IEC TC106 PT62209). IEC TC106 PT 62209 has published a standard for devices near the body (not at the side of the head) in the 30 MHz to 6000 MHz range [IEC 62209-2, Human Exposure to Radio Frequency Fields from Handheld 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), published in 2010]. The scope of this recommended practice is therefore a complement to IEC standards with a unique scope. ICES TC34 and IEC TC106 PT62209 have several common members and have held concurrent meetings. Both groups collaborate through a Category D Liaison to develop their respective standards and ensure that they are harmonized.

[d] It is beyond the scope of this recommended practice to define what constitutes a hazardous radio frequency EM field. For commonly used basic restrictions and maximum permissible exposure values, refer to the latest versions of IEEE Std C95.1, the ICNIRP Guidelines, or other national requirements. It should be noted that limits given in these documents are under review and are subject to change as new information becomes available.

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1. Overview

1.1 Scope

To specify protocols for the measurement of the peak spatial-average SAR in a simplified model of the head of users of handheld radio transceivers used for personal wireless communications services and intended to be operated while held next to the ear. It applies to contemporary and future devices with the same operational characteristics as contemporary devices that operate in the 300 MHz to 6 GHz frequency range and provides a conservative estimate[1] of the peak spatial-average SAR representative of that which

[1] As used in this recommended practice, *conservative* means that the measured value will not be less than the expected value during normal use by a majority of users—it does not mean that the measured value will not be less than the absolute maximum SAR value that could possibly occur under every conceivable combination of head size, head shape, handset orientation, and spacing relative to the head.

would be expected to occur in the heads of a significant majority of persons during normal use[2] of these devices, but which may not be the absolute maximum value that could possibly occur under every conceivable combination of head size, head shape, handset orientation, and spacing relative to the head.

1.2 Purpose

The purpose of this recommended practice is to provide a protocol for the measurement of the peak spatial-average SAR in an anatomical model of the human head of users of wireless handsets intended to be operated while held next to the ear. It provides the users with standardized and accepted protocols, measurement and validation techniques, and the means for estimating the overall uncertainty in order to produce valid and repeatable data. Specific SAR limit values are not included since these are found in other documents, e.g., the latest published versions of IEEE Std C95.1™ and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines.[3]

1.3 Background

Various national regulatory agencies, for example the Federal Communications Commission (FCC) in the US, require the peak spatial-average SAR of wireless handsets to be evaluated to ensure compliance with their rules (CFR Title 47 [B41] and guidelines of the FCC [B67], [B68]).[4] The SAR values adopted by different countries are usually based on standards such as IEEE Std C95.1 or guidelines such as those developed by ICNIRP (see Clause 2).

The SAR in a biological body exposed to a radio frequency (RF) field depends on a number of factors, including tissue geometry and dielectric properties and the orientation of the body relative to the source (Chou et al. [B31]). Since the RF energy induced in the body is scattered and absorbed at various tissue interfaces, the internal field and hence the SAR distribution is non-uniform. Energy coupling is complicated even further by source geometry and mutual coupling when the exposure is in the near field (Stuchly et al. [B190]), e.g., exposure conditions associated with handheld radio transceivers (Balzano et al. [B6]). Kuster and Balzano [B128] have shown that the peak spatial-average SAR values associated with the use of wireless handsets are mainly a function of the device geometry and square of the magnitude of the RF current density distribution on the device and the geometric position of the device relative to the head. Evaluating the SAR distributions associated with such devices is a complex task, usually accomplished by measurement techniques or numerical modeling. One means to evaluate compliance with specific SAR requirements is by measurement of the electric field (E-field) strength in a tissue-equivalent liquid using anthropomorphic models of the human head.

The current state-of-the-art regarding SAR assessment utilizes anthropomorphic-shaped phantoms made of a low-permittivity, low-loss plastic or fiberglass shell filled with homogeneous tissue-equivalent liquid. The phantom size and shape and the dielectric properties of the tissue-equivalent liquid used to represent average "head" tissue are chosen so that the measured SAR values are conservative, i.e., consistently exhibit a slight overestimation compared with heterogeneous anatomical head models.

The SAR in the tissue-equivalent liquid can be determined by the rate of temperature increase or by E-field measurements, according to Equation (1) or Equation (2):

[2] The difference between *normal use* and *intended use* is described in the NOTE of the definition of **intended use** in Clause 3.
[3] Information on references can be found in Clause 2.
[4] The numbers in brackets correspond to those of the bibliography in Annex K.