HANFORD MISSION INTEGRATION SOLUTIONS

Administrative Procedures

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Radiofrequency (RF) Radiation Safety

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Change Summary

Description of Change

The changes in the procedure will satisfy the following corrective actions:
HMIS-CR-2023-0517-001
HMIS-CR-2023-0511-002

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1.0 PURPOSE

This procedure establishes Hanford Mission Integration Solutions (HMIS) Non-ionizing Radiation Safety Program requirements in accordance with 29 CFR 1910.97 *Non-ionizing Radiation*, 29 CFR 1926.54, *Non-ionizing Radiation* (construction), and the Institute of Electrical and Electronic Engineers (IEEE) C95.7, *IEEE Standard for Electromagnetic Energy Safety Programs, 0 Hz to 300 GHz.* This procedure also establishes exposure control methods in accordance with the American Conference of Governmental Industrial Hygienists (ACGIH) guidance document, "*Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*" (2016).

2.0 SCOPE

This Level 1 Administrative Procedure applies to all HMIS facility operations that purchase, maintain, and/or use electromagnetic energy (EME) emitting devices which have the potential to exceed the Threshold Limit Value (TLV) or Maximum Permissible Exposure (MPE) values. The information in this procedure is used to control exposures to radio frequency (RF) radiation and microwave radiation originating from radio stations and other possible sources of electromagnetic radiation, such as used for telecommunication, radio navigation, security, and industrial and scientific purposes. This procedure does not apply to the deliberate exposure of patients by, or under the direction of, practitioners of the healing arts, the private use of cell phones or wireless computing devices, or incidental use of microwave ovens.

This document implements the following Integrated Safety Management System (ISMS) Core Functions: #2: Identify and Analyze the Hazards; #3: Develop and Implement Hazard and Environmental Controls; #4: Perform Work Within Controls, and #5: Provide Feedback and Continuous Improvement, as well as Guiding Principle 5: Identification of Safety and Environmental Standards and Requirements.

3.0 RESPONSIBILITIES

3.1 Radiofrequency (RF) Engineer

- Identify and maintain an inventory of all electromagnetic energy (EME) emitters, which includes radiofrequency and microwave emitting devices, that are used on the Hanford Site.
- Notify the RFSO when new EME emitters are purchased or when new antennas are to be installed on the Hanford Site.
- Notify the RFSO if power level or configuration changes occur.
- Assess the hazards associated with RF emitters that are included on the inventory sheet and provide input into Job Hazard Analysis (JHAs).

3.2 Radiofrequency Safety Officer (RFSO)

- Upon receipt, provide an initial evaluation of an RF emitter, as requested by the RF Engineer or a Buyer's Technical Representative (BTR).
- Review annually the HMIS Radiofrequency (RF) and Electromagnetic (EM) Emitters Inventory Sheet; provide input as needed.
- Assess the hazards associated with RF emitters that are included on the inventory sheet and then provide Hazard Category information, as needed.
- Provide input into JHA's, as requested.
- Describe proper controls to prevent or minimize occupational exposures to RF emitters.
- Oversee the RF Radiation Safety Program as described in this procedure and perform an assessment of the program every 3 years or as needed.

3.3 Facility/Project Managers

- Ensure all personnel who may be exposed to or operate Category 2 (or greater) RF or EME emitters have been briefed on the hazards and applicable control measures.
- Work with the RFSO and/or IH Field Support staff to determine actions in response to dosimeter alarms when working around RF or EME emitters.

3.4 Buyer's Technical Representative (BTR)

- Using the Buyers Technical Rep's (BTR) *Hazard Review and Identification Checklist,* Site Form A-6007-667, ensure the RFSO is notified when new RF/EME emitters are purchased, brought onto the Hanford Site for use by a subcontractor, or when a Statement of Work (SOW) involves the installation of a new antenna on an existing tower located on the Hanford Site.

3.5 Industrial Hygiene Field Support professionals (IH)

- Perform RF field surveys as requested.
- Perform an Industrial Hygiene Baseline Hazard Assessment (IH BHA) as requested or when changes in RF sources occur.
- Provide IH BHA results to RFSO.
- Train Workers (Craftsmen or Exempt personnel) on the proper use of RF personal dosimetry, review the alarm set points, and provide direction for the proper response to any dosimetry alarm.

- Document completed training.
- Provide pre-job briefings to Workers prior to the start of any work that will involve a potential exposure to RF radiation when hazard exceeds Craft Specific Hazard Analysis (CSHA). Review relevant CSHA and/or JHA during pre-job briefing.
- Ensure RF survey instruments are calibrated annually or as required.

3.6 Workers (Craftsmen or Exempt personnel)

- When required, attend training for RF radiation safety awareness and/or for the proper use of RF personal dosimetry.
- Attend pre-job briefings prior to working with or around RF emitters.
- Wear RF personal dosimetry when required by the IH or as directed in relevant work package documents.
- Respond to RF dosimetry alarms as instructed by the IH and/or the work package.

4.0 INSTRUCTIONS

For a RF hazard to result in harm, something that is susceptible to RF radiation needs to be present at a location and time that the RF radiation is present above a critical value. Therefore, risks of harm can be controlled by eliminating the presence of a susceptible target (i.e., employees) in areas with high levels of RF radiation and/or controlling the RF levels in the presence of susceptible targets.

The primary hazard from electromagnetic energies (RF and microwave) is *heating of the body*. The eyes and genitals/reproductive organs are the most sensitive to RF radiation. Prolonged exposure to very high sources of RF radiation can result in death.

The intent of this RF Radiation Safety Program is to help mitigate established health and safety risks associated with the unintended interactions of electromagnetic fields (EMF), currents, and/or contact voltages with people or with electronics, materials, substances, or structures (concomitant EME hazards). To mitigate risks, this safety program will identify EME hazards, categorize RF emitters based on their potential to exceed the action limit or exposure limit, and then establish controls to prevent or minimize exposures to RF radiation in accordance with the IEEE Standard C95.7 (2022) and ACGIH TLV (2016) for Radiofrequency/Microwave Radiation.

4.1 Develop an RF Radiation Safety Plan

Actionee	Step #	Action
HMIS Safety Program Manager	1.	DESIGNATE a qualified professional as outlined in IEEE Standard C95.7 to function as the HMIS RF Safety Officer (RFSO) to manage and administer this procedure.
RF Engineer, contract specialists (CS), BTRs, Facility or Project Managers (EME Custodians)	2.	As new equipment is obtained, REQUEST an exposure evaluation from the RFSO. To complete this evaluation, the RFSO may request some or all of the following information: • Emitter frequency. • dB Rating of the emitter. • Power. • EME emitter dimensions. • Height where the emitter will be mounted. • Information related to the area around the emitter. • Pulse width and repetition frequency. • Equivalent/Effective Isotopically Radiated Power (EIRP). • Effective Radiated Power (ERP). NOTE: *This information may also be requested for an exposure evaluation of existing emitters.*
RF Engineer and RFSO	3.	CONDUCT RF evaluations using the manufacturer's information or PERFORM "screening" measurements of equipment emissions after installation, major maintenance, and any modifications which could affect the RF emissions. Significant deviations from previous measurements should be resolved. a) RE-EVALUATE RF emitters as recommended by the manufacturer. b) IF a specific manufacturer's recommendation is not provided, THEN RE-EVALUATE RF emitters if power levels or configuration changes occur.
RF Engineer	4.	MAINTAIN the HMIS inventory of radio frequency (RF) and electromagnetic (EM) energy emitters. An inventory must include, at a minimum, the following information: • Device or device type (its function or use). • Operating frequency.

- Effective radiated power (for intentional radiators).
- Modulation characteristics.
- Duty factor.
- Proximity to other sources.
- Distances to source from relevant locations.
- Type of radiator (size, gain, beamwidth, directionality, electrode source for dielectric heating devices).
- Hazard category based on the potential for EME exposure.
- Identification of the custodian/organizational group for the RF/EME emitter.

NOTE: *A completed copy of the RF and EM emitters inventory will be provided for the RFSO's working files and review.*

5. CATEGORIZE each RF or EME emitter as follows:
   - Category 1 – Operational characteristics of source(s) would not cause the action level to be exceeded.
   - 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.
   - Category 3 – Potential to exceed the exposure limit in accessible areas if mitigating controls are not applied.
   - Category 4 – Exposure will exceed exposure limit in accessible areas.

   NOTE: *Elements to consider when determining the categorization of an RF or EME emitter are provided in Appendix A.*

6. PROVIDE the information from the evaluation of RF emitters, to the Industrial Hygienist.

IH

7. UPDATE any existing or new job hazard analysis documentation per HMIS-PRO-SP-079, *Job Hazard Analysis,* and the applicable Industrial Hygiene Baseline Hazard Assessments (IHBHA) per SP-PRO-SP-17916, *Industrial Hygiene Baseline Hazard Assessments*.

4.2 Implementing the RF Radiation Safety Program

To implement an RF Radiation Safety Program requires establishing controls which are based on the level of risk assigned to each RF device or hazard. The two types of controls that are used are engineering and administrative. Engineering controls (e.g. shielding, barriers, interlocks, and software controls) are preferred over administrative controls because they provide definitive "engineered" solutions, whereas administrative controls involve user discretion and action and should only be used if engineering controls are not feasible. Administrative controls (e.g. signs, barriers, safe work practices, and personal or area RF monitors) can be used to supplement engineering controls.

Post signs with a clear plan and agenda in place and good reasons for their location and verbiage. RF hazard areas must be identified to alert workers of areas that are not to be occupied during RF application. Screening measurements can be used to determine where to locate signs to alert workers approaching an RF hazard area, and which warning message (e.g. Notice, Caution, Danger) would be appropriate for a specific RF hazard area.

The hierarchy for sign placement is:

1. For areas where the levels of RF radiation fields are less than 20% of the appropriate exposure limit, no signs are required.

2. For areas where the levels of RF radiation fields are between 20% and 100% of the appropriate exposure limit, a **NOTICE** sign will be used.

3. For areas where the levels of RF radiation fields are between 100% and 300% of the appropriate exposure limit, a **CAUTION** sign will be used.

Actionee	Step #	Action
RFSO	1.	CHARACTERIZE each location where an RF or EME device is in use and determine if there is a potential for an employee to experience an exposure above the Maximum Permissible Exposure (MPE) levels.
	2.	DETERMINE the need to perform an area or source survey. A survey may be needed for: • New or modified installations. • Changes in a previously surveyed environment. • Changes in the levels of emitted power or limits, or at the request of personnel or management.
	3.	OBTAIN Site Characteristics information, such as: • Structures. • Occupancy by people. • Barriers, interlocks, signs, and visual or audible alarms.

- Surrounding UNCONTROLLED areas, such as parking lots or access roads where there may be measurable RF emissions.
- Topographical information (for directional emitters, such as parabolic antennas).

4. Prior to monitoring, OBTAIN information about the RF source, such as:
   - Emitter characteristics:
   - Frequency
   - Power Level
   - Modulation characteristics
   - Spurious frequencies or Harmonics
   - Intermittence of Output, and Antenna information (e.g. size, beam width, gain and orientation).

Industrial Hygienist (IH)

5. Based on the frequency of the RF source, CHOOSE the appropriate instrument to perform field survey.

6. PERFORM field measurements where feasible. If field measurements are not feasible.

7. CONSULT with the RF Engineer to determine potential exposure levels.

8. Based on the likelihood of an exposure or overexposure, DETERMINE the controls necessary to prevent or minimize exposures to RF radiation or EM as described in Appendix C: *Controls*.

IH Field Support

9. ENSURE RF signs are posted at all locations where it was determined that category 2 (or greater) RF emitters exist. USE the criteria established in IEEE C95.7 standard and HMIS-RD-SP-29096, *Tags, Signs, and Barriers.*

10. UPDATE the applicable CSHA, as necessary, or the JHA per HMIS-PRO-SP-079, *Job Hazard Analysis.*

Facility/Project Manager/ Field Work Supervisor (FWS)	11. PERFORM walk-down of "RF hazard area" during the preparation of a Work Package for jobs that involve working around or with an active RF/EME emitter.
	12. ENSURE workers are properly trained prior to starting work (see Section 4.3).
	13. PERFORM a pre-job briefing with the worker(s) and IH Field Support prior to the start of any job in an RF hazard area.
	14. During the pre-job briefing, REVIEW the applicable CSHA or JHA as outlined in HMIS-PRO-SP-079, *Job Hazard Analysis.*
	15. ENSURE workers have PPE, as required in the CSHA or JHA.
IH Field Support	16. PROVIDE instructions for the use of a personal dosimeter, if needed.
	17. INSTRUCT workers how to respond to a dosimeter alarm, if necessary.
Workers	18. IF high RF fields are expected, THEN ATTEND training and OBTAIN a personal RF dosimeter, as needed.
	19. ENSURE the dosimeter is turned on and ATTACH the dosimeter to front of shirt.
	20. WHEN removing panels, shielding, or other protective devices, or be protected by another means from exposure to harmful EME, THEN USE Lockout/Tagout procedures in accordance with DOE-0336, *Hanford Site Lockout/Tagout Procedure,* and ENSURE the levels are below the action level for RF radiation and electromagnetic energy.
	21. In the event the dosimeter alarms, LEAVE the RF field immediately and REPOSITION to maintain a distance of at least 20 cm (8 inches) from the RF source. NOTE: *Most RF monitor manufacturers have identified that interference from lower hazard frequencies may cause false alarms.*

22. At the completion of the work evolution, RETURN the dosimeter to the IH Field Support to verify the dose/exposure.

IH Field Support

23. EVALUATE the dosimeter and determine that the 6-minute averages did not exceed the threshold limit value (TLV).

24. IF the dosimeter indicates that a person was exposed to more than 100% of the TLV, THEN REQUEST the person to report to the Site Occupational Medical Contractor (SOMC).

    NOTE: *Possible indications of an overexposure include physical responses, such as pain, reddening of the skin, unusually elevated body temperature, or any other evidence of tissue burning.*

25. INFORM the RFSO and FWS of suspected and/or actual RF over-exposure or incidents of interference with a medical device, as soon as practicable.

SOMC

26. EVALUATE worker for possible signs or symptoms of an overexposure to RF radiation.

27. MAINTAIN medical records in accordance with HMIS-PRO-RM-10588, *Records Management Process.*

Facility/Project Manager/ Field Work Supervisor (FWS)

28. REPORT any overexposure in accordance with HMIS-PRO-SP-077, *Reporting, Investigating, and Managing Health, Safety and Property/Vehicle Events.*

RFSO/ FWS

29. PARTICIPATE in investigations to ascertain the cause of an over-exposure, and to develop appropriate strategies to reduce the likelihood of subsequent incidents.

30. PERFORM an investigation whenever the exposure exceeds the limit by a factor of 5 or more.

31. CONSIDER the following remedial options:
    - Improving the awareness of any person(s) who contributed to the occurrence of the overexposure 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.

4.3 Training

RF safety training must be provided to all employees who access areas where RF exposures (RF fields, contact currents, induced currents, or contact voltages) can exceed the applicable exposure limits. This safety awareness training must provide the information necessary to help workers understand how to recognize situations in which excessive RF exposure may occur and inform personnel how to keep their exposure below the applicable exposure limits, based on site characteristics and RF emissions at the site.

The safety training protocol is dependent on the risk and potential consequences of the work activities. Training can be in the form of instructor-led presentations, computer-based training, written informational materials, pre-job briefing, or, for some situations, suitable signage. For persons with medical devices (metal implants or electronic medical devices) who may be exposed to RF radiation, special information that addresses RF interference issues should be provided as part of their awareness training. These workers must be informed of the potential for RF susceptibility of medical devices to ensure compatibility with the work environment.

Actionee	Step #	Action
FWS	1.	ENSURE that employees who work in areas where they may be exposed to Category 2 (or greater) RF radiation receive RF safety awareness training.
FWS	2.	PROVIDE RF safety awareness training that is appropriate for the designated hazard category of the RF emitter or for the level of hazard for the RF radiation field.
Worker	3.	PARTICIPATE in required RF safety awareness training.
	4.	NOTIFY the RFSO or the Manager/FWS about any medical implants or electronic devices.
	5.	FOLLOW all instructions to minimize exposure to RF radiation fields, contact currents, induced currents, or contact voltages.
	6.	ENSURE appropriate controls are observed, implemented, and/or maintained, as instructed.

4.4 Working with or Around RF Emitters

Actionee	Step #	Action
Facility or Project Managers (RF Custodians), BTRs	1.	Prior to working with or near an RF emitter, REQUEST an exposure evaluation from the RFSO. NOTE: *In order to complete this evaluation, the RFSO may request some or all of the information listed in section 4.1.3.*
RFSO	2.	COMPLETE an exposure evaluation by comparing the information provided by the facility or project manager to existing evaluations or using sections 4.1.4 through 4.1.6.
Facility or Project Manager (RF Custodians), RF Engineer with RFSO or IH Support	3.	INSTITUTE the appropriate controls from Appendix B NOTE: *Category 1 emitters do not require additional RF controls*
Facility or Project Manager	4.	POST signs for all category 2 and above emitters using criteria established in IEEE C95.7 and HMIS-RD-SP-29096, *Tags, Signs, and Barriers.*
Employee	5.	WEAR an RF/EME monitor, as required in the table found in Appendix B or as directed by facility or project management.
	6.	IF RF monitor alarms unexpectedly at either 50% or 200%, THEN EXIT work area immediately, and CONTACT facility or project management and immediate supervisor.
Facility or Project Manager with RFSO or IH Support	7.	IF RF monitor alarms unexpectedly during work, THEN DETERMINE any follow up actions, including the following: • Identifying the cause of the alarm • Evaluating the exposure risk • Developing appropriate control measures

NOTE: *Most RF monitor manufacturers have identified that interference from lower hazard frequencies may cause false alarms.*

8. IF follow-up determination actions in Step 7 above indicate a potential exposure exceeding the applicable ACGIH TLV, THEN STOP work in accordance with DOE-0343, "Stop Work" and IMPLEMENT appropriate process requirements for the timely identification and evaluation of conditions adverse to safety, health, and operability will be implemented using the Issue Identification Form (IIF) per HMIS-PRO-PA-052, *Corrective Action Management.*

4.5 Perform Program Maintenance

Actionee	Step #	Action
Facility or Project Managers/ RF Engineer	1.	IF an RF emitter power level or configuration changes, THEN REQUEST an exposure evaluation from the RFSO. NOTE: *In order to complete this evaluation, the RFSO may request some or all of the information listed in section 4.1.3. and 4.1.4*
RFSO	2.	COMPLETE an exposure evaluation by comparing the information provided by the facility or project manager to existing evaluations or using sections 4.1.3 through 4.1.6.

4.6 Employee Training

Actionee	Step #	Action
Facility or Project Managers	1.	ENSURE that employees who work in areas where they may be exposed to Category 2 or greater RF emitters are trained on general RF safety awareness. NOTE: *The level of training required for work around or with a specific RF emitter is dependent upon the designated hazard category for that device. Training can be delivered by several different methods, depending on the potential for exposures. Training methods can include instructor-led, computer based,*

Actionee	Step #	Action
		safety briefings, signs and postings, as well as a more comprehensive training course.

5.0 RECORD IDENTIFICATION

All records are generated, processed, and maintained in accordance with HMIS-PRO-RM-10588, *Records Management Processes,* or HMIS-PRO-RM-32281, *Electronic Records Management,* as applicable.

Table 1. Records Capture Table

Name of Record	Submittal Responsibility	Retention Responsibility
Radiofrequency and Electromagnetic Emitters Inventory	*Radio Frequency Engineering*	*Radio Frequency Engineering – IDMS (copy will be provided to RFSO)*

6.0 SOURCES

6.1 Source Requirements

10 CFR 851.23, “Worker Safety and Health Program”
29 CFR 1910.97, “Non-ionizing Radiation”
29 CFR 1926.54, “Non-ionizing Radiation”
The Institute of Electrical and Electronic Engineers (IEEE) Standard C95.1, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz* IEEE Standard C95.7, *IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GH*
American Conference of Governmental Industrial Hygienists (ACGIH), "Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices" (2016)
CRD O 420.1C Chg 3 (reference attachment in DOE letter 22-NSD-000147), *Facility Safety*

6.2 References

HMIS-PRO-RM-10588, *Records Management Processes*
HMIS-PRO-RM-32281, *Electronic Records Managemen*t
IEEE Standard C95.2-1999, *IEEE Standard for Radio-Frequency Energy and Current-Flow Symbols*

IEEE Standard C95.3 (R2008), *IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz-300 GHz*
DOE-0343, *Stop Work Procedure*
HMIS-PRO-PA-052, *Corrective Action Management*
HMIS-PRO-SP-079, *Job Hazard Analysis*
SP-PRO-SP-17916, *Industrial Hygiene Baseline Hazard Assessments*
HMIS-RD-SP-29096, *Tags, Signs, and Barriers*

Appendix A. Definitions

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.

Activity-based time-average control: The method of controlling an individual's exposure by controlling the amount of time an individual spends in higher exposure conditions such that the average satisfies the applicable exposure limit.

Administrative Controls: The policies, procedures, and information used to limit the risk of exceeding the RF exposure limits.

NOTE—*Administrative controls generally depend on the awareness and participation of qualified personnel for their effectiveness. Examples include hazard communication 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.*

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.

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 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**.

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.

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 (RFSP) 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 procedure is to ensure that persons are not exposed in excess of the "Controlled Environment" MPEs.*

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**.

Electromagnetic Emission (EME): The release of electromagnetic energy by devices, either intentionally (e.g., broadcast antennas) or unintentionally (e.g., electronic equipment).

Electromagnetic Radiation: The term restricted to that portion of the spectrum commonly defined as the radio frequency region, which for the purpose of the procedure shall include the microwave frequency region.

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.

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**.

General Public Exposure: For purposes of this procedure, 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**.

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.

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

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

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

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

Intentional Radiator: An RF device that emits RF energy by radiation or induction as a means to accomplish its intended function.

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.

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**.

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.*

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**—Occupational exposure typically occurs only in controlled environments.*

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.

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.

Partial Body Irradiation: Pertains to the case in which part of the body is exposed to the incident electromagnetic energy.

Permissible Exposure Level (PEL): *See:* **maximum permissible exposure**.

Radio Frequency: For purposes of this procedure and for simplification, the frequency range extending from 3 kHz to 300 GHz.

Radio Frequency Exposure Limit: *See:* **maximum permissible exposure**; **specific absorption rate**.

RF Safety Officer (RFSO): One who has authority to monitor and enforce the control of RF hazards.

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**.

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); 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.*

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).

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

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.

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**.

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.

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.

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 (R2008).*

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**.

Threshold Limit Values (TLV): Those limiting values i.e., (static magnetic fields, sub-radiofrequency and static electric fields, and radiofrequency and microwave radiation) to which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.

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.

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.*

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.

Whole Body Irradiation: Pertains to the case in which the entire body is exposed to the incident electromagnetic energy or in which the cross section of the body is smaller than the cross section of the incident radiation beam.

Appendix B. Control Elements

Control Elements	Category 2	Category 3	Category 4
Engineering controls			
Equipment /site configuration	R	R	M
Physical barriers	R	R	M
Administrative Controls			
Use of signs	M	M	M
Safe work practices	R	R	M
Use of lockout/tag-out procedures	R	R	M
Control of source power	R	R	M
Time averaging	R	R	M
Personal and/or area monitors	R	R	M
Personal Protective Equipment (PPE)			
Selection of appropriate PPE		R	R
Maintenance and inspections		R	R
Training			
General RF safety awareness	R	M	M
Explanation of RF exposure limits	R	M	M
RF exposure mitigation controls	R	M	M
Possibility of RF interaction with medical devices and implants	R	M	M
Electro-explosive device considerations (when present in the work area/environment)	R	M	M
Sources of additional information		R	R

R=Recommended M=-Mandatory

Appendix C. RF Hazard Controls

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

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.

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.

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.

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. 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).

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.

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 and HMIS-RD-SP-29096, *Tags, Signs, and Barriers* relative to use of signal words, 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. RF safety signs should employ multiple languages where appropriate and available, to ensure recognition and understanding by persons that are not fluent in the 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.

Common practice is to apply **NOTICE** signs 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.

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.

Use of lockout/tagout 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/Tagout (LOTO) procedures, for example as specified by the U.S. Occupational Safety and Health Administration (OSHA) for the control of hazardous energy (, shall 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.

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 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 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.

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 ensure 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.

Personal and/or area RF monitors

Personal RF monitors 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.

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. Empirical investigations have studied the ability of work gloves to reduce contact currents. However, the use of PPE may also subject the user to enhanced RF exposures if improperly employed. 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.

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. Shielded

hoods can also restrict peripheral vision and may, depending on design, present an unacceptable hazard during certain tower climbing operations.

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.

Appendix D. RF Hazard Controls

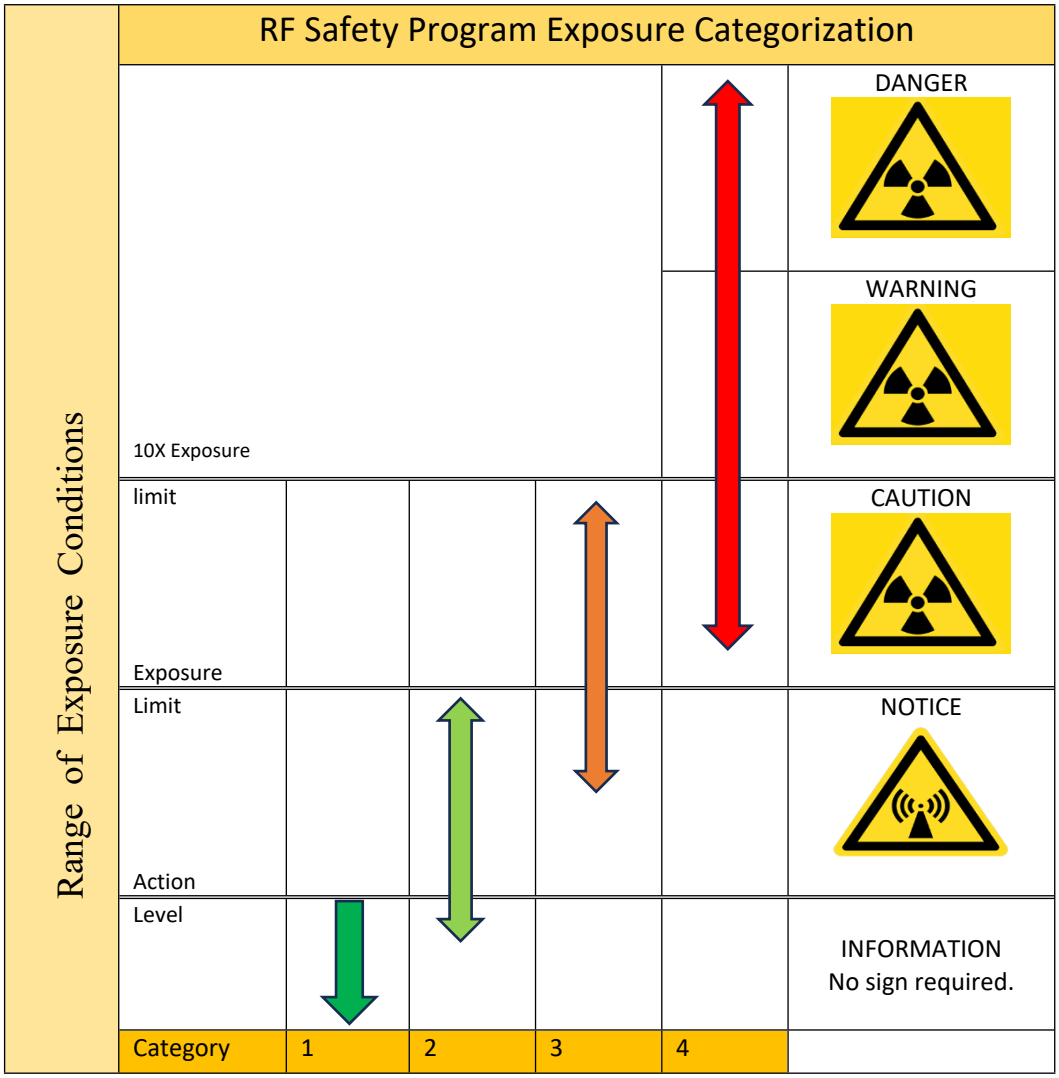

TABLE 1: Signage versus Exposure Levels