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Base Level Management of Radio Frequency Radiation Protection Program

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I. INTRODUCTION

A. The purpose of this report is to assist the base level aerospace medical team (i.e., Bioenvironmental Engineering Service (BES), Environmental Health Service (EHS), flight surgeon, occupational medicine consultants, etc.) manage their Radio Frequency Radiation (RFR) Protection Programs. In the original version of this guidebook, the authors attempted to compile a booklet that was not written in stuffy regulatory dialogue; they provided BEEs with most of the technical and practical information necessary to implement their programs. In the second edition, our intent is the same, with addition of new information based on questions and comments from the field and our experiences over the past eight years.

B. In contrast to the first guidebook, this edition includes more detailed information and less reference to other sources. With this basic approach, however, we do not intend to duplicate the information in Air Force Occupational Safety and Health Standard 161-9 (AFOSH Std 161-9), "Exposure To Radiofrequency Radiation," 12 Feb 87; this guidebook should be used in conjunction with AFOSH Std 161-9.

C. This report incorporates information already published in AFOEHL Reports. For example, we have expanded the section on the biological effects of RFR by inclusion of information from USAFOEHL Report 86-020C0111BRA, "Assessing Possible Damage Due to Radio Frequency Radiation," author: Col Bruce J. Poitrast and T.O. 31Z-10-4, "Electromagnetic Radiation Hazards." A great deal of the information for this report was taken directly from its predecessor.

D. Appendix C of this report contains updated emitter information based on reports compiled by AFOEHL, 1839 Engineering Installation Group at Keesler AFB, 485 Engineering Installation Group at Griffiss AFB, Engineering Installation Division at Oklahoma AFS, the 1843 Engineering Installation Group at Hickam AFB HI, and 7100 Combat Support Wing Medical Center at Lindsey AS Germany. In this appendix, we provide a cross-reference between report number and the surveyed emitter nomenclature.

E. Most important, this report addresses changes to the AFOSH Std 161-9. Specifically, there were major changes made to Permissible Exposure Levels (PELs) in the 1984 revision and changes in overexposure investigation procedures made in the 1987 revision.

II. RFR IN THE AIR FORCE

A. The Problem As We See It.

1. The USAF probably makes more extensive use of RFR than any other organization in the world. Devices that emit RFR are an essential part of our "fly and fight" mission. They allow us to predict the weather, "see" and confuse the enemy, control our aircraft, and communicate. Emitters are found in hospitals, on hilltops, on flight lines, in maintenance workplaces, on roofs, in kitchens, in offices, etc.

2. For many Air Force personnel, some exposure to RFR is "just part of the job"; for others, exposures are very rare. It is true almost all routine exposures today are at very low levels, with power densities much less than 1 mW/cm^2. But levels as high as 100 mW/cm^2 can be found in some areas. AFOSH Std 161-9 specifies occupational limits for RFR above which workers may not be exposed.

3. RFR is often hard to deal with because it is deceptive. Antennas of varying size and shape hide behind radomes with emissions normally undetectable to the senses. Large antenna structures are often relatively harmless, while smaller antennas may create significant hazards. Many factors can alter the power density produced by an emitter. It is often difficult to accurately predict the location of a hazard unless the surveyor understands the terrain surrounding the site, operational use of the device, accessibility of personnel, and the operational parameters of the system.

4. But even with the complexities of RFR, the possibility of exposure to excessive levels of RFR need not be a major concern. In most cases, the means of adequate protection are quite simple. This is where the BEE and staff enter the picture.

B. The BES Role.

1. The base bioenvironmental engineer and technicians are charged with conducting an RFR protection program as specified in AFOSH Std 161-9; basically a safety and health effort that identifies and controls all areas where the potential for exposures to RFR above the Permissible Exposure Limits (PELs) exist. The nuts and bolts of the program are straightforward:

a. Compile an inventory of emitters.

b. Determine which emitters require a site inspection survey.

c. Determine which emitters require a measurement survey.

d. Evaluate present measures and recommend other control measures based on emitter characteristics and survey data.

e. Periodically visit each workplace to verify implementation of control measures and note changes that will impact required control measures.

2. Unfortunately, the program usually stops here. No matter how complete your inventory is, how dedicated you are to your survey plan, how much you conclude and recommend, the RFR protection program will not be effective unless you take the time to be an <u>educator</u>. Based on AFOEHL evaluation of suspected overexposure investigation reports, the major reason for the rising number of suspected overexposure incidents within the Air Force is <u>lack of training</u>, rather than lack of survey. Insufficient RFR safety education produces workers that are poorly informed on the "real" hazards of RFR. The unfortunate results are anxiety, fear of the unknown, lost productivity, and possible physical injury.

3. While the principle tasking rests with the EHS, RFR hazard education should be a joint effort between unit radiation protection officers, EHS, and BES. While the effort may be time consuming, the payoff is a successful and effective RFR protection program.

III. UNDERSTANDING RADIO FREQUENCY RADIATION

A. The Electromagnetic Spectrum.

1. General. The known spectrum of electromagnetic (EM) waves covers a wide range of frequencies including AM, FM, TV signals, radar, as well as x-rays, gamma rays, and visible light. Figure 1 shows the EM spectrum.

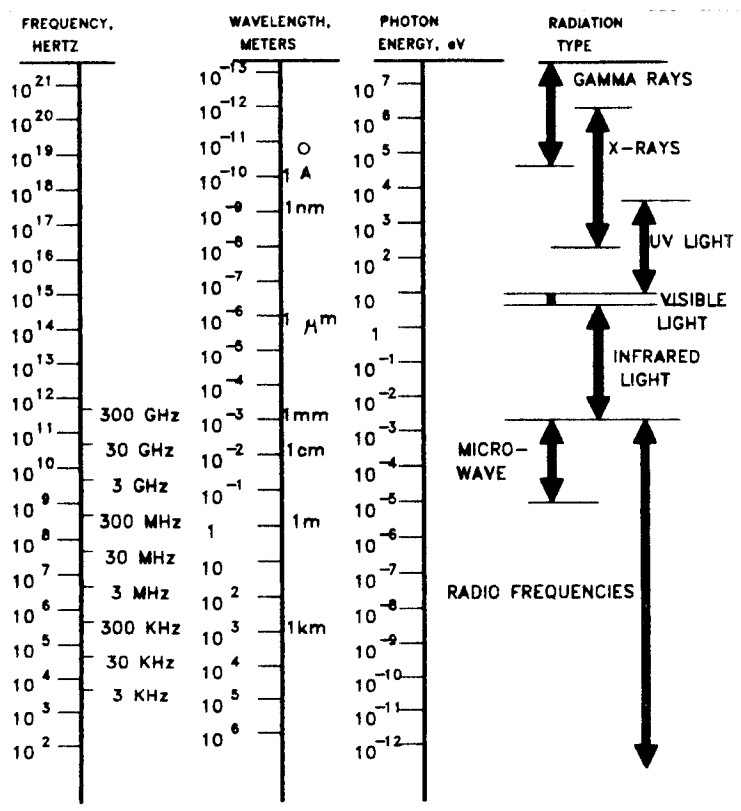


Figure 1: The Electromagnetic Spectrum

All types of EM waves travel at the speed of light (3×10^8 meter/second in free space). Wavelength and frequency of any wave are related by Equation 1:

$$\lambda = c / f, \tag{1}$$

where λ is the wavelength, f is the frequency in hertz, and c is the speed of light, 3×10^8 meters/second. For example, if a RFR source emits at 100 MHz, the wavelength of the emission would be 3 meters. See Appendix I, Example 2, for another example of the use of Equation 1.

2. Radio Frequency Radiation (RFR). RFR is just a part of the EM spectrum that extends in frequency from 10 kilohertz to 300 gigahertz. Table 1 defines the radio frequency bands. Unlike x- and gamma radiation, RFR is nonionizing. The energy of any photon is insufficient to dislodge orbital electrons and produce ion pairs. This important distinction is not well understood by many people who equate all types of "radiation." Biologically, the effects of ionizing and nonionizing radiation are totally different.

Table 1: Radio Frequency Bands

Band	Description	Frequency
ELF	Extremely Low Frequencies	30 - 300 Hz
VF	Voice Frequencies	0.3 - 3 kHz
VLF	Very Low Frequencies	3 - 30 kHz
LF	Low Frequencies	30 - 300 kHz
MF	Medium Frequencies	0.3 - 3 MHz
HF	High Frequencies	3 - 30 MHz
VHF	Very High Frequencies	30 - 300 MHz
UHF	Ultra High Frequencies	0.3 - 3 GHz
SHF	Super High Frequencies	3 - 30 GHz
EHF	Extremely High Frequencies	30 - 300 GHz

3. Electromagnetic Radiation Propagation. Electromagnetic energy is propagated through space in the form of waves composed of mutually supporting electric ("E") and magnetic ("H") fields. These two fields vary together in intensity, but their directions are at right angles to each other in space, and both are at right angles to the direction of propagation. Figure 2 depicts this relationship.

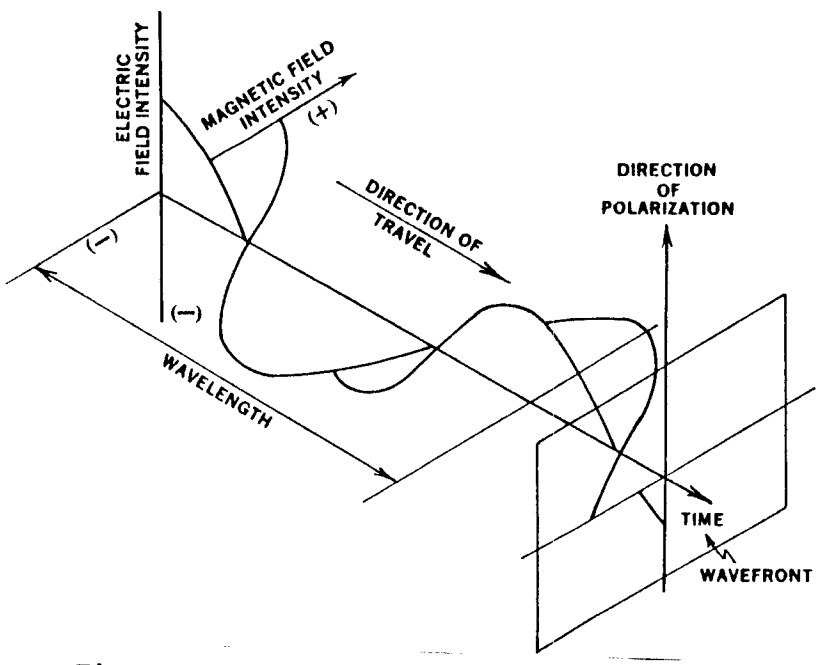


Figure 2: Electromagnetic Radiation Wave

4. More in-depth details about electromagnetic radiation can be found in T.O. 31Z-10-4 and AFOSH Std 161-9.

B. Emitters.

1. General. All RFR emitters have three basic components: a transmitter, a transmission line, and an antenna. Some confusion about RFR is rooted in misunderstanding this basic concept. Figure 3 illustrates the basic RFR emitter configuration.

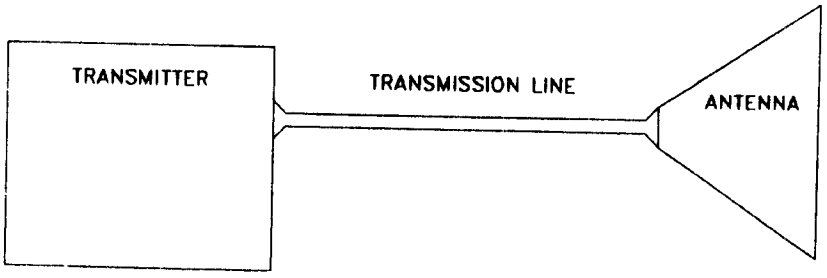


Figure 3: Basic RFR Emitter

2. Categories by Application. RFR emitters have a broad array of uses. All of the emitters you encounter on your base should fit into one of these categories.

a. Communications.

(1) Fixed. Radio communications between specified fixed points. Examples: Military Affiliated Radio System (MARS), point-to-point microwave links.

(2) Airborne. Radio communications between land station and an aircraft ("ground-to-air" or "air-to-ground") or between aircraft ("air-to-air").

(3) Land mobile. Radio communications between a base station and a mobile station or between land mobile stations. Examples: intrabase ("non-tactical") systems such as police, fire or hospital nets; tactical radios; "CB" radios.

(4) Space. Communications between land station or aircraft and spacecraft.

(5) Broadcast. Radio communication intended for direct reception by the general public. Examples: AM and FM radio, television.

b. Navigation.

(1) Fixed. Land based systems designed to provide navigational aid (distance and/or bearing) directly to indicators aboard aircraft or on the ground. Examples: VOR, TACAN, radio beacons, instrument landing systems (ILS).

(2) Airborne. Systems aboard aircraft designed to provide navigational information from the aircraft point of reference. Examples: radar altimeters, Doppler radar, terrain following radar.

c. Radar (RAdio Detection And Ranging).

(1) Fixed. Land based systems designed to detect and indicate the position of weather disturbances, aircraft, spacecraft, etc. Examples: search radar, tracking radar, height-finding radar.

(2) Airborne. Aircraft systems designed to detect and indicate the position of obstructions, weather disturbances, other aircraft, etc. Examples: fire control radar, side looking radar, tracking radar, mapping radar.

(3) Table 2 denotes the common letter designations for microwave radar bands as specified by the International Telecommunication Union. The designations are for Region II: North and South America.

Table 2: Radar Band Designations

Band	Frequency (MHz)
P	225 - 390
L	390 - 1550
S	1550 - 5200
C	3900 - 6200*
X	5200 - 10900*
K	10900 - 36000
Q	36000 - 46000
V	46000 - 56000
W	56000 - 100000

* There may be some overlap between adjacent bands.

d. Electromagnetic Countermeasures (ECM). Land-based or airborne RFR systems designed to emit signals that disrupt the effective use of a portion of the electromagnetic spectrum. Examples: communications jammers, radar jammers. Table 3 denotes the common ECM band designations.

e. Industrial/Commercial. RFR systems designed to perform a heating function for industrial applications. Examples: RFR heat sealers, microwave ovens.

f. Medical. Systems that utilize the thermal effects of RFR energy for medical applications. Examples: diathermy, cauterization, hyperthermia.

Table 3: ECM Band Designations

Band	Frequency (MHz)
A	0 - 250
B	250 - 500
C	500 - 1000
D	1000 - 2000
E	2000 - 3000
F	3000 - 4000
G	4000 - 6000
H	6000 - 8000
I	8000 - 10000
J	10000 - 20000
K	20000 - 40000
L	40000 - 60000
M	60000 - 100000

3. Transmitters.

a. General. The transmitter is one of the basic elements of the RFR emitter. The primary function of the transmitter is to generate a RFR signal. Figure 4 depicts the basic transmitter configuration.

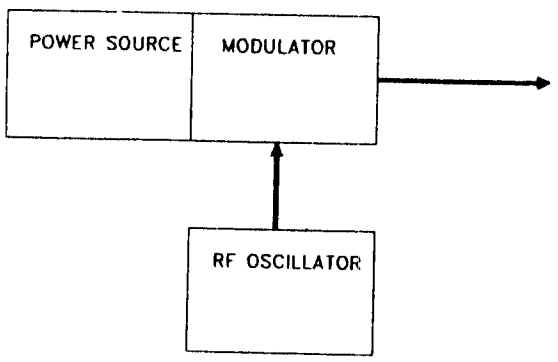


Figure 4: Basic Transmitter Configuration

b. Transmitter Types. There is a vast array of different transmitters in the Air Force. Low power hand-held or transportable transmitters can implement solid state amplifiers like common silicon transistors, IMPATT diodes, or GaAs Field Effect Transistors. Power output from these devices is typically one to ten watts. Other devices that require high power sources may contain magnetron oscillators, crossed-field amplifiers, klystrons, traveling-wave tube amplifiers, twystron amplifiers, gyrotron amplifiers, electron tubes, etc. These devices typically are found in high power radar and communication systems. On the other hand, high power radar can be powered by many

low power transmitters. The PAVE PAWS phased-array radar uses 3,584 transistor modules that individually have a power output of only 440 watts.

c. Transmitter Characteristics. Transmitter specifications can often be very complex. Often when the BEE or one of his/her technicians attempt to acquire parameters from system operators, they are overwhelmed by a lot of complex and sometimes useless (from the BEE's standpoint!) information. It is your job to weed through this information and find the useful information. Concerning transmitters, the following parameters are needed:

(1) Power. The power rating of a transmitter is necessary to evaluate a RFR system. All emitters transmit either a continuous wave (CW) or a pulsed waveform. Pulsed simply means that the transmitter is not continuously energized. For systems that provide CW RFR transmissions, power is specified as average power. For pulsed systems, most commonly radar, transmitter power is usually expressed as a peak power. The average power (P_{av}) of a pulsed system can be calculated by multiplying the peak power (P_{peak}) by the duty factor (DF). The duty factor, also called duty cycle or duty ratio is a product of pulse width (PW) and pulse repetition frequency (PRF). Equations 2 and 3 describe this relationship, while Figure 5 depicts a typical pulsed transmission. Example 1 of Appendix I provides examples of the use of these two equations.

$$P_{av} = P_{peak} \times DF \tag{2}$$

$$DF = PW \times PRF \tag{3}$$

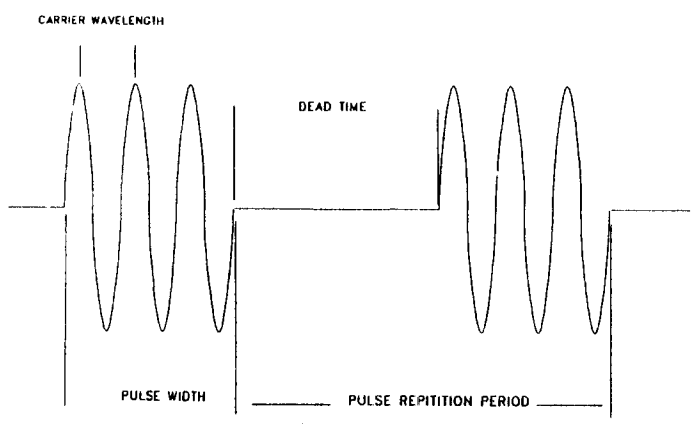


Figure 5: Typical Pulsed Transmission

Transmitter power ratings can be specified in many units. Usually they are specified in watts (W) or kilowatts (kW), but commonly, radio engineers use the unit of dBm: power output relative to 1 milliwatt (mW), i.e., 1 mW is equivalent to 0 dBm. For example, a transmitter with an output power of 50 dBm has an equivalent output power of 100 W. Equations 4 and 5 describe this relationship. Also, Appendix A provides tables to convert these units.

$$P(dBm) = 10\log_{10}[P(mW)] \tag{4}$$

$$P(mW) = \log^{-1}[P(dBm)/10] \tag{5}$$

(2) Frequency. The operating frequency of the transmitter is necessary to evaluate the RFR emitter. Most systems have their operating frequency specified in megahertz (MHz). Some systems operate at a discreet frequency, while others may operate across a continuous range of frequencies. Still, other emitters may operate at a number of discreet frequencies or discreet frequency bands. Confusing the operating frequency of the system with the pulse repetition frequency of a pulsed system or the bandwidth specification is a common error made by people evaluating an emitter. Both of these parameters will always be less than the system operating frequency. Determining the range of frequency operation is important in the evaluation and survey of an emitter; for some emitters, especially HF, the PEL and antenna gain can vary drastically across the operating frequency range. Often it is necessary to evaluate and measure an emitter at several discreet frequencies.

(3) Modulation. Modulation is the process where certain characteristics of the RFR wave (also called the carrier) are varied in accordance with the message signal. Modulation can be divided into continuous modulation where the modulated signal is always present and pulse modulation where no signal is present between pulses.

(a) Continuous Modulation. Communications systems like AM and FM radio, TV, police and fire nets, and CB radios use this type of modulated signal. Although there are numerous forms of continuous modulation, we will examine a few of the more common ones.

1 Amplitude Modulation. In amplitude modulation, the carrier wave frequency remains unchanged while its amplitude is varied according to the modulating (message) signal. Three of the most common types of amplitude modulation are double sideband (DSB), conventional amplitude modulation (AM), and single sideband (SSB). Figures 6 and 7 depict a representative carrier and message signal respectively, while Figure 8 shows a resulting conventional amplitude modulated output signal.

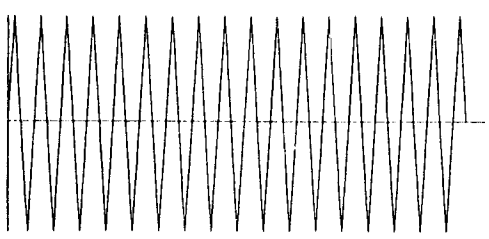


Figure 6: Representative Carrier Signal

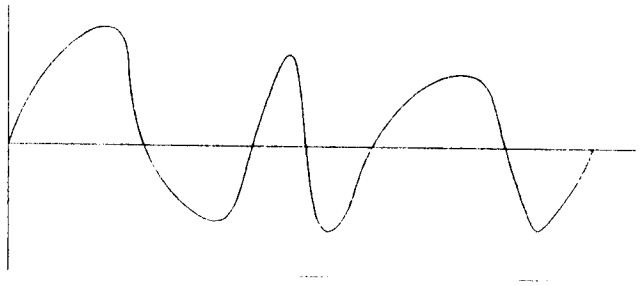


Figure 7: Representative Message Signal

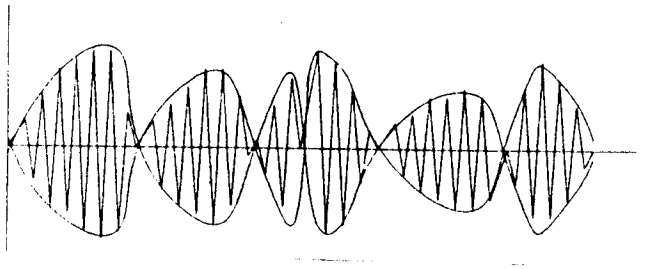


Figure 8: Conventional Amplitude Modulated Output Signal

a While performance characteristic differences between these types of amplitude modulation are important to the radio engineer, from a safety viewpoint, we are concerned with the difference between peak envelope power and the average power of a signal modulated by a voice or a tone (such as a telegraph transmission). Generally, SSB transmissions will have an average power approximately equal to ten percent of the peak envelope power.

b Additionally, it is common for amplitude modulated signals to have a suppressed carrier in the case of single and double sideband systems. For systems with a suppressed carrier, there is a zero output power during non-transmission times.

c A third factor that can influence the average power output of an emitter is keying. Some transmitters (such as hand-held radios) are voice-keyed or manually-keyed and produce a power output only when they are keyed. Other emitters (such as satellite terminals or telemetry units) employ continuous keying. Generally, these emitters carry telegraphy or electronic control signals which require no receive time, or they receive on a different frequency than they transmit. Continuously keyed transmitters usually produce a power output all of the time.

2 Frequency Modulation (FM). In frequency modulation, the carrier wave amplitude remains unchanged while the carrier frequency varies in accordance with the message signal. Figure 9 depicts a representative FM signal.

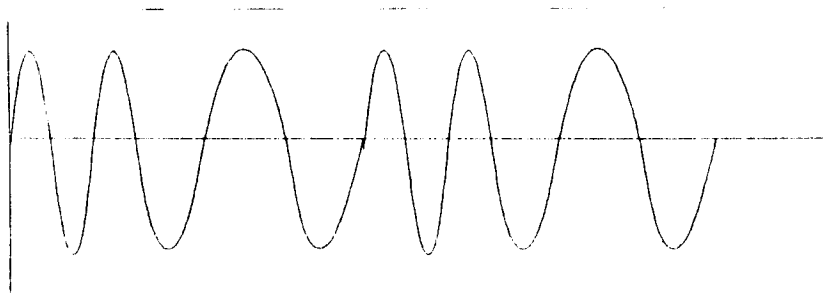


Figure 9: Frequency Modulated Signal

(b) Pulse Modulation. In pulse modulation, the unmodulated carrier is usually a series of regularly recurrent pulses. Information is conveyed by modulating some aspect of the pulse, e.g., amplitude or duration (pulse width). Figure 10 shows a pulse-amplitude modulated signal.

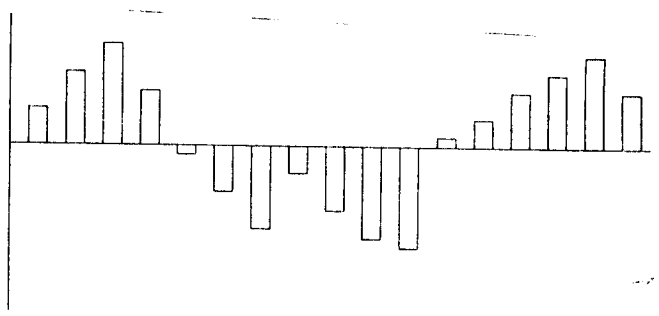


Figure 10: Pulse Modulated Signal

4. Transmission Lines.

a. General. As shown in Figure 3, the transmission line is a critical element in a RFR emitter, providing a link from the transmitter to the antenna.

b. Types. There are two types of transmission lines: one conductor and two conductor. A one conductor transmission guide propagates RFR through a hollow tube called a waveguide. Waveguides can have many shapes: rectangular, circular, square, etc. Waveguides are used to transmit RFR at microwave frequencies. There are numerous types of two conductor transmission lines, the most common being single coaxial line and parallel wires. Two conductor lines are more commonly encountered in lower frequency systems (operating below 1 GHz).

c. Losses. All waveguides and transmission lines have power losses. Power losses are mostly attributed to the production of heat in the conductor, however, a certain amount of energy can actually be leaked as RFR by the transmission line. Power losses are normally expressed in dBs; Appendix A again can be used to convert between dB and absolute units.

d. Transmission Line Antennas and Their Hazards. As noted above, transmission lines propagate RFR like an antenna. In close proximity of transmission lines RFR hazards can exist. While these hazards are system unique and dependent on transmitted power, transmission line construction, etc., the phenomena is more common in HF and UHF systems.

e. Leaky or broken waveguides can also propagate RFR like an antenna. There have been a number of overexposure investigations from leaky or broken waveguides. The size of a waveguide break is the most important factor in determining its ability to behave as an antenna. For example, if the largest dimension of the break is smaller than one-half the system wavelength, the break will not effectively emit RFR. On the other hand, if the break's greatest dimension is greater than one-half the system wavelength, the break could effectively emit RFR. Power densities from a waveguide break can be estimated using a horizontal dipole antenna model (See Table 4 of this report).

5. Antennas.

a. General. The antenna is a basic component of any RFR system. The antenna is the connecting link between free space and the transmitter. Its design is largely dependent on the intended use of the system in question. In many systems used for navigation or direction-finding, the operational characteristics of the system are designed around the directive properties of the antenna. In other systems, the antenna may be used simply to radiate energy in all directions to provide broadcast coverage.

b. Antenna Properties. Regardless of the systems application all antennas have basic properties that can be well defined. Of these, gain, size, accessibility, and radiation pattern are of principle interest in evaluating radiation hazards.

(1) Gain.

(a) The <u>gain</u> or <u>directivity</u> of an antenna is the measure of its ability to concentrate its energy in a certain direction. Directivity is closely related to the radiation pattern of an antenna. To understand antenna gain, first, picture an isotropic emitter: a hypothetical RFR source that radiates evenly in all directions from a point in space. Figure 11 shows an isotropic emitter.

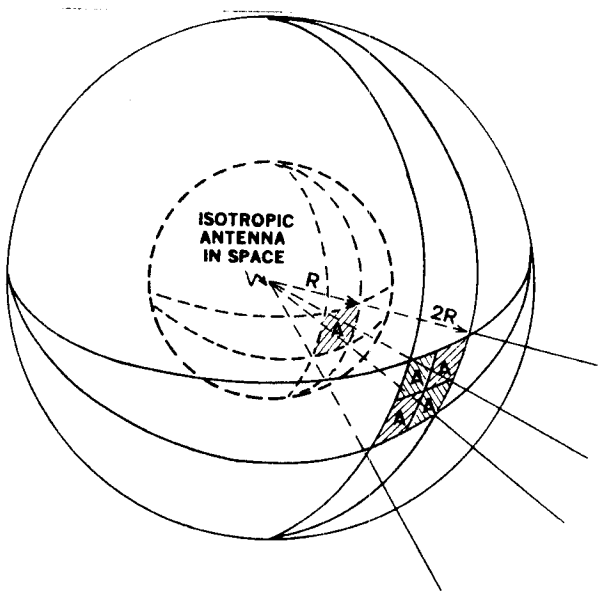


Figure 11: Isotropic Emitter

Next, imagine the addition of an antenna that emits the same total amount of energy, but redirects that energy into half as much area. The gain of this antenna is 2, because the energy in the direction of maximum radiation is doubled. Another antenna that uniformly directs the energy into a quarter of the area has a gain of 4, and so on. Gain, then, is the ratio of the maximum radiation intensity in a given direction to the intensity produced by an imaginary isotropic emitter. Antenna power gain can be expressed as a unitless number (absolute gain, G_{abs}) or, more, commonly in decibels (dB). The "i" term is often added to dB when discussing the gain of an antenna with respect to that of an isotropic antenna. Equations 6 and 7 describe this relationship and Appendix A provides tables to convert these units. See Appendix I, Example 1, for an example of Equation 7 in use.

$$\text{Gain (dBi)} = 10 \log_{10}[G_{abs}] \tag{6}$$

$$G_{abs} = \log^{-1}[\text{Gain (dBi)}/10] \tag{7}$$

(b) There are practical limits on antenna gain. The previously discussed isotropic emitter is purely hypothetical; in practice it is impossible to construct an isotropic emitter. As a result, it is theoretically impossible for a radiating antenna to have a gain of 1 dBi or less. However, maintenance personnel may erroneously claim that the gain of an antenna is less than 1, often zero. Some common reasons for incorrect gain specification are:

1 The specified gain may include transmission line losses.

2 Maintenance personnel may be confusing antenna gain (power density gain resulting from spatial concentration of energy, in dBi) with electronic gain (power gain created by electronic amplifiers, in dB).

3 The emitter may be dummy loaded, in which case the antenna gain is undefined, but may be specified as zero.

Practically, the range of antenna gains is from 2.0 dBi for a dipole, to 70 dBi for a pencil beam aperture antenna.

(2) Antenna Regions. The field radiated from an antenna varies greatly in structure depending on the distance from the antenna. In this section, we will introduce three regions around an antenna: the far-field, near-field, and transition region. Knowledge of the three regions is necessary to predict radiation field power densities and determine limitations in making field measurements. Although these three regions exist around all types of antennas, we will use an aperture antenna as an example. Figure 12 provides a two-dimensional graphic representation of the three regions using an aperture antenna.

(a) Far-Field (Fraunhofer Region). At large distances from an antenna, the propagated RFR field, as observed from any given point, takes on the appearance of a uniform plane wave. Under these conditions, the electric field and magnetic field are perpendicular to each other, and both are perpendicular to the direction of wave propagation as shown in Figure 13.

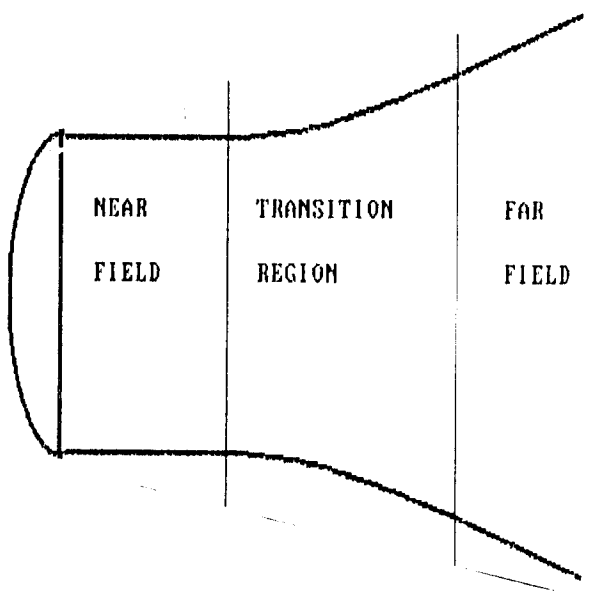


Figure 12: Antenna Regions

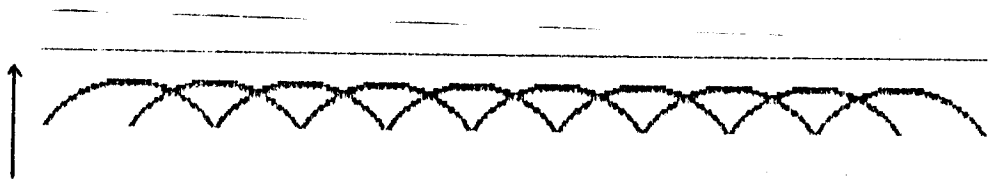


Figure 13: Uniform Plane Wave

In the far-field, both the electric and magnetic field are completely transverse to the direction of propagation and the magnitude of the electric field (E) and magnetic field (H) can be related as in Equation 8:

$$Z = E(V/m) \ / \ H(A/m), \tag{8}$$

where Z is the free space impedance of 377 Ω.

1 Power Density. Maximum power density at a given distance from an antenna is easily calculated with Equation 9: the Far-Field Equation.

$$\text{Power Density } (mW/cm^2) = \frac{P_{av}(\text{Watts}) \times G_{abs}}{40 \times \pi \times [D(\text{meters})]^2}, \tag{9}$$

where D is the distance from the antenna. Simply put, the power density is inversely proportionate with the distance from the antenna squared. This relationship holds true for all types of antennas. By rearranging Equation 9, we can solve the equation for D and thereby determine the distance from an antenna where the power density equals that of the PEL. An example of Equation 10 in use is provided in Appendix I, Example 1.

$$D \ (\text{meters}) = \sqrt{\frac{P_{av}(\text{Watts}) \times G_{abs}}{40 \times \pi \times PEL(mW/cm^2)}} \tag{10}$$

2 Boundary Definition. There are no distinct lines separating the three antenna regions, to some extent assignment of the far-field region boundary is arbitrary. There are numerous techniques used to define this region implementing evaluation of amplitude errors, phase errors, and comparison of the transverse and radial electric fields. For the purposes of the BEE, the following guide should be sufficient:

For:

$$(f > 300 \text{ MHz}): \quad \text{Far-Field} \geq [2 \times L^2]/\lambda \tag{11}$$

$$(300 \text{ MHz} \geq f \geq 30 \text{ MHz}): \quad \text{Far-Field} \geq 5 \times L \tag{12}$$

$$(30 \text{ MHz} > f): \quad \text{Far-Field} \geq 1.6 \times \lambda, \tag{13}$$

where L is the longest dimension of the antenna and λ is signal wavelength. Note that for the three equations given there is not a specified unit for antenna length, L, or signal wavelength, λ; any unit can be used provided that the same units are used for both parameters. See Example 1 of Appendix I for an example of Equation 11 in use.

(b) Near-Field (Fresnel Region). At close distances to an antenna, the field does not decrease with distance as is the case in the far-field; instead, it remains relatively constant. In the near-field, the electric and magnetic fields are not completely transverse to the direction of RF propagation, the two fields do not approximate a uniform plane wave, and the two fields cannot be related to each other by free space impedance of 377 Ω. In the near-field of an antenna, both the magnetic and electric radiation fields are complex as compared to that of the far-field. For example, in the near-field of dipoles, impedance is very high as compared to the far-field impedance of 377 Ω; in this case, the magnetic field is small with respect to the tangential electric field, as compared to their relationship in the far-field.

1 Power Density. Unfortunately, calculations to determine power densities in the near-field are not as simple as in the case of the far-field. For aperture antennas, like the one in Figure 16, and characteristic of most antennas operating at or above 300 MHz, we suggest using Equation 14 to estimate the maximum power density on the main beam axis. Example 2 of Appendix I illustrates the use of this equation. Additionally, T.O. 31Z-10-4 contains correction factors for determining power density values in the near-field of an emitter.

$$\text{Power Density} = (4 \times P_{av})/(\text{Antenna Area}) \tag{14}$$

For dipole, monopole, and similar antennas as described in Appendix H, we suggest using Tables 4 and 5 to estimate power density levels. To use the table, simply match the input power to the antenna in the left column and the PEL in the top row. These antennas normally operate below 300 MHz.

Table 4: **Estimated Hazard Distance (feet) for Horizontal Dipole Antennas**

INPUT POWER (Watts)	Permissible Exposure Limit (milliwatts/square centimeter)								
	100	50	30	20	10	5	3	2	1
10	0.13	0.19	0.24	0.30	0.41	0.59	0.76	0.93	1.3
20	0.19	0.26	0.34	0.41	0.59	0.83	1.0	1.3	1.8
30	0.23	0.32	0.41	0.51	0.72	1.0	1.3	1.6	2.3
40	0.26	0.37	0.48	0.59	0.83	1.2	1.5	1.9	2.6
50	0.29	0.41	0.53	0.65	0.93	1.3	1.7	2.1	2.9
75	0.36	0.51	0.65	0.80	1.1	1.6	2.1	2.5	3.6
100	0.41	0.59	0.76	0.93	1.3	1.9	2.4	2.9	4.1
120	0.45	0.64	0.83	1.0	1.4	2.0	2.6	3.2	4.5
150	0.51	0.72	0.93	1.1	1.6	2.3	2.9	3.6	5.1
200	0.59	0.83	1.1	1.3	1.9	2.6	3.4	4.1	5.9
250	0.65	0.93	1.2	1.5	2.1	2.9	3.8	4.6	6.5
400	0.83	1.2	1.5	1.9	2.6	3.7	4.8	5.9	8.3
500	0.93	1.3	1.7	2.1	2.9	4.1	5.3	6.5	9.3
750	1.1	1.6	2.1	2.5	3.6	5.1	6.5	8.0	11
1000	1.3	1.9	2.4	2.9	4.1	5.9	7.6	9.3	13

Table 5: **Estimated Hazard Distance (feet) for Vertical Monopole Antennas**

Input power (watts)	Permissible Exposure Limit (milliwatts/square centimeter)								
	100	50	30	20	10	5	3	2	1
10	0.18	0.26	0.34	0.42	0.58	0.83	1.1	1.3	1.9
20	0.26	0.37	0.48	0.59	0.83	1.2	1.5	1.9	2.6
30	0.32	0.45	0.59	0.72	1.0	1.4	1.9	2.3	3.2
40	0.37	0.53	0.68	0.83	1.2	1.7	2.2	2.6	3.7
50	0.42	0.59	0.76	0.93	1.3	1.9	2.4	2.9	4.2
75	0.51	0.72	0.93	1.1	1.6	2.3	2.9	3.6	5.1
100	0.58	0.83	1.1	1.3	1.9	2.6	3.4	4.2	5.9
120	0.64	0.91	1.2	1.4	2.0	2.9	3.7	4.6	6.4
150	0.72	1.0	1.3	1.6	2.3	3.2	4.2	5.1	7.2
200	0.83	1.2	1.5	1.9	2.6	3.7	4.8	5.9	8.3
250	0.93	1.3	1.7	2.1	2.9	4.2	5.4	6.6	9.3
400	1.2	1.7	2.1	2.6	3.7	5.3	6.8	8.3	11
500	1.3	1.9	2.4	2.9	4.2	5.9	7.6	9.3	13
750	1.6	2.3	2.9	3.6	5.1	7.2	9.3	11	16
1000	1.9	2.6	3.4	4.2	5.9	8.3	12	13	19

This information is provided for those interested in a more exact estimate of near-field power densities. It is perfectly acceptable to use the far-field equation to estimate power density levels in the near-field, if one is willing to accept a conservative estimate.

2 Boundary Definition. As is the case with the far-field boundary, there are many methods to define the near-field boundary. For aperture antennas operating above 300 MHz, we suggest using Equation 15.

For dipole, monopole, and similar antenna that normally operate below 300 MHz, we suggest using Equation 16. For:

$$(f > 300 \text{ MHz}): \quad \text{Near-Field} < L^2/[4 \times \lambda] \tag{15}$$

$$(f < 300 \text{ MHz}): \quad \text{Near-Field} < \lambda, \tag{16}$$

where L is the longest dimension of the antenna and λ is signal wavelength. An illustration of the use of Equation 15 is provided in Example 1 of Appendix I.

(c) Transition Region. The transition zone contains characteristics of both the far-field and near-field. Generally, the electric and magnetic field are somewhat transverse to the direction of propagation and therefore, they are approximately related by free space impedance of 377 Ω. Additionally, power density does decrease with distance from the antenna, but its level cannot be accurately predicted with the far-field equation.

(d) Field Measurements. The most practical use of understanding antenna regions is its application to performing measurement surveys. Generally, when performing measurements in the near-field it is necessary to measure both the electric and magnetic field components to ascertain accurate information about the field. Practically, this should be done for emitters that radiate below 100 MHz, while surveying in the near-field. For measurements in the far-field and usually the transition region, the electric and magnetic field are related by free space impedance of 377 Ω and there is no need to measure both fields. It is likely that the next revision to AFOSH Standard 161-9 will incorporate separate magnetic and electric field standards for systems that emit below 100 MHz, where the equivalent far-field power density values are different.

(3) Radiation Pattern.

(a) General. This important antenna characteristic determines how energy is distributed in space. Several patterns are fairly common. An omnidirectional or broadcast-type pattern is used whenever all directions must be covered equally. The horizontal-plane pattern is approximately circular while the vertical-plane pattern may be squeezed down to increase area coverage. A pencil-beam pattern is typically used when the radiation must be concentrated in as narrow an angular sector as possible. The widths of the beam in the two principal planes are essentially equal. A fan-beam pattern is similar to a pencil-beam pattern except that the beam cross section is elliptical rather than circular in shape. The beam width in one plane may be considerably broader than the beam width in the other plane. A shaped-beam pattern is used when the pattern in one of the principal planes must have a special shape for the type of coverage required. An example is the "cosecant-squared" pattern used to provide a constant radar return over a wide range of vertical angles. Of course, there are others that do not fall into any of these categories: figure-eights, cartoids, split-beams, multiple lobes, etc.

(b) Beam Width. The important characteristics of simple antenna patterns (fan, pencil, shaped, etc.) can be specified in terms of the beam width in the two principal planes: horizontal and vertical. The beam width of a radiation pattern is the angular width of the beam defined by the points where power is one half of maximum beam power. Beam width is a characteristic more commonly associated with aperture antennas; however, it can be defined for omnidirectional antennas as well. Antenna beam width is closely related to antenna gain. Naturally, antennas with large gains will have small beam widths, and conversely, antennas with small gains will have large beam widths. Normally, beam widths are specified in the horizontal and vertical planes for rectangular aperture antennas and wire antennas. A single circular width is given for circular apertures. Beam width is typically specified in degrees.

(c) Beam pattern shape, gain, typical beam widths, and pictorial examples for common antennas are given in Appendix H.

IV. THE HAZARDS

A. Classification of Hazards.

1. RFR energy can be a hazard in more than one way. The usual classifications are as follows:

a. Direct biological (personnel) hazards due to absorption of RFR energy and the subsequent heating of body tissues.

b. Indirect biological hazard due to interference with electronic medical prosthetic devices like cardiac pacemakers and other biomedical equipment.

c. Indirect hazard due to ignition of petroleum, oil, and lubricants (POL) or the detonation of electro-explosive devices (EEDs).

2. Each of these categories is linked to a different safety standard or criterion. BES has no responsibility for dealing with the indirect hazards, but one can profit by becoming familiar with them and knowing how to contact the corresponding referral agencies. Let's examine each type of hazard.

a. Direct Biological. RFR energy at sufficiently high levels causes heating in body tissues. The amount of RFR energy that is absorbed and converted to molecular energy is strongly frequency dependent. In general, with regard to human beings, it can be said that the longer the wavelength the greater the depth of penetration. Wavelengths of 3 cm or less (10 GHz or higher) are absorbed by the skin. Depth of penetration is only one factor; energy deposited is the key issue. In general, the greatest absorption in adult humans takes place at 70 to 80 MHz if they are not electrically grounded, and 30 to 40 MHz if they are. The mechanism for transfer of energy to the human body by RFR is by friction resulting from the vibration/rotation of the body's polar molecules (mainly water) within the viscous cell medium. But whatever the frequency, an RFR induced burden adds to other thermal

burdens and produces normal physiological adjustments like sweating and vasodilation. If biological or environmental factors prevent the effective dissipation of heat, the exposed tissue will be heated and possibly damaged. The effects of this type of exposure are not considered to be cumulative as they are with ionizing radiation. Exposures separated by more than a few minutes (six, by the standard) are essentially separate physiological events.

b. Indirect Biological Hazard. AFOSH Standard 161-9 is clear on cardiac pacemaker hazards. Extensive tests have been conducted, and most manufacturers have voluntarily produced devices that are unaffected by RFR fields below 200 V/m (about 10 mW/cm^2). Very high power Air Force systems can produce levels in areas that are high enough to interfere with today's pacemakers. These areas should already have control measures in place to preclude access to the direct personnel hazards and therefore, there is no need to post signs for the express purpose of warning pacemaker wearers.

c. POL Hazard. RFR energy will produce an arc under the right conditions and cause the ignition of flammable vapors. The safety standard for POL is 5 $watts/cm^2$, based on peak power. Any location where flammable vapors could be released, like the transfer of fuel from one tank to another, is suspect. T.O. 31Z-10-4 provides more information on this topic, or contact 1842 EEG/EEITE, Scott AFB IL 62225, AUTOVON 576-5596 for assistance in POL hazards.

d. Electro-Explosive Device (EED) Hazard. EEDs (also called squibs) are associated with many aircraft weapon systems. Basically, they are small explosive devices that are detonated by an electric current, often in order to detonate larger explosive devices. Many different hazard levels are defined in AFM 127-100, depending on the configuration of the EEDs in question. Concerned organizations should contact the weapons safety office on base. If they cannot solve their problem they should then contact ASD/ENACE, Wright-Patterson AFB OH 45433-6503, AUTOVON 785-7275.

e. X-ray Emissions. Radar units contain klystron, magnetron, and thyratron tubes that emit ionizing radiation as a result of high voltage being applied to the tube. Radar units also have interlock systems in the area where the high voltage is located; however, many times the interlocks are bypassed by maintenance personnel during testing. For this reason it is important to insure that maintenance personnel are not being overexposed to ionizing radiation when cabinet doors are open. Another consideration to be made during survey of x-ray emissions is that an RF-shielded survey instrument is used. A Victoreen Model 440 will not give accurate readings, the 440RF model should be used instead. To perform a survey, measurements are taken on all sides of the transmitter cabinet, especially around seals to removable panels. If possible, remove panels that are removed routinely and check for leakage. Caution should be observed when measuring x-ray emissions with panels removed because of the potential for high voltage arcing. It is good practice **not** to advance the meter beyond the limits of the cabinet frame. X-ray levels should not exceed 2 mR/hour. For more information on this topic, please consult USAFOEHL

Report 85-144RI111HXA, "Ionizing Radiation Guidebook for Bioenvironmental Engineers (BEEs)."

B. Thermal vs Athermal.

1. An important point to note when talking to people about RFR protection is that biological effects are not necessarily biological hazards. Research communities throughout the world continue to publish paper after paper on the biological effects of RFR. Scientists in Eastern Europe and Russia have reported long lists of symptoms (decreased blood pressure, feelings of apathy and depression, etc.) at levels of exposure that are well below the USAF PEL. Even though efforts in the Western world to replicate these results have failed, we cannot totally ignore them. The fact is, we just don't know all there is to know about the effects of RFR on the human organism.

2. The current USAF standard for RFR protection, given in AFOSH Standard 161-9, is designed to protect us from the known thermal hazards associated with RFR emissions. The PELs have been shown to present an insignificant thermal load to the body. We do not ignore the possibility of "athermal" (not related to heating) effects, but it is current USAF policy to classify low-level athermal effects as being nonhazardous.

C. Managing Misconceptions.

1. There are some not-so-unusual ideas floating around the Air Force about RFR. Unfortunately, these misconceptions can be dangerous. There are still supporters of the "if you can't see it, it can't hurt you" theory. People with the opposite viewpoint, weave fantastic tales about the killing of mice at ridiculously low power density levels. Both types of people can make our jobs harder.

2. Education is the best way to effectively manage these problems. Take the time to educate RFR workers on your base.

D. Electromagnetic Interference.

1. With the multitude of RFR emitters and other electronic equipment located on the typical Air Force installation, it is common to find many cases of electromagnetic interference. Nonhealth hazards like electromagnetic interference are reported IAW AFR 700-13. Though BES is not responsible for the control of electromagnetic interference, unfortunately they are often consulted about these problems. As consultants, we have had the opportunity to hear a vast array of stories concerning electromagnetic interference over the years. Stories of video display terminals losing characters, periodic interference to an AM broadcast signal, and poor FM television reception are some of the common ones. Periodically, some of the stories are more bizarre, like vending machines spuriously dropping change, warning lights on automobiles sporadically illuminating while in the vicinity of ground based search radar, and electronic typewriters typing without an operator. In the vast majority of RFR interference cases, there are no

personnel hazards, but, people often associate electromagnetic interference with the potential for personnel hazards.

2. Electronic equipment, such as televisions and video display terminals (VDTs), responds to two types of interference, conducted interference and radiated interference. Since we are concerned with radiation protection, we will discuss radiated interference. Most interference to digital equipment such as VDTs is caused by radar, because radar usually employs transmissions with high peak power and large bandwidth. When an electric field acts on a piece of digital equipment it can alter the logic state of individual devices, thereby causing spurious errors. It is important to understand that these errors are caused by peak field intensity rather than average field intensity, and therefore, radars with high peak powers and low duty factors can cause interference without being a health hazard, since the average power associated with these phenomenon are usually very low. For example, a typical VDT has an interference susceptibility threshold of 8 to 133 volts/meter (peak) or equivalent power density levels of 0.017 to 4.8 mW/cm^2. If the radar had a duty factor of 1×10^{-3}, the average power density levels would be 0.017 to 4.8 $microwatts/cm^2$, well below all PELs for RFR.

3. FM television interference can be caused by many types of RFR signal, pulsed or continuous wave. This occurs when an interfering signal modulates the broadcast signal and then causes changes in the television picture. For the television signal to be considered "interference free" it needs to be 15 dB above any interfering signal. A typical television receiver sensitivity is approximately -93 dBm, so an interfering signal only has to be -108 dBm to cause picture distortion. This corresponds to a power density level of 1.5×10^{-14} $milliwatts/cm^2$! In fact, this level is so low that a vacuum cleaner can easily cause interference to a television.

4. RFR average power density levels in the $microwatt/cm^2$ range can easily cause interference with common electronic equipment, but, interference phenomena are rarely associated with a health hazard.

V. STANDARDS

A. The Basis of Our Permissible Exposure Limits (PELs).

1. What level of RFR is safe? It's a big question, and a lot of people, educated or not, have made stabs at an answer. Many not-so-qualified writers have implied in their books and articles that there is no scientific basis for the current PEL. It is not uncommon to find government and industry accused of a massive cover-up of the "real" hazards associated with RFR. Many say that because the Soviet "standard" is lower than ours, we are either foolish or ignorant.

2. Not necessarily true. There have been volumes of paper generated over the past 35 years on subjects related to RFR biological effects. The number of papers published is in the thousands, and the research continues. National and international information exchanges have been held every year

since 1973. Millions of dollars have been spent in research facilities devoted to understanding the nature of biological responses to RFR.

3. In 1958 DoD adopted its first standard for exposures to RFR. The first standard set a PEL of 50 mW/cm^2 for frequencies between 10 kHz and 10 MHz, and a PEL of 10 mW/cm^2 for frequencies between 10 MHz and 300 GHz. The standard was based on exposures averaged over any six-minute period of time. The 10 mW/cm^2 PEL originated from physiological consideration that whole-body exposure to humans to a level of about 100 mW/cm^2 or more would cause a mild-to-severe increase in thermal load (depending on the load), and by application of a safety factor of 10. This guide was based on a belief that nearly all workers could be exposed to RFR at 10 mW/cm^2 or lower during a normal series of working days without adverse effects. Adoption of this guide also recognized that electromagnetic fields at or below the PEL could cause physiological effects, but the effects had no adverse medical consequences.

4. Since the first standard was introduced, there has been considerable research to indicate that the human body selectively absorbs RFR dependent on frequency. In 1982, the American National Standards Institute (ANSI) developed a frequency dependent standard. The standard is based on observed thermal effects from a mean whole-body specific-absorption rate (SAR) of 4 W/kg; with a safety factor of 10, the standard is 0.4 W/Kg. The SAR is a measure of the absorbed energy from an incident electromagnetic field and is normally expressed as energy absorbed per unit volume (watts/kilogram), where 1 kilogram is equal to approximately 1000 cm^3 (for most biological systems). The standard also contains a partial body limit, spacial peak SAR, that is based on 8 W/kg averaged over any one gram of tissue.

5. The localized value of SAR within a given entity is dependent on frequency, modulation, amplitude and polarization of an incident RFR field; the properties of the material; and the configuration of the material with respect to the incident field. For entities that are complex in shape and variant in distribution of its constituents, distribution of local SAR is difficult to determine. As a result, the concept of whole-body SAR was developed, because this quantity is easy to measure experimentally without the need to understand the SAR internal distribution.

6. The whole-body SAR is highly dependent on the size of the body. Figure 14 demonstrates this phenomenon by comparison of the RFR absorption of three different size bodies: a man, a rat, and a mouse. The peak absorbance of a mouse (at ~ 1050 MHz) is 5.6 times that of man (at ~ 70 MHz).

7. Note also from Figure 14, how RFR absorption for man varies with frequency. At 10 MHz and below, the human body is transparent to RFR, absorbing very little as compared to the frequencies near 70 MHz. While for frequencies above 1000 MHz, the absorbance factor is rather constant.

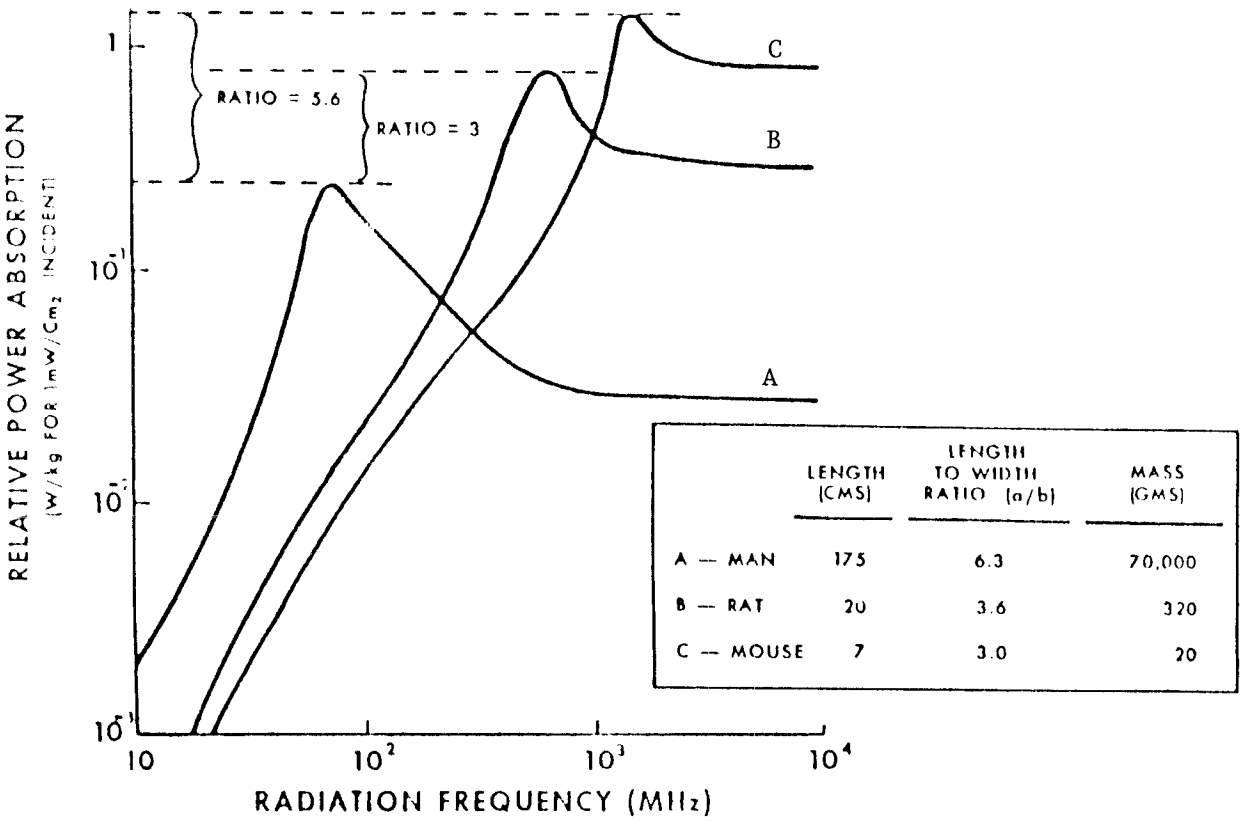


Figure 14: RFR Power Absorption Scaling Factors

8. The current Air Force standard is based on a whole-body specific-absorption-rate of 0.4 watts/kilogram and is consistent with ANSI C-95 and DoDI 6055.11. Table 6 and Figure 15 define the PELs as specified in AFOSH Std 161-9. Note how the shape of the curve in Figure 15 closely resembles the inverse of the absorbance curve (Figure 14).

Table 6: Maximum Permissible Exposure Limits for Human Exposure to RFR

Frequency (f) (MHz)	Restricted Area Power Density (mW/cm^2)	Unrestricted Area Power Density (mW/cm^2)
0.01 - 3	100	100
3 - 30	$900/f^2$	$900/f^2$
30 - 100	1.0	1.0
100 - 300	$f/100$	1.0
300 - 1000	$f/100$	$f/300$
1000 - 1500	10	$f/300$
1500 - 300,000	10	5.0

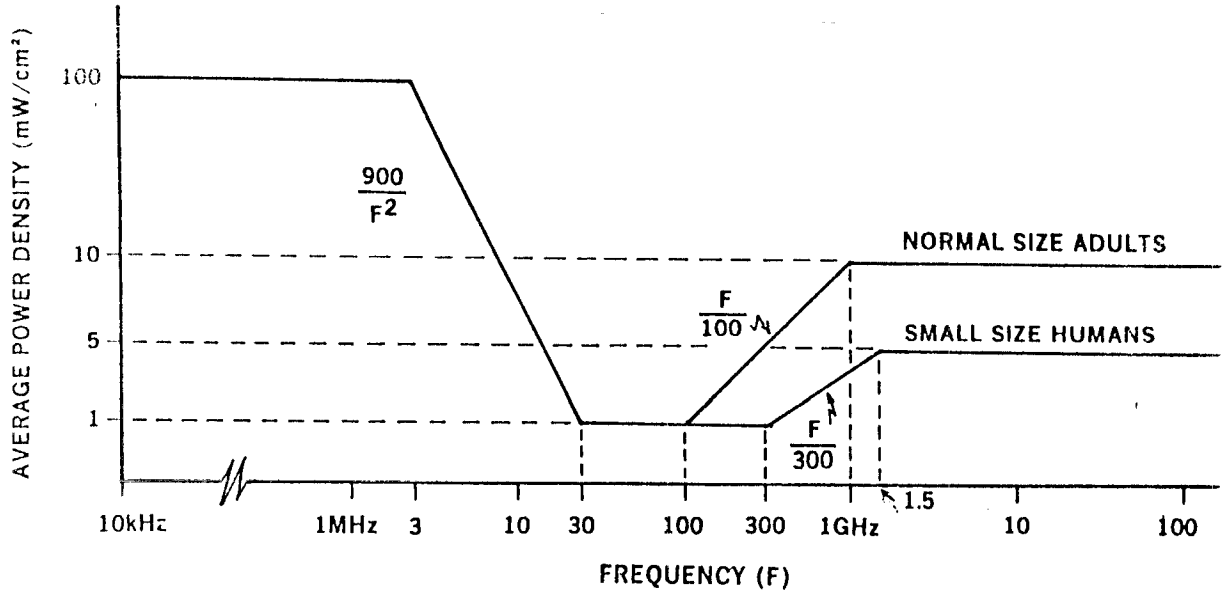


Figure 15: Permissible Exposure Limits

9. The AFOSH incorporates two separate standards: A "restricted area" standard and an "unrestricted area" standard.

a. The restricted area standard, also referred to as an occupational standard, applies to normal size adults (at least 55 inches in height). A restricted area is any location where access is limited to workers; these areas normally include flight lines, industrial work areas, communication compounds, etc. Small size (less than 55 inches in height) relates to children or interpreted as children that are normally excluded from occupational areas.

b. The unrestricted area standard, also referred to as an environmental standard, applies to normal size adults and small size humans. An unrestricted area applies to any area that is uncontrolled; these areas include public access areas on a base like base housing, commissary/exchange areas, and recreational areas.

c. The purpose of separate standards is to account for higher RFR absorbance by small size humans as compared to normal size adults.

10. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends an occupational standard identical to the AFOSH Standard restricted area standard; no environmental standard is recommended because the ACGIH is only concerned with occupational standards.

11. The pressure to lower the PEL has come from individuals and groups that continue to insist on a closer look at the possibility of hazardous athermal effects. The USSR and some Eastern European countries traditionally have more stringent safety standards than most Western countries. The Soviet standards are based on central nervous system and behavioral responses

attributed to RFR exposure in animals. In Western countries, the standards are based primarily on calculated thermal burden, because Western scientists have not been able to reproduce Soviet experimental results.

B. By the Standard.

1. The USAF PEL for RFR has two criteria:

a. The first is the power density level criteria. It is applicable in developing theoretical or measured hazard profiles around RFR emitters assuming indefinite exposure durations (greater than 6 minutes).

b. The second is a time-dependent criterion used primarily in overexposure determinations and when evaluating rotating or pulsed radars and portable communication devices.

2. The standard is relatively simple to apply. Match the operating frequency of the device to the standard; if a particular device can operate across a range of frequencies, the lowest PEL for the range of frequencies would apply. The PELs apply to all personnel. No additional restrictions are necessary for female RFR workers, even when pregnant.

3. The standard defines a single PEL for both the magnetic and electric field. For far-field conditions where free-space impedance is equal to 377 Ω, the electric and magnetic fields are related by free-space impedance and one would expect that both the measured electric and magnetic fields would result in equivalent power density values. However, in the near-field of an emitter this is not always the case; in fact, it is very common for the values to differ considerably. The "worst case" measured value of the electric or magnetic field is compared to the standard when both measurements are made. The most stringent case is what your control measures are based on.

C. Have I Been Zapped?

1. Sometimes there is confusion about application of the exposure criteria when overexposure determinations are being made. Total exposure can be quantified as either the average power density (mW/cm^2) over a given 6 minute period of time or the integrated exposure for a 6 minute period of time quantified in $mW\text{-}sec/cm^2$.

2. Under the latter method, a person is considered to have been overexposed if, during any 6 minute period, the total accumulated exposure exceeds the value of 360 times the PEL (3600 $mW\text{-}sec/cm^2$ for a PEL of 10 mW/cm^2).

3. Remember, overexposure determinations are based on average power over time. Intermittent exposures, like those from a scanning radar, must be calculated by multiplication of the fixed-beam power density with an additional scanning duty factor. The scanning duty factor is easy to calculate: simply divide the beam width (in the plane of scanning) by the total scanned sector size. For example, the scanning duty factor is 0.0083 for a radar that scans horizontally 360° and has a horizontal beam width of 3°.

D. Future Standards.

1. Currently, there is no Federal Law for control of RFR exposures to the general public. In the past, the Environmental Protection Agency (EPA) proposed three potential environmental standards. The most stringent proposal would set the standard at one-tenth the present Air Force standard. Implementation of a new standard in the near future seems unlikely because the EPA decided a standard was not needed at this time.

2. In June 1988, the American National Standards Committee C-95 on Radio Frequency Radiation Hazards met and considered changes to the ANSI Standard. If a new standard is adopted it is likely that the AFOSH Standard will follow suit. The two most notable proposed changes are listed below:

a. Separate electric and magnetic field standards for frequencies less than 300 MHz. The electric field standard will remain the same, while the standard for the magnetic field will be increased.

b. Reduced time-averaging period for frequencies greater than 10 GHz. The averaging period will gradually decrease as frequency increases.

3. The DoD has a tri-service working group developing a standard for high power microwave (HPM) and electromagnetic pulse technology applications. The standard, if developed, will define higher exposure limits for short exposure durations typical of these technologies. It is likely that the next revision of AFOSH Standard 161-9 will implement a new standard.

VI. BASE PROGRAM

A. Getting Started.

1. AFOSH Standard 161-9. Familiarity with the responsibilities set forth in the AFOSH Standard is an important first step.

2. Unit Radiation Protection Officers (RPOs). A valuable asset to BES and EHS is a unit RPO. Unit RPOs can assist in identifying emitters in their organization, assist in interfacing with workplace supervisors and personnel, help sell and promote your program and any safety requirements, and notify BES of important changes that affect safety requirements. RPOs can also help promote awareness and understanding of RFR to personnel and initially reduce tensions if a suspected overexposure to RFR is claimed. We recommend using the RPO in all unit RFR matters. If units do not have an RPO, we suggest tasking the unit commander to appoint one. AFOSH Std 161-9 requires commanders to do this. In the tasking, it is important to point out that the position is not just a figure-head; depending on the unit, the position may require a great deal of time and should require of the individual more than just a lay person's understanding of RFR.

B. Inventory.

1. General. One of the most time consuming tasks in setting up a good RFR protection program is compiling an inventory of all emitters on base. It is absolutely essential. Take a minute to review page 7 of AFOSH Standard 161-9 where it talks about inventories.

2. Case File Documentation. A copy of the standardized RFR inventory form, AF Form 2759 is included in Appendix B, along with instructions for filling it out, as specified in AFOSH Standard 161-17. This form, properly completed, makes a handy reference for quick answers to RFR questions. Getting the information to fill in the blanks on the form is not trivial, but do the best you can. If you are just starting your inventory, call the base frequency manager (usually at the base communications squadron). This individual has a listing of all the frequencies authorized for use on the base (airborne emitters excepted) and may know who to contact for further information on each. T.O.s for aircraft usually contain operating parameters for airborne emitters. Another source is the Electromagnetic Compatibility Analysis Center (ECAC/ACZ, North Severn, Annapolis MD 21402, AUTOVON 281-2681). They can provide detailed computer listings of equipment parameters and locations. Still another source is AFOEHL--call us if you need particular information on a system at your base. It is unlikely that one source will give you all the information you need; some of the information is available only through persistence. We suggest that you make a form letter requesting the necessary information, and send it to every candidate organization on base, negative replies required. This doesn't always result in complete accuracy, but it does spread the word around.

3. Central Inventory. A central inventory of all emitters on base is required by AFOSH Std 161-9, para C4a(1). Also, the Inspector General normally reviews the inventory because it provides an overall view of your RFR protection program. Beyond these reasons, the central inventory is a management tool that will help you as the base RPO keep track of all the hazardous emitters on base, pending items like suspensed items to unit RPOs, etc. We recommend the following items for the central inventory:

a. A summary list of emitters and their hazard distance, hazard code, and location on base.

b. List of the unit RPOs.

c. Copy of unit OIs for hazardous emitters.

d. Map or grid coordinates of ground based emitters.

e. Copies of measurement survey reports, locally produced or from AFOEHL, 1839 EIG, etc.

f. Copies of AF Forms 2759.

Things change--sometimes when you are not looking. A periodic review of your inventory is necessary. This could be done during regular workplace visits, or by another mailing asking if there have been any changes.

C. Hazard Evaluation.

1. Hazard Code. Once the parameters for an emitter have been inventoried and recorded, the next step is to determine the hazard code. Sometimes this task is difficult to complete for BEEs who have very little RFR experience. The major factor determining the hazard code is based on accessibility of personnel. Hazardous areas that are well above ground level or in some other way not normally accessible are labelled "IH" or "CH" and are regarded as a small concern. Sometimes only you, looking directly at a particular emitter, can make this determination. If after reviewing the list of possible codes (Appendix B), you can't decide which one to assign, AFOEHL/RZC will assist.

2. Hazard Estimate. Along the same lines as determining a hazard code for a device, you should make a more detailed determination of the hazard potential of an emitter. Several options are available for getting the hazard estimate you need; in order of preference, you could:

a. Inspect the operating parameters of the device. If the device emits less than 7 watts and has a frequency of operation less than 1000 MHz, the device is exempt from meeting the PELs specified in AFOSH Std 161-9 and is considered nonhazardous. Devices that meet this criteria should be assigned a hazard code designation of "NH" and require no survey work. Devices that typically meet these requirements are small portable hand-held radios (bricks) and some medical devices like dental descalers.

b. Look up data from past surveys of the emitter or other emitters of the same type. AFOEHL maintains an emitter survey data base that cross references survey reports from AFOEHL, Wiesbaden, 1839 EIG, and the 1842 EIG. Some of the data base is summarized in Appendix C.

c. Refer to a technical order on the system that specifies the necessary hazard information.

d. Perform a simple far-field calculation on the system parameters. This estimate will be more conservative than the others, but is useful nonetheless. If a more detailed analysis is desired, an approved method is contained in T.O. 31Z-10-4 (Chapter 4, Section II). AFOEHL can provide a computer generated analysis of this type on request.

e. Use the available information to make an educated "guess" based on experience. This becomes necessary when the system parameters are not known, or when the mathematical models do not fit. This is the case with many fixed, airborne and land mobile communications systems that operate at HF, VHF, and UHF frequencies and employ thin omnidirectional "linear" antennas. Values for estimating hazard distances around such antennas are given in Tables 4 and 5.

3. Survey Requirements. Once the background information on each emitter has been established and an estimation of the hazard zone for an emitter has been determined, the next step is to determine the necessity for performing a survey of the emitter. Many people automatically equate "survey" to "take measurements." That is not always the case. There are two types of surveys we would like to differentiate:

a. Emitter site inspection survey: Survey of an emitter site to determine accessibility of the RFR emitter to personnel, how the emitter is used, and the condition of the control measures.

b. Measurement survey: Measurement survey to determine the distance to a known power density level or to determine levels of RFR in regions accessible to personnel.

Any emitter that is considered nonhazardous (NH) because it emits less than 7 watts and has an operating frequency less than 1000 MHz does not require a survey of any type. Also, we recommend that surveys not be performed on hand-held, field portable, or vehicle mounted HF, VHF, or UHF voice or teletype communication devices that have a peak power less than 50 watts. These devices typically have a hazard code designation "SH"--hazardous levels possible, but transmission time is too short for overexposure. These devices normally transmit for a small amount of time in a 6 minute period. Typically HF devices use single sideband modulation and therefore, the average power during a transmission is 50% of peak power for a single tone signal and 10% of peak power for a voice signal.

4. Site Inspection Survey. Once the emitters as described above have been separated, it can be assumed that the remaining emitters will require some type of emitter site inspection survey. This survey, coupled with the initial hazard zone estimations, should allow you to determine if there are any potentially hazardous areas accessible to personnel. In your survey you should evaluate existing OIs for effectiveness and evaluate any existing control measures. Take time to note the work practices of shop personnel. Sometimes actual work practices vary considerably from their description!

5. For some of the emitters evaluated it will be necessary for you to complete a site inspection survey before determination can be made of the need for a measurement survey. The following examples are provided to illustrate the evaluation process.

a. Example 1: The AN/FPS-64A is an aircraft search radar located on a tower 20 feet above ground level. The radar's antenna is contained in a radome on top of the tower. The tower contains a catwalk encompassing the full 360° around the tower; access to the catwalk is restricted during operation of the radar. The radar has a continuous rotating horizontal scan rate of 5 revolutions/min and has a fixed main beam elevation of +2.6°. The radar has a fixed-main-beam hazard distance of 440 feet and a scanning hazard distance of 10 feet. Recommendations: The radar main beam is not accessible to individuals during normal operation of the radar. Survey measurements are not necessary. Insure access points are clearly marked with RF warning signs with instructions "contact operator before accessing catwalk." Access doors should be locked.

b. Example 2: The AN/ARC-164 is a UHF radio contained on the belly of C-130 aircraft. The emitter operates across the frequency range of 225-399.9 MHz, and has a peak power of 10 watts and an antenna gain of 3 dB. The most restrictive PEL is 2.25 mW/cm^2 based on operation at 225 MHz. Using the far-field equation, Equation 10, the hazard distance is 11 inches. Recommendations: Survey measurements are not necessary. This device does not

continuously transmit an RFR signal so the average power during a typical transmission is a small fraction of the emitter peak output power.

c. Example 3: The AN/APQ-128 is a terrain following radar located in the nose of F-111 aircraft. The APQ-128 operates at 16.7-17.0 GHz, has an average power output of 24 watts, and has an antenna gain of 25.5 dB. The radar can be operated continuously on ground in a fixed position. Using the far-field equation, Equation 10, the hazard distance is 8.5 feet. Recommendations: Reference actual survey data in an AFOEHL Report or other reliable source. If no actual survey data are available a baseline measurement survey should be performed.

d. Example 4: The AN/TPQ-43 is a transportable aircraft tracking radar system. During normal operation, antenna elevation is between -1.0° and +3°. The antenna height is approximately 25 feet above ground level. During maintenance, the antenna structure is lowered to a level where the antenna center is approximately 6 feet above ground level. The emitter operates between 8500-9600 MHz, has an average output power of 100 watts, and has an antenna gain of 42 dB; the antenna is circular and has a diameter of 6 feet. Using the far-field equation, the hazard distance is 116 feet. Recommendations: Reference actual survey data in USAFOEHL Report 87-156RC1065MRA, Radio Frequency Radiation Hazard Survey, Detachment 18, Forsyth MT. The report recommends a hazard distance of 10 feet for maintenance, while the emitter is nonhazardous during normal operation since the main beam is inaccessible. This emitter exhibits an obvious conflict between the actual measured hazard distance and that predicted by the far-field equation. The problem with the hazard distance calculation of 116 feet is that it is still on the fringe of the near-field region that extends out to 80.5 feet from the emitter; the far-field region begins at 638 feet from the emitter. Near-field power density values calculated with the far-field equation are always higher than actual near-field power density.

The process described above for determining the extent of survey requirements for any given emitter is not a simple process. The illustrations are provided to explain some of the logic behind the decision process; the goal of this process is to limit the amount of survey work requirements. If you researched the emitters well, most of the emitters will require no measurements.

6. Measurement Survey. Once the preliminaries are done, the next step is to perform survey measurements on the remaining emitters. When the day comes that you identify a requirement for a survey, you will be prepared. You will be able to go directly to the case file and pull out a relatively good picture of what is needed. You will know the exact location of the emitter and be familiar with its environment. You will have names and numbers of the unit RPO and workplace supervisors. You will have a good estimate of the hazards associated with the system.

a. Arrange a date and time when the emitter will be available for survey. Make sure that support personnel will be available to operate the system, as well as the necessary mobile lifting equipment, hand-held radios, climbing gear, etc.

b. Check out your equipment. Is the calibration current? Does the probe frequency range cover the output frequency of the emitter being

surveyed? Does the battery check meet the minimum levels? For pulsed radar systems have you performed a probe burnout calculation? (If not, see Section VII.B.3).

c. A successful survey is a safe survey that produces the necessary data and results in the understanding and satisfaction of all the key players. See to these matters before you start:

(1) Conduct a complete and proper briefing of all personnel involved explaining the survey. The unit RPO should be notified of any survey work being performed in their workplace.

(2) Ensure that adequate communication is provided between the operators of the emitter and the survey personnel. Be sure that absolute control over the emitter output is established and maintained during measurements. You would be surprised how many accidental exposures have occurred trying to survey RFR emitters.

(3) Always begin the survey at a distance greater than the estimated PEL distance, with the meter on its maximum range setting.

d. The exact procedures you will follow as you set-up and perform your survey will vary somewhat for different emitter types. Detailed notes on surveying ground mounted RF emitters are given in Appendix D, airborne RF emitters in Appendix E, and medical devices in Appendix F. A Radio Frequency Radiation Survey Checklist is provided in Appendix G.

7. Explain your findings from the site and/or measurement survey as best you can to the workplace supervisor, unit RPO, and other key personnel in the workplace. Don't surprise them later with unexpected requirements. Let them know about anything that could affect their operation.

8. Frequency and extent of workplace visits. Once a baseline survey is accomplished for all emitters with hazard potential, follow-up workplace visits should be scheduled. For the most part, unless there are significant changes to the RFR output of the emitter, survey measurements need be performed only once. Follow-up visits usually include evaluation of OIs and existing control measures, observation of any changes from previous survey, and could include RFR education (BES coordinate with EHS). The frequency of these visits is dependent on the emitter. For most emitters an annual workplace visit will be sufficient. For the following emitters, quarterly workplace visits are required:

a. ECM emitters in flight line and maintenance workplaces.

b. ground based radar systems that can direct stationary beams into areas accessible to personnel.

c. other hazardous emitters that have quickly changing operating conditions like emitters used in research labs, electromagnetic pulse or high power microwave testing, or in systems development labs.

D. Control Measures.

1. General. Once survey work is complete, the next step is to determine necessary control measures and/or evaluate existing control measures. For emitters that are nonhazardous or have hazard zones that are inaccessible, there is no requirement for any control measures. For emitters that create accessible hazard zones, the following paragraphs will assist in determining what control measures are required.

2. Control Measures. Below is a list of common control measures. In no way is this list meant to be totally inclusive.

a. Radio Frequency Radiation Warning Signs. AF Forms 737 and 747. Soon to be replaced with National Stock Number listed items.

b. Cones with Warning Signs Affixed. Simple orange/yellow traffic cones with an affixed RFR warning sign.

c. Roped Off Areas with Warning Signs. Temporary or permanent. A temporary area may implement wooden stands that are attached to each other with rope. A permanent area may implement wooden or metal posts that are driven into the ground. In either case, signs should be attached to the posts or rope.

d. Fences. Metal chain link fences or wooden fences. HF emitters are commonly surrounded by wooden fences, because metal fences may passively reradiate RFR.

e. Azimuth Blanking. A common practice for aircraft search radar. Azimuth blanking allows operators to null transmissions when the radar is pointed at a particular range of azimuths or mechanically (or electronically) restrict the radar from pointing in a certain azimuth. Normally this is implemented to prevent ground structures from interfering with the radar, but it can also be used to prevent RFR hazards to personnel. Caution--be sure they are being implemented; some systems allow azimuth blanking to be enabled (or disabled) by simple updates on a computer terminal.

f. Dummy Load. Commonly dummy loads are used in maintenance workplaces to allow transmitter operation while blocking free-space propagation of RFR.

g. Flashing Lights or Audible Signals. Used in areas with high RFR levels.

h. Interlocks. Device that prohibits operation of an emitter when a door, hatch, or other entry point is breached.

i. Barriers. Rope, chain, or other barrier across access to stairs, walkway, etc.

3. Specific Examples. The following examples are provided to illustrate the application of control measures.

a. Example 1. Given: An aircraft tracking radar is located on the roof of a building. The radar has a main beam hazard distance of 300 feet; the main beam is accessible from the roof but not at ground level. Seldom are personnel required to access the roof. Recommended controls: Locate RFR warning signs at all access points to the roof; the signs should contain additional text stating, "access to roof restricted, contact radar operators before gaining access." Additionally, it is recommended to put a chain across any stairs or walkways that lead to the roof.

b. Example 2. Given: A VHF base communication antenna is located on the top of a roof. The antenna has a 10 foot hazard distance. Personnel routinely access the roof. Recommended controls: Rope off the hazard area and post RFR warning signs.

c. Example 3. Given: The B-1B Defensive Avionics, AN/ALQ-161, is a multiple antenna radar system. The system has a hazard distance of 7 feet from any antenna, but is not a ground hazard since the aircraft is 14 feet above ground level. Recommended controls: Place cones beneath all AN/ALQ-161 antennas. Place warning signs on cones with additional text stating, "RFR hazards for personnel on ladders or platforms."

d. Example 4. Given: The AN/FPS-115, PAVE PAWS phased-array search and track radar has a ground hazard of approximately 50 feet in front of both antenna faces. The radar is enclosed by two barbed wire security fences at 150 and 200 feet around the perimeter; access to the ground region in front of the radar is limited to authorized personnel. Recommended controls: Place permanent poles at 50 feet in front of each antenna face and connect poles with chain or rope. Place warning signs on poles or rope.

e. Example 5. Given: An avionics maintenance function performs maintenance on aircraft radar transmitters. The system in use has a hazard distance of 50 feet without a dummy load and 0 feet with a dummy load. Recommended controls: Place warning signs at entrance to the workplace and in the vicinity of every transmitter repair work station. Dummy loads should be used for all test sets.

E. Documentation. Back at the office, analyze your data and formulate your final conclusions and recommendations. Prepare a letter or report and provide a copy to the unit RPO. File your data, photographs, drawings, correspondence, etc., for future reference in the case file. For measurement surveys, the back of the AF Form 2759 should be completed; additionally, we recommend inclusion of the data on the AF Form 2755. For all surveys, measurement or site inspection, a record of the visit should be recorded on the case file AF Forms 2759 and 2754. An additional copy or a summary of the data should be included in the RFR central inventory folder.

VII. INSTRUMENTATION

A. General. Just as complete knowledge of the emitter and its operation is essential to successfully complete a survey, a good understanding of the characteristics, capabilities, and limitations of survey instrumentation is equally important in determining the validity of survey results. There is a multitude of RFR survey instrumentation on the market today. Over the past

16 years AFOEHL and its predecessor organization have evaluated and field tested a wide variety of RFR power density instruments. At the present time, the AFOEHL inventory of instrumentation consists primarily of Narda Microwave Corporation devices; the majority of the instrumentation at base level is Narda devices as well. Narda instrumentation (and some of the other available devices) provide isotropic response by employing three mutually perpendicular sensing elements. This configuration results in accurate field measurements independent of probe position or polarization of the incident field. Other devices that implement horn antennas, single loops or dipoles, can provide accurate measurements if the field is polarized in a single plane and the operator has insured the orientation of the sensing element is the same. But, these devices cannot easily measure circularly polarized radar and have difficulty measuring near-field wave fronts where there can be both transverse and radial, electric and magnetic fields.

B. Narda Instrumentation

1. Design.

a. Narda electric field probes use a series of dipoles, while their magnetic field probes use a series of coils. These elements absorb and dissipate energy into thin-film thermocouple elements. The thermocouples' change in resistivity is proportional to the absorbed energy and ultimately the incident RFR field. These thermocouples typically have a slow response time in the order of 0.25 seconds. Because of the slow response of the thermocouple, the Narda instruments measure average power density and cannot measure peak power density of pulsed transmissions unless the pulse duration is greater than 0.25 seconds. The response time of the meter is even slower since the meter movement has high inertia.

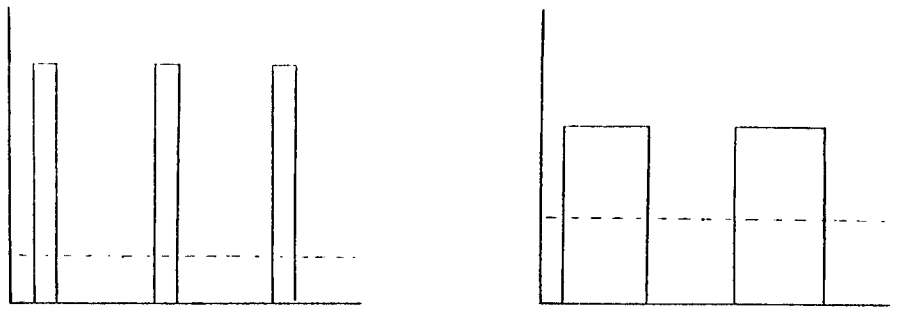
b. Due to the slow response of the Narda Meter Model 8611, it is difficult to measure radar with scanning beams. To solve this problem, most measurements of scanning radar are taken with the antenna fixed. With the Narda equipment at most bases, most BES are limited to measurements of spatially fixed beams. It is possible to obtain average main beam power density measurements of a scanned beam provided the probe is illuminated by the main beam for at least 0.25 seconds and one is using a Narda Meter Model 8616 with the maximum hold feature. It may be necessary to illuminate the probe for 3 to 4 scanning cycles to obtain a maximum measurement, but after this many scanning cycles the limitations of the meter movement inertia become negligible.

c. In 1988, Narda introduced the Model 8696 Averaging Module that monitors the Model 8616 meter movement voltage signal. The module samples at a rate of 500 samples/second and provides average power density measurements over selected temporal periods. This module is useful for measuring the average power density of a scanning beam.

2. Correction Factors. Narda probes are calibrated at many discreet frequencies. Probe correction factors are printed on the probe handle for different frequency points. If the particular emitter frequency is between two values, a correction value can be calculated by linear interpolation of the other two values. As an example, suppose one is measuring an emitter that operates at 4000 MHz and the probe correction factors for 3000 MHz and 5000

MHz are 0.90 and 0.95, respectively. Then, an appropriate correction factor for 4000 MHz is 0.925. Correction factors are multiplied by the meter reading to obtain actual power density.

3. Probe Burnout. The thin-film thermocouples are very sensitive elements that are susceptible to probe overload or burnout when exposed to very high power density fields. It is important to note that the probes are susceptible to burnout even if the meter is off or if the probe is disconnected. The maximum peak and average power densities the probe can withstand before burnout occurs are printed on the handle of the Narda probes. Probe burnout is not a real problem in making measurements of CW emissions because the probe burnout threshold is significantly higher than the maximum possible meter reading; as long as the surveyor is watching the meter and does not allow it to exceed a full scale deflection, one does not risk probe burnout. However, levels high enough to cause probe burnout are possible when making measurements of pulsed RFR signals with very short duty factors even at meter deflections less than the PEL and the full scale deflection value of the meter. In this case, the average transmitted power may be very low while the peak power is very high. If the peak power absorbed by the probe exceeds the peak overload value, the probe will fail even though the average power indicated by the meter is indicating a value less than full scale. See Figure 16 for a graphic description of this phenomena. Figure 16a illustrates an emission with a short duty factor; note the low average power represented by the dashed line. Figure 16b illustrates an emission with a long duty factor; note that even though the peak power in this case is less than that of Figure 16a, the average power is considerably larger.



a. Short Duty Factor **b. Long Duty Factor**

Figure 16: Representative RFR Signals

Equation 17, if used, can prevent a costly accident and a red face!

$$PD_{max} = DF \times BR / CF \qquad (17)$$

Where: PD_{max} = Maximum meter reading before burnout

DF = Duty Factor (Equation 3)

BR = Burnout Rating (Peak Power Density Rating)

CF = Correction Factor (Printed or probe handle for frequency of operation)

If PD_{max} is greater than full scale there is no cause for concern provided the surveyor does not exceed full scale. On the other hand, if PD_{max} is less than full scale reading, the surveyor must monitor the meter at all times. If the meter reading exceeds PD_{max}, even briefly, probe burnout is risked. Note these examples:

Example 1: PW = 2 μs, PRF = 360, DF = 0.00072, CF = 1

PD_{max} = [0.00072 x 300000 (8623 probe)]/1 = 216 mW/cm^2

Conclusion: Low risk of probe burnout since 216 mW/cm^2 is greater than full scale of 100 mW/cm^2 (8623 probe).

Example 2: PW = 0.25 μs, PRF = 800, DF = 0.0002, CF = 1

PD_{max} = [0.0002 x 300000 (8623 probe)] = 60 mW/cm^2

Conclusion: High risk of probe burnout since 60 mW/cm^2 is less than full scale of 100 mW/cm^2 (8623 probe).

The inability to zero an instrument is a telltale sign of a possible probe burnout. Test the probe cable for a possible wire break, since this condition can exhibit a like effect.

4. Zero Drift. Zero drift is inherent with instrumentation that utilizes thermocouples and other temperature sensitive components. Premature commencement of a survey without allowing the electronics to reach equilibrium and a change in ambient temperature during a survey are common causes of zero drift. To reduce errors from zero drift, we recommend:

a. Connect and turn instrumentation "on" at least 10 minutes before survey measurements are made. Locate instruments in the same environment you intend to survey--it doesn't make much sense to equilibrate instrumentation indoors if one intends to survey outdoors at a different temperature.

b. Periodically check the zero of an instrument during survey measurements, especially if one is moving between areas of significantly different ambient temperatures (sunny vs shaded). To re-zero instrumentation during a survey one can:

(1) Completely leave the RFR field.

(2) Completely shield the probe in a metal can or Narda instrument case if it provides shielding (most do!).

(3) Shield the probe with your body. Your body will effectively absorb signals with frequencies higher than 1000 MHz.

5. Out of Band Response. Potential measurement errors can occur when using a probe outside of its frequency range. Although this problem can occur with all probes, it is more marked in magnetic field probes due to periodic resonances above their rated band specification. If a signal coincides with an out of band resonance frequency of the probe, a high false meter indication may result. Electric field probes typically give a low false meter indication since resistive dipoles result in very damped resonances. Only use probes that have been calibrated and fully cover the emitter frequency range.

C. AFOEHL Equipment Loan

1. General. Most BES have a Narda 8611 meter and 8623 probe to perform RFR measurements. For the most part, this should be adequate for 90% of the required survey work. AFOEHL has a sizable inventory of Narda equipment for internal survey work and loan to other bases. Table 7 lists our current inventory of Narda equipment and features.

2. All requests for loan of Narda equipment should be made in writing unless it is an emergency request. Requests should be sent to:

AFOEHL/RZC	AV 240-3486
Brooks AFB TX 78235	Comm. (512) 536-3486,

along with emitter operating frequencies (unclassified only). Equipment should be returned to:

AFOEHL/ECH	AV 240-2142
Equipment Loan	Comm. (512) 534-2142.

Contact AFOEHL/RZC for all questions regarding equipment malfunction or technical capabilities.

3. For bases in PACAF or USAFE, be sure to coordinate first with your theater servicing laboratory.

Table 7: AFOEHL Equipment Inventory

Meters

Model No.	Inventory	Features
8611	23	Light weight, easy to use, adequate for most RF surveys.
8616	10	Recorder output, audible alarm, rechargeable batteries, max hold mode, AC/DC operation.

Accessories

Model No.	Inventory	Features
8696	4	Averaging module that allows measurement of RFR beams that are not spatially fixed, i.e., scanning beams.

Probes

Model No.	Type	Frequency Range	Power Density Ranges (mW/cm^2)	Inventory
8621B	Electric Field	300 MHz - 26 GHz	0.2, 2, 20	4
8623B	Electric Field	300 MHz - 26 GHz	1, 10, 100	31
8631	Magnetic Field	10 - 300 MHz	0.2, 2, 20	9
8633	Magnetic Field	10 - 300 MHz	1, 10, 100	11
8635	Magnetic Field	10 - 300 MHz	10, 100, 10000	1
8652	Magnetic Field	300 kHz - 10 MHz	2, 20, 200	17
8662	Electric Field	300 kHz - 300 MHz	2, 20, 200	6
8662B	Electric Field	300 kHz - 1000 MHz	2, 20, 200	6
8612	Electric and Magnetic Field	13 - 41 MHz	5, 50	5

VIII. THE RFR ACCIDENT

A. I've Been Zapped!

1. When the subject of an RFR accident comes up at your base, there is one fundamental question that must be answered before you proceed. Is the person involved curious about their work area being hazardous or is the person saying, "I've been overexposed!"? Before an investigation takes place someone must make an allegation. Even though someone swears they've been overexposed,

it isn't necessarily true. On the other hand, if someone says it happened, there's no recourse but to investigate the incident.

2. The reasons you have to proceed with the investigation should be fairly obvious. If the person was, in fact overexposed, we want to know about the details in order to provide proper medical attention. On the other hand, if the person was not overexposed, the findings of the investigation should help alleviate any anxiety held by any individual; the investigation should allow the BES to prevent future incidents by providing education. Additionally, an investigation is necessary for potential future legal problems.

3. The benefits of a good RFR emitter inventory and baseline survey show through during a suspected overexposure incident. If the BES has performed a thorough inventory and baseline on all potentially hazardous emitters, BES should be able to make an initial determination of exposure received to individuals once the workplace supervisor or unit RPO calls with initial data. In fact, from our experience, a majority of the incidents reported to us had absolutely no potential for overexposure and could have been resolved by a telephone conversation between the BES and the reporting workplace if the BES had good documentation in their case file. Even in these cases, it is good practice to make a site visit at the minimum. In the majority of these cases, the individuals reported no symptoms, rather their claims where based on confusion and fear, ultimately the lack of RFR education.

B. Who Does What?

1. Now let's suppose that you have determined that someone definitely claimed that he has been overexposed. There is a precise set of steps to follow. There are three things that should be taken care of...right now.

a. Make sure the individual reports to the flight surgeon or other available physician for a physical exam (see AFOSH Std 161-9). EHS completes an AF Form 190 in detail, correctly describing the subjective symptoms and any findings of the examination. Be careful with the wording. If one were to say, "individual was treated for a pounding headache and twitching eye because he received a massive dose of microwave radiation," you have opened the door to all kinds of trouble. Instead, "individual complains of a headache and irritated eyes and claims they are the result of his microwave exposure" would be better. The main thing is to be sure the description is correct and factual. Most of the time it is the physician's responsibility to write the narrative on the AF Form 190, this is where a good working relationship between EHS, BES, and the flight surgeon helps.

b. Next, as soon as possible get a signed narrative statement from the individual exposed and any others involved like operators or maintenance personnel who were present when the incident occurred. By the way go over these statements and make sure they are legible and make sense.

c. If desired call AFOEHL/RZC, AUTOVON 240-3486, and discuss the incident with us. We can help insure that there are no steps overlooked and advise you on how to proceed. For PACAF and USAFE bases, please contact your theater servicing lab first.

2. Some BES prefer to do their own investigations. That is fine; we are more than willing to give you telephone consultation if needed. If you determine that you do not have the ability to perform the investigation, AFOEHL is willing to investigate the incident; all requests for our assistance must be forwarded through your major command BEE. We will respond, when requested, as soon as physically possible, usually within two or three days, sooner, if necessary.

C. Investigate and Reconstruct.

1. If you choose to handle the entire matter yourself, here is the rest of your obligation.

a. Taking care to protect yourself and your instrument, reconstruct the incident. Make measurements with the system set up, as nearly as possible, as it was when the incident occurred. It may be that the power density at the point of exposure is greater than the measuring capability of your instrument (Narda 8623B, Max Scale = 100 mW/cm^2). If this is the case you should make multiple measurements starting at, say, 10 mW/cm^2 and move up in increments until you reach the limit. These data can be plotted on semi-log paper and the actual exposure value can be estimated by extrapolation. Also, AFOEHL has Narda 8644S probes that allow measurements up to 2000 mW/cm^2. These probes are being phased out, but a new probe that will allow measurements up to 1000 mW/cm^2 will replace them. In either case, this equipment can be borrowed from AFOEHL.

b. When determining the total exposure, you must know the duration of the exposure. This can be very tricky, because the time estimates of the exposee and witnesses are usually very exaggerated. Ask the exposee to repeat his actions and use a stop watch to get a better idea of the actual exposure time. The shorter the time, the more important this becomes.

c. Photographs are a very important part of your investigation. With the transmitter shut down, ask everyone to position themselves exactly as they were during the incident. Then take photographs from a few different angles. You can have the base photo lab do the photography, but you must tell them exactly what you want.

D. Crucial Documentation. Like all gratifying and rewarding jobs, this one is not finished until the paperwork is done. That's right--you must write a report. In your report, BES should detail the case as far as <u>what</u> happened, to <u>whom</u>, <u>when</u>, and <u>where</u>. You should tell what you did, how you did it, what you concluded, and what follow-up action you recommend. All this must be completed in 30 days! BES provides the report to the EHS, who then has 45 days to summarize the entire investigation (see AFOSH Std 161-9 for report requirements) and distribute it.

E. A Calming Influence. Last, but by far not least, this advice: keep your cool. You should have a calming influence on those around you. Don't show surprise at a high level reading or give your suppositions about the medical implications of the exposure. Avoid actions that only result in fanning the flames of a fire. People tend to think and expect the worst. Some suspect that the "system" will try to cover the truth. Your bearing and

attitude will go a long way to relieve anxieties and calm fears. Be frank, open, confident, and reassuring.

IX. THE VOICE OF EXPERIENCE

A. Most of Your Work.

1. By now you have probably realized that the most difficult part of setting up an RFR program is getting started--putting together that emitter inventory and making the initial surveys. Once you have this behind you, the rest falls easily in place. Most of the work is getting out and finding just where things are and how to control them.

2. When you have a feel for your emitters and their hazard-producing potential, you will also have a feel for which emitters will require survey work. If an emitter, regardless of size and output power, is located so that it is normally inaccessible, there is no need to break your neck trying to make measurements.

B. Your Knowledge Should Go A Long Way.

1. We encourage you to proceed with confidence. Take time periodically to review the guidelines we've given you. You have all you need to develop a very successful RFR protection program. If you run into a snag, we're as close as your telephone.

2. With every increasing public and command-level interest in RFR protection, the pressure is on the base level aerospace medical team to establish and conduct a viable program. In this guidebook you have the information you need to get well underway. With a little concentrated effort, your knowledge should go a long way.

APPENDIX A

Conversion Between Absolute Units and Decibel Units

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Conversion Between Absolute Units and Decibel Units

Absolute	dB	Absolute	dB	Absolute	dB
1.26	1.0	125.89	21.0	12589.25	41.0
1.41	1.5	141.25	21.5	14125.38	41.5
1.58	2.0	158.49	22.0	15848.93	42.0
1.78	2.5	177.83	22.5	17782.79	42.5
2.00	3.0	199.53	23.0	19952.62	43.0
2.24	3.5	223.87	23.5	22387.21	43.5
2.51	4.0	251.19	24.0	25118.86	44.0
2.82	4.5	281.84	24.5	28183.83	44.5
3.16	5.0	316.23	25.0	31622.78	45.0
3.55	5.5	354.81	25.5	35481.34	45.5
3.98	6.0	398.11	26.0	39810.72	46.0
4.47	6.5	446.68	26.5	44668.34	46.5
5.01	7.0	501.19	27.0	50118.72	47.0
5.62	7.5	562.34	27.5	56234.13	47.5
6.31	8.0	630.96	28.0	63095.73	48.0
7.08	8.5	707.95	28.5	70794.58	48.5
7.94	9.0	794.33	29.0	79432.82	49.0
8.91	9.5	891.25	29.5	89125.09	49.5
10.00	10.0	1000.00	30.0	100000.00	50.0
11.22	10.5	1122.02	30.5	112201.85	50.5
12.59	11.0	1258.93	31.0	125829.54	51.0
14.13	11.5	1412.54	31.5	141253.75	51.5
15.85	12.0	1584.89	32.0	158489.32	52.0
17.78	12.5	1778.28	32.5	177827.94	52.5
19.96	13.0	1996.26	33.0	199526.23	53.0
22.39	13.5	2238.72	33.5	223872.11	53.5
25.12	14.0	2511.89	34.0	251188.64	54.0
28.18	14.5	2818.38	34.5	281838.29	54.5
31 62	15.0	3162.28	35.0	316227.77	55.0
22 39	15.5	3584.13	35.5	354813.39	55.5
39 81	16.0	3981.07	36.0	398107.17	56.0
44.67	16.5	4466.84	36.5	446683.59	56.5
50.12	17.0	5011.87	37.0	501187.23	57.0

Absolute	dB	Absolute	dB	Absolute	dB
56.23	17.5	5623.41	37.5	562341.33	57.5
63.10	18.0	6309.57	38.0	630957.34	58.0
70.79	18.5	7079.46	38.5	707945.78	58.5
79.43	19.0	7943.28	39.0	794328.23	59.0
89.13	19.5	8912.51	39.5	891250.38	59.5
100.00	20.0	10000.00	40.0	1000000.00	60.0
112.20	21.5	11220.18	40.5		

APPENDIX B

Instructions for Completing AF Form 2759, Radiofrequency Emitter Survey

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Instructions for Completing the AF Form 2759, Radiofrequency Emitter Survey

Note: Do not enter classified data on this form.

Header Information

Workplace Identifier: Leave blank.

Base: Complete base name and state or country.

Organization: Official organization name, spelled out.

Workplace: Common name for this workplace.

Bldg No./Location: Include sufficient data for easy location of the building site.

Room/Area: Include sufficient data for easy location of the workplace.

Contact Points: Indentify name, grade, position, organization/symbol, and extension of the OIC, NCOIC, Unit RPO, Shop Supervisor, etc., as applicable.

Numbered Blocks--Data are entered vertically, maximum of four emitters per page.

1. **Nomenclature:** The official nomenclature for the system. If none is assigned, enter the manufacturer and model number or other identifying data.

2. **Description:** Give common names, emitter function, major system it is associated with, and remarks about any special configuration. If space is lacking, continue on the back side.

3. **Quantity:** The number of emitters of this description in this workplace.

4. **Frequency:** The frequency of operation of the emitter, in megahertz.

5. **Pulse Width:** The pulse width in microseconds. If more than one value is used, give the one that results in the highest duty factor. Enter "CW" if the output is continuous wave.

6. **PRF:** The pulse repetition frequency in pulses per second (hertz). If more than one value is used, give the one that results in the highest duty factor. Enter "CW" if the output is continuous wave.

7. **Peak Power:** The peak transmitter output power in kilowatts.

8. **Antenna Code:** Indentify the type of antenna with one or more of these codes:

RR--Rectangular Reflector	RH--Rhombic
CR--Circular Reflector	YA--Yagi or Yagi Array
PA--Phased Array	MO--Monopole or Colinear Array
BL--Blade	DP--Dipole or Dipole Array
HO--Horn	DC--Discone
SL--Slots/Slot Array	DI--Discage
HE--Helix	ST--Stub
LE--Lens	DL--Dummy Load
WH--Whip	LO--Loop
VL--Vertical Log Periodic	OD--Other, Directional
HL--Horizontal Log Periodic	OO--Other, Omnidirectional

9. **Antenna Size:** (Aperture-type antennae only). The horizontal and vertical maximum dimensions of the antenna in feet. For circular apertures give the diameter only.

10. **Antenna Beam Widths:** The horizontal and vertical far-field widths of the radiated field in degrees.

11. The horizontal and vertical far-field beam widths of the radiated field in degrees.

12. **Scanning Code:** Use one or more of the following to describe the motion of the antenna beam:

F--Fixed	S--Sector Scan (Mechanical)*
R--Rotating, 360 degrees	E--Sector Scan (Electronic)*
T--Tracker	* Note: If S or E is entered, also enter the width in degrees of the scanned sector.

13. **Scan Rate:** Give the number of complete scanning cycles per minute. For beams or trackers, leave blank.

14. **Estimated Hazard Distance:** The estimated hazard distances in feet theoretically derived. Indicate one of the following in parenthesis in addition to the numerical distance:

F--Far-field Formula

N--Near-field Correction Applied

T--Extracted from T.O. or manufacturer's data sheet

O--Other source (Detail on back)

15. **Hazard Code:** Select one or more of the following codes to describe the hazard category into which this emitter falls:

NH--No levels generated in excess of the PEL.

IH--Hazardous levels possible, but in normally inaccessible areas.

CH--Hazardous levels possible, but only in areas that require climbing.

GH--Ground-level hazardous exposures possible.

DL--Transmitter dummy loaded.

SH--Hazardous levels possible, but transmission time is too short for overexposure.

MD--Medical device; no levels generated in excess of the PEL.

MH--Medical device; levels generated in excess of the PEL.

16. **Hazard Control Code:** Select one or more of the following codes to describe the recommended controls for this system:

AS--Audible signal

FL--Flashing lights

LF--Locked fence

FE--Fence

WS--Warning signs

BA--Rope or chain barrier

CO--Constant observation when transmitting

SC--Special coordination when transmitting

SO--Standard operating procedure in effect

OM--Other (describe on back of form)

NR--No control required

17. **Hazard Distance Measurements:** Indicate measured hazard distances and dates surveys were performed. Include cross-reference to detailed survey data elsewhere, if desired. Can be from previous survey (AFOEHL, 1839 EIG).

RADIOFREQUENCY EMITTER SURVEY	DATE (YYMMDD)	WORKPLACE IDENTIFIER

(Use this space for mechanical imprint)

BASE	ORGANIZATION
WORKPLACE	
BLDG NO / LOCATION	ROOM / AREA

NAME OF KEY CONTACT	GRADE	POSITION	ORGANIZATION/OFFICE SYMBOL	DUTY PHONE

HAZARD EVALUATION AND CONTROL DATA

NOMENCLATURE				
DESCRIPTION				
LOCATION OF EMITTERS				
QUANTITY				
FREQUENCY (MHZ)				
PULSE WIDTH (microsec.)				
PULSE REPETITION FREQ (pps)				
PEAK POWER (KW)				
ANTENNA CODE				
ANTENNA SIZE (ft.) (hor. / ver.)				
ANTENNA BW (deg) (hor. / ver.)				
ANTENNA GAIN (dB)				
SCANNING CODE				
SCAN RATE (rpm)				
ESTIMATED HAZARD DISTANCE (ft)				
HAZARD CODE(S)				
HAZARD CONTROL CODE(S)				
HAZARD DISTANCE MEASUREMENTS (ft)				

PREPARED BY (Name, Grade, AFSC)	REVIEWED BY (Name, Grade, AFSC)

AF FORM 2759 JAN 82

APPENDIX C

RFR Emitter Survey Data Base

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RFR Emitter Survey Data Base

The following list of emitters is organized by nomenclature and cross-referenced by report reference number. Also included in the list are typical hazard codes (HC), typical hazard distances (HD), and common deployment platforms for the emitter. Remember, all of the values are for "typical" configurations of the emitter. Most emitters in the Air Force inventory have multiple configurations (i.e., different antennae, waveguides, or power levels) possible depending on the deployment platform. We have also seen a wide variety of local modifications (mostly of ground based emitters). Any modification of the emitter is likely to change the accessible radiation levels, the hazard distance, or the necessary controls.

NOMENCLATURE: The nomenclature of the emitter. Most nomenclatures are standard AN nomenclatures (we left the AN/ off).

ALTERNATE: Alternate nomenclature, nickname, or common name for the emitter.

RPT. REF. NO.: A code that refers to a report that AFOEHL/RZC has on file. Most of the reports contain the parameters of the system and documented field measurements of the emitter. The prefix is a code that corresponds to the agency that generated the report (see key below). The suffix corresponds to the generating agency's report reference number.

CODE	GENERATING AGENCY
OEHL	AF Occupational and Environmental Health Laboratory (AFOEHL), Brooks AFB TX 78235-5501
WIES	Environmental Health Lab (Lindsey AS, GE) 7100 Combat Support Wing Medical Center/SGB APO New York 09220-5300
OLAD	AFOEHL Operating Location, Clark AFB RP OL AD, AFOEHL APO San Francisco 96274-5300
1839	1839 Engineering Installation Group (AFCC) Keesler AFB MS 39534
485	485 Engineering Installation Group (AFCC) Special Engineering Section Griffiss AFB NY 13441
1843	1843 Engineering Installation Group (AFCC) Hickam AFB HI 96853-6348
1845	1845 Electronics Engineering Squadron Special Engineering Branch Oklahoma City AFS OK 73145

EM. TYPE: A code specifying the primary use of the emitter.

CODE	PRIMARY USE
COMM	Communications emitters. Vocal transmitters, telegraphy, telemetry, etc.
ECM	Electronic countermeasures, both radar and communications countermeasures.
FLR	Forward-looking radar. Generally, airborne multimode, tracking, search, weather avoidance radar mounted on the front of the aircraft.
TEST	Radar or communications test assemblies.
NAV	Navigational aids including radar altimeters and Doppler radars.
WTHR	Weather detection/avoidance radar.
FCR	Fire control radar. Primarily for detection and suppression of hostile fire.
SRCH	Search/detection/tracking radar.
APPR	Aircraft approach control radar.
IFF	Interrogate friend or foe transponder.

HC: Hazard code. Code which specifies typical hazard category. Can be used on AF Form 2759, Radiofrequency Emitter Survey.

HD (feet): A typical hazard distance in feet.

PLATFORM: Deployment of the emitter (by aircraft if applicable).

Nomenclature	Alternate	Rpt. Ref. No.	Em. Type	HC	HD (feet)	Platform
618T-1		OEHL 84-080	COMM			C-9A,C-9C,KC-10A
ALQ-101-(V)10		OEHL 80-3	ECM	GH 5		RF-4C,A-7D/K,F-4C/D/E/G,F-111A/D/F
ALQ-119	ECM POD	OEHL 80-41 OEHL 81-34 OEHL 81-48 OEHL 85-113 OEHL 85-179	ECM	IH 4		A-10A,A-7D/K,EF-111,F-111A/D/E/F,F-15A/B/C/D, F-16A/B/C/D,F-4C/D/E/G,RF-4C
ALQ-13[illegible]	ECM POD	WIES 88-06	ECM			A-10A,A-7D/K,EF-111,F-111A/D/E/F,F-15A/B/C/D, F-16A/B/C/D,F-4C/D/E/G,RF-4C
ALT-28		OEHL 81-25 OEHL 81-39	ECM	GH 15		B-52G/H
APA-165		OEHL 83-026 OEHL 84-235	FLR	GH 100		4-FD
APG-63		OEHL 80-26 OEHL 83-204	FLR	GH 250		F-15A/B/C/D,F-4D
APG-66		OEHL 83-204	FLR	GH 56		F-16A/B
APM-427		OEHL 85-086	TEST	GH 10		SHOP
APN-147		OEHL 84-080	NAV	NH 0		C-130A/B/E/H,C-141A,EC-130E/H,AC-130A/H,HC-13 0H/N/P,LC-130H,MC-130E,NC-130H,ETC.
APN-159		OEHL 80-36	ALTI			RF-4C
APN-218		OEHL 83-105	NAV	NH 0		B-52G/H MOST CONFIGURATIONS C-130,C-135
APN-59		OEHL 81-20	WTHR			C-130
APN-598		OEHL 81-31	WTHR			C-141
APN-59E		OEHL 80-31 OEHL 84-080	WTHR	IH 22		MOST CONFIGURATIONS C-130,C-135
APN-69		OEHL 80-31	NAV	NH		B-52G/H, MOST CONFIGURATIONS C-135
APQ-120		OEHL 81-06 1843 87-09	FCR	GH 85		F-4E/G
APQ-122		OEHL 82-028	FLR	GH 32		C-130H,NC-135A
APQ-122(V)7		OEHL 80-25	FLR	CH 27		T-43A
APQ-122(V)8		1843 87-09	FLR			MC-130E
APQ-126		OEHL 80-25	FLR	GH 18		A-7D/K

Nomenclature	Alternate	Rpt. Ref. No.	Em. Type	HC	HD (feet)	Platform
		OEHL 81-20				
APQ-128	TERRAIN FOLL. RADAR	OEHL 87-105	NAV	GH	12	F-111D
APQ-130		OEHL 81-13	FLR	GH	85	F-111D
APQ-153		OEHL 85-026	FCR	GH	17	F-5E
APQ-159		OEHL 85-026	FCR	GH	17	F-5F
APQ-99		OEHL 80-5 OEHL 83-300 OEHL 80-40 OEHL 87-057 OEHL 80-56,	FLR	GH	20	RF-4C
APS-113		OEHL 80-36	WTHR	IH	6	CT-39A,T-39A
APS-133		OEHL 85-020	FLR	GH		C-141A/B,C-5A/B,E-3A/B/C,E-4B,KC-10A,NC-141A
APY-1	AWACS	1839 84-37	SRCH	IH	1300	E-3A/B
ARC-105		OEHL 80-36	COMM	SH	3	RF-4C
ARC-123		OEHL 80-4	COMM	SH	10'	F-111D/E/F,FB-111A
ARC-164		OEHL 80-31 OEHL 80-36 OEHL 80-31 1843 87-09 OEHL 84-080	COMM	NH	0	NUMEROUS AIRCRAFT
ARC-165		OEHL 81-18	COMM	GH	0.5	E-3A/B/C
ARC-186		OEHL 84-080 485 85-41	COMM	IH	6	NUMEROUS AIRCRAFT
ARN-118	TACAN	OEHL 81-20 OEHL 84-080	NAV	NH	0	NUMEROUS AIRCRAFT
ARSR-3		1839 80-10 1845 81-05 1839 80-26 1839 80-50 1839 80-32 1839 80-29 1839 81-5 1839 83-36 1839 81-01 1839 82-13	SRCH	CH	300	GROUND
COLLINS 208U-10		OEHL 85-042 OEHL 80-32 OEHL 81-18	COMM	GH	20	GROUND

Nomenclature	Alternate	Rpt. Ref. No.	Em. Type	HC	HD (feet)	Platform
FPN-62		OEHL 81-12	APPR	NH	0	GROUND
		1839 81-23				
		1839 81-27				
FPQ-14		OEHL 82-7	SRCH	GH	3200	GROUND
		1839 86-13				
FPS-108	COBRA DANE	OEHL 85-025	SRCH	GH		GROUND
		OEHL 85-049				
FPS-115	PAVE PAWS	1839 87-21	SRCH	GH	50	GROUND
FPS-116	HEIGHT FINDER	1839 85-33	SRCH	CH	360	GROUND
FPS-117	SEEK IGLOO, MAR	1839 88-17	SRCH	CH	570	GROUND
		1839 85-19				
		1839 88-14				
		1839 82-43				
		1839 88-01				
		1839 85-02				
		1839 82-05				
		1839 84-57				
		1839 84-50				
		1839 84-41				
		1839 84-48				
		1839 84-28				
		1839 84-27				
		1839 84-56				
		1839 86-12				
FPS-118	OTH-B	OEHL 86-075	SRCH	NH	<1	GROUND
		1839 80-18				
		1839 87-37				
		1839 87-34				
FPS-19		1839 87-36	SRCH	CH		GROUND
FPS-50	BMEWS	OEHL 85-105	SRCH	IH		GROUND
FPS-64A	FPS-20	OEHL 86-009	SRCH	IH		GROUND
FPS-65A	FPS-20	1839 84-30	SRCH	IH		GROUND
FPS-67B	FPS-20	1845 81-03	SRCH	IH		GROUND
		1839 84-26				
		1839 81-10				
FPS-77		1843 87-09	SRCH	IH	50	GROUND
		1839 83-28				
		1839 81-24				
		1839 81-27				
		485 81-09				

Nomenclature	Alternate	Rpt. Ref. No.	Em. Type	HC	HD (feet)	Platform
FPS-90	HEIGHT FINDER	1839 80-10	SRCH	CH	20	GROUND
		1839 83-48				
		1839 83-07				
		1839 81-53				
		485 81-20				
		1839 81-10				
		1845 81-03				
		1839 83-47				
		1839 82-26				
		1839 80-32				
		1839 80-50				
		1839 80-26				
		1839 83-49				
FPS-91A	FPS-20R	OEHL 81-22	SRCH	IH	340	GROUND
		1839 84-07				
		1839 85-33				
		1839 85-27				
		1839 81-34				
		485 81-23				
		485 81-24				
		485 81-25				
		485 82-05				
		1839 81-22				
		1839 83-40				
		1839 86-33				
FPS-92	BMEWS	OEHL 85-105	SRCH	CH		GROUND
FPS-93	FPS-20	1839 83-49	SRCH	IH		GROUND
		1839 83-48				
		1839 83-47				
FRC-109		OLAD 86-041	COMM	CH		GROUND
FRC-117		OEHL 81-50	COMM	GH	10	GROUND
FRC-170		485 84-3	COMM	NH	0	GROUND
GPN-20		1839 80-5	SRCH	CH	105	GROUND
		1839 84-46				
		1839 80-47				
		1839 83-28				
		485 84-31				
		1845 81-01				
		1843 87-09				
GPN-22		OEHL 81-28	APPR	CH	205	GROUND
		485 81-11				
		1839 83-28				
		1839 84-38				
		1843 87-09				
		1839 80-5				

Nomenclature	Alternate	Rpt. Ref. No.	Em. Type	HC	HD (feet)	Platform
GPN-62B	PAR	1839 84-46	APPR	NH		GROUND
GPS-10		OLAD 86-038	SRCH	GH		GROUND
GRC-106		WIES 82-27	COMM	GH	17	VEHICLE
GRC-158		485 85-33	COMM	GH	5	GROUND
GRC-171		OEHL 80-56	COMM	CH		MOBILE
		OEHL 85-021				
		485 84-5				
		OEHL 85-066				
		OEHL 84-080				
		485 83-21				
		485 83-27				
GRC-175		485 85-41	COMM	IH		GROUND
		485 84-5				
GRC-211		1843 87-09	COMM	IH		GROUND
		485 85-41				
GRN-19A		1843 87-09	NAV	IH		GROUND
GRN-20B	TACAN	OEHL 80-56	NAV	IH		GROUND
		1839 84-14				
GRN-27	ILS	1839 87-15	APPR	NH		GROUND
GRN-29	ILS LOCALIZER	1839 87-15	APPR	NH		GROUND
GRN-31	ILS GLIDESLOPE	1839 87-15	APPR	NH	0	GROUND
GRT-21		1839 86-08	COMM	SH	3	GROUND
		485 84-2				
		485 84-5				
		485 83-21				
GRT-22		1839 86-08	COMM	SH	4	GROUND
		485 84-2				
		485 84-5				
		485 83-21				
GSC-42	SATELLITE TERMINAL	1839 84-58	COMM	IH	0.1	GROUND
GSC-49	DSCS EARTH TERM.	485 88-1	COMM	GH	15	GROUND
		485 85-14				
		485 85-08				
		485 85-05				
		OEHL 85-103				
		485 85-04				
		1839 84-58				
		485 85-06				
		485 85-07				

Nomenclature	Alternate	Rpt.	Ref. No.	Em. Type	HC	HD (feet)	Platform
		485	87-13				
		485	85-13				
		485	85-10				
		485	85-09				
GSC-52	SAMT	1839	87-22	COMM	NH		GROUND
		485	87-21				
MLQ-T4		OEHL	84-086	ECM	GH	88	MOBILE
		1839	88-08				
		1839	88-08				
MPN-13		OEHL	80-5	APPR	IH	60	MOBILE
		485	81-09				
MPS-T1		OEHL	82-3	SIM	CH	120	GROUND
		1839	88-09				
		1839	88-05				
		1839	83-14				
		1839	82-31				
MSQ-77		OEHL	84-086	ECM	IH	330	GROUND
		1839	88-09				
		1839	88-09				
MST-T1A	MUTES	OEHL	86-070	SIM	GH	350	GROUND
		1839	88-09				
		1839	88-08				
		1839	88-06				
		OEHL	87-156				
		1839	81-18				
SGL3-46	SPACE-GND LINK SYS.	1839	86-21	COMM	IH		GROUND
		1839	86-13				
		1839	85-17				
SGL3-60	SPACE-GND LINK SYS.	1839	86-21	COMM	IH		GROUND
		1839	87-22				
		1839	86-13				
		1839	86-01				
		1839	85-17				
		1839	86-03				
TLQ-11		OEHL	87-156	ECM	CH	5	MOBILE
		1839	88-06				
		1839	88-08				
		1839	82-31				
TPQ-43		OEHL	87-156	SRCH	IH	2	GROUND
		1839	88-09				
		1839	82-31				
		1839	88-07				
		1839	88-06				
		1839	88-05				

Nomenclature	Alternate	Rpt.	Ref. No.	Em. Type	HC	HD (feet)	Platform
		1839	88-08				
		1839	88-09				
TPS-43		OEHL	83-123	SRCH	GH	500	GROUND
TRC-97C		OEHL	85-104	COMM	GH	275	MOBILE
UPX-6		1839	88-07	IFF	NH		GROUND
		1839	88-05				
		1839	83-14				
URC-103(V)		485	85-31	COMM	IH	15	GROUND
URC-79		485	85-29	COMM	GH	15	GROUND
		485	85-18				
VLQ-5	COMFY SWORD III	1839	87-04	ECM	GH	40	VEHICLE
		1839	86-29				
WILCOX 807		1843	87-09	COMM			OV-10A
WSF-74C	ORR	485	86-16	WTHR	IH		GROUND
		485	86-13				
		485	86-12				
		485	86-11				
		485	86-8				
		485	86-14				
		485	86-15				

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APPENDIX D

Survey of Ground Based Emitters

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Survey of Ground Based Emitters

1. These systems will generally bear "AN" nomenclatures beginning with the letter F, M, G, or T, denoting the following (with examples):

   a. Fixed (AN/FPN-47, AN/FPS-116, AN/FRT-49)

   b. Mobile (AN/MPN-14, AN/MPS-9, AN/MRC-113)

   c. Ground (AN/GPN-12, AN/GRC-75, AN/GRN-9)

   d. Transportable (AN/TPS-43, AN/TRC-97, AN/TPB-1B)

2. Ground mounted radar systems are sometimes capable of operating in more than one mode. It is, therefore, vital that during the presurvey, careful consideration be given to all of the possible modes to insure that measurements will be made with the system operating in the mode that will create the "worst case" (highest peak power, highest duty factor, and narrowest beam configuration).

3. A visual inspection of the site should be made to determine if the main radiated beam is normally accessible to personnel. If not, then there is no hazard, but it must be recognized that there may be future modifications of either the emitter itself or the environment that may make the beam accessible.

4. If the main beam is normally accessible to personnel, antenna rotation (if applicable) must be stopped and access to the main beam gained at a distance from the antenna determined during presurvey. The beam size, shape, and character should be determined, then the actual PEL level should be located. In order to assure that meter readings are accurate, care must be taken to keep the probe handle parallel to the beam axis, or perpendicular to the emitter surface as appropriate. In addition, try to avoid beam reflection from nearby objects.

5. Regardless of whether or not the main beam is normally accessible, the area surrounding the antenna itself should be carefully probed for possible hazardous levels of energy, as well as a determination made as to what might be required for personnel to access hazardous levels in the immediate vicinity of the antenna.

   WARNING: When surveying aperture type systems, the area between the feedhorn and the reflector is normally very dangerous, both to personnel and to the RFR power density probes.

6. Operating personnel should be asked to accurately determine the <u>actual</u> power input value at the time measurements were made. Many ground systems have integral directional couplers and power meters available for this purpose.

7. An inspection should be conducted to determine if the system under evaluation has adequate interlock mechanisms, and ascertain if they can be or are regularly bypassed for routine maintenance purposes.

8. A visual inspection should be made to determine if there are RFR warning signs (AF Forms 737 or 747) in sufficient numbers, and at appropriate locations.

9. Operations and maintenance personnel should be interviewed relative to their acquaintance with the potential health hazards associated with radio frequency radiation emissions. It is often possible to gain further insight into this topic by observing the activities of these personnel as they go about their normal activities. Technical Orders for each emitter being evaluated should be reviewed for the presence and adequacy of warnings to personnel regarding these hazards. It should also be determined if there are up-to-date written operating and accident reporting standard operating procedures (SOPs) that provide acceptable personnel protection. SOPs are more important than the TO as far as review by BES is concerned.

APPENDIX E

Survey of Airborne Emitters

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Survey of Airborne Emitters

1. These systems usually bear "AN" nomenclatures beginning with the letter A, like AN/APQ-120, AN/APN-59B, AN/APG-63, AN/ASG-21, etc. There are, however, a number of atypical nomenclatures like MA-1, MD-9, R-14C, Multimode, etc. During the presurvey phase of an evaluation, an assessment must be made to be certain that no emitters of interest have been overlooked because of an atypical nomenclature.

2. When airborne systems are live-fired on the ground, the main beam is almost always normally accessible to personnel, and the possible hazards must be recognized by both operating and survey personnel prior to measurements.

3. Airborne antennas, in general, and RADAR antennas especially are often at or very near eye-level, and it must be recognized that, in the normal course of operations, the main beam is often directed downward.

4. Airborne RADAR systems are often capable of operating in many modes. It is vital that an adequate presurvey analysis be accomplished to insure that measurements will be made with the system operating in the mode that will create the "worst case" (highest average power output and narrowest beam widths).

5. When surveying airborne systems, it is essential that the aircraft be positioned with an ample clear area in front of the antenna to preclude unnecessary radiation of other aircraft, vehicles, buildings, etc. This distance should be determined during the presurvey. The antenna should be stopped and positioned dead ahead in azimuth, and at zero degrees or slightly above in elevation. This last point is necessary to prevent reflections from the ground and thus create unwanted, unpredictable, and possibly dangerous "hot spots."

6. The antenna should be approached from a known safe distance (based on calculations or other source) and the main beam located. Once found, its size, shape, and other characteristics should be determined, then the boundaries for the PEL should be determined. Care must be taken to maintain the probe along the main beam axis.

7. The area immediately surrounding the antenna (to the side and behind) should be probed for hazardous side lobes and back scatter. These are not commonly seen. As with ground aperture systems, the area between the feedhorn and the reflector is very dangerous and should be avoided by both the survey instrument and personnel.

8. It is highly desirable to evaluate a minimum of three transmitters (three different aircraft) of a given emitter. In addition, actual power input values should be obtained from operating personnel if possible. Many airborne systems have integral direction couplers for this purpose.

9. The potential for personnel RFR hazards in the avionics maintenance shops is great. Most systems are ordinarily fired into dummy loads in the shops,

but some require actual radiation through an antenna. In the former case, the dummy loads should be evaluated for effectiveness, in the latter case, the evaluation should be similar to that of an aircraft mounted system and should include a careful evaluation for possible reflections and scattering within the shop area. An inspection should be conducted to make certain that the area immediately in front of any radiating antenna is off limits to personnel, vehicles, etc., to a distance appropriate for the emitter.

10. The shop area should be inspected for the presence of AF Forms 737 or 747 RFR warning signs (if warranted) in sufficient numbers and at appropriate locations.

11. Both operation and maintenance personnel should be interviewed relative to their acquaintance with the potential health hazards associated with radio frequency emissions. In addition, it will be useful to observe their activities in the shop and on the flight line to gain some perception of their attitudes regarding these hazards.

12. Technical Orders for each emitter being evaluated should be reviewed for the presence and adequacy of warning to personnel regarding RFR hazards. It should also be determined if there are up-to-date written operating and accident reporting SOPs that provide acceptable personnel protection.

13. During flight line measurements, observations should be made to determine if there are adequate and effective procedures to protect personnel during routine ground firing of these systems.

APPENDIX F

Survey of Medical RFR Emitters

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Survey of Medical RFR Emitters

1. The most common medical RFR emitter is the diathermy machine. These units can usually be found in the physical therapy section of USAF Hospitals and clinics. Medical diathermy machines in the U.S. are authorized to operate on a number of frequencies, but by far the most common are 13.56 and 27.12 MHz (short wave diathermy) and 2450 MHz (microwave diathermy). Most units within the Air Force Medical Service are short wave diathermy.

2. The prime concern in evaluating diathermy units is NOT with the patient undergoing treatment, since it is assumed the therapy is being administered by or under the supervision of competent medical personnel. There are some potential hazards to operators of this equipment, particularly the S-band units (2450 MHz). Evaluation may be necessary to be assured that the therapists operate the equipment in a manner that will not cause them to be unnecessarily exposed, particularly to the head and shoulders.

3. It is important to note that the proper equipment for measuring short wave diathermy units is not available at most bases. Necessary equipment can be loaned from AFOEHL.

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APPENDIX G

Radio Frequency Radiation Survey Checklist

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Radio Frequency Radiation Survey Checklist

Presurvey Phase

Contact person(s) in charge and unit RPO; obtain and record:

- Exact location of emitter
- Description of emitter environment
- Names, office symbols, and extensions of person(s) that are knowledgeable and/or responsible
- Emitter operating parameters

Coordinate arrangements for the survey:

- Date and time when the emitter will be available
- Personnel to operate the system
- Mobile lifting equipment, climbing gear, etc., as required
- Miscellaneous support equipment

Perform calculations:

- Estimate hazard distance
- Probe burnout levels
- Probe corrections factor

Check equipment:

- Battery levels
- Probe and meter function
- Emitter frequency within probe frequency range
- Calibration due date

Survey Phase

Contact person(s) in charge and unit RPO; inbrief as necessary

Arrange for emitter set-up in "worst-case" mode

Using correct technique, locate and record (if practical):

PEL hazard radius and height above ground

All areas that the PEL could be exceeded

Levels at work stations and "normally-accessible" areas

Any "hot spots"

Observe and note:

Adequacy of warning signs and access-limiting devices

Adequacy of any standard procedures used to reduce or avoid exposure to RFR

Degree of caution exercised by workers about handling a suspected overexposure

Outbrief as necessary

Post-survey Phase

Analyze results; formulate conclusions and recommendations

Prepare letter/report for concerned offices and unit RPO

File data, photographs, drawings, correspondence, etc., in shop folder

APPENDIX H

Typical Beam Pattern Shape, Gain, and Beam Widths for Common Antennas

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Typical Beam Pattern Shape, Gain, and Beam Widths for Common Antennas

I. Introduction

A. One challenge in maintaining an RFR emitter inventory is recognizing the RFR emitters themselves. With all of the strange looking equipment on Air Force bases, how does one tell what radiates and what doesn't? The shop personnel can be a great help, but you can also help yourself by keeping your eyes open for one of the basic elements of an RFR emitter; the antenna. Antennas come in a wide variety of shapes and sizes. Practically anything, from a small slot or stub on an aircraft fuselage, to a large array of monopoles on a hillside, can act as an antenna.

B. Another challenge that the BEE shop personnel have is collecting proper emitter parameters so they can accurately evaluate an emitter. Technical Orders (TOs) are a good source of information, but TOs are often unavailable or contain information that is too generic or ambiguous to be much help. Workplace personnel are often helpful, but they may not know the specific parameters that you need, or they may give parameters that just don't make sense.

C. In this appendix we will describe a variety of antennas and give typical parameters for them. We hope that this information will save a lot of time in the day to day base level RFR work.

II. Omnidirectional Antennas. Antennas that direct their energy in all directions are considered omnidirectional. Omnidirectional antennas are used for broadcast purposes, where a wide area of coverage must be achieved.

A. Monopoles. Monopoles, also called whips, have wide application in communications. They are used for hand-held radios, vehicle mounted radios, AM broadcast stations, and many other broadcast uses. They are usually mounted vertically to the ground plane. Their radiation pattern typically covers 360° in the horizontal plane, and is squeezed down in the vertical plane to give greater coverage range. Monopoles have gains of 1-6 dB. Figure H-1 shows diagrams of monopole antennas and Figure H-2 shows their typical radiation pattern.

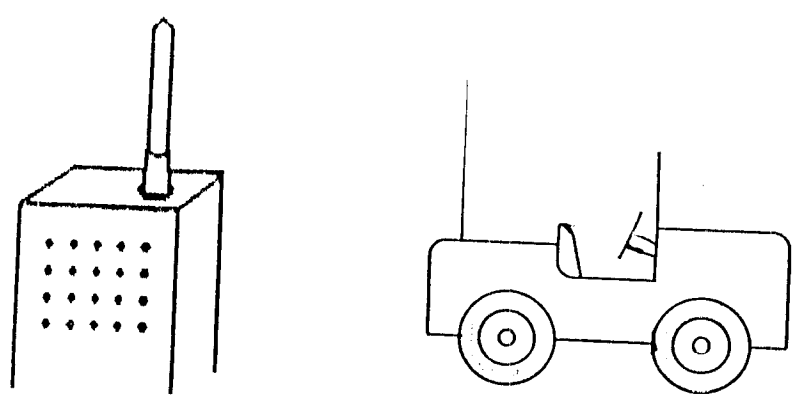
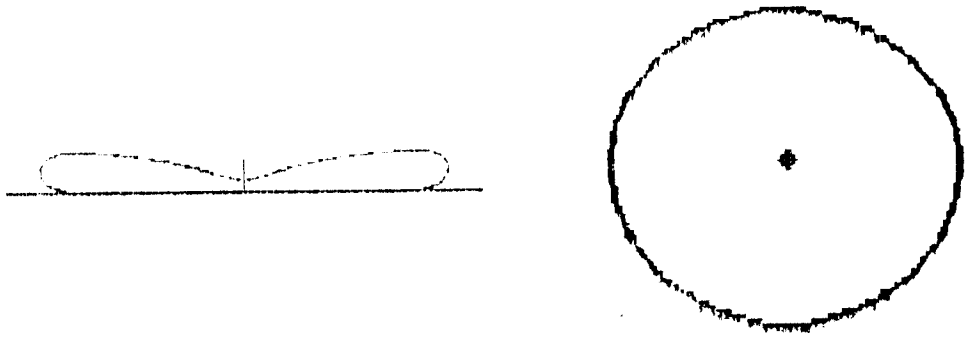


Figure H-1: Monopole Antennas



Side View **Top View**

Figure H-2: Radiation Pattern of Monopole Antennas

B. Blades, Stubs, and Fins. Usually found on aircraft fuselage, blades, stubs, and fins are actually small radomes that cover monopoles or other omnidirectional antennas. Figure H-3 shows diagrams of blade, fin, and stub antennas.

Figure H-3: Blade, Stub, and Fin Antennas

C. Dipoles. Dipole antennas are extremely common in all RF applications. They are used most often as part of other antenna structures. Yagi arrays, phased arrays, log periodic arrays, and aperture antennas are a few examples of antennas that incorporate dipoles. A single dipole has a radiation pattern shaped like a torus (a donut) with the dipole itself through the hole, and a gain of 1-4 dB. However, in combination with other dipoles, passive elements, or reflectors, the characteristics can vary greatly. Figure H-4 shows diagrams of some dipole antennas and Figure H-5 shows their typical radiation pattern.

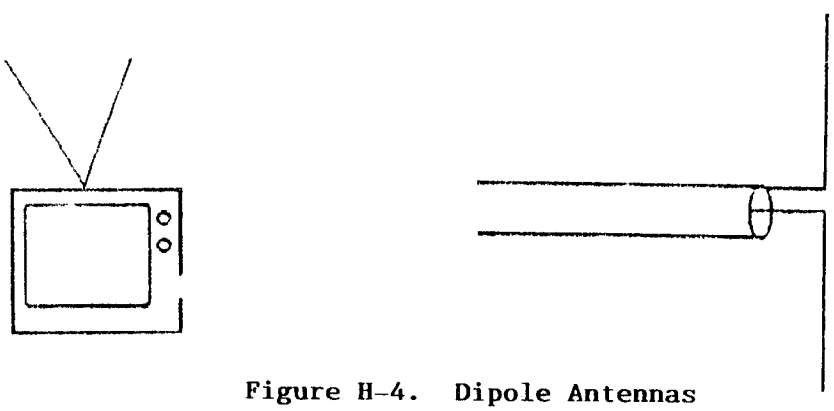
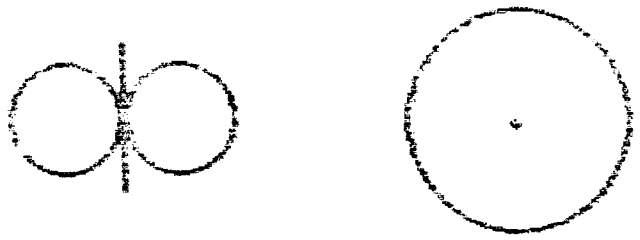


Figure H-4. Dipole Antennas



Side View **End View**

Figure H-5. Radiation Pattern of Dipole Antennas

D. Special Cases:

1. Long Wire Antennas. A long wire will behave as an omnidirectional antenna if it stands alone away from other wires and the ground plane, but it is not a desirable antenna because its radiation pattern has too many large lobes and zeros. More often, long wires are combined into arrays that magnify one lobe and cancel the others out. Long wire array antennas such as V-antennas and rhombic antennas are considered directional antennas.

2. Helical Antennas. A helical antenna can behave as an omnidirectional antenna if the dimensions of the helix are small compared to the wavelength. This mode is not very efficient and is seldom used.

3. Biconical Horns. A biconical horn antenna is a special case of a horn antenna that is omnidirectional. The biconical horn allows the vertical radiation pattern to be varied by changing the flare angle and side length. Depending on feed arrangement, the radiation field can be either horizontally or vertically polarized. Biconical horns are widely used for VHF-UHF broadcast. Their gain is highly variable, but is usually between 1-6 dB. Figure H-6 shows a diagram of a biconical horn antenna.

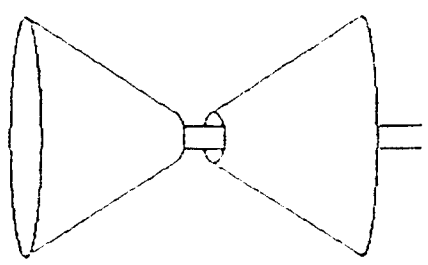
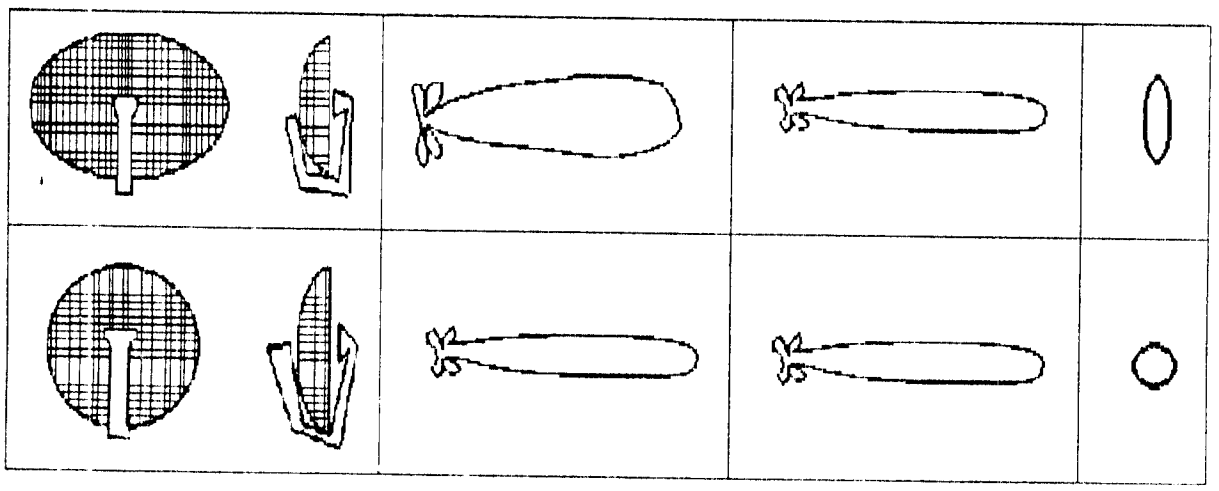


Figure H-6: Biconical Horn Antenna

III. Directional Antennas. Directional antennas are used for radar, point-to-point communications, and navigation purposes when the energy from an RFR emitter needs to be focused into a specific sector. This focusing usually results in higher power densities, longer range, and greater hazard distances.

A. Aperture Antennas. Aperture antennas are used to concentrate energy into a very small area. They are used for radar purposes on aircraft and are also mounted on towers or on the ground. Aperture antennas include reflector antennas and horns.

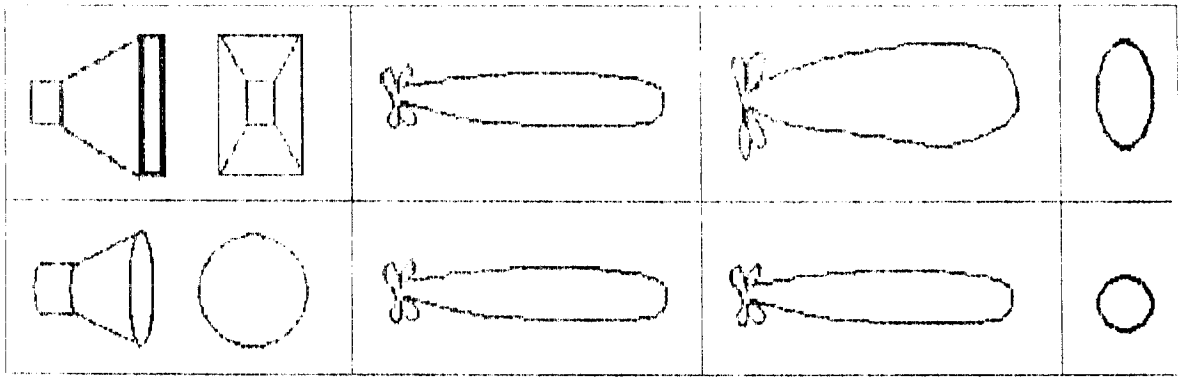
1. Reflector Antennas. Reflector antennas are made up of two basic parts, the feed and the reflector. The feed is usually a horn or a dipole that directs its energy into the reflector. The reflector (also called the dish or the sail) directs the energy from the feed into space. The reflector can be round, elliptical, rectangular, half moon, or any other shape imaginable. Round reflectors generally result in symmetrical beam patterns called "pencil beams" with gain about 35-60 dB. Non-round reflectors usually result in nonsymmetrical beam patterns called "fan beams" with gains of 25-40 dB. For fan beams, the longest dimension of the beam width is oriented with the shortest dimension of the reflector. Figure H-7 shows diagrams of typical reflector antennas and their radiation patterns.



Antennas **Side View** **Top View** **End View**

Figure H-7: Typical Reflector Antennas and Their Radiation Patterns

2. Horn Antennas. Horn antennas, except for biconical horns which are omnidirectional, have patterns similar to reflector antennas. Horns can generate pencil beams and fan beams, but their gains are only 15-25 dB. Horns are used on aircraft, test sets, speed radar, and as feed for other antennas. Figure H-8 shows diagrams and typical radiation pattern of some horn antennas.



Antennas **Side View** **Top View** **End View**

Figure H-8: Typical Horn Antennas and Their Radiation Patterns

B. Array Antennas. Array antennas are also used to form directional beams, but instead of mechanical reflectors, they use electronic means to direct the energy.

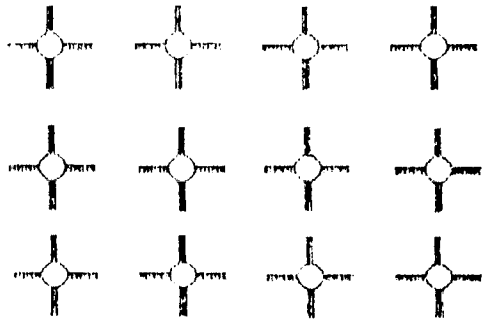
1. Phased Arrays. Phased array antennas are made up of a number of individual radiating elements. The elements are independently varied in phase and amplitude to produce different beam configurations. Phased array antennas are currently used for a great number of radar applications because of their excellent beam shaping and scanning capabilities and their frequency agility. The following examples illustrate the wide range of beam configurations and scanning characteristics possible with phased array radars.

a. The AN/APG-68 radar on the F-16C/D is an example of a phased array used for its beam shaping capabilities. The AN/APG-68 is a multimode radar that can function as a pencil beam attack radar, a fan beam mapping radar, and a wide coverage beacon. In this case the phased array antenna is used to generate several conventional beam patterns with one antenna. It is surprising that this radar, with all of its electronic beam configuration capabilities, can't electronically scan, all scanning is done mechanically.

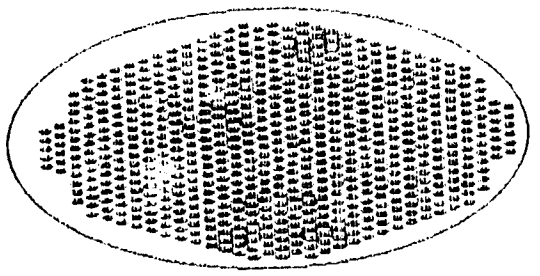
b. The AN/APQ-164 on the B-1B is an example of a phased array used for both beam shaping and scanning characteristics. The AN/APQ-164 is a multimode radar with a variety of beam configurations and scanning modes. The phased array is used to generate beam configurations as well as scanning patterns.

c. The AN/FPS-115 PAVE PAWS phased array radar is a large ground based search and track radar. The PAVE PAWS radar has a single beam configuration that scans electronically in a pseudorandom pattern.

Gain for phased array antennas could vary greatly, but typically it will be in the 20-60 dB range. Figure H-9 shows diagrams of a turnstile dipole array like the PAVE PAWS, and an open waveguide array like the AN/APG-68.



Turnstile Dipole Array



Open Waveguide Array

Figure H-9: Typical Phased Array Antennas

2. Arrays of Linear Elements. Directional arrays can be made from a number of omnidirectional elements. This is done by arranging each element so that the energy is amplified in one direction and cancelled in all others. Linear arrays are usually used for point-to-point communications. Figure H-10 shows the typical radiation pattern for a linear array antenna.

Figure H-10: Radiation Pattern for Linear Array Antennas

a. Yagi Arrays. Yagi arrays are made up of one driven dipole and a series of passive (parasitic) elements. The passive elements serve to reflect or direct the energy from the driven element. Yagi arrays are most commonly used as television reception antennas, but they can also be used for transmissions. Typical gains for Yagi arrays are 10-15 dB. Figure H-11 shows diagrams of Yagi antennas.

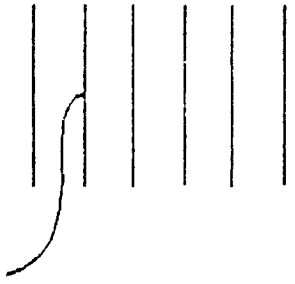


Figure H-11: Typical Yagi Antennas

b. Log Periodic Antennas. Log periodic antennas are made up of a series of dipoles of different lengths. Because the different size dipoles respond to different frequencies, log periodic antennas can be used for a range of frequencies. Like Yagi arrays, log periodic antennas are commonly used for television reception. Typical gains for log periodic antennas are 10-15 dB. Figure H-12 shows diagrams of some log periodic antennas.

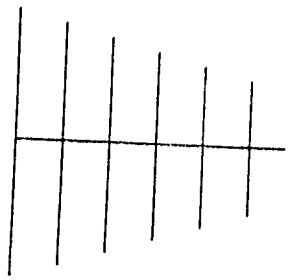
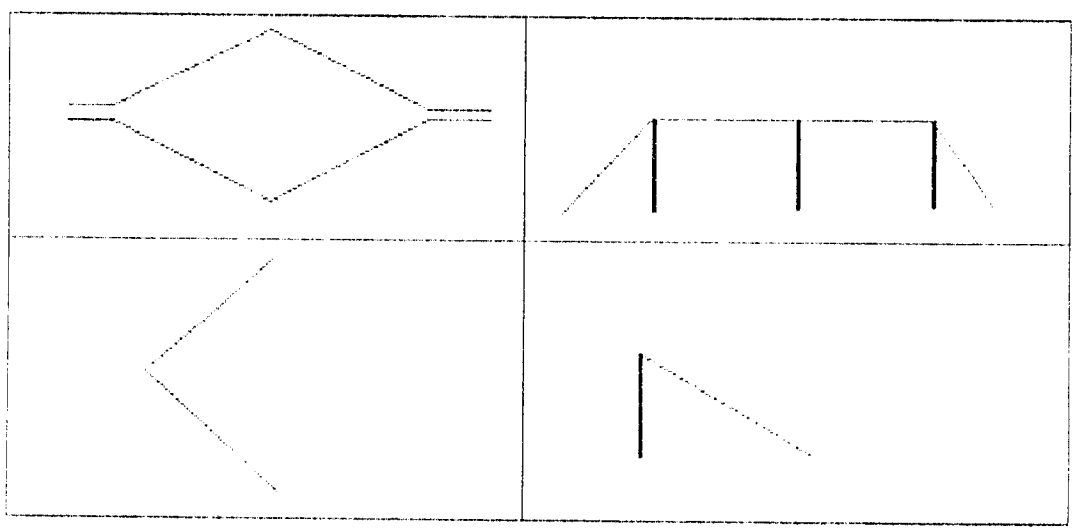


Figure H-12: Typical Log Periodic Antenna

c. Rhombic and V Antennas. Rhombic and V antennas are made of a series of long wire antennas positioned to amplify one lobe and cancel all others. These antennas can be either ground based or mounted on aircraft. They have typical gains of 15-25 dB. Figure H-13 shows diagrams of rhombic and V antennas.



Top View **Side View**

Figure H-13: Typical Rhombic and V Antennas

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APPENDIX I

Basic Emitter Evaluations With Detailed Calculations

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Basic Emitter Evaluations With Detailed Calculations

Example 1:

1. Given the AN/TPQ-43 with the following parameters, calculate the approximate PEL distance.

Frequency = 8500 - 9600 MHz	Peak Power = 195 kilowatts
Pulse Repetition Frequency = 512 pps	Pulse Width = 1 μs
Antenna Diameter = 6 feet (1.8 meter)	Beam Width = 1.3°
Antenna Gain = 42 dBi	Wavelength = 0.033 meters

2. Our first step in solving this problem is to approximate the hazard distance with the far-field equation (Equation 10). All the parameters necessary for the equation are given above; however, we must first calculate the average power and convert antenna gain to absolute units. Average power can be calculated with Equations 2 and 3; gain conversion is given in Equation 7.

a. Equation 3: $DF = PW \times PRF,$

$= 1\ \mu s \times 512\ pps,$

$= \underline{5.12 \times 10^{-4}}$

b. Equation 4: $P_{av} = P_{peak} \times DF,$

$= 195\ kW \times 5.12 \times 10^{-4}$

$= 99.84\ watts$

$\doteq \underline{100\ watts}$

c. Equation 7: $Gain_{abs} = antilog\ [Gain\ (dBi)/10],$

$= antilog\ [42/10],$

$= \underline{15849}$

d. The approximate hazard distance is calculated as follows:

Equation 8: $$D(meters) = \sqrt{\frac{P_{av}(watts) \times G_{abs}}{40 \times \pi \times PEL(mW/cm^2)}},$$

$$= \sqrt{\frac{100\ W \times 15849}{40 \times \pi \times 10\ mW/cm^2}},$$

$$= \underline{35.5\ meters}$$

3. The second step in our evaluation is to determine the validity of our calculated hazard distance by determining the near- and far-field boundaries for the emitter. For an aperture emitter operating above 300 MHz, we will use Equation 11 to estimate the far-field boundary and Equation 15 for the near-field boundary.

a. Equation 11: Far-Field $\geq [2 \times L^2]/\lambda$,

$\geq [2 \times 1.8^2\ m^2]/[0.033\ m]$

$\geq$ <u>196 meters (644 feet)</u>

b. Equation 15: Near-Field $< L^2/[4 \times \lambda]$,

$< 1.8^2\ m^2/[4 \times 0.033\ m]$

$<$ <u>24.5 meters (80.5 feet)</u>

4. From the calculations provided, it is clear that the estimated hazard distance of 116 feet is on the fringes of the near-field zone and therefore is likely to be quite conservative as compared to the actual hazard distance. The following measurement values are provided to illustrate actual main beam power density values in the near-field of an emitter. The values are based on measurement of the AN/TPQ-43 as documented in USAFOEHL Report 87-156RC1065MRA.

Distance (feet)	Power Density (mW/cm^2)	Distance (feet)	Power Density (mW/cm^2)	Distance (feet)	Power Density (mW/cm^2)
2	11	38	5.0	56	4.0
7	10	40	4.5	60	4.3
10	6.5	41	5.0	69	5.0
15	5.5	44	4.5	75	6.0
23	5.5	46	4.0	80	4.0
25	8.0	49	4.0	85	4.0
30	7.5	53	4.5	108	3.0
33	7.0				

5. The conclusion of the USAFOEHL report recommended a hazard distance of 10 feet. Enclosed is a completed AF Form 2759 as an example of how to document the emitter information and survey information.

Example 2:

1. This example will briefly explore calculations and measurements used in a possible RFR overexposure investigation. The example will assume an individual was exposed to an AN/APQ-128, terrain following radar, located in the nose of an F-111 aircraft. The individual was located approximately 5 inches from center of the antenna on the main beam axis for approximately 45 seconds. The following parameters apply to the AN/APQ-128:

RADIOFREQUENCY EMITTER SURVEY	DATE (YYMMDD)	WORKPLACE IDENTIFIER

(Use this space for mechanical imprint)

BASE	ORGANIZATION
WORKPLACE	
BLDG NO / LOCATION	ROOM / AREA

NAME OF KEY CONTACT	GRADE	POSITION	ORGANIZATION/OFFICE SYMBOL	DUTY PHONE

HAZARD EVALUATION AND CONTROL DATA

NOMENCLATURE	AN/TPQ-43			
DESCRIPTION	Transportable Aircraft Tracking Radar			
LOCATION OF EMITTERS				
QUANTITY				
FREQUENCY (MHZ)	8500 - 9600			
PULSE WIDTH (microsec.)	1			
PULSE REPETITION FREQ (pps)	512			
PEAK POWER (KW)	195			
ANTENNA CODE	CR			
ANTENNA SIZE (ft.) (hor./ver.)	6 ft Circular			
ANTENNA BW (deg) (hor./ver.)	1.3 Circular			
ANTENNA GAIN (dB)	42			
SCANNING CODE	T--Tracker			
SCAN RATE (rpm)	Not Applicable			
ESTIMATED HAZARD DISTANCE (ft)	116 feet			
HAZARD CODE(S)	IH-Normal Opera. GH-Maintenance			
HAZARD CONTROL CODE(S)	NR-Normal Opera. WS-Maintenance			
HAZARD DISTANCE MEASUREMENTS (ft)	10 feet USAF-OEHL Report 87-156RC1065MRA			

PREPARED BY (Name, Grade, AFSC) Walter K. Eichin SMSGT 90790

REVIEWED BY (Name, Grade, AFSC) Werner E. Rademacher, 1Lt, 912SA

AF FORM 2759 JAN 82

PERIODIC CHECKS

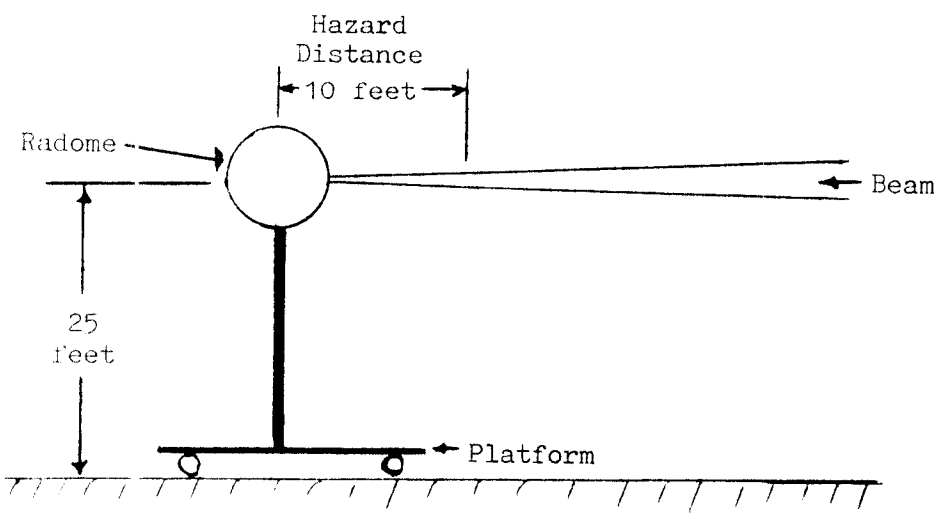
CHECK FREQUENCY

[X] ANNUALLY [ ] QUARTERLY [ ] OTHER _____

DATE (YYMMDD)	FINDINGS: SIGNS CURRENT	FINDINGS: PROCEDURES ADEQUATE	FINDINGS: OTHER	CHECKED BY (Name, Grade, AFSC)
8 8 12 30	Yes	Yes		Steven E. Rademacher 1Lt 9125A

SYSTEM DIAGRAM, CALCULATIONS, AND MEASUREMENTS

$$D_{PEL}(\text{meters}) = \sqrt{\frac{P_{av}(\text{watts}) \times G_{abs}}{40 \times \pi \times PEL(\text{mW/cm}^2)}} = \sqrt{\frac{100W \times 15849}{40 \times \pi \times 10 \text{ mW/cm}^2}} = 35.5 \text{ meters}$$



Frequency = 16.7 - 17.0 GHz
Pulse Repetition Frequency = 4045 pps
Power Average = 24 watts
Absolute Antenna Gain = 355
Horizontal Beam Width = 8.2^{o}
Reflector Width = 6.4 in

Peak Power = 30 kilowatts
Pulse Width = 0.2 μs
Antenna Gain = 25.5 dBi
Vertical Beam Width = 8.0^{o}
Reflector Length = 7.3 in

2. From the basic background information given above our first step would be to estimate the maximum power density incident on the individual. The first step in this process is to determine the near- and far-field boundaries. Since the AN/APQ-128 emits at 16.7 - 17.0 GHz, we will use Equation 1 to calculate the system emission wavelength. Equation 15 will be used to calculate the limits of the near-field zone.

Equation 1: $\lambda = c / f,$

$$= (3 \times 10^{8} \text{ m/s}) / (16.85 \times 10^{9} \text{ 1/s})$$

$$= \underline{0.0178 \text{ meters}},$$

where the frequency, f, is the median value between 16.7 and 17.0 GHz.

Equation 15: Near-Field $< L^{2}/[4 \times \lambda],$

$$< 0.185^{2} \text{ m}^{2}/[4 \times 0.0178 \text{ m}],$$

$$< \underline{0.48 \text{ meters (19 inches)}},$$

where, our value for L in the near-field equation is the longest dimension of the antenna, the reflector width of 7.3 inches; note the conversion from inches to meters:

$$7.3 \text{ in} \times \frac{2.54 \text{ cm}}{\text{in}} \times \frac{\text{meter}}{100 \text{ cm}} = \underline{0.185 \text{ meters}}$$

3. From the calculations above, it is apparent that the individual was located well within the near-field of the emitter and, therefore, a near-field estimation is most appropriate.

4. To estimate the main-beam power density, we will use Equation 13. Since antenna area is not given in our list of parameters, we must first calculate the area of the reflector. The reflector is elliptical in shape, however, for our purposes, we will assume the reflector is rectangular for simplicity. Antenna area is calculated as follows:

Area = Reflector Length x Reflector Width,

= 7.3 inches x 6.4 inches,

$= 46.7 \ \underline{\text{inches}^{2}},$

$$= 46.7 \text{ in}^{2} \times \frac{[2.54 \text{ cm}]^{2}}{\text{in}^{2}} = \underline{301 \text{ cm}^{2}}$$

Equation 13: Power Density = $(4 \times P_{av})$/Antenna Area

$$= (4 \times 24000 \text{ mW})/301 \text{ cm}^2$$

$$= \underline{318 \text{ mW/cm}^2}$$

5. A power density of 318 mW/cm^2 is an extremely large value when compared to the standard for this frequency range, 10 mW/cm^2. A value of this magnitude is very common for an emitter of this size and type. Equation 13 theoretically predicts the maximum peak power density in the main beam; however, for a small emitter like the AN/APQ-128, the spatial region where the field intensity is this large is likely to be very small; it is unlikely that Narda instrumentation will be able to detect this field because the effective area of the probe elements are greater than the spatial region of interest. This concept is illustrated very well in USAFOEHL Report 87-105RC0028GRA, "Investigation of Possible Overexposure to Radio Frequency Radiation (RFR) at Cannon AFB NM"; the report documents a maximum measured power density of 180 mW/cm^2 at 5 inches from the AN/APQ-128 antenna.

6. To estimate the exposure to the individual we will perform a simple time average of the exposure over a 6-minute period as shown below:

$$\text{Power Density Average} = \frac{(180 \text{ mW/cm}^2 \times 45 \text{ s}) + (0 \text{ mW/cm}^2 \times 315\text{s})}{360 \text{ seconds}},$$

$$= \underline{22.5 \text{ mW/cm}^2}$$

The individual was therefore overexposed.

APPENDIX J

Terms List

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Terms List

Antenna: The part of an emitter that transfers RF energy from the enclosed system to free space.

Antenna Gain: A measure of the antenna's ability to concentrate energy in a given direction. It is usually expressed in decibels and referenced to a perfectly isotropic antenna.

Amplitude Modulation (AM): A modulation scheme in which the amplitude of the carrier is varied according to the message signal.

Athermal Effects: Biological effects not caused by heating of the tissues.

Average Power: The power averaged over a period of time.

Bandwidth: The width (in MHz) of the range of frequencies over which an emitter can operate.

Beam Width: The angular width of the beam defined at the half-power points.

Carrier Signal: The radio frequency signal that is modulated by the message signal.

Continuous Wave (CW): A waveform with a continuous carrier signal.

decibel (dB): A logarithmic unit for comparison of a power or voltage level to a particular reference level, usually 1 volt or 1 watt. (See Eqns. 4 and 5).

dBm: A logarithmic unit for comparison of power to 1 milliwatt.

dBi: A logarithmic unit for comparison of transmitted power density to that from a perfectly isotropic emitter.

Direct Biological Hazard: Hazards due to absorption of RFR energy by body tissues.

Double Sideband (DSB): An AM modulation scheme in which both sidebands are used to transmit information.

Duty Factor (DF) (also Duty Cycle or Duty Ratio): The ratio of transmission time to nontransmission time in a pulsed waveform. A product of the pulse width and the pulse repetition frequency.

Electro-Explosive Devices (EED): Explosive devices detonated by an electric charge. Usually used to detonate larger explosive devices.

Electro-Explosive Devices (EED) Hazard: Hazard due to detonation of EEDs by RFR energy.

Electromagnetic Interference: Interference to the operation of electrical or electronic equipment from radiated electromagnetic fields.

Electromagnetic (EM) Spectrum: The total range of wavelengths (or frequencies) of electromagnetic waves including radio frequency radiation, light, and x-radiation.

Electromagnetic Wave: A system consisting of mutually supporting, time-varying electric and magnetic fields that are perpendicular to each other and to the direction of travel. By definition, electromagnetic waves travel at the speed of light

Emitter: A system that emits RFR. Usually includes a transmitter, a waveguide or transmission line, and an antenna or dummy load.

Fan Beam: A radiation pattern similar to a pencil beam but with an elliptical cross section.

Far-Field (Fraunhofer Region): The radiation field at a distance from the antenna where the electric and magnetic fields approximate a plane wave and the power density decreases with the square of the distance.

Frequency Modulation (FM): A modulation scheme in which the frequency of the carrier is varied according to the message signal.

Hertz: A measure of frequency equivalent to cycles per second.

Indirect Biological Hazard: Hazard due to interference with electronic medical devices (i.e., cardiac pacemakers).

Isotropic Emitter: A purely theoretical emitter that distributes power equally in all directions.

Measurement Survey: A measurement of RFR emissions using field instrumentation, to determine necessary controls or exposure levels.

Message Signal: A signal that carries a message.

Modulation: The process where certain characteristics of the carrier signal are varied in accordance with the information in the message signal.

Near-Field (Fresnel Region): The radiation field relatively near an antenna where the electric and magnetic fields do not approximate a plane wave and the power density does not decrease with the square of distance.

Omnidirectional: A radiation pattern that distributes energy evenly in all directions in a particular plane.

Peak Envelope Power: The maximum power in a modulated signal.

Peak Power: The maximum instantaneous power output of a system.

Pencil Beam: A radiation pattern that concentrates energy in a small angular sector.

Permissible Exposure Limit (PEL): The level of RFR energy to which an individual may be exposed, that will not cause detectable bodily injury in light of present medical knowledge.

Petroleum, Oils, and Lubricant (POL) Hazard: Hazard due to ignition of POLs by RFR energy.

Power Density: The amount of power per unit area in an RFR field, usually expressed in milliwatts per square centimeter (mW/cm^2).

Prefixes: When added to a unit of measure, the numerical value is multiplied by:

Giga (G) = 10^9

Mega (M) = 10^6

Kilo (K) = 10^3

Centi (c) = 10^{-2}

Milli (m) = 10^{-3}

Micro (μ) = 10^{-6}

Nano (n) = 10^{-9}

Pulsed Waveform: A waveform that has individual pulses separated by nontransmission times.

Pulse Modulation (PM): A modulation scheme in which the carrier is a series of pulses that are modulated by varying their amplitude, width, or phase.

Pulse Repetition Frequency (PRF): The number of pulses per second (PPS) of a pulsed transmission.

Pulse Width (PW): The duration (time) of a single pulse of a pulsed transmission.

Radar (RAdio Detection And Ranging): A system that radiates electromagnetic waves into space and uses the reflected waves to detect objects.

Radiation Pattern: The shape of the energy distribution in free space.

Single Sideband (SSB): An AM modulation scheme in which only one of the sidebands are used to transmit information.

Site Inspection Survey: A visual inspection of an emitter site to determine if further controls or investigation are needed.

Suppressed Carrier: An AM modulation scheme (either DSB or SSB) in which the output is zero when there is no message signal.

Thermal Effects: Biological effects caused directly by heating of the tissues.

Transition Region: The region between the far-field and the near-field regions where the field has some characteristics of both.

Transmission Line: The part of an emitter that carries the signal from the transmitter to the antenna.

Transmitter: Part of an emitter that generates and amplifies an RF signal.

Watt (W): A unit of power; equal to joules per second.

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