ELECTROMAGNETIC RADIATION IN PROLONGED SPACE ENVIRONMENTS

Although still in the developmental stages, it is generally agreed that the Space Station Program system will include some unique parameters which involve humans, nature and electronic/electrical equipment. Because of the low level signal voltages and currents and the high circuitry impedances required for some of the units in the program, the electromagnetic environment (EME) must be closely controlled to achieve equipment and system compatibility. Firm technical management controls should be established for an effective program, to implement EMC, and to maximize safety and minimize human hazard conditions.

Of particular interest to the Space Station Program are the radiation hazard problems wherein the subject astronaut displays greater susceptibility to some portions of the frequency spectrum than to other areas of the spectrum. Telemetering transmitters and their associated antennas are designed to operate in the S-band, which coincides with the portion of the spectrum of maximum human hazard to radio frequency energy, as listed in Tables 1 and 2. Originally, military requirements have specified a level of 10 milliwatts per square centimeter averaged over the frequency spectrum, with no limits as to duration of exposure. Later, the USA Standards Institute specified the limit at 10 milliwatts per square centimeter for 0.1 hour (194.1 V/m field intensity), or in terms of energy density, one milliwatt hour per square centimeter during a 0.1 hour period. The USSR, for continuous exposure, has defined the limit as 0.01 milliwatts per square centimeter or 6.1 V/m field intensity.

Radio frequency radiation incident on a body may be reflected, absorbed, or passed through. A combination of these conditions is also possible. Although the eyes and testes are the most vulnerable parts of the human body to electromagnetic radiation, other systems can be affected, including the brain, nerves, skin and muscles. The effects may vary, depending on frequency and intensity, from a mild heating of the skin to damage to the central nervous system. One thermal effect is "Pearl-chain" formation at 21 megahertz. Since this is a unique effect, it requires some explanation. Particles, suspended in a fluid whose dielectric constant is different from that of the particle, become electronically polarized when they are subjected to a high frequency alternating field, with the result that electrical charges appear on the particles' boundaries. In effect, an electrical dipole is formed, which then is influenced by the electric field so as to align with the field. When the distance between particles is small and the field strength is of sufficient magnitude, characteristic chains will form. "Pearl-chain" formations can occur in the blood stream of man and mammals.

EM Radiation Hazards
- Below 1 GHz
  - Penetration—Thermal
- 1 to 3 GHz
  - Susceptibility—Maximum
- Above 3 GHz
  - Surface—Minimum Penetration
- 21 MHz
  - Pearl-chain Effects
  - Athermal

Thermal—Average
- Body
  - 102.2°F (37°C + 2°C) or 100 mW/cm^2
- Testes
  - 98.6°F (35.5°C + 1.4°C) or 5 mW/cm^2
- Eye
  - 113°F (37°C + 8°C) or 155 mW/cm^2
    - Cataracts
    - 10 mW/cm^2

Table 1. Radiation Hazards.

Another area particularly susceptible to radiation effects are bone implant areas. When bones are broken, implants are sometimes installed to provide additional structural support, and are generally of metal such as stainless steel or platinum. In performing the necessary surgery for the implant, nerve endings are severed, reducing the signaling to the brain of thermal activity in the implant areas. This loss of thermal sensitivity results in increased burning of tissues from radio frequency radiation. A similar condition exists in fillings in teeth. Because fillings are made of conductive materials, the filling material will increase in temperature when subjected to EM radiation; and with the isolation provided between the filling and the nerve, it is only the poor thermal conductivity of the tooth which provides the warning of a local temperature rise. However, the temperature rise is far higher than if the nerve were sensing the temperature of the filling.

Source	USASI	BTL	USN Bu. Med. & Surgery	USSR
Power Density	10 mW/cm^2	0.1 mW/cm^2	10 mW/cm^2	1 mW/cm^2
Time	0.1 hr	Avg. Continuous	Avg. Continuous	15-20 min/Working Day (Protective Goggles Req.) 0.1 mW/cm^2 2 hrs/Working Day 0.01 mW/cm^2 Irradiation/Working Day
			300 millijoules/cm^2 Intermittent/30 Sec Interval	
Energy Density	1 mW/cm^2			
Time	Any 0.1 Hr Period			

Table 2. EM Radiation Hazard Limits for Humans.

The EME in space is normally not of sufficient magnitude to constitute a problem except when a solar flare occurs. The resulting "solar winds" form a path between the sun and the planets circling the sun. These "solar winds," which contain high energy particles, including electrons, create high energy electric and magnetic fields. The earth, though provided some protection from the "solar wind" by the magnetosphere and the Van Allen Belts, is affected by the high intensity EM energy from the sun. Evidence of the effects are communication blackouts, both hard-line and RF transmission, and large perturbations on power transmission lines, which in some cases have resulted in blackouts. Solar flares and the effects of solar flares have nominal time duration of two to three days. Maximum solar flare activity occurs in 11-year cycles, with the next maximum activity expected to occur during the later part of 1989 and all of 1990, and then again in 1999 and all of the year of 2000. Though the applicable EMC specifications do not provide for protection or equipment compatibility from solar flares, these effects must be factored into the design of the system equipment design.

An additional personnel hazard condition to be investigated and controlled relates to grounding. The National Electrical Code previously had a limit of 5.0 milliamps leakage current for electrical devices. The revised limit is now revised to 0.5 milliamps which represents the latest data accumulated by the Underwriters' Laboratories on personnel hazards. Protection for the astronauts must be provided by monitoring current flow between the instrumented astronauts and the vehicle. The current monitoring unit must open all circuits connecting to personnel with manual reclosing of the circuits. Since signal currents are small, relay contacts must be capable of working under dry circuitry conditions.

Space vehicles, which still remain in orbit though they are no longer active or providing useful data to earth, constitute an addition to the naturally complex space EME as bodies capable of reflecting and refracting energy to the manned vehicle, altering the EME external and internal to the vehicle when it is in the vicinity of the "space debris."

In order to address human sensitivity in terms of the space EM environment, an EMC program organization must consider equipment and human electromagnetic compatibility in excess of the applicable EMC specification requirements. Guidelines in these areas of EMC must be provided.

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