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IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz

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IEEE Std C95.7™-2014
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IEEE-SA Standards Board

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Abstract: Elements of a radio frequency (RF) exposure safety program that provide reasonable and adequate guidance for preventing exposures in excess of recognized limits to electromagnetic fields from RF sources that operate in the frequency range of 3 kHz to 300 GHz are described in IEEE Std C95.7™-2014. The means for accomplishing this are classifying exposure locations into one of four categories based on the potential hazard, as defined by exposure limits, and specifying appropriate controls for each category. Such controls include engineering and administrative controls as well as the use of personal protective equipment, placement of appropriate RF safety signage, designation of restricted access areas, the use of personal RF monitors, and RF safety awareness training. These recommendations are not intended to apply to the purposeful exposure of patients by or under the direction of medical practitioners, but can be used in the development of safety programs for medical staff and other persons working with or incidentally exposed to RF fields, and for those wearing implanted or external medical electronic devices. Although designed to complement IEEE Std C95.1™, this recommended practice may also be used for the development of programs to ensure conformance with other guidelines, standards, or regulations for controlling human exposure to electromagnetic energy as well as IEEE Std C95.6™ in which case, appropriate modifications will be necessary to address the low frequency region addressed by IEEE Std C95.6™.

Keywords: access restriction, electromagnetic exposure, electromagnetic fields (EMF), exposure assessment, exposure categorization, IEEE C95.7™, non-ionizing radiation (NIR), personal monitors, personal protective equipment (PPE), radio frequency (RF), radio frequency safety program (RFSP), RF awareness training, RF exposure, RF protection, RF safety committee, RF safety officer, signage

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Introduction

This introduction is not part of IEEE Std C95.7™-2014, IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz.

In 1960, the American Standards Association approved the initiation of the Radiation Hazards Standards project under the co-sponsorship of the Department of the Navy and The Institute of Electrical and Electronics Engineers. Prior to 1988, C95 standards were developed by an accredited standards committee C95 and submitted to the American National Standards Institute (ANSI) for approval and issuance as ANSI C95 standards. Between 1988 and 1990, the committee was converted to Standards Coordinating Committee 28 under the sponsorship of the IEEE Standards Board. In 2001, the IEEE Standards Association Standards Board approved the name "International Committee on Electromagnetic Safety" (ICES) for SCC28 to better reflect the scope of the committee and its international membership. In accordance with policies of IEEE, C95 standards are issued and developed as IEEE standards, as well as submitted to ANSI for recognition.

The present scope of IEEE ICES is the:

"Development of standards for the safe use of electromagnetic energy in the range of 0 Hz to 300 GHz relative to the potential hazards of exposure of man, volatile materials, and explosive devices to such energy. It is not intended to include infrared, visible, ultraviolet, or ionizing radiation. The committee will coordinate with other committees whose scopes are contiguous with ICES."

Subcommittee 2 of ICES is responsible for this recommended practice. There are five subcommittees concerned with:

1. Techniques, procedures, and instrumentation
2. Terminology, units of measurement, and hazard communication
3. Safety levels with respect to human exposure, 0 kHz-3 kHz
4. Safety levels with respect to human exposure, 3 kHz-300 GHz
5. Safety levels with respect to electro-explosive devices

Three standards, two recommended practices, and one guide have been issued. Current versions are:

IEEE Std 1460™-1996 (Reaff 2002), IEEE Guide for the Measurement of Quasi-Static Magnetic and Electric Fields.

IEEE Std C95.1™-2005, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

IEEE Std C95.2™-1999 (Reaff 2005), IEEE Standard for Radio-Frequency Energy and Current Flow Symbols.

IEEE Std C95.3™-2002 (Reaff 2008), Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz–300 GHz.

IEEE Std C95.4™-2002 (Reaff 2008), IEEE Recommended Practice for Determining Safe Distances from Radio Frequency Transmitting Antennas When Using Electric Blasting Caps During Explosive Operations.

IEEE Std C95.6™-2002 (Reaff 2007), IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz.

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This Recommended Practice for Radio Frequency Safety Programs (RFSPs), IEEE Std C95.7™, represents a unique product for ICES. Heretofore, no single document has been available that provided guidance for the development of RFSPs. While RF exposure limits are prescribed in IEEE Std C95.1™-2005, RF measurement techniques in IEEE Std C95.3™-2002, and RF safety signs and labels in IEEE Std C95.2™-2005, none of those documents provide specific insight on how to integrate the subjects of those standards with exposure assessment to arrive at practical measures for controlling exposure of persons subject to RF fields so that applicable RF limits are not exceeded. This recommended practice provides a practical means for accomplishing this by first characterizing areas into one of four exposure categories according to the potential risk for exposure above defined RF exposure limits and then specifying the appropriate controls. A table is provided that specifies which of the several potential elements described in the document should be included in the RFSP based on the assigned category.

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1. Overview

1.1 Scope

This recommended practice presents guidelines and procedures that could form the basis of a radio frequency exposure safety program[1] (RFSP) that provides reasonable and adequate guidance for preventing exposures above applicable radio frequency (RF) limits associated with RF sources that operate in the frequency range of 3 kHz to 300 GHz under many circumstances. This is a general-purpose document intended for application in most RF exposure scenarios with the goal of avoiding potentially hazardous exposures to electromagnetic fields, currents, and/or contact voltages. In some complex cases, however, the required elements of an adequate RFSP may exceed those described in this document. In such cases, additional guidance may be necessary to affect a satisfactory RF safety solution. There are many ways of accomplishing the goal of a satisfactory RF safety program. While this recommended practice outlines certain schemes for providing a safe environment for persons who may be exposed to excessive levels of electromagnetic energy, other schemes may be equally effective.

[1] For the purposes of this document, the term "RF safety" is a shorthand notation used to mean "RF exposure safety." See definitions.

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1.2 Purpose

These guidelines are provided to assist in the development of RF safety programs for the safe use of RF energy-producing devices, equipment, and systems, and to prevent exposures in excess of applicable RF limits for workers or the public. The means for accomplishing this are by first characterizing areas into one of four exposure categories according to the potential risk for exposure above prescribed RF exposure limits, as described in 1.3, and then, where relevant, specifying the appropriate controls to reduce the likelihood of over-exposure. For many situations, this guidance will assist in the development of site-specific RF safety programs, while in others the programs may be developed to apply across a wide range of exposure environments. These guidelines are designed to complement the ICES TC-95 family of standards on electromagnetic safety, but may find use in the development of effective programs for conformance with other guidelines, standards, or regulations for controlling human exposure to electromagnetic energy. This recommended practice provides guidelines for establishing RF safety programs, but other recommendations may already exist that are deemed sufficient by local regulatory authorities for achieving RF safety in particular environments. Hence, other recommendations could potentially replace or be used in conjunction with the recommendations in this document. Guidelines developed for specific applications, for example, radio amateur operations [B4][2] and electrical transmission/distribution personnel working near mobile phone base-station antennas installed on electric utility structures [B22], represent two such examples.

1.3 Application

The objective of this recommended practice is to provide guidance for the implementation of an RF safety program. Such programs are recommended whenever exposures have the potential to exceed a defined action level or exposure limit (also called the RF safety program initiation level—RFSPIL). RFSPILs, or action levels or exposure limits, are typically defined in the applicable safety standard. How the levels or limits are defined and controlled is an important part of an RFSP. For purposes of this recommended practice, the RFSPIL is any of the following criteria (where applicable):

— The lower tier exposure levels of IEEE Std C95.1[3]

— The general public reference levels (lower tier) of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines [B16]

— The general population/uncontrolled maximum permissible exposures of the U.S. Federal Communications Commission (FCC) [B12]

— One fifth of the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) [B2]

The assessment of the RFSPIL includes all applicable aspects of temporal and spatial averaging as specified in the associated standards, guidelines, and regulations. It also includes a consideration of the precedence of fundamental limits [such as basic restrictions (BRs)] over derived limits (such as MPE levels, investigation levels, and reference levels). For example, devices or systems that have been determined to not be capable of producing exposures that would exceed the BRs of the relevant exposure limits may need no RF safety program, even though the external fields may exceed the RFSPIL. Exposure conditions may also consist of the presence of an RF field and/or the potential to touch or grasp objects energized by RF fields.

A practical means for developing an RF safety program is to first categorize the RF sources and systems according to their potential for producing RF exposure above the RFSPIL or exposure limits, and then to specify appropriate controls for each category. The term “controls” refers to both engineering and

[2] The numbers in brackets correspond to those of the bibliography in Annex I.
[3] Information on references can be found in Clause 2.

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administrative means for preventing exposure above defined RF exposure limits. (See Clause 4 for details on possible controls.)

Differentiation between uncontrolled, or general public, exposure environments, and controlled, or occupational, exposure environments, is primarily a matter of awareness and informed acceptance. The design of an RFSP should carefully address the characteristics of the population defined as "general public" to ensure that the administrative and engineering controls implemented are sufficient to protect that population. For example, if a controlled area is otherwise easily accessible by a visually handicapped person, signage may not be sufficient to delineate the boundary between uncontrolled and controlled areas.

In simple situations, the examples in Annex B and Annex C can be used to determine the exposure category. Some circumstances may require only a very minimal program, while others could require exposure assessment by a competent RF safety professional. It should be noted, however, that the operation of many RF sources and systems may be such that an RFSP is not needed at all (see Table 1, Category 1). RF sources and systems with the potential for producing greater exposures in accessible locations (Table 1, Category 2, Category 3, and Category 4), e.g., near RF dielectric heaters or high power broadcast antennas, will normally require additional RFSP elements. The categories shown in Table 1 are based on the potential for producing exposures in accessible areas in excess of the RFSPIL or applicable exposure limit (see definition of "RFSPIL" relative to the potential for RF shocks and/or burns). Situations should be evaluated by sequentially determining which set of exposure conditions applies, beginning first with those for Category 1. A summary of the recommended actions for each category is also included in Table 1.

Table 1—Summary of RFSP categories based on RF exposure conditions

RFSP category	Maximum potential exposure condition[a]	Control actions required
1	Operational characteristics of source(s) would not cause the RFSPIL or lower tier limit to be exceeded.	None, unless maintenance or other conditions alter category
2	Operational characteristics of source(s) may cause the lower tier exposure limit to be exceeded in accessible areas, but the upper tier limit would *not* be exceeded.	See Table 3
3	Lower tier exceeded and potential to exceed the upper tier exposure limit in accessible areas unless mitigating controls are applied.	See Table 3
4	Exposure will exceed *ten times* the upper tier exposure limit in accessible areas.	Restrict source output to achieve Category 3, 2, or 1 conditions, or prevent personnel access (see Table 3)

[a]In assessing the characteristics of an RF environment, consideration should be given to the potential for excessive exposure in the case of an accidental failure of systems that normally preclude excessive exposure such as breaks in waveguides. See text in this subclause for more information.

An effective RFSP can be used to ensure that employees and the general public are provided adequate protection against RF exposure in excess of applicable limits contained in applicable standards or guidelines, a few of which are listed in Annex I [B2], [B6], [B7], [B9], [B12], [B16], [B17], [B26]. This document describes the various elements that can be included in an RFSP. It also recommends when a specific element of the RFSP is needed based on the potential risks from RF hazards. While most of the recommendations contained in this document focus on occupational exposure situations, they will also be found applicable to public exposure settings. An RFSP is generally recommended anytime and anywhere persons may have the opportunity to occupy areas wherein RF exposures can exceed the exposure limits or RFSPIL as defined in the applicable standards or regulations. For purposes of this recommended practice, the applicable exposure limits are those values that are relevant to the appropriate level of control, be it for occupational or controlled environment exposures, or for general public or uncontrolled environment exposures.

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Owners and operators of equipment that produce (intentional or incidental) RF emissions and any consequent exposure of persons will generally be responsible for the development of an RFSP. It should be recognized, however, that there may be similar responsibilities carried by those who simply own, operate, or manage facilities in or on which RF sources may be located [B28]. While the actual legal assignment of liabilities between these parties may vary between different countries and even between local and/or state jurisdictions, the provider or owner of the RF source equipment should inform facility management of those actions that they deem important for compliance with applicable exposure limits and, where relevant, provide necessary guidance for any required action. For example, property management organizations having locations with RF sources, but who bear no direct operational responsibilities, should share a common goal of ensuring the safety of both their own employees (and any subcontractors) and the general public. Furthermore, in many cases, the successful implementation of an RFSP can be highly dependent on the level of cooperation between property management and the regulated entities operating the RF sources [B28]. This same concept extends to broadcast sites where independent but multiple broadcast stations use but do not own the site [B10]. To this end, this recommended practice offers guidance to such organizations relative to the administrative and technical considerations of RFSPs.

A device with potentially higher exposure capability might be placed in Table 1, Category 1 due to its operational characteristics. For example, the inherent duty-factor characteristics of a radar transmitter may produce time-averaged RF fields that are less than the RFSPIL level in accessible areas (source-based time averaging). Repetitive antenna rotations may also play a significant role in reduction of time-averaged exposures (e.g., exposure from a rotating antenna versus a non-rotating antenna). However, Category 1 is not intended to include situations in which compliance with the applicable exposure limit requires some action by the exposed person, such as limiting the amount of time spent in certain locations (time averaging). Furthermore, there may be situations in which high power systems may be incapable of producing significant exposure under normal conditions, but could produce serious exposures under other than normal conditions. Examples of such systems include waveguides carrying high power, which do not produce significant exposures as long as the waveguide remains intact with no leaks due to breaks in the waveguide itself or at the flange seals. Alternatively, high power systems that are protected with interlocks to avoid significant exposures may be considered of no special consequence, but may produce high-level exposures if the interlock system fails. When evaluating the characteristics of an RF exposure environment for purposes of categorization, consideration should be given to the potential significance of an equipment failure relative to the requirement of an appropriate RFSP. Figure 1 provides a graphical representation of the categorization process described above and shows recommended RF safety signage appropriate to the exposure category.

The guidance of Table 1 is formulated to permit adaptation to either one-tier or two-tier RF exposure limits. An example of one-tier exposure limits is found in the ACGIH threshold limit values for exposure to RF fields [B2]. Examples of two-tier exposure limits are IEEE Std C95.1™-2005 [B17], FCC regulations [B11], the ICNIRP guidelines [B16], and the National Council on Radiation Protection and Measurements (NCRP) recommendations [B26].

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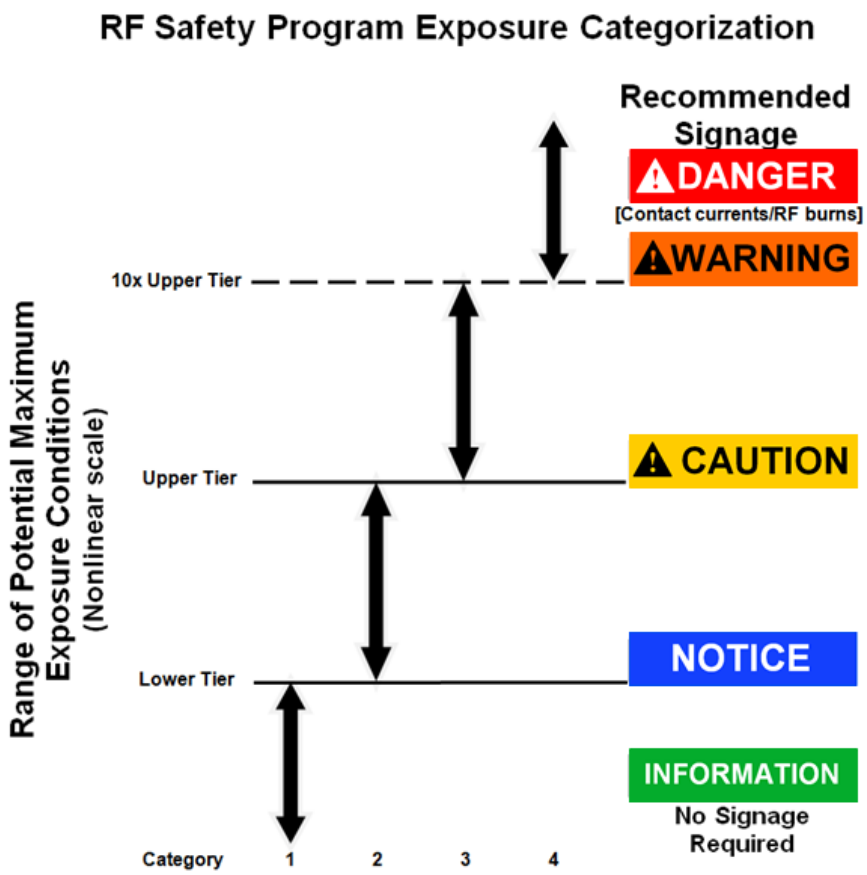

Figure 1—Graphical representation of the RF safety program categorization process corresponding to Table 1, Category 1 through Category 4

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std C95.1™, IEEE Standard for Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.[4, 5]

IEEE Std C95.2™, IEEE Standard for Radio-Frequency Energy and Current Flow Symbols.

IEEE Std C95.3™, IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz–300 GHz.

IEEE Std C95.4™, IEEE Recommended Practice for Determining Safe Distances From Radio Frequency Transmitting Antennas When Using Electric Blasting Caps During Explosive Operations.

IEEE Std C95.6™, IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz.

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3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause. [6]

access control: A practice of restricting access to areas wherein RF exposure may exceed applicable exposure limits via physical means such as indicative or positive access control barriers or by the installation of appropriate signage. RF safety signage, when used in controlled environments and combined with appropriate RF safety training or information, can be a sufficient means of access control.

action level: *See:* **RFSPIL**.

administrative controls: Procedures and information provided to personnel for the purpose of reducing exposure to potential RF hazards and that generally depend on the awareness and participation of personnel for their effectiveness. Examples include warning/alerting signs and visual/audible alarms, indicative barriers (e.g., rails and chains), standard operating procedures (safe work practices), personal protective equipment (PPE), time limits on the duration of exposure (time averaging), and RF safety training.

ancillary hazards: Those hazards that are subordinate to the primary hazard. Ionizing radiation, toxic/hazardous chemicals and gases, electrical hazards, and mechanical hazards are examples of ancillary hazards. *Syn:* **associated hazard**.

averaging time (T_{avg}): The appropriate time period over which exposure is averaged for purposes of determining compliance with an exposure limit, maximum permissible exposure (MPE), or reference level.

basic restrictions (BRs): Exposure restrictions that are based on established adverse health effects that incorporate appropriate safety factors and are expressed in terms of the *in situ* electric field (3 kHz to 5 MHz), specific absorption rate (100 kHz to 3 GHz), or incident power density (3 GHz to 300 GHz). Depending upon the frequency of the electromagnetic field, the physical quantities used to specify these restrictions are internal electric field strength (E_{int}), current density (J), specific absorption rate (SAR), specific absorption (SA), and power density (S). They are formulated in metrics that quantify RF field induced inside the body, which consequently provide a more accurate measure of potentially harmful exposure compared to derived limits based only on ambient field-strength (E and H) exposures. However, BR quantities are often difficult and impractical to measure.

contact current (I_C): Current induced at the point of contact between the body and an energized RF conductor. Contact current at a person's fingertip (touch contact) is typically estimated by measuring current at the wrist using a clamp-on type of current transformer instrument. Contact may be via a grasp or touch. *See also:* **grasp contact** and **touch contact**.

NOTE—Limits on contact currents are designed to protect against the possibility of RF shocks or burns that may result from high current densities at the point of contact, particularly at the fingertip.[7]

contact voltage: Voltage between a body and an energized RF conductor. In practice, the open circuit voltage that exists between an object, typically immersed in an RF field, and the body of a person about to touch the object.

[6] *IEEE Standards Dictionary Online* subscription is available at: http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.
[7] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

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