ICNIRP STATEMENT RELATED TO THE USE OF SECURITY AND SIMILAR DEVICES UTILIZING ELECTROMAGNETIC FIELDS

The International Commission on Non-Ionizing Radiation Protection*

INTRODUCTION

OVER ONE million Electronic Article Surveillance (EAS) systems, developed to protect against theft, are installed world-wide. Even more Radiofrequency Identification (RFID) systems are in operation to provide identification of persons or objects, or to improve the controlled transportation and logistics of various items. Millions of metal detectors systems are used to locate a ferrous or conductive target.

All of these systems use electromagnetic fields to detect or communicate over a short distance (usually up to a few meters). For the general public, they involve brief exposure times of generally less than a few seconds. For occupational exposure, extended exposure times may occur.

The objective of this statement is to address the possible adverse effects from exposure to pulsed and continuous wave (cw) electromagnetic fields (EMFs) associated with the use of electronic security and similar devices. This document summarizes the results of the Concerted Action QLK4–1999-01214 "Development of advice to the EC on the risk to health of the general public from the use of security and similar devices employing pulsed and continuous electromagnetic fields" within the program Quality of Life (QoL), Key Action 4 "Environment and Health" of the Fifth Framework Programme of the European Commission (EC) (full report: ICNIRP 2002).

The statement includes a review of the characteristics of systems and devices and of the scientific evidence of possible harm to human health from EMF exposure relevant to fields at the operating frequencies of such devices, a review of the applicability and limitations of currently available exposure assessment techniques, and recommendations for future health risk assessment and research priorities.

The task was undertaken by experts drawn from the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and its scientific standing committees. An important aspect of the approach used was the liaison with and input from other experts including those participating in the World Health Organization (WHO) International EMF project, the United States Food and Drug Administration (FDA) and European expert groups.

The report for the EC was prepared by members of the Concerted Action "Pulsed Fields" during two meetings, held respectively in June 2001 (organized by the Istituto Superiore di Sanitá, Rome, Italy) and in November 2001 (organized by the Institute for Radiation Hygiene in Munich, Germany).

The work started with a review of the technology of security, radiofrequency identification, and metal detection systems and the field exposure characteristics of such equipment currently in use, the collection of available details of relevant emission characteristics, compilation of a summary of these data, and the provision of an overview of existing and possible future technology. For the collection of these data, a workshop was held in Helsinki in September 2000 (organized by the Finnish Institute of Occupational Health) with technical input from representatives of the manufacturers of such devices.

The second phase of the work started at the Finnish meeting comprising the international group of experts during which the scientific evidence on adverse effects on human health from EMFs was discussed. Mechanisms of interaction, cellular and animal studies, electrophysiological stimulation studies and effects on the central nervous system were reviewed. Another important issue was the review of data concerning possible interference of electromagnetic fields of such devices with implanted medical devices such as cardiac pacemakers, implanted defibrillators and nerve stimulators.

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To collect more information about the issue of medical device electromagnetic interference (EMI) from electronic security systems, another workshop was organized at the Institute for Radiation Hygiene of the German Federal Office for Radiation Protection in March 2001 in Munich. During this workshop, representatives of the manufacturers of security systems and medical devices discussed the issue with invited physicians with specialized knowledge in this area.

CHARACTERISTICS OF SYSTEMS AND DEVICES

Electronic Article Surveillance (EAS), Radiofrequency Identification (RFID), and metal detector systems operate over a wide range of frequencies using continuous wave or different pulse modalities. Emission frequencies for devices currently in use range from tens of hertz (Hz) to several gigahertz (GHz).

These systems are deployed to protect against theft, provide identification of persons or objects, improve the controlled transportation and logistics of various items, or improve security. Well over one million systems are installed world-wide.

All of these systems share several characteristics:

- They use electromagnetic fields to detect or communicate over a short distance (usually up to a few meters);
- They employ a defined detection zone through which the item or person being monitored passes;
- For the general public, they generally involve brief exposure times, typically up to a few seconds. Under certain circumstances longer lasting exposures up to a few minutes are possible; and
- For occupational exposures, extended exposure times up to a length of a working shift may occur.

The three types of systems differ in principle by the information content being transferred and the nature of the receivers on the "targets." EAS and metal detector systems respond only by indicating the presence of the target within the detection area. In contrast, RFID tags or transponders may be capable of transmitting more elaborate information such as identification codes, etc. The electromagnetic fields interact with special sensors (so called "tags") for EAS, integrated circuit "chips" in RFID tags or transponders, and conductive objects for metal detectors.

EAS systems

EAS systems protect merchandise and other assets from theft. They are basically composed of three components: (1) labels and hard tags—electronic sensors that are attached to merchandise; (2) deactivators and detachers—used at the point of sale to electronically deactivate labels and detach reusable hard tags as items are purchased; and (3) detectors that create a surveillance zone at exits or checkout aisles. In addition, systems that activate tags may sometimes be used, e.g., in the retail industry.

EAS systems operate from a simple principle regardless of the manufacturer or the specific type of technology used. A transmitter sends a signal at defined frequencies to a receiver. This creates a surveillance area, usually at a checkout aisle or an exit in the case of retail stores. Upon entering the area, a tag or label with special characteristics creates a disturbance, which is detected by the receiver. The exact means by which the tag or label disrupts the signal is a distinctive part of different EAS systems.

The physics of a particular EAS tag and resultant EAS technology determines which frequency range is used to create the surveillance area. EAS systems range from very low to very high frequencies (currently from 20 Hz to 2.45 GHz). Similarly, these different frequencies play a key role in establishing the features that affect operation and determine the exposure conditions of the customers and the employees at the site.

Although over the past four decades many technologies have been employed to meet the EAS market demands, the market currently comprises four main categories of technology (Table 1).

RFID systems

The objective of any RFID system is to carry data in suitable transponders, generally known as "tags," and to retrieve those data by machine-readable means at a

Table 1. Different EAS technologies.[a]

Category	Frequency range	Primary tag component	Units installed world-wide
Electromagnetic (EM)	20 Hz–18 kHz	Magnetic strip or wire	~300,000
Acoustomagnetic (AM)	58–60 kHz	Resonant magnetostrictive	~200,000
Radiofrequency (Swept RF)	1.8–10 MHz	Resonant LC circuit	~400,000
Microwave	902–928 and 2,400–2,500 MHz	Diode	~100,000

[a] Notes: Parts of the nomenclature are specific for this industry, e.g., the use of the terms "EM" and "AM."

suitable time and place to satisfy particular application needs. Data within a tag may provide identification for an item in manufacture, goods in transit, a location, a vehicle, an animal, or an individual. By including additional data, the system enables supporting applications through item specific information or instructions immediately available on reading the tag, for example, the destination and flight number for a suitcase entering the luggage sorting system, the set-up instructions for a flexible manufacturing cell, or the manifest to accompany a shipment of goods.

A system requires, in addition to tags, "readers" for interrogating the tags and some means of communicating the data to a host computer or information management system. A system also includes a facility for entering or programming data into the tags, if this is not undertaken at source by the manufacturer. Quite often an antenna is distinguished as if it were a separate part of an RFID system. While its importance justifies the attention, it is more appropriately viewed as a feature that is present in both readers and tags, essential for the communication between the two.

RFID systems may be roughly grouped into three categories:

- Portable data capture systems;
- Networked systems; and
- Positioning systems.

Portable data capture systems are characterized by the use of portable data terminals with integral RFID readers. The hand-held readers/portable data terminals capture data that are then either transmitted to a host information management system via a radiofrequency data communication (RFDC) link or held for delivery by line-linkage to the host on a batch processing basis.

Networked systems applications can generally be characterized by fixed position readers deployed within a given site and connected directly to a networked information management system. The transponders or tags are positioned on moving or moveable items or people.

Positioning systems use transponders to facilitate automated location and navigation support for guided vehicles. Readers are positioned on the vehicles and linked to an on-board computer and RFDC link to the host information management system. The transponders are embedded in the floor or ground of the operating environment and programmed with appropriate identification and location data. The reader antenna is usually located beneath the vehicle to allow closer proximity to the embedded transponders.

Communication of data between tags and a reader is by wireless transmission. Two methods distinguish and categorize RFID systems, one based upon close proximity electromagnetic or inductive coupling and one based upon propagating electromagnetic waves. Coupling is via "antenna" structures forming an integral feature in both tags and readers. While the term antenna is generally considered more appropriate for propagating elements, it is also loosely applied to inductive systems.

The range that can be achieved in an RFID system is essentially determined by:

- The power available at the reader/interrogator to communicate with the tag(s);
- The power available within the tag to respond; and
- The environmental conditions and structures.

Although the level of available power is the primary determinant of range, the manner and efficiency with which that power is deployed also influence the range. The field delivered from an antenna extends into the space surrounding it, and its strength diminishes with distance. The antenna design will determine the shape of the field or propagation wave delivered so that range will also be influenced by the angle subtended between the tag and antenna.

RFID tags are available in a wide variety of shapes, sizes, and protective housings. Animal tracking tags, inserted beneath the skin, can be as small as a pencil lead in diameter and one centimeter in length. Tags can be screw-shaped to identify trees or wooden items, or credit card-shaped for use in access applications. Thumb-sized anti-theft hard plastic tags can be attached to merchandise in stores.

As standards emerge, technology develops, and costs decline, considerable growth in terms of application numbers and new areas of application may be expected. The main current RFID applications are automotive anti-theft, livestock and pet tracking, access control, asset tracking, manufacturing automation, and automated payment. The emerging applications include libraries, airline bags, express parcels, product and document authentication, ski pass and leisure parks, transports, supply chain pallets and containers, and high value item tracking. Use of RFID for the identification of low value items, such as those in supermarkets, does not appear likely in the near future.

Metal detection systems

Metal detectors are devices that employ time-varying magnetic fields to sense the presence of a ferrous and/or conductive object within the field. This type of equipment is currently used by consumers for locating coins, relics, mineral deposits, etc.; in commercial applications for locating metal objects in foods, industrial waste, etc.; and in security applications for weapons detection and loss prevention. The general public is most likely to encounter metal detectors in the security environment and therefore the following information addresses primarily this application area.

Metal detectors for security applications are available in two distinct forms. Stationary archway type metal detectors are used to screen the entire body as the person walks through the device. Hand-held devices are used as a secondary detection means to pinpoint the location of a metal object on the body.

Archway type metal detectors employ low frequency electromagnetic sensing. Typically, each side panel of the archway contains one or more transmitting coils and/or one or more receiving coils. These are effectively air core coils whose electromagnetic field envelops the entire archway.

Hand-held metal detectors currently on the market use non-modulated sine wave technology.

Recent advances in metal detection technology have employed increasingly sophisticated electronics to provide reliable performance with improved sensitivity, discrimination and the ability to work in "electromagnetically noisy" environments.

There is also some research on the application of high frequencies such as millimeter waves to the metal detection and explosive detection arena. Low dose x-ray technology is currently on the market and is used on a very limited basis. It is anticipated that these systems will evolve and may displace current technologies for some, but not all, applications.

While individual systems generally use single frequencies or narrow bands of frequencies, future applications may also exploit combinations of different frequency bands used simultaneously (although not necessarily exactly time and phase coincident).

There is a large global market for such devices and, with regard to exposure of the general public, it is important to note that EAS systems are likely to become ubiquitous in retail stores. Together with low cost tagging of goods they will become standard pieces of equipment at stores' points of sale and checkouts. The applications of radiofrequency identification devices are also likely to increase and perhaps include libraries, airline baggage checking, parcels and products transport, and generally high value goods checking. The primary application for metal detecting devices is weapon discovery and metal object theft prevention.

EXPOSURE ASSESSMENT

There is a wide and complex range of exposure situations related to the use of security and identification devices. The complexity is manifested by the number of different spatial and temporal characteristics of emissions (e.g., range of frequencies and pulse modalities) and by differences in the physical design of equipment. There is a need to further collect reliable emission data for these systems in order to improve the exposure assessment.

EAS, RFID, and metal detection systems, except those emitting microwave radiation, employ inductive fields. Hence, there is negligible propagating field and exposures of people are generally limited to the near-field magnetic field. Microwave systems use predominantly a short range propagating microwave field, and the field-generation element is a helical coil antenna or similar field generator. The field power levels are low and, although they do propagate, they are constrained in area by the antenna directivity.

The ICNIRP reference levels (ICNIRP 1998) are derived from the basic restrictions using conservative considerations about the exposure situation. Both reference levels and basic restrictions are derived in a scientifically cautious manner and, therefore, include safety factors. In situations where simultaneous exposure to fields of different frequencies occurs, the possibility that these exposures will be additive must be considered. Calculations based on such additivity should be performed separately for each effect underlying the basic restrictions at those frequencies; thus, separate evaluations should be made for electrical stimulation and for thermal effects on the body. The ICNIRP guidelines specify separate summation regimens reflecting the different basic restrictions. All exposures between 0 Hz and 10 MHz should be added in a linear fashion as fractions of the relevant reference level or basic restriction on induced current density. All exposures between 400 kHz and 300 GHz should be summed on a field-strength-squared basis as fractions of the reference level, or in a linear fashion as fractions of the relevant basic restriction.

The majority of systems produce magnetic fields with waveforms that are either sinusoidal or amplitude-modulated sinusoids. Sometimes systems whose emissions are described as "pulsed" in fact produce pulse-modulated fields, where the signal is a sinusoid emitted in short bursts. Some metal detectors, however, do produce a series of monophasic or biphasic pulses. For pulsed fields, ICNIRP has produced specific advice related to the measurement and assessment of compliance with basic restrictions on exposure (ICNIRP 2003).

Exposures from EAS systems

Typical peak magnetic flux densities within magnetic type EAS gates show that the reference level for the general public is exceeded inside the gate for all of the measured systems and in most cases the occupational levels are also exceeded (ICNIRP 2002). As described in the ICNIRP guidelines, a field in excess of the reference levels may still conform with the guidelines provided it meets the basic restrictions. In these cases, this can be confirmed by numerical modeling; for radiofrequencies relevant averaging times may be applied.

Cashiers in shops and supermarkets may be continuously exposed to magnetic fields from an adjacent EAS gate and deactivator. The cashier desk is commonly located from 1 to 3 m from the gate, though EAS gates also are often quite distant from operators. The results of a Finnish (Eskelinen et al. 2001) study on occupational exposure of librarians and cashiers to pulsed magnetic fields from EAS devices indicated that the ICNIRP reference level was exceeded only inside the gates. The maximal peak magnetic flux density at the cashier's desk remained below 2 μT (occupational reference level 44 μT; general public reference level 8.7 μT). This study indicates that the exposure of cashiers from the magnetic type gates is well below the ICNIRP reference levels; however, more data are needed. Nevertheless, long term occupational exposure can easily be avoided by careful location, e.g., positioning the gate at a suitable distance from the cashier desk.

There are few data available to assess whether induced current densities meet the basic restrictions. Based on the work of Gandhi, it is indicated that, although the reference levels are exceeded in these cases, the basic restrictions on induced current density may be satisfied (Gandhi and Kang 2001). For example, for a magnetic type device calculated induced current densities will not exceed more than 64% of the basic restriction in the central nervous system, whereas the measured field values exceed the reference level by a factor of about 6. This can be partly explained by the non-uniformity of the field and by the body posture as regards the efficiency of its coupling to the field and also reflects the cautionary manner in which the reference levels have been developed.

Measurement data for radiofrequency EAS systems in the frequency range from 8.8 to 10.2 MHz show that the magnetic flux density remains generally below 0.2 μT at a distance of 20 cm or more from the coil (Harris et al. 2000). The ICNIRP occupational reference level (0.2 μT, 10–400 MHz) is not exceeded, and in most cases the exposure is also below the reference level for the general public (0.092 μT). Data on the electric field strength are not given.

Another component of EAS systems is for activation and deactivation of tags at the point of purchase. The majority of deactivators use either permanent magnets (DC field), or time-varying fields. The fields are usually higher in absolute amplitude than the main detection fields, though they are necessarily confined to a small region near the deactivator (and usually for a very short duration). The fields are spatially confined by design because otherwise they would deactivate concealed tags, so allowing the goods to be stolen. Generally the deactivators are mounted at reasonable distances from the general public (30 cm +). Occupational exposure might be closer but normally would be a similar distance (arms reach). Desk or countertop heights are usually in the range 70–90 cm.

As an example, exposure assessment of an 8 MHz RF desktop deactivator has been described (Chadwick 1999). The fields from this type of deactivator are very localized and are likely to give rise only to significant exposure of the hands of the operator. Nevertheless, it has been calculated that even if the deactivator were in close contact with the body or trunk of the operator, the ICNIRP basic restrictions would not be exceeded.

Exposures from RFID equipment

Exposure data are currently not available. In most cases, short range low power devices (100 mW, up to 2 W) are used for RF identification applications, e.g., controlling access of people. This results in a low near field exposure of short duration. For special purposes, e.g., for large animal tracking, large gates may be used. In this case, higher exposures may occur up to distances of a few meters. There is a need to check whether an electromagnetic interference of active medical devices worn by the employers can be avoided. Other systems—for example, luggage sorting systems—need sufficiently high electromagnetic fields for operating without obstruction. Technical data, like frequency, power, modulation, etc., are not yet standardized. Such systems are still under development, so that there are no data for an exposure assessment. Overall, there is a need to collect emission data required for an exposure assessment.

Exposures from metal detection equipment

There are two different energy schemes that are currently employed in archway type metal detectors. These schemes are single and multiple frequency sine wave and low frequency pulse systems. In both cases low frequencies are used to enable the necessary material analysis mechanisms to occur. A study of archway metal detectors (Health Canada 2001) found operating frequencies ranging from 630 Hz to 7,375 kHz with peak-to-peak field strengths of 10 to 45 μT and modulating frequencies from 89 to 909 Hz on some models. Recent magnetic field measurements around 10 walk-through metal detectors yielded magnetic flux densities up to 375

μT (frequencies between 0.1 kHz and 3.5 kHz, Boivin et al. 2003).

Hand-held metal detectors currently on the market use unmodulated sine wave technology. The Health Canada study found that hand-held metal detectors operate in the range of 13 kHz to 1.9 MHz with peak-to-peak field strengths of 0.3 to 10 μT at a distance of 2.5 cm from the probe surface.

In particular, exposures to radiofrequency magnetic fields are considered as if they were uniform far-field, plane-wave exposures. Because in practice exposures are generally spatially non-uniform (near-field exposure conditions), it may often be necessary to assess compliance with the basic restrictions directly using a combination of field measurements and calculations.

Measurement and computational dosimetric tools are currently available to carry out health related exposure assessments. However, there is a need to further develop such tools, particularly computational methods. While anatomically realistic computational phantoms for adult males have been used to provide exposure data over a wide range of frequencies and exposure situations, few such data are available for adult females or for children. Given the widespread use of security and identification devices in areas where the general public has access, exposure of women and children is most relevant. It is, therefore, important that computational tools specifically addressing differences in body size, anatomy, and age are further developed.

MECHANISMS

There are different thermal and non-thermal interaction mechanisms by which electromagnetic fields can interact with biological systems. At frequencies below about 100 kHz, electric fields and currents are induced in the body by time-varying external magnetic fields. According to Faraday's law, their intensity is proportional to dB(t)/dt and to the size of the target: they are thus greater at the periphery of the body and minimal at its center. Induced electric fields in the body may lead to a variation of membrane potentials at the cellular level. Electric excitation of the membrane might be the result of such membrane potential changes. ICNIRP's basic restrictions are provided on current density to prevent effects on nervous system functions. Between 100 kHz and about 10 MHz transition from induced currents to RFR absorption occurs and heating becomes the dominant mechanism.

Many other mechanisms of EMF interaction with biological systems have been proposed, most directed at ELF or RF effects that can not be readily explained in terms of classical mechanisms. These include non linear effects and solitons, ion resonance, stochastic resonance, biogenic magnetite, and radical pair mechanisms.

Two types of phenomena (heating and membrane stimulation and related effects on the central nervous system) underlie most possible hazards from acute exposure to electromagnetic fields. Because of the weak coupling between external fields and the body, these generally require very high field strengths or currents to be passed directly into the body.

Comparing the thresholds of these effects is complicated by the fact that they vary in different ways with frequency or pulse width. Membrane excitation requires high membrane potentials and is a fast process (milliseconds). Coherent activity of populations of neurons can be affected by fields of a few tens of Hz. Thermal damage is a much slower process, both because of the thermal inertia of the process and because of the kinetics of thermal damage itself. In general, the hazards from low-frequency fields are associated with membrane effects and those from high frequency fields are associated with heating (ICNIRP 1999).

Between 100 kHz and about 10 MHz, a transition in the critical action occurs from membrane effects to heating effects from high frequency electromagnetic energy absorption. Many other mechanisms of EMF interaction with biological systems have been proposed, most directed at observed low or high frequency effects that cannot be readily explained in terms of classical mechanisms. However, up to now no such mechanism with relevance for security systems has been established. ICNIRP's basic restrictions accommodate all known biophysical mechanisms in the frequency range of EAS/RFID systems.

High frequency fields of EAS/RFID systems will produce no heating and no thermoregulation stress. There are also no relevant contact currents. Although it is known that pulsed EMF's produce more excitations and less heat, there is little evidence that pulsed fields are more efficient than continuous electromagnetic fields in eliciting effects in the EAS frequency range. Specific effects of high peak powers are not relevant to EAS.

EPIDEMIOLOGICAL STUDIES

No epidemiological studies appear to have been carried out specifically related to the exposure of people to the fields from electric article surveillance, radiofrequency identification, or metal detection devices. However, many epidemiological studies on exposure to power frequency in both occupational and general public environments have been published. Epidemiological studies on exposure to radiofrequency fields are more restricted to occupational environment. These studies have been extensively reviewed by several national and international panels of experts.

Low frequency EMF

ICNIRP Standing Committee I on Epidemiology carried out a review of the epidemiological literature of EMF and Health (ICNIRP 2001). Addressing a number of general points about epidemiology of EMF and cancer, they noted: "The epidemiological studies conducted on possible health effects of EMF have improved over time in sophistication of exposure assessment and in methodology. Several of the recent studies on childhood leukemia and occupational exposures in relation to adult cancer are close to the limit of what can realistically be achieved by epidemiology, in terms of size of study and methodological rigor, using presently available measurement methods. In the absence of evidence from cellular or animal studies, and given the methodological uncertainties and in many cases inconsistencies of the existing epidemiological literature, there is no chronic disease outcome for which an etiological relation to EMF exposure can be regarded as established." The International Agency for Research on Cancer (IARC) has concluded that magnetic fields are "possibly carcinogenic" to humans. This is based on pooled data from studies of children exposed to consistently high level residential magnetic fields showing an increased risk of childhood acute lymphoblastic leukemia.

The few studies examining brain cancer and residential EMF exposure in adults have found no consistent evidence of an association.

Most studies exploring the link between EMF and adult cancers have been based on occupational groups with possibly high exposures. Among them, a number of studies have reported an increased risk of leukemia for electrical workers. Some occupational studies have also reported a higher risk of brain cancer for workers in electrical occupations. Neither finding, however, is consistently seen. The majority of these studies suffer from difficulties in assessing exposure to electric and magnetic fields.

The available epidemiological studies investigating effects of power frequency EMFs on human reproduction all have limitations that prevent drawing clear-cut conclusions. With regard to the totality of scientific knowledge, there is no convincing evidence today that occupational or daily life EMF exposure of pregnant women or potential fathers do any harm to the human reproductive process. Similarly, there is no convincing evidence for an association with neurologic disease, birth defects, heart disease, or suicide.

Radiofrequency EMF

Human data on the possible adverse effects of radiofrequency EMF come largely from studies of mobile phones use and brain tumors, acoustic neuroma and salivary gland. The studies to date, conducted largely using data on exposure to analogue phones, have been largely negative. Further investigation of cancer and digital phones is underway.

HUMAN LABORATORY STUDIES

In the low frequency region (up to 300 Hz), stimulation effects produced by surface electric charges due to low frequency electric fields can be perceived by people. Electrically excitable cells in the retina can be affected by current densities of 10 mA m^{-2} or more, induced by low frequency magnetic fields or directly applied electric current, but with no known adverse effect on health. International guidance on limiting human exposure (ICNIRP 1998) seeks to limit the annoying effects of surface charges and avoid adverse effects of induced current on the neural circuitry of the retina and other parts of the central nervous system.

In the frequency region (300 Hz–10 MHz), sometimes referred to as the intermediate frequency region, the threshold for effects of induced current on electrically excitable cells in the central nervous system will only predominate over possible heating effects at low frequencies (up to about 100 kHz). At some point, as frequencies increase from about 100 kHz to about 10 MHz, heating effects become dominant, depending on other exposure conditions (e.g., pulse modality). International guidance (ICNIRP 1998) in this region is based on the extrapolation of neural tissue thresholds identified in the low frequency region according to the known frequency dependence of nervous tissue responses and the heating effects identified at frequencies greater than 10 MHz.

In the high frequency region (10 MHz–300 GHz), heating effects are well established in volunteer and animal experiments. International guidelines on limiting exposure to electromagnetic fields (ICNIRP 1998) seek to prevent adverse effects of excessive whole-body and localized heating. In addition, guidance is given concerning the avoidance of the annoying auditory perception of pulsed EMF. There are no established adverse health effects below these levels of exposure, although the possibility has been raised in connection with RF fields emitted by mobile phone that there may be subtle transitory effects on nervous system function and behavior (e.g., effects on cognitive performance and EEG).

ANIMAL AND CELLULAR STUDIES

A large number of animal studies have been carried out at low and high frequencies. Many have focussed on effects on the nervous system and behavior or on possible effects on carcinogenic processes. However, most indices of general physiological status appear relatively unaffected by exposure, and there is at present no convincing evidence of adverse health effects for humans or animals. In contrast, at intermediate frequencies, few studies have been carried out and the scientific literature is scant.

With regard to cellular studies, the possibility that there are subtle biological effects due to low frequency exposure cannot be ruled out. However, the results that are claimed to demonstrate a positive effect of exposure tend to show only small changes whose biological and adverse health consequences are not clear.

In the intermediate frequency region, few cellular studies have been carried out; the evidence to date concerning signal transduction, protein expression, and cell proliferation is largely contradictory.

High frequency radiation can affect cellular processes when sufficiently intense to induce heating. Generally, however, exposures from security and similar devices are at levels many times below those that would induce a physiologically relevant heating.

Generally, below these levels of exposure, no consistent effects have been found in either animal or volunteer studies. In particular, there is no consistent evidence of any effect on reproduction and development, on hematology or the immune system, or on carcinogenesis.

ELECTROMAGNETIC INTERFERENCE WITH MEDICAL DEVICES

Electromagnetic interference between the emissions from security systems and medical devices that results in clinically significant effects[†] happens relatively infrequently and thus does not appear to be a major public health problem. However, there are several dozen incident reports suggesting that certain types of electrically powered active medical devices, worn by people who are ambulatory and may pass through security systems, can have their medical function disrupted by the emissions from the security systems. Examples include implanted defibrillation devices, cardiac pacemakers, neurostimulators, and infusion pumps. In addition, there are several hundred records of interference of medical devices with security systems, including both clinical data and in-vitro laboratory studies designed to deliberately provoke such interactions. The reported cases of electromagnetic interference with certain critical medical devices remain a concern.

[†] Serious disturbances including endangering of life.

RECOMMENDATIONS

It is recommended that the following actions be taken to improve the health risk assessment of the exposure from EAS and RFID systems.

Characteristics of systems and devices

- The identification of possible risks to health from the use of security devices depends on the availability of information on their operating characteristics, specifically their operating frequencies, intensity of the produced electromagnetic field, details of their physical design, and the pulse modalities used.
- Information relevant to a health risk assessment on a particular system should be made available by the manufacturer to the purchaser.

Exposure assessment

- Support should be provided for the further development and dosimetric application of anatomically realistic computational phantoms based on medical imaging data—such phantoms should include adult male and female phantoms and child phantoms at different stages of growth.
- Support should be provided for experimental studies measuring the dielectric properties of relevant body tissues. Such studies should address all frequencies of relevance to the practical exposure of people and the variations of dielectric properties as a function of age.
- There is a need to continue to measure levels of exposure to people passing security systems and at work places near security systems. Where measurements and/or calculations are made to assess the exposure of the general public, they should include assessments of the exposure of children.
- There is a need to collect exposure data about RFID systems. When such technical information becomes available during the development of a new product or application, a health risk assessment should be undertaken to identify likely problems in complying with exposure guidelines. Awareness of the magnitude of the potential exposure of people as a result of the envisaged use of a system should be an integral part of the development process.
- There is a need to collect data to identify high-exposure groups, so that future human health studies would be more practicable if needed in the future. Where possible, efforts should be made to differentiate between exposure to low-frequency and to radiofrequency devices.

Electromagnetic interference with medical devices

- It is recommended that the following actions are taken to address the issue of medical device electromagnetic interference (EMI) by security systems.

- There is a need to minimize the risks of EMI caused by emissions due to security systems. In this respect, it is recommended that the development of security systems should address as far as is practical the minimization of exposures as a primary design criterion.
- There is a need for more knowledge about how such devices interact with the emissions and how to design and test both medical devices and emitting equipment to reduce their risks of EMI. There is a need for collaboration between the medical device and security system industries, with physician input, so that both industries can work to minimize the risks of EMI caused by emissions from security systems.
- Medical device manufacturers should provide physicians and device users with information to make them aware of the possibility of EMI problems. This information should enable physicians to advise their patients about relevant EMI sources and means to minimize their risk. The security industry should address these risks in their product information and device labeling (such as recommended in the document "FDA Guidance on Labeling for Electronic Anti-theft Systems," FDA 2000).
- More data are needed on the interference of EAS, RFID, or metal detector systems with all kinds of active implantable medical devices. The data must be publicly available so that the device manufacturers, physicians, and patients can make informed choices.
- Further studies should be carried out on functional and technology imposed limitations of various medical devices, the characterization and influences of emitted waveform types and the refinement of medical device electromagnetic field interaction models for security systems exposures. Electromagnetic compatibility between new developed devices (i.e., neurostimulators) and security systems should be tested.
- The ultimate goal should be for complete compatibility between the security systems and medical devices that may pass through the systems. Generally, a standard, which is set as safe for the general public, should provide an acceptable level of protection for all members of the general public. The risk for the public, including medical device users, resulting from EMI from the security systems should be minimized. This task addresses standardization bodies, manufacturers of emitting devices, and manufacturers of active implantable medical devices. It will be necessary for product standards for emitting systems and for active implantable medical devices to both rely on the same limiting values concerning EMI problems. As long as older devices are still in use, means are needed to manage the remaining incompatibilities between existing emitting systems and existing active implantable medical devices. This task addresses authorities, system users, physicians and patients.

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