Ch-8 – Microwave Radiation Hazards [Short Notes]

[A. Das & S. Das – Tata McGraw Hill Companies]

Microwaves are used in the scientific and industrial applications as well as the military and civilian world, but these are some adverse effects of high-power microwave radiations.

Introduction :-

1) Hazards of Electromagnetic Radiation to Personnel (HERP)
2) Hazards of Electromagnetic Radiation to Ordinance (HERO)
3) Hazards of Electromagnetic Radiation to Fuel (HERF)

HERP is the potential of electromagnetic radiation to produce harmful biological effects in humans.

HERO is the potential of electroexplosive devices to be adversely effected by electromagnetic radiation.

HERF is the potential of electromagnetic radiation to cause spark ignition of volatile combustible such as vehicle fuels.

HERP :-

Since applications of microwaves extend to the human body on medical treatments and there are possible exposures of the bodies of human and animals to MW power in domestic, public and military applications.

Independent studies have revealed that MW energy can be hazardous to personnel to cause:

→ Cataracts
→ Skin Cancer
→ Headaches and dizziness
→ Blood disorders / leukemia
→ Birth defects in pregnant women
→ Central nervous system damage
→ Temporary sterility in men
→ Cardiovascular problems
→ Interference with some pacemakers
→ Increased stress
→ Decrease in immune system competency

There is also possibility that weak electric and magnetic fields from high power transmission lines may affect biological cellular processes at the cell nucleus.

HERP is caused by the thermal effect of radiated energy. Since biological substances, such as blood, brain, bone, muscle and fat, behave as conductive or lossy dielectrics, the MW energy directed on to the body may be scattered, reflected and absorbed depending on the field strength, frequency, the dimension of the body and electrical properties of the tissue.

The absorbed microwave energy produces molecular vibration and converts this energy into heat.

If the organism can't dissipate this heat (energy) as fast as heat is produced, the (internal) temperature of the body will rise. This heat may damage these biological substances (permanently).

e.g If the lense of the eye is exposed to microwaves, its circulatory system would be unable to provide sufficient flow of blood for cooling and may cause cataracts. Similarly, the stomach, intestines and bladder are especially sensitive to thermal damage from high-power MWs.

Some biological effects can't be explained a temperature rise in the body. Persons energy in microwave fields have reported headaches, eyestrain, overall fatigue and disturbances of sleep. These effects have been associated with the interaction microwave fields with the central nervous system of the body. Such effects have been labelled as "non-thermal" interactions. These effects may be due to long-term prolonged exposure to low-levels of electromagnetic fields.

(HERO)

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MW energy is also dangerous to ordinance weapon systems, safety and emergency devices and other equipments containing sensitive electro (explosive) devices (EEDs), in additions to attending

V. Personnel and associated equipment.

→ Radiated fields can cause unintentional triggering of EEDs.

→ Ordnance is more sensitive than human partially because they don't have a circulatory system to dissipate internal heat. However, EEDs can more easily be protected from the effects of RF energy than humans by enclosing them with metallic enclosures which reflect back the incident microwave energy.

HERF :-

HERF occurs due to possibility of accidentally igniting fuel vapours by RF-induced (electrical spark) arcs during fuel-handling operations in proximity to high-level RF fields.

Radiation Hazard levels for personnel

The most widely used parameter for the measure of microwave radiation levels is average power density for a plane wave in free space

$$P_d = EH = \frac{E^2}{377} = 377 H^2 \qquad \left[\because \eta = \frac{E}{H} = 377\right]$$

But, the majority of hazardous fields in practice are not simple plane waves but have complicated amplitude, phase and polarization distribution due to their

Standing wave & modulation characteristics.

Therefore, some standards consider Specific Absorption Rate (SAR) as the unit of measure to determine the radiation exposure limits.

→ SAR is the rate of energy absorption per unit mass of substance measured in W/kg. [W=watt]

$$SAR = \frac{\sigma E^2}{m_d} \quad \frac{W}{Kg}$$

Where σ = Conductivity of the material (S/m)

E = rms electric field within the material $\left(\frac{V}{m}\right)$

m_d = mass density of the material $\left(\frac{kg}{m^3}\right)$

→ It is found that the microwave absorption depends on the variation in body size and orientation with respect to wavelength.

→ The typical average SAR value for human being is about 0.03 W/kg for an incident power density of 1 mW/cm² at 2.45 GHz.

→ The rate of temperature rise due to MW heating can be expressed by

$$\frac{dT}{dt} = \frac{Q}{S_p} \quad (^{\circ}C/s)$$

Where Q = SAR + metabolic rate of heat production per unit mass − the rate of heat loss per unit mass in $\frac{W}{kg}$

S_p = Specific heat of the substance in K Cal °C/Kg.

Note :- Due to MW radiation, the temperature initially increases rapidly for a few minutes and then the thermoregulatory system of the body tends to stabilize the temperature. But the body temperature will start to rise again if the system can't remove excess heat at the same rate and therefore hazard occurs.

Radiation Hazard limits

[No need to remember the datas of diff. organization → Refer 1 or 2 data]

Various International agencies have defined safety limits for radiation exposure.

→ International Radiation Protection Association (IRPA) sets the permissible Exposure levels (PEL) for the general public.

→ IRPA gurdelines are divided into 2 categories

1. Occupational Permissible Exposure levels, which applies to ~~residents~~, personnel who work in the vicinity of RF for 8 hours a day

2. General Public permissible Exposure levels, which applies to residents, who are exposed to the RF electromagnetic environment all throughout the year.

The limit taken into consideration the skin depth and SAR.

→ The US Navy's Bureau of Medicine and Surgery established the biological hazard level that personnel should not ~~exceed~~ be exposed to a power density above 10 mW/cm², when averaged over any 0.1 hour period, in the freq. range of 10 MHz – 100 GHz. This limit is 100 mW/cm² where the exposure is not continuous (Pulsed).

→ The American National Standards Institute (ANSI) developed ANSI C 95.1-1982 electromagnetic hazard limit of HERP and ordinance. The ANSI standard uses the idea of a constant average SAR limit of 4 W/kg, which is $\frac{1}{10}$ the value of threshold for adverse effects.

→ The limit ~~of~~ for ordinance is generally lower than the limit ~~of~~ for humans because ordinance is more sensitive than humans as they don't have natural system to dissipate heat.

→ The RF limits for HERP in the US is based on the body-heating effects. However, the Soviet limits for HERP is 0.01 mW/cm², which is 30 dB lower than the US limit [10 mW/cm²], because they studied that there were biological effects other than thermal. The Chinese limit is 0.05 mW/cm²,

Radiation Protection :-

Radiation protection can be practised by preventing radiation, from entering into the the beam of the transmitting antenna or from coming close to any microwave generators or porpagating medm.

In areas where high power radars are used, the service and maintenance personnel must wear microwave absorptive suit made out of stainless steel woven onto a fire retardant Syntetic fibre. The suit is light weight, Comfortable, and easy to put on. The attenuation produced by such a suit is above 20 dB at 2450 MHz, 20-35 dB from 650 - 1150 MHz and 35-40 dB from 1 - 11 GHz.

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