IEEE

C95.7™

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

IEEE Standards Coordinating Committee 39

Sponsored by the
IEEE International Committee on Electromagnetic Safety

IEEE
3 Park Avenue
New York, NY 10016-5997, USA

22 March 2006

IEEE Std C95.7™-2005

Recognized as an
American National Standard (ANSI)

IEEE Std C95.7™-2005

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

IEEE Standards Coordinating Committee 39

Sponsored by the

IEEE International Committee on Electromagnetic Safety

Approved 22 September 2005

IEEE-SA Standards Board

Approved 2 February 2006

American National Standards Institute

Abstract: Elements of a radio frequency (RF) exposure safety program that can prevent or control potential risks associated with exposure to the electromagnetic fields from RF sources that operate in the frequency range of 3 kHz to 300 GHz are described in this recommended practice. 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 insure conformance with IEEE Std C95.6 and with other guidelines, standards, or regulations for controlling human exposure to electromagnetic energy.
Keywords: access restriction, electromagnetic exposure, electromagnetic fields (EMF), exposure assessment, exposure categorization, non-ionizing radiation (NIR), personal monitors, personal protective equipment (PPE), radio frequency (RF), radio-frequency exposure, radio frequency safety program (RFSP), RF awareness training, RF protection, RF safety committee, RF safety officer, signage

---

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2006 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 22 March 2006. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

Print: ISBN 0-7381-4836-9 SH95390
PDF: ISBN 0-7381-4837-7 SS95390

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied "**AS IS**."

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

NOTE—Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center. Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

This introduction is not part of IEEE Std C95.7-2005, 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, Inc. Prior to 1988, C95 standards were developed by 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 (SCC 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 SCC 28 to better reflect the scope of the committee and its international membership. In accordance with policies of the 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 as follows:

"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 the ICES is responsible for this recommended practice. There are five ICES subcommittees, each of whose area of responsibility is described below in correspondence with its designated subcommitte number:

1) Techniques, Procedures, and Instrumentation;
2) Terminology, Units of Measurements and Hazard Communication;
3) Safety Levels with Respect to Human Exposure, 0-3 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 (R2002), IEEE Guide for the Measurement of Quasi-Static Magnetic and Electric Fields.

IEEE Std C95.1™, 1999 Edition, 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 (R2005), IEEE Standard for Radio-Frequency Energy and Current Flow Symbols.

IEEE Std C95.3™-2002, 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, 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, IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz.

Copyright © 2006 IEEE. All rights reserved.

This recommended practice 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 C95.1-1999, RF measurement techniques in IEEE Std C95.3-2002, and RF safety signs and labels in IEEE Std C95.2-1999, 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. 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.

Notice to users

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: http://standards.ieee.org/reading/ieee/updates/errata/index.html. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: http://standards.ieee.org/reading/ieee/interp/index.html.

Copyright © 2006 IEEE. All rights reserved.

Participants

The Terminology, Units, and Hazards Communications Subcommittee wishes to especially acknowledge the very helpful assistance of Mr. Tim Harrington during the technical editing phase of preparing this recommended practice for publication.

This recommended practice was prepared by Subcommittee 2 on Terminology, Units and Hazard Communications of the IEEE ICES. The following persons participated on the Subcommittee 2 balloting committee that approved this recommended practice:

Richard A. Tell, *Chair*
David A. Baron, *Secretary*

E. R. Adair
V. Anderson
E. Aslan
D. Baron
R. Bodemann
A. Brecher
J. T. Bushberg
C. K. Chou
J. Cohen
R. A. Curtis
J. DeFrank
K. Gettman
W. Hammer
D. L. Haes, Jr.
E. Hare
R. Johnson
K. Joyner
J. Leonowich
E. D. Mantiply
R. I. Needy
J. M. Osepchuk
R. C. Petersen
B. J. Roberts
W. G. Scanlon
R. R. Strickland
R. A. Tell
P. A. Testagrossa
A. G. Varanelli
L. A. Williams
M. C. Ziskin

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

E. R. Adair
M. Ammann
R. Arefi
D. Baron
A. Brecher
C. K. Chou
R. Cleveland
J. Cohen
R. A. Curtis
J. D'Andrea
G. Dhingra
D. Fichtenberg
M. Glaser
D. L. Haes, Jr.
E. Hare
T. Harrington
J. Hatfield
M. Ikehata
S. Johnston
K. Joyner
E. Karabetsos
J. Leonowich
G. Lotz
R. Markus
A. Mousa
M. Murphy
M. Newman
J. M. Osepchuk
R. C. Petersen
V. Punj
B. Roberts
E. Root
W. G. Scanlon
A. R. Sheppard
R. R. Strickland
R. A. Tell
P. A. Testagrossa
D. Umbdenstock
A. G. Varanelli
L. A. Williams

Copyright © 2006 IEEE. All rights reserved.

When the IEEE-SA Standards Board approved this standard on 22 September 2005, it had the following membership:

Steve M. Mills, *Chair*
Richard H. Hulett, *Vice Chair*
Don Wright, *Past Chair*
Judith Gorman, *Secretary*

Mark D. Bowman
Dennis B. Brophy
Joseph Bruder
Richard Cox
Bob Davis
Julian Forster*
Joanna N. Guenin
Mark S. Halpin
Raymond Hapeman
William B. Hopf
Lowell G. Johnson
Herman Koch
Joseph L. Koepfinger*
David J. Law
Daleep C. Mohla
Paul Nikolich
T. W. Olsen
Glenn Parsons
Ronald C. Petersen
Gary S. Robinson
Frank Stone
Malcolm V. Thaden
Richard L. Townsend
Joe D. Watson
Howard L. Wolfman

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Richard DeBlasio, *DOE Representative*
Alan H. Cookson, *NIST Representative*

Michael D. Fisher
IEEE Standards Project Editor

Contents

Copyright © 2006 IEEE. All rights reserved.

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

1. Overview

1.1 Scope

This recommended practice presents guidelines and procedures that can form the basis of a radio frequency exposure safety program[1] (RFSP) that provides guidance for controlling hazards associated with radio frequency (RF) sources that operate in the frequency range of 3 kHz to 300 GHz. 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 effect 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.

1.2 Purpose

These guidelines are provided to assist in the development of RF safety programs for the use of RF energy-producing devices, equipment, and systems, and to control any potentially hazardous exposure of 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, then 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 IEEE C95 family of standards on electromagnetic safety, but may find use in the development of effective programs to ensure 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. Guide-

[1]For the purposes of this document, the term "RF safety" is a shorthand notation used to mean "RF exposure safety." See definition 3.1.35.

Copyright © 2006 IEEE. All rights reserved.

lines developed for specific applications, for example, radio amateur operations (see ARRL [B4][2]), and electrical transmission/distribution personnel working near mobile phone base-station antennas installed on electric utility structures (see IEEE P1654 [B23]), 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. 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, action levels are any of the following criteria (where applicable):

- The lower tier limits of IEEE Std C95.1.
- The general public (lower tier) of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines (see ICNIRP [B16]).
- The general population/uncontrolled exposure limits of the U.S. Federal Communications Commission (FCC) (see FCC 47 CFR 1.1310 [B12]).
- 1/5 of the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) (see ACGIH [B2]).

The assessment of the action levels 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 action level. Exposure conditions may also consist of the presence of an RF field and/or the potential to contact 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 action levels or exposure limits, and then to specify appropriate controls for each category. The term “controls” refers to both engineering and administrative controls for eliminating or reducing the potential exposure above the applicable RF exposure limits. Clause 4 gives 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 assure 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 more intense 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 action level or applicable exposure limit (see Clause 3, definition 3.1.1 for “action level” relative to the potential for RF shocks and/or burns). Situations should be

[2]The numbers in brackets correspond to those of the bibliography in Annex I.

 Copyright © 2006 IEEE. All rights reserved.

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	Exposure condition[a]	Control actions required
1	Operational characteristics of source(s) would not cause the action level to be exceeded.	None, unless maintenance or other conditions alter category.
2	Operational characteristics of source(s) could cause the action level to be exceeded, but would not cause the exposure limit to be exceeded in accessible areas.	See Clause 4 and Table 3.
3	Potential to exceed the exposure limit in accessible areas, if mitigating controls are not applied.	See Clause 4 and Table 3.
4	Exposure will exceed exposure limit in accessible areas.	Restrict source output to achieve Category 3, 2, or 1 conditions, or prevent personnel access (see Clause 4 and 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 control RF exposure of employees and the general public in areas where RF exposure may exceed the exposure limits contained in applicable standards or guidelines, a few of which are listed in Annex I (see ACGIH [B2], Australian Radiation Protection and Nuclear Safety Agency [B6], Canada Safety Code 6 [B7], Department of Defense, Instruction 6055.11 [B9], FCC 47 CFR 1.1310 [B12], ICNIRP [B16], IEEE Std C95.1-1991 [B18], and NCRP Report 86 [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 action levels 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 exposures.

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 (see NCRP [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 relevant to ensure 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 depen-

Copyright © 2006 IEEE. All rights reserved.

dent on the level of cooperation between property management and the regulated entities operating the RF sources (see NCRP [B28]). This same concept extends to broadcast sites where independent but multiple broadcast stations use but do not own the site (see FCC [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 action level in accessible areas. Repetitive antenna rotations may also play a significant role in reduction of time-averaged exposures (for example, exposure from a rotating antenna vs. 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 abnormal 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.

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 (see ACGIH [B2]). Examples of two-tier exposure limits are IEEE Std C95.1-1999 [B18], FCC regulations [B11], the ICNIRP guidelines [B16], and the National Council on Radiation Protection and Measurements (NCRP) recommendations [B26].

Copyright © 2006 IEEE. All rights reserved.

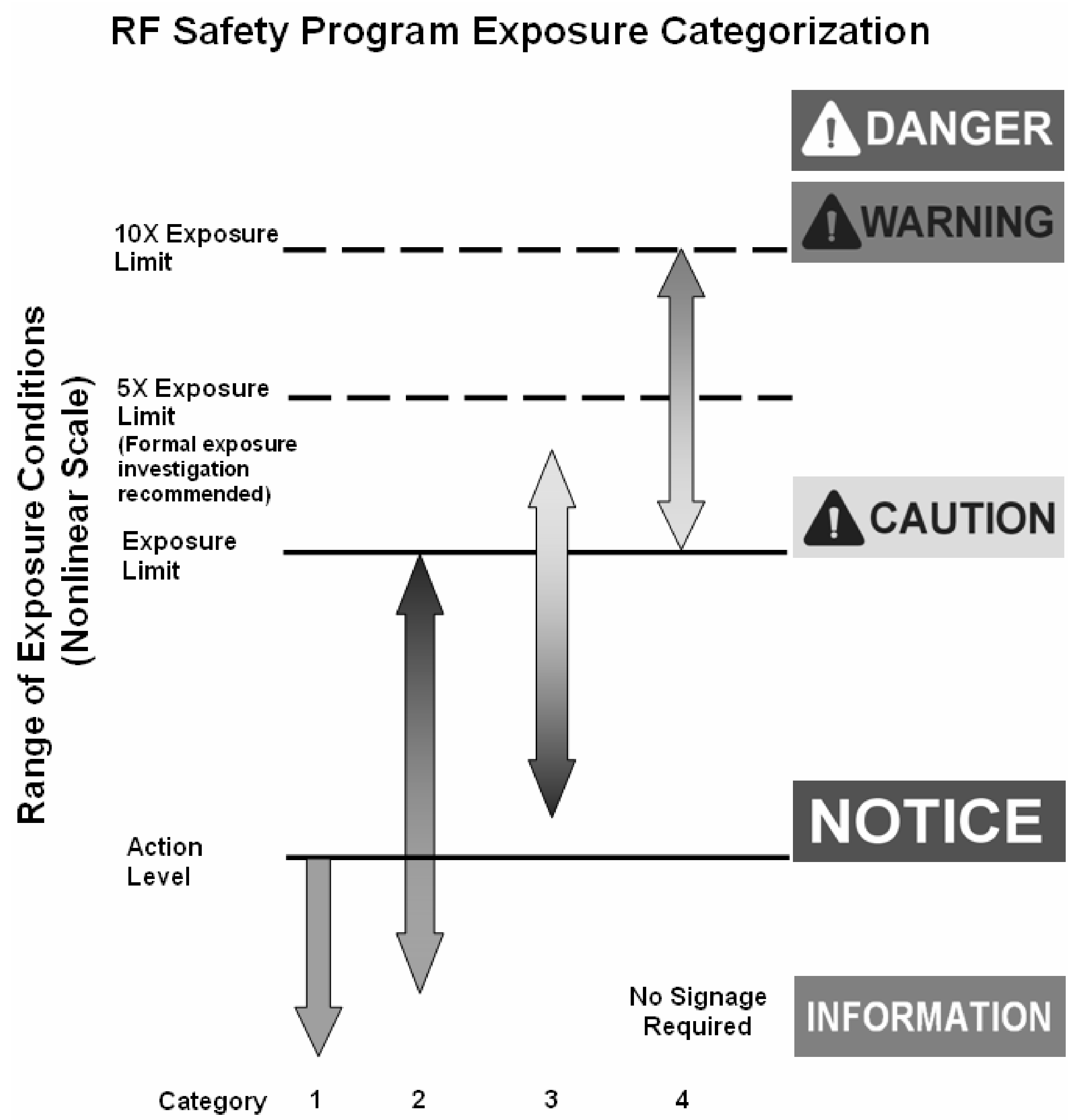

Figure 1—Graphical representation of the RFSP categorization process corresponding to Categories 1–4 of Table 1

2. Normative references

The following referenced documents are indispensable for the application of this document. In each case, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Copyright © 2006 IEEE. All rights reserved.

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

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.

3. Definitions, abbreviations, letter symbols for quantities, and unit symbols

For the purposes of this document, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* [B17] should be referenced for terms not defined in this clause.

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 voltage above which steps should be initiated to avoid exposures that exceed the upper tier of the applicable standards, guidelines and regulations, and in areas that are in close proximity (e.g., < 2 m) to RF conductors that may cause shock and burn hazards on contact.

3.1.2 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 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.

3.1.3 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**.

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

3.1.5 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 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.

3.1.6 contact current (I_C): Current induced at the point of contact between the body and an energized RF conductor. Limits on contact currents are designed to protect against the possibility of RF shocks or burns

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).
[4]The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

 Copyright © 2006 IEEE. All rights reserved.

that may result from high current densities at the point of contact, particularly at the fingertip. Contact current at a person's fingertip 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:* **grasping contact** and **touch contact**.

3.1.7 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.

3.1.8 controlled environment: An area where the occupancy and activity of those within is subject to control and accountability as established by an RF safety program for the purpose of protection from RF exposure hazards. *See also:* **general public exposure** and **occupational exposure**. *Contrast:* **uncontrolled environment**.

NOTE—Implementation of an effective RF safety program such as outlined in this recommended practice is to ensure that persons are not exposed in excess of the "Controlled Environment" MPEs.

3.1.9 derived limit: Alternative basis of compliance with a BR limit for whole-body SAR. A derived limit incorporates exposure metrics that can be measured outside of the body, and are consequently easier and more practical to measure than exposure metrics used with BR limits. However, derived limits are also a less direct and less accurate means of determining induced RF exposures in the body, but are formulated to comply with the BRs under typical or expected conditions for ambient exposures and body characteristics. Hence, RF exposures above the derived limits do not necessarily imply that the BRs on whole-body SAR have been exceeded for particular circumstances. The MPE levels in the IEEE standards and the reference levels in the ICNIRP guidelines are derived limits. Derived limits include limits for ambient electric field strength (E), magnetic field strength (H), magnetic flux density (B), currents flowing through the limbs (I_L) and contact current (I_C). *See also:* **maximum permissible exposure**.

3.1.10 electro-explosive device (EED): An explosive or pyrotechnic component that initiates an explosive, burning, electrical, or mechanical exothermic event and is activated by the application of electrical energy. An electric blasting cap is an example of an electro-explosive device

3.1.11 engineering controls: Controls and performance guidelines to reduce RF exposures as implemented by use of specific types of equipment, such as interlocks, protective housings, radomes, man-proof barriers, or the configuration of equipment at a site. Engineering controls do not depend on the awareness of personnel for their effectiveness in reducing exposure.

3.1.12 exposure limit: For purposes of this recommended practice, the root-mean-square (rms) or peak electric and magnetic field strengths, their squares, or the plane-wave equivalent power densities associated with these fields, and the induced and contact currents and contact voltages that are used to define the exposure categories and to which a person may be exposed without harmful effect and with an acceptable safety factor. *See also:* **derived limit**; **maximum permissible exposure**; **reference level**; **basic restriction**.

3.1.13 general public exposure: For purposes of this recommended practice, RF exposure of persons who have not received any form of RF safety awareness information or training. Typically, general public exposure occurs in uncontrolled environments and includes individuals of all ages and varying health status, including children, pregnant women, individuals with impaired thermoregulatory systems, individuals equipped with electronic medical devices, and persons using medications that may result in poor thermoregulatory system performance. *See also:* **uncontrolled environment**. *Syn:* **general population exposure**.

3.1.14 grasping contact: An electrical connection with a large energized conductor made by firmly holding the conductor in the hand. In this standard, a contact area of 15 square centimeters is assumed for such contact.

Copyright © 2006 IEEE. All rights reserved.

3.1.15 hazard: An intrinsic property or condition of a device, or location, that has the potential to cause harm to people or damage to property.

3.1.16 incidental radiator: A device that is not intentionally designed to emit RF energy, but does so as a by-product of its operation.

3.1.17 indicative barriers: Barriers, such as chains and rails, that require awareness and participation of personnel as a form of administrative controls.

3.1.18 industrial hygiene: A science devoted to the protection and improvement of the health and well-being of workers exposed to chemical and physical agents in their work environment.

3.1.19 insignificant radiator: An RF device that cannot under any circumstances emit RF energy sufficient to cause exposures that exceed the applicable limits.

3.1.20 intended use: The use of a device over its full range of functions, in accordance with the instructions provided by the manufacturer.

NOTE—Intended use, i.e., the way a manufacturer specifies that a device should be used, and the way that a device is actually used may not be the same.

3.1.21 limb current (I_L): RF current induced in a person's limb. Limits on limb currents are designed to protect against excessive RF heating in the wrists and ankles, and are most often measured using RF current transformers.

3.1.22 man-proof barriers: Locked doors and ladder cages, man-proof fences, etc., that are a form of engineering controls and that provide a positive restriction on access.

3.1.23 maximum permissible exposure (MPE): Derived limits in RF exposure standards for time averaged and peak exposures to ambient electric (*E*) and magnetic (*H*) fields, e.g., the root-mean-square (rms) or peak electric and magnetic field strengths, their squares, or the plane-wave equivalent power densities associated with these fields, and the induced and contact currents and contact voltages to which a person may be exposed without harmful effect due to the effects identified in the standard, and with an acceptable safety factor for protection from such effects as described in the standard. *See also:* **derived limit.** *Syn:* **permissible exposure level**; **radio frequency protection guide**; **investigation level**.

3.1.24 normally accessible area: For RF protection purposes, an area that can be accessed without recourse to special actions, special equipment, or personal protective equipment without which access is not feasible.

NOTE—Any location can be made accessible using sufficient effort, ancillary equipment, or personal protective equipment.

3.1.25 occupational exposure: RF exposure of persons induced as a consequence of their employment who have been made fully aware of the potential for exposure and can exercise control over their exposure such as through the use of administrative or engineering controls or safe work practices (e.g., use of personal protective equipment or time averaging of exposures). *See also:* **controlled environment**.

NOTE 1—Awareness can be effected by the owner, operator, or party responsible for the source or site, by the RF safety officer (RFSO) or RF safety professional, and through specific training as part of an RFSP in which written and/or verbal information has been provided about appropriate safe work practices for controlling or mitigating personal exposures.

NOTE 2—Occupational exposure typically occurs only in controlled environments.

3.1.26 operation, source: The performance of the RF source or system over the full range of its intended functions (normal operation). This does not include *maintenance* or *service* as defined in this clause.

 Copyright © 2006 IEEE. All rights reserved.

3.1.27 overexposure incident: An incident in which RF exposure of a person exceeds the exposure limit after spatial averaging and time averaging have been taken into account. Documentation of overexposure incidents are normally a requirement of an RFSP.

3.1.28 permissible exposure level (PEL): *See:* **maximum permissible exposure**.

3.1.29 personal protective equipment (PPE): Equipment designed to protect personnel from serious workplace injuries or illnesses resulting from exposure to RF energy, contact with chemical, radiological, and physical agents, and electrical, mechanical and other workplace hazards. For purposes of RF safety, PPE includes electrically insulating gloves and RF-attenuating clothing in the form of coveralls, gloves, socks, and shielding hood assemblies.

3.1.30 personnel: For purposes of this recommended practice, persons responsible for operating, servicing or maintaining RF sources or those requiring access to areas wherein RF exposure may occur during the course of their work.

3.1.31 radio frequency: For purposes of this recommended practice and for simplification, the frequency range extending from 3 kHz to 300 GHz.

3.1.32 radio frequency exposure limit: *See:* **maximum permissible exposure**; **specific absorption rate**.

3.1.33 radio frequency hazard area: For purposes of this recommended practice, an area in which RF fields or contact/induced currents or contact voltages may exceed the exposure limit or reference levels of an RF exposure regulation, standard, or guideline. *See also:* **hazard**.

3.1.34 radio frequency protection guide (RFPG): *See:* **maximum permissible exposure**.

3.1.35 radio frequency safety: A shorthand term widely used to mean safety with respect to exposure to RF energy.

3.1.36 radio frequency safety committee (RFSC): A group of persons having overall responsibility for the development of policies relative to RF safety programs. An RFSC may have only a very few members or numerous members, depending on the nature of the organization. In larger organizations, it is common that the RFSC could include representation from the health and safety, legal, human resources, property management, and field operations departments. The actions of an RFSC may be included in the activities and responsibilities of an existing general safety committee.

3.1.37 radio frequency safety officer (RFSO): One who has authority to monitor and enforce the control of RF hazards and effect the knowledgeable evaluation and control of RF hazards. *See also:* **occupational exposure**.

NOTE—Throughout this recommended practice, it should be understood that wherever duties or responsibilities of the RFSO are specified, it is taken to mean that the RFSO either performs the stated task or ensures that the task is performed.

3.1.38 radio frequency safety professional: A person who is considered competent by way of training and/or experience, knowledgeable of applicable standards and guidelines, capable of identifying workplace hazards relating to the specific operation, and who is designated by the employer, site owner, or regulatory body and has authority to take appropriate actions to correct unsafe conditions including, if necessary, removal of workers. *See also:* **occupational exposure**.

3.1.39 reference level: Limits for the exposure field strength and contact current values derived or estimated from the BRs. The reference levels associated with direct effects are electric field strength (E), magnetic field strength (H), magnetic flux density (B), power density (S), and currents flowing through the limbs (I_L);

Copyright © 2006 IEEE. All rights reserved.

reference levels associated with perception and other indirect effects are contact current (I_C) and, for pulsed fields, incident energy density. *See also:* **derived limit**; **maximum permissible exposure**.

NOTE 1—In any particular exposure situation, measured or calculated values of any of these quantities can be compared with the appropriate reference level or MPE.

NOTE 2—Compliance with a reference level generally ensures compliance with the relevant BR. If the measured or calculated exposure exceeds the reference level, it does not necessarily follow that the BR will be exceeded. However, whenever a reference level is exceeded, further analysis may be used to evaluate compliance with the relevant BR to determine whether additional protective measures are necessary.

NOTE 3—Compliance with electric field reference levels or MPE values of an exposure standard may not ensure compliance with MPE values for induced currents.

3.1.40 RF safety program (RFSP): 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.

NOTE 2—A 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 similar to the elements described in this recommended practice.

3.1.41 safe work practice: Those operating and maintenance procedures that are effective in preventing accidents and preventing excessive RF exposure.

3.1.42 specific absorption rate (SAR): The time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of given density (ρ). SAR is expressed by the unit of watt per kilogram (W/kg).

$$SAR = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}W}{\mathrm{d}m}\right) = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}W}{\rho\,\mathrm{d}V}\right)$$

3.1.43 secured enclosure: An enclosure to which casual access is impeded by secure engineering controls, e.g., a door secured by a mechanical lock, magnetically or electrically operated lock or latch, or by fasteners that can only be removed with a tool.

3.1.44 service, RF source: The performance of those procedures or adjustments described in the manufacturer's service manuals/instructions which may affect any aspect of the performance of an RF source or system. *See:* **maintenance**.

3.1.45 signal word: The word or words in a sign or label that designate a degree of safety alerting. Signal words include: (A) DANGER indicates an imminently hazardous situation that, if not avoided, will result in serious injury or death. This signal word is to be limited to the most extreme situations. (B) WARNING indicates a potentially hazardous situation that, if not avoided, could result in serious injury or death. (C) CAUTION indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices. (D) NOTICE indicates a statement of policy relating directly or indirectly to the safety of personnel or protection of property.

3.1.46 spatial average, field strength or power density: The ambient field exposure (E or H), or power density (S) averaged over a number of spatial locations. Different spatial averaging schemes are defined in various standards and guidelines. For frequencies up to 3 GHz, the average of the field strength squared or equivalent power density over an area equivalent to the vertical cross section of the adult human body, as applied to the measurement of electric or magnetic fields in the assessment of whole-body exposure.

Copyright © 2006 IEEE. All rights reserved.

NOTE—The spatial average is measured by scanning (with a suitable measurement probe) a planar area equivalent to the area occupied by a standing adult human (projected area). In most instances, a simple vertical, scan of the fields along a 2 m high line, through the center of the projected area, will be sufficient for determining compliance with the maximum permissible exposures (MPE) values. For frequencies exceeding 3 GHz, the average should be in terms of incident power density over the appropriate area defined in exposure standards. See C95.3-2002. It should be noted that alternative spatial averaging schemes are specified in other standards, e.g., ARPANSA [B6] and Canada [B7], and these approaches may be used in assessing the spatially averaged value of exposure.

3.1.47 source equipment, RF: RF generating equipment that may emit RF fields into the environment either intentionally, such as a broadcast antenna, or unintentionally, such as a dielectric heat sealer or induction heater. *See also:* **intentional radiator**; **unintentional radiator**. *Syn:* **source**; **emitter**.

3.1.48 standard operating procedure (SOP): Formal written description of the safety and administrative procedures to be followed in performing a specific task. *See also:* **safe work practice**.

3.1.49 time averaging: The process of managing exposure by controlling the exposure duration such that the plane-wave equivalent power density S, electric field strength squared E^2, magnetic field strength squared H^2, limb currents squared, and SAR, when averaged over a specified averaging time, complies with the exposure limit. BRs and derived limits that protect against RF heating effects generally incorporate an averaging time of several minutes for the assessment of the exposure. Such limits include BRs for SAR and power density and derived limits for ambient E & H and limb currents. BRs and derived limits that protect against RF shocks and burns or high power pulse effects generally allow only very short (< 1 s) or no time averaging of exposure. Such limits include BRs for E_{int} (*in situ* electric field strength in the tissue), J (current density) and SA (specific absorption) and derived limits for peak ambient E & H and contact currents (I). Time averaging to control exposures is generally not feasible for such limits. *See also:* **averaging time (T_{avg})**.

3.1.50 touch contact: A contact of small area made between the human body and an energized conductor. In this standard, a contact area of one square centimeter is the assumed touch contact area.

3.1.51 uncontrolled environment: Any area other than a controlled environment. *See also:* **general public exposure.** *Contrast:* **controlled environment**.

NOTE 1—The preferred term is *general public exposure*.

NOTE 2—The uncontrolled environment includes locations where persons are non-occupationally exposed and are not made fully aware of the potential for exposure by the owner, operator or party responsible for the source or cannot, or do not understand how to, exercise control over their exposure. These exposures may occur in residential or work locations where there are no expectations that RF exposure levels may exceed the exposure limits for the lower tier of a two-tier standard, including those for induced currents.

3.2 Abbreviations

BR	basic restriction
CW	continuous wave
EMC	electromagnetic compatibility
ICES	International Committee on Electromagnetic Safety
ICNIRP	International Commission on Non-Ionizing Radiation Protection
MF	medium frequency (0.3 MHz–3 MHz)
MPE	maximum permissible exposure
RF	radio frequency
RFSP	radio frequency exposure safety program
SA	specific absorption
SAR	specific absorption rate
UHF	ultra high frequency (300 MHz–3 GHz)
VHF	very high frequency (30 MHz–300 MHz)

Copyright © 2006 IEEE. All rights reserved.

WBA	whole body average

3.3 Letter symbols for quantities

E	electric field strength
E_{int}	maximum allowed *in situ* electric field strength
B	magnetic flux density
H	magnetic field strength
I	current
I_L	limb current
I_C	contact current
J	current density
MPE	maximum permissible exposure value
P	power
SA	specific absorption
SAR	specific absorption rate
S	power density
T_{avg}	averaging time

3.4 Unit symbols

A	ampere	
GHz	gigahertz	(10^9 Hz)
kHz	kilohertz	(10^3 Hz)
MHz	megahertz	(10^6 Hz)
V	volt	
W	watt	

4. RF Safety Program elements

The steps and questions shown in Table 2 constitute a “Quick-Start” procedure for implementing the recommendations of this document. Table 3 summarizes the minimum recommended components for an RFSP, with numbering corresponding to the following subclauses that provide details.

 Copyright © 2006 IEEE. All rights reserved.

Table 2—Quick-Start procedure for implementing the RF exposure safety program recommendations of IEEE Std C95.7

a) Determine why an RF Safety Program should be considered (what problem must be solved)? 1) New RF equipment or process 2) A significant increase in RF exposure levels at an existing site or facility 3) Employee concerns 4) External concerns (neighbors, etc.) 5) External audit query (regulatory, insurance underwriter, etc.)
b) What compliance criteria (safety standard) will be applied? How will you know when you have succeeded? 1) IEEE Std C95.1 2) ACGIH 3) FCC 4) ICNIRP 5) etc.
c) What are the sources and recipients of the potential RF exposure? 1) Inventory/list sources 2) Determine exposure population
d) Evaluate the potential exposure(s). 1) Information from source equipment provider(s) 2) Calculation 3) Measurement—refer to IEEE Std C95.3, for example 4) Accident reports—e.g., are persons experiencing RF burns or shocks?
e)Determine the appropriate RFSP Category for the RF source or system according to Table 1 and Figure 1.
f) Implement the controls specified for the RFSP Category of the RF source or system if necessary, using Table 3 as a guide (see Clause 4). It should be noted that where the applicable exposure limit is equivalent to the action level, Category 2 becomes equivalent to Category 1 and no specific recommended program elements are required. This could be the case when using this recommended practice to achieve compliance with the lower tier of exposure limits of two-tier guidelines, standards, or regulations such as the exposure limits for general public/uncontrolled exposure specified by the FCC [B12] or ICNIRP [B16].

Copyright © 2006 IEEE. All rights reserved.

Table 3—Minimum recommended elements of an RFSP for the RFSP Categories of Table 1

*** Required √ Optional – Not applicable**

RFSP Elements	Category 1	Category 2	Category 3	Category 4
4.1 Administrative				
4.1.1 Policy	–	√	*	*
4.1.2 Program Administrator (RFSO)	–	√	*	*
4.1.3 Documentation/record keeping	–	√	*	*
4.1.4 Employee involvement	–	√	*	*
4.1.5 RF Safety Committee	–	√	√	√
4.1.6 Procurement of RF source equipment	–	√	√	–
4.2 Identification of Potential RF Hazards				
4.2.1 Inventory of RF sources and exposure situations for categorization of RFSP	–	√	*	*
4.2.2 Exposure assessment	–	√	*	*
4.3 Controls				
4.3.1 Engineering controls				
4.3.1.1 Equipment/site configuration	–	√	√	–
4.3.1.2 Physical barriers	–	√	√	*
4.3.2 Administrative controls				
4.3.2.1 Use of signs (see Note)	–	*	*	*
4.3.2.2 Safe work practices	–	–	√	*
4.3.2.3 Use of lockout/tag-out procedures	–	–	√	*
4.3.2.4 Control of source power	–	–	√	–
4.3.2.5 Time averaging (see Note)	–	*	√	–
4.3.2.6 Personal and/or area monitors	–	√	*	*
4.4 Personal Protective Equipment (PPE)				
4.4.1 Selection of appropriate PPE	–	–	√	√
4.4.2 Maintenance and inspection	–	–	√	√
4.5 Training				

 Copyright © 2006 IEEE. All rights reserved.

Table 3—Minimum recommended elements of an RFSP for the RFSP Categories of Table 1 *(continued)*

*** Required √ Optional – Not applicable**

RFSP Elements	Category 1	Category 2	Category 3	Category 4
4.5.1 General RF safety awareness	–	√	*	*
4.5.2 Explanation of RF exposure limits	–	√	*	*
4.5.3 RF exposure mitigation controls	–	√	*	*
4.5.4 Possibility of RF interaction with medical devices & implants considerations	–	√	*	*
4.5.5 Over-exposure incident response	–	–	*	*
4.5.6 Electro-explosive device considerations (when present in the work environment)	–	√	*	*
4.5.7 Sources of additional Information	–	–	√	√
4.6 Program Audit				
4.6.1 Implementation (Program in use?)	–	*	*	*
4.6.2 Adequacy of present program (program audit)	–	*	*	*
4.7 Assess Ancillary Hazards	–	√	√	√

NOTE 1—Table 3 row numbers correspond to respective subclauses within Clause 4.

NOTE 2—The potential for RF interference with some medical devices is sometimes noted through installation of appropriate signage.

NOTE 3—Suitable training or access control is an acceptable alternative to signage for Category 2 exposures.

NOTE 4—Time averaging of exposures may be necessary to qualify the exposure conditions under Category 2.

4.1 Administrative recommendations

4.1.1 Policy

If an RFSP is determined to be necessary, it should have a written statement of policy as to company or organization expectations regarding the control of human exposure to RF fields. This may be expressed in the form of an institutional operating procedure that is part of a general health and safety policy statement.

Copyright © 2006 IEEE. All rights reserved.

4.1.2 Program administration

The categorization of an RFSP is initially based on the potential for exposure by the RF source(s). However, the following factors should be considered when determining the complexity of the RFSP. An RFSP is usually not necessary for Category 1 locations containing only sources that cannot produce fields exceeding the action level or applicable exposure limit, because of their intended use or operating characteristics during operation, maintenance or service. Careful consideration must be given, however, to sources that may be categorized as Category 1 under normal circumstances but, if specific accidents were to occur, could lead to significant exposures (see 1.3). In some cases, this could mean that special training (see 4.5) may be necessary for workers located in such environments. Category 1 locations that could change to a higher category, e.g., during service or maintenance, require an RFSP commensurate with the higher category and an RF Safety Officer (RFSO) to administer the program.

Category 2 and Category 3 locations always require some elements of an RFSP, and in the case of Category 3 locations, an RFSO to administer the program. The RFSO is a designated person who has authority and responsibility to monitor and enforce the control of RF exposures and effect the knowledgeable evaluation and control of such exposures. The duties/functions of the RFSO may be accomplished by controlling the RF-energy-producing device, or by other means such as controlling access to potentially hazardous areas.

4.1.2.1 Duties of the RFSO

The RFSO identifies, evaluates and specifies control measures for RF sources that may produce fields exceeding the applicable exposure limits. While regions that are normally accessible and exhibit intense RF fields will generally demand a higher priority when allocating resources for RFSPs, it is crucial that RFSPs also address such areas that are normally not easily accessible. Examples include situations in which antennas are mounted so that special effort, equipment, or gear must be used to gain access to high-field areas. The RFSO is responsible for safety analyses, for which the extent and complexity depends upon the applicable exposure category from Table 1. The safety analyses may address potential exposure to personnel, and potential hazards to susceptible materials and processes. RF interference with medical devices and electro-explosive devices should be a part of any RFSP. Specific duties of the RFSO include, but are not limited to, the following:

a) Providing an initial evaluation of the potential for exposure, and monitoring changes (e.g., in the nature of the RF sources and/or access to certain areas) that may affect the Table 1 category designation;
b) Maintaining an inventory of relevant RF sources;
c) Evaluating previously recommended safety procedures (e.g., use of signs, barricades, published safety procedures for identified user activities);
d) Documenting the existing RF exposure safety program;
e) Monitoring all relevant regulations and standards relating to RF safety;
f) Disseminating information on RF safety policy within the organization;
g) Providing authoritative advice to staff on the interpretation of all relevant policies and procedures related to RF safety;
h) Reviewing and authorizing RF surveys and hazard control measures;
i) Authorizing designation of qualifying personnel as RF safety personnel and maintaining a list of approved RF safety personnel;
j) Managing medical fitness assessments of RF safety personnel for potential exposures above the action levels;
k) Coordinating RF safety awareness or measurement training for appropriate staff and maintaining training records;
l) Conducting or arranging regular site audits (for example, once every three years) for compliance with RF safety policies;

 Copyright © 2006 IEEE. All rights reserved.

m) Conducting an annual review of RF hazard survey policies and procedures to ensure that they adequately reflect best practices and regulatory requirements, and submitting amended drafts to the appropriate person or RF Safety Committee (see 4.1.5) for comment and approval;

n) Managing the investigation of any breaches of the RF safety policies and procedures, including accidental RF over-exposure incidents, and developing appropriate policy amendments if required;

o) Developing or approving appropriate RF hazard assessment tools;

p) Arranging for the regular calibration of RF hazard survey or monitoring equipment, including all RF field measurement kits, RF personal monitors and RF current probes;

q) Ensuring proper control and central archiving of all documentation associated with RF safety in the organization.

A prerequisite for the designation as RFSO should include at least appropriate training (see Annex A).

4.1.3 Documentation/record keeping

RFSPs should be described in documents readily available to relevant personnel. Records of periodic checks for compliance with the safety program and discovered departures from the program should be maintained as an aid in correcting repeated deviations. Technical information and activities including source inventories, personnel exposure assessments when it has been determined that an actual over-exposure occurred, field strength calculations and/or measurements, RF safety awareness training, and incident reports should be documented. All records should be filed and stored in a manner required by applicable national, federal, state and/or local regulations and organization policies.

Quality, not quantity, is the more important characteristic of RFSP documentation. For example, in the simplest of cases with a very small organization or operation, the program documentation may consist of a single page that lays out the RF safety policy and lists the procedures used for complying with the adopted RF exposure limits. In other instances, however, more elaborate documentation may be appropriate. Characteristics that influence the need for additional and/or more detailed documentation include:

a) Number and locations of sites at which RF exposure must be controlled.

b) Complexity of the site or sites addressed by the program (number of emitters, range of relevant frequencies, and RF field source configurations such as antenna mounting heights).

c) Relative potential for exposure exceeding the exposure limits.

d) Number and geographic distribution of managers that may be involved in RFSPs.

e) Geographic distribution of potentially exposed personnel.

f) Number of personnel covered by the program, including job descriptions or assigned work sites.

For large operations, for example a major broadcast site with multiple stations operating at high powers, documentation should include insight concerning the potential for exposure based on previous studies of the site. For operations in which personnel may work intermittently at many different sites, for which formal RF exposure assessments have not been conducted, the program should assure the capability of workers to recognize and characterize their potential for excess exposure at specific sites. This can be accomplished through the use of proper RF measurement instrumentation, previous experience, and RF safety awareness training. Annex B provides some examples of key aspects of RFSPs for selected exposure scenarios, and Annex A lists elements of RF safety training.

4.1.4 Employee involvement

Employee involvement in decisions that affect their safety and health may be sought to make full use of their collective insight on RF safety and to encourage their understanding of and commitment to the established RFSP. For example, RF measurements might be made in the presence of employees to facilitate their understanding of the program. Employees can often provide effective insight to practical methods for accomplish-

Copyright © 2006 IEEE. All rights reserved.

ing RF safety in the context of routine safe work practices, and this insight should be sought when appropriate.

4.1.5 RF Safety Committee

In some cases, depending upon the complexity of operations at a site or facility, an RF Safety Committee (RFSC) may be appropriate to provide overall organizational policy and guidance for an appropriate RFSP. Depending on the operation, the functions of an RFSC may be accomplished by an established general safety committee. In some cases the RFSC may be dedicated solely to RF safety operations. In the case of small organizations, a formalized RFSC may be unnecessary, impractical, or inappropriate. The RFSO would normally be a member or the leader of the RFSC.

4.1.6 Procurement of RF generating equipment

In some instances, the potential for exposure to RF fields may be eliminated or reduced through the use of RF generating equipment that has been specially designed to reduce the presence of RF fields to levels below applicable exposure limits. An administrative aspect of any RFSP should include the recognition of such equipment and the potential utility in procurement of such equipment for compliance with the RFSP. For example, some models of RF dielectric heat sealers are designed to include shields that can substantially reduce operator exposure to RF fields.

4.2 Identification of potential RF hazards

Hazard identification begins with an understanding of the RF sources at a site or within an organization. This understanding is normally accomplished by development of an inventory of RF sources and exposure situations that can be used for subsequent categorization as defined in this recommended practice.

4.2.1 Inventory of RF sources and exposure situations for categorization of an RFSP

An inventory should include, at a minimum: device or device type (its function or use), frequency, radiated power or output power over time, antenna type (if applicable), and a description or brief summary of the potential for RF exposure. Information from the inventory is used to determine whether an exposure assessment is necessary. Annex C provides information useful in developing an inventory of relevant RF sources. Information from the inventory can be used to determine the necessary hazard evaluation steps and the control and training steps necessary to ensure that the potential exposure from the operation of relevant emitting devices is below the exposure limits.

4.2.2 Exposure evaluation

The process of identifying potential RF hazards may include the use of existing evaluations previously prepared for a particular site and/or on-site measurements and analyses (using formulas and software) of RF fields and associated currents and voltages. Data from existing evaluations or on-site measurements and subsequent technical analyses are then used with information on the potential for persons to occupy such areas to assess potential exposure. NCRP Report 119 [B27] provides comments and guidance on calculations for exposure assessment. The appropriate method(s) of exposure assessment should be determined by the RFSO for the particular circumstance. Annex D provides information on RF field measurement issues that may be relevant when performing an exposure assessment. Annex E provides information on calculations for estimating potential exposure to RF fields.

4.3 Controls

The RFSP may use different methods of exposure control including, but not limited to, those noted in this clause. Control of RF exposure by use of engineering controls should be implemented whenever feasible.

 Copyright © 2006 IEEE. All rights reserved.

Administrative controls, since they imply/require user knowledge/interpretation or action, should be used if engineering controls are not feasible, or to supplement engineering controls.

4.3.1 Engineering controls

Engineering controls are effective for controlling RF exposure independent of the awareness of hazards by personnel and may include shields to reduce stray fields from dielectric heat sealers, sector blanking for moveable antennas such as radars or phased array antennas, software controls, barriers, and interlocks. Engineering controls are recommended when potential exposures can exceed the applicable exposure limit by a factor of 10. In some circumstances, the source power will have to be reduced to allow access to high-power systems, because implementing engineering controls could be counterproductive to the required work or prohibitively expensive or impractical.

4.3.1.1 Equipment/site configuration

Careful placement and layout of equipment configurations at a site can minimize potential exposures in many circumstances. Examples are placement of directional antennas to preclude personnel from entering the main beam region or using sufficient antenna mounting heights to preclude exposure within the aperture of the antenna. Use of auxiliary antennas during maintenance procedures, if available, is another technique for reducing worker exposure.

4.3.1.2 Physical barriers

One approach for ensuring compliance with RF exposure limits is by installation of physical barriers (e.g., locked doors, ladder cages, fences, walls) as an engineering control to positively restrict access to certain spaces wherein RF fields may exceed applicable exposure limits.[5] Physical indicative barriers (e.g., chains, rails) as an administrative control are usually not considered as an effective means to ensure compliance because they can often be easily breached. The decision to use physical barriers should be carefully considered because the barriers themselves may become a potential hazard under some circumstances. If barriers are to be used, consideration should be given to their durability, longevity, and visibility for the intended environmental and climatic conditions. Feasible engineering controls (such as man-proof barriers and interlocks) are more effective than administrative controls (such as training, signage, and use of PPE).

4.3.2 Administrative controls

Administrative controls, in contrast to engineering controls, depend for their effectiveness on the awareness and participation of potentially exposed personnel. For example, audible and visual alarms are only effective if personnel are aware of their meaning and respond appropriately.

4.3.2.1 Use of signs

Areas where the potential exists for RF exposures that exceed exposure limits should be clearly marked with appropriate signs, indicative barriers, or floor, roof, or ground markings. These control measures should be used when engineering controls or other methods are not adequate. Signage may also be used as a complement to other administrative controls. Signs should be of standard design and conform to established specifications, such as those contained in IEEE Std C95.2-1999 [B19] and ANSI Z535-1998 [B4] relative to use of signal words (see 3.1.45), symbols, text fonts and sizes, and colors. RF safety signs should be installed before reaching the specific region of concern, but as close as practical, with an attempt to avoid demarcating unnecessarily large regions. Signs should be installed according to the potential for access to different exposure conditions as described in Table 1. RF safety signs should employ multiple languages where appropriate and available, to ensure recognition and understanding by persons that are not fluent in the

[5]In some cases, conductive materials may scatter or reflect RF fields. In situations where this may be an issue, consideration should be given to the use of nonconductive materials, where practical.

Copyright © 2006 IEEE. All rights reserved.

primary language of the region. Warning signs alone, however, may not provide adequate protection. In such cases, other warning devices, such as flashing lights, audible signals, or indicative barriers are recommended depending on the potential risk of exceeding the applicable exposure limits (see Department of Defense [B9]).

Common practice is to apply **NOTICE** signs (refer to 3.1.45) to alert persons to the potential for exposures exceeding the lower tier (e.g., an action level) of two-tier standards, and to indicate policy statements. **CAUTION** signs are more commonly applied to alert personnel to the possibility of exposures exceeding the upper tier (e.g., an MPE level) of two-tier standards. **WARNING** signs are normally used to advise of potential RF exposures that may exceed the upper tier of standards by a factor of 10; an example is the use of warning signs when the resulting exposure would exceed the standard by an amount equal to the safety factor that may have been inherent to the derivation of the applicable standard or guideline. **DANGER** signs are normally only used for situations in which immediate and serious injury will occur such as in the case of RF burns and/or RF electrical shocks.

4.3.2.2 Safe work practices

Limiting or restricting access to areas where the potential exists to be exposed in excess of the appropriate exposure limit can be accomplished with appropriate safe work practices. For example, locking and alarming doors, permanent indicative barriers, and similar access control methodologies may be sufficient to limit access. Appropriate safe work practices, such as those specified by the manufacturer, should be followed during the repair and maintenance of RF equipment. Occasionally, service personnel must remove cabinet panels and/or defeat interlocks to allow access for maintenance. Failure to properly replace a panel, or internal shield, or re-set interlocks, may result in RF leakage, leading to elevated RF exposure of personnel. RF screening measurements can be used to determine which panels can be removed during operation (assuming other hazards, such as electrical shock, are controlled) and to ensure that the shielding is reinstalled properly. In the context of an RFSP, safe work practices should be developed and followed as part of a policy of systematic avoidance of excessive RF exposure.

4.3.2.3 Use of lockout/tag-out procedures

The most direct way to control potential RF exposures is to turn off equipment during times that personnel may be exposed to RF fields. This common-sense approach must, however, be used with a full understanding of the potential consequences of turning off systems without notification of the owners/operators. Furthermore, care must be taken to assure that, when deactivated, equipment cannot be returned to service until personnel have cleared the critical area, especially when reactivation is by remote control. Lockout/tag-out (LOTO) procedures, for example as specified by the U.S. Occupational Safety and Health Administration (OSHA) for the control of hazardous energy (see OSHA [B31]), should be considered for inclusion in safe work practices when RF transmitting equipment is removed from service, particularly for high-power systems.

Many communications sites rely on battery-powered uninterruptible power supplies, such that disconnecting the AC mains for the site will not result in the transmitter being turned off. This feature of some transmitter sites, if present, is particularly prevalent at mobile phone base stations and must be understood before selecting the best approach to eliminating potential RF exposure.

4.3.2.4 Control of source power

Although removing equipment from service, as discussed above, is the most direct and positive way to control potential RF exposure, in many cases such actions are not practical because of commercial or public service uses. In such cases, it may be possible to devise procedures wherein a prescribed power reduction can be accomplished prior to personnel access to certain high-field-strength areas. For example, a rooftop broadcast site might present excessive exposure to personnel working on the roof when stations operate at full licensed power. However, when transmitters are operated at lower power settings, the roof may not present

 Copyright © 2006 IEEE. All rights reserved.

any exposure issues and it may be practical to implement a low-power operating condition as part of the RFSP for those times that personnel must be on the roof. A crucial aspect of such power reduction schemes, however, is ensuring that the power reduction has, in fact, taken place prior to personnel entering critical areas and that the power reduction is maintained until personnel have left the area. In this context, personal RF monitors (4.3.2.6) can be valuable tools for ascertaining relevant transmitter status.

If a particular RFSP calls for a definitive method to eliminate potential exposure during certain safe work practices, by disconnecting transmission lines between the transmitter and antennas, for example, consideration should be given to the task of returning the site to full operational status at a later time. Generally, such matters should be discussed and coordinated with the relevant owner(s)/operator(s) at the site. This may require special communications between the RFSO and various transmitter operators and may also require installation of area monitors or transmitter power detection circuits that can reliably indicate a reduction in RF fields. Control of source power may also require the use of LOTO procedures.

4.3.2.5 Time averaging

Time averaging should be consistent with all aspects of the appropriate exposure limits including instantaneous values of exposure metrics that may be applicable, e.g., peak values of the electric or magnetic fields, currents, or voltages. Time averaging requires the measurement of a person's activity and/or RF source "on time" to ensure that the allowable, time-weighted exposure does not exceed the applicable exposure limit. For example, the ratio of the time that an RF field source is active (on) to the total time (on-time plus off-time) is the duty factor. The duty factor allows calculation of the time-averaged exposure that may be compared with an exposure limit. While the use of time averaging is a legitimate approach to managing exposure of humans to RF energy, it is normally used only in occupational environments wherein personnel have been appropriately trained in RF safety procedures. Time-averaged exposure situations generally require adequate operational or administrative controls to insure that the averaging times are controlled or maintained.

Reliance upon time averaging for demonstrating compliance with RF exposure limits may not be suitable for environments in which the general public may be present. Examples would be when the duty factor of the source cannot be reliably assumed or for situations where exposure depends on the movement of persons through an RF field that exceeds the limit for continuous exposure. However, in some cases involving the general public, time averaging may be routinely relied upon for demonstrating compliance with applicable exposure limits, for example when the exposure involves sources that operate with a predetermined duty factor. Examples include the use of wireless devices such as mobile phones using hardware control (e.g., TDMA) of the transmitter and exposure to the predictable scanning beams of radar systems.

4.3.2.6 Personal and/or area RF monitors

Personal RF monitors[6] can be useful tools in RFSPs. However, care must be used in selecting a monitor that is appropriate for the range of potential frequencies of the exposure fields and which responds appropriately to the type of modulation of the RF exposure field. In addition, training on appropriate use of personal monitors and their limitations (such as frequency response and detection angles) is important if monitors are to be used effectively. Area monitors may also prove effective for indicating the presence of stray RF fields near certain systems or in certain environments but, just as with personal monitors, the monitors can only detect RF fields incident upon them. Placement of monitors such that they do not respond fully in actual exposure scenarios will not provide sufficient warning of potential exposures in excess of the applicable exposure limits.

[6]Per IEEE Std C95.3, "Personal monitors are typically small, portable broadband detectors, suitable for attachment to workers' clothing, which are equipped with an alarm feature for alerting the wearer to the presence of high-level RF fields that may approach the MPE of interest."

Copyright © 2006 IEEE. All rights reserved.

4.4 Personal protective equipment

Personal protective equipment (PPE) may, under some selective conditions, be used to reduce RF exposures. Examples of protective equipment include gloves and protective clothing in the form of overalls that include shielded hoods for protection of the head, conductive socks, and footwear that is appropriate and effective for the exposure conditions. In some instances, it may be desirable to wear shoes that can facilitate effective grounding and, in other cases, insulating soles may be useful to avoid excessive body currents. RF burn and shock hazards can be mitigated, for example, via the use of gloves. Gloves of almost any fabric can be effective at frequencies below a few megahertz, but may offer only limited current reduction performance at higher frequencies. RF burn and shock hazards are more commonly associated with tall conductive objects immersed in medium (MF) or lower frequency fields. It should be noted that the use of PPE may make it possible to work in a category that would otherwise not be permitted. Laboratory investigations have, in some cases, characterized the RF shielding properties of RF protective clothing (see Tell [B35] for an extensive review of testing results). Empirical investigations have studied the ability of work gloves to reduce contact currents (see Tell [B34]). However, the use of PPE may also subject the user to enhanced RF exposures if improperly employed (see Olsen [B30]). For example, when used in extremely intense RF fields, surface arcing may exist on suit materials that are conductive. Hence, care should be used in determining whether RF protective clothing is appropriate for the specific exposure circumstance.

4.4.1 Selection of appropriate PPE

The RFSO should determine the suitability of the use of PPE for a given RF work environment and for anticipated work procedures intended to be accomplished. Although PPE may reduce RF exposure, all limitations must be thoroughly understood. For example, while RF protective clothing can substantially reduce RF energy specific absorption rates for personnel working in RF fields, the clothing itself can present an additional heat load that should be considered prior to its use (see Adair [B3]). Shielded hoods can also restrict peripheral vision and may, depending on design, present an unacceptable hazard during certain tower climbing operations.

4.4.2 Maintenance and inspection

Proper training for all persons using PPE, such as RF protective clothing, must be carried out prior to performing tasks requiring use of the PPE. Inspection and appropriate maintenance of RF protective clothing should be performed at intervals specified by the manufacturer. For example, tears and holes in the fabric may lead to inadvertent high-level exposures or possible unanticipated direct contact with RF-energized conductors (see Joyner [B24]).

4.5 Training

RF safety awareness training is normally the single most important aspect of controlling hazardous exposures to RF energy and is often not sufficiently emphasized in RFSPs. Awareness training should be provided to all persons who have the potential to be exposed to RF energy above applicable limits. The extent of RF safety training, however, will normally be dependent on the potential for exposure exceeding the relevant exposure limits and the relative magnitude of the RF exposure levels and will, generally, be related to the Exposure Category.

4.5.1 General RF safety awareness

RF safety awareness training should be provided to all persons who have the opportunity to access areas where RF exposure (RF fields, contact currents, induced currents, and contact voltages) can exceed the applicable exposure limits. This same training should be a prerequisite for the designated RFSO and, where applicable, should be provided to RF Safety Committee members. RF safety training may take various forms including live presentations, video presentations, interactive CDROM based training, internet-based train-

 Copyright © 2006 IEEE. All rights reserved.

ing, written informational materials, and, in some instances, suitable signage. There may also be certain situations where individual considerations are required due to medical/health issues such as wearers of metallic implants, or users of medical electronic devices. Special information concerning these issues should be provided as part of the awareness training (see 4.5.4). In some scenarios, only one of the above training methods may be sufficient and in others more than one may be necessary. The most appropriate method is best determined on a case by case basis.

A key element of any type of training program is provision of information that will help a person understand how to recognize the potential risks for overexposure and how to avoid such risks. For example, in some cases, signs and labels may be sufficient to provide the necessary degree of information needed to avoid excessive exposure. A label or small sign attached directly to the surface of an antenna may be entirely sufficient to avoid excessive exposure if it specifies a minimum approach distance. Another example of where signage, without specific training, could be sufficient is a region where an action level may be exceeded, but where the exposure limit could not be exceeded (Category 2).

In other cases, a short RF safety briefing at the job site prior to commencing work may be sufficient. In yet other cases, an in-depth treatment of RF safety will be more appropriate. The level and content of the training should be adapted to the nature of the work crew and the likelihood of RF exposures above the limits. For example, in some situations detailed technical discussions may be unnecessary or even counterproductive for the intended purpose. In other situations, and especially for supervisory personnel, a more comprehensive training approach should be followed. Annex A lists various topics suitable for inclusion in RF safety awareness training.

4.5.2 Explanation of RF exposure limits

Training should address the potential likelihood that exposures in a given occupational environment may exceed the applicable exposure limits. For RFSOs the training should also include an explanation of the RF exposure limits and include details on any specific peculiarities of the limits, for example any frequency dependence, whether the exposure limits are based on spatially-averaged values or spatial peak values, and time-averaging criteria for assessing compliance with the limits.

4.5.3 RF exposure mitigation controls

An important aspect of RF safety training is providing information that will help people to understand how to recognize situations in which excessive RF exposure may occur, and to inform personnel about how to keep their exposures below the applicable exposure limits. This may include information about exposure control, as described in 4.3. The RFSO should prepare site-specific training based on the particular characteristics of RF emissions at the site and/or the nature of how work is to be carried out at the site.

4.5.4 Medical devices and implants

RFSPs should make sure that personnel are informed of the potential RF susceptibility of medical devices, and personnel should be encouraged to discuss the device manufacturer's information with appropriate occupational medical personnel to resolve any questions concerning compatibility with the work environment. Personnel should also be encouraged to inform the RFSO of their reliance on electronic devices so that additional guidance may be provided regarding their potential for RF exposure and the possibility that strong RF fields may interfere with electronic medical devices. This process is best accomplished as part of a job safety analysis that includes a fitness-for-work health assessment. Consultation with the employee's medical advisor is also recommended. Useful information that addresses possible RF interference issues may also be available from the RF source manufacturer.

Some medical devices, such as cardiac pacemakers, defibrillators, and drug delivery systems can exhibit improper operation when subjected to strong RF fields. Devices and systems that are used external to the body can be substantially more susceptible to interference. For personnel who use electronic medical

Copyright © 2006 IEEE. All rights reserved.

devices or systems and may need access to areas near RF sources, a request for an evaluation of the potential interference can be referred to the manufacturer for the manufacturer's own evaluation and guidance on electromagnetic compatibility (EMC). This may require contact with the device manufacturer and/or appropriate regulatory authorities and an evaluation of the RF fields where the subject employee may need access. It is important to note that device interference may occur at RF field strengths that are substantially less than human exposure limits (see AAMI TIR18:1997 [B1]).

4.5.5 Over-exposure incident response

Any person suffering harm from an RF over-exposure incident should receive medical treatment. Personnel should be instructed to inform the RFSO of suspected and/or actual RF over-exposure or incidents of interference with a medical device, as soon as practicable. Symptoms such as pain, reddening of the skin, unusually elevated body temperature, or any other evidence of tissue burning, are possible indications of over-exposure (see COMAR [B8]).

Without physical evidence of an over exposure, it can be very difficult to ascertain the severity of the exposure. However, the mere belief such an exposure has occurred can lead to heightened anxiety manifested in actual physiological reactions (such as headaches and nausea). See COMAR [B8] for more information on medical considerations.

Information about the exposure incident should be used to make an administrative determination of whether an actual over-exposure took place. Technical information should be gathered for evaluation by a knowledgeable person, including location, frequency, source power levels, source description, and exposure duration. In some cases, reconstruction of the exposure may prove effective in determining exposure levels during the incident. The exposure reconstruction may include RF field measurements and should be carried out under the guidance of the RFSO.

Following an assessment of potential exposure and medical evaluation, where applicable, details of the incident should be documented in the records of the RFSP. A formal investigation to ascertain the cause of an over-exposure, and to develop appropriate strategies to reduce the likelihood of subsequent incidents, should be performed whenever the exposure exceeds the limit by a factor of 5 or more. Remedial options that could be considered include:

— Improving the awareness of any person(s) who contributed to the occurrence of the over exposure incident through counseling or retraining
— Reviewing the adequacy of local controls implemented at the exposure site
— Reviewing the adequacy of the corporate procedures for the RF safety program

Annex G provides an example format for an Over-Exposure Incident Reporting Form that can be used in documenting over-exposure incidents.

4.5.6 Electro-explosive device considerations

RFSOs must remain aware and concerned about the potential for RF energy to detonate electro-explosive devices (EEDs), such as electric blasting caps and squibs, that are typically employed in military, law enforcement, and commercial blasting environments, primarily to promote the detonation or rapid burning of explosive or energetic materials. Hazards from electrical blasting operations are likely to arise in relatively close proximity to transmitting antennas. However, it should be noted that these hazards could exist where the electromagnetic field strengths are substantially less than those normally considered a hazard to human health. Hazard zones may be defined for both fixed and mobile transmitters and, unless it can be shown otherwise, the effect of two or more transmitter fields must be taken as additive. Refer to C95.4-2002 [B21] for guidance on the use of electric blasting caps in RF environments.

 Copyright © 2006 IEEE. All rights reserved.

4.5.7 Sources of additional information

Annex A provides a list of training elements that should be considered for inclusion in general RF safety awareness training as well as additional topics suitable for more in-depth RF safety training such as that appropriate for RFSOs. It should be noted that in many practical situations involving work crews, RF safety awareness training can be relatively brief and still be effective in accomplishing the desired goal. This means that only selected elements from the more comprehensive list of topics in Annex A may be entirely sufficient for achieving the training task. The nature of the work situation should be taken into consideration when deciding on the necessary topics to cover in the awareness training. A significantly abbreviated awareness training session, or streamlined series of informational materials that are carefully structured to meet the necessary requirement of RF safety for the particular site or required work and the work crew, can often be more effective than a longer and more technically detailed session. Annex F provides a list of information sources that may be useful for additional reading and education about RF safety programs.

4.6 RFSP Audit

4.6.1 Implementation and continuation

An RFSP, no matter how well designed and intentioned, will provide no exposure control if not implemented. Implementation requires a concerted effort on the part of the organization, small or large, in coordination with the RFSO, to ensure that all potentially affected workers are routinely reminded of the existence of the program and the expectation of their cooperation and compliance with established work procedures and safety precautions. The RFSO and organizational management must be committed to the policy that the RFSP is to be active at all times without any lapse in program implementation. Implementation of the RFSP should include a description of how ongoing workplace practices shall occur in a manner to provide for any required actions such as moving from one area to another at a work site, to avoid excessive RF exposure.

4.6.2 Adequacy of present program (audit)

A mechanism for periodic (e.g., annual) reviews of the RFSP should be incorporated into the program so that any program deficiencies can be identified and resolved. Feedback from employees can provide valuable insight to the appropriateness and effectiveness of safe work practices and other controls implemented within the program and how the program can be improved. For example, an archival record of exposure incidents can be valuable in determining weak points within a program. Periodic RF screening measurements may, in some situations, be necessary to ensure that conditions have not changed and that the RFSP continues to be effective in minimizing the potential for exposure to RF fields in excess of the limits. Further, periodic inspections should include a check on the proper functioning of engineering controls.

4.7 Ancillary hazards

While not directly related to the issue of RF safety, ancillary hazards can be encountered at facilities where sources of RF fields are located. Ancillary hazards that should be diligently avoided by all personnel, including those performing on-site exposure assessments, include but are not limited to:[7]

a) Electric shock (static not RF) e.g., from dc or ac high-voltage electrical supplies in electronic equipment (http://www.osha-slc.gov/SLTC/electrical);

b) Ionizing radiation (http://www.hps.org/);

c) Mechanical: unguarded gears, belts, power transmission systems, unexpected mechanical motion (antennas) (http://www.osha-slc.gov/SLTC/machineguarding/index.html);

d) Eye hazards associated with site equipment such as low-mounted antenna elements;

[7]Internet addresses are given as examples for where to find more detailed information about each topic.

Copyright © 2006 IEEE. All rights reserved.

e) Heat exchange systems, hot fluids, burns;
f) Falls from heights, e.g., when tower climbing or working on rooftop antennas;
g) Falls through openings;
h) Confined space entry;
i) Trip hazards, e.g., roof-surface mounted cable trays and electrical conduits;
j) Welding and cutting operations;
k) Heat stress from working in hot environments[8] (http://www.osha-slc.gov/dts/osta/otm/otm_iii/otm_iii_4.html);
l) Toxic chemicals and gases (http://www.aiha.org);
m) Refrigerants for cooling;
n) Optical radiation sources, coherent (lasers) and non-coherent sources; ultraviolet, visible, and infrared (http://www.osha-slc.gov/SLTC/laserhazards/index.html).

[8]Most RF exposure standards are predicated on the basis of limiting the thermal loading on the body from RF exposure. In this context, RFSPs should include consideration of the combined thermal impact of RF exposure in combination with other forms of heat stress where relevant.

 Copyright © 2006 IEEE. All rights reserved.

Annex A

(informative)

Topics for inclusion in RF safety awareness training

A.1 General RF safety awareness training topics

a) Introduction to RF sources and RF safety
   1) importance of an RFSO
   2) examples of RF sources
   3) definitions/ units
   4) electromagnetic spectrum
   5) basic physics of electromagnetic exposure
   6) differences between ionizing and nonionizing radiation
   7) rationale/importance for complying with RF standards
   8) importance of avoiding areas designated as restricted
b) RF generators, transmission lines, wave propagation
   1) types of generators/amplifiers, e.g., klystrons, magnetrons, traveling-wave-tubes (TWTs), etc.
   2) types of transmission lines and their uses, e.g., coax, parallel line, twin lead, twisted pair, waveguides
   3) RF wave propagation, i.e., guided/unguided, free-space radiation, absorption, reflection, ground waves, sky waves, etc.
c) Antennas
   1) transmitting/receiving
   2) antenna types - directional/omni-directional/array
   3) resonant: single element/ multi-element
   4) antenna patterns
   5) antenna gain (directivity), beam widths
   6) locations of antennas, e.g., towers, atop of buildings/vehicles, etc.
   7) parasitic re-radiators
   8) areas to avoid
d) Biological effects/hazards
   1) interaction with body
   2) potential hazards, i.e. overheating, RF shock/burn, hot spots
   3) penetration depth, resonance
   4) susceptible parts of the body
   5) ancillary hazards, e.g., electric shock/electrocution
e) Standards, basis of standards/regulations
   1) units: specific absorption rate (SAR), currents, electric fields (volts/meter), magnetic fields (amps/meter), power density (milliwatts per square centimeter), etc.
   2) whole-body exposure/ local exposure
   3) safety factors incorporated in standards

Copyright © 2006 IEEE. All rights reserved.

4) quantitative exposure limits, dependence on frequency
5) spatial averaging for determining compliance
6) time averaging in determining compliance
7) induced current/contact current limits
8) pregnant workers (note no difference in guidelines if applicable)

f) Elements of an RF exposure safety/protection program
1) RFSO (main contact for RF safety)
2) documentation/record keeping
3) inventory of sources
4) training of employees and documentation
5) control procedures to prevent overexposure
6) administrative (signs, alarms, indicative barriers, etc.)
7) engineering (elevation/azimuth interlocks, sector blanking, software controls, fences, barricades etc.)
8) Reporting procedures in case of overexposure/point of contact in case of overexposure

g) Procedures to be observed for suspected overexposures
1) whom to contact
2) medical exams to be performed
3) evaluation of incident, i.e., circumstances, type of system, average power levels, exposure time duration,
4) proximity of person(s) to radiating source, whole-body or local (partial) body exposure, etc.
5) procedures to prevent reoccurrences

h) RF signs, alarms, barricades
1) types of signs (Notice, Caution, Warning, Danger)
2) meanings of each and when to use

i) Site evaluation
1) types/numbers of sources
2) location of antennas and proximity to personnel
3) identifying potentially hazardous/restricted areas, where to post RF signs, etc.

j) Medical implant concerns
1) defibrillators/pacemaker wearers
2) metallic implants
3) possible effects, e.g., electromagnetic interference (EMI), shocks, burns
4) importance of guidance from physician or manufacturer on avoiding EMI

k) Sources of additional information

A.2 Topics for in-depth RF safety training for RFSOs and/or supervisors

a) Introduction to RF sources and RF safety
1) importance of an RFSO
2) examples of RF sources
3) definitions/units
4) electromagnetic spectrum

 Copyright © 2006 IEEE. All rights reserved.

5) basic physics of electromagnetic exposure
6) differences between ionizing and nonionizing radiation
7) rationale/importance for complying with RF standards
8) importance of avoiding areas designated as restricted

b) RF generators, transmission lines, wave propagation
1) types of generators/amplifiers, e.g., klystrons, magnetrons, traveling-wave-tubes (TWTs), etc.
2) types of transmission lines and their uses, e.g., coax, parallel line, twin lead, twisted pair, waveguides
3) RF wave propagation, i.e. guided/unguided, free-space radiation, reflection, ground waves, sky waves, etc.

c) Antennas
1) transmitting/receiving
2) antenna types - directional/omni-directional/array
3) resonant: single element/ multi-element
4) antenna patterns (elevation, azimuth)
5) antenna gain (directivity), beam widths
6) locations of antennas, e.g., towers, top of buildings/vehicles, etc.
7) RF emission regions, i.e., reactive near field, near field, far field, parasitic re-radiators
8) areas to avoid

d) Biological effects/hazards
1) interaction with body
2) potential hazards, i.e., overheating, RF shock/burn, hot spots
3) penetration depth, resonance
4) susceptible parts of the body
5) ancillary hazards, e.g., electric shock/electrocution, general heat stress

e) Standards, basis of standards/regulations
1) units: specific absorption rate (watts per kg), currents (amperes), electric fields (volts per meter), magnetic fields (amperes per meter), power density (milliwatts per square centimeter), etc.
2) whole body exposure/ local exposure
3) safety factors incorporated in standards
4) quantitative exposure limits, dependence on frequency
5) spatial averaging for determining compliance
6) time averaging in determining compliance
7) exposure from multiple emitters
8) induced current/contact current limits
9) pregnant workers (note no difference in guidelines if applicable)

f) Analytical parameters/methods for estimating RF fields
1) reasons for analysis before measurements
2) technical parameters: continuous wave (CW), pulsed-fields, peak power, average power, pulse width, pulse repetition frequency, duty factors, etc.
3) antenna parameters: antenna radiating area, gain, illumination, efficiencies, beam width, etc.
4) equations for near field/far field range calculation, power density, etc.
5) Provide analytical examples

Copyright © 2006 IEEE. All rights reserved.

g) Instrumentation, personal protective equipment (PPE)
   1) units of measurement
   2) when to make measurements
   3) broadband measuring equipment
   4) frequency ranges
   5) electric field
   6) magnetic field
   7) induced current meters
   8) contact current meters
   9) alert monitors (room, personal/body mounted), emphasize when to use and limitations
   10) protective clothing: effectiveness/limitations
   11) measuring techniques and associated uncertainties
   12) calibration of equipment/accuracy of calibrations/measurements
h) Elements of an RF exposure safety/protection program
   1) RFSO (main contact person for RF safety)
   2) documentation/record keeping
   3) inventory of sources
   4) training of employees and documentation
   5) control procedures to prevent overexposure
   6) administrative (signs, alarms, indicative barriers, etc.)
   7) engineering (elevation/azimuth interlocks, sector blanking, software controls, fences, barricades, etc.)
   8) reporting procedures in case of overexposure
   9) point of contact in case of overexposure
i) Procedures to be observed for suspected overexposures
   1) who to contact
   2) medical exams to be performed
   3) evaluation of incident, i.e., circumstances, type of system, average power levels, exposure time duration, proximity of person(s) to radiating source, whole-body or local (partial) body exposure, etc.
   4) procedures to prevent reoccurrences
j) RF signs, alarms, barricades
   1) types of signs (Notice, Caution, Warning, Danger)
   2) meanings of each and when to use
k) Site evaluation
   1) types/numbers of sources
   2) location of antennas and proximity to personnel
   3) identifying potentially hazardous/ restricted areas, where to post RF signs, etc.
l) Medical implant concerns
   1) defibrillators/pacemaker wearers
   2) metallic implants
   3) possible effects, e.g., electromagnetic interference (EMI), shocks, burns
   4) importance of guidance from physician or manufacturer on avoiding EMI
m) Electro-explosive devices

 Copyright © 2006 IEEE. All rights reserved.

    1) types of RF sources/frequencies capable of interference
    2) types of areas to avoid/procedures to be observed
    3) personnel to be contacted

n) Risk communication, risk management

o) Sources of additional information

Copyright © 2006 IEEE. All rights reserved.

Annex B

(informative)

Examples of key aspects of RFSPs for selected exposure scenarios

The items in Table B.1 represent examples of various scenarios in which an RFSP is relevant and highlights some of the key elements that might be part of the program. It should be noted that other program elements not mentioned here are likely to be appropriate for inclusion.

Table B.1—Example exposure scenarios and example elements for corresponding RFSP

No.	Scenario	RFSP elements, requirements
1	Broadcast site with tower-mounted high power antennas. Spatial peak RF fields at all points on ground less than exposure limit for lower tier or action level. Spatial average RF fields on towers, near antennas greater than upper tier exposure limit.	a) Ensure that changes at site do not result in ground level RF field changes that would exceed applicable exposure limit/ MPE value/action level (maintain information on addition of new antennas or increases in power); b) Restrict personnel from climbing tower during operations (signage, training); or c) Require power reductions before tower work to meet upper tier exposure limits.
2	Building rooftop antenna site with antennas mounted to exterior surface (façade) of building (antenna location would be considered not normally accessible). No other antennas present.	RFSP should provide for mechanism to alert operator of need for personnel to gain access to front of antennas during building repairs or maintenance work and signage to alert personnel to possibility of RF fields directly in front of antennas that may exceed applicable exposure limits. Upon notification, selected antennas should be shut down or reduced in power during immediate access. Coordination with building manager necessary.
3	Factory RF heat sealer operation where RF fields exceed lower tier but do not exceed upper tier.	RFSP includes training of workers about RF field hazards, exposure limits, contact currents and work procedures to eliminate excessive exposures. Factory floor area becomes restricted area for visitors unless briefed on RF safety issues.
4	Electrical service contractor company dispatches electrician crew to broadcast antenna site to replace emergency generator.	RFSP should include training of crew on RF safety awareness, use of personal RF monitors; need to check area for excessive RF fields prior to beginning work.

Copyright © 2006 IEEE. All rights reserved.

Table B.1—Example exposure scenarios and example elements for corresponding RFSP *(continued)*

No.	Scenario	RFSP elements, requirements
5	Broadcast site where the spatially averaged RF fields caused by building and ground reflections exceed action level in a limited area but do not exceed upper tier MPE values.	This represents a Category 2 scenario. If site is remote, Notice signage is adequate to alert persons to presence of RF fields exceeding lower tier limits and to keep clear of area. If the site is frequently accessed by members of the public, install fencing to restrict access in addition to signage.
6	Factory that manufactures radio communication equipment conducts testing of transmitters for performance. Transmitters are connected to dummy loads during operation. Ambient RF fields are less than lower tier exposure limit.	RFSP must establish that use of dummy load is required work practice (transmitters to never be operated without connection to dummy load).
7	Tower service company dispatches crews that perform on-tower installation, maintenance, and rigging work at numerous sites.	RFSP must include RF safety awareness training for all tower workers and use of RF personal monitors. Work area on towers must be "cleared" prior to commencing work aloft. RF safety plan for site, if available, should be followed that prescribes power reductions or station shut down during tower work.
8	Vehicle-mounted very-high-frequency (VHF)/ultra-high-frequency (UHF) taxicab and police radios (typical 20-200 W EIRP)—situation where a radio operator is normally shielded by the vehicle structure from roof- or trunk-mounted antennas, but persons external to but near the vehicle or in the rear seat are closer to the antenna(s).	RFSP would normally include a determination that RF fields associated with operation of the taxicab or police radio will not cause exposures in excess of the applicable exposure limit, and appropriate RF safety awareness training for radio operators. The radio operator may be considered to be in an occupational exposure situation if properly trained to be aware of exposures and control RF transmissions, but bystanders and passengers are generally considered to be in general public exposure conditions.
9	Facility with high-power industrial microwave ovens with minimal leakage fields resulting in essentially no exposure under normal operating conditions.	RFSP must include a mechanism for checking on the adequacy of equipment interlocks and door leakage levels to insure proper operation since a failure could result in significant personnel exposure. Personnel should be provided with RF safety awareness information that discusses equipment failure modes.

Copyright © 2006 IEEE. All rights reserved.

Annex C

(informative)

Identifying RF sources and categorization of potential exposure conditions

The initial step for RFSP categorization is identifying RF sources and potential exposure situations. RF emissions occur from a variety of different sources. Each type of source has a different RF-exposure potential, and can require unique analysis. Guidance on determining the nature of various broadcast services requiring environmental evaluation is available, for example in FCC [B11]. Each type of source may need to be discussed separately in the documentation of an RFSP.

Passive sources of RF fields may exist in the form of metallic structures found near active RF sources that can reflect and scatter fields into areas not anticipated. When inspecting a site, attention should be given to the possibility that conductive objects may distort RF fields in their vicinity even though they are not actively energized by a transmitter or generator and produce RF fields exceeding MPEs.

Regardless of the method selected, the minimal information listed in C.1, C.2, and C.3 must be understood.

C.1 Emitter characteristics

a) Operating frequency
b) Average and peak transmitter output power or generator RF power rating
c) Effective radiated power
d) Modulation characteristics
e) Duty factor
f) Proximity to other sources
g) Distance to source
h) Type of radiator (size, gain, beamwidth, directionality, electrode source for dielectric heating devices)

C.2 Site characteristics

a) Structures on the site (buildings, towers, etc.)
b) Antenna mounting heights relative to accessible areas
c) Occupied areas
d) Engineering controls at sites

C.3 Environmental characteristics:

a) Topography of the site
b) Existence of multiple roof levels, etc.
c) Existence of other tall or taller structures that persons may occupy.

Copyright © 2006 IEEE. All rights reserved.

Annex D

(informative)

RF fields—general measurement issues

Measurement of RF fields is mostly a complex and specialized task and, therefore, only a general introduction is provided here. Readers should refer elsewhere for more details, e.g., IEEE Std C95.3 and references therein. Direct RF field measurement normally includes the use of a probe with (or without) a cable connecting it to a metering device to determine the field strength or power density of an electromagnetic field. Specific training in the use of the equipment and the measurement techniques is usually required for its proper use.

Field-strength measurements may provide the most realistic assessment of RF exposure. For example, measurements must frequently be made, even after computations have been performed, due to the uncertainties inherent in the particular exposure environment. One example is for re-radiating fields from conductive objects. In a multiple-source environment, or in the case of leakage sources (such as RF heat sealers, induction heaters, and other unintentional radiators), the computations may become so cumbersome that measurements may be the most expedient method for assessing exposure. However, in the case where there are multiple, intermittent sources, care must be taken to determine that the worst-case exposure situation has been examined. In some cases, induced body and/or contact current measurements are required to accurately assess exposure near certain near-field sources, such as dielectric sealers. Also, in the extreme near-field of broadcast towers (when workers are on or within a short distance, of a tower, e.g., one meter) exposure can be over or under-estimated if only field strength is measured.

D.1 Instrumentation

Several commercially available instruments permit direct broadband field strength measurements. Special care must be taken to avoid measurement errors in low-frequency, multiple-frequency, amplitude-modulated and intermittent field environments. The RFSO should be familiar with the operation and limitations of the equipment as provided by the manufacturer and discussed in other references, e.g., IEEE Std C95.3-2002 [B20] and NCSL [B29]. All field strength and current measurements should be performed in accordance with established standards such as IEEE Std C95.3-2002 [B20] or equivalent.

It should be noted that erroneous RF field assessments could result when some equipment is used in environments for which it has not been tested. This is commonly true for RF field probes used in moderate to high-strength 60-Hz electric fields, e.g., near electric power lines.

D.2 Calibration

Instruments used for exposure assessment should be properly calibrated and validated to confirm that the instrument is operating correctly with appropriate documentation (see IEEE Std C95.3-2002 [B20] and NCSL [B29]). Recalibration may be necessary if the instrument has been dropped, damaged, repaired or modified, or shows signs of erratic behavior/operation. In cases where measurements must be made with an instrument that has exceeded its regular calibration cycle, for example in the response to an urgent exposure issue, a post-calibration of the instrument is acceptable. In this case, the response of the instrument before adjustments are made in the calibration process should be noted so that the previous measurements can be appropriately corrected. In some instances, comparison of instrument readings with those of another instrument can be useful in judging the consistency of measurements.

Copyright © 2006 IEEE. All rights reserved.

D.3 Measurement techniques

Measurement protocols should include an evaluation of repeatability. For example, measurements made with the operator standing in different positions relative to the field sources for a given probe location can result in highly variable readings due to interaction between the incident RF fields and the person performing the field measurement. Efforts should be made to obtain the best estimate of the unperturbed RF field at points where it is suspected that fields may exceed the applicable MPE or reference level, which may require an averaging of multiple measurements taken from different azimuth positions relative to the measurement point. Other effects can include erroneously high readings due to the presence of static charge on the probe (e.g., when using a probe during high wind velocity conditions that can result in the induction of static charge on the probe), high voltage power lines and CRT displays. The technique used should be documented along with the results. In some cases, measurements of contact or induced body currents may prove more effective in examining compliance with the applicable exposure limits, especially when local RF hot spots are encountered (see Tell [B32]). Where evaluation of the RF exposure field is to be based on spatial averages, the measurement technique should follow recommended practices and include the relevant dimensions and postures of the body of the exposed person.

Exposure assessment is the correlation of measurement data with the human factors associated with the work area. The exposure assessment requires knowledge of RF fields and the effects on the areas occupied by persons. Hence, it is critical to know where people will be when deciding where measurements or calculations should be performed. In some cases it may be more meaningful to measure currents induced in the operator (for example, with RF heat sealers and induction heaters), or contact currents incurred when people touch extended metal objects which are in the vicinity of high-power low-frequency sources like AM radio towers.

D.4 Interpretation/conclusions

RF field strength assessments are distinguished from exposure assessments by one important ingredient, namely, the location and activities, or work practices, of people. Field assessments are useful for identifying accessible areas that cannot exceed the exposure limit, or conversely, those areas within which the exposure limit may be exceeded. Measurements and/or calculations provide important information for demarcation of those areas where, if occupied, the exposure limit would be exceeded. Exposure assessments, therefore, are dependent on the fundamental bases of the RF exposure limits, such as spatial and time averaging of the fields and, in some cases, currents. These conclusions should be applied to the determination of safe working practices.

 Copyright © 2006 IEEE. All rights reserved.

Annex E

(informative)

Estimating RF exposure potential

E.1 Field calculations

Several analytical formulas and/or computer programs are available for computation of radiated emissions and field strengths for a variety of configurations (see for example FCC [B11], IEEE Std C95.3-2002 [B20], and NCRP [B27]). These calculations create a theoretical model of the electromagnetic field in the space around the radiator. An understanding of the relationship between theoretical field strength and the appropriate exposure criteria is essential. Calculations are most helpful for understanding what equipment is needed to perform direct measurements, for example, selecting a probe with the proper dynamic range. Users should be aware of these differences and note that point-in-space calculated values typically over-estimate the actual spatially averaged field.

Generally, analysis of RF fields is fairly straightforward for intentional radiators using well-defined antennas. However, unintentional radiators can be extremely difficult to accurately model since the nature of the field generating element(s) is not well characterized. Often, field measurements are the more expedient approach to assessing possible exposure near unintentional emitters.

E.2 Induced current calculations and measurements

Several theoretical and empirically derived expressions exist for predicting the magnitude of induced currents from incident RF field levels (see Ghandi [B13] and [B14], Hill [B15], Lubinas [B25], and Tell [B32] and [B33]. These methods can obviate the necessity for performing induced current measurements once the field strengths have been quantified. Contact current exposures may be estimated using method of moment (MOM) computer programs that model the interaction of the human body impedance with the contact current source—typically a re-radiating object or more generally, large objects in the vicinity of high-power low-frequency emitters, for example a tall crane with a cable existing in the vicinity of a medium-wave broadcast station.

Copyright © 2006 IEEE. All rights reserved.

Annex F

(informative)

Example reference materials

Air Force Occupational Safety and Health Standard 48-9 (Aug.1997). (http://www.e publishing.af.mil/pubfiles/af/48/afoshstd48-9/afoshstd48-9.pdf)

Commonwealth of Virginia RF Radiation Exposure Compliance Plan for Building- and Tower-based Antenna Sites, Mobiles and Maintenance, Apr. 2000. (http://www.vita.virginia.gov/docs/alerts/Alert_RadioFreqExGuide_exp.pdf)

Corley, B. (2001), EME ELECTROMAGNETIC ENERGY, Evaluation and Management for Antenna Sites, Dec. 2001. (http://www.osha.gov/SLTC/radiofrequencyradiation/corley_motorola_eme_report.pdf)

Curtis, R., "Elements of a comprehensive RF protection program: role of RF measurements," Apr. 1995. (http://www.osha.gov/SLTC/radiofrequencyradiation/elem_com.html)

European Telecommunications Standards Institute (ETSI) TR 101 870 V1.1.1 (2001-11), Fixed radio transmitter sites; Exposure to non-ionising electromagnetic fields; Guidelines for working conditions.

Hitchcock, R. T., and Patterson, R. M., Radio-Frequency and ELF Electromagnetic Energies: A Handbook for Health Professionals, ACGIH, 1995.

International Labor Office (1998), Safety in the use of radiofrequency dielectric heaters and sealers. Geneva. (http://www.ilo.org/public/english/protection/safework/cops/english/download/e000014.pdf)

Kitchen, R., RF and Microwave Radiation Safety Handbook (second edition), 2001.

Lawrence Livermore National Laboratory Environment, Safety, and Health (ES&H) Manual, Volume II, Part 20: Ionizing Radiation/Nonionizing Radiation, Document 20.7, Nonionizing Radiation and Fields (Electromagnetic Fields and Radiation with Frequencies Below 300 GHz). (http://www.llnl.gov/es_and_h/hsm/doc_20.07/doc20-07.pdf)

Merewood, P., Power Flux Density and Field Strength Measurements, Good Practice Guide, National Physical Laboratory, Teddington, UK, Apr. 2004.

TB MED 523, Control of Hazards to Health from Microwave and Radio Frequency Radiation and Ultrasound, Headquarters, Dept. of Army, 1996. (http://www.army.mil/usapa/med/DR_pubs/dr_a/pdf/tbmed523.pdf)

 Copyright © 2006 IEEE. All rights reserved.

Annex G

(informative)

Example over-exposure incident report form format (use for designing organization specific form)

SAMPLE OVER-EXPOSURE INCIDENT REPORT FORM

Name of overexposed person: …

Site name where incident occurred: …

Date when incident occurred: …

NATURE OF ANY INJURIES INCURRED FROM THE RF OVER-EXPOSURE INCIDENT

Were any injuries incurred as a result of the over-exposure (Y/N)? ☐ Yes ☐ No

If so: What type of injury was incurred? …

What was the bodily location of the injury(ies)? … … … … … … … … … … … … … … … …

What medical treatment was applied? (check)

☐ None ☐ First Aid ☐ Doctor only ☐ Hospital

RF EXPOSURE DETAILS OF THE INCIDENT

Where on site did the incident occur, and what was the RF source? … … … … … … … … … …

… …

Provide estimates of the frequency, duration and level of the RF overexposure.

… …

OTHER INCIDENT DETAILS

Who saw the accident happen? …

How did the accident happen? …

What RF safety documentation and signage was provided on site?.....................................

What steps have been taken to prevent re-occurrence? (e.g. further training, better signage)

… …

EMPLOYEE CERTIFICATION

By signing this affidavit, I certify that the above information is correct to my knowledge.

Employee signature: … … … … … … … … … … … … … … Date: … … … … … … … … … … … …

Person taking this report: … … … … … … … … … … … … … … Date: … … … … … … … … … … … …

Copyright © 2006 IEEE. All rights reserved.

Annex H

(informative)

Glossary

H.1 electric blasting cap: A device for detonating charges of explosives electrically.

H.2 intentional radiator: An RF device that emits RF energy by radiation or induction as a means to accomplish its intended function.

H.3 maintenance: Activity intended to keep equipment (hardware) or programs (software) in satisfactory working condition, including tests, measurements, replacements, adjustments, repairs, program copying, and program improvement. Maintenance is either preventive or corrective and does not include operation or service as defined in this recommended practice.

H.4 squib: A device similar to an electric blasting cap but containing gunpowder composition that simply ignites but does not detonate an explosive charge.

H.5 unintentional radiator: A device that generates RF energy for use within the device, or that sends RF signals by conduction to associated equipment via connecting wiring, but which is not intended to emit RF energy by radiation or induction.

Copyright © 2006 IEEE. All rights reserved.

Annex I

(informative)

Bibliography

[B1] AAMI TIR18:1997—Guidance on electromagnetic compatibility of medical devices for clinical/biomedical engineers—Part 1: Radiated radio-frequency electromagnetic energy.

[B2] ACGIH, "Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices," American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 2004.

[B3] Adair, E. R. (1999), Potential for Over-Exposure to Directed Electromagnetic Energy in an Open Operational Environment. In Proceedings of the RTO HFM Symposium on "Countering the Directed Energy Threat: Are Closed Cockpits the Ultimate Answer?", Antalya, Turkey, 26–28 April 1999, and published in RTO MP-30, pp. 8-1 to 8-8.

[B4] ANSI Z535-1998, American National Standard for Environmental and Facility Safety Signs.

[B5] ARRL, RF Exposure and You, The American Radio Relay League, 1998–2004, #6621.

[B6] Australian Radiation Protection and Nuclear Safety Agency, "Maximum Exposure Levels to Radiofrequency Fields—3 kHz to 300 GHz," Radiation Protection Series Publication No. 3, 2002.

[B7] Canada, "Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range of 3 kHz to 300 GHz," Safety Code 6, Environmental Health Directorate, Cat. H46-2/99-237E, 99-EHD-237, 1999.

[B8] COMAR, Medical aspects of radiofrequency radiation overexposure. IEEE Committee on Man and Radiation, *Health Physics*, Vol. 82, No. 3, pp. 387–391, 2002.

[B9] Department of Defense, Instruction 6055.11, Protection of DoD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers, February 21, 1995.

[B10] FCC *Second Memorandum Opinion and Order and Notice of Proposed Rulemaking*. In FCC Docket 93-62, response to petitions and amendment of certain aspects of FCC guidelines for evaluations the environmental effects of radiofrequency (RF) emissions produced by FCC-regulated transmitters. Federal Communications Commission document FCC 97-303, 1997.

[B11] FCC, *Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*. FCC Bulletin No. 65, Edition 97-01, Federal Communications Commission, Office of Engineering and Technology, Washington, DC, 1997 (see: www.fcc.gov/rfsafety).

[B12] FCC, Federal Communications Commission, "Radiofrequency radiation exposure limits," 47 CFR 1.1310 *et seq*. Federal Communications Commission, Washington, DC, 1997 (see: www.gpoaccess.gov).

[B13] Gandhi, O. P.; Chatterjee, I.; Wu, D.; and Gu, Y-G, "Likelihood of high rates of energy deposition in the human legs at the ANSI recommended 3-30 MHz RF safety levels," *Proceedings of the IEEE*, vol. 73, no. 6, June, pp. 1145–1147, 1985.

Copyright © 2006 IEEE. All rights reserved.

[B14] Gandhi, O.P.; Chen, J-Y; and Riazi, A. "Currents induced in a human being for plane-wave exposure conditions 0–50 MHz and for RF sealers," *IEEE Transactions on Biomedical Engineering*, vol. BME-33, pp. 757–767, 1986.

[B15] Hill, D. A. and Walsh, J.A., "Radiofrequency current through the feet of a grounded human," *IEEE Transactions on Electromagnetic Compatibility*, vol. EMC-27, no. 1, February, pp. 18–23, 1985.

[B16] ICNIRP, "International Commission on Non-Ionizing Radiation Protection guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (Up to 300 GHz)," *Health Physics*, vol. 74, no. 4, pp. 494–522, 1998.

[B17] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.

[B18] IEEE Std C95.1-1991 (R1997), IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

[B19] IEEE Std C95.2-1999, IEEE Standard for Radio Frequency Energy and Current Flow Symbols.

[B20] IEEE Std C95.3-2002, IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields with Respect to Human Exposure to Such Fields, 100 kHz–300 GHz.

[B21] IEEE Std C95.4-2002, IEEE Recommended Practice for Determining Safe Distances From Radio Frequency Transmitting Antennas When Using Electric Blasting Caps During Explosive Operations.

[B22] IEEE Std C95.6-2002, IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz.

[B23] IEEE P1654, Draft Guide For Establishing A Safety Program For Protection Of Electrical Workers In The Vicinity Of Wireless Communication Antennas Adjacent or Attached To Electrical Power Line Structures, Nov. 2003.

[B24] Joyner, K. H.; Copeland, P. R.; and MacFarlane, I. P. (1989), An evaluation of a radiofrequency protective suit and electrically conductive fabrics. *IEEE Transactions on Electromagnetic Compatibility*, Vol. 31, No. 2, May, pp. 129-137.

[B25] Lubinas, V. and Joyner K. H., *Measurement of Induced Current Flows in the Ankles of Humans Exposed to Radiofrequency Fields*, Telecom Australia Research Laboratories report no. 8000, Telecom Research Laboratories, Clayton Victoria, Australia 3168, 1991.

[B26] NCRP, "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report 86, National Council on Radiation Protection and Measurements, Bethesda, MD, 1986.

[B27] NCRP, "A Practical Guide to Determination of Human Exposure to Radio Frequency Radiation," NCRP Report 119, National Council on Radiation Protection and Measurements, Bethesda, MD, 1993.

[B28] NCRP, "Letter Report on Wireless Telecommunications Radiofrequency Safety Issues for Building Owners and Managers," National Council on Radiation Protection and Measurements, Bethesda, MD, Scientific Committee 89-6, December 20, 2002.

[B29] NCSL, RP-1, Recommended Practice, Establishment & Adjustment of Calibration Intervals. National Conference of Standards Laboratories (NCSL), March 1996.

 Copyright © 2006 IEEE. All rights reserved.

[B30] Olsen, R. G. and Van Matre, B. J. (1994), Measurements of ankle specific absorption rate and body-to-ground current in a suit-protected human model for near-field exposures, 2–400 MHz. Applied Occupational and Environmental Hygiene, vol. 9, No.6, June, pp. 442–446

[B31] OSHA, The control of hazardous energy (lockout/tagout), 29 CFR 1919.147, U.S. Department of Labor, Occupational Safety & Health Administration, Washington, DC.

[B32] Tell, R. A., "RF hot spot fields: the problem of determining compliance with the ANSI radiofrequency protection guide," *44th Annual Broadcast Engineering Conference Proceedings, National Association of Broadcasters Engineering Conference*, March 30–April 3, 1990, Atlanta, GA, pp. 419–431.

[B33] Tell, R. A., Induced Body Currents and Hot AM Tower Climbing: Assessing Human Exposure in Relation to the ANSI Radiofrequency Protection Guide, Technical report prepared for the Federal Communications Commission, Office of Engineering and Technology, Washington, DC, FCC/OET RTA 91-01, 1991.

[B34] Tell, R. A., RF Current Reduction Provided by Work Gloves at AM Radio Broadcast Frequencies, Technical report prepared for the Federal Communications Commission, Office of Engineering and Technology, Washington, DC, FCC/OET RTA 93-01, 1993.

[B35] Tell, R. A. (1995), *Engineering Services for Measurement and Analysis of Radiofrequency (RF) Fields*, Technical report prepared for the Federal Communications Commission, Office of Engineering and Technology, Washington, DC, FCC/OET RTA 95-01.

Copyright © 2006 IEEE. All rights reserved.