Integrating ANSI-Compliant RF Signs into Corporate RF Safety Programs

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ABSTRACT

Current practices in controlling and marking RF sites range from the very simple to the complex. Most broadcast facilities have signs that do not meet current ANSI standards for informing people of the key facts: the level of risk, the nature of the risk, the consequence of the risk and the action to take to avoid the risk. A new set of ANSI-compliant signs is presented with a protocol for incorporating them into an RF management program. Comparison is made with the Motorola RF protocol, which is oriented to the two-way radio industry, and with current thinking at OSHA. Use of the new signs as part of an RF management program at broadcast facilities should reduce ambiguity and improve compliance with FCC RF exposure management regulations.

INTRODUCTION

Years ago, all one needed to do is put a DANGER, HIGH VOLTAGE! Sign on an AM tower fence, and a broadcaster's RF safety program would be complete. Nevertheless, significant risk was still tolerated; tower workers might climb on the roof of the AM "doghouse" and leap through the air to mount a live tower. Transmitters, for the most part, had interlocks and grounding sticks, although there might be an exposed RF relay or contact in the transmitter shack. Inside the equipment rack, there might have been some homebrew control circuit with exposed mains AC power terminals.

Today, the industry exercises more sophistication in managing its radio frequency (RF) plants, but many of those risky installations still linger, and risky work practices are sometimes still condoned with a wink and a nudge. Signage that informs people of risk still may take the role of an afterthought—something that is done just to give the appearance of responsible site management.

Arguably, the most visible change to RF plant management came with the first Radio Frequency Radiation Hazard Warning Symbol in 1982.[1] High Voltage signs were supplemented or replaced by the official, but rather friendly looking RF symbol. Its light yellow triangle and symbol that looks like a lighthouse does not convey much meaning to the uninitiated. Even today, this is all that is found at many transmitter and tower sites.

The science of marking potential hazards is well developed and supported by standards. The RF industry is reliant on the same signage fundamentals that other disciplines are. This paper explores the foundation of hazard communication and develops an RF signage protocol based on that foundation.

ANSI STANDARD

The American National Standards Institute (ANSI) oversees the formation of all manner of standards. However, ANSI itself does not form standards. The process of setting standards involves the formation of an expert panel of individuals with an interest in the standard and from the various disciplines necessary to develop the standard. There are procedures to follow in creating the standard. Some organizations, such as the Institute of Electrical and Electronics Engineers (IEEE) and the Electronic Industry Alliance (EIA), to name two in the electronics field, are accredited by ANSI to develop standards under the ANSI protocol, and are called sponsors or secretariats. ANSI standards are inherently voluntary, but are sometimes codified in federal, state or local regulations.

Sponsors must adhere to certain principles in the creation of a standard. Among them are due process, consensus, and balance. The development of the standard is based on open participation where the group decides, without undue influence from a dominant party or group, on the final form of the standard.

Such a group is embodied in the Z535.2 committee responsible for environmental and facility safety signs.

[1] American National Standard Radio Frequency Radiation Hazard Warning Symbol, ANSI C95.2-1982

This committee is formed under the secretariat of the National Electrical Manufacturers Association (NEMA).

The current Z535.2 standard was updated in 1998, and describes some of the characteristics that should be common to all environmental and facility safety signs. Those who use radio frequency energy can benefit from understanding the purpose and meaning of the features of this generic standard. The principles also apply to other workplace hazards that those in the radio industry may encounter, such as electrical power supplies and controls, mechanical hazards from machinery, noise, and even tanks of nitrogen. This paper focuses on the manner in which standard ANSI Z535.2 Environmental and Facility Safety Signs relates to the radio frequency systems at broadcast facilities.

IEEE

In parallel with the ANSI/NEMA facility sign standards, IEEE maintains ANSI standards relating to human exposure to radio frequency energy. Radio frequency system operators are familiar with the ANSI/IEEE C95 committee standards, such as C95.1-1999 *Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields.* It is a common misperception that the FCC adopted IEEE RF exposure standards in its regulations. In fact, the primary source for the FCC's exposure regulations is the National Council on Radiation Protection and Measurements (NCRP) Report No. 86, *Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields.* The FCC mentions the IEEE C95.1 standard in 47 CFR §1.1310 because its RF exposure limits are similar to the NCRP limits.[2]

By not adopting the full IEEE C95.1 standard, the FCC left a number of features out of its RF exposure regulations. For instance, C95.1 addresses contact currents for those such as tower climbers who may be climbing a hot tower that otherwise may be compliant with the exposure standard. The FCC does not address contact currents. Because C95.1 is a voluntary standard, it may be advisable to observe the contact current limitations in the standard, but it is not required.

STANDARDS IN CORPORATE PRACTICE

The same could be said for the Z535.2 standard. It is not adopted as a regulatory control, as far as we know, but it is a consensus standard prepared under the auspices of an accredited industry entity. Often such standards are considered in court and by regulatory agencies such as OSHA as a reference for industry or employer conduct.

SIGNAGE IN RF ENVIRONMENTS

Operators of radio frequency equipment, then, have an amalgam of responsibilities in the realm of RF safety. Before signage can be considered, the safety implications of the RF environment must be threshed out.

The RF exposure standards presently have two thresholds, occupational/controlled and general population/uncontrolled conditions. IEEE identifies only *controlled* and *uncontrolled* environments, while the terms *general population* and *occupational* are employed by NCRP and refer to the classification of the individuals who are exposed. (This paper uses the term *public* interchangeably with *general population*) Accepting the value of both designations for different contexts, the FCC combined the two classifications.

Ultimately, the choice of which exposure tier applies in a given situation falls upon whether the exposed individual(s) are aware of their potential exposure and have the knowledge and ability to control it.[3] It may be obvious to say that occupational/controlled exposure can only occur, then, in a space that is under the control of the RF system operator. To succeed in maintaining control, the operator may have to delegate control of the location and control of exposure to those who are qualified to do so. Controlled locations, then, must have a secured perimeter to permit only qualified and authorized access. All other locations outside such perimeters would be general population/uncontrolled environments.

RISK OF HARM?

The occupational/controlled Maximum Permissible Exposure (MPE) limits are often mistaken as a threshold of harm—a *danger limit*, so to speak. In fact, the occupational/controlled MPE is a factor of ten times lower than the levels at which the science shows *biological effects*—effects that are not necessarily harmful. Thus, the occupational/controlled MPE is better termed a *safety limit*, because it errs on the side of safety. Below, when the role of hazard communication is discussed, the question of risk of harm will come into play.

Meanwhile, the RF safety environment is complicated by the second exposure tier, the general population/uncontrolled MPE. This MPE is set an additional factor of five lower than the

[2] This relationship is discussed in a note in 47 CFR §1.1310 and in the opening section of FCC Office of Engineering and Technology Bulletin 65.

[3] FCC OET Bulletin 65, Definitions

occupational/controlled MPE.[4] There is no scientific reason for this increased "margin of safety" but to many it makes intuitive sense. The public are not given the same choice to manage their exposure, so it seems sensible to afford them a greater buffer than the informed worker. Yet, if the public are informed properly, is that sufficient to apply the occupational/controlled MPE at a location otherwise uncontrolled? The FCC definition of a controlled environment includes locations where the general population might have brief transient exposure up to the occupational/controlled limits, as long as the individuals are informed and can leave the area at will.

As the above discussion implies, there are hazard communication issues not only for workers in controlled environments, but also potentially for the public in uncontrolled areas.

SAFETY SIGN STANDARDS

Taking a closer look at the NEMA-sponsored standard ANSI Z535.2-1998, *Environmental and Facility Safety Signs,* will reveal the basic tenets of safety communications reflected in its protocol for signage. The standard identifies several characteristics for safety communications.

Format

Signs are expected to meet formatting criteria so that they are uniform in appearance and meaning. Safety signs have up to three functional panels:

A *Signal Word* panel
A *symbol* or *pictorial* panel
A *Word Message* panel

SIGNAL WORDS

Signal words convey the urgency of the information presented in the sign. The Signal Word protocol is structured in this fashion:[5]

DANGER

Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations. This signal word should not be used for property damage hazards unless personal injury risk appropriate to this level is also involved.

Note: The DANGER signal word is appropriate for signs in the area of, or inside of enclosures containing, a Danger-level hazard.

WARNING

Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury. This signal word should not be used for property damage hazards unless personal injury risk appropriate to this level is also involved.

Note: The WARNING signal word is appropriate for signs placed outside of the area of, or on the exterior of the enclosures containing, a Danger-level hazard.

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices that may cause property damage.

[4] The lower limit for general population/uncontrolled exposure is, in theory, mitigated somewhat by an increase in the averaging time to calculate general population/uncontrolled exposure. However, as a practical matter, the averaging time is moot in general population/uncontrolled environments. The exposure time over which general population/uncontrolled exposure is computed is increased by a factor of five, from a six-minute averaging time for occupational/controlled exposure, to thirty minutes. In theory, this permits a member of the public to exceed even the six-minute MPE for controlled environments as long as the remaining 25 minutes of exposure yields an average exposure that is less than the general population/uncontrolled MPE. Since an uncontrolled location is uncontrolled by definition, allowing members of the public access for any length of time, the practical way to limit public exposure is to keep the levels in an uncontrolled area below the general population/uncontrolled MPE at all times. This effectively renders the 30-minute averaging time moot, except in cases where the RF emissions are deliberately managed by the operator to ensure public exposure averages out over the 30-minute period. Those who use RF systems for communication do not have the luxury of managing RF public exposure by fiddling with their power levels or duty cycles to meet thirty-minute averages in uncontrolled locations.

[5] Definitions are taken from Z535.2-1988, Section 4, American National Standard - Environmental and Facility Safety Signs

NOTICE

Signs used to indicate a statement of company policy directly or indirectly related to the safety of personnel or protection of property. This signal word should not be associated directly with a hazard or hazardous situation and shall not be used in place of "DANGER," "WARNING," or "CAUTION."

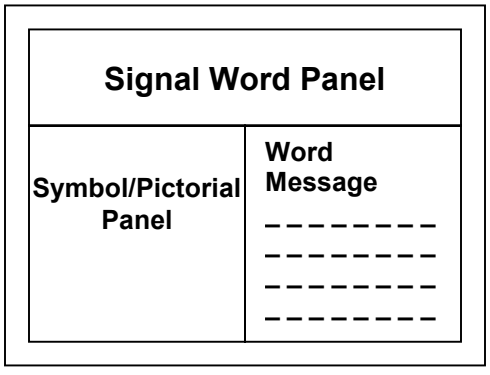
Colors

Each Signal Word is associated with a certain safety color:
DANGER = Red
WARNING = Orange
CAUTION = Yellow
NOTICE = Blue.

The precise characteristics of each color are defined in the standard.

SYMBOL OR PICTORIAL PANELS

With the Signal Word placed at the top of the safety sign, two additional panels are available for use. The Symbol or Pictorial Panel should contain the appropriate hazard communication symbol. Whether it be a biological hazard symbol, an electrocution symbol, an RF energy symbol, a hearing protection symbol, or one of a myriad of other familiar symbols, the symbol in the symbol panel invokes a standard graphic image that conveys meaning in a uniform fashion, without words. Any standard hazard symbol may be employed in the Symbol/Pictorial Panel, depending on the hazard being communicated.



ANSI Z535.2 Sign Format "Example D"

Between the three components— the simple Signal Word, its standard color, and the Symbol or Pictorial image— a good safety sign conveys familiar information instantly and uniformly. One characteristic of the safety sign remains to fill in information that may require more than simple recognition.

WORD MESSAGE PANEL

The Word Message Panel gives the sign owner the opportunity to convey more complex information about the safety issue or hazard that is the subject of the sign. There are here components to the Word Message:

-Identify the hazard
-Explain the consequence of the hazard
-Explain what action to take to avoid the hazard

The Z535.2 standard gives the sign owner the option of including only the information that is not self-evident in the context of the sign. In some cases, signs are in locations where trained workers laboring under strict protocols may not need much more than an identification of the hazard. Other cases may demand that the avoidance behavior or the nature of the hazard be listed most prominently because of its importance.

Size

The size of the lettering on a safety sign is defined based on the distance from which the sign should be readable. One-inch Word Message lettering and 2-inch Signal Word lettering is defined as being legible from 12.5 feet away (a 1:150 height to distance ratio).

ALIGNING RF EXPOSURE LIMITS WITH SIGN CRITERIA

Armed with the distinction among the Signal Words—Danger, Warning, Caution, and Notice—where does each sign belong? Fundamentally, it depends on how the exposure standards are related to risk. If Danger represents imminent risk of serious injury or death, it is difficult to argue that merely exceeding the occupational exposure limits by a small degree poses such a risk. The occupational limits have a substantial safety margin built into them. Yet, there is no additional definition in the in the FCC MPE limits of what constitutes an imminent hazard. The IEEE and NCRP standards, likewise, establish MPE's, but do not establish thresholds above the MPE's that indicate imminent risk of serious injury.

Danger Signs

The Danger Signal Word is to be used at a location where a imminent, life- or serious-injury-threatening hazard actually exists. Considering a typical broadcast facility, the only imminent hazard that is not so rare is the exposed RF conductor or radiator. In some cases an exposed conductor may have enough potential to create a risk of electrocution. The Danger Signal Word then, is likely to be applied most at the base of an AM tower,

or near an exposed RF contact or conductor in the tuning and feed components of the system.

Warning Signs

The Warning Signal Word is to be used at the entrance to an area where a Danger condition exists. Thus, on the door or gate into the fenced tower compound, a Warning sign might be sufficient, as long as a Danger sign on the live tower and feed line is visible and legible before one gets to close. On the fence of the AM tower compound, a Warning might be appropriate, as long as a fence climber has room after crossing the fence to see and take action on a Danger sign at the tower base. It might, nevertheless, be more prudent to mount danger signs on the fenced compound if the hazard inside the fence is imminent.

Similarly, tuning sheds and tuning cabinets may have exposed live contacts that must be respected. The Danger Signal Word would be suitable for marking actual contact hazards, while the Warning Signal Word would be suitable for marking the shed entrance or cabinet cover, if the act of opening the shed or cabinet still leaves the individual with some room to prevent injury. If the system should be de-energized before opening a cabinet or shed because there is no margin of safety with the door open, then the Danger Signal Word would be appropriate on the door or cover. If the door is interlocked, then the posting Danger word on the door may not be necessary.

The electrocution hazard of contacting or being too close to energized RF conductors is a self-evident application for the Danger and Warning Signal Word protocol. In fact, an electrocution hazard, even if caused by RF energy, is best illustrated with an electrocution symbol rather than the customary RF symbol.

Not so clear as electrocution risk is the degree of risk from being exposed to the thermal effects of excessive RF emissions, those effects which the MPE's are intended to prevent. RF lore includes stories of individuals who were stationed in cold climates and used the energy from high power radars to warm up, sometimes getting injured or killed in the process. Broadcast facilities tend not to have such situations, with one exception—on the tower itself. The possibility of exceeding the human capacity to dissipate heat exists in close proximity to some broadcast antennas.

No Further Thresholds above MPE's

The only exposure limits available for controlling worker exposure to RF energy are in the occupational/controlled environment limits. Since these are safety limits, the thresholds of danger are not codified. Without any designation of what constitutes that imminent hazard or risk of serious injury, there is no exposure level other than the assigned safety limit to use as a reference. There is no distinction in the standard between a benign amount of overexposure, or an exposure that *could* result in serious injury or death (Warning condition), or an imminently hazardous situation that *will* result in serious injury or death from overexposure (Danger Condition).

Consider, for example, that a worker is climbing a tower or is on an RF-active rooftop at which RF emissions must be reduced or disabled to limit worker exposure. The moment a worker exceeds the exposure limit, it is reasonable to assume that the condition could result in injury, not necessarily because there is imminent risk of serious injury, but because the worker is over the limit and the threshold between benign overexposure and serious injury is not known.

Warning as Boundary Indication

Since the Danger Signal Word is supposed to be reserved for directly marking the most extreme conditions, the Warning Signal Word is applied at the threshold of a location containing a Danger condition. Consider, for example, a 300-foot tall FM or television tower with the sole antenna at the top. Energy on the ground may very well be within the public MPE. At some point up the tower the energy level will cross the public MPE and remain below the occupational MPE. At some further point up the tower, the occupational MPE threshold occurs. Beyond this, workers are not supposed to go without taking precautions, such as power control, shut down, exposure time management, or protective gear. Yet the threshold of serious injury is likely to be somewhere above the occupational MPE threshold on the tower. If one were to mark the warning point where serious injury *could* occur, there is no obvious place to do so. In fact, if the Warning is posted closer to the antenna than the occupational MPE, it will benefit no one, because no one may cross the occupational MPE line without doing something to reduce exposure. The only role for an RF energy Danger or Warning Signal Word, then, is to caution an unauthorized visitor, already past the occupational threshold, of the increasing risk of thermal injury as he gets closer to the antenna.

Caution Signs

The Caution Signal Word presents a similar problem. It is supposed to indicate a risk of minor or moderate injury. If there were degrees of overexposure to RF energy, from minor to serious, to imminently serious, then it would make sense to apply all three words, Danger, Warning, and Caution to situations where the occupational/controlled MPE's are exceeded. The difficulty even with the Caution Signal Word's

relationship with *minor injury,* is that the safety threshold of either the public MPE or the occupational MPE is not an actual threshold of minor injury.

OSHA APPROACH

In 2001 OSHA proposed five levels, i.e. "categories," for managing RF exposure.[1] A relationship was proposed between the categories and corresponding Signal Words. They are summarized in the text box.

First, the Category 1 Area requires little discussion—RF levels are always within the public MPE. No safety program is necessary.

Category 2 Areas

The Category 2 Area states that controls must be used to ensure compliance with the public exposure limits. The controls would be most reliable if they did not rely on members of the public to comply with exposure limits. That is, rather than controlling the behavior of untrained individuals, control of power levels and duty cycles is the best way to ensure public MPE compliant 30-minute averages.

However, there is one exception to the general population/uncontrolled MPE. The FCC says in OET Bulletin 65, in its definition of Occupational/Controlled exposure, "Occupational/controlled exposure limits also apply where exposure is of a transient nature as a result of incidental passage through a location where exposure levels may be above general population/uncontrolled limits, as long as the exposed person has been made fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means." Thus, a member of the public can be exposed to MPE's above the general population limit so long as the exposure is transient and incidental to passage. The individual must be made aware, through signage, for instance, of

OSHA-Suggested Area Categories

Category 1 Areas
•Locations where RF fields are less than the FCC general population (public) limits.
••No controls, including time averaging.
•••NO RF SAFETY PROGRAM NEEDED

Category 2 Areas
•Potential exposures are controlled to ensure compliance with FCC Public limits.
••Must maintain controls, such as time averaging and shielding, to remain below public limits.

A Notice Signal Word is suggested for the public entering Category 2 Areas.

Category 3 Areas
•Locations where RF fields are less than the FCC Occupational limits.
••No controls, including time averaging.

A Notice Signal Word announcing a worker program is in effect is suggested for those entering Category 3 Areas.

Category 4 Areas
•Potential exposures are controlled to ensure compliance with FCC Occupational limits.
••Must maintain controls, e.g. time averaging and shielding, to remain below Occupational limits.

The Caution Signal Word is suggested at the point of access to Category 4 areas.

Category 5 Areas
•Exposure conditions which can not be controlled to comply with FCC Occupational limits.
••Includes surfaces which will cause serious RF burns if contacted.

The Warning Signal Word is suggested when powering down equipment or use of protection gear is necessary prior to accessing a Category 5 area.

The Danger Signal Word is suggested when personal protection equipment (PPE) will not suffice, and powering down is the only way to enter a Category 5 area in a compliant manner.

Shocks and Burns
With respect to shocks and burns, the OSHA-proposed Signal Words are:
Caution for risk of RF shocks without PPE.
Warning for risk of RF burns without PPE.
Danger if RF burns are possible even with PPE.

the exposure and how to control it. This means a member of the general population can be elevated to occupational status by reading a sign in an area of transient passage.

It is difficult, however, to ensure that all members of the public 1) can read signs, 2) will understand them, and 3) will comply with them. Indeed, OET Bulletin 65 says in Section 1, "…it is often not possible to control [public] exposures to the extent that averaging times can be applied…[so] it is often necessary to assume continuous exposure." This seems to contradict the principle of transient passage contained in the definition of occupational/controlled environments. The intent of the transient public exposure exception, then, must be to ensure that a member of the public lingers for such a short time above the public MPE that his 30 minute-average remains below the public MPE.

Unless the public is passing through a location on a people mover, or is subject to some other inherent limit on exposure time, it is prudent to assume continuous exposure. Consequently, the OSHA Category 2 Area may be more academic than useful. It seems contradictory to control an occupational environment for public MPE to meet the qualifications of an uncontrolled environment. (See also the discussion in footnote 4 above, relating to averaging time and the management of public exposure by managing the intensity and duty cycle of emissions.)

Category 3 Areas

The OSHA Category 3 Area raises the question of how to define an "area." Category 3 Area is an area that is above the public MPE and below the occupational MPE. Those who have managed and measured RF sites know that RF levels in an area can vary widely above and below one or both thresholds. Also, even with fairly static operations, the power densities in a space can fluctuate over time.

It may be difficult to define an irregular area that is the boundary between levels below and above the public MPE. OSHA's approach of saving the Caution Signal Word for above-occupational MPE conditions leaves the more innocuous Notice Signal Word as the boundary between public and occupational space. It is also suggested for Category 2 Area, the boundary between public and occupational space. In the case of Category 2 Area, the Notice sign is to inform the public not to linger, while Category Area 3 Notice signs are to inform the worker that an exposure policy is in effect.

Fundamentally, Category 2 and 3 Areas appear to be the same from the perspective of hazard communication and signage. Information about exposure policies in occupational exposure areas is suggested to go on Notice signs. Such information could address public transience (if this kind of information is any guarantee of public compliance) and inform of official exposure policies at the same time.

OSHA makes a reasonable case that the Notice Signal Word should be used to inform individuals of either class of the presence of an RF exposure policy or program within a designated area. As a practical matter, however, facilities with locations above public MPE levels run the risk of overexposing a member of the public. If that exposure is not transient in nature, FCC rules have been violated.

Because power density levels within a secured area may vary across the two MPE thresholds, and because the risk of public overexposure is serious, in a regulatory sense, it may be prudent to place Caution Signs at the perimeter of the secured area containing occupational exposure levels instead of Notice signs.

On the other hand, if a transmitter building remains fully within the public exposure limits (and no shock or burn hazard exists), no Caution sign is necessary at the door. However, there may still be value in placing a Notice sign at the point of access because RF exposure and control policies relating to the transmitters in the building or the emissions from the tower are still in effect.

Category 4 & 5 Areas

OSHA Category 4 and 5 Areas are those that exceed occupational MPE's. The Category 4 Area requires personal protection or time averaging (or power reduction) to maintain compliance while the Category 5 Area cannot be controlled other than by cessation of operation. OSHA suggests Warning signs would apply to Category 4 and Danger to Category 5. The difficulty with this approach is that something that is dangerous to an unprotected individual is given only the level of Warning, in order to reserve the Danger Signal Word for situations that are dangerous to protected individuals. This approach violates the ANSI Z535.2 definition of a Warning. If it can be safely assumed that all personnel who approach a Warning sign are already fully informed of the importance of complying with the instructions on the sign, then a Warning to an unprotected individual may be sufficient to prevent serious injury or death. However, untrained personnel, or members of the public with or without permission to be there would be better served by maintaining the ANSI Z535.2 Signal Word protocol—Warning for access to a dangerous area and Danger for an actual serious hazard *to unprotected individuals*.

For example, the door from a tuning shed to an AM tower compound would have a Warning sign because it is the point of access to a risk of serious injury or death.

However, in the OSHA protocol, if personal protection or time averaging can be applied to prevent serious injury, the hazard in the compound is only marked with a second Warning sign.

The different risks to protected versus unprotected individuals are not easily divided among the various Signal Words. Instead, They should be managed through the Word Messages and official safety programs rather than trying to make the Signal Words custom-fit the RF energy discipline.

In summary, the five-category approach suggested by OSHA attempts to address the boundaries between various exposure classes and to fit Signal Words with those boundaries. It would be better to use the categories in the execution of RF exposure management programs and to leave the Signal Words to their already-defined purposes.

MOTOROLA STANDARD

Motorola maintains an internal standard that it shares with its vendors and customers, *R-56, Standards and Guidelines for Communications Sites*. In the Appendix E, Electromagnetic Energy Information, R-56 takes a different position on the role of Signal Words in RF environments:

Excerpts, Motorola Publication R-56, Appendix E.5

The notice sign is used to distinguish the boundary between the General Population/Uncontrolled and the Occupational/Controlled areas. This boundary will usually be the fence for the property, gate entrance, or roof door to the equipment room. The limits associated with this notification must be less than the Occupational/Controlled MPE.

The caution sign identifies RF controlled areas where RF exposure can exceed the Occupational/Controlled MPE. Generic guidelines apply in all situations and will be posted at all sites; however, site-specific guidelines may be associated with some areas to ensure work is always performed in compliance with the FCC guidelines.

The warning sign denotes the boundary of areas with RF levels substantially above the FCC limits, normally defined as those greater than ten (10) times the Occupational/Controlled MPE.

Motorola does not address the Danger Signal Word.

The Motorola boundary for a Warning sign is set to ten times the occupational/controlled MPE, presumably because the MPE has a ten-fold safety factor built into it. IEEE C95.1-1999 takes the science demonstrating measurable biological effects at various frequencies and divides the resultant amplitude versus frequency curve by a safety margin of ten to produce the controlled exposure MPE in the standard. Motorola must be defining the risk of serious injury by this unofficial threshold (see *No Further Thresholds above MPE's* discussion above).

The Caution sign is reserved, as with OSHA, for the boundary between of occupational/controlled MPE. Like OSHA, Motorola reserves Notice signs for the lowest boundary, the general public/uncontrolled MPE.

What Motorola and OSHA have most in common is the objective to manage workplace exposure. Little consideration is given to the concept that a member of the general public may be the one most in need of a serious and emphatic message, due to his lack of awareness and training. Considering the reaction of some members of the public to RF emissions, Motorola even goes a step farther, perhaps as a public relations move, in its signage objectives, "While signs can be effective if used properly, they can convey the wrong message and create undue alarm if used incorrectly." This may be one of the reasons for avoiding the placement of Caution signs on the outsides of RF facilities. It would be better not to alarm the public about what may amount only to regulatory risk (above public MPE exposure) to a trespasser in the RF facility.

On the other hand, even in a transmitter building with fully complaint public MPE energy levels, there may be enough risks to the uninitiated entering the building that a Notice or Caution sign is warranted. Equipment under service or equipment failures, or even absent-minded mischief may be all that stands between an uninitiated individual in a transmitter facility and occupational exposure or more.

Since FCC regulations effectively presume harm to the public above the public MPE's, by virtue of prohibiting it, and since the regulations presume harm, in effect, for occupational MPE's, it stands to reason that these safety thresholds be presumptive thresholds of possible minor or serious injury, respectively. Thus, in spite of the extremely minor risk of harm at even occupational exposure levels, the boundary between public and occupational exposure levels deserves the Caution signal word, while the boundary of the occupational MPE deserves the Warning signal word.

The alternative to this approach is a watered down communication program. Simple Notice signs would mark the entrance to any controlled area, giving a member of the general population no sense that the conditions in a particular space may have serious consequences.

While this approach may more literally conform to the definitions of Caution and Warning, it undercuts the seriousness of the exposure standards by assuming they do not serve to protect from harm. For these reasons, this paper proposes no cookbook answer to the placement of Caution and Warning signs. Rather, these Signal Words should be applied in context. The context may depend on whether the audience is the general population or informed workers. There may be situations where it is appropriate to mark a Caution for the public, such as the entry to a building that inside does have additional caution signs marking over-threshold conditions, but with no further obstacles to over exposure. The same may be true for the occupational entry point to controlled areas within which there are marked areas that are not separately secured against overexposure.

If there is any general alignment of Signal Word to MPE threshold, it is that exceeding either MPE deserves a Caution sign intended for the respective public or occupational audience. While exceeding an MPE is not necessarily a cause of minor injury, They are the regulatory thresholds for protection from injury, and the seriousness of those thresholds may deserves more than a bland Notice Signal Word to underscore it in some situations.

IMPLEMENTATION OF SIGNS

Below is a family of facility safety signs that conform to ANSI Z535.2. The Signal Words are employed in the context of the above discussion, setting Caution as a threshold to the occupational/controlled space and Warning as a threshold to spaces that exceed the occupational/controlled MPE. The Danger sign is tailored to the most certain risk of serious injury or death in an RF environment—electrocution (i.e. RF shocks or burns).

Since it is argued here that there should be no direct relationship between the Signal Words and the boundaries of the two MPE classes, these signs are only examples of the manner in which Signal Words and colors can be augmented with Word Messages to convey the important information.

The Message Panels contain the three components of a good hazard communication message—
-Identification of the hazard;
-Explanation of action to take;
-Explanation of consequence of hazard.

While the other signs employ the standard RF energy warning symbol, the Danger sign employs a vivid electrocution hazard symbol based on one used in the United Kingdom. It has far more visual impact than the lone lightning bolt or the not-so-urgent "do not touch" symbol (below)

"Do Not Touch" Symbol

HOW TO HANDLE BOUNDARIES

Without knowing whether occupational over exposure in a given situation is inconsequential or injurious, the MPE stands as the last boundary between safety and *possible* harm. Therefore the MPE could be applied presumptively as a *safety threshold indication* of a Warning or Caution condition, depending on the intensity of the expected overexposure rather than a *literal indication* of minor or serious injury potential.

Amember of the general population is at greater risk of exceeding the general population/uncontrolled exposure limit if he were to enter a controlled area. Also, an area that may be at occupational/controlled exposure levels is likely to have a greater degree of risk due to the presence of operating RF equipment, from possible exposed contacts, the potential for exposure from equipment failure, or exposure due to maintenance activity. Since at many facilities the boundary of the controlled area is chosen by the convenience of a existing locked door, the choice of Signal Word at the door will depend on what is inside the locked door. Fully contained equipment with little opportunity for exposure above the public MPE might not need to be considered a controlled area at all. However, it may be prudent to make such an area controlled, due to the possibility of open service panels, exposed contacts under test, reliance on interlocks, or other conditions that raise the risk for the uninitiated. Such a space moght be satisfactorily be marked with a Notice sign.

If the enclosed space has locations that exceed public MPE limits, or that has exposed RF contacts or other conditions that require a knowledgeable person to stay away, and those conditions rea only marked with yellow paint and Caution sign, it would be prudent to mark the space with the entrance to the space with hte Caution Signal Word.

RF MANAGEMENT BY "ENVELOPES"

The best form of control is by lock and key. That is, if an owner of an RF emitter wants to ensure compliance with RF exposure regulations, the best form of control is by controlling access. This is best done by visualizing each tier of access as an "envelope" within which certain rules apply. The public could be kept out of the transmitter building, except under escort of trained, authorized individuals- the outer envelope. Within the transmitter building there may be mostly public-MPE-compliant RF energy. However, a location in the building might require cordoning off with markers, or an internal fence or wall separating it from the rest of the space, for trained employees only, in which case a Caution sign could serve to mark this next envelope. Exposed RF contacts should be protected in some fashion from accidental contact, however, and Warning and Danger signs should be posted for any such hazard, even those with protective covers. The protective cover, or a designated safe radius would serve as another envelope. At the base of a non-radiating tower, the power density on the ground would determine the level to assign to the envelope. The envelope here would be the fence securing the tower. Or it could begin at a point on the tower at which signage instructs workers (and trespassers) about the risks and actions to take above that point.

Positive and Passive Envelopes

In general, there are two forms of envelope, positive and passive. The positive envelope is the one under lock, key, and access policy. The operator has positive control over those who enter. As suggested above, the positive envelope may be an envelope of convenience. That is, most of the secured area may have nothing to do with potential overexposure of one of the two MPE's. But a small locus of higher exposure risk within that secured space may be accessible once the individual has entered the envelope. This locus would be within a passive envelope. It might be marked with a sign or yellow tape or paint, or might be behind an unlocked door or panel. This envelope of passive control would have a higher risk threshold than the outer envelope that is positively controlled. There may be Caution, Warninig, or even Danger conditions within the passive envelope, depending on the circumstances.

Since the passive envelope is highly dependent on the compliance of the individual, it should be contained within a larger positively controlled envelope. The marking of the positively controlled envelope should relate to the nature of the passive envelope(s) within it.

For example, an FM transmitter shed may have no exposure issues, under normal operation, but may rely merely on an electrical interlock for access to the inside of the transmitter. The shed becomes the outer positive envelope, and is probably suited to a Notice sign. The transmitter door becomes an inner passive envelope and could be marked with a Caution or Warning, depending on the risk of harm within the door if the interlock fails

or if the individual opening it does not follow posted procedures.

In another case, an AM tower fence accessed through a shed with a locked door to the outside and a locked door to the fenced compound has some envelopes. The entry from outside is the first. If there are exposed components in the shed (they ought to be shielded at least with Plexiglas!), then the envelope is at a high level, possibly deserving Warning signs due to the imminent risk of harm upon entry to the shed. A caution sign might suffice if there is enough space and passive protection to the individual after entering the building before reaching the live components. A Notice sign would only apply if all contacts insider were fully secured against access such that there is no risk of injury at all.
The entrance to the fenced compound would also be marked either Caution or Warning, depending on the immediacy of the risk after entering the fenced area. The fenced area, like the shed, would be considered a positively controlled envelope, as long as there was an access policy that is enforced with the locking up of the space. It may deserve the same level of hazard communication, but different message text, as the shed envelope. Or if the shed fits a lower level of hazard (such as Caution or Notice), the fenced compound might be take a higher level (such as Warning or Caution).

In terms of the MPE limits at this AM site, the positive envelope remains the same—the door to the shed. It is likely that the occupational MPE would apply in at least part of the shed, such that the entire shed envelope should be not only the threshold of occupational/controlled MPE space, but also it should be posted with information about complying with station policy and requiring training to enter.

As these examples show, the rigid use of certain Signal Words at certain MPE thresholds ignores the realities of the RF exposure environment. The Signal Words have specific purposes that are entirely useful on their own. They can be applied to passive and positive envelope boundaries in their contexts, with higher risk applying to passive boundaries due to the reduced control over these.

It is the content of the messages that makes it clear what is going on inside an envelope and what to do about it. The Signal Words serve to convey the urgency of the message.

CONCLUSION

RF energy exposure management relies on the assessment of risk and the setting of policy to protect individuals in RF environments. The ANSI standard for safety signs applies to the communication of these risks and policies in these environments. Attempts have been made by others to align the Signal Words, Notice, Caution, Warning, and Danger, with the occupational and public exposure limits and with other conditions in the RF environment.

A method is proposed of describing RF management “envelopes” and marking them with appropriate information in the sign message panels. An envelope is a space designated by structure or markings within which certain hazard communication information applies. The selection of the appropriate Signal Word and color for each sign at the entrance to an envelope would be dependent on the risk contained within the envelope, not on the occupational/controlled or general public/uncontrolled exposure thresholds. As the degree of risk increases in a space, additional envelopes may be nested within other envelopes, and secured and/or marked accordingly.

The concept of a positively controlled envelope was developed, in which the use of lock and key or other impenetrable physical barrier is used as the last line of active defense against injury or overexposure. Passive envelopes, which are those that only employ visual or easily penetrated barriers such as flags, signs, colored paint, railings, etc, should be enclosed in a positively controlled envelope. When a positively controlled envelope contains one or more passive envelopes, the Signal Word at the entrance to the positively controlled envelope should be strong enough to communicate the importance of complying with the passive envelopes within. On the other hand, when a positively controlled envelope (such as a locked transmitter building) contains only other positively controlled envelopes (such as secondary locked access doors or locked transmitter cabinets), the level of hazard communication on the outer envelope need not be as strong as it would be if passive envelopes were within the outer envelope.