Bioenvironmental Engineering Site Assessment I

Unit 10: Non-ionizing Radiation, Radio Frequency Radiation (RFR)

Unit Description: For this unit, you'll be stationed at Lakefront Field, a bare base in Rawah, Iraq. During your assignment, you'll identify and analyze non-ionizing radiation health threats through various scenarios. When you're done, you'll be able to describe the situations where BE may encounter non-ionizing radiation health threats and the control options that are appropriate for those situations.

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Lesson 1: Principles of Radio Frequency Radiation

Lesson Description

In this lesson, you will be preparing to conduct an HRA at a communications and radar site. Upon completion of this lesson, you will be able to describe the principles of radio frequency radiation (RFR).

Lesson Overview (Page 1 of 5)

Radio frequency radiation (RFR) is one of the most frequently encountered types of non-ionizing radiation in both deployed and garrison situations. It is important to understand the basic principles of RFR to properly identify, analyze, and control any potential health threats RFR may pose to base personnel.

To complete this lesson, you will recall the characteristics of radio frequency radiation (RFR).

Audio Script

OIC: Airmen with the combat communications squadron are setting up field deployable antennas for radio communication and radar surveillance equipment north of tent city. I'm assembling an HRA team to identify any possible health threats the equipment could present for personnel at the base. Before we go to the site, I need you to review the principles of radio frequency radiation.

Characteristics of RFR Energy (Page 2 of 5)

RFR is a form of electromagnetic radiation (EMR) which has no mass and no charge.

As with other forms of EMR, the three basic characteristics of RFR are:

- Frequency.
- Wavelength.
- Energy.

RFR was originally associated only with communications, but now all frequencies at the **lower frequency range of the EMR spectrum** are commonly thought of as RFR.

RFR can cause health effects by inducing current flow within the body and producing heat.

Frequency

Frequency is defined by the number of cycles that occur per second and is measured in Hertz (Hz).

Wavelength

Wavelength is the distance from one point on a wave cycle to the same point on the next wave cycle. It's usually referenced in millimeters, centimeters, or meters.

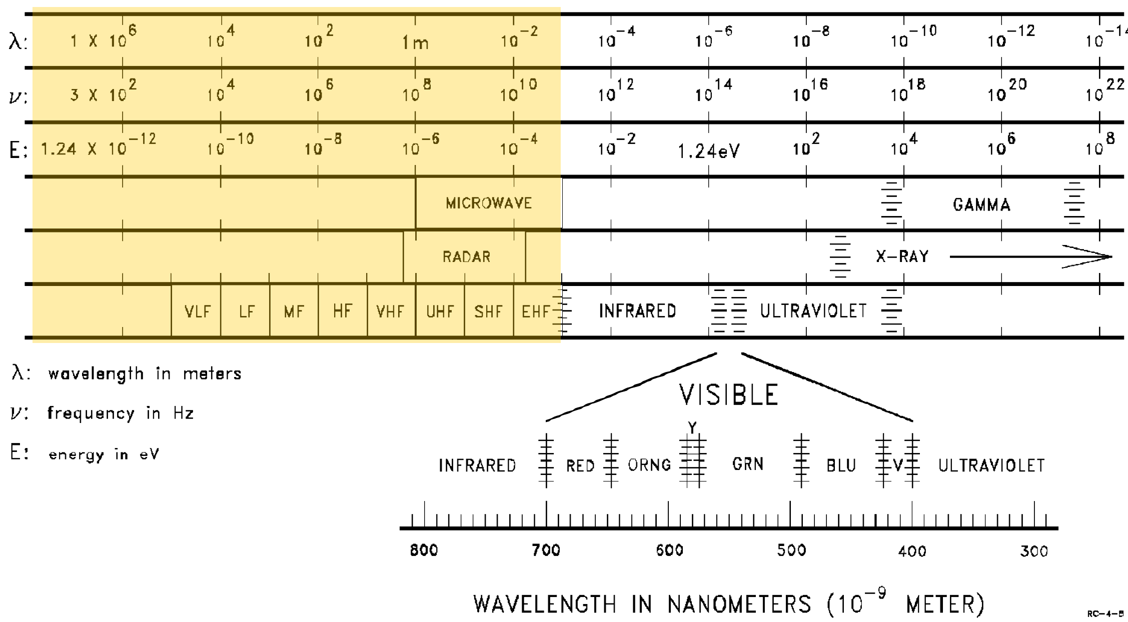
Energy

The amount of energy produced is determined based on the relationship between wavelength and frequency. For instance, each wavelength cycle has the same amount of energy. Because of this, the amount of energy produced is determined by the number of cycles that can fit inside the time span of one second. Due to this relationship, as frequency increases, the energy increases and the wavelength gets shorter.

The amount of energy produced is described using electron volts (eV).

Lower EMR Frequencies

The frequencies associated with RFR on the electromagnetic spectrum are 3kHz to 300Ghz ($3x10^3$ to $3x10^{11}$ Hz).



Subcategories of RFR Energy (Page 3 of 5)

RFR includes several subcategories that are determined based on their frequency ranges and applications.

Very Low Frequency (VLF)

VLF RFR occurs between 3 and 30 kHz. Sources include:

- Hand-held radio communications.
- Long-range navigation.

Low Frequency (LF)

LF RFR occurs between 30 and 300 kHz. Sources include:

- Navigation aids.
- Marine and long-range communications.

Medium Frequency (MF)

MF RFR occurs between 300 and 3,000 kHz (3MHz). Sources include:

- AM radio.
- Amateur radio.
- Navigation.

High Frequency (HF)

HF RFR occurs between 3 and 30 MHz. Sources include:

- CB radios.
- "Over the horizon" backscatter radars.

Very High Frequency (VHF)

VHF RFR occurs between 30 and 300 MHz. Sources include:

- Long-range communication applications such as satellite detection.
- FM radio.
- Fire and police radios.

Ultra High Frequency (UHF)

UHF RFR occurs between 300 and 3,000 MHz. Sources include:

- Long-range surveillance for missiles and spacecraft.
- Aircraft radar systems.

Super High Frequency (SHF)

SHF RFR occurs between 3 and 30 GHz. Sources include:

- Police speed guns.
- Long-range weather radar.
- Military 3-D radar.
- Height-finding radar.
- Satellite communications.

Extremely High Frequency (EHF)

EHF RFR occurs between 30 and 300 GHz. Sources include:

- Satellite communication systems.
- Radio relay.
- Navigation aids.
- Ultrasonic cleaning.

Appraisal (Page 4 of 5)

Following are several questions to check your knowledge of the characteristics of RFR. Select the correct answer for each question.

Which one of the following RFR characteristics refers to the distance from one point on a cycle to the same point on the next cycle?

A Frequency

B Wavelength

C Energy

Which one of the following RFR characteristics is measured by the number of cycles that occurs per second and is expressed in Hertz (Hz)?

A Frequency

B Wavelength

C Energy

Which one of the following terms accurately completes the statement about the relationship between frequency, wavelength, and energy?

As frequency decreases, the energy _________ and the wavelength gets longer.

A Stays the same

B Increases

C Decreases

Lesson Summary (Page 5 of 5)

In this lesson, you recalled the characteristics of RFR energy.

You have learned that, because of the relationship between the characteristics of RFR, as frequency increases, the energy increases and the wavelength gets shorter. Typical sources of RFR, which can range from cell phone communications to radar surveillance, can be identified based on variations in wavelength, frequency, and energy.

Audio Script

OIC: I just got off the phone with the communications squadron commander. They've completed the set up and initial tests on all of the communication and radar equipment at the site. I've also finished rounding out our HRA team. The other members will be meeting us at the site tomorrow morning.

Lesson 2: RFR Exposures

Lesson Description

In this lesson, you will lead a team to conduct an HRA at a communications and radar site. Upon completion of this lesson, you will be able to differentiate types of RFR emitters and describe health threats related to an RFR exposure.

Lesson Overview (Page 1 of 10)

Because of the prevalence of RFR emitters in both garrison and deployed locations, it is important to be able to identify the emitters as well as the potential health effects they can cause.

As you and your team work on the HRA, you will:

- Recall types of RFR emitters.
- Recall parts and functions of RFR emitters.
- Recall principles of absorption.
- Relate Specific Absorption Rate (SAR) to Permissible Exposure Limits (PEL).
- Recall the potential effects of an RFR exposure.
- Associate potential biological effects to the dose of RFR.

Audio Script

OIC: Something's come up, and I won't be able to go with you to the communications and radar site. I need you to lead the team to conduct an HRA of the site. It's just north of tent city. Some of the BE Techs I've assigned to the team don't have much experience with RFR, so you may need to help them out. Let me know if you find anything that needs my attention.

Scenario Challenge Point (Page 2 of 10)

After you arrived at the communications and radar site, you assigned a BE Tech to identify potential RFR emitters at the site and in surrounding areas. Match each RFR emitter that the BE Tech found with the category to which it belongs.

RFR Emitter
Hand-held Radio
Electronic Counter Measure
Tactical Automated Security System
Early Warning System

	Category
______________________	Ground Fixed
______________________	Mobile Systems
______________________	Field Deployable
______________________	Aircraft Mounted

RFR Emitters and the Air Force (Page 2a of 10)

Radio Frequency Radiation (RFR) is a common form of radiation found throughout the Air Force. RFR emitters are present in both deployed and garrison situations and can be used for radar and electronic countermeasures, communications systems, navigation aids, repair and maintenance purposes, and medical and industrial purposes.

Typical sources and locations of RFR emitters found in the Air Force vary greatly depending on their application. Read more about the types of sources below.

Aircraft Mounted

Aircraft mounted sources generally emit the most hazardous levels of RFR. Examples of this type of emitter include:

- F-15 fire control radar which is designed to detect and track aircraft and small high-speed targets at distances beyond visual range.
- Airborne Warning and Control Systems (AWACS) such as the rotating radar dome installed above the E-3 Sentry aircraft.
- B-52 Electronic Counter Measure (ECM) pods.
- Radio antennas.

Ground Fixed

Ground fixed emitters can include receiving antennas, transmitting antennas, or a combination of the two. Examples of ground fixed emitters include:

- Satellite communication systems.
- Early warning systems.

Mobile Systems

Mobile systems include man-portable systems, such as hand-held radios, and vehicular systems, such as vehicle-mounted radars.

Field Deployable

Field deployable systems are completely mobile systems which can be set up anywhere. This type of RFR emitter is primarily seen in deployed environments. Examples of RFR emitters that are field deployable systems include:

- Tactical Automated Security System (TASS).
- High-power microwave (HPM) transmitters.
- Radiofrequency weapons (RFW).

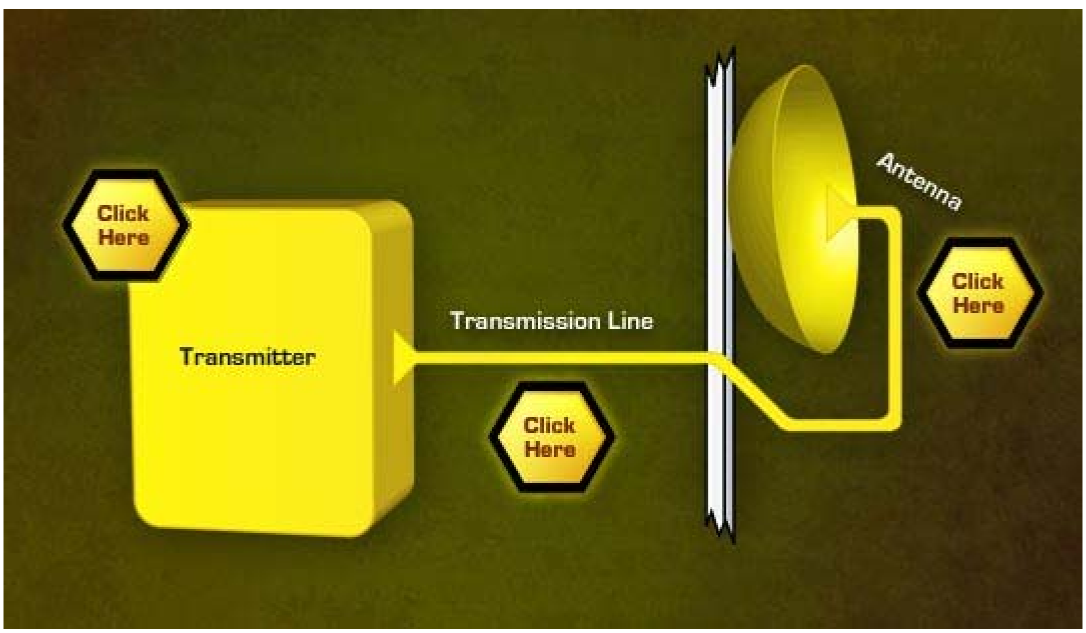
Medical / Industrial

Medical / Industrial emitters are used for a variety of purposes ranging from therapy to remote system monitoring. These types of RFR emitters are primarily found in medical facilities and industrial shops. Examples of medical / industrial RFR emitters include:

- Medical diathermy machines used to generate heat in the body tissues.
- Medical telemetry equipment.
- Robotic equipment controls.

Parts and Functions of RFR Emitters (Page 3 of 10)

Regardless of the intended application, every RFR emitter is made up of three basic components. You can read about each component below the diagram.



Transmitter

The transmitter is the part of the emitter that generates the RFR signal. The RFR signal produced can be generated using two modes of operation.

- **Continuous Wave**
- **Pulsed Wave**

Continuous Wave

The continuous wave mode of operation transmits an RFR signal continuously without any breaks. In this mode of operation, the average power of the signal is the same as the maximum peak power because the signal is on constantly.

Radio and television broadcasts are examples of a continuous wave mode of operation.

Pulsed Wave

The pulsed wave mode of operation occurs when an emitter repeatedly turns the signal carrier on and off in a cyclic pattern. A pulsed wave is commonly measured in microseconds.

Most radars operate in a pulsed mode. When the pulse is on, the radar's signals are transmitted. When the pulse is off, the radar can receive signals returning to the device but is not transmitting signals.

Transmission Line

The transmission line of an RFR emitter carries the signal from the transmitter to the antenna. The signals are transmitted through one of two types of transmission lines.

- **One Conductor**
- **Two Conductor**

One Conductor

The one conductor type of transmission line, commonly called a waveguide, is a hollow, metallic tube which confines and guides the transmission of electromagnetic waves. This type of transmission line is commonly used on guidance systems.

Two Conductor

The two conductor type of transmission line consists of insulated conductive tubing through which a central, insulated conductor runs. This type of transmission line is used to transmit low frequency telephone or TV signals.

Antenna

The antenna is the point on an emitter where RFR energy radiates into free space. Most RFR hazards emanate from antennas; therefore, it is important for you to be able to identify them.

Antennas are divided into three classes.

- **Wire**
- **Aperture**
- **Horn**

Wire

Wire antennas are divided into three types which include dipoles, whips, and yagis. Dipoles are straight electrical conductors and are one of the simplest forms of wire antennas. Whip antennas are flexible "rubber duck" antennas commonly found on hand-held two-way radios and cell phones. A yagi is a directional antenna that is made up of a dipole and a series of focusing elements.

Aperture

Aperture antennas are commonly called satellite dishes. They usually include a concave disk which can send and receive signals.

Horn

A horn antenna is used for the transmission and reception of microwave signals. It gets its name from the flared appearance at the end of the antenna. A horn antenna is primarily used for short-range radar systems like those used by law-enforcement to measure speeds of approaching or retreating vehicles.

Appraisal (Page 4 of 10)

Match each part of an RFR emitter with the description of its function.

Function	Transmitter	Transmission Line	Antenna
The point on an emitter where RFR energy radiates into free space.			
The part of the emitter that generates the RFR signal.			
The part of an RFR emitter that carries the signal between other parts.			

Lakefront Field Scenario (Page 5 of 10)

Now that a list has been created of potential RFR emitters around the area, you need to determine which emitters present a potential health threat to personnel.

You assign part of the BE Team to begin monitoring the emitters and collecting survey data while you speak with a communications squadron technician to gain more information about the safety procedures currently in place.

Audio Script

BE Tech: Good morning.

Squadron Technician: Good morning. I just spoke with my OIC. He said you were here to look at the communications and radar equipment?

BE Tech: Yes, we want to make sure the level of radio frequency radiation produced by the equipment is within permissible limits. I noticed some of the equipment here are vehicle-mounted radars. Are those units operated continuously or only at certain times?

Squadron Technician: This equipment will be operating continuously until more permanent units can be installed.

BE Tech: What type of safety precautions are currently being used for personnel around the units?

Squadron Technician: We're working to set up temporary cones and warning signs around the equipment. Personnel are also required to constantly monitor the equipment's operation.

Scenario Challenge Point (Page 6 of 10)

Using the information you obtained from your conversation with the technician, you begin to focus on the emitters which have the greatest potential for health effects on personnel.

Which one of the following frequency ranges identifies where optimal absorption of RFR takes place for adult humans?

A 50-60 MHz

B 60-70 MHz

C 70-80 MHz

D 80-90 MHz

Principles of Absorption (Page 6a of 10)

In addition to being able to identify the various components and functions of RFR emitters, you should be able to describe the health threats associated with an RFR exposure.

RFR causes adverse health effects through absorption, the process through which energy is taken in by biological matter. The rate at which this occurs is known as the **specific absorption rate (SAR).**

The ability for biological matter to be affected by absorption is greatly influenced by the RFR's frequency. For instance, optimal absorption takes place between 70 and 80 MHz for adult humans. These frequencies are called resonant frequencies. If a person is in perfect ground contact, the resonant frequencies will shift to between 35-40 MHz.

Specific Absorption Rate (SAR)

The absorption rate is an expression of how much RFR energy is imparted to each kilogram of biological body mass per second. SAR is expressed in units of watts per kilogram (W/kg).

Scenario Challenge Point (Page 7 of 10)

Because the installation of the communications and radar units is considered a mission critical objective, you determine that some levels of RFR exposure will be unavoidable. You still need to compare the exposures received by personnel to the permissible exposure limit (PEL).

Which one of the following statements *best* describes the relationship between the permissible exposure limit (PEL) and specific absorption rates (SARs)?

A The SAR is determined based on the potential biological effects associated with the PEL.

B The SAR is based on the whole-body PEL of 0.4 watts per kilogram (W/kg).

C The PEL incorporates a safety factor of 20 below a SAR of 4.0 watts per kilogram (W/kg).

D The PEL is based on the whole-body SAR of 0.4 watts per kilogram (W/kg).

Audio Script

Narrator: The members of the BE Team conducting the monitoring have returned to analyze the data. Using the data collected, they will compare the results to the appropriate standards**.**

Permissible Exposure Limits and Specific Absorption Rate

(Page 7a of 10)

Because RFR emitters are common and have widespread uses in both public and private sectors, a certain degree of RFR exposure will inevitably occur. It's important to identify the limits at which an RFR exposure begins to cause damaging biological effects.

The **permissible exposure limit (PEL)** is based on the whole-body SAR of 0.4 W/kg and incorporates a safety factor of ten below the health effects threshold of 4.0 W/kg.

Permissible Exposure Limit (PEL)

The permissible exposure limit (PEL) is the value to which an individual may be exposed without exhibiting damaging biological effects and is based on the emitter's frequency. The PEL can be determined based on Table 2.1 and Table 2.2 in AFOSH Std 48-9, *RFR Safety Program*. The commonly used PEL for hazard distance assessments is shown in power density (mW/cm^2 or W/m^2).

Scenario Challenge Point (Page 8 of 10)

After comparing the team's results to the PEL, you determine personnel working around a radar system on site could be exposed to levels exceeding the PEL and could experience a variety of potential health effects from the exposure.

Build a list of direct / thermal effects that personnel could experience from an RFR exposure above the PEL.

Word Bank	**List**
Tissue Heating	____________________
Microwave Hearing Effect	____________________
Pacemaker Interference	____________________
Cancer	
Immune System Alterations	
DC Magnetic Fields	
Induced Current	

Effects of RFR Exposure (Page 8a of 10)

When an RFR exposure occurs above the PEL, the potential exists for three types of exposure effects. Read more about these effects below.

Direct / Thermal Effects

Direct effects are primarily thermal and occur due to the absorption of electromagnetic energy which results in excessive heating of the affected area. Examples of direct effects include increased tissue heating, the microwave hearing effect, and induced current.

Increased tissue heating, also known as deep heating, occurs when energy is absorbed into the body's tissues. This type of effect can burn or irritate the surface level of skin, or it can damage the body's internal tissues. Since internal organs have no heat sensors, deep heating of the body tissue is more hazardous than surface heating because the person cannot feel the effects of the exposure to take corrective actions.

Another direct effect is the microwave hearing effect, which is the sensation of a clicking, buzzing, or chirping sound which seems to originate within or near the head. This type of effect is often the result of exposure to pulsed wave emitters.

Induced currents are direct effects which occur when a current passes through the body and creates burns at the point of contact. Induced currents only occur with emitters operating at less than 100 MHz.

Indirect Effects

Aside from the health effects caused directly by the RFR energy, personnel and equipment may be subject to additional hazards associated with RFR emitter operation.

Electromagnetic interference is an indirect RFR hazard which can lead to the reprogramming or disruption of microprocessor-controlled medical devices such as pacemakers. RFR energy can produce arcs which could ignite combustible gases or flammable materials. Many aircraft weapon systems use small explosive devices that are detonated by an electric current, often in order to detonate larger devices. Electromagnetic interference can inadvertently set off one of these devices.

High voltage is an ancillary hazard associated with RFR emitters that can cause a potentially lethal electrical shock. Strong electric fields, such as those produced in high-powered radar systems, can create x-ray emissions. Some systems may include sources of strong-static and low-frequency DC magnetic fields which can cause injury due to rapid movement of metal objects.

Athermal Effects

Biological effects not associated with thermal absorption may occur, although they have not been well-documented. Low levels of RFR have been found to cause alteration in animal behavior or changes in the functioning of cell membranes. Examples of these athermal effects may include immune system alterations and cancer.

These effects cannot be substantiated by leading Air Force, industry, or academic scientists. While the Air Force is not discounting the remote possibility of athermal effects, not enough data has been collected to establish a set of standards based upon observed athermal effects. Therefore, the current Air Force standard for RFR is designed to protect personnel from known thermal hazards associated with RFR emissions.

Scenario Challenge Point (Page 9 of 10)

Before reporting back to your OIC about the RFR health threats at the communications and radar site, you explain to another BE Tech on your team how the biological effects of an RFR exposure are related to the dose.

Which one of the following factors primarily determines the biological effects of RFR exposures?

A The SAR is determined based on the potential biological effects associated with the PEL.

B The SAR is based on the whole-body PEL of 0.4 watts per kilogram (W/kg).

C The PEL incorporates a safety factor of 20 below a SAR of 4.0 watts per kilogram (W/kg).

D The PEL is based on the whole-body SAR of 0.4 watts per kilogram (W/kg).

Biological Effects and Dose of RFR (Page 9a of 10)

The **biological effects** of RFR exposures are determined based on the frequency of the RFR. For instance, as the frequency of the RFR increases, individual organs become more susceptible to damage. Remember that optimal absorption takes place in the resonant frequencies, between 70 and 80 MHz.

Tissues with high water content such as skin, muscle, and internal organs, absorb much more energy than those with low water content, such as bones. Organs most affected by RFR exposures are those with the decreased ability to dissipate heat due to lack of blood flow. These critical organs include:

- Eyes.
- Testicles.
- Gall Bladder.
- Urinary Bladder.

For biological effects to occur, very high levels of RFR energy must be present. If the exposures stay below the PEL, personnel should not experience any biological effects related to the critical organs.

Biological Effects and Frequency

The threshold where a tingling or prickling sensation begins is between 3 kHz and 100 kHz, while the threshold related to a sensation of heat or warmth is between 100 kHz - 100 MHz.

These sensations are indicators that a person is being exposed to RFR and that further biological effects could be induced with continued doses.

Lesson Summary (Page 10 of 10)

You have learned that Radio Frequency Radiation (RFR) is found throughout the Air Force and that it's important to identify how the permissible exposure limit (PEL) and specific absorption rates (SARs) of RFR impact the potential biological effects of an exposure, which could include direct, indirect, and athermal effects.

Identifying the type of emitter and the biological effects of an RFR exposure are vital to ensuring the safety of personnel who work around RFR emitters.

In this lesson you:

- Recalled types of RFR emitters.
- Recalled parts and functions of RFR emitters.
- Recalled principles of absorption.
- Related Specific Absorption Rate (SAR) to Permissible Exposure Limits (PEL).
- Recalled the potential effects of an RFR exposure.
- Associated potential biological effects to the dose of RFR.

Audio Script

Narrator: After contacting your OIC to discuss the findings of the RFR HRA, a meeting was set up with the communications squadron commander to discuss additional controls that could be implemented to protect personnel working around the mobile radar equipment.

Lesson 3: RFR Risk Assessment

Lesson Description

In this lesson, you will conduct an HRA at a radar site to determine if personnel are exposed to hazardous levels of RFR. Upon completion of this lesson, you will be able to perform and RFR risk assessment.

Lesson Overview (Page 1 of 12)

As part of the HRA process, it is important to identify where emitters are used, what potential health threats they pose, and who may be at risk for exposure. While completing your RFR risk assessment, you will:

- Determine why and when RFR risk assessments are performed.
- Outline the RFR risk assessment process.
- Recall the steps for performing RFR measurement surveys.
- Recall the RFR risk assessment calculations.
- Perform RFR risk assessment calculations.

Audio Script

OIC: I received an email yesterday from the range squadron commander letting us know they've set up a new mobile radar unit that will be fully operational in a few days. I'm a bit concerned because the radar site is near the dining facility.

I need you to conduct an RFR risk assessment to determine whether personnel around the dining hall will be exposed to RFR levels above the PEL.

Performing RFR Risk Assessments (Page 2 of 12)

In order to protect personnel from exposure to potentially harmful levels of RFR, BE must assess RFR systems for compliance with accepted PELs. PELs are based on whether the exposure occurs in a **controlled environment** or an **uncontrolled environment.**

You will perform an RFR risk assessment whenever you identify an emitter with the potential to produce RFR levels at or above the PEL. This is done to establish a safe perimeter around the emitter.

Controlled Environments

In controlled environments, personnel are aware of the potential for RFR exposures associated with their employment or duties. Inadvertent exposure of other individuals is physically controlled by fences, chains, locks, and signs.

Examples of controlled environments include:

- Hospitals.
- Flightlines.
- Permanent radar sites.

Uncontrolled Environments

An uncontrolled environment is an area where exposures may be incurred by people who have no knowledge or control of the hazard.

Examples of uncontrolled environments include:

- Recreational areas.
- Farm fields.
- Base housing areas.

Appraisal (Page 3 of 12)

Which one of the following describes why an RFR risk assessment should be conducted?

A To determine the strategic value of the emitter.

B To identify maximum operating levels of the emitter.

C To establish a safe perimeter around the emitter.

D To document operation techniques of the emitter.

Scenario Challenge Point (Page 4 of 12)

While traveling to the radar site, you review the process for completing an RFR risk assessment with SrA Charles, a BE Tech who will be assisting you. Place the phases of the RFR risk assessment process in the order in which they should be completed.

Word Bank	Order
Control	1. ______________________
Identify	2. ______________________
Analyze	3. ______________________

The RFR Risk Assessment Process (Page 4a of 12)

Once it is determined that an RFR risk assessment will be conducted, the health threat must be properly identified, analyzed, and controlled. After completing the risk assessment, an emitter will be classified as a **non-hazardous emitter** or a **potentially hazardous emitter,** based on accessibility to personnel. Select each tab to learn more about the RFR risk assessment process.

Non-hazardous Emitter

IAW with AFOSH Std 48-9, *RFR Safety Program,* non-hazardous emitters are defined as low-power devices.

For RFR frequencies between 100 kHz and 1.5 GHz, the PEL may be exceeded under certain conditions for non-hazardous devices in which the radiating structure is not maintained within 2.5 cm of the body.

Exclusion Conditions Based on Type of Environment

Controlled Environment Exclusions	Uncontrolled Environment Exclusions
• At frequencies between 100 kHz and 450 MHz, the PEL may be exceeded if the radiated power is 7 watts or less.	• At frequencies between 100 kHz and 450 MHz, the PEL may be exceeded if the radiated power is 1.4 watts, or less.
• At frequencies between 450 and 1,500 MHz, the PEL may be exceeded if the radiated power is (7)(450/f) watts, or less, where the frequency of the emitter (f) is in MHz.	• At frequencies between 450 and 1,500 MHz, the PEL may be exceeded if the radiated power is (1.4)(450/f) watts or less, where the frequency of the emitter (f) is in MHz.

At frequencies above 1500 MHz, engineering judgment should be used when granting a low-power exclusion.

Potentially Hazardous Emitter

Potentially hazardous emitters are those emitters that do not fit the criteria for low-powered devices and are capable of emitting levels at or above the PEL identified in AFOSH Std 48-9, *RFR Safety Program*. These emitters, listed in order of evaluation priority, include:

1. Ground level hazard emitters.
2. Climbing hazard emitters.
3. Inaccessible emitters.
4. Short duration emitters.

Tab: Identify

Identification of potential RFR emitters is the first phase of the RFR risk assessment process. It begins with an initial, comprehensive survey followed by continuous annual surveillance. It's important to conduct this type of surveillance to ensure that all RFR emitters are identified and that new emitters which are introduced will not cause adverse health effects.

When the emitter is identified, all **pertinent information** will be gathered to determine the emitter's hazard potential. This information will be documented and maintained using *AF Form 2759, Radiofrequency Radiation Emitter Survey Data*.

Pertinent Information

The information gathered when an emitter is identified includes:

- Frequency (MHz).
- Peak power.
- Antenna size.
- Hazard distance measurements.
- Estimated hazard distance.
- Pulse specifications, if applicable.
- Movement parameters for rotating/moving antennas, if applicable.

Tab: Analyze

The ultimate goal for the analysis phase of the RFR risk assessment process is to determine a safe distance for personnel to work in relation to the emitter. During the analysis phase of this process you should:

- Identify the applicable PEL for each emitter using Tables 2.1 and 2.2 in AFOSH Std 48-9.
    - You should be aware that sometimes you will not be given a specific frequency of an emitter. This could be because the information is classified for that particular emitter, or it could be because the frequency range is all the information that is available. If you only have a range of frequencies for an emitter, you should use the frequency that represents the worst-case PEL.
- Perform the estimated hazard distance calculation to estimate the distance from the emitter to where the PEL is exceeded.
- Conduct a site visit to verify the conclusions of the identification phase and to determine the accessibility, locations, and conditions that may present hazards.
- Take measurements to identify the actual location of the health threats and to define the controls in place for those hazards.
- Determine a final risk assessment rating (**low risk**, **moderate risk**, **high risk**) which should be assigned to each emitter.

Low Risk

A low risk rating indicates a system which either cannot produce levels at or above the PEL or has a transmission time that is too short to exceed the average power density allowed for that frequency.
Examples of low-risk emitters include:

- Hand-held radar guns.
- Hand-held radio.

Moderate Risk

A moderate risk rating indicates a system which is capable of producing power densities in excess of the PEL, but has controls in place to prohibit exposure to personnel under normal operating conditions, tests, or maintenance procedures.

An example of a moderate-risk system is a TACAN antenna found on most flying bases. If the antenna rotation slows down from the design speed of 900 rpms, for any reason, the radiation emissions automatically shut down. The system presents only a moderate risk of exposure to personnel because, although it can produce levels of energy above the PEL, the interlock system must fail before any significant risk of exposure could reasonably occur.

High Risk

A high risk rating is applied to systems with average power densities at or above the PEL that can be accessed by personnel during normal operating conditions, routine tests, and/or maintenance procedures. Signs, rope barriers, cones, or other control measures must be posted prior to transmitting with these types of systems.

An example of a high-risk system would be nose-mounted radar on small aircraft, where the beam is accessible from the ground and routinely operated in a stationary mode for maintenance or testing while other maintenance personnel are working on or near the aircraft.

Tab: Control

During the control phase of the RFR risk assessment process, the primary goal is to control the health threat by:

- Examining the present controls.
- Defining the appropriate controls for the hazard.
- Determining protection requirements for workers and the general public.

Lakefront Field Scenario (Page 5 of 12)

When you and SrA Charles arrive, you review the layout of the site and any buildings around the area. You then speak with the radar technician on site to gather more information about the radar.

Audio Script

BE Tech: Good afternoon. We're with Bioenvironmental Engineering and we're conducting an assessment on the new radar system. Do you have time to answer a few questions?

Radar Technician: Sure.

BE Tech: Great. What type of radar system is set up here?

Radar Technician: It's a mobile radar, pulsed wave system. We use these almost exclusively in deployed settings in situations like this bare base.

BE Tech: What's the operating frequency?

Radar Technician: This system has an operating frequency of 3,333 MHz. The pulse repetition frequency is 725 pps.

BE Tech: And the pulse width?

Radar Technician: 22 μsec.

BE Tech: All right, thank you very much for helping me out. I'll probably need your help again in a little while, when we conduct a survey of the area.

Radar Technician: No problem. I'll be at the control truck.

BE Tech: Okay, thanks.

Scenario Challenge Point (Page 6 of 12)

As you review the notes from your conversation with the technician, you realize you need some more information about the radar system. Which two of the following are additional pieces of information you should ask the operator to provide?

A Gain

B Duty Factor

C Peak Power

D Hazard Distance

RFR Measurement Survey Preparation (Page 6a of 12)

Before an RFR measurement survey can begin, several pieces of information must be obtained about the RFR emitter. This information will be obtained using several sources and methods. Select each tab to learn about the information needed for an RFR measurement survey.

Tab: Information Obtained From the Operator

The information that should be obtained from the operator about the RFR emitter includes:

- **Type of system.**
- **Operating frequency.**
- **Peak power (Pp) / Average Power.**
- **Pulse repetition frequency (PRF).**
- **Pulse width (PW).**
- **Gain.**

Type of System

Remember, RFR systems are classified as either a continuous wave system where the signal is always turned on or a pulsed wave system where the emitter is turned off and on intermittently.

Operating Frequency

All RFR emitters are referenced by their frequency, which is usually provided in GHz. In order to perform the RFR survey, you will need to use the SI conversions, because PELs are referenced in MHz.

SI Conversion Chart

Prefix Equivalent	Decimal Equivalent	Exponential
Pico	0.000000000001	1×10^{-12}
Nano	0.000000001	1×10^{-9}
Micro	0.000001	1×10^{-6}
Milli	0.001	1×10^{-3}
Centi	0.01	1×10^{-2}
Deci	0.1	1×10^{-1}
None	1.0	1×10^{0}
Deka	10.0	1×10^{1}
Hecto	100.0	1×10^{2}
Kilo	1000.0	1×10^{3}
Mega	1,000,000.0	1×10^{6}
Giga	1,000,000,000.0	1×10^{9}

Peak Power (P_p) / Average Power

Peak power (P_p) is the maximum power density during the on time for a pulsed wave system. The average power must be calculated for a pulsed wave system.

The peak power is the average power for a continuous wave system.

Pulse Repetition Frequency (PRF)

The pulse repetition frequency (PRF) is the number of times the signal is on per unit of time. The PRF only applies to pulsed systems and is expressed in pulses per second (pps).

Pulse Width (PW)

The pulse width (PW) only applies to pulsed systems and is the length of time the signal is on. The information given is usually in microseconds (µsec) or milliseconds (ms).

Gain

Gain, also referred to as directivity, is the antenna's ability to concentrate its energy in a certain direction. The gain is expressed in decibels (dB) and is used to calculate the absolute gain.

Large gains mean the beam is smaller and the energy is more concentrated. Small gains mean the beam is wider and the energy is spread out further. Generally, the higher gain antennas are more hazardous due to the concentrated energy.

Tab: Information Obtained Using References

You will use AFOSH 48-9, *RFR Safety Program*, to look up the PEL. For controlled environments, the PEL can be found in **Table 2.1**. For uncontrolled environments, the PEL can be found in **Table 2.2**.

Table 2.1

Permissible Exposure Limits for Controlled Environments				
Frequency Range (f) (MHz)	**Electric Field (E) (V/m)**	**Magnetic Field (H) (A/m)**	**Power Density (S) (E & H Fields) (mW/cm^2)**	**Time (T_{avg}) (mins)**
0.003 - 0.1	614	163	10^2, 10^6	6
0.1 - 3.0	614	16.3/f	10^2, $10^4/f^2$	6
3 - 30	1842/f	16.3/f	$900/f^2$, $10^4/f^2$	6
30 - 100	61.4	16.3/f	1.0, $10^4/f^2$	6
100 - 300	61.4	0.163	1.0	6
300 - 3000	-	-	f/300	6
3000 - 15000	-	-	10	6
15000 - 300000	-	-	10	$616000/f^{1.2}$

V/m = volts per meter
A/m = amperes per meter
f = frequency of the emitter

Table 2.2

Permissible Exposure Limits for Uncontrolled Environments					
Frequency Range (f) (MHz)	**Electric Field (E) (V/m)**	**Magnetic Field (H) (A/m)**	**Power Density(S) (E & H Fields) (mW/cm^2)**	**Averaging Time (T_{avg}) (mins)**	
				E^2	**S or H^2**
0.003 - 0.1	614	163	(10^2, 10^6)	6	6
0.1 - 1.34	614	16.3/f	(10^2, $10^4/f^2$)	6	6
1.34 - 3.0	823.8/f	16.3/f	($180/f^2$, $10^4/f^2$)	$f^2/.3$	6
3.0 - 30	823.8/f	16.3/f	($180/f^2$, $10^4/f^2$)	30	6
30 - 100	27.5	$158.3/f^{1.668}$	(0.2, 9.4 x $10^5/f^{3.336}$)	30	$.0636f^{1.337}$
100 - 300	27.5	0.0729	0.2	30	30
300 - 3000	-	-	f/1500	30	-
3000 - 15000	-	-	f/1500	90000/f	-
15000 - 300000	-	-	10	$616000/f^{1.2}$	-

V/m = volts per meter
A/m = amperes per meter
f = frequency of the emitter

Tab: Information that Can Be Calculated

Before performing an RFR measurement survey, you will need to calculate several pieces of information to be used in the survey. The absolute gain (G_{abs}), duty factor (DF), and average power (P_{avg}) must be calculated first in order to calculate the estimated hazard distance (D_{pel}). You can learn more about these calculations below.

Absolute Gain (G_{abs})

The absolute gain (G_{abs}) of an antenna, for a given direction and polarization, is the ratio of the power that would be required at the input of an ideal isotropic radiator to the power actually supplied to the given antenna, to produce the same radiant intensity in the far-field region.

The formula used to calculate the absolute gain (G_{abs}) is:

$$G_{abs} = 10^{(gain/10)}$$

Duty Factor (DF)

The duty factor (DF) is a unit-less number which only applies to pulsed wave systems. The DF is the ratio of time the emitter is on to the total operating time. It will be used to calculate the estimated hazard distance. The formula used to calculate the DF is:

DF = Pulse Width (PW) x Pulse Repetition Frequency (PRF)

Average Power (P_{avg})

The average power calculation applies to pulsed systems only. The peak power (P_p) is used to calculate the average power (P_{avg}) for such systems. (For continuous wave systems, the peak power (P_p) is the average power and does not have to be calculated.)

It's important to remember that data must be converted to watts before this calculation can be performed properly. Typically the information needed to perform the calculation is given in watts. However, if it is listed in joules you should divide the pulse energy in joules by the pulse duration to get the output energy in watts.

The formula used to calculate the average power (P_{avg}) is:

$$P_{avg} = \text{Peak Power } (P_p) \times \text{Duty Factor (DF)}$$

Estimated Hazard Distance (D_{pel})

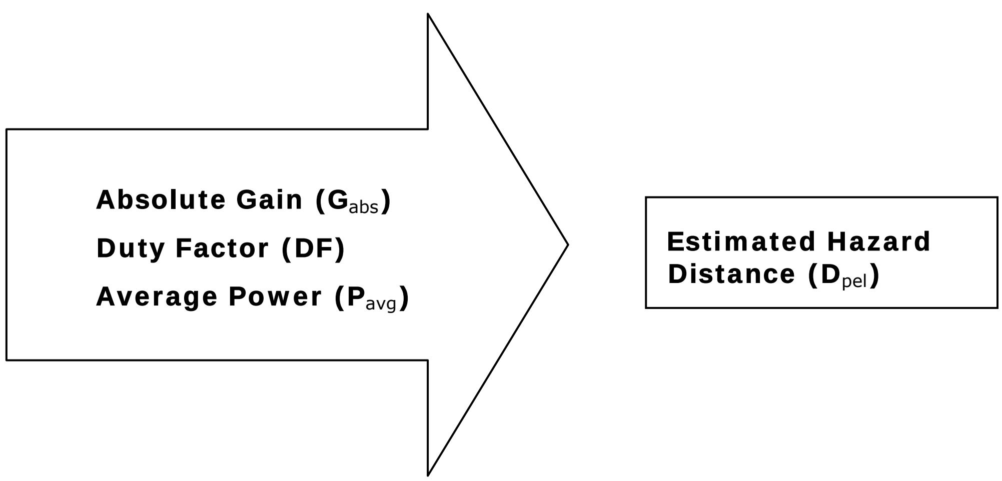
The estimated hazard distance is the distance from the antenna to the point where the power density equals the PEL. This is used to determine a safe starting point when conducting a survey. The D_{pel} must be calculated before attempting any field measurements.

It's important to recognize that the measured D_{pel} will likely be different than the estimated D_{pel}.

The formula used to calculate the D_{pel} is:

$$D_{pel} = 3.28\sqrt{\frac{P_{avg} \quad G_{abs}}{40 \quad \pi \quad PEL}}$$

The formula shown calculates the D_{pel} in feet.



Lakefront Field Scenario (Page 7 of 12)

Based on the information gathered from the technician and your observations of the radar site, you know that the RFR emitter is located in an uncontrolled environment and has an operating frequency of 3,333 MHz.

Since this emitter is located in an uncontrolled environment, **Table 2.2** should be referenced to find the applicable PEL of 2.22 mW/cm^2.

Note: From Table 2.2, the PEL for the frequency range of 3,000 to 15,000 MHz is listed as the frequency divided by 1,500. Therefore, 3,333 MHz divided by 1,500 is equal to 2.22 mW/cm^2.

Table 2.2

Permissible Exposure Limits for Uncontrolled Environments					
Frequency Range (f) (MHz)	Electric Field (E) (V/m)	Magnetic Field (H) (A/m)	Power Density(S) (E & H Fields) (mW/cm^2)	Averaging Time (T_{avg}) (mins)	
				E^2	S or H^2
0.003 - 0.1	614	163	(10^2, 10^6)	6	6
0.1 - 1.34	614	16.3/f	(10^2, $10^4/f^2$)	6	6
1.34 - 3.0	823.8/f	16.3/f	($180/f^2$, $10^4/f^2$)	$f^2/.3$	6
3.0 - 30	823.8/f	16.3/f	($180/f^2$, $10^4/f^2$)	30	6
30 - 100	27.5	$158.3/f^{1.668}$	(0.2, 9.4 x $10^5/f^{3.336}$)	30	$.0636f^{1.337}$
100 - 300	27.5	0.0729	0.2	30	30
300 - 3000	-	-	f/1500	30	-
3000 - 15000	-	-	f/1500	90000/f	-
15000 - 300000	-	-	10	$616000/f^{1.2}$	-

V/m = volts per meter
A/m = amperes per meter
f = frequency of the emitter

Lakefront Field Scenario (Page 8 of 12)

Before conducting the RFR measurement survey, you need to determine a safe position from which to begin.

Use the given information, determine the absolute gain, duty factor, and average power, in order to calculate the estimated hazard distance (D_{pel}).

Absolute Gain (G_{abs})

- Type of System = Pulsed System
- Operating Frequency = 3,333 MHz
- Peak Power = 50 kW
- Pulse Repetition Frequency= 725 pps
- Pulse Width= 2.2 µsec
- Gain= 24 dB
- PEL=2.22 mW/cm^2

$$G_{abs} = 10^{\,Gain/10}$$

$$\_\_\_ = 10^{\,24dB/\,10}$$

Note: Round your answer to the nearest whole number.

Absolute Gain (G_{abs})

Duty Factor (DF)

Average Power (P_{avg})

Estimated Hazard Distance (D_{pel})

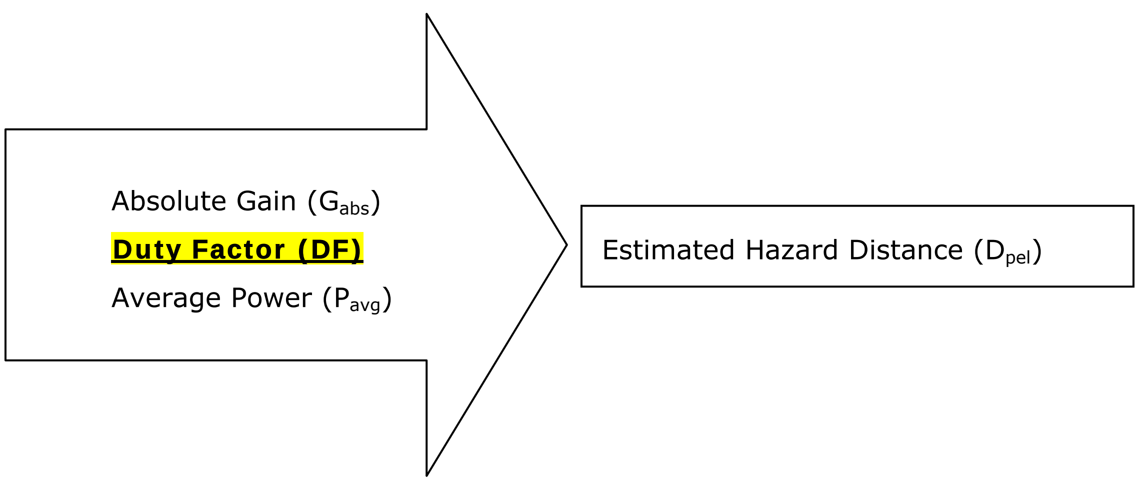
Duty Factor (DF)

- Type of System = Pulsed System
- Operating Frequency = 3,333 MHz
- Peak Power = 50 kW
- Pulse Repetition Frequency= 725 pps
- Pulse Width= 2.2 μsec
- Gain= 24 dB
- PEL=2.22 mW/cm^2

DF = Pulse Width (PW) x Pulse Repetition Frequency (PRF)

_.__ = (2.2 x 10^{-6}) seconds x 725 pps

Note: Round your answer to 4 significant digits.



Average Power (P_{avg})

- Type of System = Pulsed System
- Operating Frequency = 3,333 MHz
- Peak Power = 50 kW
- Pulse Repetition Frequency= 725 pps
- Pulse Width= 2.2 μsec
- Gain= 24 dB
- PEL=2.22 mW/cm^2

P_{avg} = Peak Power (Pp) x Duty Factor (DF)

___._ = W = 50,000 *W* x 0.0016

Absolute Gain (G_{abs})

Duty Factor (DF)

Average Power (P_{avg})

Estimated Hazard Distance (D_{pel})

Estimated Hazard Distance (D_{pel})

- Type of System = Pulsed System
- Operating Frequency = 3,333 MHz
- Peak Power = 50 kW
- Pulse Repetition Frequency= 725 pps
- Pulse Width= 2.2 μsec
- Gain= 24 dB
- PEL=2.22 mW/cm^2

$$D_{pel} = 3.28\sqrt{\frac{P_{avg} \quad G_{abs}}{40 \quad \pi \quad PEL}}$$

$$\_\_\_ \cdot \_ \; ft = 3.28\sqrt{\frac{80\ \text{W} \quad 251}{40 \quad \pi \quad 2.22}} \ \text{mW/cm}^2$$

Note: Round your answer to the nearest tenth**.**

Absolute Gain (G_{abs})
Duty Factor (DF)
Average Power (P_{avg})

Estimated Hazard Distance (D_{pel})

Scenario Challenge Point (Page 9 of 12)

Now that you have performed the pre-survey calculations and determined the frequency of the emitter to be *3,333 MHz*, you instruct the BE Tech assisting you to select the equipment needed for the survey. Your assistant selects a probe without considering the potential for probe burnout. Using the information provided below, what is the maximum power density (S_{max}) the probe selected can be exposed to before there is a potential for burnout?

- Frequency Range 300 kHz – 3 GHz
- Probe Correction Factor of 1.1
- Probe burnout rating 200mW/cm^2
- Duty Factor 0.0016
- $S_{max} = \dfrac{\text{duty factor x burnout rating}}{\text{probe correction factor}}$

A 0.0024 mW/cm^2

B 0.29 mW/cm^2

C 0.20 mW/cm^2

D 3.52 mW/cm^2

Selecting RFR Measurement Survey Equipment (Page 9a of 12)

Before beginning an actual survey, you'll need to determine the monitoring equipment needed. If the appropriate surveying equipment is not selected, the results from the meter will not be accurate. Furthermore, the person conducting the monitoring could be exposed to potentially harmful levels of RFR because the meter may indicate levels of RFR lower than what is actually present. When selecting monitoring equipment for RFR surveys, you should consider the frequency range of the probe, the power density of the emitter, and whether you are monitoring the E- or H-Field of the emitter. Learn more about selecting RFR measurement survey equipment by reading the information below.

Tab: Frequency Range of Equipment

The first consideration for equipment selection is the frequency range for the probe being used. The frequency range is printed on the handle of the probe.

It is very important to select a probe that monitors the frequencies of the emitter being surveyed. If the proper probe is not selected, the data returned will not be accurate.

Tab: Power Density of Emitter

The second consideration for selecting the appropriate equipment is the power density of the emitter. You must determine whether the probe can withstand the RFR being emitted.

Probes and meters used to monitor RFR are very sensitive to overload. Meters do not have to be on or the probe connected to the meter for burnout to occur. Pulsed RFR systems pose the greatest risk for probe burnout because of the slow response of both the meter and probe to take measurements.

When surveying continuous wave systems, preventing probe burnout is as simple as watching the meter to ensure it does not exceed the full scale. However, to **prevent probe burnout** on pulsed wave systems; you should use the **probe burnout calculation.**

Prevent Probe Burnout

In order to prevent probe burnout, the probe should be better than the meter. For instance, if the probe can handle intensity far above the full scale value of the meter, you are relatively safe from probe burnout. However, the meter does not protect the probe. You protect the probe by not allowing the meter to peg-out. Not allowing your meter to peg is a standard practice when using any type of measuring equipment.

Probe Burnout Calculation

The probe burnout calculation is used when monitoring pulsed wave systems to calculate the maximum power density to which the probe can be exposed prior to burnout (S_{max}). The formula used to calculate probe burnout is:

$$S_{max} = \frac{\text{duty factor} \times \text{burnout rating}}{\text{probe correction factor}}$$

The burnout rating can be found in the manufacturer's literature. The probe correction factor is located on the probe's handle and corresponds to frequency.

If the calculated value is above the full scale value of the meter, the likelihood of burnout is low. If the calculated value is below the full scale value of the meter, the likelihood of burnout is high.

Tab: E- or H-Field of Emitter

The third consideration for equipment selection is whether the E-Field or H-Field is being monitored.

The E-Field is the electronic field component of an electro-magnetic wave measured in Volts/Meter. H-Field is the magnetic field component of an electromagnetic wave measured in Amps/Meter.

You will most commonly monitor the E-Field because it is the more hazardous of the two fields.

RFR Measurement Survey Objectives (Page 10 of 12)

Once you have calculated the estimated hazard distance (D_{pel}) and selected the appropriate equipment, you can survey the emitter. The primary objectives for conducting an RFR measurement survey are to:

- **Find the actual hazard distance.**
- **Identify hot spots.**
- **Check for leaking transmission lines.**

Find the Actual Hazard Distance

When surveying RFR emitters, you should determine the actual hazard distance, which is the area where the meter reads the PEL value. This is important because the D_{pel} only provides an estimate.

Identify Hot Spots

Hot spots are locations where the PEL is exceeded and may be found in unexpected areas due to reflections from objects. In addition, some properties of antennas cause lobes of energy to the side or back which can lead to hazardous levels of RFR in locations other than the main beam.

Check for Leaking Transmission Lines

It's important to check for leaking transmission lines because they can cause a significant health threat if the lines are positioned near personnel.

Scenario Challenge Point (Page 11 of 12)

Before beginning the survey, the BE Tech assisting you asks you to describe the process you'll follow for completing the survey. Place the steps of the RFR measurement survey in the order in which they should be completed.

Word Bank	Order
Begin surveying outside the calculated D_{pel}.	1. ______________________
Take small steps toward the emitter.	2. ______________________
Have the emitter operator turn the system off.	3. ______________________
Obtain absolute control of the emitter.	4. ______________________
Continue surveying until the PEL is found.	5. ______________________

Performing RFR Measurement Surveys (Page 11a of 12)

Once you have performed the pre-survey tasks and selected the appropriate equipment, you can begin actual survey procedures. To perform an RFR measurement survey, you should use the following steps:

1. Control the Emitter

Before you begin an RFR measurement survey, you should obtain complete control over the operation of the emitter. This is to ensure the safety of personnel while the survey is being conducted. In addition, you should make sure all emitters in the area are turned off so they do not introduce any interference.

2. Begin Surveying Outside the Calculated D_{pel}

To begin the survey, you should start outside of the calculated D_{pel} leading in with the probe. You should hold the meter in front of you, slightly off-center, and hold the probe parallel to the beam while watching the meter.

You should never approach any emitter without measurement equipment or begin a survey in a suspected hotspot.

3. Take Small Steps Toward the Emitter

As you move closer to the emitter, take small steps while periodically stopping to define the beam and find a spatial average, which is taking the average of several readings while you move the meter from side to side over the vertical cross-section of your body.

4. Continue Until the PEL is Found

Once you have found the actual D_{pel}, you have met your primary objective.

You should also identify any lobes from the antenna, delineate the area of concern, and search for hotspots. It's also important to check for transmission line leakage while you are at the site.

5. Have the Emitter Operator Turn the System Off

After identifying the actual D_{pel}, you should stop and instruct the emitter operator to turn the system off while you measure from the antenna to where your probe stopped.

Lesson Summary (Page 12 of 12)

You have learned that RFR risk assessments are performed on any system capable of producing RFR above the PEL in order to establish a safe perimeter around the emitter. When conducting an RFR risk assessment, you follow a specific process to ensure the health threat is properly recognized, evaluated, and controlled.

Before beginning a survey, you should obtain or calculate all necessary information about the emitter. Then, you can select the appropriate equipment and proceed with the survey.

In this lesson you:

- Determined why and when RFR risk assessments are performed.
- Outlined the RFR risk assessment process.
- Recalled the steps for performing RFR measurement surveys.
- Recalled the RFR risk assessment calculations.
- Performed RFR risk assessment calculations

Audio Script

Narrator: After completing the survey, you determined personnel in the dining facility were not exposed to RFR that exceeds the PEL for uncontrolled environments. You reported the findings of your survey to your OIC. Based on this information, appropriate warning signs and fencing were added to the area. Routine monitoring was implemented to ensure that RFR levels remain below the PEL for any future base assets which may be placed around the radar site.

Lesson 4: Investigating an RFR Overexposure or Accident

Lesson Description

In this lesson, you will perform an RFR overexposure investigation. Upon completion of this lesson, you will be able to outline the process for investigating a suspected RFR overexposure or accident.

Lesson Overview (Page 1 of 14)

There are many RFR emitters used for a variety of purposes throughout the Air Force. It's important to provide careful monitoring of RFR exposures to ensure the safety of personnel.

While identifying whether the maintenance worker was overexposed, you will:

- Determine why and when suspected RFR overexposure / accident investigations are performed.
- Recall procedures for investigating suspected RFR overexposures / accidents.

Audio Script

OIC: Earlier this morning, a radar technician was testing the nose-mounted radar unit on one of the Pave Hawk helicopters, and a maintenance worker accidently walked in front of it while it was on. I need to you begin an RFR overexposure investigation and determine whether the worker was exposed to levels above the PEL.

Lakefront Field Scenario (Page 2 of 14)

Audio Script

BE Tech: Good morning. I'm beginning an overexposure investigation of the incident that occurred earlier this morning with the nose-mounted radar unit. Do you know anything about it?

Avionics Technician: Yeah, I was about 30 yards away when it happened. Is the maintenance worker okay?

BE Tech: Sorry, I don't have any information about his condition right now. Can you tell me a little bit about what you saw?

Avionics Technician: Well, I was working on another aircraft and was facing the opposite direction, but I can tell you what I know about it. The radar technician told me he was running routine calibrating procedures on the radar unit. Then, the maintenance worker, who was working on another aircraft, walked through the beam to get to a tool chest.

BE Tech: Do you know how far away the maintenance worker was from the nose of the helicopter?

Avionics Technician: No, like I said, I didn't see it. I just heard someone yell, and I went to see what happened.

BE Tech: Okay, thanks for the information. Can you take me to where the incident occurred?

Avionics Technician: Sure.

Scenario Challenge Point (Page 3 of 14)

While you're walking toward the area where the alleged exposure occurred, the technician asks you what type of information you're trying to find out about the incident. Build a list of the reasons why an RFR overexposure investigation is conducted.

Word Bank	**List**
To determine if RFR emitters should be allowed in the area.	____________________
To identify operation deficiencies to avoid recurrence.	____________________
To identify if the radar unit is functioning properly.	____________________
To determine the severity of the exposure.	
To calculate the PEL for the area around the radar unit.	
To determine if the individual was, in fact, exposed.	

Performing an RFR Overexposure or Accident Investigation (Page 3a of 14)

RFR overexposure or accident investigations are conducted whenever a report occurs of personnel potentially being overexposed to RFR.

RFR overexposure or accident investigations are performed to:

- Determine if the individual was, in fact, exposed.
- Determine the severity of the exposure to ensure proper medical assessments are performed.
- Identify operation deficiencies to avoid recurrence.

Lakefront Field Scenario (Page 4 of 14)

Audio Script

Nurse: Good morning. I'm a nurse at the MTF and I was given your name to call about the worker who was possibly overexposed to RFR at the flightline today. Is there anything you need us to do while he's here, aside from a routine exam?

BE Tech: Other than performing a standard medical history workup and a routine medical exam, the patient will also need an eye exam or visual acuity test if the eyes were involved.

Nurse: All right, I'll let the doctor know.

BE Tech: Also, please let the worker know that I'm at the flightline currently; but, I'll be on my way to the MTF shortly to interview him about the incident.

Nurse: Okay, I'll let him know.

BE Tech: Thank you.

Scenario Challenge Point (Page 5 of 14)

While you're still at the flight-line, you arrange to interview the technician who was working on the radar when the exposure occurred. Which two of the following pieces of information should be obtained when conducting interviews after a potential overexposure has occurred?

A Duration of exposure to the emitter.

B Length of time performing this type of work.

C Maintenance records for the aircraft and radar.

D Distance between the worker and the emitter.

Beginning an RFR Overexposure or Accident Investigation

(Page 5a of 14)

When a potential RFR overexposure or accident occurs, the personnel involved should inform their supervisor that they think they've been overexposed. Once the supervisor is informed of the incident, the local BE office, the MAJCOM BEE, AFMSA/SG3PB, and the USAFSAM / ESOH Service Center should be notified. This notification prompts the RFR investigation.

After proper notification of the incident has occurred, you should:

- **Perform an initial estimation of the exposure.**
- **Ensure the exposed individual reports for medical screening and treatment.**
- **Conduct interviews with the exposed individual and witnesses.**

Perform an Initial Estimation of the Exposure

While performing an initial estimation of the exposure, you should gather all information currently known about the incident. This would include considering the type of emitter and the potential for the individual to be exposed to RFR above the PEL.

When determining if a person has received an exposure in excess of the PEL, you need to consider the average exposure time and whole-body spatial averaging that could be associated with the incident.

Ensure the Exposed Individual Reports for Medical Screening and Treatment

You should ensure that personnel who were potentially overexposed report for a post-exposure medical examination within 72 hours after the alleged exposure. Any symptoms which may be associated with the exposure should be reported to the attending physician and recorded for medical investigation purposes.

This examination should include:

- A standard medical history.
- A routine medical examination.
- An eye examination or visual acuity test, if the eyes were involved.

Conduct Interviews with the Exposed Individual and Witnesses

You should conduct interviews with the exposed individual and witnesses to describe the circumstances surrounding the incident. The information obtained from these interviews will assist you when reconstructing the incident to determine the actual exposure to the individual.

This information includes:

- Type of emitter.
- Distance between the individual and the emitter.
- Duration of exposure.

All interviews should include a signed narrative statement for documentation purposes.

Lakefront Field Scenario (Page 6 of 14)

Audio Script

BE Tech: I understand you were performing work on the chopper's radar when the maintenance worker passed in front of the unit.

Radar Technician: Yeah, I planned to set up barriers, but they haven't arrived at the base yet. I yelled at him when he started to walk in front of the chopper, but I don't think he heard me. It gets pretty loud out here.

BE Tech: I understand. About how far away from the radar was he when he passed in front of the beam?

Radar Technician: I can't be sure, but I think he was about three feet away.

BE Tech: Do you know how long he was in front of the radar?

Radar Technician: Probably three or four seconds.

Narrator: As you continue the interview with the radar technician, you document other information about the radar and the incident. After the interview is complete, you go to the medical facility to interview the maintenance worker who was exposed.

Lakefront Field Scenario (Page 7 of 14)

Audio Script

BE Tech: I'm with Bioenvironmental Engineering, and I'm conducting an investigation about the exposure you experienced this morning.

Maintenance Worker: Yeah, it's been quite a day.

BE Tech: I'm sure it has. Have you seen the doctor yet?

Maintenance Worker: Yeah, just a little while ago. As soon as the nurses finished getting my medical history, he came in and did a full exam.

BE Tech: How are you feeling?

Maintenance Worker: I feel okay, except my eyes are a bit irritated.

BE Tech: Did they check your eyes?

Maintenance Worker: No, but they did say they were making an appointment for me to have my eyes checked.

BE Tech: That's good. Can you tell me about how you were exposed?

Maintenance Worker: Sure. I just started work on repairing the hatch for a chopper when I noticed that somebody had moved the tool box further down the flight-line. I started walking over to get a tool I needed, but when I got about halfway there, I heard someone yell. It was too late and I walked right through the radar beam.

BE Tech: Is it normal to walk across the flight-line to get a tool?

Maintenance Worker: Yeah, it's pretty common. Normally there's one set of tools for every three maintenance crews.

BE Tech: How far in front of the radar do you think you were?

Maintenance Worker: I'd say about three feet.

BE Tech: Do you recall how long you were in the beam?

Maintenance Worker: No more than a few seconds, I'd say.

BE Tech: Is it common on the flight-line for radar tests to be conducted without cones and ropes around the aircraft?

Maintenance Worker: I'd like to say the proper safety measures are always used but I don't see too many precautions used when radar tests are being done.

BE Tech: All right, thank you for the information. If you think of anything else about the incident, please feel free to contact me.

Maintenance Worker: Okay, I sure will. Thanks.

Scenario Challenge Point (Page 8 of 14)

After interviewing the maintenance worker, you call your OIC on the way back to the flight-line to get approval to reconstruct the incident using the information you've gathered.

As you're working to recreate the incident, the radar technician who is assisting you asks how the radar's parameters should be set.

Which one of the following statements *best* describes how the radar's parameters should be set when reconstructing the incident?

A The parameters should be set as low as possible and increased gradually as you proceed.

B The parameters should be set as high as possible and decreased gradually as you proceed.

C The parameters should be set as near as possible to those used when the incident occurred.

D The radar system should be turned off completely while you reconstruct the incident.

Reconstructing the Incident (Page 8a of 14)

After gathering and documenting the information available, you should arrange with the unit Radiation Safety Officer (RSO) to reconstruct the incident. When reconstructing the incident, you should employ safety precautions to protect yourself, others, and the measurement instruments from harm.

When ready to begin reconstructing the incident, the system parameters should be set as near as possible to those used when the incident occurred. If the beam is rotational, lock it in a stationary position.

While reconstructing the incident, you should take measurements at the **point of exposure** to determine the actual levels and duration of exposure. In addition, you should take photographs representing the positions of the emitter and personnel as they were at the time of the exposure.

Point of Exposure

If the power density at the point of exposure is greater than your measuring instrument will report, you should:

- Make multiple measurements.
- Plot data on semi-log paper.
- Extrapolate to determine the actual exposure value. To perform this extrapolation, take measurements further from the antenna where the power density is within the measurement range of the meter and probe. Then, back-calculate to determine the exposure at the location of the incident.

Lakefront Field Scenario (Page 9 of 14)

Now that you've completed interviewing personnel involved in the incident and you have reconstructed the incident, you return to the BE office to calculate the information needed to determine if an actual overexposure has occurred.

Scenario Challenge Point (Page 10 of 14)

Before you begin your calculations, you review your notepad with the information you've collected about the incident to this point.

After reviewing the data, you begin work to perform the required calculations.

- Distance from emitter = 3 ft
- Duration of Exposure = 3 seconds
- Frequency = 10 GHz
- Peak Power = 1.5 kW
- Pulse Repetition Frequency = 15 kHz
- Pulse Width = 20 μsec
- Power Average = 0.45 kW
- Antenna Gain = 29 dBi
- Absolute Antenna Gain = 794
- Vertical Beam Width = 10°
- Horizontal Beam Width = 10°
- Reflector Length = 0.25 m
- Reflector Width = 0.25 m

Near-Field Boundary (NFB)

First, you need to determine if the maintenance worker was located within the near-field boundary (NFB). Remember that when calculating the System Wavelength you are dividing by GHz, which will require unit conversion for the equation to work out properly.

System Wavelength Calculation:

$$\lambda = \frac{c}{f} \qquad \_.\_\_\ m = \frac{3 \times 10^8\ m/\sec}{\_\_.\_\ Ghz}$$

Near-Field Boundary Calculation:

$$\frac{L^2}{(4)(\lambda)} \qquad \_.\_\_\ m = \frac{\_.\_\_\ m^2}{(4)(\_.\_\_\ m)}$$

Where:
λ = wavelength
f = frequency
c = velocity of EMR (3 x 10^8 meters per second)
L = longest dimension of the antenna (meters)

Based on the calculations you've performed and the information you've been provided, is the maintenance worker's exposure considered a near-field or far-field exposure?

A Near-Field Exposure

B Far-Field Exposure

Main-Beam Power Density (S)

You've determined the maintenance worker's exposure occurred outside of the near-field boundary, so now you need to calculate the main-beam power density (S) for situations where the individual is exposed within the far-field.

- Distance from emitter = 3 ft
- Duration of Exposure = 3 seconds
- Frequency = 10 GHz
- Peak Power = 1.5 kW
- Pulse Repetition Frequency = 15 kHz
- Pulse Width = 20 μsec
- Power Average = 0.45 kW
- Antenna Gain = 29 dBi
- Absolute Antenna Gain = 794
- Vertical Beam Width = 10°
- Horizontal Beam Width = 10°
- Reflector Length = 0.25 m
- Reflector Width = 0.25 m

Round your answer for the main-beam power density to the nearest whole number.

Main-Beam Power Density – Exposed Within Far-Field:

$$S_{ff} = \frac{(P_{avg})\,(G_{abs})}{(40)(\pi)(\text{distance [in meters]}^2)}$$

$$\_\_\_\_\_ \ \ \text{mWcm}^2 = \frac{(\_\_\_\_\_\_\_\_\_\_\text{kW})\ (794)}{(4)(\pi)(0.9\text{m}^2)}$$

Where:
G_{abs} = absolute gain
P_{avg} = average power

Power Density Average (S_{avg})

Finally, you should determine the exposure to the individual by performing the power density average calculation.

- Distance from emitter = 3 ft
- Duration of Exposure = 3 seconds
- Frequency = 10 GHz
- Peak Power = 1.5 kW
- Pulse Repetition Frequency = 15 kHz
- Pulse Width = 20 μsec
- Power Average = 0.45 kW
- Antenna Gain = 29 dBi
- Absolute Antenna Gain = 794
- Vertical Beam Width = 10°
- Horizontal Beam Width = 10°
- Reflector Length = 0.25 m
- Reflector Width = 0.25 m

Power Density Average:

$$S_{avg} = \frac{(I \times T_{exp})}{360\ \text{seconds}}$$

$$\underline{\hspace{3cm}}\ \text{mW/cm}^2 = \frac{(3510\ \text{mW/cm}^2 \times \underline{\hspace{3cm}}\ \text{seconds})}{360\ \text{seconds}}$$

Where:
I = intensity (measured or calculated as the main-beam power density)
T_{exp} = duration of exposure

Calculating the Exposure (Page 10a of 14)

Conducting **interviews** and reviewing **manufacturer's information** about the emitter can provide important data about the potential exposure. This information allows you to perform the near-field boundary (NFB), main-beam power density (S), and power density average (S_{avg}) calculations which help you determine the individual's amount of exposure.

Information Obtained from Interviews

Information obtained from interviews which can be used to calculate the exposure includes:

- Type of emitter.
- Distance between worker and emitter.
- Duration of exposure.

Information About the Emitter

Information about the emitter which is used to calculate the exposure includes:

- Frequency.
- Absolute Antenna Gain.
- Average Power.
- Peak Power.
- Pulse Width.

Tab: Near-Field Boundary (NFB)

The first step to determining the maximum power density on the potentially exposed individual is to determine the near field boundary (NFB). The NFB is used to determine the appropriate maximum main-beam power density (S) calculation to use. For example, if the exposed individual was located within the near-field range of the emitter, the near-field power density calculation is most appropriate. If the individual was located outside the near-field range of the emitter, the far-field power density calculation should be used.

In order to calculate the NFB, you must first determine the wavelength of the emitter. This is done by using the following equation:

$$\lambda = \frac{c}{f}$$

Where:
λ = wavelength
f = frequency
c = velocity of EMR (3×10^8 meters per second)

Once the wavelength is determined, the NFB can then be calculated. The NFB provides a range in meters that will establish the near field and far-field boundary. The NFB is calculated using the following equation:

$$\frac{L^2}{(4)(\lambda)}$$

Where:
λ = wavelength
L = longest dimension of the antenna (meters)

Tab: Main-Beam Power Density (S)

After determining the NFB, you can select which main-beam power density equation is most appropriate for the exposure you are working with. You should select the equation based on where the individual was exposed in relation to the emitter.

- **Exposed Within Near-Field**
- **Exposed Within Far-Field**

Exposed Within Near-Field

If the individual was exposed within the near-field range of the emitter, you should calculate the power density using the power density near-field calculation (S_{nf}). Before this can be done, you may need to calculate the area of the antenna using the following formula:

Area = Reflector Length x Reflector Width

Once you have determined the area of the antenna, you can perform the power density near-field calculation. The formula used to calculate the near-field estimation is:

$$S_{nf} = \frac{(4)(P_{avg})}{\text{antenna area}}$$

Where:
P_{avg} = average power

If the emitter involved is a scanning emitter, you will also need to calculate the rotation reduction factor (RRF_{nf}) and multiply it by the calculated near-field power density (S_{nf}). The RRF_{nf} can be calculated using the following formula:

$$RRF_{nf} = \frac{A_d}{RQ_S}$$

Where:
A_d = antenna dimension in the plane of motion
R = distance from a point in the near field, where the person was standing, to the antenna
Q_s= scan angle in radians

Exposed Within Far-Field

If the individual was exposed outside the near-field range of the emitter, you should calculate the power density using the far-field power density calculation (S_{ff}). The far-field power density can be calculated using the following formula:

$$S_{ff} = \frac{(P_{avg})\,(G_{abs})}{(40)(\pi)(\text{distance [in meters]}^2)}$$

Where:
G_{abs} = absolute gain
P_{avg} = average power

If the emitter involved is a scanning emitter, you will also need to calculate the rotation reduction factor (RRF_{ff}) and multiply it by the calculated far-field power density (S_{ff}). The RRF_{ff} can be calculated using the following formula:

$$RRF_{ff} = \frac{B}{Q_S}$$

Where:
Q_s= scan angle in radians
B = half-power beam width

Tab: Power Density Average (S_{avg})

After determining the NFB and the power density, you're ready to determine the amount of exposure to the individual. This is done by performing the power density average (S_{avg}) calculation which is a time-weighted average of the exposure over a 6-minute period of time. The formula used to calculate the power density average is:

$$S_{avg} = \frac{(I \times T_{exp})}{360 \text{ seconds}}$$

Where:
I = intensity (calculated or measured)
T_{exp} = duration of exposure

Scenario Challenge Point (Page 11 of 14)

Before contacting your OIC to report your findings, you use the information obtained from the calculations to determine if an actual overexposure has occurred.

Comparing the calculated power density average of 29.3 mW/cm^2 to the PEL of 10 mW/cm^2, did the maintenance worker receive an overexposure?

A Yes

B No

Compliance Factors (Page 11a of 14)

When performing an RFR overexposure investigation, you should consider how the measured and calculated results relate to appropriate standards.

To determine the relationship between the measured levels and the standard, you should identify the PEL for the calculated power density using the emitter's frequency range. Once the PEL is known, you should compare the power density average (S_{avg}) to the standard power density of the PEL to determine if the individual was actually overexposed.

If the individual was **exposed to multiple frequencies,** you should calculate the combined PEL and compare the sum to unity.

Exposed to Multiple Frequencies

When an individual has been exposed to multiple frequencies, you should use the following calculation to combine the PELs.

$$\text{Combined PEL} = \frac{\text{exposure}_1}{\text{PEL}_1} + \frac{\text{exposure}_2}{\text{PEL}_2} + \ldots$$

Scenario Challenge Point (Page 12 of 14)

Which two of the following recommendations would be appropriate to recommend based on the criticality of the mission being performed?

A Implement improved safety practices for personnel around the choppers.

B Implement additional PPE for all maintenance workers on the bare base.

C Implement restrictions on the number of nose-mount radars allowed on base.

D Implement training for personnel who work around the choppers.

Audio Script

BE Tech: Good morning, Sir. I've finished collecting the data for the overexposure investigation. Turns out, the maintenance worker was exposed to levels of RFR that exceeded the PEL.

OIC: Have you contacted the maintenance worker about your findings yet?

BE Tech: Not yet. I'll let him know he needs to continue to be monitored by the physician until cleared.

OIC: Have you developed any recommendations we can submit to the commander to keep something like this from happening again?

BE Tech: I can think of a couple things that should be done.

Narrator: Which two of the following recommendations would be appropriate to recommend based on the criticality of the mission being performed?

Recommending Corrective Actions (Page 12a of 14)

After all information about the incident is analyzed, you should provide **recommendations** for corrective actions so incidents of this nature will be less likely to occur in the future.

Your primary responsibility when providing recommendations is to communicate to decision-makers any hazardous practices that contributed to the incident. This includes any typical worker activities which may be safety hazards and could lead to future incidents.

Recommendations

Typical recommendations to decision-makers for corrective actions may include:

- Improved safety practices for personnel who work near emitters.
- Training for personnel who work near emitters.

Scenario Challenge Point (Page 13 of 14)

After submitting your recommendations to your OIC, you begin work on completing the final report needed for the investigation. Within how many days of the investigation's completion should you submit the report to Public Health (PH)?

A 7

B 10

C 45

D 90

Preparing the Investigation Report (Page 13a of 14)

To conclude the investigation, a **complete and detailed report** must be prepared. The report should include who was involved, what specifically occurred, when it happened, and where the incident occurred, as well as photographs, measured data, and any medical findings that were collected.

The investigator should prepare the final report and **submit it to Public Health (PH)** within 45 days following its completion.

Complete and Detailed Report

At a minimum, the investigation report should include:

- Date of incident.
- Last name, first name, middle initial of exposed individual.
- SSN.
- Rank.
- Employer.
- Location of incident (base).

- Emitter nomenclature.
- Emitter frequency (MHz).
- PEL (mW/cm^2).
- Maximum Exposure Level measured (mW/cm^2).
- Exposure duration (minutes).
- Time weighted average exposure (mW/cm^2 x exposure time/6-minutes).
- Target organ(s).
- Final conclusion of whether the person was overexposed.
- Initial medical action taken.
- Description of symptoms, if any.
- Follow-up actions recommended by the attending physician.
- Investigator's name, rank, phone number.
- Any additional information or comments that seem pertinent.

Submit to Public Health (PH)

Once the final report is received by PH, a summary of the BE findings will be prepared and distributed, along with the detailed final report, to the following addressees:

- USAFSAM.
- Bioenvironmental Engineers of all MAJCOMs involved.
- Public Health officers of all MAJCOMs involved.
- Safety offices of all MAJCOMs involved.
- Commander of the operational unit (squadron, etc.) involved.
- Safety office of the installation where the incident occurred.
- AFMSA/SG3PB.

The operational unit commander will ensure that the shop supervisor receives a copy of the final report.

Lesson Summary (Page 14 of 14)

You've learned that RFR overexposure or accident investigations are conducted whenever a report of a potential overexposure to RFR is made. The purpose of the investigation is to determine whether the individual was exposed, to what extent, and whether any operation deficiencies exist.

You also learned that, while conducting the investigation, you should conduct interviews and use the information to reconstruct the incident. Then, you perform calculations to determine if the exposure exceeded the PEL. Finally, you should make recommendations to prevent future occurrences and file a final report with PH.

In this lesson you:

- Determined why and when suspected RFR overexposure / accident investigations are performed.
- Recalled procedures for investigating suspected RFR overexposures / accidents.

Audio Script

OIC: Good work on the RFR overexposure investigation. Once you finish your report, we'll forward it to Public Health. I have a meeting scheduled with the commander tomorrow morning to discuss the recommendations we talked about. If I have any questions before then, I'll give you a call.

Lesson 5: RFR Threat Control Options

Lesson Description

In this lesson, you will recommend controls for a NEXRAD Doppler weather radar site. Upon completion of this lesson, you will be able to determine RFR threat controls options for a given scenario.

Lesson Overview (Page 1 of 7)

RFR is found throughout the Air Force and can cause a variety of health effects to exposed personnel. BE identifies and analyzes potential RFR health threats to recommend appropriate controls.

While working with the OIC at the Doppler radar site, you will:

- Recall RFR control options.
- Determine appropriate controls for RFR.

Audio Script

OIC: The communications squadron has finished installing the NEXRAD Doppler weather radar next to tent city. It's not operational yet, but I need you to assist me with recommending the appropriate controls for the radar site. Meet me at the site in 20 minutes.

Lakefront Field Scenario (Page 2 of 7)

When you and your OIC arrive at the radar site, you find that no controls have been implemented to protect personnel from coming within close proximity of the radar system.

You proceed with conducting an RFR measurement survey to determine the data needed to recommend appropriate controls.

Scenario Challenge Point (Page 3 of 7)

As you and your OIC arrive at the site, you begin to consider possible controls that may be appropriate to implement at the radar site. Build a list of engineering controls and a list of administrative controls that could be implemented at the radar site.

Word Bank
Warning Signs
Training
Azimuth Blanking
Safe Work Practices
Coveralls
Personal Warning Devices
Interlocks
Flashing Lights

Engineering Controls	Administrative Controls
____________________	____________________
____________________	____________________
____________________	____________________

RFR Controls (Page 3a of 7)

As with other health threats, RFR must be controlled so personnel do not receive an exposure above the accepted standard. With RFR, only administrative and engineering controls should be used. PPE or personal warning devices are not recommended for use with RFR because they do not effectively protect personnel from hazardous exposures. To learn more about the types of controls used for RFR read the information before.

Tab: Engineering Controls

Engineering controls are primarily focused on the emitter. Engineering controls used for RFR include:

- **Azimuth blanking.**
- **Dummy loads.**

- **Flashing lights/audible signals.**
- **Interlocks.**
- **Kill switches/panic buttons.**
- **Electric shock or burn equipment.**

Azimuth Blanking

Azimuth blanking refers to a safety mechanism commonly found in search radars, where the system stops emitting energy when the antenna is pointed at a particular angle either horizontally or vertically. It is used to prevent ground structures from interfering with the radar and to prevent RFR hazards to personnel.

Dummy Loads

A dummy load is a device that can be used in a repair and/or maintenance facility to allow a transmitter to transmit while not allowing RFR energy into the free space of the workplace, which otherwise might cause workers to be exposed.

Flashing Lights/Audible Signals

Flashing lights and audible signals are normally located outside of the hazardous area to warn workers of the potential for a hazardous exposure. These controls are used in areas with high RFR levels.

Interlocks

Interlocks are used to switch off the RFR emitter when a door, hatch, or other entry point is breached. There should be standard operating procedures identifying all tasks that require safety interlock systems and documenting what alternative safety procedures are to be implemented when bypassing the interlock.

Kill Switches/Panic Buttons

Kill switches or panic buttons are usually installed inside rooms where antennas are located and are used to alert operators, open the exit door, and shut down power to the system if an individual is accidentally locked inside the room. This type of control should not be used as a first line of defense against exposure. Instead, it should be used in conjunction with other control measures.

Electric Shock or Burn Equipment

Electric shock and burn safety equipment is required for controlled areas where frequencies are below 30 MHz, which is where electric burns are the primary hazard.
Examples of these controls include:

- Electrical safety mats.
- Electrical safety shoes.
- Other isolation techniques.

Tab: Administrative Controls

As with any administrative control, the primary focus is on the worker. Common administrative controls used for RFR include:

- **Prior coordination.**
- **Training.**
- **Safe work practices.**
- **Warning signs and barriers.**
- **Fences.**
- **Constant observation.**

Prior Coordination

Prior coordination includes informing the owner or operator of the emitter when you or someone else will be entering the area where the emitter poses a hazard. Prior coordination is used to prevent workers from inadvertently entering areas where exposures could exceed the PEL.

Training

RFR safety and health training should be conducted for all Air Force personnel who routinely work in or enter areas where RFR levels exceed the PEL.

Training ultimately falls under the responsibility of the unit; however, BE may be called upon to review the training materials for accuracy. Training should be provided any time there is a change to the existing emitters or after a survey has been performed that establishes the hazard distance of an emitter.

Safe Work Practices

Safe work practices ensure that all workers properly address the hazards associated with RFR. This includes verifying that required warning signs and safety devices are in place or properly set before beginning work.

Work should always be performed in a manner that keeps exposures to RFR as low as reasonably achievable (ALARA), but always below the PEL. Techniques that should be used to accomplish this include:

- Ensuring all parties involved understand the procedures and signals used for current operations.
- Reporting suspected or alleged RFR overexposures to supervisors as well as the responsible area supervisor, unit commander, and medical facility.
- Following guidance regarding RFR in applicable technical orders (TOs), equipment manuals, operation instructions (OIs) and Air Force standards, AFIs, regulations, and policies.

Warning Signs and Barriers

As a general rule, warning signs must be placed where they are visible from all directions of approach and posted at access points for areas that exceed the PEL for that type of RFR environment.

When using cones to indicate the barrier around the hazard, you should also use rope between them to restrict entry to the area at the designated entry points.

Fences

For permanent RFR emitters, metal chain link or wooden fences may be used to control entry to the hazard area.

Wooden fences are commonly used around high-frequency emitters due to the potential for metal objects to passively reradiate RFR.

Constant Observation

Posting a qualified operator or technician to observe the illuminated area during transmissions is a physical or administrative control measure that may be implemented in instances where permanent posting or roping off of an area is not feasible, such as during field deployment exercises when posting requirements would compromise the location of the unit or otherwise interfere with the mission.

Under normal conditions, an observer may not be substituted for mandatory posting or other recommended controls. Constant observation is typically used in conjunction with other control measures for added protection.

Lakefront Field Scenario (Page 4 of 7)

Your OIC decides that recommendations for controls are needed for the newly installed radar site because the site is a permanent asset which will eventually be located in a controlled area. The data from the survey indicates current RFR levels in the area at 10 times above the PEL.

Scenario Challenge Point (Page 5 of 7)

Using the conclusions from your survey, you begin selecting controls you feel are *most* appropriate to maintain the safety of personnel and ensure the effectiveness of the mission.

Based on the information available, which of the controls shown on the next page should you and your OIC recommend implementing at the NEXRAD Doppler weather radar site to protect non-radar personnel in the area? Select all that apply.

Available Controls

____	Flashing Lights	____	Kill Switches and Panic Buttons
____	Personal Warning Devices	____	Warning Signs
____	Constant Observation	____	Wooden Fence
____	Roped Off Areas with Warning Signs	____	PPE
____	Azimuth Blanking	____	Dummy Load
____	Interlocks	____	Cones with Warning Signs Affixed

Guidelines for Implementing RFR Controls (Page 5a of 7)

Because each type of RFR emitter is different, control decisions should address the unique factors surrounding the emitter.

Guidelines for mandatory posting requirements are based on the placement and power of the emitter. These guidelines include requirements for:

- **Controlled Areas.**
- **Uncontrolled Areas.**
- **High Level Areas.**

The only situations where RFR health threats do not require control measures are those involving low-powered, non-hazardous emitters. While implementing various administrative and engineering controls, you should consider the mandatory posting requirements for warning signs, IAW AFOSH Std 48-9, RFR Safety Program.

Controlled Areas

RFR warning signs must be posted at all access points to areas in which levels exceed the controlled environment PEL listed in Table 2.1 of AFOSH Std 48-9.

AFOSH Std 48-9
Table 2.1
Permissible Exposure Limits for Controlled Environments

Frequency Range (f)	Electric Field (E)	Magnetic Field (H)	Power Density (S) (E,H Fields)	Time (T_{avg})
(MHz)	(V/m)	(A/m)	(mW/cm^2)	(mins)
0.003 - 0.1	614	163	10^2, 10^6	6
0.1 - 3.0	614	16.3/f	10^2, $10^4/f^2$	6
3 - 30	1842/f	16.3/f	$900/f^2$, $10^4/f^2$	6
30 - 100	61.4	16.3/f	1.0, $10^4/f^2$	6
100 - 300	61.4	0.163	1.0	6
300 - 3000	-	-	f/300	6
3000 - 15000	-	-	10	6

15000 - 300000	-	-	10	$616000/f^{1.2}$

Uncontrolled Areas

Where the RFR levels exceed the uncontrolled environment PEL given in Table 2.2 of AFOSH Std 48-9, RFR warning signs shall be posted in areas as determined by BE.

AFOSH Std 48-9
Table 2.2
Permissible Exposure Limits for Uncontrolled Environments

Frequency Range (f)	Electric Field (E)	Magnetic Field (H)	Power Density (S) (E & H Fields)	Averaging Time (T_{avg})	
(MHz)	(V/m)	(A/m)	(mW/cm^2)	(mins)	
				E^2	S or H^2
0.003 - 0.1	614	163	$(10^2, 10^6)$	6	6
0.1 - 1.34	614	16.3/f	$(10^2, 10^4/f^2)$	6	6
1.34 - 3.0	823.8/f	16.3/f	$(180/f^2, 10^4/f^2)$	$f^2/.3$	6
3.0 - 30	823.8/f	16.3/f	$(180/f^2, 10^4/f^2)$	30	6
30 - 100	27.5	$158.3/f^{1.668}$	$(0.2, 9.4 \times 10^5/f^{3.336})$	30	$.0636f^{1.337}$
100 - 300	27.5	0.0729	0.2	30	30
300 - 3000	-	-	f/1500	30	-
3000 - 15000	-	-	f/1500	90000/f	-
15000 - 300000	-	-	10	$616000/f^{1.2}$	-

High Level Areas

In areas where personnel may have access to 10 times the controlled environment PEL, warning signs alone do not provide adequate protection. Depending on the potential risk of exposure, other warning devices are required, such as flashing lights, audible signals, barriers, or interlocks.

The risks in such an area must be assessed by a qualified BEE, who will provide written instructions which clearly document the necessary control measures.

Without proper evaluation and approval by the installation BEE, safety controls inherent in the equipment design, guidelines established by other safety or measurement agencies, and requirements established by the operational group may not be removed.

Appraisal (Page 6 of 7)

Which one of the following statements is true regarding controls for RFR hazards?

A In areas where personnel may have access to 10 times the controlled environment PEL, warning signs provide adequate protection.

B RFR warning signs must be posted at only the main access point to areas in which levels exceed the controlled environment PEL.

C The only situations where RFR health threats do not require control measures are those involving low-powered, non-hazardous emitters.

D Kill switches and panic buttons should be used as a first line of defense against exposure.

Lesson Summary (Page 7 of 7)

You've learned that the primary controls used for RFR are administrative and engineering controls and that PPE is not recommended for use with RFR because it does not effectively protect personnel from hazardous exposures.

Because each type of RFR emitter is different, control decisions should address the unique factors surrounding the emitter. Guidelines for mandatory posting requirements are based on the placement and power of the emitter.

In this lesson you:

- Recalled RFR control options.
- Determined appropriate controls for RFR.

Audio Script

Narrator: After the assessment was completed, your OIC submitted the recommendations for appropriate controls to the communications squadron commander.

The controls have been implemented and now the NEXRAD Doppler weather radar is fully operational with controls in place.

Resources

- AFOSH Std 48-9, Radio Frequency Radiation (RFR) Safety Program
- IEEE C95.1-2005, Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300Ghz
- NARDA Safety Test Solutions

Answer Key: Appraisals / Scenario Challenge Points

Lesson 1: Principles of Radio Frequency Radiation

Page 4 of 5

You will see several questions to check your knowledge of the characteristics of RFR. Select the correct answer for each question.

Which one of the following RFR characteristics refers to the distance from one point on a cycle to the same point on the next cycle?

B Wavelength

Which one of the following RFR characteristics is measured by the number of cycles that occurs per second and is expressed in Hertz (Hz)?

A Frequency

Which one of the following terms accurately completes the statement about the relationship between frequency, wavelength, and energy?

As frequency decreases, the energy _________ and the wavelength gets longer.

C Decreases

Lesson 2: RFR Exposures

Page 2 of 10

After you arrived at the communications and radar site, you assigned a BE Tech to identify potential RFR emitters at the site and in surrounding areas. Match each RFR emitter that the BE Tech found with the category to which it belongs.

RFR Emitter	Categories
Early Warning System	Ground Fixed
Hand-held Radio	Mobile Systems
Tactical Automated Security System	Field Deployable
Electronic Counter Measure	Aircraft Mounted

Rationale: An early warning system is an example of a ground fixed RFR emitter. A hand-held radio is an example of an RFR mobile system. A Tactical Automated Security System is an example of a field deployable RFR emitter. An Electronic Counter Measure (ECM) Pod is an example of an aircraft mounted RFR emitter.

Page 4 of 10

Match each part of an RFR emitter with the description of its function.

Function	Transmitter	Transmission Line	Antenna
The point on an emitter where RFR energy radiates into free space.			X
The part of the emitter that generates the RFR signal.	X		
The part of an RFR emitter that carries the signal between other parts.		X	

Rationale: The transmitter is the part of the emitter that generates the RFR signal. The transmission line for an RFR emitter carries the signal from the transmitter to the antenna. The antenna is the point on an emitter where RFR energy radiates into free space.

Page 6 of 10

Using the information you obtained from your conversation with the technician, you begin to focus on the emitters which have the greatest potential for health effects on personnel. Which one of the following frequency ranges identifies where optimal absorption of RFR takes place for adult humans?

C 70-80 MHz

Rationale: Optimal absorption takes place for adult humans between 70 and 80 MHz. These frequencies are called resonant frequencies. If a person is in perfect ground contact, the resonant frequencies will shift to 35-40 MHz.

Page 7 of 10

Which one of the following statements *best* describes the relationship between the permissible exposure limit (PEL) and specific absorption rates (SARs)?

D The PEL is based on the whole-body SAR of 0.4 watts per kilogram (W/kg).

Rationale: The permissible exposure limit (PEL) is based on the whole-body specific absorption rate (SAR) of 0.4 watts per kilogram (W/kg) and incorporates a safety factor of 10 below a SAR of 4.0 W/kg, which is the threshold for the occurrence of potentially harmful biological effects in humans.

Page 8 of 10

Build a list of direct / thermal effects that personnel could experience from an RFR exposure above the PEL.

List
Tissue Heating
Microwave Hearing Effect
Induced Current

Rationale: Direct / thermal effects occur due to the absorption of electromagnetic energy and the production of heat. Examples of direct / thermal effects include increased tissue heating / deep heating, a microwave hearing effect, and induced current. Electromagnetic interference, which can lead to inference in medical devices such as pacemakers, is an example of an indirect effect. Cancer and immune system alterations are examples of potential athermal effects, although these effects are still being studied.

Page 9 of 10

Before reporting back to your OIC about the RFR health threats at the communications and radar site, you explain to another BE Tech on your team how the biological effects of an RFR exposure are related to the dose. Which one of the following factors primarily determines the biological effects of RFR exposures?

D **The PEL is based on the whole-body SAR of 0.4 watts per kilogram (W/kg).**

Rationale: While emitter location, past exposures, and wavelength are variables that should be considered, the biological effects of RFR exposures are primarily determined based on frequency.

Lesson 3: RFR Risk Assessment

Page 3 of 12

Which one of the following describes why an RFR risk assessment should be conducted?

C To establish a safe perimeter around the emitter.

Rationale: An initial measurement survey must be taken on any system that has the capability of producing RFR levels at or above the PEL. These RFR risk assessments are performed to establish a safe perimeter around the emitter. An RFR risk assessment does not address the strategic value, maximum operating levels, or the operation techniques of the emitter.

Page 4 of 12

While traveling to the radar site, you review the process for completing an RFR risk assessment with SrA Charles, a BE Tech who will be assisting you. Place the phases of the RFR risk assessment process in the order in which they should be completed.

Order
1. Identify
2. Analyze
3. Control

Rationale: Once it is determined that an RFR risk assessment will be conducted, the health threat must be properly identified, analyzed, and then controlled.

Page 6 of 12

As you review the notes from your conversation with the technician, you realize you need some more information about the radar system. Which two of the following are additional pieces of information you should ask the operator to provide?

A Gain

C Peak Power

Rationale: The additional information that should be obtained from the operator about the pulsed RFR emitter includes the gain and peak power. The duty factor and hazard distance must be calculated using the information obtained from the operator.

Page 8 of 12

Absolute Gain (G_{abs})

$G_{abs} = 10^{Gain/10}$

$\mathbf{251} = 10^{24dB/10}$

Rationale: The absolute gain is 251. To arrive at this answer using the Windows calculator, you should enter the following sequence: 10 x^y (24/10) =

Duty Factor (DF)

DF = Pulse Width (PW) x Pulse Repetition Frequency (PRF)

0.0016 = (2.2×10^{-6}) seconds x 725 pps

Rationale: The duty factor is 0.0016. To arrive at this answer using the Windows calculator, you should enter the following sequence: (2.2 x 10 x^y 6 +/-) x 725 =

Average Power (P_{avg})

P_{avg} = Peak Power (Pp) x Duty Factor (DF)

80.0 = W = 50,000 *W* x 0.0016

Rationale: The average power is 80.0 watts. Multiplying 50,000 watts by 0.0016 gives you 80.0 watts.

Estimated Hazard Distance (D_{pel})

$$D_{pel} = 3.28\sqrt{\frac{P_{avg} \quad G_{abs}}{40 \quad \pi \quad PEL}}$$

$$27.8\,ft = 3.28\sqrt{\frac{80\text{ W} \quad 251}{40 \quad \pi \quad \boxed{\mathbf{2.22}}}} \text{ mW/cm}^2$$

Rationale: The estimated hazard distance is 27.8 feet. To arrive at this answer using the Windows calculator, you should enter the following sequence: 80 x 251 = / (40 x pi x 2.22) = x^y 0.5 x 3.28 =.

Page 9 of 12

What is the maximum power density (S_{max}) the probe selected can be exposed to before there is a potential for burnout?

B 0.29 mW/cm^2

Rationale: The maximum power density (S_{max}) the probe can be exposed to before there is a potential for burnout is
0.29 mW/cm^2.

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Place the steps of the RFR measurement survey in the order in which they should be completed.

Order
1. Obtain absolute control of the emitter.
2. Begin surveying outside the calculated D_{pel}.
3. Take small steps toward the emitter.
4. Continue surveying until the PEL is found.
5. Have the emitter operator turn the system off.

Rationale: When beginning an RFR measurement survey, you should make sure you obtain complete control over the emitter. Then, you can begin taking measurements outside of the calculated D_{pel}. While taking measurements, you should take small steps towards the emitter until the PEL is found. Once the PEL is found, stop and have the emitter operator turn the system off. Then, you should measure the distance to the antenna.

Lesson 4: Investigating an RFR Overexposure or Accident

Page 3 of 14

Build a list of the reasons why an RFR overexposure investigation is conducted.

List
To determine the severity of the exposure.
To identify operation deficiencies to avoid recurrence.
To determine if the individual was, in fact, exposed.

Rationale: RFR overexposure or accident investigations are performed to determine whether the individual was exposed, to determine the severity of the exposure so proper medical assessments are performed, and to identify operation deficiencies to avoid recurrence. They are not performed to determine if RFR emitters should be allowed in the area, to calculate the PEL, or to identify if a radar unit is functioning properly.

Page 5 of 14

Which two of the following pieces of information should be obtained when conducting interviews after a potential overexposure has occurred?

A **Duration of exposure to the emitter.**

D **Distance between the worker and the emitter.**

Rationale: When conducting interviews after a potential overexposure, you should determine the type of emitter, distance between the worker and the emitter, and the duration of exposure. You should not be concerned about the length of time the individual has been performing the work or the maintenance records for the aircraft and radar.

Page 8 of 14

Which one of the following statements *best* describes how the radar's parameters should be set when reconstructing the incident?

C **The parameters should be set as near as possible to those used when the incident occurred.**

Rationale: When you are ready to begin reconstructing an incident, you should set the system parameters as near as possible to those used when the incident occurred.

Page 10 of 14

Near-Field Boundary (NFB)

First, you need to determine if the maintenance worker was located within the near-field boundary (NFB). Remember that when calculating the System Wavelength you are dividing by GHz, which will require unit conversion for the equation to work out properly.

System Wavelength Calculation:

$$\lambda = \frac{c}{f} \qquad 0.03m = \frac{3 \times 10^8\, m/\sec}{10.0Ghz}$$

Near-Field Boundary Calculation:

$$\frac{L^2}{(4)(\lambda)} \qquad 0.52m = \frac{0.25\ m^2}{(4)(0.03m)}$$

Based on the calculations you've performed and the information you've been provided, is the maintenance worker's exposure considered a near-field or far-field exposure?

B Far-Field Exposure

Rationale: The system wavelength for this nose-mounted radar is 0.03 m. Which you find by dividing the velocity of EMR by 10 GHz, or 10x10^9.

Once you determine the near-field boundary (NFB), by dividing the longest dimension of the antenna in meters (.25 m) by 4 times the wavelength of this system (0.03 m), you can determine that the maintenance worker had a far-field exposure because the worker's distance from the emitter was 0.9 m.

Main-Beam Power Density (S)

You need to calculate the main-beam power density (S) for situations where the individual is exposed within the far-field. Round your answer for the main-beam power density to the nearest whole number.

Main-Beam Power Density – Exposed Within Far-Field:

3510 $\mathrm{mWcm}^2 = \dfrac{(0.45\ \mathrm{kW})\,(794)}{(4)(\pi)(0.9\mathrm{m}^2)}$

Rationale: The power average for this emitter is 0.45kW and the worker's distance from the emitter is 0.9 m. Therefore, the main-beam power density for this nose-mounted radar is 3,510 mW/cm^2.

Power Density Average (S_{avg})

Finally, you should determine the exposure to the individual by performing the power density average calculation.

$$29.3\ \text{mW/cm}^2 = \frac{(3510\ \text{mW/cm}^2 \times 3.0\ \text{seconds})}{360\ \text{seconds}}$$

Rationale: The power density average for this nose-mounted radar is 29.3 mW/cm^2.

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Comparing the calculated power density average of 29.3 mW/cm^2 to the PEL of 10 mW/cm^2, did the maintenance worker receive an overexposure?

A Yes

Rationale: Based on the fact that the maintenance worker's exposure exceeded the PEL of 10 mW/cm^2, you determine an overexposure has taken place.

Page 12 of 14

Which two of the following recommendations would be appropriate to recommend based on the criticality of the mission being performed?

A Implement improved safety practices for personnel around the choppers.

D Implement training for personnel who work around the choppers.

Rationale: Recommendations for corrective actions in this situation may include improved safety practices for personnel who work near emitters and training for personnel who work near emitters.

Page 13 of 14

After submitting your recommendations to your OIC, you begin work on completing the final report needed for the investigation. Within how many days of the investigation's completion should you submit the report to Public Health (PH)?

C 45

Rationale: The investigator performing an RFR overexposure or accident investigation should prepare a final report and submit it to Public Health (PH) within 45 days following its completion.

Lesson 5: RFR Threat Control Options

Page 3 of 7

Build a list of engineering controls and a list of administrative controls that could be implemented at the radar site.

Engineering Controls	Administrative Controls
Azimuth Blanking	**Warning Signs**
Flashing Lights	**Training**
Interlocks	**Safe Work Practices**

Rationale: Warning signs, training, and safe work practices are examples of administrative controls that can be used at the radar site. Azimuth blanking, flashing lights, and interlocks are all engineering controls that can be used at the radar site. Coveralls or personal warning devices are not recommended for use with RFR because they do not effectively protect personnel from hazardous exposures.

Page 5 of 7

Based on the information available, which of the following controls should you and your OIC recommend implementing at the NEXRAD Doppler weather radar site to protect non-radar personnel in the area? Select all that apply.

X	Flashing Lights		Kill Switches and Panic Buttons
	Personal Warning Devices	X	Warning Signs
	Constant Observation	X	Wooden Fence
	Roped Off Areas with Warning Signs		PPE
X	Azimuth Blanking		Dummy Load
X	Interlocks		Cones with Warning Signs Affixed

Rationale: The best control recommendations for the radar site are to install a wooden fence, post warning signs and flashing lights, install interlocks, and ensure the radar is using azimuth blanking. While constant observation, roped off areas with warning signs, and cones with warning signs affixed may be appropriate controls, they are not the best choices because the radar site will be a permanent asset. Kill switches, panic buttons, and dummy loads are not the best choices for controls because they would be more appropriately used in other control situations such as when a worker is in close proximity to the emitter or located in a maintenance shop. Finally, PPE or personal warning devices are not recommended because they are not effective at controlling RFR.

Page 6 of 7

Which one of the following statements is true regarding controls for RFR hazards?

C **The only situations where RFR health threats do not require control measures are those involving low-powered, non-hazardous emitters.**

Rationale: The only situations where RFR health threats do not require control measures are those involving low-powered, non-hazardous emitters. In areas where personnel may have access to 10 times the controlled environment PEL, warning signs alone do not provide adequate protection. RFR warning signs must be posted at all access points to areas in which levels exceed the controlled environment PEL. Kill switches and panic buttons should not be used as a first line of defense against exposure.

Course Glossary

Acronyms

AAR
After Action Report

ACADA
Automatic Chemical Agent Detection Alarm

AFI
Air Force Instruction

AFMIC
Armed Forces Medical Intelligence Center

AFMS
Air Force Medical Service

AFMSA
Air Force Medical Support Agency

AFOSH
Air Force Occupational and Environmental Safety, Fire Prevention and Health

AFRRAD
Air Force Radiation and Radioactive Recycling and Disposal

ALARA
As Low As Reasonably Achievable

AMC
Aerospace Medicine Council

amu
Atomic Mass Unit

AO
Area of Operations

AOC
Area of Concern

AOR
Area of Responsibility

BE
Bioenvironmental Engineering Flight

CBRN
Chemical, Biological, Radiological, Nuclear

CE
Civil Engineering

COA
Course of Action

COC
Contaminant of Concern or Constituent of Concern

CONUS
Continental United States

CSM
Conceptual Site Model

CV
Coefficient of Variability

DIA
Defense Intelligence Agency

DF
Duty Factor

DOD
Department of Defense

DOE
Department of Energy

DOS
Department of State

DOT
Department of Transportation

D_{pel}
Estimated Hazard Distance

DRI
Direct Reading Instruments

EHF
Extremely High Frequency (Occurs between 30 and 300 GHz)

EMR
Electromagnetic Radiation

EPA
Environmental Protection Agency

EPD
Electronic Personal Dosimeters

FPWG
Force Protection Working Group

G_{abs}
Absolute Gain

HF
High Frequency (Occurs between 3 and 30 MHz)

HRA
Health Risk Assessment

HRE
Health Risk Estimate

HRM
Health Risk Management

IATA
International Air Transport Association

IPE
Individual Protection Equipment

LCL
Lower Confidence Limits

LET
Linear Energy Transfer

LF
Low Frequency (Occurs between 30 and 300 kHz)

MAJCOM
Major Command

MEDIC CD
Medical Environmental Disease Intelligence and Countermeasure CD

MIO
Medical Intelligence Officer

MF
Medium Frequency (Occurs between 300 and 3,000 kHz (3MHz))

MOPP
Mission Oriented Protection Posture

MPE
Maximum Permissible Exposure

MSP
Mission Support Plan

NFB
Near-Field Boundary

NGIC
National Ground Intelligence Center

NHZ
Nominal Hazard Zone

NIOSH
National Institute for Occupational Safety and Health

NOHD
Nominal Ocular Hazard Distance

NRC
Nuclear Regulatory Commission

OCONUS
Outside the Continental United States

OEH
Occupational and Environmental Health

OEHSA
Occupational and Environmental Health Site Assessment

OEL
Occupational Exposure Limits

OEL-C
Occupational Exposure Limits-Ceiling

OEL-STEL
Occupational Exposure Limits-Short Term Exposure Limit

OEL-TWA
Occupational Exposure Limits-Time Weighted Average

OH
Occupational Health

ORM
Operational Risk Management

OSHA
Occupational Safety and Health Administration

OSI
Office of Special Investigation

P_{avg}
Average Power

PEL
Permissible Exposure Limit

PH
Public Health

P_p
Peak Power

PPBS
Planning, Programming and Budgeting System

PPE
Personal Protective Equipment

PPM
Parts per million

PRF
Pulse Repetition Frequency

PW
Pulse Width

RFR
Radio Frequency Radiation

RSO
Radiation Safety Officer

S
Main-Beam Power Density

SAR
Specific Absorption Rate

S_{avg}
Power Density Average

SEG
Similar Exposure Group

SHF
Super High Frequency (Occurs between 3 and 30 GHz)

SLM
Sound Level Meter

S_{max}
Maximum Power Density

SPL
Sound Pressure Level

TLD
Thermoluminescent Dosimeters

TWG
Threat Working Group

UHF
Ultra High Frequency (Occurs between 300 and 3,000 MHz)

USACHPPM
United States Army Center for Health Promotion and Preventive Medicine

UTC
Unit Type Code

VA
Vulnerability Assessments

VHF
Very High Frequency (Occurs between 30 and 300 MHz)

VLF
Very Low Frequency (Occurs between 3 and 30 kHz)

Definitions

Absolute Gain (G_{abs})
The ratio of the power that would be required at the input of an ideal isotropic radiator to the power actually supplied to the given antenna, to produce the same radiant intensity in the far-field region.

Action Level
An airborne exposure level that dictates active air monitoring, medical monitoring, and employee training. The Action Level is one-half the Occupational Exposure Limit for time-weighted average (OEL-TWA) exposures, except where 29 CFR 1910 Subpart Z designates a different concentration or where the statistical variability of sample results indicates that a lower fraction of the OEL should be used as the Action Level.

Activity
The number of disintegrations or transformations of radioactive material per unit of time (usually expressed in seconds).

Antenna
The point on an RFR emitter where RFR energy radiates into free space.

Asbestos
A natural material that is made of tiny threads or fibers. The fibers can enter the lungs as a person breathes. Asbestos can cause many diseases, including cancer. Asbestos was used to insulate houses from heat and cold. It has also been used in car brakes and for other purposes. Some old houses still have asbestos in their walls or ceilings.

Asbestosis
A lung disease caused by breathing asbestos fibers over a period of time. The fibers eventually scar the lungs and make breathing difficult. Symptoms are similar to asthma.

Atomic Mass Unit (amu)
Approximately equal to the mass of a proton or a neutron and is used to describe the mass of an atom.

Becquerel (Bq)
The international standard for the unit of measurement for activity.

Breathing Zone
The location where exposure is measured in air sampling. The breathing zone is located forward of the shoulders within 9 inches of the nose and mouth. Breathing zone measurements are taken beneath a welder's helmet or face piece but outside of any respiratory protective devices.

Bremsstrahlung
An interaction that causes a form of x-ray production in which high-speed beta particles penetrate the electron cloud and interact with the nucleus.

Carcinogens
Hazardous materials that stimulate the formation of cancer.

Ceiling Limit (OEL-C)
The limit for an employee's exposure which shall not be exceeded during any part of the work day. If instantaneous monitoring is not feasible, the OEL-C will be evaluated during the worst-case 15-minute exposure period.

Chrysotile
The most common asbestos type. Chrysotile asbestos fibrils may appear crinkled, like permed or damaged hair, under plane-polarized light.

Coefficient of Variation (CV)
For an air sampling method, the CV is the standard deviation of the sampling and analytical error divided by the mean of the sample results. The CV is used to calculate the confidence limits for sampling. OSHA uses the term sampling and analytical error (SAE) to account for the total variation or error in the method.

Compton Scatter
A gamma/x-ray interaction which takes place between a photon and an outer electron where the photon has more energy than the electron can accept, so it imparts only a portion of its energy to the electron.

Conceptual Site Model (CSM)
Articulates the health threats and exposure pathways and begins when data or information is gathered during Predeployment and Baseline Activities.

Confidence Limits
The upper confidence limit (UCL) and lower confidence limit (LCL) are the boundaries for a single sample or a series of samples that have a specified probability (usually 95 percent) of including the true value of the level of exposure.

Controlled Environments
An area where personnel are aware of the potential for RFR exposures associated with their employment or duties.

Counts per minute (cpm)
The amount of radiation detected by an instrument each minute.

Diffuse Reflection
Situations where a laser beam is bounced off a dull or uneven surface that breaks the beam apart.

Disintegration per minute (dpm)
The number of atoms that decay or transform in a given amount of material per minute.

Disintegration per second (dps)
The number of atoms that decay or transform in a given amount of material per second.

Dose
The quantity of radiation absorbed.

Dose Rate
The quantity of radiation absorbed per unit of time.

Duty Factor (DF)
A unit-less number which only applies to pulsed wave systems that describes the ratio of time an RFR emitter is on to the total operating time.

Electromagnetic Radiation (EMR)
Waves of energy that can travel through space and matter.

Electromagnetic Spectrum
The entire frequency range of electromagnetic waves, or wave radiation.

Energy
The ability to do work.

Estimated Hazard Distance (D_{pel})
The distance from the antenna to the point where the power density equals the permissible exposure limit (PEL).

Excitation
Occurs when there is an addition of energy to an atomic system, changing the atom from a "ground" state to an excited state.

Exposure
Exposure occurs when an employee is subjected to a hazardous material through any of these routes: inhalation, ingestion, skin contact, or skin absorption. Airborne exposures are specified as the duration and concentration of hazardous materials measured in the breathing zone of an individual worker without regard for personal protective equipment used by the worker.

Exposure Assessment
An exposure assessment is a process of estimating or calculating potential exposure of a health threat for an individual or population at risk. The assessment includes professional judgment, calculations based on estimates or models, actual measurements, collection and analysis of samples, and statistical evaluation.

Exposure Pathway
Includes a threat and the opportunity for the population to come into contact with the threat.

f
Algebraic express that means, "a function of."

Fission
The splitting of the nucleus of an atom into nuclei of lighter atoms, accompanied by the release of energy.

Frequency
A value of how often a wavelength cycle occurs in a second.

Gain
The antenna's ability to concentrate its energy in a certain direction.

Hazardous materials
Materials that pose a hazard and require a Material Safety Data Sheet as defined in FED-STD 313, Federal Standard, Material Safety Data, Transportation Data and Disposal Data for Hazardous Materials Furnished to Governmental Activities.

Health Risk
The health risk equals threat "combined with" vulnerability (health risk = (threat) + (vulnerability)). A health risk is an identified health threat and the vulnerability of the population at risk of coming into contact (i.e., completion of an exposure pathway) with the health threat.

Health Risk Assessment (HRA)
Health risk assessment is the process of identifying and analyzing or evaluating (exposure and toxicity assessments) OEH threats in populations or at locations over time (HRA = f [(health risk) "+" (HRE) "+" (COA)]). The HRA "product" is the validated health threat, qualified by the HRE, and the COA which includes overall mission impact, recommended control options, associated uncertainties, risk mitigation estimate(s), and a cost-benefit analysis if applicable.

Health Risk Communication
Health risk communication is the process of effectively communicating potential health effects, outcomes, and control measures to all stakeholders (i.e., commanders, supervisors, AF personnel, military, families, and the public). It provides detailed information about the HRA and should occur throughout the HRA process.

Health Risk Estimate (HRE)
Health Risk Estimate is the probability and severity of loss from exposure to the health threat. The HRE is a function of probability and severity when either or both increase the Health Risk Estimate increases. The HRE is also referred to as a health risk level.

Health Risk Management (HRM)
Health risk management is a decision-making process to evaluate and select COAs, minimize OEH risks, and maximize benefits for operations and missions. HRM is the health component of the ORM process and health risk management recommendations and decisions are integrated into the commander's ORM decision-making.

Health Threat
A health threat is a potential or actual condition that can cause short or long-term injury, illness, or death to personnel. A health threat can be occupational or environmental in origin; internal or external to the installation; or continuous, intermittent, or transient; and includes enemy capability and intent.

Ionization
Occurs when beta particles interact with nearby atoms causing an electron to be removed, creating an ion pair.

Ionizing Radiation
Radiation which has enough energy to change the atomic structure of matter.

Isotope
Elements with the same number of protons, but a different number of neutrons.

Kinetic Energy
Energy of motion.

Laser
Light amplification by stimulated emission of radiation.

Linear Energy Transfer (LET)
Energy lost by particles along the path through which they are traveling.

Mass
Description of how much matter there is present in an object.

Maximum Permissible Exposure (MPE)
The level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eyes or skin.

Mesothelioma
Cancer that generally occurs in the chest, abdominal region, and areas surrounding the heart. It is typically associated with exposure to asbestos.

n
Algebraic express that means, "Number of samples."

Nominal Hazard Zone (NHZ)
The area within a laser workplace in which the exposure from direct beam, specular reflection, and diffuse reflection could exceed the Maximum Permissible Exposure (MPE).

Nominal Ocular Hazard Distance (NOHD)
The distance along the laser beam beyond which the exposure is not expected to exceed the appropriate Maximum Permissible Exposure (MPE).

Non-aqueous Phase Liquids (NAPLs)
Non-aqueous phase liquids are liquids that are sparingly soluble in water. Because they do not mix with water, they form a separate phase. For example, oil is an NAPL because it does not mix with water, and oil and water in a glass will separate into two separate phases. NAPLs can be lighter than water (LNAPL) or denser than water (DNAPL). Hydrocarbons, such as oil and gasoline, and chlorinated solvents, such as trichloroethylene, are examples of NAPLs.

Non-ionizing Radiation
Radiation which does not have enough energy to change the atomic structure of matter.

Nuclear Stability
Describes the certain combinations of neutrons and protons within a nucleus of an atom which are required for that atom to be considered stable.

Occupational and Environmental Health Site Assessment (OEHSA)
The key operational health tool for producing data or information used for health risk assessments (HRA) and to satisfy Occupational and Environmental Health (OEH) surveillance requirements.

Occupational Exposure Limit (OEL)
The limit for the airborne concentrations of a specified substance for a specified time. Employees will not be exposed to concentrations greater than the OEL. The term OEL includes all OEL-TWAs, OEL-STELs, OEL-Cs, and acceptable ceiling concentrations, that apply to a specific substance. For each hazardous material, the OELs are the most stringent limits found in the latest edition of the TLV Booklet published annually by the American Conference of Government Industrial Hygienists, in 29 CFR 1910 Subpart Z, and in AFOSH Standards for specific substances. OELs apply to occupational exposures for each individual worker for a single 8-hour work shift except where 29 CFR 1910 Subpart Z allows 40-hour averages. Exposure during work shifts that exceed 8 hours must be adjusted before applying an OEL.

Operational Risk Management (ORM)
A systematic process of identifying hazards, assessing risk, analyzing risk control options and measures, making control decisions, implementing control decisions, accepting residual risks, and supervising/reviewing the activity for effectiveness.

Optical Cavity
The component that houses the laser.

Pair Production
Occurs when a photon disappears in the vicinity of a nucleus, and an electron and positron appear in its place.

Particulate Radiation
Fast-moving atomic or subatomic particles that may be charged positively or negatively or not at all.

Peak Power (P_p)
The maximum power density during the on time for a pulsed wave system.

Permissible Environment
Operational environment in which host country military and law enforcement agencies have control as well as the intent and capability to assist operations that a unit intends to conduct.

Permissible Exposure Limit (PEL)
The value to which an individual may be exposed without exhibiting damaging biological effects and is based on the emitter's frequency.

Photochemical Reaction
A chemical reaction which is induced by the absorption of energy in the form of visible, infrared, or ultraviolet radiation.

Photoelectric Effect
An "all or none" energy loss where gamma rays impart all of their energy into an electron.

Pleural Effusion:
When too much fluid collects between the lining of the lung and the lining of the inside wall of the chest.

Positron
Created when a proton changes into a neutron and a positron because there are too many protons in the n:p ratio.

Potential Energy
Energy of position.

Pulse Repetition Frequency (PRF)
The number of times the signal is on per unit of time.

Pulse Width (PW)
The length of time the signal is on for a pulsed wave system.

Quality Factor (Q)
A dimensionless quantity assigned to each type of radiation that allows doses to be normalized in relation to each other.

Radiation
Energy in the form of waves or moving subatomic particles emitted by an atom or other body as it changes from a higher energy state to a lower energy state.

Radiation Absorbed Dose (RAD)
The amount of radiation absorbed by the tissue.

Radioactive Decay
The spontaneous disintegration or transformation of an atom in an attempt by that atom to reach a stable state.

Radioactive Material (RAM)
Material which contains unstable (radioactive) atoms that give off radiation as they decay or transform.

Radioactivity
The spontaneous emission of matter or energy from the nucleus of an unstable atom.

Radioisotopes
Unstable isotopes that, in an attempt to become a stable atom, emit energy in the form of radiation.

Regulated Area
An area under the supervisor's control where entry and exit are restricted and controlled to prevent exposure to hazards. An area shall be established when a requirement in 29 CFR 1910 or 29 CFR 1926 exists, or when BE determines that employees entering the area might be exposed to a hazard unless access is controlled.

Short Term Exposure Limit (OEL- STEL)
A time-weighted exposure for a 15 minute (or shorter) period which shall not be exceeded during the work day. The definition of STEL is different in 29 CFR 1910.1000 (a) (5) (ii) and in the TLV Booklet. The definition must correspond to the reference being cited. As with other OELs, OEL-STELs are the most stringent limits found in the latest TLV Booklet, in 29 CFR 1910 Subpart Z, and in AFOSH Standards for specific substances.

Short-Term Public Emergency Exposure Guideline (SPEGL)
An acceptable peak concentration for unpredicted, single, short-term emergency exposures of the general public. These limits do not apply to occupational exposures.

Specific Absorption Rate (SAR)
An expression of how much RFR energy is imparted to each kilogram of biological body mass per second. SAR is expressed in units of watts per kilogram (W/kg).

Specular Reflection
Situations where a laser beam is reflected from shiny, mirror-like surfaces.

Spontaneous Fission
Spontaneous fission is a natural mode of decay in which nuclei disintegrate.

Stakeholders
Any individual who is affected by the content of the communication and/or will be making decisions based on the information provided.

Stratigraphy
The layering of rock or ice strata, from which information on succession, age relations, and origin can be deduced.

Threshold Limit Values—(TLVRs)
Exposure guidelines published annually by the American Conference of Governmental Industrial Hygienists (ACGIH) in Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. TLVRs are employed as OELs when they are more stringent than the OSHA PELs.

Time-Weighted Average (OEL-TWA)
Eight-hour average concentration for which the average is mathematically adjusted for the duration of exposure. The method for calculating OEL-TWAs is shown in 29 CFR 1910.1000 (d) and in the TLV Booklet.

Toxicology Assessment
Process of estimating the human toxicological impact of a specific material based on published and unpublished literature sources and taking into consideration: uptake, metabolism/biotransformation, transport and storage, and excretion including acute (short-term) and chronic (long-term) human health endpoints.

Transmission Line
Carries the RFR signal from the transmitter to the antenna.

Transmitter
The part of an RFR emitter that generates the RFR signal.

Uncontrolled Environments
An area where exposures may be incurred by people who have no knowledge or control of the hazard.

Wavelength
The distance from one peak of a wave to the next peak of a wave.