RADIO FREQUENCY AWARENESS

Radio Frequency Safety Awareness for the
Telecommunication Worker

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ABSTRACT

There is recognition among federal, state, and occupational health agencies that the explosion in use of cell phones, pagers and other wireless devices has increased awareness that the risk of radio frequency (RF) exposure is a concern not only with employees and employers but with the general public as well. Wireless towers and rooftop antennas are sprouting up at a fast pace and people are living in close proximity thus causing increased concern about safety and health.

The Federal Communications Commission (FCC), the American National Standards Institute (ANSI) and the Institute of Electrical and Electronic Engineers (IEEE) (FCC, 2001 and ANSI/IEEE, 1992) have established consensus standards to assist in providing a safe and healthful work environment in the identified at risk population. The Occupational Safety and Health Administration (OSHA) promulgated a standard related to radio frequency exposure in 1982 and amended it in 1996. The amended standard is very broad in coverage however, it does reflect changes in the telecommunications industry that were present at that time. However the rapid growth in telecommunications industry since 1996, with the explosion of antennas on rooftops for example, has made it somewhat outdated.

Awareness of the actual and potential exposure and sources of RF radiation when working around antennas, whether they are mounted on rooftops or wireless towers, will allow employers the ability to provide a safe work environment by mitigating the exposure through the use of controls.
Research has been carried out extensively on animal subjects but not on humans. Exposure standards have been established based on this research but there is not consensus on the specific effects of short-term RF exposure. Research on the long-term effects of exposure to RF radiation is inconclusive and this must be addressed in future studies.

This paper will provide information relevant to radio frequency (RF) education that will be beneficial in developing and implementing a RF safety program. The information is directed at occupational health professionals to aid in educating site managers, tower technicians, and all other personnel in providing a safe and healthful work environment related to developing and implementing a RF safety awareness education program.
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CHAPTER I
Introduction

Background Information

Broadcast stations for radio and television as well as wireless towers for cell phones and pagers transmit their signals through electromagnetic waves. Electromagnetic waves are made up of electric and magnetic energy radiating through space at the speed of light. Together, they form electromagnetic energy and are referred to as the electromagnetic spectrum as seen in Figure 1.1.

Radio waves and microwaves emitted by transmitting antennas are only one form of electromagnetic energy. These waves can be a significant source of radio frequency energy in the environment. Together they are known as radio frequency or RF radiation/energy. (FCC, 2001).

Ground-level intensities of the RF electromagnetic fields resulting from broadcast transmissions and waves are emitted from all antennas whether they are mounted on rooftops or wireless towers. RF fields depend on several factors including the type of broadcast station, amplitude frequency (AM) or frequency modulation (FM) type of antenna, anticipated emission pattern, power transmitted to the antenna, height of the antenna, distance from the antenna, number of antennas on site, and any surrounding emissions from adjacent sites. Specific mathematical calculations can be performed to predict what field strengths (the magnitude of an electric, magnetic or electromagnetic field at a given point) would exist at various distances from an antenna. Since the human
Figure 1.1 The Electromagnetic Spectrum

body absorbs energy at some frequencies more readily than energy at other frequencies; the existence of a possible hazard would depend on the frequency of the transmitted signal as well as its intensity.

Public access to broadcasting antennas and wireless towers is usually restricted so that the general public is not exposed to high-level fields that might exist near an antenna or tower site. However, this is not always the case when antennas are mounted on rooftops of tall buildings or other tall structures such as water towers. Tower technicians and maintenance workers are occasionally required to climb antenna structures for such purposes as painting, repairs, or beacon replacement. Heating, ventilating, and air conditioning (HVAC) mechanics and roofers are often required to perform maintenance on rooftops as well. Both the Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) have reported that in these cases it is possible for a worker to be exposed to high levels of RF radiation if work is performed on an active tower or in areas immediately surrounding a radiating antenna. Therefore, precautions should be taken to ensure that any personnel working in these situations are not exposed to hazardous field intensities. It is also vitally important to educate the general public on safety related to these potential sources of RF. However, measurements made by the FCC, EPA, and others have shown that RF radiation levels in inhabited areas near broadcasting facilities are typically well below levels that are considered to be hazardous.

There are a variety of antenna types utilized within the telecommunications industry. The parts of an antenna are called the “elements.”
The elements formulate the design characteristics. The arrangements of the elements determine the operating characteristics, and coupled with the antenna placement determine the RF emissions pattern that can occur. It is imperative for the individual working in or near that area to know the anticipated emission pattern of the antenna, to better protect themselves, and to be able to identify the RF radiation hot spots and blind spots. A hot spot in reference to RF radiation refers to an area near the RF source where RF radiation is more pronounced. These areas are characterized by a rapid change in field strength with distance (FCC, 1997). For example, an area directly in front of an antenna, in the direction that the antenna is transmitting would be considered a hot spot.

Controversy related to human exposure to electromagnetic energy dates back as far back as the early 1950s. During the past 30 years, there have been significant advances in instrumentation and measurement techniques for complex electromagnetic fields (Peterson, 1990) which has increased awareness of the need for better education and protection of employees.

There are identified precautions that can be utilized to protect the individual required to work in the vicinity of possible sources of RF radiation. Hazard control can be accomplished on several levels such as engineering controls, administrative controls, work practice controls, and personal protective equipment (PPE).

Limits for exposure to electromagnetic fields from exposure to RF radiation have been debated and subject to controversy (FCC, 2001 and ANSI/IEEE, 1992). The debate and controversy stems from the lack of absolute
documentation of the long-term effects of radiofrequency and the variances in research studies regarding the short-term effects. Many studies have been carried out on animal subjects with little documentation on human subjects regarding the effects from RF exposure. Schilling (1997 and 2000) has the only documented follow up of antenna engineers exposed to high frequency RF waves which reflects the need for further research on RF exposure. Schilling's studies revealed that the exposed engineers suffered an immediate sensation of intense heating of the parts of the body in the electromagnetic field followed by a variety of signs and symptoms which included pain, headache, numbness and parasthesia, malaise, and skin erythema. The most prominent problem was that of an acute then chronic headache involving the part of the head which was most exposed. Most research and existing standards entertain a limited discussion regarding the potential long-term effects of RF exposure (Erdreich, 2001). It is a direct reflection on the gap in current research with the surge in the telecommunications industry.

There is a plethora of research that has been done on the subject of RF exposure, omitting the long-term effects. The IEEE has compiled a list in excess of 400 different articles that relate to this topic. The Radiofrequency Radiation Division (OER) of the Occupational and Environmental Health Directorate, Armstrong Laboratory at Brooks Air Force Base in San Antonio, Texas, contains a large source of RF radiation research and testing. OER conducts extensive research and computer modeling to support the development of health and safety
standards for electromagnetic radiation. However, the research in this area must be better refined to address human exposure as it relates to RF radiation.

The OSHA standard that was promulgated in 1982 was revised and updated in 1996 to reflect changes in the telecommunications industry, but is still very broad in nature. This paper will address the issues that occupational health and safety personnel need to know to aid in providing a safe and healthful work environment related to developing and implementing a RF safety awareness education program.

Terminology

In order to understand the principles of RF exposure it is necessary to review some basic concepts. To begin with, it is essential to understand the difference between ionizing and non-ionizing radiation. Ionization is the process by which electrons are stripped from atoms or molecules producing molecular changes that can lead to significant genetic damage in biological tissue such as effecting DNA. Ionizing radiation has enough energy to change the chemical structure of matter when it is absorbed. Sources of ionizing radiation are gamma radiation, x-rays and cosmic waves and do not include RF energy. This exposure is cumulative over time acquiring environmental and personal dose.

The energy levels associated with RF radiation are not great enough to alter molecular structure therefore it is classified as non-ionizing. Non-ionizing radiation does not have enough energy to create ions, so the energy is absorbed as heat. When RF energy is absorbed it causes an increase in molecular movement.
Sources of non-ionizing radiation include RF radiation, microwaves, visible light, infrared radiation, and extremely low frequency radiation. Exposure to non-ionizing radiation is not cumulative over time. It occurs at the time of exposure. Once exposed and symptoms develop there is no specific test to perform to determine the amount of exposure. Determining the amount of exposure requires specific measurements of length of exposure (time), distance from the source (distance), and the frequency that the source emits. The effects of RF exposure can be classified as thermal, due to the heating of tissue by the RF energy, or non-thermal which is from the lower levels of exposure where the production of harmful effects has not been significantly proven. RF monitors are available to obtain RF emissions from the source but they would not provide data on the thermal exposure as this involves multiple factors such as distance from the source, length of time exposed, and the RF emissions. Non-thermal effects cause no significant thermal input therefore there is no increase in core body temperature (Elder, 1987). Examples of non-thermal effects are immune system effects, neurological effects, and behavioral effects.

Electromagnetic energy exists in a variety of forms – television and radio waves, heat lamp radiation, microwaves, light from the sun, and other sources including electrical currents passing through wires. Electromagnetic energy occurs in two forms, electrical and magnetic. When current passes through electrical wires, electromagnetic energy is created as fields around the wires. The units of electrical fields are measured in volts per meter (V/m) and the units for magnetic fields are amperes per meter (A/m). These fields, called
electromagnetic fields (EMF), have both electric and magnetic components. EMF uses $V/m$ and $A/m$ to provide information about the levels of electrical and magnetic field strength at a field measurement location. Electromagnetic energy can also move from one point to another by waves propagated through space, such as visible light and radio waves. Another term used for characterizing the magnitude of RF electromagnetic fields is power density, which is measured in terms of power per unit area ($mW/cm^2$) (WHO, 1989).

The movement of electrical charges in an antenna generates the RF waves that are emitted from antennas, characterized by wavelength and frequency. The wavelength is the distance covered by one complete cycle of the electromagnetic wave, while the frequency is the number of electromagnetic waves passing a given point in one second. Wavelengths and frequencies classify different forms of electromagnetic energy. The frequency of a RF wave is typically expressed in terms of a unit called the hertz (Hz). One Hz equals one cycle per second. One megahertz (MHz) equals one million cycles per second. Microwaves are a specific category of radio waves that can be defined as RF energy where frequencies range from hundreds of MHz to several gigahertz (GHz) (FCC, 2001). The RF section of the electromagnetic spectrum is generally defined by IEEE as that part of the spectrum where electromagnetic waves have frequencies in the range of 3 kilohertz (kHz) to 300 GHz (ANSI/IEEE, 1992). In the lower frequencies, the wavelengths are longer with less frequency and less electron volts having a decreased risk of biological effects. Figure 1.2 shows the frequencies and associated wavelengths and radio services.
<table>
<thead>
<tr>
<th>Frequency</th>
<th>Low Frequency/Long Wavelength</th>
<th>Radio Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-300 kHz</td>
<td></td>
<td>Radio navigation, Maritime</td>
</tr>
<tr>
<td>Low Frequencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300-3000 kHz</td>
<td></td>
<td>AM Broadcast, Mobile, Induction, heat sealers and diathermy</td>
</tr>
<tr>
<td>Low Frequencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-30 MHz</td>
<td></td>
<td>Mobile, Maritime</td>
</tr>
<tr>
<td>30-300 MHz</td>
<td>Maximum Absorption Frequencies</td>
<td>FM/TV Broadcast, Paging, Mobile, TV</td>
</tr>
<tr>
<td>Human Resonance Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300-3000 MHz</td>
<td>Broadcast, Cellular, PCS, SMR, Paging, Mobile, Microwave Ovens, 2-way radios</td>
<td></td>
</tr>
<tr>
<td>High frequencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-30 GHz</td>
<td>Microwave, Satellite, Radio location</td>
<td></td>
</tr>
<tr>
<td>High frequencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-300 GHz</td>
<td>Microwave, Satellite, Radar</td>
<td></td>
</tr>
<tr>
<td>High frequencies</td>
<td>Higher Frequency/Short Wavelength</td>
<td></td>
</tr>
</tbody>
</table>
A useful quantity measurement in determining a person’s exposure to RF radiation is the specific absorption rate (SAR). The SAR is the rate at which electromagnetic energy is absorbed into the human body or tissue is measured by watts per kilogram (W/kg) of tissue (COMAR, 2000 and ANSI/IEEE, 1992).

OSHA sets permissible exposure limits (PEL’s) to protect workers against the health effects of exposure to hazardous substances. PEL’s are regulatory limits on the maximum amount or concentration of a substance to which one can be exposed based on a time weighted average. RF is a wavelength and is not measurable as a concentration. OSHA defines PEL’s for hazardous substances and since RF is not a substance the FCC utilizes maximum permissible exposure (MPE) in place of PEL’s for RF exposure. Exposure limits are defined by the FCC as MPE limits. MPE is the RF field strength limit or standard to which a person can be exposed without harmful effects and with an acceptable safety factor. The MPE limit is defined as the root-mean-square (rms) and peak electric and magnetic field strength, their squares, or the plane wave densities associated with these fields (FCC, 1997).

Near field and far field regions are important when evaluating an antenna site for areas that exceed the MPE limits. The near field is the area in close proximity to the antenna and the far field region is the area that is some variable, ‘R’, distance away from the antenna.

Correct models must be used to determine area. If a far field calculation model or equation is used to predict or estimate an antenna’s power density for an
area, which is in close proximity to the antenna, the power density will be grossly over-estimated.

Table 1.1 shows equations that are utilized when determining far and near field gains.
### Table 1.1 Near & Far Field

<table>
<thead>
<tr>
<th><strong>Near Field</strong></th>
<th><strong>Far Field</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Smaller apertures = Higher RF fields</td>
<td><strong>S</strong> = Power density (mW/cm²)</td>
</tr>
<tr>
<td>( S_{\text{near fields}} = \frac{P}{2 \pi h(Rh)} )</td>
<td><strong>P</strong> = power into the antenna (mW)</td>
</tr>
<tr>
<td><strong>Far Field</strong></td>
<td><strong>h</strong> = aperture length (cm)</td>
</tr>
<tr>
<td>Higher Antenna Gains = Higher RF fields</td>
<td><strong>R</strong> = distance from antenna to point of interest</td>
</tr>
<tr>
<td>( S_{\text{far field}} = \frac{PG}{4 \pi R^2} )</td>
<td><strong>G</strong> = antenna gain (numeric)</td>
</tr>
<tr>
<td></td>
<td><strong>\Pi = 3.1414926</strong></td>
</tr>
</tbody>
</table>

**Pi**
The equations show the differences that an antenna gain and aperture height can have when calculating RF fields or power densities. An antenna with a small aperture (6’ long) will have higher RF fields close to it than an antenna with a longer aperture (20’ long), if both antennas are operating at the same frequency and input power. In the near field, the equation that makes use of the aperture length is used when calculating power densities and in the far field the equation that makes use of the antenna’s gain is used. Antennas with higher gains will produce higher RF fields in the far field than antennas with lower gains. In both cases, as the distance from the antenna ‘R’ increases the RF field decreases as a result, the ‘R’ variable is the denominator for both equations.

The FCC standards include the two principles of spatial averaging and time averaging. Spatial averaging is a fundamental aspect that is applied to power densities (S) that are spatially averaged. Spatial averaging is performed by taking RF field measurements over an area equivalent to the vertical cross-section of the human body from ground level to a six-foot height and then averaging the field measurements. Spatially averaged RF field levels most accurately relate to estimating the whole-body averaged SAR that will result from exposure and the MPE limits are based on this concept. This means that local value exposures that exceed the stated MPE’s may not be related to non-compliance if the spatial average of RF fields over the body do not exceed the MPE’s (FCC, 2001).

Another principle of the RF exposure guidelines and standards is that exposures, in terms of power density (S), may be averaged over certain periods of time with the average not to exceed the limit for continuous exposure. The
averaging time for general public / uncontrolled exposure is 30 minutes since it is not possible to control exposures to the extent that time averaging times can be applied. In this situation, it is often necessary to assume continuous exposure. Workers or members of the general public that have had no education regarding RF awareness and safety or control over possible exposure, would be classified into this category. This would include roofers, building maintenance workers, and HVAC mechanics. The 100% MPE limit for an occupational / controlled area for the frequency range of 30-300 MHz is 1 mW/cm² for six minutes. All workers that have been educated on RF safety and awareness and know there is potential exposure are included in this group. Examples of jobs included in this category are tower technicians and antenna engineers. It is permissible to exceed the MPE limits for short periods of time as long as the average exposure does not exceed the MPE limits. If the field level measured at the site is 2 mW/cm² an employee can be in the area for 3 minutes. If the field level measures 3 mW/cm² an employee can be in the area for 2 minutes and so on. Since it is very difficult to measure and keep track of exposure times, it is recommended that if an area exceeds 100% of the MPE limits, that the employee stay completely out of the area or use some form of hazard prevention, mitigation or control to reduce or control the exposure. See Table 1.2
Table 1.2
Time Averaging for Occupational / controlled MPE limits for the 30-300 MHz range.

<table>
<thead>
<tr>
<th>Field Level Milliwatts/centimeter squared</th>
<th>Allowed Exposure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mW/cm²</td>
<td>6 minutes</td>
</tr>
<tr>
<td>2 mW/cm²</td>
<td>3 minutes</td>
</tr>
<tr>
<td>3 mW/cm²</td>
<td>2 minutes</td>
</tr>
<tr>
<td>4 mW/cm²</td>
<td>1.5 minutes</td>
</tr>
<tr>
<td>6 mW/cm²</td>
<td>1 minute</td>
</tr>
</tbody>
</table>
Figure 1.3 shows the FCC RF exposure limits. The exposure limits for the solid line depict occupational / controlled and the broken line depicts general public / uncontrolled exposure. As shown in the graph, the strictest limits are set for the frequencies between 30-300 MHz, (the human resonance range). The general public / uncontrolled exposure limits are one-fifth of the occupational / controlled limits.
Figure 1.3 FCC Limits for MPE

FCC Limits for Maximum Permissible Exposure (MPE)

(Source: Curtis, 2001).
CHAPTER II
Radiofrequency Radiation

Source Types, Frequencies, and Significance

In considering the possible hazards from exposure to RF sources, there are several considerations that need to be addressed including ‘what is the source of the RF’, ‘what is the frequency that the source is operating at’ and ‘what significance does the source have to the workers’. The source type is critical information to evaluate. Antennas are primarily designed to provide multiple selections of patterns of distribution, multiple electrical specifications, and dependability. A RF antenna transfers a guided wave into and receives guided waves out of open space converting alternating current into electromagnetic fields. This is done by the part of the antenna known as the elements. The arrangement of the elements within the antenna formulates the design of the antenna, which determines the operating characteristics.

The parts of an antenna system consist of the transmitter, the receiver, the transmission line, and either a transmitting or receiving antenna or one antenna for each system. The transmitter sends the signal while the receiver receives the signal. The transmission line, otherwise known as coaxial cable in regards to antennas, is the medium that forms the path for the energy to travel. Antennas operate by exposing positive and negative charges to air. These charges flow into open space creating fields of energy. These two-fields formulate a simple antenna called a di-pole. These two fields are attracted to each other and generate an electrical current between them called the electrical (E) field strength. A
peripheral magnetic field called the magnetic (H) field strength is established as the current flows between the positive and negative poles. When the signal passes between the poles, the current generates the waves.

Despite the fact that two-way antenna systems usually utilize dual function antennas, there are distinct considerations for receiving and transmitting. Certain parts of the antenna system can be adjusted to allow a poor quality antenna to emit the signal. Receiving antennas must be able to operate independently by attempting to capture waves that are sufficient to induce a low voltage that generates a small current that flows down the transmission line to the receiver. Antennas have distinct characteristics such as they must be able to resist signals from frequencies other than their own. Lower frequencies travel farther than higher frequencies and lower frequency antennas are typically larger in size. The physical size determines the power capability of the antenna. These physical characteristics allows the workers to determine the frequency band levels of the antenna by its size (ComTrain, 1999).

It is important to consider the type of antenna that is used and its characteristics when working near an antenna as well as the anticipated RF emission pattern and how the antenna is mounted. Antenna selection is determined by taking into consideration polarization, RF radiation pattern, and gain characteristics. Figure 2.1 shows the most common antenna types and their anticipated RF emission pattern.
Figure 2.1 Antenna Pictures and Anticipated RF Emission Patterns

<table>
<thead>
<tr>
<th>Antenna Name</th>
<th>Antenna Picture</th>
<th>Antenna Anticipated RF Emission Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omni Directional</td>
<td><img src="http://www.superpass.com/SPDG-20.html" alt="Omni Directional Picture" /></td>
<td><img src="http://www.indiamart.com/starantennas/colinear-antenna.html#stacked-dipole" alt="Omni Directional Pattern" /></td>
</tr>
<tr>
<td>Dipole</td>
<td><img src="http://www.indiamart.com/starantennas/colinear-antenna.html#stacked-dipole" alt="Dipole Picture" /></td>
<td><img src="http://www.indiamart.com/starantennas/colinear-antenna.html#stacked-dipole" alt="Dipole Pattern" /></td>
</tr>
<tr>
<td>Yagi</td>
<td><img src="http://www.indiamart.com/starantennas/colinear-antenna.html#stacked-dipole" alt="Yagi Picture" /></td>
<td><img src="http://www.indiamart.com/starantennas/colinear-antenna.html#stacked-dipole" alt="Yagi Pattern" /></td>
</tr>
<tr>
<td>Corner Reflector/Parabolic</td>
<td><img src="http://www.strandnet.com/rozendal/antennas/fourfoot.html" alt="Corner Reflector/Parabolic Picture" /></td>
<td><img src="http://www.strandnet.com/rozendal/antennas/fourfoot.html" alt="Corner Reflector/Parabolic Pattern" /></td>
</tr>
</tbody>
</table>


The simplest and most common antenna utilized is called the Omni directional antenna. The Omni, with its 360° RF emissions pattern is designed to receive and transmit signals from all directions. Figure 2.1 shows the range of radiation of the antenna if it is mounted without obstructions, such as at the top of a wireless tower. If the Omni antenna is mounted with some type of obstruction such as another antenna, then the RF emissions pattern becomes distorted.

A second type of antenna, called a dipole antenna, appears to have paper clip like attachments on the main pole. The location of the attachments to the main pole determines the path of signal. They can be on the same side of the pole or set at different angles from the center pole. A di-pole antenna can be used to improve the reception of FM broadcast signals. The anticipated RF emissions pattern shown in Figure 2.1 shows that there is concern in all areas surrounding the antenna however, the closer you get to the antenna the greater the risk of exposure.

A third type of antenna is the Yagi antenna, which looks similar to the rooftop TV antenna used years ago. Yagi antennas, commonly used for cellular telephones, are considered directional and utilize multiple, graduated length radials to focus the signal away from the structure. A Yagi antenna would be utilized when high directivity and gain are necessary. The Yagi antenna as seen in Figure 2.1 shows a very different RF emissions pattern. There is a large oblong field of RF emissions directly in front of the antenna and a smaller tail on the backside of the antenna. With this knowledge in mind, the worker can have a sense of where the hot spots are when performing work near an antenna. A hot
spot on the Yagi would be directly in front of the antenna and should be considered the highest RF emissions zone. When working in this area the worker must take necessary precautions to protect themselves. This is discussed in chapter VI.

A fourth type of antenna, known as a corner reflector antenna, has the appearance of two Yagi antennas turned on the side and mounted at an angle to each other. The elements can be solid or graduated radials and they are designed to radiate away from the back of the plane. A corner reflector antenna is very similar to a parabolic antenna. The parabolic antenna, which has the appearance of a bowl, is also known as a microwave “dish”. The transmitter receiver that is mounted in the center of the bowl is called the horn and faces the reflector. This type of antenna is considered a high gain antenna. Satellite broadcasting utilizes the dish antenna model. The anticipated RF emissions pattern comes out at an angle from the edges of the dish with minimal exposure behind the dish, which is unlike the Omni-directional or the dipole antenna.

Finally, another common antenna that is utilized is the panel antenna. Just as their name insinuates, panel antennas are typically flat, rectangular in shape and can be either fat or thin (ComTrain, 1999). Panel antennas are used for cellular and personal communication services (PCS) because they offer a wide range of gains and beam patterns. In viewing the panel antenna in Figure 2.0 it is significant to notice that there are reflectors all around the top, bottom, and sides of the panel reflecting the RF emissions directly in front of the antenna, much like the angle that is seen with a dish antenna.
Another consideration is the frequency at which the source operates. Wireless communication devices operate at a variety of frequencies. Frequency determines the wavelength. Longer waves have lower frequencies and shorter waves have a higher frequency (refer to Figure 1.2 in Chapter I).

A third consideration is the power output of the source and the body’s distance from the source. Cellular phones and other communication headsets operate at comparatively lower power levels but are typically used in close proximity to the body whereas base stations operate at higher power levels, but their transmitting antennas are located some distance from the body. (COMAR, 2000).

**Exposure Limits**

As per Table 2.1, there are a number of agencies, including governmental agencies that have developed standards, guidelines, recommendations, and consensus standards for human exposure to RF fields. These include the IEEE, the National Council on Radiation Protection and Measurements (NCRP), and the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the ANSI, FCC, and OSHA.
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<th><strong>Table 2.1 Agencies and their roles in RF radiation</strong></th>
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These guidelines, standards, recommendations, and consensus standards listing specific limits were developed by scientific committees who identified the potential hazards of RF radiation exposure (COMAR, 2000). A well-developed RF safety awareness program will incorporate all appropriate guidelines, standards, recommendations, and consensus standards to ensure that it meets all local, state, and federal requirements, guidelines, standards, recommendations, and consensus standards.

Environmental levels of RF radiation routinely experienced by the general public are far below the levels necessary to produce significant heating and increased body temperature. The US EPA has estimated that 98-99% of the population in certain US urban areas studied is exposed to less than 0.002 mW/cm². However, there may be certain instances in workplace environments such as rooftops or wireless towers where there are antennas and where RF safety standards are exceeded and people can be exposed to potential harmful levels of RF radiation.

In the case of RF exposure, a MPE greater than 100% exceeds the FCC’s RF exposure standards and will require some form of RF exposure mitigation to control or reduce it. Zero to 100% MPE limit is acceptable. It is important to remember that MPE values are not thresholds between safe and dangerous exposure levels.

These FCC standards as well as IEEE-C95.1-1991, incorporate two separate tiers of exposure limits that are dependent on the situation in which the exposure takes place and/or the status of the individuals who are subject to RF
exposure. The two tiers include occupational / controlled and general public / uncontrolled exposure limits that were mentioned earlier. These standards have limits for power density that are five times higher for controlled environments for occupational exposure than for the general public at frequencies up to 3000 MHz. (COMAR, 2000).

Occupational / controlled exposure limits apply in situations in which persons are exposed as a consequence of their employment and which those persons who are exposed have been made fully aware of the potential for exposure and can exercise control over their exposure. Higher exposure limits are permitted under this category. Antenna installers, wireless radio engineers, and tower technicians are examples of workers that would be in this category. Occupational / controlled exposure limits apply in situations in which workers are exposed as a result of their job, provided these workers are made fully aware of the potential for exposure and thus can leave the area for a period of time to reduce the length and amount of exposure. An example of exercising control over their exposure would be to leave the area when they are aware they have exceeded the MPE. Limits for occupational / controlled exposure are also applicable in situations where a worker is passing through a location where occupational / controlled limits apply provided the worker is made aware of the potential for exposure. The occupational / controlled exposure limits also apply to amateur radio operators and members of their immediate family.

General public / uncontrolled exposure limits set the maximum exposure to which most people may be subjected. People in this category include the
general public not associated with the installation and maintenance of the transmitting equipment (FCC, 1997). This category also applies to situations in which anyone may be exposed or in which workers are exposed as a consequence of their employment and the worker is not fully aware of the potential for exposure or cannot exercise control over their exposure. This would include a tenant in a building that is having a picnic on a rooftop unaware of the potential exposure to RF radiation. Therefore, members of the general public would always be considered under this category when exposure is not employment-related. Another example, would be the case of a telecommunications tower that exposes persons in a nearby residential area.

The MPE limits adopted by the FCC for both occupational / controlled and general population / uncontrolled have been established to be considerably below levels generally acknowledged as having the potential to cause adverse health effects.

**Multiple Emitters**

It is common for a rooftop or tower site to have multiple RF sources co-locating at the site. Some rooftops are referred to as antenna farms due to this multitude of antennas that are clustered together. In the event that there are multiple transmitters at the site, there must be relevant technical information gathered to permit an overall analysis of the RF environment by either calculations or computer modeling.

According to the FCC standards for multiple transmitter sites, licensees must ensure that the site is in compliance. The responsibility of this compliance
is to be shared among all licensees whose transmitters produce a field strength or power density levels at the area in question in excess of 5% of the exposure limit applicable to their particular transmitter. (Peterson, 1992). In other words, if an accessible area at an antenna site, regardless if it is a wireless tower or other tall structure, is determined to exceed 100% of the applicable MPE limits, then all existing licensees and / or applicants that contribute or would contribute at least 5% of the MPE limit to an area that exceeds the respective MPE limit, are required to share in the compliance responsibility and work together to ensure compliance by utilization of hazard mitigation strategies as written in the FCC standards (47 CFR Sec. 1.1307). In other words, if an antenna contributes more than 5% to the percentage above the MPE, all license holders at the site must work together to reduce the exposure overage by utilizing appropriate control strategies. Calculating predicted exposure levels might be complicated if different transmitters at a single site operate more than one channel or if the operating power per channel differs from one transmitter to the next or if some channels are used periodically. In this situation it is advised by the FCC to estimate a “worst case” exposure distance for compliance by assuming that the total power of all transmitting antennas at the site is concentrated in the areas that are under question (FCC, 1997).

Computer modeling or hand calculations using the equations from the FCC’s Office of Engineering and Technology (OET) Bulletin 65 is an ideal way to calculate and determine the MPE. With the same equations, solving for the distance or extrapolating the emissions levels at certain distances from the
antennas can be a good way to determine the owners 5% contribution. However, to cover all bases, an environmental evaluation of the site should also be performed (including documentary photographs of any off-site RF contributors that could influence the emissions at the site). If the transmitter is pointed to as a contributor to the RF emissions at an adjacent site, the antenna owner will be able to recoup at least part of whatever costs are incurred by invoking the same strategy on other contributors to the site.
CHAPTER III
Symptomology and Post Exposure Care for Radio Frequency Exposed Workers

Effects on the Human Body from RF Exposure

The public sector has long questioned the effects of RF radiation on the human body. A plethora of time and money, in the form of in-depth, scientific research has been allotted to study the effects. Several studies reflect RF radiation effects exists to some degree. (NRPB, 1992, WHO, 1989 & 1998, Braune, 1998). Another study (Schilling, 1997) explored densities in the human body related to RF exposure. As of yet, there are no substantial reports to indicate a link exists between RF radiation and cancer, birth defects, or other health hazards or health risks (WHO, 1998).

Later studies reflect that RF radiation can cause heating in biological tissue. (NRPB, 1992 and WHO, 1998). RF energy penetrates tissue and produces a thermal effect. This induced heating can cause a variety of physiological and thermoregulatory responses similar to the effects that occur from heat stress. The effects caused by RF exposure depends on the frequency of energy, the power density of the RF field that strikes the body, duration of exposure and even the polarization of the RF waves (WHO, 1998).

At frequencies near the body’s natural resonant frequency, RF energy is absorbed more efficiently and maximum heating occurs. Body size determines the frequency at which RF energy is absorbed. For example, larger bodies would absorb more RF waves due to a larger surface area. In the range 30-300 MHz frequency range maximum absorption of RF radiation by the human body is seen.
The primary sources of radiation in this range include but are not limited to TV and FM broadcast, and paging and mobile radio communications. In Figure 1.2 (Chapter I), frequency ranges are exhibited on the left-hand side with radio services that use those frequencies listed on the right.

The FCC exposure limits are based on scientific research data showing that the human body absorbs RF energy at some frequencies more efficiently than at other frequencies (FCC, 2001). This is the rationale for the FCC MPE limits being so stringent for the frequency range of 30-300 MHz. This range is where whole-body absorption of RF is most efficient. At other frequencies, whole-body absorption is less efficient, and consequently, the MPE limits are less restrictive (FCC, 2001). As mentioned earlier, energy absorption from RF fields in tissues is measured as the SAR. A SAR of at least 4 W/kg is needed to produce adverse health effects in people exposed to RF fields in this frequency range (Erdreich, 2001). The SAR stated is roughly equivalent to 2.5 times the resting energy production rate of the human body (IEEE, 1995).

Health effects from RF radiation can be classified in terms of thermal and non-thermal effects. Thermal effects occur from localized heating of the human body tissues caused by absorbed radiation. Non-thermal effects are those not associated directly with localized heating and occur with relatively low levels of RF radiation but there is controversy over whether there are indeed non-thermal effects from RF radiation (FCC, 2001).

The primary health effects are a result of the thermal response. Effects, which are known to occur at “thermal” intensities, include heat stress, heat
exhaustion, depressed sperm count, increase heart rate (Braune, 1998) and ocular effects such as cataracts as well as headache and nausea (WHO, 1989).

 Depositing RF radiation energy into the body increases its overall thermal load. The thermoregulatory system responds to the increased thermal load by transfer of energy to the surrounding environment through convection, evaporation of body water, and radiation. Tissue heating depends on the frequency of the source, water content and thickness of the tissue. The more conductive the tissue, the more energy absorbed and heat generated. When the RF radiation causes localized heating of certain organs, such as the eyes, prolonged exposure to this thermal stress can directly damage that organ. However, short duration exposure to RF-induced thermal load will usually not cause damage and the heat will be dissipated. For this reason, RF radiation exposure is not cumulative, unlike ionizing radiation exposure (WHO, 1989).

 Numerical models of thermoregulatory responses in humans can be used to predict RF exposure conditions that may cause undesirable temperatures in the human body (Spiegel, 1982 & 1984). A healthy person exposed to RF in hot and humid environments would experience some degree of discomfort along with an increase in body temperature and heart rate and profuse sweating. These responses would continue to increase with time and after approximately 60 minutes a healthy person would be near collapse, with unpleasant but reversible symptoms such as those reported in experiments on human heat tolerance. An ambient temperature of 41.1° C and 80% relative humidity the calculations predict
that a SAR of 1 W/kg would increase rectal temperature to 39.2°C in 60 minutes (Stolwijk, 1980).

Microwave exposure can produce a skin effect – the employee can literally sense their skin starting to heat up. RF radiation may penetrate the body and be absorbed in deep body organs without the skin effect. Without the skin heating up to warn the body of danger burns generally occur from the inside out allowing more damage to occur than with microwave exposure. Elder and Cahill (1984) determined that in the range of frequencies between 300kHZ and 300 GHz, cutaneous perception of heat and thermal pain may be an unreliable sensory mechanism for protection against potentially harmful RF radiation exposure levels. RF energy can be absorbed in tissue below the cutaneous thermal receptors and adverse effects occur at temperatures below the threshold of thermal pain (Elder, 1984). RF penetrates deeper than laser radiation, and can effect internal organs. Tissues such as blood, muscle, peripheral nerves, skin, and brain will absorb greater amounts of energy than fat and bone (Schilling, 1997). This causes the RF radiation to pass through the surface fatty tissue only to be deposited in the deeper tissues, such as muscle and brain (Schilling, 1997). Effects which are known to occur at thermal intensities include heat stress, depressed spermatogenesis, teratogenesis, increased heart rate, and ocular effects such as cataracts and damage to the endothelium layer of the cornea (WHO, 1989).

In a study in 1982 and one in 1984, a phenomenon called “RF sound” was discussed. This is also known as electrophonic effect (Scherer, 1994). The
earliest report of "RF sound" was in 1956 (Airborne, 1956). RF sound or hearing as it is often referred to occurs when the human head is exposed to pulsed radiation such as a radar. An audible sound, often described by those exposed as a click, chirp, buzz or knocking sensation is perceived by some workers. The sound appears to originate from within the head and varies with pulse duration and pulse reception (Chou, 1982, Elder, 1984 and Scherer, 1994).

Other principle effects which may be thermal but on a cellular level include but are not limited to thermorgulatory, reproductive effects, immunologic central nervous system, and behavioral changes. All have been shown in animal studies (Health Council, 1998).

Most thermoregulatory responses, such as peripheral vasodilation, evaporation, metabolism, and behavior have been recorded in laboratory animals exposed to RF radiation at normal room conditions of temperature, humidity, and airflow. Therefore it can be predicted that the threshold for effects due to RF heating are lower at ambient conditions that exacerbate thermal effects (Elder, 1984). Dose rates of 3.6-7 W/kg are lethal to rats, rabbits, dogs and rhesus monkeys exposed for 1-4 hours at ambient conditions due to heat stress from absorbed RF energy (Berman, 1985 and Lotz, 1985). RF radiation was determined to be teratogenic at exposure conditions that approached lethal levels for pregnant animal subjects (Berman, 1984).

Effects on the blood forming and immune systems have been documented at SARs greater than 0.4 W/kg; however, there is a lack of significant evidence for RF radiation effects on these systems without some type of thermal involvement.
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(Smialowicz, 1984). In addition, an association between RF-induced thermal loading or increased body temperature and changes in the blood, blood-forming and immune systems has been shown (Rudnev, 1985). Morphological alterations in the central nervous system can occur with acute or chronic continuous- or pulsed-wave irradiation of animals at SARs greater than 2 W/kg (Gage, 1984).

In general, behavioral studies have been done on rats with few on other animal species. Reductions in conditioned behavior were reported during exposure at a SAR of 2.5 W/kg (de Lorge, 1980) and such behavior stopped at a SAR of 10 W/kg (D’Andrea, 1976). Changes in locomotor behavior occurred after continuous-wave exposures at a SAR as low as 1.2 W/kg (D’Andrea, 1979). There are several more current studies that investigate the effects of a single episode of RF exposure on mice. Changes in cell proliferation (division) at SARs of 0.000021-0.0021 W/kg were noted (Kwee, 1997); decreases in reproductive functions in mice exposed to RF intensities of 160-1053 nW/square cm (SAR was not calculated) (Magnras, 1997); Phillips (1998) observed DNA damage at 0.024-0.0024 W/kg; and changes in eating and drinking habits were noted in rats exposed to 0.0317 W/kg (Ray, 1990).

Effects of low-level RF radiation, actual or alleged, involved temperature increase that is too small to measure, transient, or is too localized to distinguish. The significance of these effects on humans is a much-debated topic among scientists, public health officials, and the medical community. Current research is investigating synergistic effects that include cancer promotion (Slesin, 1997 and
Moulder, 1999). However, there are very few substantiated, published accounts of chronic exposure to RF radiation (Schilling, 1997 and Moulder, 1999).

Substantial agreement exists within the scientific community regarding thermal effects (Schilling, 1997, FCC, 2001, Health Council, 1998), and safety and health guidelines, standards, and recommendations are set based on these effects. Although thermal effects are the basis for current RF radiation exposure standards; scientific investigations during the 1980s have focused on effects of low-level exposure. Cancer, birth defects, and behavioral changes have been investigated using low-level RF radiation below MPE limits. These investigations include epidemiological studies, animal studies, and other research efforts (Havas, 2000). No conclusive evidence substantiates claims of low-level RF radiation effects (Jauchem, 1997). Some experts believe most non-thermal effects require much higher field levels compared to thermal heating effects (Schillings, 1997). Research in this area continues and must be monitored for any developing consensus. Considering this uncertainty, a precautionary approach seems appropriate until further research has been carried out.

Adverse health effects, such as cataracts and skin burns, tend to occur from RF exposure to RF emissions above 10 GHz, and power densities above 1000 W/m² (WHO, 1998). These densities are not found in normal daily life but they do exist in very close proximity to powerful radars and antennas. (WHO, 1998). Typically the employee that is exposed to levels of RF radiation between 30 MHz-300 MHz will develop symptoms that include headaches, dizziness, fatigue, and buzzing in the ears (WHO, 1989). Two employees employed by a
telecommunications company complained of headache and nausea after working around antennas on a cell tower approximately 185 feet off of the ground. Measurements done at the site 2 days later utilizing the NARDA Alert monitor showed no levels above acceptable MPEs. The treating physician based his diagnosis of RF exposure solely on subjective information by the employees (SpectraSite, 2001).

Frequency is addressed in the standards by use of time averaging based on frequency start. Duration of exposure is generally addressed in the standard such as lifetime exposure limits or hours per day. The consistent factor that is noted in all of the standards that are available for RF radiation is that the "endpoint is threshold acting and not cumulative, that no effects of long-term exposures have been identified" (Erdreich, 2001. p. 436).

Since the effects of non-ionizing radiation are not cumulative, when symptoms develop the worker should be removed from the RF source immediately. Treatment is aimed at focusing on alleviating the symptoms but recognizing that body effects may not be visible on the skin surface. There is no quantitative measure that can be done to diagnose RF exposure and it is therefore usually diagnosed based on the worker's subjective presentation of facts.
Applicable Standards and Guidelines

To be able to accurately evaluate and control a hazardous situation or source, benchmark standards must be in place. There are several of these that are used in relationship to RF exposure.

The National Environmental Policy Act of 1969 (NEPA) requires agencies of the Federal Government to evaluate the effects of their actions on the quality of the human environment. To meet these responsibilities under NEPA, the FCC adopted requirements for evaluating the environmental impact of its actions. The FCC licenses and approves equipment that generates RF and microwave radiation. The FCC is not focused primarily on health and safety and therefore relies heavily on other agencies and organizations to provide input on health and safety issues. These other agencies include the OSHA, ANSI, IEEE, and the National Council on Radiation Protection (NCRP).

In 1985, The FCC adopted the 1982 ANSI standards (ANSI C95.1-1982) for evaluating the effects of RF electromagnetic fields on the environment, noting that the ANSI standard was widely accepted and was both technically and scientifically supportable. ANSI adopted a new standard for RF exposure in 1992 (ANSI/IEEE C95.1-1992), that replaced the standard promulgated in 1982. The new standard was more restrictive in the amount of environmental RF exposure permitted.
The FCC issued *the Notice of proposed Rule Making*, on April 8, 1993, to consider amending and updating the methods and standards that were currently used by the FCC. The FCC suggested adopting the ANSI/IEEE C95.1-1992 standards over the 1982 standards. There were a large number of comments that were received from greater than 100 parties, which included comments from telecommunication organizations, other Federal Government agencies, both state and local authorities as well as individuals in response to the Notice.

Upon thorough evaluation of these comments the FCC adopted standards for evaluating the environmental effects of RF electromagnetic fields that are generally based on elements of the exposure criteria recommended by the NCRP, in the NCRP Report No. 86 as well as those contained in the ANSI/IEEE C95.1-1992 standard. Effective September 1, 2000, all facilities, operations and devices must comply with the FCC newly adopted RF exposure standards. The FCC environmental processing rules are contained in 46 CFR 1.1301 – 1.1319. It is imperative to remember that the FCC’s RF exposure standards constitute exposure limits, not emissions limits.

The FCC is not the only federal agency that is concerned with RF environments. The Occupational Safety and Health Act of 1970 provides job safety and health protection for employees by requiring employers to “assure, so far as possible, every working man and woman in the nation safe and healthful working conditions” as written in the general duty clause. Further there is an existing OSHA standard, 1910.97 which was promulgated in 1982 and had a technical amendment revision in May of 1996. This standard is very broad in
scope and has not been updated to incorporate the standards that have been recommended by ANSI/IEEE. It serves as a very basic guide to the employer's responsibilities on a federal level, but does not begin to let the employer know the specifics steps necessary to provide a safe and healthy work environment for their employees. The National Association of Tower Erectors (NATE), a non-profit trade association, is working with agencies such as OSHA and FCC to have input into revision and promulgation of standards related to RF emissions as well as providing members with uniform safety standards, improved communications and a unified voice helping to improve the future of the tower industry.

**Environmental Evaluations**

Environmental evaluation is the process of analyzing a communication site to determine whether or not, due to its operation, it could have a significant environmental effect. (47 CFR 1.1307).

The FCC requires that certain facilities and devices, owned and operated by FCC license holders, be evaluated to determine whether or not they would have a significant effect on the environment. To determine the environmental effect, the FCC states that a routing environmental evaluation is required. (FCC, 2001). This is also known as site mapping. The FCC environmental regulations related to RF exposure specify particular categories of existing and proposed transmitting facilities, operations and devices for which licensees or applicants are required to conduct site mapping.

FCC licensees are required to perform these evaluations when any of the following occur:
• filing for a new license or building a new site under a blanket area license,

• modifying an existing license, or

• renewing an existing license.

For example, a site mapping survey should be performed as part of the routine environmental evaluation to collect site data, which is required to perform predictions, or as part of the field measurements themselves. A site mapping survey of the communication site should start with a general discussion with site owner/manager to explain the process and purpose of the activity and to reveal potential RF exposure problems at a site that are not easily detected by visual inspections, measurements, or predictions alone. The survey form that is utilized should incorporate the following information:

• Basic site information (physical location, description, background information),

• Site owner information,

• Information regarding each tenant,

• Date and time of survey,

• Equipment description,

• Detailed antenna data,

• Antenna site diagram,

• Access and operational procedures,

• RF field measurements and information regarding the type of meters used to obtain the readings and their calibration information,
• Outline of existing RF exposures, and
• Current antenna site control procedures (lock out /tag out procedures, signage, PPE requirements, RF warning devices, RF safety training requirements etc.).

Recording spatially averaged RF field levels at predetermined or accessible areas at a site is known as field measurements. Field measurements assist in determining the RF levels at a site. All field measurements must be documented in a detailed site drawing, which is a required part of the site mapping survey.

There are both advantages and disadvantages in using field measurements. These measurements can be used to measure very complex antenna sites, such as antenna farms, (antenna farms are rooftops which have a multitude of different antenna types all on the same site), which would ultimately make accessing the antennas easier from a safety standpoint. These measurements can be used to measure RF fields in equipment areas, shelters and near guyed wire anchors as well as satisfy local zoning requirements. There is no required detailed site data or antenna data needed to perform field measurements. The field measurements can be used to measure areas at a site that cannot be predicted as well as reassure the public, site owners, and site managers of the safety at the site.

Field measurements can only be taken directly from the site, which can be expensive when including travel, time, and expenses associated with obtaining the measurements. Field measurements cannot be used to measure proposed installations or modifications. Another disadvantage is that these measurements
can be dangerous to obtain when taking vertical measurements on a tower. The equipment used to obtain these measurements is both expensive to purchase and to maintain. Lastly, the remaining disadvantage to obtaining and using field measurements is that contributor percentages (also known as the 5% rule) are an unknown factor, which can skew the measurements that are obtained. This will be addressed later in the paper.

Field measurements are part of the site mapping survey. On rooftops or other tall structures that house antennas, field measurements should be taken inside the radio equipment room, inside/on the structure on the highest area which is accessible by the public, at preset distances away from each existing antenna and at other various locations on the main rooftop or top of the structure. The field measurements for tower antenna sites should be taken inside the radio equipment shelter, on the rooftop of the equipment shelter if it is accessible, inside and outside of the fence surrounding the tower and any areas outside the fence where the general public commonly travels.

Once site mapping is completed then hazard mitigation and control can be initiated to provide a safe working environment.

**Hazard Mitigation and Control**

Hazard prevention and control methods are organized into a hierarchy to determine what should be done first in a specific occupational situation. The hierarchy controls, in the order that they should be considered and implemented for RF exposure are as follows: substitution, engineering controls, administrative
and work practice controls, and personal protective equipment (PPE) (Balge, 2000).

There is insufficient research to reflect utilization of hazard mitigation strategies specifically related to RF exposure. Therefore this section was developed based on applying basic principles of hazard mitigation as it relates to RF exposure and utilizing lecture data from competent individuals in the communications industry.

Once an area has been identified to have RF radiation hazards, compliance with or RF exposure mitigating action must be taken to control the hazard. The worker population that is at risk for the exposure must be identified so that strategies can be addressed to include them. Additionally, procedures must be developed and put into place to prevent future risk of exposure. Figure 4.1 was developed in conjunction with the work on the NC OSHA Tower Communication Standard to assist employers in educating themselves and their workforce. This document was developed to assist NC OSHA with implementing the Tower Communication Standard. It is a tangible tool for employers to give to workers regarding RF safety awareness and to be used as reference tool.

Substitution is at the pinnacle of hierarchy in control measures but is not applicable related to RF exposure due to the nature of the work. All antennas on cell towers and rooftops emit RF and therefore can potentially expose the workers so other mitigation strategies must be utilized.
Radio Frequency (RF) Exposure

What Happens to the Body?

The primary health effects are a result of the thermal response to radio frequency (RF) exposure. The absorption of RF varies with frequency. RF radiation may penetrate the body and be absorbed in deep body organs without affecting the skin surface.

Induced heating in body tissues may provoke various physiological and thermo-regulatory responses, including a decreased ability to perform mental or physical tasks as body temperature increase. Induced heating may affect the development of a fetus.

RF burns to the skin can also occur from coming into contact with antennas and other objects that are energized with significant power – an electrical arc will cause immediate burning at the point of contact. These burns are very uncomfortable and take a long time to heal because they occur from the inside out.

The human body is made up of ~97% water. RF emissions heat the water in the body and causes the “thermal” effects mentioned above.

What Should Be Done if Excessive RF Exposure Occurs?

- Remove the person from the source of the RF emissions.
- Move the person to a cool shaded area. Don’t leave the person alone.
- Loosen any heavy or outer clothing.
- Treat any side effect that occur such as headache and nausea
- Put ice or cold water on skin burns
- Remember that burns can occur deep in the body that may not be visible therefore observation may be necessary.

**NOTE: Workers Are At Increased Risk**

- When workers have a cardiac pacemaker or any other mechanical implant they must check with their primary physician and safety administrator before working in area where RF exposure is possible.
Figure 4.1-Educational Handout-Side B

Important Guidelines to Follow When Working Around RF Sources:

1. All workers must have RF awareness training before working around sources of RF emissions.
2. Only authorized workers may enter restricted zones where RF emissions are present.
3. Obey all posted signs.
4. Assume all antennas are active unless instructed otherwise.
5. Before working on antennas notify owners.
6. If you are working in an area where RF exposure is possible review the Standard Operating Procedure (SOP).
7. Never disable a transmitter without notifying the owner first – it may disrupt emergency services such as police and fire.
8. Do not stop in front of any antennas.
9. Keep at least 3 feet minimum from all antennas.
10. It is recommended that personal RF monitoring devices be worn when working near RF antennas.
11. Never operate transmitters without shields during normal operations.
12. It is recommended that base station antennas not be operated in equipment rooms.
13. When you begin to experience any symptoms of RF exposure leave the work area immediately and notify your supervisor.
14. According to federal regulations, the antennae licensee is held responsible for mapping information related to RF emissions. This information should be available to workers at their request.

Hazard Control

- Restrict access to area (General Population/Uncontrolled exposure are for people who have not been made fully aware of the potential for exposure or who cannot exercise control over their exposure. Occupational/controlled exposure is for workers who have been trained and are fully aware of possible exposure and have knowledge of control and protection measures.
- Verify that proper warning signs are posted.
- Map site of antennas and RF emission patterns and mark accordingly to determine hot spots.
- Follow all applicable standards: OSHA (1910.97); FCC MPE law; ANSI/IEEE C95.1-1992 field and current limit; as well as any other federal, state, and local applicable standards and guidelines.
- Antennae installation shall take into consideration future RF exposure and may result in the antennae being raised to accommodate this potential exposure.

Sources of RF

There is a broad spectrum of RF emissions and sources. This list is not all-inclusive but should give the worker an overall idea of where potential hot spots could be located.

LOW frequencies: <30 MHz
- AM broadcasting (1 MHz)
- Induction, heat sealers and diathermy (<30 MHz).

Human resonance range: 30-300 MHz
- FM broadcasting (~100 MHz)
- TV

HIGH frequencies: >300 MHz
- Microwave Ovens (~2450 MHz)
- Cell phones (860-900 MHz)
- PCS phones (1800-2200 MHz)
- 2-way radios (~850 MHz)

Maximum Permissible Exposure (MPE) time averages exposure

There are existing standards that specify how to calculate exposure limits. Here are 2 examples:

- controlled standards are based on 6 minute time averages
  (Can be exposed to 100% of the frequency maximum time of 6 minutes.)
- Exposure above limits for 6 minutes time averages allowed with the reduction of time exposed.
  (Can be exposure to 200% of the RF maximum time of 3 minutes)
The principles of engineering controls are to remove or eliminate the hazard and include enclosure, isolation, and ventilation. Engineering controls are implemented to be made part of process equipment, which would reduce the need for human intervention to assure safety. (Blage, 2000). Engineering controls, the preferred method for controlling RF exposure hazards, uses technological means to isolate, minimize or remove RF exposure hazards from the antenna site. Examples of this would be installing a fence around the tower site or raising an antenna and utilizing enclosures and shielding for coax cables and wave-guides (Curtis, 1995).

An antenna site can also be modified or altered as an engineering control. An example of this control would be the relocation of a RF exposure source. This can include raising an antenna higher on a rooftop or tower to reduce RF exposure or moving the antenna to an area that is more difficult to access (Curtis, 1995). Another engineering control includes powering down a RF exposure source when work is required in the area where RF exposure has been identified.

Administrative controls are utilized when the risk of RF exposure exists and cannot be reduced through engineering or work practice controls. Administrative controls means removing the worker from the hazard, either partially or totally, which reduces the risk to the workers. Administrative controls include scheduling maintenance and installations during off-peak hours when fewer transmissions are broadcasting to eliminate the amount of RF that is emitted. Adjusting work schedules and rotating inexperienced or new employees
to job sites and tasks that are free of RF fields. Site mapping is also considered an
administrative control (Motorola, 1996). Lock out / tag out procedures utilized on
transmitters before working on antennas is considered an administrative control as
well.

Training and education of the workforce is essential with regard to proper
use of hazard mitigation strategies and proper work practice procedures, which
will minimize the risk of exposure (Rogers, 1994). Training and education fall
under the administrative control heading.

Another form that can be utilized in performing routine environmental
evaluations is computer predictions. Sophisticated computer software is required
to analyze the contributions of all antennas at a site for each square foot of the tall
structure or vertical height of the tower, or ground around the base of a tower.
Detailed dimensional site parameters, antenna data, and equipment specifications
are input into the RF prediction computer model and a graphical output of the
MPE levels are displayed. If the computer prediction model indicates that the
MPE levels are exceeded than the model can be manipulated to demonstrate
corrective measures for RF compliance (Motorola, 1996).

RF warning devices can also be considered an administrative control. RF
warning devices are used to identify hazardous areas. These devices emit visual,
audible, or restraining mechanisms to alert employees of RF exposure areas. RF
warning devices must be placed at prominent locations at the antenna site and be
visible from all directions of approach. The devices should be attached securely
to the antenna site. Signs, barriers, sirens, flashing lights, and fences are examples of RF warning devices (Curtis, 1995).

Proper signage is also an administrative tool that should be utilized. There are three types of signs that are utilized based on the type of RF exposure hazard that has been identified. The NOTICE sign is utilized for areas that are accessible to the general public in an area that exceeds MPE limits. A CAUTION sign is appropriate when individuals may have access to areas in which the RF fields exceed the occupational MPE limits in controlled areas. The general public should not be allowed to pass this point. The WARNING sign should be utilized in areas that are close to RF sources when the RF exposure exceeds the MPE limits by 10 times (Curtis, 1995).

Finally, proper equipment maintenance is also considered an administrative control. It is essential that as part of the RF safety and health program, maintenance of the antenna site be done on a routine, scheduled basis. Maintenance should also include any existing equipment and equipment that is being installed so that any RF leaks can be determined due to defective radio cabinets, combiners, and cabling systems (Curtis, 1995).

Work practice controls are also focused on behavioral control, the behavior control of the employees in their performance of their normal job duties (Balge, 2000). Work practice controls reduce the likelihood of exposure to high RF fields by changing the way that a task is performed at an antenna site. Other key work practice controls that should be utilized are as follows:

- Do not operate the base station antennas in the radio equipment room,
• Do not stop in front of antennas,
• Maintain a minimum of 3 feet clearance from all antennas,
• Obey all posted safety and warning signs,
• Only authorized personnel should enter the site,
• All authorized personnel are required to complete RF radiation safety training,
• Always assume all antennas are operating,
• Before working on an antenna, notify owners and disable the appropriate transmitters,
• Use personnel RF monitors while working near antennas or in the radio equipment room, and
• Never operate transmitters without shields during normal operations.

It is strongly recommended that these work practice controls be placed on a sign at the access point to the site in a place that is highly visible to alert anyone entering the site that special precautions are required (Motorola, 1996).

Another control related to RF radiation exposure includes utilization of proper equipment to measure RF emissions. Proper equipment includes the use of personal monitors/meters and RF probes. The ‘shaped’ broadband probe measures a wide range of frequencies that are common at most antenna sites. The frequency range of a probe is usually between 300 kHz and 50 GHz. The meter must be utilized with the probe. The meter is a hand-held, battery operated device, which processes the information that is taken in by the probe, linked by a cable. The meter determines the level of RF radiation in the area that the reading
was obtained. This process involves sampling field strengths at different frequencies and normalizing them to a composite level performance. The meter’s output is reported as a percentage of the MPE limit. Most meters have advance options that include data storage, time and spatial averaging functions as well as built-in testing sources. The broadband probes and meters can cost around $3000 which can cause a significant financial impact to the employer who has several crews that are working at a multitude of antenna sites.

The final tier in the hierarchy of controls is personal protective equipment. PPE is the least desirable of the hierarchy of controls because it can be difficult to ensure proper fit, availability may be an issue, and consistent use can be problematic (Balge, 2000). If the hazard of RF is still present, then PPE is a choice of last resort for worker protection. Personal Protective Equipment (PPE) is also a control that works best in combination with other controls as described above. When PPE is utilized as a control there should be an action plan developed as part of management’s control of workplace hazards to work towards the 'top' of the hierarchy of controls to gradually eliminate or minimize workplace hazards and therefore meet the employer’s duty of care. PPE protects against but does not eliminate the risk or hazard and therefore when used by itself remains a high-risk control. Personal protective equipment should only be used for short term or emergency procedures or as additional protection when the other measures do not provide sufficient protection. The reason for this is that it is difficult to fully protect employees with protective equipment. These items, even
if fitted properly may be uncomfortable, restrict movement, and contribute to heat
stress.

PPE is specialized clothing or equipment that is worn or utilized by the
employee for protection from RF exposure. Proper selection and utilization of
PPE is essential to provide adequate protection and ensure the safety of the
employees. Employees must be trained in the proper selection, use, and
maintenance of PPE. Examples of PPE available for use for RF exposure are
personal RF monitors, suits, shoes, gloves, and eye protection.

There are a variety of models and types of personal RF monitors that are
available. Some monitors are set to alarm when they measure exposure that is
50% of the controlled MPE standards while other monitors allow their alarm
thresholds to be adjusted in the field. Personal monitors do not pick up RF
emissions from all directions as a broadband probe does; therefore, it is strongly
recommended that the employee wear the personal monitor between their body
and the emitters or RF radiation sources at the site. Personal monitors can be
costly (in excess of $1000) and also require yearly calibration.

A study conducted by Tell in 1995 for the FCC investigated the use of RF
personal monitors and RF protective clothing used for controlling exposure.
Results of the study raised questions as to the accuracy and reliability of induced
current meters under all conditions. The personal monitoring device appeared to
act as a reliable RF detector but had some deficiencies. If used properly, RF
protective clothing was judged to provide a significant reduction in whole-body
RF absorption.
Personal monitors are considered to be warning devices to alert the person wearing them by use of an audible alarm to the presence of RF fields that approach the MPE limits for occupational / controlled exposure. Devices such as these can be a reliable method of detecting RF fields but should only be viewed as a warning device due to deficiencies found in the Tell study (Tell, 1995).

RF protective clothing attenuates or decreases the amount of exposure that an employee receives (Adair, 2002). In most cases RF protective clothing can decrease the RF fields by a factor of 10. The use of RF protective suits should be considered that last resort for reducing or eliminating worker exposure to RF fields that exceed the occupational / controlled MPE limits. RF protective clothing is typically used when other hazard prevention controls are not feasible for the antenna site or until other controls can be implemented. It is essential to remember that PPE serves as a supplement to minimize the employees’ RF exposure, not as a primary source of controlling exposure. If used properly, RF protective clothing was determined to provide a significant reduction in whole-body RF absorption (Tell, 1995 and Motorola, 1996).

PPE in itself as the sole hazard control method can be expensive without having a well-planned and implemented control program in place. The primary goal of a hazard mitigation / control program is to limit or reduce the true exposure to the employees to acceptable or tolerable levels (Balge, 2000). Therefore much time and effort should be put into the upper level tiers of the hierarchy and PPE used as final method of control.
In a company with diverse operations it is likely that all forms of all the tiers of hierarchy will be utilized at some point. The process of hazard mitigation and control must be viewed as a continuous process and be evaluated for effectiveness. Processes change, equipment and workers age, new equipment, and PPE can change the work routine; therefore, continual re-evaluation is vital to provide a safe and health work environment.
CHAPTER V
Conclusions and Recommendations

Role of the Occupational Health Nurse

Effective occupational health nursing practice requires expertise in the occupation and environmental health sciences, knowledge of principles of business and management, and an understanding of regulatory processes (Salazar, 2001). Occupational health nurses (OHN) plan, implement, provide, and evaluate health care services to workers and worker populations by focusing on health promotion, “protection and restoration of workers’ health within the context of a safe and healthy work environment” (AAOHN, 1994). Therefore, the OHN employed in the telecommunications industry must look at the actual or potential RF hazard that effects the workforce of the employer. In order to be able to do this, the OHN must have a basic understanding of the concepts and principles associated with industrial hygiene, which include hazard recognition, evaluation, and control. This would be consistent with the scope of practice for an OHN to provide workplace surveillance and hazard detection (Rogers, 1994). In order to do this the OHN must be aware of existing regulations and legislation on all levels federal, local, and state to ensure that all requirements are being met and implemented appropriately. (Serocki, 1988).

Since there is no specified written standard protocol for worker protection in regards to RF exposure safety, the OHN must work with the appropriate interdisciplinary staff members to ensure that a well thought out, research based, education plan is put into place. An education plan for RF safety awareness should include relevant definition review, principles of RF exposure, sources of
RF exposure, safety precautions on all levels, and treatment for exposed employees. Collaborative practice with other professionals such as industrial hygienist, safety professionals, and risk managers enables the knowledge and skills of other professionals to work together to develop a comprehensive RF safety awareness program (Balge, 2000). Utilization of nursing principles, synthesized with the knowledge and skills of multiple disciplines will develop a thorough program to promote health and safety (Barlow, 1992).

Identifying and controlling hazards in any workplace is vital to providing a safe and healthy work environment as mandated by the general duty clause of the OSH Act of 1970. In order to accomplish this there must be a multidisciplinary collaboration between the OHN, industrial hygienists, safety and quality specialist, workers, and risk management professionals (Rogers, 1994).

When occupational health professionals identify workers in an at risk population because of actual or potential exposures in the work environment, they have an opportunity for intervention at the primary, secondary, or tertiary preventive levels (Chalupka, April, 2001). Primary prevention strategies would include risk assessment, policy development, education on awareness, counseling the workers with specific concerns related to the identified exposure, identifying the sources of exposure and possible routes of exposure as well as specific hazard mitigation measures. An example of primary prevention would be the OHN being aware of any worker that has an implanted electronic pacemaker or other medical device and defer them from working in areas where the risk of RF
exposure is high. Pacemakers are electronic devices and are susceptible to electromagnetic signals that could cause them to malfunction (FCC, 2001).

The next tier of intervention would be at the secondary prevention level. At this level the OHN must provide information to the workers regarding RF, exposure routes and pathways and potential health effects including immediate and delayed reactions as well as short term and long term effects. Since there is no specific test to measure levels of exposure there is no specific medical surveillance that would take place at this level. Occupational health nurses should advocate for any company policy and procedural changes at this level to improve the safety and health of workers when working around sources of RF.

Once a worker has been exposed there are tertiary prevention strategies that should occur. The OHN should direct the worker to appropriate medical care if needed as well as perform follow up if directed by the primary care provider. Tertiary prevention strategies must involve the encouragement of compliance with medical direction and facilitation of communication between the workers, the primary care provider and the employer, in addition to the workers' compensation carrier and case manager.

During the late 1990s and early 2000, there were multiple changes observed in the work environment and in work related hazards coupled with changes in the workforce. Directly related to these changes in the workplace work demands have changed. Workers are working longer hours, performing more work and performing unfamiliar work (Rogers, 2000). The increase in the demand for cell tower use and construction combined with the influx of antennas
on rooftops and other tall structures mandates that the occupational health nurse employed by a telecommunications company embrace the need for research in this area to develop her role in surveillance and education. Extensive literature review is necessary as well as keeping current with changes in relevant standards.

Occupational health nurses working in the telecommunications industry are poised to assume a leadership role regarding the topic of RF exposure and safety awareness due to the lack of information in literature currently. Sound epidemiological research is essential in identifying key risk factors for RF exposure and the long and short-term effects (Chalupka, March, 2001). North Carolina OSHA is in the process of promulgating a Tower Communication Standard which has a subpart that encompasses exposure to non-ionizing radiation which would be important knowledge for the OHN working in North Carolina. Since this standard is not fully developed it would provide an ideal opportunity for an OHN to contribute to state OSHA standards related to RF. Issues directly affecting the practice and performance of OHN’s are too important to leave to politicians and non-occupational health professionals. Political involvement is a mechanism to influence public policy and improve the practice of occupational health (Ennen, 2001).

The National Institute for Nursing Research sponsored the Environmental Health Sciences Working Group to identify critical gaps and research opportunities specifically related to environmental health. Key areas that were identified that are relevant to RF exposure are:
• Developing key surveillance methods to at risk populations for adverse health effects resulting from worksite radiation.

• Implement cohort studies to related health effects and exposure to environmental hazards.

• Examine ways to improve accuracy of subjective exposure data related to self-reporting due to the lack of measurable tests for exposure to some environmental hazards (Chalupka, April, 2001).

To meet this challenge head on, OHN’s have a significant opportunity to promote health and safety in the workplace through direct clinical services, education, advocacy, and research.

**Policy Guidelines**

The National Safety Council recommends the following elements as a standard for successful safety and health programs.

• Element 1: Hazard Recognition, evaluation and control. To establish and maintain safe and healthful working conditions it is imperative to identify and control hazards and plan action priorities. Examples of key points in this element would be controlling exposure time and distances between the RF source as well as lock out/tag out procedures.

• Element 2: Workplace design and engineering. It is both easier and more economical to address safety and health issues when processes and equipment are being designed. This would be helpful for the
telecommunications industry when installing new antennas to have this element in mind.

- **Element 3: Safety Performance Management.** Standards must be determined for safety performance. Job performance appraisals should also reflect employee and supervisor accountability for compliance.

- **Element 4: Regulatory Compliance Management.** This is where applicable federal and state standards would be referenced such as ANSI/IEEE, OSHA, and FCC.

- **Element 5: Occupational Health.** Occupational Health programs run the gamut from simple to complex but all focus on the needs of the workers. Medical surveillance programs would be addressed here as well as educational offerings to address worker safety and health. Educational offerings related to RF safety and health training would ensure that all employees understand the RF hazards to which they may be exposed and the means by which the hazards have been controlled.

- **Element 6: Information Collection.** Recordkeeping, industrial hygiene surveys, accident/incident investigations, and miscellaneous audits and health assessments would be incorporated in this element. Thorough analysis of this data would help in evaluating current programs and identifying needs for future programs.

- **Element 7: Employee Involvement.** It is imperative that employees have buy in and an understanding of the relevance of the safety
procedures that they are performing. Once employees become active participants in the area of safety and health they can offer insight into the needs of the workers and offer valuable input into the procedures. Employees can participate in tailgate meetings to review the hazards of RF as well as perform safety audits and participate on the safety committee.

- **Element 8: Motivation, Behavior and Attitudes.** Behavior based actions often lead to accidents or mishaps; therefore, it is necessary to focus on behavior changes and employee motivation to follow policy and procedures related to health and safety. Three motivational techniques that could help in this element are communications, incentives/award/recognition, and employee surveys.

- **Element 9: Training and Education.** All employees must have training about what is expected of them and what the hazards are at the job site. The employees must also have training on policies and procedures so that they can perform them safely and efficiently. Training and education programs must include hazard recognition, regulatory compliance, and prevention strategies. These should be reviewed annually.

- **Element 10: Organizational Communications.** It is essential to keep all employees current about policies, procedures, goals, and progress. Communication should be effective and encourage exchange of ideas and comments between management and employees.
• Element 11: Management and Control of External Exposures. Contingency planning is critical to anticipate disasters, contractor activities, and other liability exposures that may effect the employees’ safety and well being.

• Element 12: Environmental Management. Environmental issues can be addressed with safety and health issues to provide overall coverage. Aggressive environmental management would incorporate pollution prevention and other actions related to environmental improvement.

• Element 13: Workplace Planning and Staffing. Issues such as work safety rules, employee assistance programs (EAP) and any requirements that stem from the Americans with Disabilities Act would be addressed in this area. In regards to RF exposure it would be important to be aware if a worker had a cardiac pacemaker as exposure to RF radiation could affect the ability of that device to work properly, therefore the employer would need to make sure that the employee was adequately protected.

• Element 14: Assessments, Audits, and Evaluations. Tools such as these are necessary to measure success, monitor conditions, monitor compliance, and assess progress. There are numerous tools and resources that could be utilized to achieve this element including external resources such as OSHA and internal resources such as safety auditors. (National Safety Council, 1994). This would include RF
hazard identification and periodic surveillance by a competent person who can effectively assess RF exposures.

Telecommunication companies should have specific safety and health programs and procedures that address all relevant safety and health issues. RF safety and health programs should include the above 14 elements to provide a safe and health work environment for their workers. This would include addressing both potential and actual exposure risks and targeting the population at risk for exposure. Management leadership partnered with employee participation will ensure successful implementation of these programs. All programs must have continuous quality improvement to measure outcomes and address areas that need improvement and additional attention.

**Discussion and Conclusions**

Federal and state agencies must keep current with changes in all industries to be able to lead employers in providing a safe and healthful work environment. ANSI and IEEE are continuing to revisit the standards that were established for exposure to RF radiation but other federal agencies have not revised their standards to reflect the new knowledge provided by scientist and researchers. North Carolina’s state OSHA program is attempting to create a new standard specific to the telecommunications industry that will incorporate the most current standards that were previously discussed. The goal of NC OSHA is that once they have received state approval, federal OSHA will adopt the state standard and make it uniform across the United States.
However, based on current guidelines, standards, and recommendations that are readily available, most exposure to RF radiation can be managed utilizing the appropriate hierarchy of controls and training the workforce to protect those who may come into contact with RF radiation. It is imperative that employers are aware of not only the guidelines, standards, and recommendations that are available and hazard mitigation options but also be aware of current research to be abreast of changes in the telecommunications industry as well as synthesizing the available information. It would benefit companies that are managing antennas on rooftops and other tall structures to educate the building/structure owners on RF safety awareness. This education would serve to protect other workers such as air conditioning repairmen and roofers, about the precautions needed when working around antennas and other RF sources.

Research definitely must continue in this area to better determine consensus agreement on the description of short-term exposure effects on humans and to document any long-term exposure effects as well. There is currently a feasibility study that commenced in November 1998 to ascertain the feasibility of undertaking an epidemiological investigation into workers exposed to RF, in response to the increasing concern regarding a possible link between RF exposure and health effects. The study aims to quantify personal exposure to RF in a wide range of different working conditions, at the same time determinants of exposure will be investigated using information on work characteristics obtained through observations or with diaries. This information will then be used to estimate levels of exposure of all employees within the cohort, based upon information regarding
their working practices. The final report for this study will be presented in November 2002 (Institute, 2002).

Occupational health nurses can take this opportunity to partner with groups like NC OSHA to assist in the development of standards to make sure that expectations of medical surveillance and education are met. OHN’s can also partner with other federal and state agencies to participate in developing standard medical surveillance and education programs as well as standards to address the needs of employees working in the telecommunications industry.
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OSHA Regulation Standards


• 29 CFR 1926.54(l), Construction. Limits worker exposure to 10 mW/sq.cm. for construction work (including the painting of towers).

• 47 CFR 1.1307


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