RF RADIATION HAZARDS

Introduction

This article presents for EMC engineers a brief overview of various types of radiation hazards (RADHAZ) due to high-level RF emissions. Three broad RADHAZ categories are considered:

1. Personnel: direct biological effects and indirect effects resulting from the performance of cardiac pacemakers.
2. Explosives: both munitions and other applications (blasting caps, seat ejectors, etc.), primarily those utilizing electro-explosive (EED) devices.
3. Fuel: ignition due to RF-induced sparks.

RF Radiation Hazards To Personnel

Biological Effects

Biological hazards to personnel due to whole-body radiation are measured by incident power density or energy flux, respectively, in milliwatts or millijoules per square centimeter. Biological damage to living tissue is known to be caused by the heating effect on the tissue. (Some other reversible effects are known or suspected, but are not considered here.) Skin burns, eye cataracts, and overheating of delicate body organs can be caused by radio-frequency (RF) radiation. Organs with limited circulation to dissipate heat, such as the lungs, testicles, and liver, may be damaged by RF radiation. At present, the generally accepted threshold level in the United States is a time-averaged power density of 10 milliwatts per square centimeter (10 mw/cm^2), for a limited duration of 6 minutes during any hour period, over the frequency range from 10 MHz to 100 GHz.

Proposed revisions to ANSI C95.1[1] are to decrease the level, present it in terms of the square of field strength (electric and magnetic), and to make it a function of frequency. These proposed changes are particularly significant since, once ANSI approved, they are likely to be adopted widely by the military and civilian organizations. As of 7 August 1981, revisions *proposed* to ANSI C95.1 were:

All values averaged over 0.1-hr. period.

f (MHz)	E^2 (V^2/m^2)	H^2 (A^2/m^2)	P (mW/cm^2)
0.3 - 3	400,000	2.5	100
3 - 30	4,000/(900/f^2)	0.25 (900/f^2)	900/f^2
30 - 300	4,000	0.025	1.0
300 - 1,500	4,000 (f/300)	0.025 (f/300)	f/300
1500 - 100,000	20,000	0.125	5.0

Note that for 300 kHz$<f<$100 GHz, values may be exceeded provided average whole-body specific absorption rate (SAR)$<$0.4 W/kg, and peak spatial SAR$<$8 W/kg averaged over 1 g of tissue.

Some foreign countries identify more stringent limits for continuous exposure to RF radiation. For example, the Academy of Medical Sciences of the USSR specifies 0.01 milliwatt per square centimeter as a level for continuous exposure.[2]

Cardiac Pacemakers

Personnel with implanted cardiac pacemakers are exposed to an additional hazard, indirectly, from RF emissions interfering with the operation of cardiac pacemakers. Cardiac pacemakers, especially the widely-used demand type, are sensitive to RF emission, not necessarily limited to high-power-density emitters. A low-energy transient voltage can give the pacemaker a false trigger, causing a change in rate or suppression of output. (In less direct fashion, interference with the operation of diagnostic medical equipment can result in responses that lead to a false diagnosis, with subsequent danger to a patient.)

The leads of a pacemaker act as antennas to receive undesired signals.† In addition, there may be interference resulting from case penetration. With a sensitivity of 0.2-1 mV, these devices have been interfered with by transient emissions from household appliances, such as electric mixers and electric razors. From such incidents, it is apparent that the modulation of the emitter becomes a factor in addition to field strength. For more detail on pacemaker EMC performance, see the Susceptibility Sources section of this issue of ITEM..

Safe levels and criteria for pacemakers in RF fields have not yet been established, although several research groups have generated values for specific emitters (not available in the open literature).

RF Radiation Hazards To Ordnance

Electroexplosive devices (EEDs) are electrically initiated primers used in initiating explosives. They may be used in a demolition charge or may be incorporated in a complex weapon system. The EED is the most sensitive link in the system whose susceptibility to RF emissions is based on receiving enough energy to detonate or cause dudding. (AF Regulation 127-100 identifies 50 mW as the minimum fire power for this situation.[4]) The wire leads of the EED may act as a dipole, or as a loop antenna when the ends are shorted. The most stringent hazard criteria in the ARM 127-100 are based on the "worst-case" configuration of the EED, and are given as a function of frequency for three situations: transport or storage, exposed, and on taxiing aircraft.

†The leads may be as long as 54 cm and unshielded.[3]

The basic problem in determining an ordnance-system susceptibility to RF radiation lies in evaluation of the antenna-like couplings that exist between illuminating fields and the various EEDs employed in the system. RF energy may enter a weapon as a wave radiated through a hole or crack in the weapon skin. RF energy may also be conducted into the weapon by the firing leads or other wires that penetrate the weapon enclosure. The precise probabilities of EED actuation are relatively unpredictable, being dependent upon variables of frequency, field strength, geometric orientation, environment, and metallic or personnel contact with the ordnance or the ordnance platform (aircraft, ship, vehicle, etc.). The most susceptible periods are during assembly, disassembly, loading, unloading, or testing in electromagnetic fields. The most likely effects of excessive RF energy are dudding, reduction of reliability, or propellant ignition.

Each of the U.S. military services has published documents specifying safe radiation levels for its particular weapon systems.

RF Radiation Hazards To Fuel

The probability of ignition of fuel vapors by RF-induced arcs is based upon a minimum-length spark containing sufficient energy to cause ignition occurring in a flammable fuel-air-mixture environment.

In an idealized laboratory setup with the above (worst-case) conditions existing, a peak power density of 5 W/cm^2 or less is considered safe.[5]

A power-density criterion of the emitter identifies the amount of radiated power available. The configuration of the refueling operation determines how much of this available power is received. The size and shape of an aircraft, for example, on a carrier, and its orientation with respect to the emitters and the refueling equipment used will determine the voltage and power that is available between the nozzle and the fuel filler to ignite fuel vapors.

References

1. *Electromagnetic Radiation with Respect to Personnel, Safety Level of,* Standard C95.1-1974, American National Standards Institute, New York.
2. "Biological Effect of Microwaves in Occupational Hygiene," Pub. No. 273-1976, Ministry of Hygiene, USSR.
3. J.R. Bridges et al, "Susceptibility of Cardiac Pacemakers to ELF Magnetic Fields," Technical Memorandum #1, Project '6185, IIT Research Institute, April 1971
4. *Explosives Safety Manual,* AFM 127-100, U.S. Air Force, December 1971 (Revised 1974), and Change 1, 31 March 1978.
5. *Electromagnetic Radiation Hazards,* T.O. 31Z-10-4, U.S. Air Force, 1 August 1965, and Change 3, 10 February 1978.

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PROPOSED NEW RADHAZ REQUIREMENTS

The American National Standards Institute (ANSI) is considering a major revision of its C95.1-1974 document "Safety Level with Respect to Human Exposure to Radio Electromagnetic Fields." The existing ANSI document specifies an electromagnetic radiation level of 10 mW/cm^2 from 10 MHz through 100 GHz. This is the level currently being used by military agencies and of that adopted by OSHA and other organizations. ANSI normally sets the guidelines for RADHAZ standards and, if adopted, the proposed new standard will have a significant impact on everyone concerned.

The purpose of the ANSI standard is to recommend maximum radiation levels to prevent harmful effects in human beings exposed to electromagnetic fields. These recommendations are intended to apply to non-occupational, as well as occupational, exposures. The recommendations are not intended to apply to the purposeful exposure of patients under the direction of practitioners of the healing arts.

The proposed standard has several definitions which are of critical importance. There are as follows:

Radioprotection Guide (RFPG). The radio frequency field strength or equivalent plane wave power density should not be exceeded without (1) careful consideration of the reasons for doing so, (2) careful estimation of increased energy disposition in the human body, and (3) careful consideration of the increased risk of unwanted biological effects.

Specific Absorption Rate (SAR). The time rate at which radio frequency electromagnetic energy is imparted to an element of mass of a biological body.

For human exposure to electromagnetic energy of radio frequencies from 300 kHz to 100 GHz, the Radio Frequency Protection Guide, in terms of equivalent plane wave free-power density is as follows:

FREQUENCY RANGE (MHz)	POWER DENSITY (mW/cm^2)
.03 - 3	100
3 - 30	900/f^2
30 - 300	1.0
300 - 1500	f/300
1500 - 100,000	5.0

For mixed or broadband fields consisting of a number of frequencies for which there are different values of radio frequency protection guide, the fraction of the radio frequency protection guide incurred within each frequency interval should be determined, and the sum of all such fractions should not exceed the unity.

At all frequencies between 300 kHz and 100 GHz, the protection guide may be exceeded if the exposure condition can be shown by laboratory procedures to produce specific absorption rates (SAR) below 0.4 w/kg, as averaged over the whole body, and spartial peak SAR values below 8 w/kg, as averaged over any 1 gram of tissue. Furthermore, at frequencies between 300 kHz and 1 GHz, the protection guide may be exceeded if the radio frequency input power of the radiated device is 7 watts or less.

Both for pulsed and non-pulsed fields, the power density and the values of SAR or input power, as applicable, are averaged over any 0.1-hour period. The time-average values should not exceed either the power densities given above or in the exclusions. Measurements to determine adherence to the recommended protection guides shall be made at a distance of 5 centimeters or greater from any object (refer to ANSI C95.3-1979 for radio frequency measurements).