RF Radiation Overview: New Tools Assist the Safety Officer

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Foreword

The topic of RF safety is important to every organization that either uses RF and microwave energy to deliver an end product such as a wireless service or employs it to perform an industrial function such as packaging, cooking, and drying of materials or products. Maintaining a safe environment for employees as well as the general public is not simply a good idea – it's the law, and it is being enforced more rigorously every year. An RF safety program is the key to establishing and maintaining an environment that offers personal protection and is legally defensible. The thought of establishing such a program often strikes fear into the hearts of organizations, bemoaning yet another layer of bureaucracy, endless paperwork, and the need to learn about RF and microwave technology.

Fortunately, a credible RF safety program for many organizations is often not complicated, but does require a long-term corporate commitment, discipline, and yes, some difficult work. However, the time is well spent, since even the step of determining if a program is required answers the question of where the organization falls in the "RF safety spectrum," something many companies simply do not know – but should.

I've created this RF Safety Guide to provide the basic information needed to create an RF safety program. It assumes only that the reader knows that his or her organization employs electromagnetic (EM) energy, which to a wireless carrier is obvious but to a manufacturer sometimes is not. The guide is not intended to be a complete treatise on the subject, but rather an overview that covers the elements of RF safety necessary to begin the implementation of an RF safety program. Additional information is available in the guidances and standards and other resources referenced at the end of the RF Safety Guide. Narda-STS can also provide assistance with RF safety equipment and measurements, and conducts training sessions on RF safety training and measurements throughout North America every year.

Specifically, this guide can help organizations that employ equipment generating EM energy to understand the RF safety environment, assist them in determining if their facilities require an RF safety program, and provide basic guidelines about how one should be constructed. In many cases an RF safety program may not even be required, but the only way to determine this is to thoroughly evaluate facilities where EM energy is present. All of these steps can be aided by using this RF Safety Guide as an outline and help from consultants who specialize in this area.

However, it is essential that every affected organization have employees who are tasked with the responsibility of learning the regulatory, technical, and procedural aspects of RF safety, rather than resorting exclusively to outside sources.

Disclaimer

The information and forms contained in this document are intended to provide general guidelines for RF radiation safety and to aid individuals intending to implement an RF safety program. However, every situation in which RF energy is encountered is unique, as are the requirements for administrative and engineering controls, and the depth and breadth required of the RF safety program. In addition, state, country, provincial, and other regulations, as well as regional interpretations must often be considered along with the national and international standards discussed in this guide. Consequently, the information presented here should not be relied on exclusively or in place of legal advice relating to the circumstances of a specific situation. Forms in this document are intended only as a teaching tool and before use must be modified or expanded to accommodate the needs of a particular situation.

The Importance of RF Safety

The use of RF and microwave technology is pervasive throughout the world, and its incorporation into more and more types of devices is growing every year. As a result, more and more people are becoming aware that EM energy is employed in consumer products and the infrastructure used to support them, in medical devices such as magnetic resonance imaging (MRI) systems, and within industrial equipment at the workplace such as RF heaters, dryers, induction welders, and vinyl welders.

While the question of whether or not electromagnetic energy at extremely weak levels can cause bodily harm continues to elude a conclusive answer, the situation is different when the body is exposed to EM energy at high levels at certain frequencies. In the latter case, heating of the body by EM energy is known to cause harm. When compared to other “controlled hazards”, it is not as visible and it is easily possible to be exposed to levels in excess of established limits without knowing it.

Together, the uncertainty about low-level exposure and the demonstrated effect of EM energy at high levels have produced exposure limits contained in international regulations to which all organizations must adhere in order to protect workers and the general public from potential bodily harm. In the US, federal regulations dictated by the Federal Communications Commission (FCC) have the force of law, as do regulations from the Occupational Safety and Health Administration (OSHA).

The requirements of these standards, guidances, and regulations must be addressed when employees work around EM fields, whether at broadcast sites (such as cellular, paging, public safety, paging, TV and radio, etc.) or in industrial or medical environments. RF safety programs, when effectively administered, can help ensure companies that their facilities are legally defensible in the face of claims made to the contrary. In short, if employees must work around RF energy, it is important to know what the levels are and how to construct a basic RF safety program if one is needed.

The RF Safety Environment

Only 20 years ago, hardly anyone paid much attention to EM energy, except RF and microwave equipment manufacturers, satellite communications providers, and the aerospace and defense community. This is certainly not the case today, since "wireless" capabilities are highly desirable for virtually any product traditionally tethered to a wired connection, and advances in semiconductor and other technologies have brought them to a bewildering array of products – with many more to follow.

The explosive growth of the cellular telephone industry in the 1990s sparked interest in the possible health effects of EM energy, as millions of people became "glued" to their phones. The result of this attention was a media frenzy culminating in books on the subject, headlines in the most respected newspapers and magazines, and television news stories, as "experts" provided their opinions on the merit of various scientific studies. All of this resulted in little more than arousing the public and boosting the careers of those involved. Industry-sponsored studies were conducted that not surprisingly largely concluded that EM energy either has no effect at the miniscule levels to which cellular phone users are exposed or has some possible effect, the extent of which that would require further study. That study continues today at a muted level and the headlines are gone, essentially because unless conclusive proof (supported by multiple *undisputed* studies) is presented, the ubiquity of wireless technology, along with the beneficial uses of EM energy in medical and industrial applications, will render moot the question of the hazards of low-level EM exposure.

A Point to Remember

Nevertheless, from a legal standpoint, it simply does not matter whether "proof positive" of bodily harm does or does not exist. Challenges to employers can come from unlikely places, not just the underfunded, understaffed government agencies charged with protecting workers and the general public. A classic example of the truth of this claim comes from recent US court rulings. In 2007, the Alaska State Supreme Court upheld a lower court ruling awarding temporary total disability and medical benefits to an employee who was exposed to levels greater than allowed, but below thermal "thresholds of harm". This type of court ruling is important because it directly challenges the popular notion of standards.

In Orchitt v. AT&T Alascom[1] (a satellite communications provider), John Orchitt, an employee of AT&T, was accidently exposed in 1998 to RF radiation emitted by a leaky waveguide feeding a satellite communications uplink antenna while working at a satellite communications terminal. The transmitter serving the antenna was supposed to have been turned off, but another was mistakenly turned off instead. Consequently, the transmitter serving the waveguide Orchitt was working near was delivering about 90 W of power at 6 GHz. Orchitt later filed for workers' compensation benefits claiming he had suffered head, brain, and upper body injuries as a result of overexposure to EM radiation. AT&T disagreed, but after a contested hearing, the Alaska Workers' Compensation Board awarded him temporary total disability and medical benefits.

AT&T unsuccessfully appealed in superior court, alleging that procedural irregularities deprived it of due process and that the board's decision was not supported by competent scientific evidence. AT&T then appealed to the state supreme court, which ruled that substantial evidence supported the compensation board's findings and --because the board's procedural decisions did not deprive AT&T of due process --the superior court's judgment that affirmed the compensation board's ruling should stand.

The lesson here is that while the disability benefits themselves were not huge in monetary terms, the case resulted in a string of expert witnesses on both sides, eight years of litigation, tens of thousands of dollars (or more) in legal fees for AT&T — and still the company lost. Even if AT&T had won, the costs of victory would still have been substantial, perhaps not so much to a

Fortune 500 company, but certainly to a small manufacturer without deep pockets. This precedent should be a warning to any company that believes RF safety cannot cost them dearly and that the threat comes only from government agencies directly involved with RF safety.

Step 1: Choose the Right Standard

An organization's important first step is to decide which standard or guidance to follow. In the discipline of RF safety, standards continue to evolve and differ from one another at lower frequencies -- below 100 MHz. However, there is general agreement between them in the microwave region of the spectrum, above about 300 MHz. Most major standards accept a basic Maximum Permissible Exposure (MPE) level of 0.4 W/kg of Specific Absorption Rate (SAR), but do not always agree on the EM field levels needed to create that energy level in the body.

For some organizations there is no decision to be made about standards: FCC licensees must follow FCC limits and the U.S. military usually follows IEEE Standard C95.1: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz[2]. However, all other organizations have a choice. In fact, there are many guidelines adopted by countries throughout the world[3]. However, the four shown in Table 1 are highly regarded because of the effort expended by the participants in their standards committees or the governments that sponsored them. Any of these standards can be used for establishing an RF Safety Program.

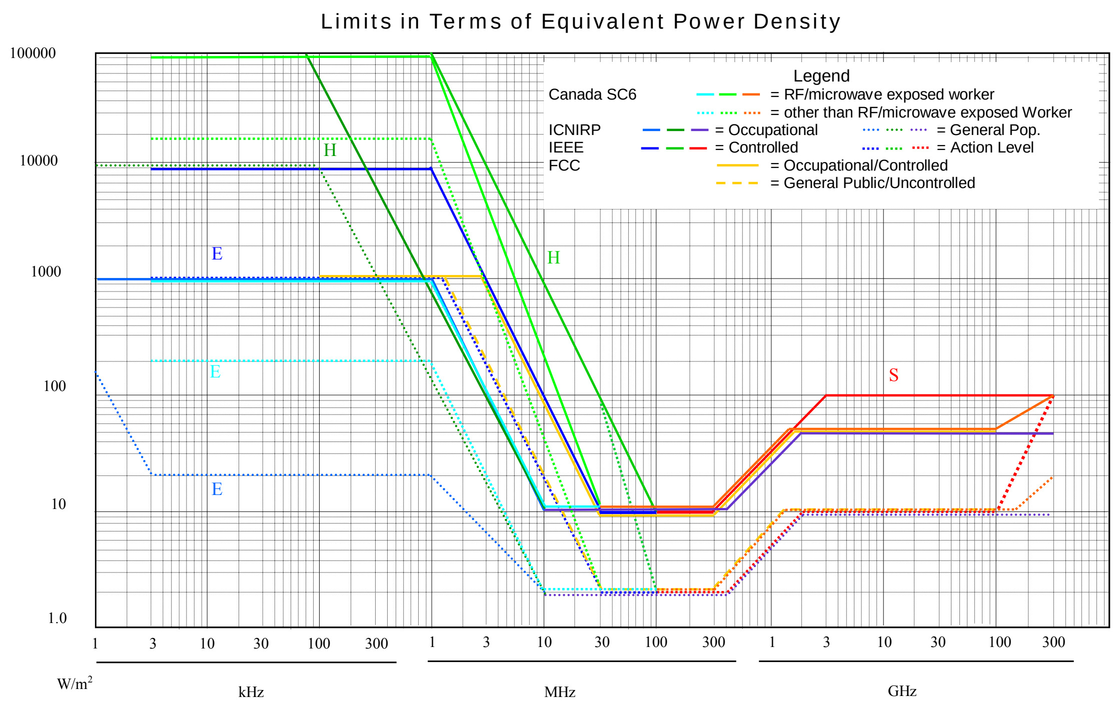

Table 1.

One guideline surprisingly out of date is OSHA's CFR 1910.97, and employers are cautioned that this document employs EM field limits specified by the American National Standards Institute (ANSI) in 1966. Obviously, enormous regulatory and scientific changes have taken place since this time, not only in MPE limits but in recommended engineering and administrative controls as well. Consequently, even though it is an official document of a government agency, it should not be used as a definitive resource.

Understanding Controlled and Uncontrolled Environments

After the FCC issued its latest RF safety rules that took effect in 2000, licensees informed the commission that no standard was available that provided specific guidelines about how an RF safety program should be conducted. This resulted in creation of IEEE Standard C95.7-2005 "IEEE Recommended Practice for Radio Frequency Safety Program, 3 kHz to 300 GHz[4], which is now the primary resource that contains all of the elements of an RF safety program for all types of organizations – not just those falling under the jurisdiction of the FCC. Like all standards it is somewhat "dense" in its treatment of the subject and while providing a tremendous amount of useful information, leaves lots of room for interpretation. Nevertheless, it should be consulted early when an RF safety program is being considered.

IEEE C95.7 is also an essential tool because it is consistent with all standards and guidance's that employ two tiers of exposure: "Occupational/Controlled" and "General Population/Uncontrolled" (which can be simplified as "Controlled" and "Uncontrolled"). The two differ by the amount of knowledge and control a person has over his or her ability to be overexposed. The more stringent "uncontrolled" rules or guidelines are designed for the public or untrained worker who is assumed to have no control over his or her exposure or any technical knowledge about RF radiation, so permissible exposure levels are more restrictive. "Controlled" exposure levels are less restrictive since trained workers who encounter RF energy in their work know (or should know) what is not safe and how to avoid overexposure. A site at which no RF safety program is in place is considered uncontrolled *regardless of the RF levels present*, but by adding an RF safety program becomes a controlled environment, raising the acceptable exposure levels to the "Controlled" range.

Controls	**Category 2**	**Category 3**	**Category 4**
Engineering			
- **Site Configuration**	○	○	…
- **Physical Barriers**	○	●	●
Administrative			
- **Signs**	●	●	●
- **Safe Work Practices**	…	○	●
- **Lock-out/Tag-out**	…	○	●
- **Control of Source Power**	…	○	○
- **Time Averaging**	○	○	…
- **Personal or Area Monitors**	○	●	●
Personal Protective Equipment			
- **RF Suits, Gloves**	…	○	○
Training			

- **General RF Safety Awareness**	○	●	●
- **Exposure Limits**	○	●	●
- **RF Controls**	○	●	●
- **RF and Medical Devices**	○	●	●
- **Overexposure Incidents**	…	●	●
- **Electro-explosives**	○	●	●
- **Sources of Additional Info.**	…	○	○
Program Audit			
- **Implementation**	●	●	●
- **Adequacy**	●	●	●
- **Assess Ancillary Hazards**	○	○	○
Legend - ● = required, ○ = optional, … = not applicable			

Table 2: Categories of RF Exposure.

The recommended practice also establishes four categories, into one of which all facilities will fall (Table 2). A Category 1 location contains only RF sources that cannot produce fields that exceed the MPE and do not require an RF safety program. As a general rule, this includes devices emitting 5 Watts or less of RF power because this RF power level is not high enough to produce levels of EM radiation that exceed MPE limits. Categories 2 through 4 are locations that require an RF safety program with increasing levels of controls required depending on their field strength level. As Table 2 shows, the elements required in a safety program increase in direct proportion to the exposure levels likely to be encountered at the location. Items marked as optional muddy the waters somewhat, since their use is left to the discretion of the organization implementing the program.

Step 2: Perform an Inventory of EM emitters

The next step is to prepare a detailed list of all the emitters of EM energy at a facility over which the organization has control. Broadcasters must also inventory not just their own emitters at sites they occupy, but also those at these sites over which they have no control (more on this later). Narda Safety Test Solutions has developed a simple, inventory form that can be modified to meet specific situations (Attachment 1).

There are essentially two types of emitters that must be considered: intentional emitters and unintentional emitters. As its name implies, an intentional emitter is one that intentionally emits EM energy as its end product. A broadcast antenna is a perfect example. An unintentional emitter is not intended to emit RF energy but can do so unintentionally because it employs EM energy to perform one or more of its functions. An unintentional emitter could also be a re-radiator on a rooftop or a waveguide carrying high levels of RF power that leaks and sends high levels of EM energy into the environment. While it is relatively easy to calculate fields around a properly-functioning antenna (an intentional emitter), it is much more difficult to calculate the potential effect of a waveguide or heat sealer shield that has failed (an unintentional emitter).

In industrial and medical environments, the task of identifying emitters is less clear cut, since some sources of EM energy may not appear to be emitters at all. For example, induction heaters and welders, vinyl welders, sputtering, and ashing equipment employ high levels of RF or microwave energy to perform their intended functions, but since the RF and microwave functionality is embedded in the equipment, its use is often not readily apparent. Medical equipment such as diathermy machines or electro-surgical devices also radiates EM energy, as do other types of medical diagnostic and surgical equipment. If in doubt about whether a particular device or piece of industrial equipment generates RF energy (and how much), a call to the manufacturer should quickly provide the answer.

Step 3: Make Measurements

Obviously, an RF safety program cannot be implemented until the areas are identified where potentially hazardous conditions exist and their levels are measured. That's the job of RF safety measurement equipment. Calculations can be effective for establishing a basic idea of EM energy levels that are present, but they are limited because in many environments (like a rooftop), some of the emitters may be controlled by other organizations and calculations cannot be made without information about each one.

For the purposes of selecting the best type of measurement equipment, the facility potentially requiring an RF safety program can be placed into two categories:

• Broadcast: Cellular, paging, public safety, broadcast infrastructure, radar, satellite communications uplinks, or other transmitting sites.

• Industrial: Primarily manufacturing facilities in which equipment is employed that uses EM energy for some purpose.

While the two types of measurement equipment, narrowband and broadband, can be used in either application, narrowband instruments are increasingly used in broadcast environments, while broadband equipment is generally best suited to industrial applications. The reasons will become clear once the measurement environments and equipment characteristics are described.

Considerations for Broadcast Application

Making EM field measurements until the early 1980s was a comparatively simple procedure. Standards during this time specified a single MPE level for all frequencies, so antennas employed by EM measurement equipment were equally sensitive at all frequencies and rather simple. To make the measurements, a technician or engineer simply measured the total field strength at various places around the site, and assuming the total was below that mandated by the current applicable standard, compliance was assumed.

If the total field strength was above the specified maximum level, the accepted procedure was "last on-first off", a matter of seniority. That is, the most recent company to add its transmitter to the site was deemed the "problem" and had to remedy the situation. This could mean that the company had to uproot its transmitting facilities and find another location. Of course, since there were fewer multi-emitter sites at that time, only one organization -- the sole occupant of the site – would be affected.

Later in the 1980s, standards became frequency-dependent, reflecting the fact that the human body absorbs radiation more readily at some frequencies than others. This complicated the measurement process because a more complex "shaped" probe (antenna) was required whose sensitivity mirrored the requirements of a particular standard. For example, many standards and guidances then (as now) set E-field MPE limits at 614 V/m (100 mW/cm^2) below 1 MHz and 61.4 V/m (1.0 mW/cm^2) from 30 to 300 MHz – a difference of 20 dB or 100 times the power at the higher frequencies. To accommodate this, today's shaped probes are 100 times more sensitive in the 100 MHz region than at 1 MHz. As noted earlier, the latest standards have two sets of maximum permissible exposure (MPE) limits instead of one. In addition, a factor called the "5% rule" must be accommodated by FCC licensees. The ability to determine compliance is compounded by the proliferation of sites with multiple emitters, each owned by different organizations.

Fortunately, the introduction of narrowband measurement equipment allows the required measurements to be made regardless of how many services are located at a site. These instruments complement the standard broadband types that were previously the only type available. Nevertheless, broadband instruments may still be a viable option in some cases, so it is important to know when to use each one.

If there is only one emitter at a site, a broadband instrument is obviously the most cost-effective choice because control of the transmitter rests with a single organization and its frequency is known. A broadband instrument may even be acceptable when there are several emitters at a site. For example, a site may have five emitters owned or controlled by a single organization, so their specifications – especially service types and operating frequencies – are known, and the authority to selectively turn each one on and off probably resides with a single person or group.

In other cases, particularly "multi-emitter-multi-operator" situations, a narrowband instrument is really the only practical choice. At a five-emitter site where each emitter is owned and operated by a different organization, there can be several important unknowns, such as the type of service and frequency of operation. In some cases, the owners and operators of these systems also may not be known. Even once information is be obtained, it will generally be extremely difficult or even impossible for a single organization to gain the authority to turn all transmitters on and off for measurement purposes. A narrowband instrument thus makes it possible for any organization wishing to know its contribution and the contributions of others at the site to quickly evaluate compliance.

Considerations for Industrial Situations

Industrial environments are considerably different from their broadcast counterparts. The equipment emitting RF energy is almost invariably controlled by a single organization, which eliminates the problem faced by broadcasters of isolating specific emitters operated by multiple organizations. In addition, industrial environments, while not static, tend to change far more slowly, as new equipment is added less frequently.

In addition, the measurements required in industrial requirements need not be as detailed as those in broadcast environments because only gross levels of RF emissions need to be considered. As a result, broadband measurement equipment is well suited to these situations. It provides a high level of accuracy and like its narrowband counterpart provides information about the percentage of an applicable standard that an emitter is producing. The narrowband and broadband instruments also share the ability to allow measurement data to be offloaded to a PC where it can be stored and used to perform trend analysis that can identify equipment whose emission levels are gradually increasing over time.

The measurements obtained by both types of instruments will provide definitive information about RF emission levels that will in most cases directly dictate the level of controls that must be instituted.

Step 4: Identify Exposure Potential and Risk

Once the inventory has been completed and measurements have been made, the risk potential of intentional emitters should be evaluated first, since they emit the highest power levels and pose the greatest exposure potential. This risk assessment can be made considerably easier when the basic principles of failure analysis are applied using Failure Mode, Effects and Criticality Analysis (FMECA). This results in a risk priority number (RPN) that is assigned to the emitters, which provides a starting point for implementing changes or controls. FMECA is not included in IEEE C95.7-2005 but this should b4e considered only an omission, since FMECA is an extremely valuable tool in assessing risk at any industrial or broadcast facility. When thoughtfully employed, it provides not only the basis for determining risk, but the rationale for why every element of an RF safety program was established.

The Value of FMECA

FMECA allows the probability that a failure mode will occur to be charted along with the severity of its consequences. It is an extension of traditional Failure Mode and Effects Analysis (FMEA) that is widely utilized for conducting reliability analyses in virtually industry. FMEA and FMECA may be familiar to any organization that has been through the certification process for ISO 9001, QS 9000, ISO/TS 16949, or Six Sigma, or when implementing FDA Good Manufacturing Practices (GMPs), since it is a fundamental task required by each one. FMECA builds on FMEA by focusing on the level of criticality (severity) and probability of occurrence that is assigned to each probable failure mode.

The goal of using FMECA is to reduce or eliminate failure modes with high severity and probability. It lets an organization identify the areas of an industrial or wireless facility that have the greatest potential for overexposure to EM energy. Equally important, FMECA allows the places where remedial actions will provide the greatest benefit. A FMECA analysis can be recorded on a simple paper form, in an Excel spreadsheet, or with commercial software designed specifically for the purpose. The level of detail in a FMECA analysis depends on the complexity of the system being analyzed and in some cases can be very complex. Fortunately, this is rarely the case when used in creating an RF safety program.

To perform an analysis using FMECA, values for Detectability (D), Severity (S), and Occurrence (O) are calculated on a 10 point scale of increasing importance and an RPN is obtained by multiplying them. The first question many people ask is how these values are obtained, since on first inspection the process may seem completely arbitrary. In truth, the process is to some degree arbitrary. However, the more that is known about a particular emitter and the modes that can potentially allow it to cause harm, the less arbitrary the process becomes. Armed with the failure scenarios for the identified intentional and unintentional emitters, it is relatively easy to apply a value to for Detectability, Severity, and Occurrence with a high degree of confidence. Table 3 includes some suggested multipliers that can be used to calculate RPN.

FMECA	Type of Emitter	Suggested Multipliers for Determining RPN		
		1	5	10
Detectability	Intentional	Always aware of operation, signs present	Sometimes aware of operation, signs not always present	Never aware of operation, hidden antenna, no signs or safety program
	Unintentional	Multiple interlocks or shielding	Single Interlock or passive shielding	No Interlocks, signs, shielding or awareness of failures
Severity	Intentional	Low (< action) exposure level potential	Medium (> action) exposure levels	Can or will expose persons to higher than allowed limits
	Unintentional			
Occurrence	Intentional	Emitter is only used < 10% of the time or not normally accessible	Emitter is accessible to persons sometimes, during maintenance	Emitter is mounted in an accessible area with minimal barriers or restriction to access
	Unintentional	System rarely exposes persons due to design	System has failed in the past or may fail without any other notice	System has failed in the past and no design changes have been implemented

Table 3

A waveguide system operating at 10 GHz with 50 Watts of power is a good example. At this power level, a leak can be felt, so Detectability could arguably be 5, a middle value that does not reflect other factors such as pressurization (or the lack of it). In addition, Severity would be 10 because 50 Watts is enough power to potentially overexpose someone close by. Occurrence could be assigned a value of 5 if the waveguide is of the flexible type and mounted outside where it is exposed to the elements and potential tampering or unintentional damage.

However, if the waveguide is unpressurized there is an inherently greater level of risk because a leak in a pressurized system will be detected by the system's sensors and will send an alert to someone who can provide a remedy -- *assuming the system is correctly designed*. An unpressurized system can leak for a long time without being noticed since there is no inherent method of detection. Consequently, a Detectability value higher than 5 would be assigned to an unpressurized system, and a lower value to a pressurized system, since it inherently provides a level of control.

Reducing the RPN that results from assignment of the initial values of Detectability, Severity, and Occurrence can be accomplished with administrative controls, engineering controls, or both. For example, if the area around either type of waveguide is protected from unauthorized entry or posted with clearly-labeled signage, this would reduce the value for Occurrence. Pressurizing an unpressurized waveguide system would allow the Detectability element of the RPN to be lowered. In addition, employing an area RF monitor with battery backup that sends an alert to someone when specific EM field levels are exceeded would further reduce the RPN. The use of administrative and engineering controls is discussed in detail later in the RF Safety Guide.

Step 5: Initiate a Program

If an RF safety program is required, several basic activities must be performed to create its framework. First and foremost, it is essential to understand that from a legal perspective an RF safety program does not exist if its presence cannot be documented. The first thing any inspecting agency or attorney will ask for is proof that such a program exists. The program must not only be documented but must be continually updated with notations about all activities or events that occurred after it was established. In Table 2, which identified program elements according to the safety program categories, the check list covers everything from administrative details to performing an inventory of potential hazards, exposure assessment, administrative and engineering controls, measurements, training, the use of protective equipment, and periodic auditing of the program.

An RF safety program involves employees at several levels of the organization. It must be endorsed and made mandatory by corporate-level management, understood by all managers whose direct reports and vendors are exposed to EM energy in their work, by the RFSO (Radio Frequency Safety Officer) whose job it is to administer the program, by the RF safety committee (optional) that works together with the RFSO to ensure the program is carried out, and most important, by all employees of the company who could potentially be exposed to EM energy in their work.

The duties of the RFSO are not trivial, since he or she is responsible for administration of the entire program, which can include facilities in multiple locations and potentially hundreds or thousands of employees. This requires comprehensive training in RF safety awareness and a reasonable understanding of all elements of RF exposure. This level of training is available from consulting organizations as well as from Narda Safety Test Solutions. Once the RFSO has been trained, the process of training the others involved in safety program administration and ultimately the employees themselves can begin. In organizations with the greatest number of affected facilities, it is often wise to increase the members of the RF safety committee proportionately to ensure the program is properly administered.

Once the program has been created, it must be periodically audited to ensure it still reflects the current situation, is it still needed, or if it should be improved. This is especially important in broadcast (cellular, paging, public safety) "co-located" environments with multiple licenses. Changes to the equipment at these sites can change without notice to the organizations with antennas there, so periodic inspection (and proof that it was performed) are essential. Every licensee at the site must have an RF safety program that will pass muster by the FCC or other government agency at any time.

In every case, the most important ingredient in assuring the success of an RF safety program is discipline. Without it the program will fail to provide the required level of protection to employees and will not hold up under scrutiny if the organization is challenged in court.

Step 6: Institute Controls

The next step will be to implement controls, the level of which is determined by the level of risk assigned to the facility. Two major types of controls are typically employed: engineering and administrative. Engineering controls are changes or modifications designed into the system. An example of an engineering control would be raising an antenna or moving it to the edge of the roof where people cannot normally get in front of it. Pressurizing waveguide is an engineering control, as are system interlocks designed into vinyl welder shields. Engineering controls are almost always favored over administrative controls because they provide definitive "engineered" solutions.

Administrative controls include signs, barriers, and RF monitors (personal and area). They can be used where engineering controls are not possible, such as when local zoning restricts antenna height. In this case, there may be no choice but to erect barriers and post signage in front of the antennas in order to control the areas directly in front of them. However, be careful posting signs without a clear plan and good reasons for their location and what they say. Table 4 shows the level of sign verbiage and graphics required at various RF exposure levels. To be effective, signs must be deployed consistently, and it is as detrimental to "over-sign" as it is to "under-sign" a location.

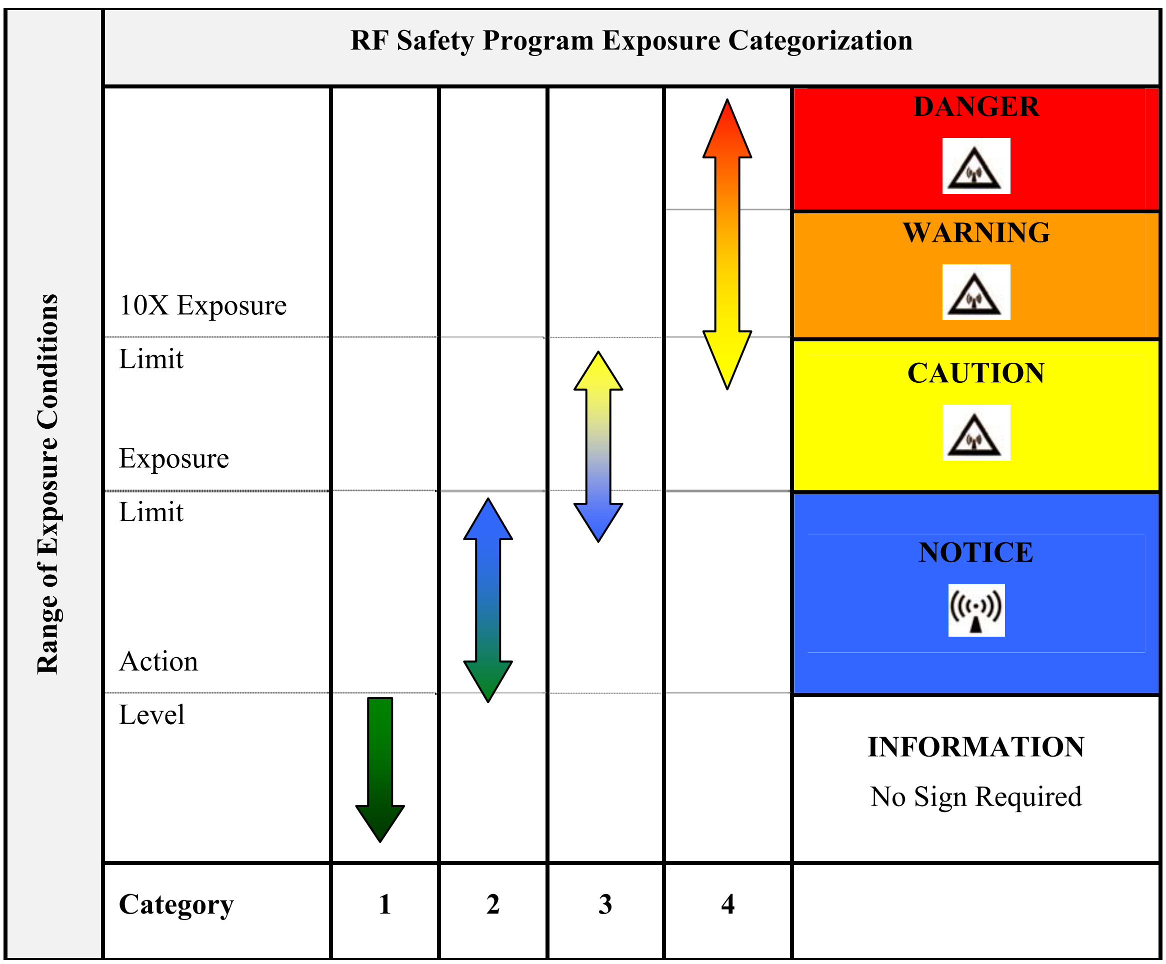

Table 4: Signage vs. Exposure Levels.

The IEEE standard allows an organization to insert its own text under the warning symbol, which is a great advantage in some complicated environments. Custom signs are widely available from vendors on the Web that can include site-specific safety procedures in multiple languages. These specialized signs can significantly improve an RF safety program with clear, consistent messages. Common practice on a rooftop with RF emitters is to place a "NOTICE" sign at the entrance(s) to the roof and "CAUTION" sign(s) where needed to "educate" the user as to what areas of the roof should not be entered.

If this practice was undertaken and updated on every rooftop containing RF emitters, everyone would have the knowledge required to avoid overexposure. However, this is generally not the case when multiple wireless licensees occupy a rooftop, since someone would have to take the responsibility of providing the signs on behalf of all parties. Consequently, many wireless carriers require their employees and contract workers to wear personal RF monitors, since they have no idea how well signs on a rooftop depict the actual situation, and they have no control over or knowledge of the rationale for their placement. A wearable RF monitor's purpose is to immediately alert the wearer when he or she approaches an area in which high levels of EM energy are present. An RF *area* monitor is mounted near a probable leakage source, continuously monitors for excess leakage, and alerts via remote control if conditions change or an event occurs.

When implementing a safety program for a Category 3 or 4 emitter such as a broadcast tower, multiple controls should be employed, beginning with signs on the tower where EM energy levels warrant. Standard RF monitors that alarm at or below the limits of permissible exposure are not effective controls because they will continuously alarm. An alternative is RF clothing and RF monitors that alarm at a higher threshold. However, it may be easier to simply restrict access to those areas of the tower where high levels of EM energy are present. The RF safety program can also specify certain areas of the tower that can be approached when the main antenna is being used and other areas that can be accessed when a standby antenna is in use. Commonly-accepted "lock-out/tag-out" procedures are an effective safety control for sites emitting the highest power levels.

Table 5 provides typical controls that can be implemented based on specific EM energy levels. Engineering controls such as barriers are well suited for wireless licensees that exceed the exposure limits because FCC rules must be met, even though the IEEE standard calls the controls "optional". For that reason, they are labeled in the table as "required" for Category 3 emitters.

Training

Training is a fundamental, essential element of every RF safety program, without which no program can be successful. Unfortunately, the quality of training provided to employees is directly related to the quality of the trainer. Many "trained" employees are either taught the wrong information or simply do not get any useful information at all. Training should include basic information about EM radiation, potential health effects, standards, and information about the controls to be employed, such as signs and personal RF monitors, and what to do when personal monitors alarm. Employees also need to know what to do when they suspect they have been exposed to high levels of EM energy and that they should let the RFSO know if they have implanted metal or medical devices.

Summary

After reading this far, it should be apparent that RF safety is an important issue for any organization in which EM energy is employed, both to protect employees, contractors, and the public, and the organization itself. The most technically difficult task in creating an RF safety program is the process of selecting the category into which the organization falls because in most cases it cannot be done without making comprehensive RF field measurements and interpreting the results.

The most challenging task overall is implementing the program, from assigning and training the RFSO through creating the administrative procedures, and training employees. However, in the long term, the most daunting task for most organizations is ensuring that the program is properly administered, which takes discipline and a corporate commitment to RF safety. Nevertheless, even though this commitment may never be challenged, it only takes a single accident to drive home the point that the effort was worthwhile.

To become more knowledgeable about RF and microwave technology, RF safety programs, standards and guidances, and other related topics, the resources in the References and For Further Reading sections provide a wealth of information.

References

1. Supreme Court of the State of Alaska: AT&T Alascom v. John Orchitt and The State of Alaska, Department Of Labor And Workforce Development, Division of Workers' Compensation.(http://www.emrpolicy.org/litigation/case_law/docs/att_alascom_v_orchitt.pdf)

2. IEEE Standard C95.1-2005: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, http://ieee.org/web/standards/home/index.html.

3. "Index of EMF Standards," World Health Organization, http://www.who.int/docstore/peh-emf/EMFStandards/who-0102.

4. IEEE Standard C95.7-2005: IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz, http://ieee.org/web/standards/home/index.html.

FOR FURTHER READING:

FCC Office of Engineering and Technology, Bulletin 65, 08/1997, http://www.fcc.gov/oet/info/documents/bulletins/#65.

ATTACHMENT 1

ELECTROMAGNETIC APPLICATIONS QUESTIONNAIRE
ORGANIZATION PROFILE

Organization ____

Address ____

City ________________ State __________________ Zip Code ________

Individual Completing Form

Name _______________________ Title __________________________

Phone Number (____) ____________ Ext. ________ Fax (____) _________

E-mail ___________________________

Number of Employees ______________

Brief description of organization (products, services, etc.)

____

____

____

Number of completed forms enclosed: Form A __________
Form B __________

Date questionnaire completed ______________________

FORM A

MANUFACTURING

1. Person completing form:
Organization ______________________
Name____________________________
Title/Dept. ________________________
Telephone/ Ext. ____________________
E-mail ___________________________
Date Completed ___________________

2. Does your facility utilize any of the following devices?

	YES	NO
a. Flow solder machines	____	____
b. Induction Heaters	____	____
c. Plasma etching or cleaning	____	____
d. Heat Sealers, Vinyl Welders or High Frequency Welders	____	____
e. Matcal soldering irons	____	____
f. Sputtering Equipment	____	____

3. If yes to any questions above, have the systems been surveyed for electromagnetic leakage at any time?

If so, when and by whom?
(Attach report if available)

____

____

4. Do you know if you have any other systems that may generate electromagnetic fields, or if you have any devices you are unsure of, please list them below.

____

____

FORM B

ENGINEERING, RANGE MAINTENANCE, OPERATION, TEST, CALIBRATION/METROLOGY AND Q.A.

1. Person completing form:
Organization ______________________
Name____________________________
Title/Dept. ________________________
Telephone/ Ext. ____________________
E-Mail ___________________________
Date Completed ___________________

2. Is your department involved in the Engineering, Range Maintenance/Operation, Test or Quality Assurance of any of the following types of systems?

	YES	NO
a. RF or microwave amplifiers (Power out > 5 Watts)	____	____
b. Radar Systems	____	____
c. Elec. Warfare (EW) systems	____	____
d. Telemetry Systems	____	____
e. Navigation	____	____
f. Communications (Power out > 5 Watts)	____	____
g. EMC Immunity or Susceptibility (> 10 V/m)	____	____

3. If yes to any question above, please give a brief description and nomenclature, if applicable (if classified, list “classified”).

____

____

4. Emitters: Please fill in a line for each source of RF energy with greater than 5 watts of output power. Attach additional forms if required.

Emitters	**Frequency Range (Check all that apply)**				**Power Range**		
	< 30 MHz	**30 to 300 MHz**	**0.3 to 3 GHz**	**> 3 GHz**	**5 to 100W**	**0.1 to1 kW**	**> 1 kW**
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

5. Do you know if you have any other systems that may generate electromagnetic fields, or if you have any devices you are unsure of, please list them below.

____

____