DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE FOR OPERATIONAL HEALTH (AFMC)
BROOKS CITY-BASE TEXAS

4 April 2007

MEMORANDUM FOR 193 MDG/SGPB
ATTN: TSGT RICHARD PANZAR
MIDDLETOWN PA 17057

FROM: AFIOH/SDR
2350 Gillingham Drive
Brooks City-Base TX 78253-5103

SUBJECT: Consultative Letter, IOH-SD-BR-CL-2007-0035, Radio Frequency Radiation Hazard Survey for Commando Solo

1. Introduction: A request for a radio frequency radiation survey for EC-130J Commando Solo aircraft was made by Dale A. Bashore from the 193rd Special Operations Wing of the Pennsylvania Harrisburg Air National Guard Base. Capt Krystyn Clark and Capt Piper Williams from the Air Force Institute for Operational Health (AFIOH), Radiation Surveillance Division (SDR), Health Physics Consulting Branch (SDRH) performed a radiofrequency radiation survey from 23-27 Oct 06. The purpose of the survey was to perform an in-flight survey to measure power densities generated by Radio Frequency Radiation (RFR) emitters used with the EC-130J Commando Solo aircraft. A survey was also performed for RFR transmitters at three of the base shops. No hazardous levels of RFR exist to personnel in the shops or in-flight for the aircraft surveyed. Administrative data is shown in Attachment 1.

2. Background:

a. The EC-130J Commando Solo, a specially-modified four-engine Hercules transport, conducts information operations, psychological operations and civil affairs broadcasts in AM, FM, HF, TV and military communications bands. Many modifications have been made to the Commando Solo to include enhanced navigation systems, self-protection equipment, air refueling and the capability of broadcasting radio and color TV on all worldwide standards. The Air Force Special Operations Command’s 193rd Special Operations Wing, Middleton, PA, has total responsibility for the Commando Solo missions. The only aircraft used for their mission is the EC-130J. Measurements were made in the aircraft during flight, focusing on nine locations of interest, and transmission lines within the aircraft for eight RFR emitters.

b. RFR systems were surveyed in three shops that support training and maintenance missions. These radar systems were surveyed in the Mission Systems Low Power Shop, High Power Shop, and Partial Test Trainer (PTT) to assess occupational hazards during equipment testing and flight broadcasting simulation training.

c. The current Air Force Occupational Safety and Health (AFOSH) Standard, 48-9, *Radio Frequency Radiation (RFR) Safety Program*, 1 August 1997, establishes maximum permissible exposure limits (PELs) for controlled and uncontrolled environments. The personnel theoretical far-field hazard distance is the distance where the power density equals the PEL. Measurement locations with associated power density levels and general findings are listed in the following sections.

3. Findings:

a. The Commando Solo, tail number 1932, was surveyed in flight on 25 Oct 06. Survey time for the emitters was limited due to Federal Communications Commission restrictions which require transmissions to be 200 miles off the coast, over international waters. Of the eight transmitters, seven transmitters could be broadcast simultaneously in flight. A combination of the most hazardous frequency within the optimal range of the RFR emitter and maximum power was selected for each emitter. All seven emitters were broadcast simultaneously to create a worst-case scenario because of the limited available survey time. Antenna locations and antenna/frequency pairs are shown in Attachments 2 and 3. After all transmitters were employed a survey was accomplished at nine locations of interest within the aircraft, shown at Attachment 4. These locations were selected based on regular occupancy by crew members during flight and findings from previous RFR surveys on Compass Call aircraft (Consult Letter, IOH-SD-BR-CL-2006-0043, *Radio Frequency Radiation Hazard Survey for the Compass Call Electronic Counter Measure Systems*). Areas around the transmitters and transmission lines were also surveyed for potential leaks. The spatially averaged power densities at all manned locations within the aircraft were below the controlled PEL and indistinguishable from background (Attachment 5). A spatially averaged measurement pertains to an average value of power densities representative of a whole body exposure where a typical person may be located. A localized hot spot may be found that exceeds a whole-body exposure limit but when spatially averaged, the power density level does not exceed the PEL. There are separate limits that apply for extremities and hot spots. The only hot spots identified during the survey were in the tail of the plane at the hinge and along the side seams of the rear cargo door during HF transmission (Attachment 6, Figures 1-4). However, these elevated readings were on contact with the rear cargo door or when inserting the probe into the hinge area which is only large enough for either a foot or hand and is not representative of a whole-body exposure. The highest HF measurement was found when the probe was placed inside the hinge area at 13.4 mW/cm^2 compared to the PEL for 29 MHz of 1.1 mW/cm^2 for electric field (E) and 8.2 mW/cm^2 compared to the PEL of 11.9 mW/cm^2 for the magnetic field (H). The hinge and seams around the rear cargo door do not pose a hazard to personnel within the aircraft because they only allow a person to receive a partial body exposure. For partial body exposures, the peak value of the mean squared field strength (E and H Fields) cannot exceed 20 times the square of the allowed spatially averaged values ($<20E^2$, or less than 20×1.07^2 mW/cm^2) at frequencies below 300 MHz before becoming a concern (AFOSH Std 48-9).

Measurements below 22.9 mW/cm^2 are of no concern. Power density measurements and hazard distance calculations were not performed for the outside of the aircraft because broadcasting is not permitted on the ground.

b. Average RFR power density measurements for the general shop areas were indistinguishable from background (Attachment 7). There were two areas of interest in the High Power Shop, which are identified in Attachment 8. The first location was at the vent on top of the HF and MF emitter housing. Measurements above background were found for the HF and MF emitters. The HF emitter in the magnetic field was 30.6 mW/cm^2 at 16 MHz and 10kW but below the whole-body PEL of 39.1 mW/cm^2. Electric field measurement for the HF emitter was 0.8 mW/cm^2 but below the 3.5 mW/cm^2 whole-body PEL. Measurements for the MF emitter ranged from 0.3 mW/cm^2 to over range for the *Narda* probe at 1.7 MHz and 10 kW for the magnetic field compared to a whole-body 3460 mW/cm^2 PEL. The electric field MF emitter measurement in the same location was 0.2 mW/cm^2 and below the 100 mW/cm^2 whole-body PEL. The second area of interest was located at overhead cables between the HF and MF emitter housing and the wall. While transmitting with the HF emitter, the E-field measurement was 0.8 mW/cm^2. The measurement was well below the whole-body PEL of 3.5 mW/cm^2. That location is not readily accessible to personnel during normal duties unless someone climbs a ladder and has direct contact with the vent or cables. Furthermore, a person could only receive a partial body exposure from either of these RFR hot spots.

4. Recommendations:

a. There are no hazardous levels of RFR to personnel working in the shops or aircraft that were surveyed. Equipment should be turned off prior to maintenance to reduce a potential introduction of an RFR leak.

b. Because of the unique modifications to each Commando Solo aircraft, a consideration should be made for surveying the two remaining aircraft under the same conditions as this survey to verify that no hazardous levels of RFR exist for crew members.

c. Ensure air crew members are aware of leaks around the rear cargo door seams. There is no occupational RFR hazard when moving through or briefly standing in these areas. However, personnel should not sit or lie directly on the seams for prolonged periods of time during HF-80 transmission. In all cases the power densities were measurable only within about 5 inches of the rear cargo door seams.

d. All seating areas of the aircraft were at background levels of RFR and meet the exposure criteria for a controlled environment. Areas within the aircraft are considered to be a controlled environment because all personnel are aware of the presence of RFR. There was no leakage around the emitters or transmission lines.

5. For informational purposes, a RFR Awareness Training Example is included in Attachment 9. If you have questions concerning this report or follow-up survey

measurements, please contact Capt Clark at DSN 240-4297 or krystyn.clark@brooks.af.mil, or the ESOH Service Center at 1-888-232-ESOH. In order to improve our services, please complete and return the attached critique (Attachment 10).

//signed//

SCOTT M. NICHELSON, Lt Col, USAF, BSC, CHP, CIH
Chief, Radiation Surveillance Division

Attachments:
1. Administrative Data
2. Seating and measurement locations
3. Antenna locations on EC-130J
4. EC-130J Antennas Paired with Frequency Ranges
5. Commando Solo Data
6. Locations of Hot Spots on EC-130J, Tail Number 1932
7. Shop Survey Data
8. Locations of Shop Special Interest Areas
9. RFR Awareness Training Example
10. Critique

cc:
193 MXS/DOOW-E
193 MXS/MXMVM

Attachment 1
Administrative Data

1. Personnel Contacted

Haldeman, Marlin L CMSgt 193 SOS/DOOW-E
Hein, Barry E SMSgt 193 SOS/DOOW-E
Bashore, Dale, CMSgt 193 SOW/CCC
Wetzel, Scott A SMSgt 193 MXS/MXMVM
Panzar, Richard, MSgt 193 MDG/SGPB
Redline, Jeffrey, MSgt 193 MDG/SGPB
Cummings Patrick W TSgt 193 MOF/MXOP

2. Equipment Used

Narda Meter 8715, S/N 20014, Calibrated 02/06
Narda Probe 8733D, S/N 15004, Calibrated 02/06
Narda Probe 8752D, S/N 10001, Calibrated 02/06

Narda Meter 8715, S/N 20013, Calibrated 02/06
Narda Probe 8723D, S/N 18006, Calibrated 02/06
Narda Probe 8764D, S/N 09005, Calibrated 02/06

3. Emitters Surveyed

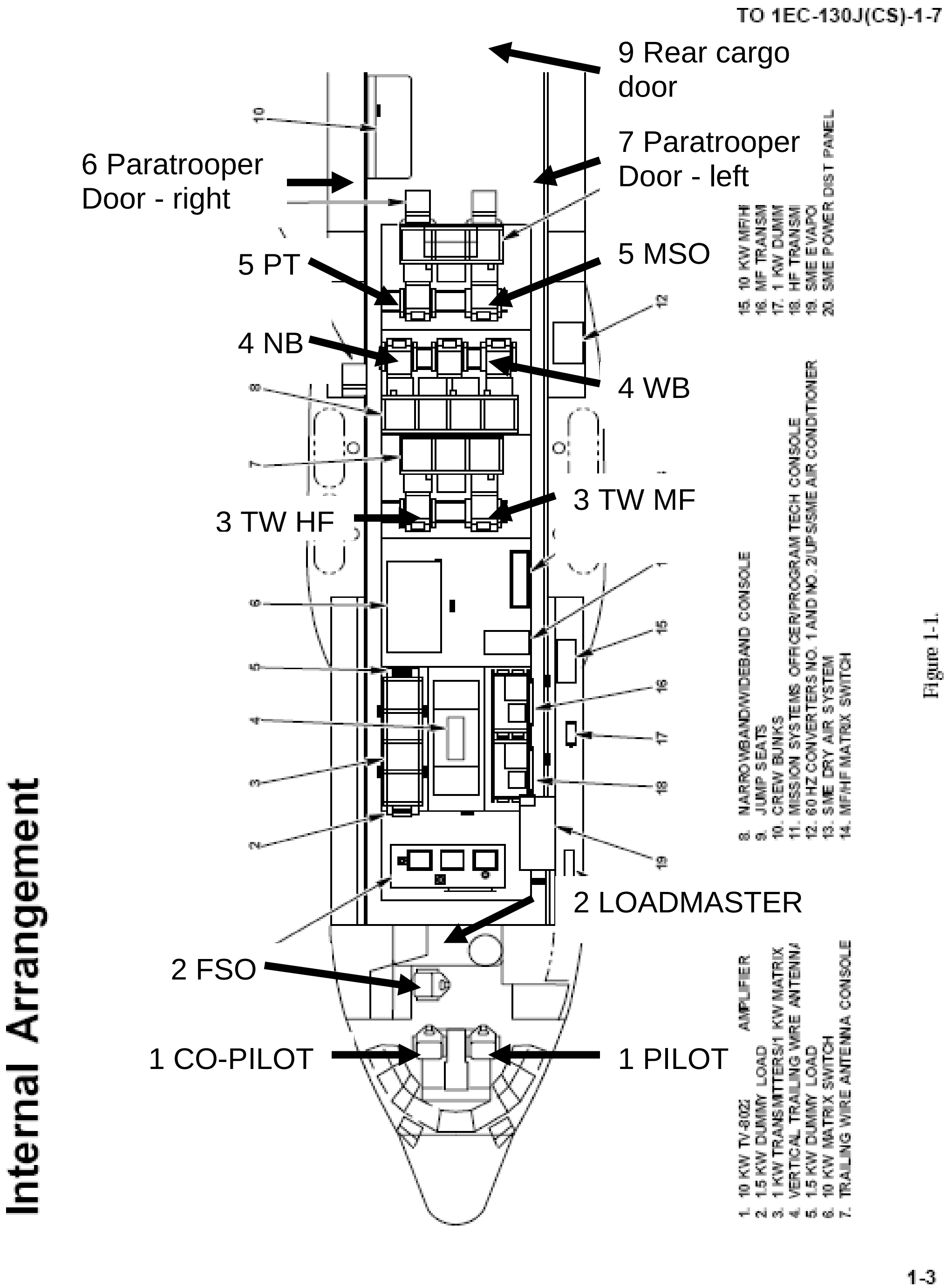
High Power Shop
MF at 1.7 MHz, 10 kW
HF at 16 MHz, 10 kW
TV at 67.25 MHz, 10 kW

Low Power Shop
VHF lo at 120 MHZ, 953 W
V hi at 270 MHz, 1 kW
V hi at 400 MHz, 1 kW

Partial Test Trainer
TV at 211.25 MHz, 10 kW
V lo at 60 MHz, 1 kW
VHF at 750 MHz, 1 kW
MF at 1.2 MHz, 10 kW
HF at 16 MHz, 10 kW

EC-130J Tail Number 1932
MF-80 at 0.5 MHz, 10 kW
HF-80 at 29 MHz, 10 kW
MPD-Vlo at 130 MHz, 1 kW
MPD-Vlo_2 at 120 MHz, 200 W
MPD-Vhi at 100 MHz, 700 W
MPD-Vhi_2 at 200 MHz, 1 kW
MPD-UHF at 500 MHz, 750 W
TV-80 Vhi at 211.25, 10 kW

Attachment 2
Seating and measurement locations



1. Pilot/Copilot
2. Loadmaster/Flight Systems Officer
3. Tailing Wire High Frequency (HF)/Mid-Frequency (MF)
4. Narrow Band (NB)/Broad Band (WB)
5. Program Tech (PT)/Mission Systems Officer (MSO)
6. Paratrooper Door – right
7. Paratrooper Door – left
8. Transmission lines
9. Rear cargo door

Attachment 3
Antenna locations on EC-130J

TO 1EC-130J(CS)-1-7

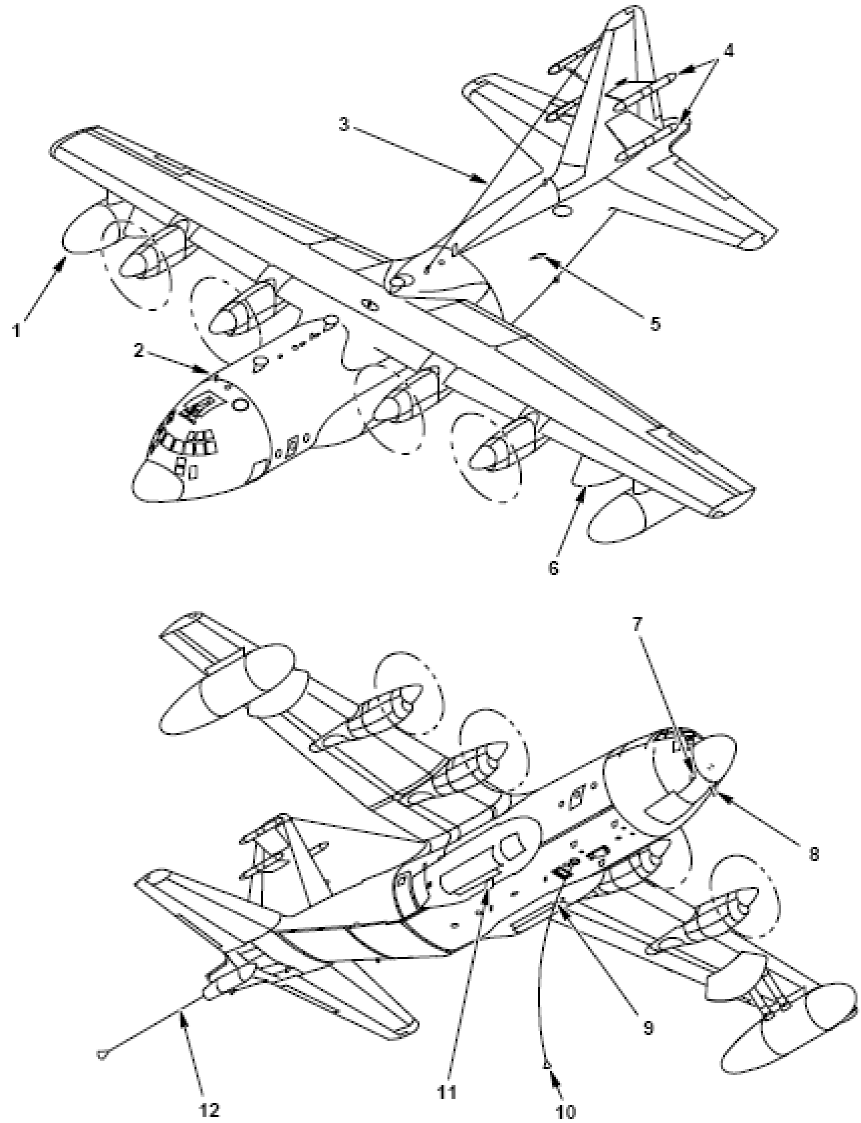


Figure 1-6. Mission Systems Antenna Locations (Sheet 1 of 2)

Attachment 4

EC-130J Antenna Locations Paired with Frequency Ranges

Item No.	Antenna	Frequency Range
1	VHF High Band/UHF	162 – 230 MHz, 470 – 910 MHz
2	UHF Receive	0.5 – 2.0 GHz
3	MF/HF Receive	450 kHz – 30 MHz
4	VHF Low Band 10 kw	47 – 88 MHz (41 – 47 MHz and 88 – 108 MHz degraded)
5	VHF High Band 1 kw	100 – 500 MHz
6	VHF Low Band Wing Blade	30 – 150 MHz
7	AM/FM/TV Receive	190 – 1750 kHz, 88 – 108 MHz, 57 – 866 MHz
8	VHF/UHF Receive	20 – 500 MHz
9	UHF 1 kw (fwd)	500 – 1000 MHz
10	Vertical Trailing Wire	450 kHz – 30 MHz
11	VHF High Band (fwd)	100 – 500 MHz
12	Horizontal Trailing Wire	450 kHz – 30 MHz

Figure 1-6. Mission Systems Antenna Locations (Sheet 2 of 2)

Attachment 5
Commando Solo Data

Transmitter nomenclature	**MF-80**	**HF-80**	**MPD-V/lo1**	**MPD-V/lo2**	**MPD-V/hi1**	**MPD-V/hi2**	**MPD-UHF**	**TV-80 V-hi**
Freq range (MHz)	0.450-1.999	2.0-29.999	30-230	30-230	100-500	100-500	470-1000	170-230
Frequency surveyed (MHz)	0.5	29	130	120	100	200	500	211.25
Power surveyed (W)	10,000	10,000	1000	200	700	1000	750	10,000
Gain (dB)	0	0	0	0	0	0	0	7
Antenna	VTWA	HTWA	Wing Blade L	Wing Blade R	VHF High Fwd	VHF High Aft	UHF Fwd	VHF High 10Kw
Pluse Width	CW	CW	CW	CW	CW	CW	CW	CW
Electric field PEL controlled Power Density (S-mW/cm^2)	100.00	1.07	1.00	1.00	1.00	1.00	1.67	1.00
Magnetic field PEL controlled Power Density (S-mW/cm^2)	40,000.00	11.89	1.00	1.00	1.00	1.00	N/A	1.00

Attachment 6
Locations of Hot Spots on EC-130J, Tail Number 1932

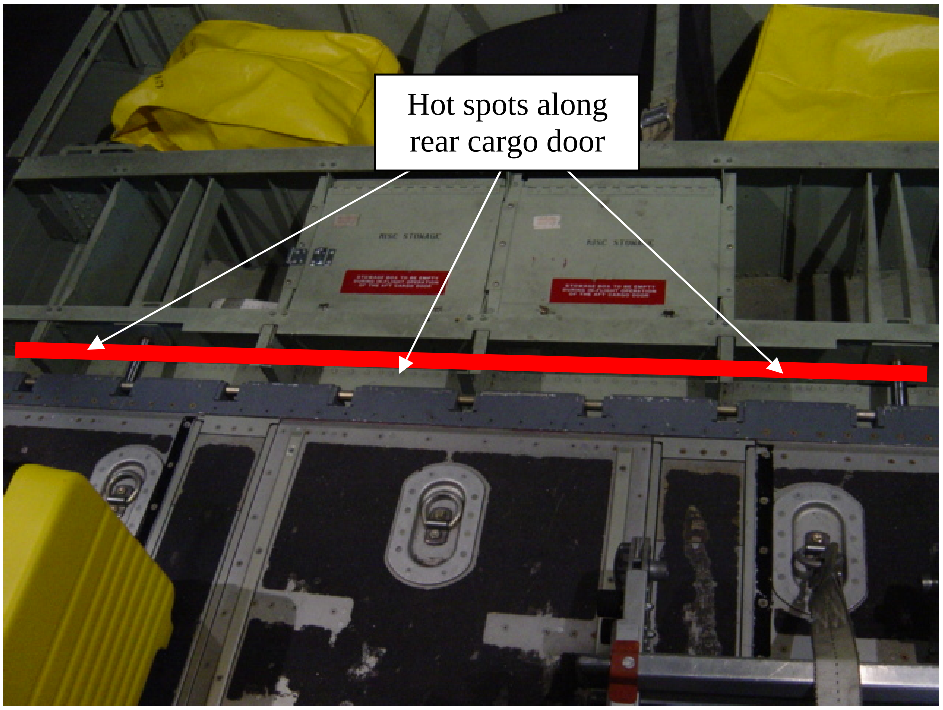


Figure 1. Rear cargo door seam -- high RFR levels when probe placed in holes, measurable up to a few inches away.

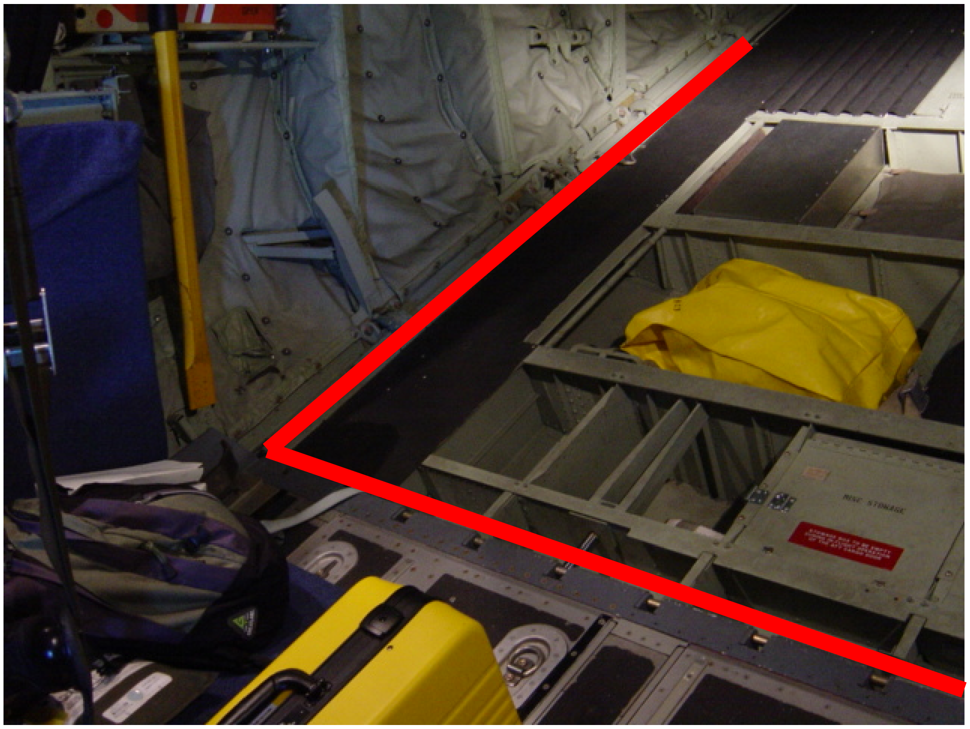


Figure 2. Starboard side, seam of rear cargo door, hot spots indicated in red.

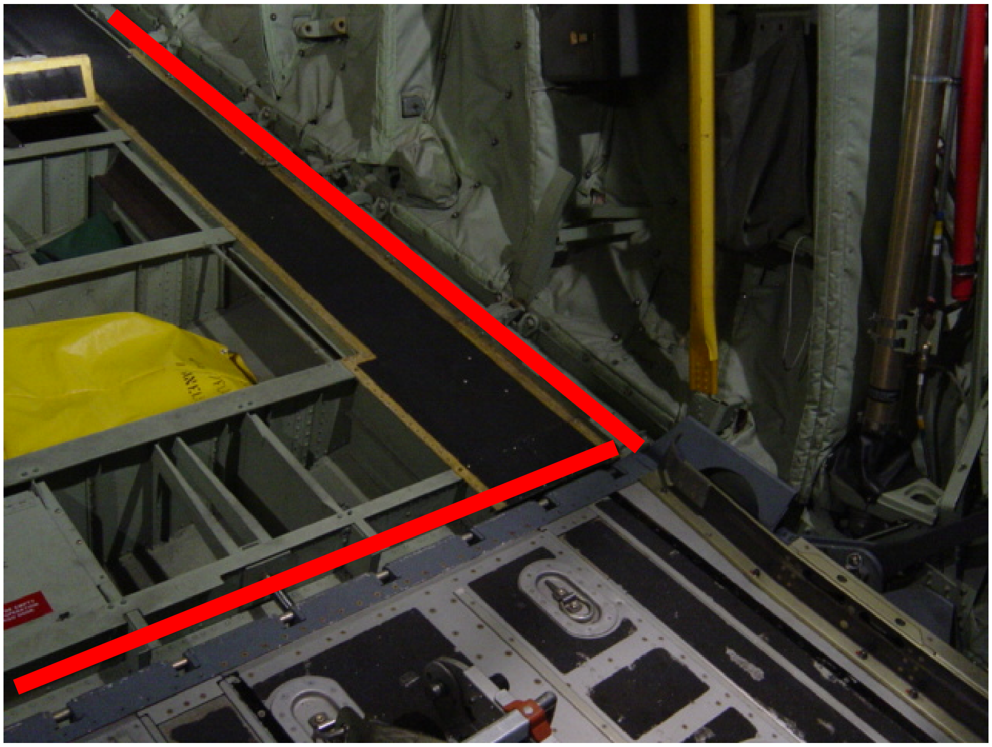


Figure 3. Port side, seam of rear cargo door, hot spots indicated in red

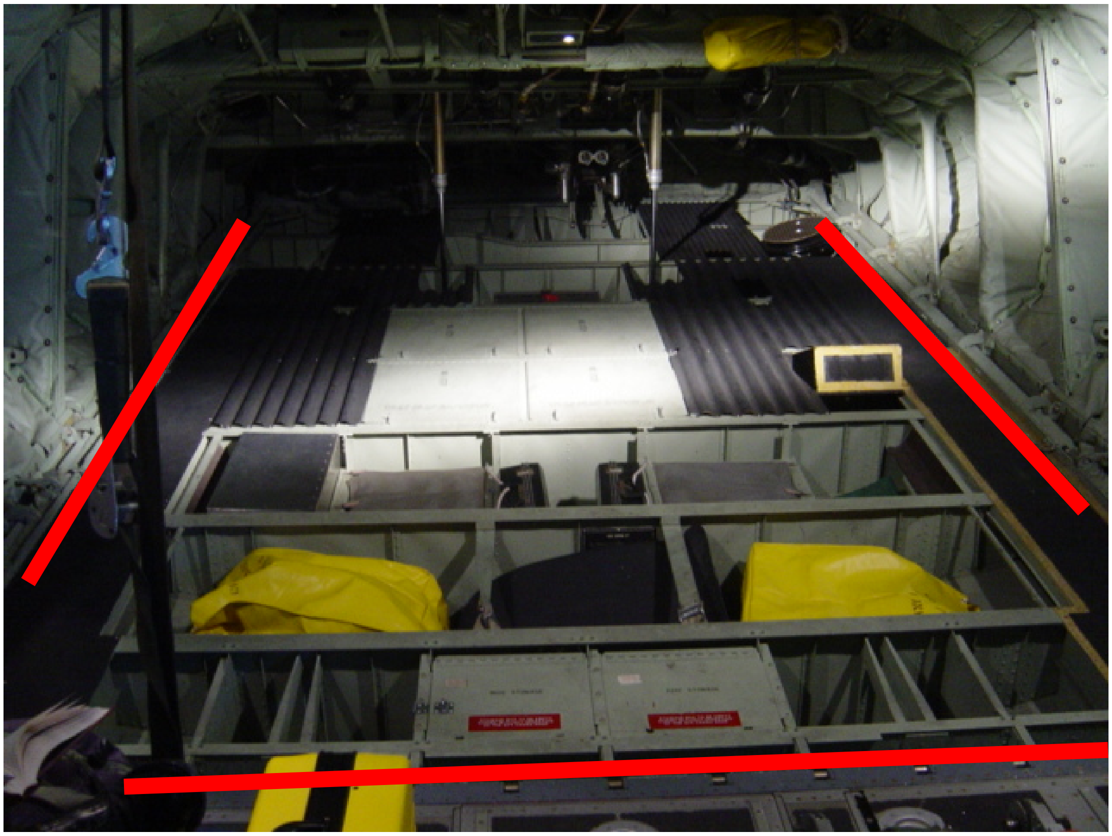


Figure 4. Rear cargo door, hot spots indicated in red

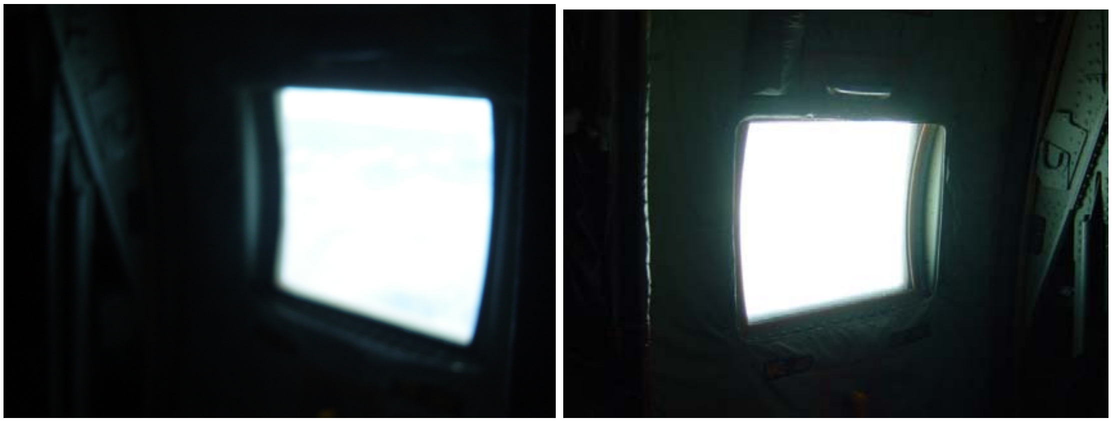


Figure 5. No measurements above background at paratrooper windows

Attachment 7
Shop Survey Data

Low Power Shop			E-field		H-field	
Nomenclature	Frequency (MHz)	Power (W)	Measurement (mW/cm^2)	PEL controlled (mW/cm^2)	Measurement (mW/cm^2)	PEL controlled (mW/cm^2)
VHF lo	120	953	0.00	1.00	0.00	1.00
VHF hi	270	1,000	0.00	1.00	0.00	1.00
	400	1,000	0.00	1.33	N/A	N/A
UHF	500	1,000		1.67	N/A	N/A
Partial Test Trainer (PTT)						
Nomenclature	Frequency (MHz)	Power (W)	Measurement (mW/cm^2)	PEL controlled (mW/cm^2)	Measurement (mW/cm^2)	PEL controlled (mW/cm^2)
TV	211.25	10,000	0.27	1.00	0.00	1.00
VHF lo	60	1,000	1.07	1.00	0.00	2.78
VHF hi	750	1,000	0.00	2.50	N/A	N/A
MF	1.2	10,000	0.61	100.00	0.78	6944.40
HF	16	10,000	0.15	3.52	0.00	39.06
High Power Shop						
Nomenclature	Frequency (MHz)	Power (W)	Measurement (mW/cm^2)	PEL controlled (mW/cm^2)	Measurement (mW/cm^2)	PEL controlled (mW/cm^2)
MF	1.7	10,000	0.19	100.00	0.29	3460.21
HF	16	10,000	0.31	3.52	0.00	39.06
TV	67.25	10,000	0.14	1.00	0.20	2.21
High Power Shop hot spots						
MF	1.7	10,000	0.19	100.00	0.3 - over range	3460.21
HF	16	10,000	0.82	3.52	30.58	39.06

Attachment 8
Locations of Shop Special Interest Areas

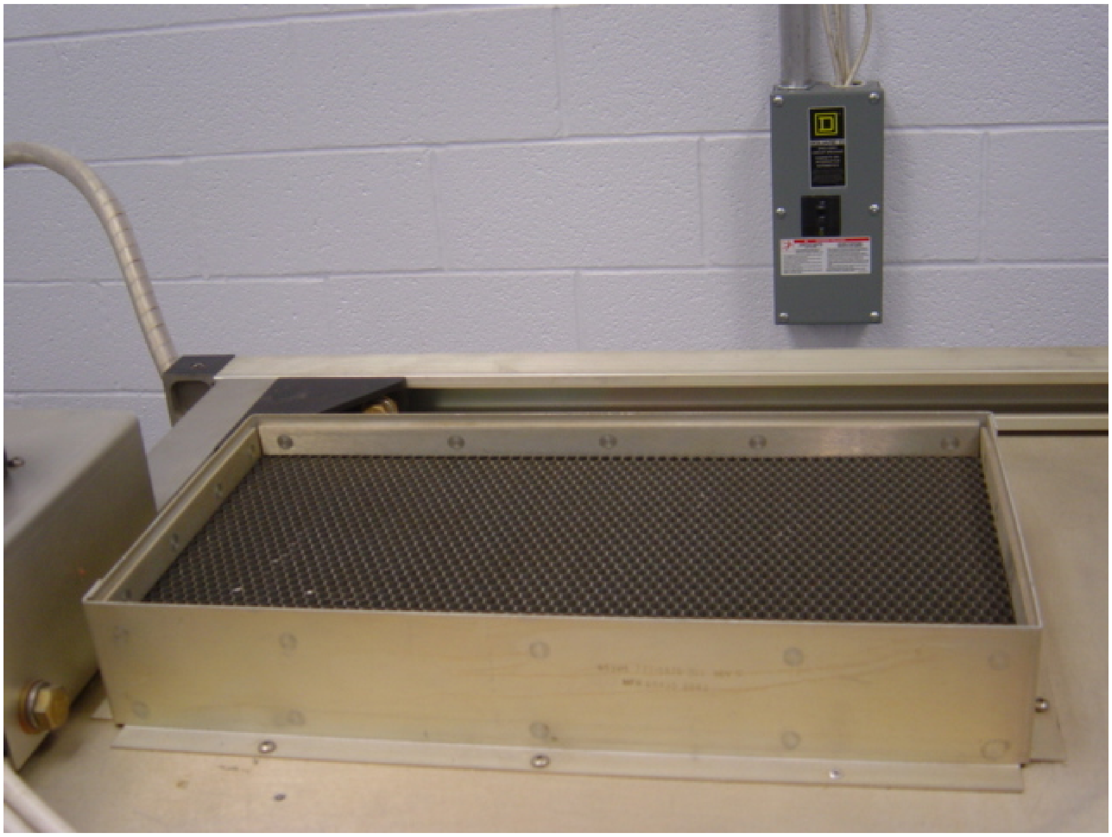


Figure 6. Location of vent in High Power shop for HF and MF emitters with RFR measurements above background.

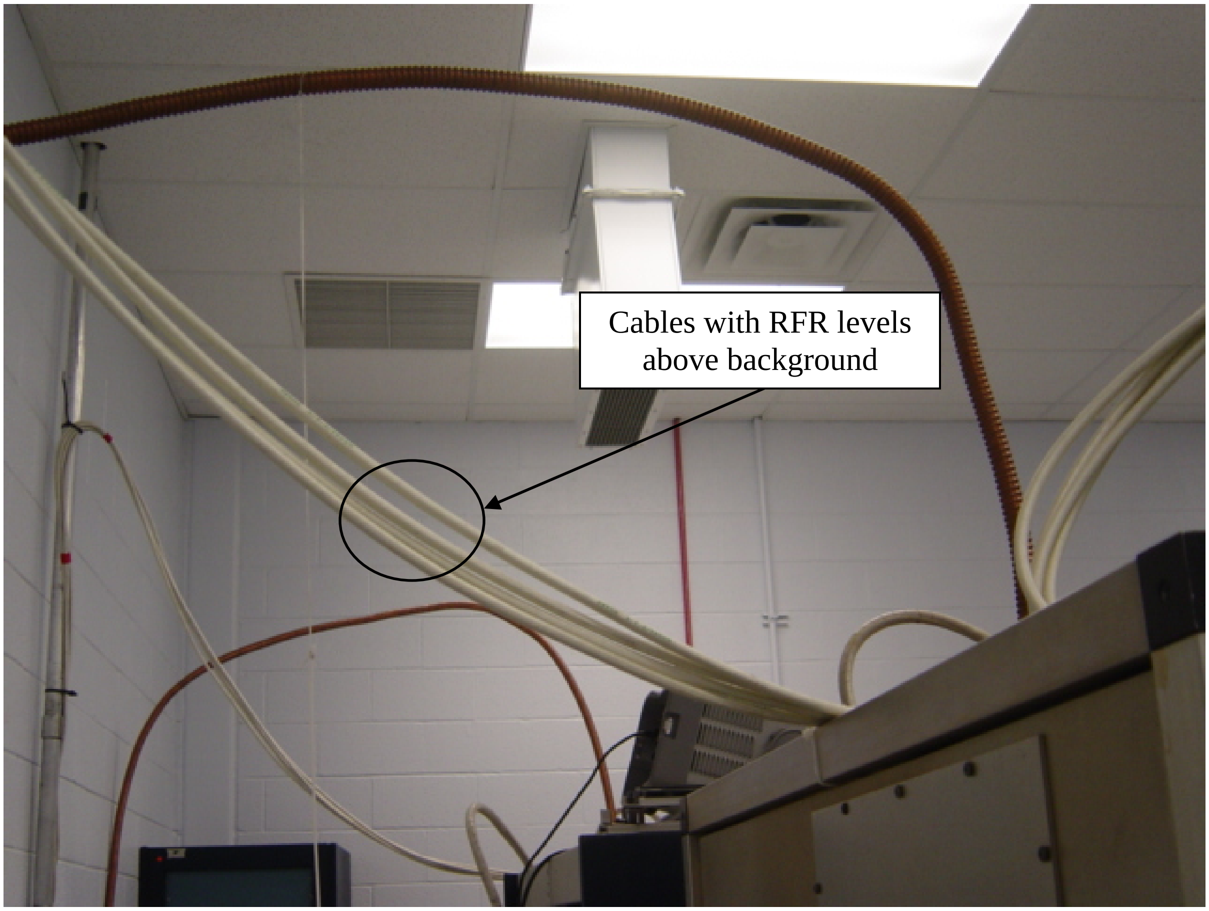


Figure 7. Location of overhead cables in High Power shop with RFR measurements above background.

Attachment 9

Radio Frequency Radiation (RFR) Awareness Training Example

Shop Name:___________________

Supervisor:____________________

I. General Information on Radiofrequency Radiation.

The electromagnetic spectrum covers a wide range of frequencies including AM, FM, TV and cell phone signals, as well as x-ray, gamma rays and visible light. Figures 1 & 2 below provide a summary of the electromagnetic (EM) spectrum. Note that all types of EM waves travel at the speed of light (3 x 10^8 meters per second in free space).

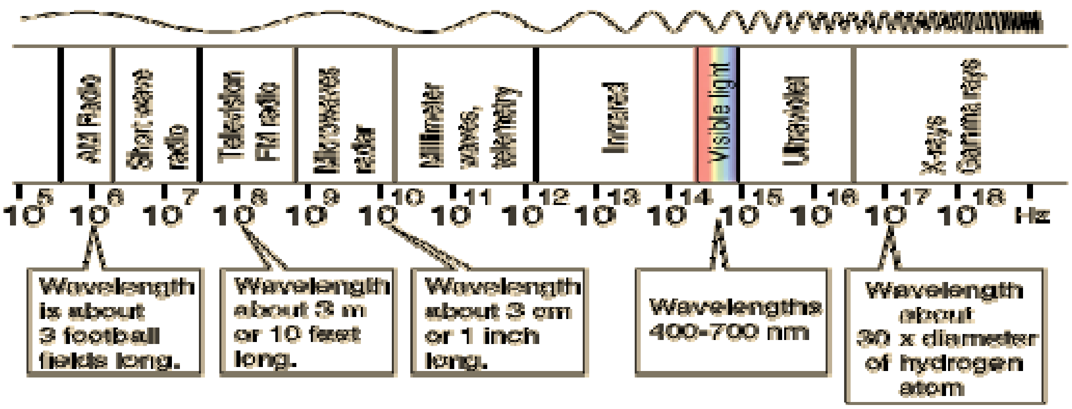


Figure 1. ***The Electromagnetic Spectrum***

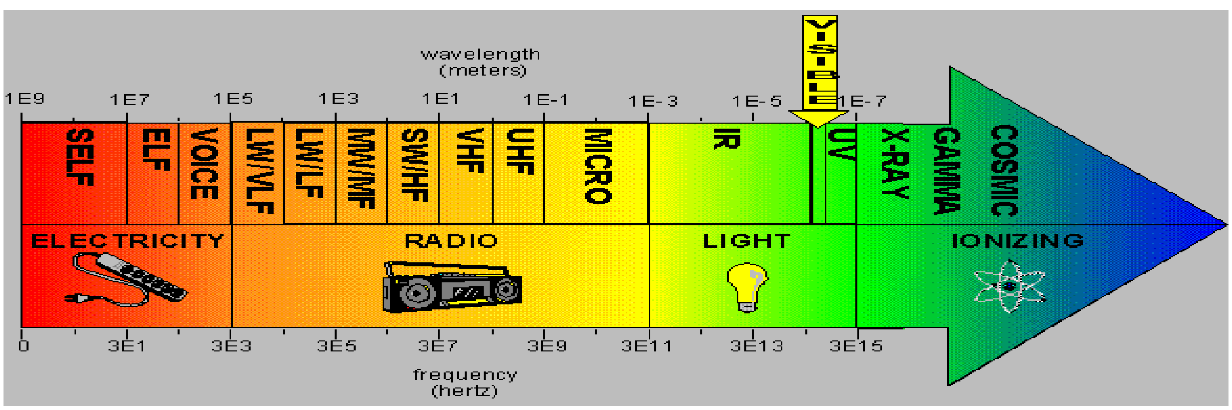


Figure 2. ***The Electromagnetic Spectrum***

What is Radio Frequency Radiation (RFR)? RFR is just part of the electromagnetic spectrum that extends in the frequency range of 10 kilohertz (kHz) to 300 gigahertz (GHz). RFR is considered nonionizing radiation and therefore has significantly different biological effects than that of ionizing radiation. Ionization is the process by which electrons are removed from atoms and molecules. Molecular changes can lead to genetic defects and biological tissue damage. RFR is a less energetic form of radiation and can not ionize atoms and molecules. EM energy is propagated through space in the form of waves composed of mutually supporting electric (E) and magnetic (H) fields that are at right angles to each other and travel at the speed of light. RFR decreases in power density from an antenna as identified in the equation below:

$$\mathbf{D_{PEL} = [(P_a \times G_{abs})/(40 \times \pi \times PEL)]^{-1/2}}$$

D_{PEL} = Distance in meters from antenna where power density equals the PEL
P_a = average power in watts (if pulsed source, a duty factor must be used)
G_{abs}= absolute gain (calculated from antenna gain in decibels)
PEL = Permissible Exposure Limit IAW AFIOSH 48-6 in mW/cm^2

Note: *This equation assumes far-field conditions. Near-field calculations are complex and must be determined by your Bioenvironmental Engineering office.*

What are the common band classifications for RFR?

Spectral Bands for RFR Radiation

Band	Description	Frequency
VLF	Very Low Frequency	3 - 30 kHz
LF	Low Frequency	30 - 300 kHz
MF	Medium Frequency	300 - 3000 kHz
HF	High Frequency	3 - 30 MHz
VHF	Very High Frequency	30 - 300 MHz
UHF	Ultra High Frequency	300 - 3000 MHz
SHF	Super High Frequency	3 - 30 GHz
EHF	Extremely High Frequency	30 - 300 GHz

Where are potential RFR hazards found? Potential RFR hazards can be found in some workplaces were RF emitters are used or tested, on the flightline during certain maintenance operations and around some antennas and radar systems. To better understand where potential RFR hazards exist a basic understanding of the RF emitter is needed. RF emitters consist of three basic components: a transmitter, a transmission line, and an antenna. Note that there are several variations of each of the above named components.

RF Transmitter. The transmitter generates and amplifies the RF signal. The active components of the transmitter can range from transistors and diodes used in low-power sources such as handheld radios, to high-power klystrons, magnetrons, and thyratrons used in microwave emitters. Transmitters may be continuous wave (CW), pulsed or have the capability to transmit RF signals under both conditions. This is important since the PEL is based on a six minutes exposure time interval. Transmitters normally do not present a RFR hazard under normal operating conditions however; other hazards are possible such as high-voltage and exposure to low-energy x-rays during certain maintenance procedures. Examples of different transmitters are provided below:



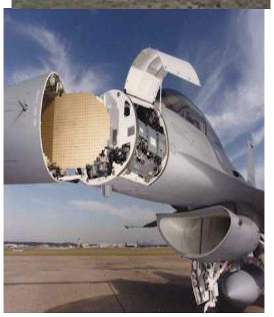
Transmission line. The transmission line is a critical element in an RF emitter in that it provides a link from the transmitter to the antenna. Its job is to transfer RF energy with a minimal signal loss. Low frequency sources use parallel pair lines and coaxial cables (for frequencies below 3,000 MHz). Normally waveguides or traveling wave tubes (TWT) are used for frequencies above 30 GHz. Damaged coaxial cables/waveguides and poor connections can result in potential for exposure to RFR above the PEL. The use of pressurized gas is often used in TWTs to monitor and ensure structural integrity thus ensuring a minimal loss of RFR. RFR surveys around non-pressurized waveguides, connection points, and/or were transmitters are commonly connected to coaxial resistors should be preformed to ensure leakage is minimal. Examples of waveguides and coaxial cables are provided in the pictures below:




Antenna. The antenna is of primary concern because this is the point where RFR is transmitted into free space. The antenna design is largely dependent on the intended use of the system in question. The antenna's characteristics determine the shape of the RFR field or beam and how directional (concentrated in one direction) the beam is. For example, a system that uses an antenna with a high gain of 50 dB (pencil beam) concentrates the RFR in a very tight beam where the RFR could exceed the PEL for thousands of feet. Hypothetically, an emitter that uses the same power and frequency as the last example but uses an antenna with a low gain of 1 dB (isotropic pattern), the RFR hazard distance may be very short in comparison (less than 10 feet). Note that high power transmitters used with antennas with medium to high gain antennas can also have hot spots or side lobes where high RFR levels can be found outside of the primary beam.







What is the Standard for RFR? Air Force Occupational Safety and Health Standard 48-9, *Radio Frequency Radiation (RFR) Safety Program*

What is the Permissible Exposure Limit (PEL) for RFR? The PEL is the exposure value to which an individual may be exposed without exhibiting damaging biological effects. The PELs are derived from the recommended exposure levels in ANSI/IEEE C95.1-1991, which serves as a consensus standard developed by representatives of industry, scientific communities, government agencies, and the public. These values are based upon a whole-body specific absorption rate (SAR) of 0.4 watts per kilogram, and incorporate a safety factor of 10 below a SAR of 4.0 W/kg, which is the threshold for the occurrence of potentially deleterious biological effects in humans. (Source: AFOSH Std 48-9, para. 2.1.1)

PELs are established values for any 6-minute period of time for specific frequencies less than 15 GHz. Refer to para 2.2.1 in AFOSH Std 48-9 for variation to this in the higher frequency ranges. Note that PELs are set for controlled environments and uncontrolled environments and is frequency dependent. PELs for uncontrolled environments include an additional safety factor for locations where individuals may be unaware of potential RFR exposure.
PELs for controlled environments are located in Table 2.1 (page 10) of AFOSH Std 48-9 and PELs uncontrolled environments are located in Table 2.2 (pages 11 – 12).

What are the short-term and long-term health effects to RFR exposure above the PEL? The following excerpt is provided directly from Attachment 5 of AFOSH Std. 48-9.

INTRODUCTION TO RADIO FREQUENCY RADIATION AND BIOEFFECTS

A5.5. Biological Effects of Radiofrequency Radiation.

A5.5.1. Introduction. Induction of heat in biologic tissue by RF radiation has been known for more than 80 years. This fact has been the basis of RF diathermy as used in the practice of physical therapy. Energy from the RF field is transferred to tissue by increasing the rotational energy of dipoles in the tissue. The principal dipole in biologic material, the water molecule, has the property of high viscosity (or long relaxation time). This makes it a very good absorber of RF energy. Changes result from the absorption of energy which may, or may not, produce temperature increases; however, the underlying mechanisms are basically driven by thermodynamic principles and the physiological responses thereto. There has been a substantial increase in research regarding the biologic effects of RF radiation and a great deal has been learned about the absorption and distribution of RF energy in biologic material and the resulting physiological consequences.

A5.5.2. Absorption of RF Radiation.

A5.5.2.1. The absorption of RF energy by biologic materials is strongly influenced by the frequency of the incident radiation and by the orientation of the object in the electromagnetic field. Using prolate spheroids, ellipsoids, and scaled models of man, studies have shown that whole-body absorption of RF energy is very strongly dependent upon the orientation of the long axis of the body relative to the electric field. Furthermore, the greatest absorption in this orientation occurs when the body length is approximately 0.4 of the free-space wavelength. This optimal absorption occurs at frequencies of about 70-80 MHz for adult humans. These frequencies are termed "resonant frequencies". When a person is in perfect ground contact, the resonant frequencies will shift to 35-40 MHz. A small separation from ground, e.g., wearing shoes, in most cases returns the resonant frequency to free-space conditions (70-80 MHz).

A5.5.2.2. The concept of a specific absorption rate (SAR) was developed to facilitate comparison of exposure conditions from experiment to experiment and from experiment to man. The SAR is the mass normalized rate of RF energy absorbed under different exposure conditions and/or for different frequencies. The SAR concept has been particularly useful for the extrapolation of experimental data from animals to man. It is possible to equate the SAR at a particular frequency and power density required to produce a discrete bioeffect in an experimental animal to the frequency and power density required to produce that same SAR in man. SAR's are given in units of watts per kilogram (W/kg).

A5.5.3. Biological Effects. The preponderance of studies reported to date have not defined any deleterious health effects from exposure to RF energy below a SAR of 4W/kg. Studies that have been reported which show effects below a SAR of 4W/kg either report effects which are not considered hazardous, or effects which have not been substantiated by replication in other laboratories. Extensive research continues in order to establish the validity and true nature of these effects. SAM-TR-87-03 provides a critique and summary of the relevant RF bioeffects literature to date, and is periodically updated to maintain currency with the extensive research underway in the world today.

A5.5.3.1. Athermal Effects. An important point to get across when discussing the effects of RF energy, is that biological effects are not necessarily hazards. Research communities throughout the world continue to publish paper after paper on the biological effects of RF Radiation. Some scientists have reported long lists of symptoms at levels of exposure that are well below the PEL. Some recent studies indicate a normal response in nerve cell tissues may be triggered by long term exposure to low levels of RF energy. All efforts to replicate such results have failed. Epidemiological studies conducted by various communities have attempted to correlate exposures to extremely low frequencies to childhood leukemia. Yet, epidemiological studies conducted by the Navy on radar technicians indicated no increase in the risk of cancer. The fact is, there is so much controversy in the scientific community surrounding these alleged effects that we cannot totally ignore them. The Air Force is not discounting the remote possibility of the "athermal" effects, but these still appear to be effects that may be observable under laboratory conditions, but have not demonstrated the potential to cause harm. Furthermore, these effects cannot be substantiated by leading Air Force, industry, or academic scientists. Certainly, not enough data has been collected to establish a set of standards based upon observed athermal effects. Therefore, the current US Air

Force standard for RF Radiation protection, is designed to protect personnel from known thermal hazards associated with RFR emissions.

A5.5.3.2. Direct Biological Effects. RFR energy at sufficiently high levels causes heating in body tissues. The amount of RFR energy that is absorbed and converted to molecular energy is strongly frequency dependent. Generally, it can be said that the longer the wavelength the greater the depth of penetration. Wavelengths of 3 cm or less (10 GHz or higher) are absorbed by the skin. Depth of penetration is only one factor; energy deposited is the key issue. The mechanism for transfer of energy to the human body by RFR is by friction resulting from the vibration/rotation of the body's polar molecules (mainly water) within the viscous cell membrane. Regardless of frequency, an RFR induced thermal burden adds to other thermal burdens and produces normal physiological adjustments like sweating and vasodilation. If effective dissipation of heat is prevented by biological or environmental factors, the exposed tissue will be heated and possibly damaged. The effects of this type of exposure are not considered to be cumulative as they are with ionizing radiation. Exposures separated by more than a few minutes (6 by the standard) are essentially separate physiological events.

A5.5.3.2.1. Microwave Hearing Effect. The so-called "microwave hearing effect" has been known for more than 30 years and consists of an audible sound which seems to originate within or near the head. The sensation is described as clicking, buzzing, or chirping sound depending upon the pulse repetition rate and pulse width of the incident RF radiation. The mechanism responsible for the sensation is similar to that produced by ordinary sound. The pulses of RF energy appear to produce a thermoelastic wave or pressure wave described as a cochlear microphonic. This wave is conducted by inner ear structures to receptors, and then by nerve impulses to the brain as in ordinary sound perception. For 15 microsecond pulses the threshold for this response is approximately 700 mW/cm2. Most operational systems will not produce power densities in accessible locations that reach this threshold. This effect, of itself, is not considered to be hazardous. However, any reports of this effect should be treated as a possible overexposure and carefully investigated.

A5.5.3.2.2. Ophthalmologic Considerations. RF energy has been shown to produce cataracts in experimental animals when the exposure is sufficient to raise the temperature of the lens to around 41 degrees Celsius. Localized exposure experiments in rabbits, exposure for 1 hour to 2450 MHz radiation at 100 mW/cm2 is sufficient to induce a cataract. However, these experiments would produce burns to the skin tissue surrounding the eye before a cataract would form. Whole body exposures did not produce the same results as localized exposures to the eyes, because the animal would expire before the end of the experiment.

A5.5.3.3. Indirect Biological Effects:

A5.5.3.3.1. Electronic medical prosthetic devices such as artificial cardiac pacemakers can respond to pulsed RF radiation fields. Significant disruption of normal pacemaker function requires RF radiation signals having a primary frequency between 0.1 and 5 GHz, pulse widths of greater than 10 microseconds, and electric field strengths greater than 200 V/m. Access to areas where these parameters and field strengths are used is restricted. However, it is prudent for individuals dependent on such devices to recognize the possibility of interference and avoid controlled areas.

A5.5.3.3.2. Metal Implants. Little is known concerning the interaction of RF radiation with metal implants such as cranial plates or orthopedic pins. However, it is thought that PELs in this standard provide adequate protection against harmful effects from any interaction with such implants, and no instances of adverse reaction to RF fields from metal implants have been reported.

A5.5.3.4. Conclusion. The PELs given in this standard are the result of extensive scientific research on the characteristics of RF radiation interactions with living organisms. The frequency dependent interactions of RF radiation with geometric and biological objects, including humans, have been published in the "Radiofrequency Radiation Dosimetry Handbook", SAM TR-85-73. Data in this handbook can be used to determine the incident power density as a function of frequency to limit whole body SARs to 0.4 W/kg or less and may also be used to extrapolate exposures causing effects in animals to those in man required to produce the same SAR.

II. Shop Specific Requirements.

1. Training Requirements: RFR safety awareness training is required for Air Force personnel who routinely work directly with equipment that emits RFR levels in excess of the PELs listed in table 2.1 of AFIOSH 48-9 or for those whose work environment contains equipment that routinely emits RFR in excess of the PELs listed in table 2.2. It is the unit's responsibility to provide and document training. The required training consists of initial training for workers before initial assignment of duties and annual refresher training. The Bioenvironmental Engineering Flight can provide assistance with training and any additional local requirements. The minimum required training requirements are listed as follows:

Initial Training

- Locations where the PEL can be exceeded
- Control measures that must be observed by workers to limit/avoid personal exposure
- Overview of the bioeffects that result from overexposure to RFR
- Exposure incident reporting procedures and follow-up technical and medical investigation process

Refresher Training (annual)

- New equipment, modifications, or other changes that affect the location of hazardous areas
- Control measures that must be observed by workers to avoid personal exposure
- Incident reporting procedures

Training must also be documented on AF Form 55, Employee Safety and Health Record, or an equivalent computer-generated product.

2. Locations of Potential RFR Hazards:

RFR Emitter Name	Location of Hazard	Safety Control Measures
Insert emitter name	Sources include T.O.s and BEE reports. Identify the area were RFR can exceed the PEL and the hazard distance if applicable.	List any required safety procedure or engineering controls identified in your T.O.s, SOPs, Bioenvironmental Engineering survey reports and/or manufactures publications. Example include: Warning signs, controlling areas, fences, special coordination, constant observation and engineering controls such as azimuth blanking, dummy loads, RF hats, interlocks, flashing lights & kill switches.

3. Incident Reporting Procedures: If an individual believes that an exposure to RFR occurred above the PEL, the following steps should be followed:

1) Immediately report suspected exposure incident to your supervisor and shop Radiation Safety Officer (RSO) or shop safety officer.

2) Prevent further RFR exposure to yourself and other workers.

3) If supervisor/RSO or shop safety officer suspects/confirms that worker was exposed above the PEL and/or worker experienced symptoms associated with exposure to high-level exposure to RFR, send worker to the medical treatment facility immediately.

4) Immediately notify the Base Bioenvironmental Engineering Flight or Base Radiation Safety Officer of alleged overexposure and facts surrounding incident.

5) Conduct an investigation IAW Attachment 6 of AFOSH Std 48-9. Ensure all witnesses are interviewed to gather required information to determine potential RFR exposure and events leading to alleged overexposure. Investigation should be conducted jointly with the Bioenvironmental Engineering Flight.

6) Work with the Bioenvironmental Engineering Flight to modify safety procedures and/or conduct needed RFR awareness training to prevent future exposures and/or worker misunderstanding of RFR environments.

7) Follow local reporting requirements established by the Bioenvironmental Engineering Flight and the unit/shop RSO or Safety officers.

4. Miscellaneous Information:

Where can I get more information on RFR?

AFOSH Standard 48-9, *Radio Frequency Radiation (RFR) Safety Program*
Equipment Technical Orders and manufacturer's publications on RF emitters
Unit/Shop Standard Operating Procedures
Bioenvironmental Engineering Flight survey reports for your shop
Unit or shop RSO
Contact your local Bioenvironmental Engineering Flight at XXX-XXXX.

Attachment 10
Critique

POINT OF CONTACT:	**Capt Krystyn Clark**	**BASE NAME:**	**Brooks City-Base**
POC PHONE:	**DSN 240-4297**	**DIVISION:**	**AFIOH/SDRH**
STINFO NUMBERS:	**IOH-SD-BR-CL-2007-0035**		

This survey is used to help us improve our service to you. Your answer will be held in confidence and will significantly impact on how we allocate resources to meet your needs. Please return this completed form promptly.

Grading Scale:

1	**2**	**3**	**4**	**5**	**6**
Extremely Dissatisfied	Dissatisfied	Slightly Dissatisfied	Slightly Satisfied	Satisfied	Extremely Satisfied

A	Timeliness: Did you receive your results within the published time limits?	1	2	3	4	5	6
B	Accuracy: Is the report in the proper format? Are your address and other data correct?	1	2	3	4	5	6
C	Content: Does the report answer your questions and provide the necessary data? Are our services per dollar adequate when compared to civilian sector?	1	2	3	4	5	6
D	Customer Support: Have we been courteous and helpful in meeting your special needs (priority service, reporting, format, etc.)?	1	2	3	4	5	6
E	Consult Service: Have we answered your questions and provided necessary materials or reviewed to support your mission requirements?	1	2	3	4	5	6
F	Overall Rating: How would you rate our overall service to you?	1	2	3	4	5	6

Comments / Suggestions: Are there other services that you would like provided in the future? Are there any specifics of your current service you would like to discuss? (Use additional pages if more space is required)

Please return to:

AFIOH/SDR
Attention: Lt Col Scott M. Nichelson
Chief, Radiation Surveillance Division
2350 Gillingham Drive
Brooks City-Base TX 78235-5103