IEEE Standards Interpretations for 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

October 2011

Interpretation Request #1
On page 28 of IEEE Std C95.1-2005, 4.6, it states "Relaxation of the power density MPE for localised exposures." We are not sure if this standard is applicable if the RF radiating devices is 0.1m from the human body. Can this standard be applied, using the relaxation of power density MPE? 2. On page 29 of IEEE Std C95. last paragraph of 4.7, it states that "A practical guideline for eliminating the need to assess whether the whole body average SAR exceeds the basic restriction of 0.4W/kg (or 0.08 W/kg) is to determine if the power of the sources(s) exceeds 28W (upper tier) or 5.6W (lower tier) for an average man (70kg)." It is not clear how to interpret this statement. If each individual RF source passes their full body SAR, can their individual measured SAR be totaled and ensure that they do not exceed 0.4W/kg or 28W (based on 70kg for average person)?

Interpretation Response
An interpretation of IEEE Std C95.1-2005 has been requested regarding:

1. Relaxation of the power density maximum permissible exposure (MPE) for localized exposures (4.6).
2. The assessment of the basic restriction based upon the power of the sources (4.7).

Subclause 4.6 (relaxation of the power density MPEs for localized exposures) states, in part, "Compliance with the MPE of Table 8 (upper tier) is determined from spatial averages of power density or the mean squared electric and magnetic field strengths over an area equivalent to the vertical cross section of the human body (projected area) at a distance no closer than 0.2 meters from the field source." Because of measurement uncertainty, relaxation of the power density MPEs for localized exposures at distances

closer than 0.2 meters from the source is not permitted. That is, the provisions of 4.6 (relaxation of power density MPE values) do not apply for exposures determined by field measurements made within 0.2 meters of a source. Additional reasons for the recommendation against relaxation of MPEs for localized exposures within the 0.2 meter exclusion distance specified in 4.6 include the following:

- RF burns are possible when accidentally contacting RF sources and these probably constitute the most harmful RF exposure hazard (C.1.2.1 Risk profile for adverse effects).
- Near sufficiently high powered RF sources there can be localized RF heating effects that are undeniably realistic hazards, but occur much less commonly than RF burns (C1.2.2 Risk profile for adverse effects).

Therefore, relaxation of the power density MPE for localized human RF exposures within 0.2 m from a source is not permitted by 4.6 of IEEE Std C95.1-2005.

Regarding the source power levels discussed in 4.7 (assessing compliance with this standard) that are used for determining SAR, the governing portion of 4.7 states: "A practical guideline for eliminating the need to assess whether the whole-body average SAR exceeds the basic restriction of 0.4 W/kg (or 0.08 W/kg when the lower tier is used as an exposure limit for the public) is to determine if the power of the source(s) exceeds 28 W (upper tier) or 5.6 W (lower tier) for an average man (70kg)." Therefore, if the sum of the power of the sources is less than 28 W for the upper tier or 5.6 W for the lower tier, then the need to assess whether the whole-body average SAR exceeds the basic restriction is eliminated. Bear in mind that the last sentence of 4.7 states: "Such a determination, however, does not necessarily imply that the basic restriction on local SAR would not be exceeded." In summary:

1. The provisions of 4.6 of IEEE Std C95.1-2005 do not permit relaxation of the power density MPEs for localized exposures at distances closer than 0.2 meters from a source.
2. If the sum of the power of the sources is less than 28 W for the upper tier or 5.6 W for the lower tier, then the need to assess whether the whole-body average SAR exceeds the basic restriction is eliminated, according to 4.7 of IEEE Std C95.1-2005. Such a determination does not imply that the basic restriction on local SAR would not be exceeded.

Interpretation Request #2
Topic: The correct limit to use for the general public when an RF Safety Program is in place.

An interpretation of IEEE Std C95.1-2005 is requested regarding the correct limit to use for the general public when an RF Safety Program is in place. Is it the Action Level or the Upper Tier?

Below is a hypothetical situation to help illustrate the need for interpretation. The frequency was chosen to simplify the example.

1. A company has an RF emitter that operates at 15 GHz. It's installed on company property and there are no local RF exposure standards except for the company-adopted IEEE Std C95.1-2005.
2. The RF emitter is located inside a fenced-in area and is controlled by an RF Safety Program. Access to the area is limited to personnel trained in accordance with the site specific RF Safety Program. The RF Safety Program also has established "keep-out" zones to prevent any access to areas above the Upper Tier, as well as signage and other controls commensurate with the power density levels capable of being produced by the RF emitter.
3. Outside of the fenced-in area is the general public, who is unaware of what is happening on the other side (company property). The company's RF Safety Program limits the power density levels from the RF emitter to which the general public is being exposed.
4. As part of the company's RF Safety Program, what level must not be exceeded outside of the fence for the general public, 1 mW/cm2 or 10 mW/cm2?

Cited below are portions of IEEE Std C95.1-2005 relevant to the above situation. Sections underlined, support the interpretation that the answer is the upper tier limit of 10 mW/cm2.

1.3.2 RF risk assessment and RF safety programs
Throughout the RF spectrum to which this standard is applicable, the MPEs apply to exposure of individuals. Areas wherein intense RF fields exist (that exceed the MPEs) would be an exposure issue only when individuals have access to those areas and may become exposed. Hence, compliance with this standard is to be determined by assessing whether persons may be exposed to RF fields exceeding the MPEs and not necessarily by whether RF fields simply exceed the MPEs. This standard recommends that when and where there may be access to RF fields, currents, and/or voltages that exceed the lower tier MPEs (action levels); exposures are to be controlled through the implementation of an RF safety program, as described in IEEE Std C95.7-2005. Application of an RF safety program results in various control measures that can be taken to reduce the probability of a person's exposure exceeding the BRs and MPEs of the upper tier.

3.1 Definitions

3.1.1 action level: The values of the electric and magnetic field strength, the incident power density, contact and induced current, and contact voltages above which steps should be initiated to protect against exposures that exceed the upper tier, specifically, implementation of an RF safety program.

3.1.35 lower tier: A set of limits that provide an additional margin of safety, i.e., a margin of safety greater than that for the upper tier. See: action level.

NOTE—The lower tier, which is recommended as an action level above which an RF safety program should be implemented, recognizes public concerns, uncertainties in exposure assessment, and supports the process of harmonization with other standards.

3.1.59 RFF safety program (RFSSP): An organized system of policies, procedures, practices and plans designed to protect against hazards associated with RF fields, contact voltage, and contact and induced currents. RFSPs shall be documented in writing.

NOTE 1—Implementation of an effective RF safety program is to ensure that persons are not exposed in excess of the MPEs of the upper tier.

3.1.79 upper tier: A set of RF exposure limits that are scientifically based and that provide a margin of safety for all, including those in a controlled environment.

Table 6—BRs for frequencies between 100 kHz and 3 GHz

		Action level[a] SAR[b] (W/kg)	Persons in controlled environments SAR[c] (W/kg)
Whole-body exposure	Whole-Body Average (WBA)	0.08	0.4
Localized exposure	Localized (peak spatial-average)	2[c]	10[c]
Localized exposure	Extremities[d] and pinnae	4[c]	20[c]
[a]BR for the general public when an RF safety program is unavailable.			
[b]SAR is averaged over the appropriate averaging times as shown in Table 8 and Table 9.			
[c]Averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube).*			
[d]The extremities are the arms and legs distal from the elbows and knees, respectively.			

*The volume of the cube is approximately 10 cm^3.

See footnote "a" in Table 6 above.

f = 100 kHz to 110 MHz

Condition	Action level[a] (mA)	Persons in controlled environments (mA)
Both feet	90	200
Each foot	45	100
Contact, grasp[b]	—	100
Contact, touch	16.7	50
NOTE 1—Limits apply to current flowing between the body and a grounded object that may be contacted by the person.		
NOTE 2—The averaging time for determination of compliance is 6 minutes.		
[a]MPE for the general public in absence of an RF safety program.		
[b]The grasping contact limit pertains to controlled environments where personnel are trained to make grasping contact and to avoid touch contacts with conductive objects that present the possibility of painful contact.		

See footnote "a" in Table 7 above.

4.3 BRs for frequencies between 3 GHz and 300 GHz
BRs to protect against adverse effects associated with heating are established for incident power density for frequencies between 3 GHz and 300 GHz. Such restrictions are derived with consideration of adverse effects thresholds (based on the literature review and evaluation), their distribution among the population, and safety factors. The BRs for frequencies between 3 GHz and 300 GHz are the same as the corresponding MPEs shown in Table 8 and Table 9, and are considered appropriate for all human exposure.

Table 9—Action level (MPE for the general public when an RF safety program is unavailable) (see Figure 4 for graphical representation)

4.8 RF safety programs
Throughout the RF spectrum applicable to this standard, the MPEs apply to exposure of people, i.e., compliance with this standard is determined by whether or not exposures of people to RF fields, currents and voltages exceed the applicable MPEs. Where there may be access to RF fields, currents, and/or voltages that exceed the lower tier (Action Level) of this standard, an RF safety program such as detailed in IEEE Std C95.7™-2005 shall be implemented to ensure that exposures do not exceed the MPEs or BRs for persons in a controlled environment. Application of an RF safety program results in various mitigative measures that can be taken to reduce the probability of exceeding the MPE for the upper tier. This program typically includes RF awareness training, implementation of protective measures such as signage and the use of personal protective equipment (PPE),

incident response, periodic evaluation of program effectiveness, and assigned responsibilities for implementing the program (IEEE Std C95.7-2005).

C.1 Introduction
In summary, this standard incorporates a reasonably large margin of safety and an RF safety program is required to provide part of the margin of safety for those exposed above the relevant action level (lower tier). This standard may also be considered especially conservative, since the safety factors are applied against perception phenomena (electrostimulation and behavioral disruption), which are far less serious effects than any permanent pathology or even reversible tissue damage that could occur at much higher exposure levels than those for perception phenomena.

C.1.1.2 Differences
a) IEEE Std C95.1, 1999 Edition contains two tiers; an upper tier for "exposures in controlled environments" and a lower tier for "exposures in uncontrolled environments." In this standard, two tiers have also been set. As in the 1999 Edition of this standard, an upper tier has been set for exposure of persons in controlled environments. While the weight of scientific evidence supports the conclusion that no measurable risk is associated with RF exposures less than the upper tier of this standard, it is impossible to scientifically prove absolute safety (the null hypothesis). Thus a lower tier has been set with an extra margin of safety that applies to all other individuals. The lower tier, called an "action level," recognizes public concerns, takes into account uncertainties in laboratory data and in exposure assessment, and supports the process of harmonization with other standards, e.g., the NCRP recommendations [B95] and the ICNIRP [B62] guidelines. For practical purposes, the lower tier may be used for the general public or as an action level, above which an RF safety program shall be implemented to protect against exposures that exceed the upper tier. (See Clause 3 for definitions of "lower tier," "upper tier," and "action level.")

C.2.2.1 Basic restrictions for whole-body exposure
Within the committee that drafted this standard, a strong scientific argument, based on the biological effects database for potentially adverse effects was made for a single tier standard at 0.4 kg WBA SAR. The upper tier is considered protective for all with an acceptable margin of safety. Nevertheless, similar to IEEE Std C95.1, 1999 Edition [B70] a lower tier, with an additional margin of safety is included. The upper tier in this standard applies to persons in controlled environments; the lower tier, with an extra margin of safety, applies to all other individuals.

Since publication of ANSI C95.1-1982 [B69], significant advances have been made in our knowledge of the biological effects of RF exposure. This increased level of knowledge strengthens the basis for and confidence in the statement that the MPEs provided in this standard are protective against established adverse health effects with an adequate margin of safety. Nonetheless, because of the inherent limitations of the biological effects data base, these MPEs are presented as upper limits of exposure. While the weight of scientific evidence supports the conclusion that no measurable risk is associated with

RF exposures less than the upper tier of this standard, it is impossible to scientifically prove absolute safety (the null hypothesis). The lower tier thus recognizes public concerns, serves as an action level above which implementation of an RF safety program is required, helps account for uncertainties in laboratory data and exposure assessment, and supports the process of harmonization with other standards, e.g., the NCRP recommendations [B95] and the ICNIRP [B62] guidelines. While exposures slightly in excess of the MPEs are not necessarily harmful, such exposures are not desirable and should be avoided. Wherever RF exposures can exceed the Action Levels of this standard, steps should be taken to ensure that the MPEs will not be exceeded.

Arguments supporting the lower tier are: a) It is traditional to afford the general public a greater margin of safety. The general public includes, but is not limited to, children, pregnant women, the aged and infirm, individuals with impaired thermoregulatory systems, individuals equipped with electronic medical devices, and persons using medications that may result in poor thermoregulatory system performance. b) This approach is consistent with the previous IEEE Std C95.1 standard and most other health and safety standards for RF exposure. c) It is traditional to warn individuals of exposures to potentially harmful agents, and to implement safety measures to mitigate the hazards. Therefore the lower tier can be a useful criterion, or "action level," for determining when RF "awareness" communication is required and above which other elements of an RF safety program shall be implemented. RF "awareness" is particularly important for protecting against accidental excessive exposures. d) Exposure standards such as IEEE Std C95.1 traditionally have been used as the basis for environmental limits (limits for the general environment whether people are there or not) through a lower tier that incorporates a larger margin of safety.

C.6.3 Conclusions

There is no substantiated evidence of illness or injury resulting from exposure to electromagnetic energy in the RF range when the exposures are within the limits of this standard. The experience of RF burns is well known to the occupational RF and medical communities, and is a principal hazard to be protected against by compliance with this standard. Transient electrical sensations, even those that are painful, are sometimes experienced by electrical workers; these are made improbable by compliance with this standard. Over all, the standard incorporates a reasonably large margin of safety. An RF safety program shall be employed for those potentially exposed above the lower tier. Indeed, the standard may be considered especially conservative, since the safety factors are applied against perception phenomena (electrostimulation, behavioral disruption) which are far less serious than reversible tissue damage and any permanent pathology that would occur at exposure levels much higher than those for perception phenomena.

Interpretation Response

In IEEE Std C95.1-2005, two tiers of exposure values (derived limits, i.e., MPEs) are provided. The lower tier (called an Action Level) applies when an RF safety program is unavailable; the upper tier applies to exposures in controlled environments. The Action Level is intended to trigger the application of an RF safety program to ensure that no

one is exposed above the MPE values for the upper tier. As declared in the title of Table 9, the Action Level is the appropriate "MPE for the general public when an RF safety program is not available." This means that when an RF safety program is in effect, the applicable exposure limit for all persons, including members of the general public affected by the safety program, is the upper tier MPEs (MPEs for people in controlled environments).1 The crucial factor is whether actions have been taken to ensure that no one can be exposed above the upper tier (i.e., an RF safety program applies to areas in which exposures may exceed the Action Level). A corollary is: for circumstances in which exposures of persons are not controlled via an RF safety program, the lower tier (Action Level) becomes the MPE. Hence, in the question cited in the beginning of this Request for Interpretation, when an RF Safety Program is in place the correct limits to use for workers or the general public affected by the Safety Program is the upper tier (MPEs for exposures in controlled environments).

To be clear, within those regions in which an RF safety program is practiced, namely, controlled environments, the upper tier becomes the MPE for everyone, including members of the public affected by the safety program, because within those regions, exposures are controlled to not exceed the MPE. However, for those regions beyond which the RF safety program applies, the applicable exposure limit for all persons is the lower tier Action Level. Normally, the extent of the region controlled by an RF safety program would likely be the legal property boundaries of the facility or, perhaps, a physical boundary such as the edge of a rooftop installation or, as in the case cited in the request, a fence line. Hence, any RF safety program must ensure that exposures that may occur beyond the boundaries, for which the program applies, do not exceed the Action Level. This is because beyond these boundaries, a safety program applicable to the facility or site cannot be assumed to also limit exposure of persons to sources that are located outside the facility. For any RF safety program, it is important to carefully identify the geographic extent of the region in which the program applies and, thus, the area in which the upper tier MPE is applicable to all persons including the general public who may enter the facility.

For any RF safety program, it is important to carefully identify the geographic extent of the region in which the program applies and, thus, the area in which the upper tier MPE is applicable to all persons including the general public who may enter the facility.

In the question posed in item 4 of the request, "As part of the company's RF Safety Program, what level must not be exceeded outside of the fence for the general public, 1 mW/cm2 or 10 mW/cm2?", the answer depends on whether the company RF safety program applies beyond the fence. For any region that is under the control of the company RF safety program, the answer is 10 mW/cm2. For all regions that are not under the control of the company RF safety program, the answer is 1 mW/cm2.

1 See: C.1.1.2 a) "In this standard, an upper tier has been set for exposure of persons in controlled environments." [i.e., an environment in which an RF safety program exists]. And "…a lower tier has been set with an extra margin of safety that applies to all other individuals." [i.e., all persons not under the control of an RF safety program regardless of whether they are workers or members of the general public.]