RF Safety on Building Rooftops

A Guide for Understanding and Working near Rooftop Antenna Systems

June 20, 2011

©2011 RF Safety Solutions LLC
This presentation is copyrighted. No right to distribute copies publicly for sale, rental, lease, and lending is authorized without written authorization from the author.
The explosive growth of telecommunications services during the past 10 to 15 years has led to a proliferation of the antennas that are key components of these systems. All telecommunications systems—fire, police, and emergency services; cellular, PCS, and GSM personal communications; paging, radio and television broadcast services; and satellite communications—require transmitting antennas. Although many of these antennas are mounted on towers, especially the majority of high-power radio and television broadcast, many communications antennas are installed on existing structures. Antennas are found on water towers, grain silos, large industrial chimneys, in church steeples, on utility light poles, and on building rooftops. Installing antennas on an existing structure is usually much less expensive than building a tower; plus, it is usually faster and normally requires far fewer steps in gaining approval from local authorities.

While water authority personnel and, occasionally, painting contractors may need to ascend a water tank, the number of personnel that climb a water tank is quite limited. In contrast, rooftop installations are by far the most challenging antenna installation sites to manage; it can be challenging to ensure personal safety and regulatory compliance due to the broad range of personnel that may need to visit a rooftop. Personnel who may need to visit a rooftop site may include, but are not limited to:

- Building maintenance personnel
- Security guards
- Heating, ventilating, and air conditioning (HVAC) personnel
- Electricians
- Elevator maintenance and repair personnel
- Painting contractors
- Window washers
- Insurance agents
- Inspectors from municipal agencies
- Roofing contractors
- Electronics personnel that install and maintain antenna systems

There are two points common to most rooftop antenna sites:

- The vast majority of personnel who visit a rooftop will have little or no knowledge of antennas.
- There are locations near some of these antennas where it is not safe for personnel to remain for more than 2 or 3 minutes.
Personal Safety, Regulatory Compliance, and Reduction of Liability

Building owners and managers must be concerned with three types of risks:

1. Personal safety
2. Regulatory Compliance
3. Liability

The revenue from renting rooftop space for antennas can be very lucrative but, as with most business ventures, a small portion of this revenue should be invested in risk minimization.

Using this Guide

Reading this guide should help you understand the issues associated with rooftop antenna systems. It may provide all the answers that you need for some rooftops with certain types of antenna installations. For others, more will have to be done to minimize risks. The most common solutions are to train personnel and to use wearable RF personal monitors. Both subjects are covered in detail in Section 3: Risks and Recommendations.
Table of Contents

Executive Summary

OVERVIEW ................................................................................................................................................................... 2
PERSONAL SAFETY, REGULATORY COMPLIANCE, AND REDUCTION OF LIABILITY .................................................. 3
USING THIS GUIDE ....................................................................................................................................................... 3

Section 1: Rooftop Antennas

Identifying Antennas and Potential Hazard Areas

OVERVIEW .................................................................................................................................................................. 6

TYPICAL ROOFTOP ANTENNAS .................................................................................................................................. 7
OMNIDIRECTIONAL WHIP ANTENNAS ........................................................................................................................ 7
DIRECTIONAL PANEL OR SECTOR ANTENNAS .......................................................................................................... 8
MICROWAVE POINT-TO-POINT ANTENNAS ............................................................................................................ 9

OTHER ANTENNAS OCCASIONALLY FOUND ON ROOFTOPS ............................................................................. 10
FM RADIO BROADCAST ANTENNAS ....................................................................................................................... 10
TELEVISION BROADCAST ANTENNAS ..................................................................................................................... 10
SATELLITE-UPLINK ANTENNAS ............................................................................................................................ 11

Section 2: Standards and Regulations

Rooftop Environments Must Comply with FCC Regulations

STANDARDS AND REGULATIONS .......................................................................................................................... 12
OVERVIEW OF STANDARDS AND REGULATIONS ................................................................................................. 12
FEDERAL COMMUNICATIONS COMMISSION (FCC) REGULATIONS ................................................................ 12
OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) REGULATIONS ........................................... 14
APPLICABLE EXPOSURE LIMITS FOR ROOFTOPS ............................................................................................... 14
Section 3: Risks and Recommendations

How to Reduce RF Safety Risks on Rooftops

RISKS ........................................................................................................................................................................... 15

RECOMMENDATIONS................................................................................................................................................ 15

OVERVIEW ................................................................................................................................................................. 15
EVALUATE THE ROOFTOP ......................................................................................................................................... 15
  How to Evaluate a Rooftop .................................................................................................................................. 16
USE RF PERSONAL MONITORS ................................................................................................................................. 16
TRAIN YOUR STAFF ................................................................................................................................................... 16

Appendices

APPENDIX A: RF ENERGY AND THE HUMAN BODY ................................................................................................. 17
  Types of Radiation ................................................................................................................................................ 17
  Heating the Human Body .................................................................................................................................... 17
  Time Averaging ..................................................................................................................................................... 18
APPENDIX B: AUTHOR’S QUALIFICATIONS .............................................................................................................. 19
Rooftop Antennas
Identifying Antennas and Potential Hazard Areas

Overview

A building rooftop can be an excellent location to install antennas. The most desirable locations provide an unobstructed “view”\(^1\) for the antenna that is not blocked by another building or a mountain.

Antennas for the following types of services are commonly found on building rooftops:

- Personal communications. This group includes traditional cellular, GSM, and PCS. All of these systems are used with what everyone calls a “cell phone.”
- Paging. Although paging services are far less popular than they were a few years ago, there are still paging systems in use.
- Fire, police, and emergency services.
- Two-way radio systems. Taxi cab companies and many delivery truck companies use two-way radio systems to communicate between base and driver.
- Microwave point-to-point systems.

Although less common, some rooftops will have antennas for the following types of services:

- FM radio broadcast. Very high-power FM radio systems are almost exclusively located on towers, but the antennas for low- to medium-power stations are sometimes installed on rooftops.
- Television broadcast. Traditional high-power television antennas are almost never installed on a rooftop unless there is a tower on a rooftop. Some lower-power television systems that support television on smart phones have been installed on many rooftops.
- Satellite communications systems. Most satellite antennas found on rooftops are receive-only (RO) designs, but satellite antennas that transmit, or “uplink,” signals to the satellite are occasionally found on rooftops.

\(^1\) Radio frequency (RF) energy travels in a straight line, just like light.
• SiriusXM Radio. Most users receive SiriusXM radio signals from a satellite, but there are also high-power terrestrial antenna systems installed on rooftops in major metropolitan areas.

Each of these antenna systems has different characteristics that determine what area around them might be a concern.

**Typical Rooftop Antennas**

The three most common antenna designs found on rooftops are:

1. Omnidirectional “whip” antennas that are used by fire, police, and emergency services; paging systems, and two-way radio systems. They are also used for SiriusXM Radio’s terrestrial broadcast system.

2. Directional “panel” or “sector” antennas that are used by all the personal communications services systems and sometimes for paging systems. They are also used for SiriusXM Radio’s terrestrial broadcast system.

3. Microwave point-to-point antennas that are used by a variety of systems to communicate between two fixed locations.

**Omnidirectional Whip Antennas**

Most omnidirectional whip antennas range from 6 to 20 feet tall. All radiate equally in all directions horizontally, but none have much energy directed downward. A good rule of thumb is if the bottom of a whip antenna is a minimum of 1 foot above the top of your head, you can safely ignore the energy radiating from the antenna. This is often the case where one or more whip antennas are mounted on a small, upper roof area above a stairwell or elevator shaft. Personnel who remain on the main roof have nothing to be concerned about from the antennas mounted on the upper roof.

These omnidirectional whip antennas have very little energy directed downward, so they are not a concern for anyone who remains on the main roof level where this picture was taken.
Directional Panel or Sector Antennas

Panel or sector antennas radiate over a broad angle horizontally, but the height of the vertical beam is equal to the height of the antenna. There is a modest amount of energy directed downward because the antennas are aimed at a slight downward angle. Older designs were simply mounted using adjustable mounting brackets while new designs do this internally using electronic adjustment. The average panel antenna is aimed downward at a 3- to 4-degree angle, and it is extremely rare to find one that is tilted more than 10 degrees. A good rule of thumb is if the bottom of a panel antenna is a minimum of 2 feet above the top of your head you can safely ignore the energy radiating from it. The reason that 2 feet is recommended rather than the 1-foot spacing for the whip antennas is twofold:

- The antennas are tilted.
- A panel antenna has a more intense beam of energy than an omnidirectional antenna of the same height and input power level because the energy is confined to an angle that is much smaller than 360 degrees.

Tower-mounted panel antennas are almost always 120-degree designs. This is why there are always sets of three antennas on towers. Some rooftops also use 120-degree antennas, but it is more common to find a 90-degree antenna on each side of the building. However, in large cities it is not uncommon to find antennas with much narrower beams of energy that can be aimed down a wide street, such as Sixth Avenue in Manhattan. Note that it is almost impossible to determine the rated beamwidth by simply looking at the antenna as they all look very similar.

Panel antennas have no energy directed backward, regardless of the rated horizontal beamwidth.

The roof of this seven-story building contains only 120-degree panel antennas—there are no omnidirectional antennas. All but one of these antennas, which is mounted above one of the two stairwells (which can be seen in the top left portion of the picture), is mounted against a chain link fence close to the edge of the roof. The only RF safety concerns would be (1) if somebody were to climb a ladder in front of the one elevated antenna or (2) if somebody climbing over the fence, such as a window washer, were to get too close to one of the antennas.
Microwave Point-to-Point Antennas

Microwave point-to-point antennas work on the same principle as a conventional flashlight—the energy emits from a focal point that is aimed at a parabolic reflector. The energy radiating from these antennas is in a cylindrical beam that is the same size as an antenna.

Most people are surprised to learn that this type of system is not an RF safety concern. This is because these systems operate at a maximum power level of only 2 Watts, and most operate with less than 1 Watt of energy. When even 2 Watts is spread out over the area of a circle that is usually 4 feet in diameter or more, it results in an extremely weak beam of energy that is a small fraction of the level about which to be concerned.

The RF energy level emitted by these microwave point-to-point antennas is very low. It is safe to walk or stand in front of them without limitation.

ENERGY
Other Antennas Occasionally Found on Rooftops

FM Radio Broadcast Antennas

It is surprising how many FM radio stations are found on building roofs. Most are mounted on towers well above the surface of the roof, but occasionally one finds antennas much lower. **FM antennas should never be installed less than about 30 feet above the surface of a roof unless it is part of an extremely low-power system.** The RF energy levels from an FM antenna can be very dangerous.

These are all FM radio antennas. Unfortunately, there are several different designs, and it is not easy to know whether a particular antenna is used for an FM broadcast system. However, FM broadcast systems never use omnidirectional whip antennas or panel antennas.

Television Broadcast Antennas

Most television antennas found on rooftops are either:

- Very low-power\(^2\) systems used with local organizations, such as schools, that are designed to cover a small area, like a college campus.

- Television systems that support television on smart phones have been installed on many rooftops

\(^2\) The term "very low power" is relative to a typical television broadcast system. Even a very low-power television system will operate at power levels higher than virtually anything else found on a rooftop and is a potentially significant RF safety concern. **Any rooftop with a TV antenna needs evaluation by a professional.**
Satellite-Uplink Antennas

Personnel should avoid getting into the beam of any satellite-uplink antenna. Most satellite antennas found on rooftops are receive-only (RO) designs, but satellite antennas that transmit, or “uplink,” signals to the satellite are found on some rooftops. It can be difficult to determine whether a satellite antenna is a RO or the less commonly found uplink type. One clue is the cable or waveguide transmission line that is used. When the cable to the feed (at the focal point facing the reflector) is about a quarter-inch in diameter and looks like the common coaxial cable used for home television installations, the antenna is invariably RO, as a small cable like that can not handle a significant amount of power.

The energy level in the beams of these two satellite-uplink antennas might be an RF safety concern. However, the beam of energy from each antenna is above the head of anyone who remains at roof level. Personnel need to be aware not to climb a ladder in front of these antennas.
Standards and Regulations

Rooftop Environments Must Comply with FCC Regulations

Overview of Standards and Regulations

The two major RF exposure standards and regulations in the United States are the

- Federal Communications Commission (FCC) Regulations and
- Institute of Electrical and Electronic Engineers (IEEE) standard.

All rooftop antenna systems on commercial buildings must be in compliance with the FCC Regulations.

In addition, the Occupational Safety and Health Administration (OSHA) was established, and still exists, to protect workers from workplace hazards. Exposure to the energy from rooftop antennas is an area covered by OSHA.

Federal Communications Commission (FCC) Regulations

The FCC updated its RF safety regulations in 1997. The regulations require that all transmitting sites in the United States must meet all aspects of these regulations as of September 1, 2000.

The FCC Regulations are based on setting limits for human exposure. The FCC limits are similar, but not identical, to the limits of several other major standards. There are two sets of exposure limits.

- Occupational/Controlled
- General Population/Uncontrolled

These are Maximum Permissible Exposure (MPE) limits averaged over the body and averaged over time. The Occupational/Controlled limits are five times higher than the General Population/Uncontrolled limits at all frequencies above 3 MHz. The averaging period for Occupational/Controlled exposure is six minutes for exposure to frequencies below 15 GHz. The averaging time decreases as the frequency increases from 15 GHz to 300 GHz. The FCC does not allow time
averaging for General Population/Uncontrolled exposure. The MPE limits are the same for both the electric field and the magnetic field.

The FCC provides definitions for the two types of exposure and attempts to define when they apply. A simplified view, endorsed by the Occupational Safety and Health Administration (OSHA), is that the more restrictive General Population/Uncontrolled limits apply unless

- the organization is operating under a written RF safety program, and
- the individuals who may be exposed to levels above the General Population/Uncontrolled limits have received RF safety training.

A planned Notice of Proposed Rulemaking is aimed at further defining when an organization is allowed to use the higher MPE limits for Occupational/Controlled exposure. The terms fully aware and exercise control are referred to in the current FCC Regulations when defining the requirements for establishing an Occupational/Controlled Environment. The Notice further defines these two important terms.

The phrase fully aware refers to workers who

- have received both written and verbal information regarding RF radiation.
- have received training that includes how to control or mitigate RF radiation exposure.

The phrase exercise control refers to workers who

- understand how to use administrative controls to reduce their exposure level. Administrative controls include time averaging.
- understand how to use engineering controls to reduce their exposure level. Engineering controls include Personal Protective Equipment (PPE), specifically RF personal monitors and RF protective clothing.

The FCC’s MPE limits for the two classes of exposure are shown in the tables below. Limits are spatially averaged over the whole body. The Occupational/Controlled limits are time averaged. The General Population/Uncontrolled exposure limits are instantaneous.

Table 1: FCC Maximum Permissible Exposure Limits

Table 1A: Occupational/Controlled Exposure

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Power Density (S) (mW/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03–3</td>
<td>100</td>
</tr>
<tr>
<td>3–30</td>
<td>900/f²</td>
</tr>
<tr>
<td>30–300</td>
<td>1.0</td>
</tr>
<tr>
<td>300–1,500</td>
<td>f/300</td>
</tr>
<tr>
<td>1,500–100,000</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Table 1B: General Population/Uncontrolled Exposure

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Power Density (S) (mW/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03–1.34</td>
<td>100</td>
</tr>
<tr>
<td>1.34–30</td>
<td>180/f²</td>
</tr>
<tr>
<td>30–300</td>
<td>0.2</td>
</tr>
<tr>
<td>300–1,500</td>
<td>f/1,500</td>
</tr>
<tr>
<td>1,500–100,000</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Occupational Safety and Health Administration (OSHA) Regulations**

OSHA still has an outdated standard on its books that is based on the first American National Standards Institute (ANSI) standard developed in the 1960s. This is a single-tier standard that suggests limiting exposure to 10.0 mW/cm² at all frequencies. The FCC limits are far more restrictive. Under the “General Duty” clause of its regulations, OSHA has been using modern, “consensus” standards, such as the FCC’s, as a model for enforcement. OSHA defined its position relative to the FCC Regulations in a reply to an official request from the Personal Communications Industry Association (PCIA) in October 1998. In essence, OSHA went on record stating that, while it was not relinquishing its role as the agency responsible for worker health, organizations that satisfy FCC requirements would also satisfy OSHA requirements. This may be the official position of OSHA, but the evaluator could not identify the corresponding compliance directive. Therefore, local OSHA offices may not be aware of it.

Only FCC MPE limits are considered in this Rooftop Safety Guide since compliance with the FCC Regulations should also satisfy OSHA requirements.

**Applicable Exposure Limits for Rooftops**

Extremely few rooftops can qualify for the higher, time-averaged FCC Maximum Permissible Exposure limits for Occupational/Controlled exposure because the space will not be tightly access controlled with only qualified personnel allowed in restricted areas. Therefore, the FCC limits for General Population/Uncontrolled exposure, which are instantaneous and not time averaged, are applicable.
Risks and Recommendations

How to Reduce RF Safety Risks on Rooftops

Risks

There are always risks associated with high-power RF transmission equipment. The goal is always to understand and manage operations so that risks are minimized. Building owners and managers must be concerned with three types of risks:

1. Personal safety
2. Compliance with FCC Regulations
3. Liability

Recommendations

Overview

Compliance with the FCC Regulations achieves three additional goals:

1. Satisfies OSHA requirements for its employees.
2. Significantly reduces concern over personal injury from exposure to excessive levels of RF energy.
3. Reduces an organization’s liability. Compliance with FCC and OSHA regulations strengthens an organization’s position should it have to defend itself against claims of personal injury.

The recommendations contained herein are designed to significantly reduce the chance of personal injury while complying with federal and local regulations and ordinances and, thereby, achieving a reduction in liability.

Evaluate the Rooftop

Many companies talk about having an RF survey completed. The problem with most surveys is that they are conducted by relatively junior technicians with a limited understanding of RF safety issues.

The goals in evaluating a rooftop in terms of RF safety issues should be to determine:

- what areas of the roof may be visited at any time, by any individual, without restriction or concern;
• what areas of the roof may have excessive RF energy levels that require limiting access to personnel with the knowledge and tools needed to work in such areas; and

• what areas of the roof do not have restrictions for personnel that remain at roof level but may result in excessive RF exposure should personnel use a ladder or other type of lift device.

**How to Evaluate a Rooftop**

Most people think that somebody has to make measurements in order to evaluate a rooftop. That is not true—a knowledgeable person can tell a great deal by looking at pictures of the antenna installations.

In many cases, the typical surveys that are conducted and the largely “canned” reports fail to consider how personnel are likely to perform their jobs. For example, the RF field levels for a person standing at roof level may be relatively low in an area because the antennas are elevated. But there may be a potential hazard for anyone climbing a ladder in the vicinity of the antennas—simply going up 3 or 4 feet may change the RF exposure from a benign level to a potential overexposure situation.

For many installations, it is actually more accurate to perform calculations using software designed specifically for typical rooftop antennas.

**Use RF Personal Monitors**

Monitors can be very useful tools, and you probably will only need one monitor for a rooftop. However, simply giving a monitor to an untrained person can often cause more problems. When monitors are used by personnel who have had a modest level of RF safety training, they are very useful in ensuring that no one remains in an area of excessive RF energy.

**Train Your Staff**

Training your staff accomplishes several things:

• The chances of personal injury are greatly reduced.

• It is an important step in achieving regulatory compliance. In particular, trained personnel are fully aware and able to exercise control over their exposure. Therefore, they can work in areas that exceed the MPE limit for General Population/Uncontrolled exposure and, more significantly, can safely and legally use time averaging to walk or climb past antennas.

Training does not need to be expensive. In fact, it is often possible to train your entire staff for less than the cost of a single RF personal monitor.
Appendices

Appendix A: RF Energy and the Human Body

Types of Radiation

Much of the confusion and concern over exposure to RF energy comes from confusion over the two forms of radiation that people might encounter. I hear it in the classes that I teach and make it a point to explain the difference in every class, even if the students are all professional engineers.

Say the word “radiation,” and everybody gets concerned. Radioactive materials and X-rays generate what is known as ionizing radiation, which can be very dangerous. Ionizing radiation kills or mutates human cells; its effects are cumulative; and there is no practical minimum. So, continuous exposure to low levels of ionizing radiation can eventually lead to serious health problems. Just getting an X-ray kills or mutates millions of cells in your body. But your body will repair itself within two weeks, provided there is no additional exposure. However, the person giving you the X-ray has to be very careful to get behind the lead in the door so that they don’t get exposed. Unlike you, their exposure could be repetitive and cause cumulative effects.

In contrast, radio frequency energy and the energy from most of the light frequencies are forms of non-ionizing radiation. This form of energy can heat tissue when it is concentrated enough and is the principle behind the common microwave oven and lasers. But exposure to very tiny amounts of RF energy has much less impact on you than if the temperature in the room you are in were to change by a small fraction of a degree. Problems occur with exposure to RF energy only when it is so concentrated that your body has a problem dealing with the excess heat. The effects are very similar to overexertion.

Heating the Human Body

The amount of heat produced within the body as a result of exposure to RF radiation depends on many factors but the two most important are:

- how strong or intense the RF energy is, and
- how effective the human body is at capturing or absorbing the energy. At some frequencies, the height of a person makes them a very effective antenna, which results in more energy being absorbed.

It is important to note that the higher the frequency, the shorter the wavelength. The term “microwaves” simply refers to the higher frequency range of the radio frequency spectrum. A person makes a very good antenna when his or her height is equal to a quarter to a half of a wavelength. Most adults make good antennas in the frequency range used by television channels 2 through 6 and FM radio. People make far less effective antennas and, therefore, absorb less energy at microwave frequencies.
Time Averaging

Because the primary effect involves heating of body tissue, the effects of exposure to RF radiation is not instantaneous. It takes a few minutes to heat the body. All the major worldwide standards and regulations evaluate exposure based on the average exposure over any 6-minute interval of time. The FCC Regulations for Occupational/Controlled exposure allow for time averaging, and it is one of the most useful tools taught to personnel during RF safety classes. But unless personnel meet the FCC criteria of being fully aware and able to exercise control over their exposure, the MPE limits for General Population/Uncontrolled exposure apply, and those limits are not time averaged.
Appendix B: Author’s Qualifications

Richard Strickland founded RF Safety Solutions in 2001 after 10 years as Director of Business Development for Narda Safety Test Solutions, the world’s leading supplier of RF safety measurement and monitoring products. As director of the RF safety business at Narda, Mr. Strickland determined which products were developed and their performance characteristics. He frequently functioned as program manager, as he did with the Nardalert XT RF personal monitor. He initiated the development of RF radiation training courses at Narda and has conducted courses ranging from basic employee awareness seminars to in-depth, application-specific courses. Audiences have included environmental health and safety professionals, engineers, technicians, attorneys, communications industry professional consulting engineers (PEs), and senior managers of major corporations, government organizations, and professional groups. Mr. Strickland has taught approximately 300 public and private seminars on RF radiation safety. In-house course clients include the National Association of Broadcasters, NASA, National Public Radio, Society of Broadcast Engineers, AT&T Mobility, Sony, Motorola, NYNEX Mobile, ABC, CapRock, the U.S. Army, Bell Atlantic Mobile, Ameritech, Primeco, NORTEL, Texas Instruments, and Northrup-Grumman. He has been both a featured speaker and a member of the radio frequency radiation panel at the National Association of Broadcasters, the Radio Club of America, and the International Wireless Conference and Exposition. He is a member of IEEE SC 28 P1466. The project scope of this group is “Preparation of a guidance document for the development of RF safety programs.” Mr. Strickland is the author of more than 25 articles on RF safety practices and measurement issues.

Customers
Richard Strickland provides advice regarding RF radiation safety to several major companies. Services include RF surveys and RF safety reports, development of RF safety programs, and RF safety training.

Clients include:

- ABC Radio
- ABC Television
- American Tower
- AT&T Mobility
- British Aerospace
- Cornell University
- ESPN
- Hughes Network Systems
- Lockheed Martin Corporation
- NASA
- NBC Television
- Raytheon Corporation
- Society of Broadcast Engineers
- U.S. Coast Guard
**Education**
- MBA, University of Massachusetts, 1980
- BA Physics, Bridgewater College, 1972
- Advanced (radar & IFF) and basic electronics courses, U.S. Coast Guard

**Presentations & Publications**
- More than 40 articles published in technical publications on RF safety, high-power amplifiers, and radomes
- Organized and conducted approximately 250 public and in-house training courses
- Featured speaker for numerous professional organizations including NATO, National Public Radio, National Association of Broadcasters, Society of Broadcast Engineers, and Radio Club of America

**Professional Memberships**
- Member of the International Electrotechnical Commission (IEC) Technical Advisory Group (TAG) 106: Methods for the Assessment of Electromagnetic Fields Associated with Human Exposure
- Member of the IEEE CS 28 P1466, guidance document for the development of RF safety programs
- Member of the Association of Federal Communications Consulting Engineers (AFCCE)

**Awards**
- Winner of the R & D 100 Award for the Nardalert XT RF Personal Monitor. Mr. Strickland was the originator of this product. He functioned as project manager and decided on all of its features and design details. The R & D 100 Awards are given annually to the top 100 scientific and technological achievements in the world. They are frequently referred to as “the Nobel Prizes of Applied Research.”