# 11. PROTECTIVE MEASURES

In situations where recommended limits can be exceeded, protective measures need to cover at least three types of potential hazards.

- exposure to RF electric and magnetic fields;
- contact with ungrounded or poorly grounded metallic objects; and
- interference with implantable and other medical devices.

A programme of measurement surveys, inspections and education on worker safety, is necessary for an effective protection programme. Protective measures can be broadly divided into three categories: engineering controls, administrative controls, and personal protection.

## 11.1 Engineering measures

Engineering controls for limiting human exposure to RF fields include design, siting, and installation of generating equipment. These depend on the purpose of the equipment and its operational characteristics. While strong fields around antennas of deliberate radiators, such as broadcast transmitters or radars, are unavoidable, appropriate design of the generating equipment can ensure negligibly weak fields around cabinets housing generators and other electronic circuits, and around transmission lines, such as cables and waveguides. The limitation of leakage fields at the design and manufacturing stages is more effective and less costly than later remedies, such as additional shielding, barriers, etc. At the frequency bands allocated for telecommunication, leakage (stray) fields are frequently at such low levels that they are an electromagnetic interference (EMI) problem rather than a health problem.

However, at frequencies allocated for industrial, scientific, and medical (ISM) uses, human exposure to strong stray fields is more likely to occur, as exemplified by RF industrial heaters (West et al., 1980; Stuchly et al., 1980; Eriksson & Mild, 1985; Joyner & Bangay, 1986b).

The siting and installation of deliberate transmitters must take into account exposure standards, as well as other technical considerations. It is important that an assessment of RF fields around various antennas is made and particularly, in the near-field, is verified by measurements. In siting deliberate radiators and evaluating exposure fields, the existence of multiple RF sources has to be taken into account where applicable. Often, broadcasting and other communication or navigation transmitters are located on the same tower. Furthermore, metal structures can cause reflections, and, thus, produce local enhancement of the fields. However, depending on the shape and location of the structure, it may also reduce the field. The reduction usually occurs for fields of frequencies below approximately 10 MHz. If after the erection of a radio-transmitting structure, a building is also to be erected, then it is recommended that planning authorities seek guidance as to whether the new building could reflect fields in such a way that exposure limits could be exceeded. This would entail:

(*a*) obtaining assurances from the broadcasters that the field intensities at the new site will not exceed relevant exposure limits, and

(*b*) seeking assurances from the broadcasters and the builders that the new building will not adversely affect broadcast coverage or significantly increase fields in the vicinity, due to reflections, such that the new levels exceed exposure limits.

Engineering controls against excessive contact currents include the grounding of metal fences and other permanently located metal objects, and the installation of special grounding straps on mobile metal objects. Special techniques have to be used to ensure the effective grounding of fences and other objects. Furthermore, the contact currents should be measured after the grounding of the object.

*RF hot spot - a special case*

Tell (1990) conducted measurements and calculations directed to applications in the VHF and UHF broadcasting bands, but the concepts are also applicable to assessing RF hot spots near AM radio stations. He summarized the problem of RF hot spots as shown below.

An RF hot spot may be defined as a point or small area in which the local values of electric and/or magnetic field strengths are significantly elevated above the typical ambient field levels and often are confined near the surface of a conductive object. RF hot spots usually complicate the process of evaluating compliance with exposure standards, because it is often only at the small area of the hot spots that fields exceed the exposure limits.

RF hot spots may be produced by an intersection of narrow beams of RF energy (directional antennas), by the reflection of fields from conductive surfaces (standing waves), or by induced currents flowing in conductive objects exposed to ambient RF fields (re-radiation). RF hot spots are characterized by very rapid spatial variation of the fields and, typically, result in partial body exposures of individuals near the hot spots. Uniform exposure of the body is essentially impossible because of the high spatial gradient of the fields associated with RF hot spots.

Several conclusions relevant to the exposure limit compliance issue have been drawn from the results and experience of this investigation:

(*a*) In the RF hot-spot situation, involving re-radiating objects, the high, localized fields at the hot spot do not generally have the capacity to deliver whole-body SARs to exposed individuals in excess of exposure guidelines, where SARs are limited to 0.08 W/kg, regardless of the enhanced field magnitude. When the ambient RF field strengths are already at, or above, the exposure limits, the partial body exposure that accompanies proximity of the body to the object will generally increase the whole-body SAR only slightly.

(*b*) The high-intensity, electric and magnetic fields accompanying RF hot spots are not good indicators of whole-body or spatial peak SARs in the body, because of the high variability in coupling between the body of an exposed person and the hot-spot source.

(*c*) A measurement of the contact current that flows between the exposed person and a re-radiating object provides a meaningful alternative to field measurements and makes possible the evaluation of the peak SAR that may exist in a person touching the hot-spot source.

(*d*) For most practical exposure situations, when hand contact is made with a RF source, the greatest RF current will flow in the body, resulting in the worst-case situation for peak SAR. The contact case will result in significantly greater local SARs than for the non-contact condition and should be assumed to be the exposure of possible concern. This maximum SAR will be in the wrist, the anatomical structure with the smallest cross-sectional area through which the contact current can flow.

(*e*) Determining the wrist SAR for contact conditions requires a measurement of the contact current, knowledge of the conductivity of the tissues, and knowledge of the effective, conductive, cross-sectional area.

(*f*) To determine whether a particular RF source meets absorption criteria would be difficult and could be done only by a properly qualified laboratory or by an appropriate scientific body for a general class of equipment. In no case could a routine field survey determine conformance with the SAR criteria. The dosimetric procedures required for accurate SAR assessments remain complex and are relegated, for many cases, to the laboratory setting.

(*g*) Complex exposure environments, such as the interior of antenna towers, that present highly localized RF fields on climbing structures (e.g., ladders) are candidate locations where contact current measurements may prove effective in evaluating compliance with the exposure standards.

(*h*) Contact current measurements appear the only practical avenue of evaluating RF hot spots found in public environments, where ambient field levels are usually well within the standards, but local fields are apparently excessive.

(*i*) Maximum contact currents are associated with the points on a conducting object that generally exhibit the greatest surface electric field strengths. Apparently this is because such points have relatively low impedance and current is transferred when contacted by the relatively low impedance of the human body.

## 11.2 Administrative controls

Administrative controls that can be used to reduce or prevent exposure to RF fields are:

- access restriction, e.g., barrier fences, locked doors;
- occupancy restriction (only to authorized personnel);
- occupancy duration restriction (applicable only to workers);
- warning signs, and visible and audible alarms.

Protective measures should be applied also against ancillary hazards such as the ignition of flammable gases and detonators or blasting caps. Specific guidance on how to deal with these problems is given elsewhere (Hall & Burstow, 1980; ANSI, 1985).

## 11.3 Personal protection

Protective clothing, such as conductive suits, gloves, and safety shoes, can be used. However, very few are commercially available and they are useful for RF shielding only over a specific frequency range. The results of testing a few microwave suits have been published recently (Guy et al., 1987; Joyner et al., 1989). Such suits should not be used indiscriminantly. Their use should be confined to ensuring compliance with exposure standards, when engineering and administrative controls are insufficient to do so (Joyner et al., 1989). Safety shoes have been proposed to reduce high local SARs for people on the ground plane (Kanai et al., 1984). Safety glasses have also been proposed for RF protection, but there is no convincing evidence that any of them are effective. On the contrary, they may act as receiving antennas and locally enhance the field.

## 11.4 Medical surveillance

Medical surveillance of workers should only be instituted if, in the normal course of their work, they could be exposed to RF-field intensities that would significantly exceed the general population limits. Other than a pre-employment general medical examination to determine baseline health status, a medical surveillance programme would serve little purpose, unless workers could reasonably be exposed to RF levels that approach or exceed occupational limits.

Medical surveillance of RF workers involves:

(*a*) The assessment of the health status of the worker before commencing work (pre-employment assessment), during work, if overexposures occur, and on termination of work involving RF exposure.

(*b*) The detection and early treatment of signs of any adverse health effects that might be due to RF exposure.

(*c*) The maintenance of precise and adequate medical records for future epidemiological studies. The nature of the work and the physical parameters of RF exposure (field strengths, exposure durations, etc.) for each worker should be documented very carefully.

In many countries, the initial and periodic medical examinations of workers are a legal requirement; in others, industries and governmental agencies may require pre-employment and periodic examinations. Contraindications to employment involving RF exposure should be identified by national authorities.

*Over-exposures*

When RF exposure exceeding occupational limits occurs, depending on the circumstances, a medical examination may be required. It should be noted that no unique syndrome for RF exposure has been identified requiring highly specialized treatment. Treatment can be expected to be symptomatic. From very high local exposures to RF of frequencies in the GHz range, deep burns and local tissue necrosis may be observed with a long-term and severe evolution. Very strong fields in the kHz and low MHz range could result in symptoms due to involuntary muscle contractions or stimulation of nervous tissue.

When RF over-exposure exceeds occupational limits, the following is suggested (Hocking & Joyner 1988):

(*a*) The circumstances causing the over-exposure should be determined and corrected.

(*b*) An investigation should determine the extent of over-exposure of the worker(s).

(*c*) A medical examination should be conducted using data on the over-exposure to direct the type of clinical examination.

## 11.5 Interference with medical devices and safety equipment

The susceptibility of electronic devices, particularly emergency equipment, to interference from electromagnetic fields must be evaluated in hospitals, clinics, and industry. Certain devices are subject to interference at some frequencies at electric field strengths below those permitted in many standards (Maskell, 1985). Shielding of the devices or hospital rooms is a practical solution to the problem.

A separate concern relates to electromagnetic interference with implantable medical devices and, most prominently, cardiac pacemakers. Improvements in pacemaker design have largely eliminated their susceptibility, however, in some instances, interference may still occur (Irnich, 1984; Sager, 1987). Cardiac pacemaker wearers need to be informed by their physician about its susceptibility to electromagnetic interference. RF workers who have implanted medical devices should be evaluated prior to commencing (or resuming) work (Hocking et al., 1991).