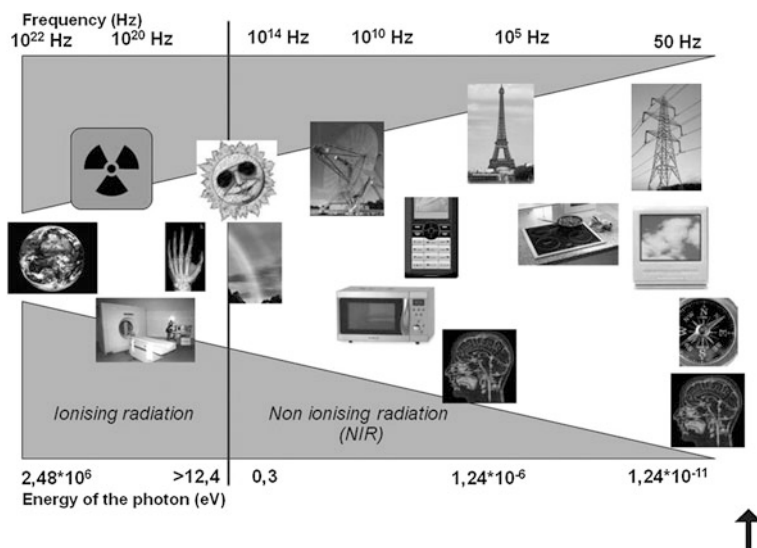


Chapter 2

MRI and Static Electric and Magnetic Fields

Anne Perrin



2.1 Introduction

Static electric and magnetic fields are permanently present in the environment. Whereas the static electric field is associated with the presence of fixed electrical charges, the magnetic field is due to the physical movement of electrical charges.

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Unlike the other categories of fields covered in this work, static fields do not vary over time.

The nuclear magnetic resonance imaging (MRI) technique is the most widespread source of intense static magnetic field, with several thousands of devices used throughout the world, and will therefore be explored in some depth in this chapter. Nevertheless, the principle of this technology is based on the use of a static magnetic field but also gradients of magnetic fields (spatial and temporal) and a radiofrequency* radiation (RF). The latter is only present during the image acquisition phases, whereas the high intensity static field, obtained with a superconducting magnet, is emitted permanently. Safety instructions therefore need to take this triple exposure into account.

2.2 Physical Reminders

Any immobile electrically charged body creates an electrostatic field. A direct current in a circuit creates a static magnetic field.

The electric field is expressed in volts per metre (V/m) and is easily attenuated by appropriate shielding.

The magnetic field (H) linked to the displacement of electrical charges is proportional to the intensity of the current and is measured in amperes per metre (A/m). In fact, it is the magnetic induction¹ (B), expressed in tesla (T) that is usually given. Through misuse of language, the magnetic induction or magnetic flux density B is often called “magnetic field”.

The quantities and units employed to characterise static fields are the same as those described for the components of variable fields of 50/60 Hz.

Therefore, it is not a question of electromagnetic field or wave in this chapter. From the point of view of interactions and effects produced, the static electric field should be considered separately from the static magnetic field.

2.3 Natural and Artificial Sources

Unlike variable electric and magnetic fields mainly derived from industrial activities, static fields, although they also have industrial origins, exist in the natural state in the atmosphere.

¹ According to the relation: $B = \mu H$, where μ corresponds to the absolute permeability of the material or medium, $\mu = \mu_0 \mu_r$ where $\mu_r = 1$ in vacuum, it is the relative permeability (compared to μ_0) and $\mu_0 = 4\pi \times 10^{-7}$ USI.

2.3.1 Natural Sources

2.3.1.1 Static Electric Field

The static electric field at the surface of the Earth is around 100–150 V/m in good weather. In stormy weather, its average value is 10–15 kV/m.

2.3.1.2 Static Magnetic Field

Due to the fact that the Earth behaves like a magnet, the terrestrial magnetic field exhibits significant local variations. Its value is not negligible. On average, it varies between 30 and 70 μT and is around 50 μT in France. This magnetic field, linked to the organisation of the magma at the centre of the Earth, is not aligned with the Earth's rotational axis. The angle created in this way is known as the “magnetic declination”, which varies over time. The vertical component of the magnetic field is at a maximum at the poles with a value of around 65–70 μT and zero at the equator, whereas its horizontal component is at a maximum at the equator, around 30 μT , and zero at the poles. The magnetic field may be modified near to metal structures.

It is this geomagnetic field that directs the needle of a compass and also plays a decisive role in the orientation and the migration of certain animal species thanks to specific biological mechanisms enabling sensitivity to the magnetic field or magnetoreception*.

2.3.2 Artificial Sources

2.3.2.1 Static Electric Field

A potential difference* that creates a static electric field mainly appears in two situations: around equipment placed at a high potential or by rubbing electrically insulated objects. Rubbing can lead to a separation of positive and negative charges. It happens that, in dry atmospheres, a person receives a charge by walking on a floor covered with an insulating material (carpet or plastic material). When the person comes into contact with a non charged object, the local static electric field at the level of the contact is equal to the potential difference divided by the distance. If this field exceeds the breakdown field in air (around 30 kV/cm), the air becomes a conductor and the person discharges onto the object: this is what is known as an “electrostatic discharge”, the effects of which are felt to a greater or lesser degree, depending on the individual.

In our environment, the only source that creates a static electric field of intensity comparable to that of the Earth's field and non localised exposure is the transmission

of electrical energy under direct current voltage. However, this mode of transmitting electricity is rarely used today. Furthermore, direct current was used at the start of the electrification of the railways. In France, certain rail networks (mainly in the south-east and south-west) are supplied from 1,500 V direct current catenaries. Screens equipped with cathode ray tubes also represent artificial sources, for which an electric field from 10 to 20 kV/m can be measured in their vicinity.

2.3.2.2 Static Magnetic Field

The transmission of electrical energy under a very high direct current voltage creates a static magnetic field of the order of 20 μT .

Rail transport using traction under direct current voltage also creates a magnetic field of around 50 mT in areas generally inaccessible to both the public and rail staff. Rail transport using magnetic levitation, such as the MagLev² (for *magnetic levitation*), can create static magnetic fields of the order of 10–100 mT near to the motors. On the other hand, the field actually recorded inside these types of train is well below 0.1 mT.

Numerous objects commonly encountered in our environment are equipped with a permanent magnet (magnets, doors closing mechanisms, paper clip holders, etc.), which locally generate static fields of several milliteslas (mT).

For the public, the highest exposure occurs during medical diagnostic examinations using MRI (detailed below), where the intensity of the field may be more than 50,000 times greater than the Earth's magnetic field.

Concerning occupational exposure, certain industrial applications use continuous currents that lead to significant exposure to magnetostatic fields, of the order of several mT to 50 mT. This is the case in the electrochemical industry (production of aluminium or chlorine for example) or the manufacture of magnetic materials using electrolysis techniques. The use of gas welding (arc welding) involves a field of around 5 mT at 1 cm from the welding cables, as it does near to superconductor generators, including nuclear magnetic resonance equipment, near to particle accelerators and also in isotope separation units.

2.3.3 MRI Technology

Nuclear magnetic resonance (NMR) is used to selectively distinguish signals from certain atoms due to the magnetic behaviour of their nuclei. To achieve this, they are placed in a very intense magnetic field (B_0) and subjected to an electromagnetic

² A magnetic levitation train was brought into service in Shanghai in 2004 and another is planned in Japan around 2025, but the costs and constraints associated with this mode of transport mean its use is quite limited.

wave, the frequency of which is specific to the atom studied (frequency known as the “Larmor frequency”). Once the electromagnetic perturbation stops, the atom emits in return an electromagnetic wave.

Depending on the analysis of these signals and the atomic nucleus in question, the technique gives rise to resonance spectra, which is known as nuclear magnetic resonance spectroscopy (MRS), or instead images, known as magnetic resonance imaging (MRI), which is the most widely used application and first appeared in the 1980s. The device is sometimes called an “NMR scanner” but, unlike real scanners, it does not use or emit X rays. This technique enables two (2D) or three dimensional (3D) images to be obtained of parts of the body, particularly images of the brain with high spatial ($1\text{--}3\text{ mm}^3$) and temporal ($1\text{--}2\text{ s}$) resolution. The most widely used magnets today in medical imaging centres are 1.5 T, sometimes 3 T, in which patients are exposed for a limited time ($<1\text{ h}$). This increase in the field value goes hand in hand with improvements in image resolution and the possibility of observing smaller and smaller volumes. The fields used for research are higher and can now exceed 10 T for imaging³ and even 20 T for spectroscopy. Outside of the magnet, the field is less strong. It ensures from this that operators and medical personnel receive an exposure that can locally exceed 1.5 T near to the magnet while dealing with patients or during an intervention, and they can be exposed to static fields of the order of 0.2–0.5 T at the control console over long periods.

To understand the origin of an NMR signal, it should be recalled that an atom is composed of a nucleus around which gravitate electrons. The nucleus is constituted of nucleons (neutrons and positively charged protons). The nucleus of hydrogen contains a single proton, provided with a movement around an axis of rotation, and one of its characteristics is to have a magnetic spin moment*. This may be represented schematically as a small magnetised bar that can take up any orientation outside of a magnetic field. Not all nuclei can be observed and only those which have spin can be oriented within the magnetic field.

Suitable nuclei are certain isotopes such as carbon 13, phosphorous 31, nitrogen 15, oxygen 17 and fluorine 19, which are the most widely studied in NMR. MRI uses the resonance of hydrogen, which is present in large quantities in the body, particularly in the water molecule (H_2O), the major constituent of the human body ($\approx 60\%$), which explains why the technique mainly concerns soft tissues.

In concrete terms and very schematically, the NMR technique is based on the use of a very intense permanent static field (B_0), generated by superconducting coils cooled by liquid helium inside a first sealed enclosure, itself enveloped by liquid nitrogen.⁴ To obtain a signal, the nuclear magnetisations orientated by the

³ For example, a high field MRI is currently being installed at the Neurospin brain research centre (CEA Saclay). This system generates 11.7 T, i.e. 234,000 times the Earth’s field. With the field increase, many technical difficulties can be overcome. Apart from an additional lowering of the temperature of the superconductor (from -269 to $-271\text{ }^\circ\text{C}$), it is also necessary to oppose the tendency of the instrument to collapse on itself under the effect of its own magnetic field and to ensure that the noise generated is supportable for the ears of the patients.

⁴ The whole assembly constitutes the tunnel.

Table 2.1 Spectrum of frequencies used in MRI

Static magnetic field	Magnetic field gradients	Radiofrequency electromagnetic field
0 Hz	100–1,000 Hz	10–400 MHz

static magnetic field are subject to a RF electromagnetic field to orient them differently for a short time (pulses). The resonance frequency enabling this effect is specific to the nucleus considered. As soon as this RF exposure is stopped, the return of the spins to their state of equilibrium in the static field produces an induced current that is captured in turn by the antennas of the acquisition chain, and then processed. This resonance signal also depends on the environment of the nucleus within a molecule and, from the quantitative point of view, its intensity is proportional to the number of nuclei present.

In order to obtain an MRI image, gradient coils produce magnetic fields that are added together and are entrenched at B_0 . They are responsible for a rapid gradual variation of the magnetic field in space and enable the spatial coding of the image. Two coils are needed to produce a magnetic field gradient. Thus, the device has three pairs of coils, one for each direction of space. The most recent are capable of varying at a speed of 200 T/m.s, making it possible to go from zero to the maximum in 200 μ s. Each electric pulse in the coils leads to a vibration that is behind the characteristic operating noise of the device. The exposure to the magnetic field gradient is specific to the MRI technique, it only occurs during image acquisition.

It is during this phase that exposure to pulsed RF occurs at a frequency between 10 and 400 MHz, depending on the case (see [Chap. 6](#)). This can lead to a rise in temperature (“microwave” effect) that has to be limited to 1 °C in localised regions of the body or in the whole body. In its findings on examinations by magnetic resonance published in 2004, ICNIRP states that, in the case of pregnant women, children or persons with cardiovascular problems, in whom thermoregulation mechanisms are less efficient, it is recommended to take care not to exceed a temperature increase of 0.5 °C.

The spectrum of frequencies used in MRI is summarised in [Table 2.1](#).

A variant of the technique, functional MRI (fMRI) uses the paramagnetic* characteristics of deoxyhaemoglobin* to locate areas of activity in the brain. In fact, neuronal metabolism is dependent on oxygen blood input. Neuronal activity causes an increase in oxygen consumption and an even more important increase in local blood flow (neurovascular coupling). This neuronal activation then results in a relative increase in oxyhaemoglobin compared to deoxyhaemoglobin in the activated areas. This relative reduction in the concentration of deoxyhaemoglobin, used as endogenous contrast agent, leads to a slight variation in the signal, detectable with MRI. It is the principle behind BOLD (blood oxygenation level dependent) contrast. In this way, it is possible to superpose a mapping of the active areas of the brain in different situations over the MRI image.

Interventional MRI is now also expanding, completing the panel of neuro-navigation techniques, during which interventions are carried out in a mainly non-invasive manner, with monitoring in real time. New forms of exposure of personnel working near to the devices are also appearing with this technique.

Furthermore, it is possible to obtain images of the cardio-vascular system. This is nuclear magnetic resonance angiography* (MRA), also known as MRI angiography.

Other applications of MRI exist in different fields, such as diffusion MRI (which enables fibres to be marked out), fatty tissue MRI (with an image of water and an image of fat), elasticity MRI (MRI elastography), etc.

2.4 Measures and Dosimetry

To analyse biological effects through *in vitro** or *in vivo** studies or on humans, it is necessary to know what are the exposure parameters that can influence and define the values as accurately as possible. In addition to direct measurements of the field with appropriate probes, numerical simulations make it possible to characterise electrostatic and magnetostatic fields using models. However, it is not always easy to know the field level, and this can lead to bias in the results of studies. Currently, research programmes in dosimetry are still in progress in this domain.

2.5 Interactions with the Living

2.5.1 *Interactions of Static Electric Fields with the Living*

The threshold of perception of the electric field in rodents seems to lie around 20 kV/m. Certain species of fish are markedly more sensitive; the weever fish uses a very weak electric field of the order of 500 nV/m to orient itself. Sharks have a special organ, the Lorenzini ampoule, which allows them to detect not just the fields emitted by other fish but also the Earth's field.

The behaviour of rodents, under a field going up to 12 kV/m, does not show any signs of distress. The variations observed during previous studies, which showed perturbations of the electroencephalogram* in rats, seems to be the result of the noise produced by the field generator. No modification of the intracerebral concentration of various neurotransmitters has been found by exposing, for example, male rats to a field of 3 kV/m.

No variation in haematological and biochemical parameters has been observed either in mice after exposure to a field of 340 kV/m for 32 weeks or in rats after exposure to fields varying between 2.8 and 19.7 kV/m.

Finally, as regards reproduction and development, exposing gestating mice, then their offspring, to a field of 340 kV/m, did not lead to any differences in the offspring compared to the control groups.

2.5.2 Interactions of Static Magnetic Fields with Living

2.5.2.1 Mechanisms Brought into Play

Three types of interactions of static magnetic fields with living material have been demonstrated: magnetic induction, magneto-mechanical interactions and electronic interactions.

Generally speaking, the possibilities of interactions with the organism increase with the intensity of the field.

Magnetic induction itself derives from two types of phenomena:

- *electrodynamic interactions* (or magnetohydrodynamic interactions) with moving charged particles, leading to an induced current and electric field. In fact, just as the magnetic field results from the movement of electrical charges (electrical current), the magnetic field exercises a physical force on moving electrical charges (Laplace-Lorentz force). This interaction entails a change of direction of the charges without change in velocity, which can nonetheless result, in humans and in animals, in a reduction in blood flow. Up to 8 T, the effects do not appear to be capable of affecting the working of the heart. Above 8 T, no experimental studies* have been published. According to theoretical calculations, this diminution could be 10 % in the aorta in the presence of a 10 T field.
- *induced electric fields and currents* created by magnetic fields varying over time, such as those that may be encountered in MRI field gradients or by the movement of matter in a static field. In fact, the amplitude of the electrical fields and induced currents increases with that of the gradient and with the rate of movement. Calculations suggest that they can become significant for normal movements of an individual in a static field of the order of 2–3 T. They can lead to dizziness, nausea and magnetophosphenes* reported by patients or volunteers moving about in such fields. Surface electric fields from 0.015 to 0.3 V/m have been able to be measured in the upper part of the body for a subject walking and turning beside a 3 T imager, whereas within a 4 T magnet the authors have estimated that a maximum electric field of 2 V/m could be induced.

Magnetomechanical effects are of two types:

- *magneto-orientation* concerns paramagnetic molecules that are oriented in the static field. The forces involved are considered as too weak to affect living matter, which exhibits a very weak magnetic susceptibility. However, this effect

is involved in magnetoreception in certain species of birds and fish. Experimentally, a reorientation of structures, which takes place during cell division (mitotic spindle*), has been observed in frog embryos subjected to a very intense static magnetic field (>17 T).

- *magnetomechanical translation* occurs in the presence of a field gradient for paramagnetic or diamagnetic* materials for which the direction of the force is respectively identical or opposite to that of the gradient. This effect, particularly important in the case of ferromagnetic materials, which have a strong magnetic susceptibility, is responsible for their violent acceleration. The force is proportional to the product of the magnetic flux density (B , in teslas) multiplied by its gradient (dB/dx). In 1994, authors showed an effect on the distribution of a volume of water placed in an 8 T magnet with a gradient of 50 T/m. In 2000, a reduction in blood flow was observed in rats fully exposed to 8 T. In 2005, other measurements carried out on water attach importance to a pressure exerted from the interior to the exterior of a 10 T magnet, nonetheless insufficient to affect human blood circulation according to the authors.

Interaction of Electronic Spin

The effects on the electronic spin states of reactional intermediates can affect the rate of recombination of pairs of free radicals whose electrons are transiently not matched during certain metabolic reactions. This mechanism seems to be brought into play in the navigation systems of certain birds.

For MRI, in addition to effects linked to static fields, known wave-matter interactions in the range of RF lead to a warming up of tissues following the absorption of energy by the material. This effect occurs when the body's thermoregulation system is no longer able to dissipate heat through blood circulation and transpiration, which implies a limitation of the power emitted.

2.5.2.2 Biological Effects

In vitro studies have been conducted on animal cells and on bacteria*, or on elementary systems (membranes, isolated enzymes, etc.) to examine the influence of exposure on major cell functions, gene expression* and the integrity of genetic material (DNA*). For a range of flux densities extending up to 8 T, positive or negative results have been obtained, but without much coherence when any effects are observed, and not necessarily correlated with the intensity of the field. They are rarely reproduced and no effect has been clearly established. The most consistent result could be the effect observed in 2002 on the mitotic spindle cited previously, which had already been described in 1998 by another team. The results do not indicate either any mutagenic* effect, which could be the consequence of a perturbation in the flow of free radicals. The few studies relating to the effects on

DNA (genotoxic) do not shown any effect up to 9 T, except one study where the repair system appeared to be deficient. Above 1 T, an effect on the orientation of cells is systematically observed, the significance of such an effect in vivo not being established.

In Vivo Studies on Animals

Numerous studies have been conducted on animals. In rats, experiments have shown an aversion above a flux density of around 4 T, which stems from an interaction with the vestibular device*. There is no proof of an effect on behaviour or memory at 2 T, nor any effect on the electrical excitation of nerve tissues.

On the other hand, the induction of Hall effect currents, due to blood circulation in the vascular system and around the heart, has been demonstrated for exposures between 0.1 and 2 T lasting from several hours to several days, depending on the studies. These result in a modification of the electrocardiogram* (ECG). Similar results have been obtained for different animal models and in humans, without the blood flow, blood pressure or rate of heart beat being altered. Experiments conducted on volunteers have not highlighted any consequences on health. Pigs subjected for several hours to a flux density of 8 T did not undergo any alterations to their cardiac functions. Other studies have shown effects on different cardiovascular parameters in rodents (blood pressure, peripheral micro circulation, etc.). Without independent replication of these studies, it is not possible to draw conclusions because other factors, such as the anaesthesia, could also have an influence on these parameters.

Studies on reproduction or foetal development have not shown any effects of static fields up to 6.3 T, under the conditions tested.

Experimental studies were carried out on genotoxic or carcinogenic effects, direct or through tumoral promotion (associated with other carcinogenic factors), on the hormonal system and on hematopoiesis*. They do not provide proof of any potentially harmful effect on health.

As regards the mechanisms of magnetoreception in animals, two molecular types sensitive to magnetic fields are involved: magnetite* and radical reactions involving cryptochromes*. Studies have shown that a combined action of the Earth's magnetic field and light, at specific wavelengths (certain colours), is vital for the choice of direction to take. In humans, although molecules of magnetite and cryptochromes have been detected in some tissues, it has not been possible to demonstrate any magnetoreception ability.

Biological Effects in Humans (MRI)

Such effects mainly involve exposure to NMR and MRI equipment. Detailed monitoring of physiological parameters* has been carried out (temperature, respiration, oxygenation, heart rate, etc.) in the presence of a magnetic field up to 9.4 T.

The aforementioned induced current effects no longer enabled the ECG to be interpreted above 8 T but the heart rate was not affected, whereas the systolic pressure (the upper pressure figure) increased by 4 % at the most. This was the only physiological effect observed. This is logically explained by a phenomenon of resistance to the aforementioned magnetohydrodynamic effects. Nevertheless, other authors have failed to observe this effect at 9.4 T under MRI acquisition conditions (with field and RF gradient).

Numerous neurological parameters have been tested up to 8 T. No effects have been observed, particularly with regard to short term memory, speech or audio-motor reaction time. On the other hand, in the vicinity of a magnet (0.5, 1.6 and 7 T) negative effects on eye-hand coordination, the perception of contrast and visual tracking have been observed following variation of the field over time (for example from 0.3 T to 1.6 T/s) during movements of the head.

During exposure of short duration (acute), induced currents cause perturbations of the electroretinogram* observed from 1.5 T. Magnetophosphenes can appear from 2 to 3 T as well as general manifestations such as a metallic taste in the mouth and a sensation of dizziness or nausea. These symptoms disappear when the exposure is stopped. Their seriousness can be reduced by reducing the speed of the movements; they can be intense if the subject is in the cavity of the magnet. Nevertheless, they are not systematic and could reveal differences in magnetic susceptibility in keeping with different characteristics from the vestibular organ* depending on the individuals. There are no repercussions on cognitive performance.

Epidemiological Studies

These concern long exposure times in occupational situations. Several studies have been conducted in the aluminium and chlorine industries without providing any proof of any modification in the incidence of cancers due to the magnetic field (at several tens of mT). It should be noted that the exposure factors of subjects are multiple in this type of activity, particularly on account of the use of chemicals.

Other health effects have been studied, particularly a study in 1993 which focused on the effects of a field of around 1 T on fertility and pregnancy in women working with MRI. The authors noted several statistically significant differences compared to housewives, but not when the comparison was made with women working in other activity sectors, not exposed to a static magnetic field.

Overall, epidemiological studies do not point to the existence of any significant risk, but they are not able to show up weak effects because they concern few cases and have methodological limitations.

2.6 Interactions with Medical Implants

Given the phenomenon of magnetisation, passive ferromagnetic implants such as vascular clips, clamps, cardiac valves, movable metal dental prostheses, dental implants, auditory or orthopaedic implants, etc., or any other object containing a ferromagnetic metal (shell splinters, etc.), are capable of being moved in the magnetic field, depending on its force. A list of compatible materials is regularly kept up to date.

Active implants such as pacemakers, cardiac defibrillators or neurostimulators, or any other electronic implant, can be perturbed or damaged by an intense magnetic field.

In MRI, implants or implanted electrodes (for electroencephalograms for example), could in addition undergo excessive warming through interaction with RF waves.

Given the increasingly widespread use of this investigation technique, many people fitted with pacemakers may have to undergo such an examination. MRI compatible implants are now commercially available.

Moreover, during the MRI examination, it is advisable to avoid:

- The presence, near to the magnet, of ferromagnetic materials which could be violently attracted and become dangerous projectiles.
- Make up or tattoos containing metal ions, which can create local artefacts on the images.
- Jewellery and all metal accessories that can concentrate electromagnetic fields and lead to burns.

Generally speaking, access to the area near to MRI and NMR magnets is regulated for people fitted with passive or active implants. A medical opinion is indispensable before any examination. Furthermore, apart from the potential health risk, the presence of the implant can lead to artefacts on the images.

2.7 Limit Exposure Values

The limits of exposure to static magnetic fields proposed by the ICNIRP in 1994 for workers and the public were revised in 2009.

As regards occupational exposure limits, they essentially aim to prevent the onset of dizziness, nausea and other sensations described previously. The acute exposure values are respectively 2 and 8 T for the head and the limbs. There have been no other experimentations to date at higher field levels, on which possible higher limits could be based.

For the general public, the limit is set at 400 mT, based on the biological effects directly due to exposure to the magnetic field. Persons of the public may be authorised to occasionally enter, under well controlled conditions, areas where the

Table 2.2 Static magnetic field exposure limits

Type of exposure	Magnetic induction, exposure limits	
	ICNIRP-1994	ICNIRP-2009
Occupational exposure		
8 h/day on average	200 mT	
Head and torso	2 T	2 T ^a
Limbs	5 T	8 T
Persons of the public		
All parts of the body	40 mT	400 mT

^a Occasionally possible up to 8 T under controlled conditions for a volunteer informed of possible sensations

static magnetic field exceeds the limits. Nonetheless, persons fitted with pace-makers, other electronic devices or ferromagnetic implants may not be sufficiently protected by these limits. Accidents can also arise due to the movement of objects attracted by the magnet (missile effect). On account of these indirect effects, it is recommended that the areas where the magnetic flux density exceeds 0.5 mT are marked out by red lines and appropriate warning panels.⁵

On the other hand, the average exposure limit weighted over a full day has been done away with because current knowledge points to the existence of acute effects in certain conditions, whereas the absence of cumulative effects is now accepted. All in all, the new prescribed limits are less restrictive (Table 2.2).

It is worth noting that a European directive 2004/40/EC relative to the exposure of workers and aiming to limit their exposure to electromagnetic fields up to 300 GHz was adopted in 2004, based on the recommendations of the ICNIRP in 1994. Its application has turned out to be incompatible with certain MRI examinations during which the levels of exposure can exceed the authorised limits, as well as with the research perspectives in the field. Since it risks in addition favouring a reorientation of patients towards more invasive investigation techniques, this document is currently being revised in order to define the relevant standards without being unnecessarily restrictive. The European directive limiting occupational exposure is likely to be transposed in EU countries in 2013. The current project of the European commission provides an exemption from compliance with limit values for the MRI technique. Furthermore, there is no objective reason to rule out normal activity for pregnant women who work in MRI units.

In 2004, the ICNIRP published recommendations for MRI, relative to the exposure of patients or volunteers (for research). This document is based on a review of the more specific literature of the types of exposures encountered during an MRI examination, to take into account the safety instructions applied in medical imaging centres. The document stipulates that the exposure conditions may,

⁵ Not an ICNIRP recommendation but one of the International Commission for the Safety of Equipment (International Electrotechnical Commission (2002) Safety of magnetic resonance equipment for medical diagnosis. IEC, Geneva: IEC 60601-2-33).

if necessary, be pushed to the extreme depending on the estimation of the risk/benefits ratio for the patient. The latter will also be considered with attention in the case of pregnant women, particularly at the start of pregnancy, for whom nevertheless the data obtained on humans do not indicate to date any deleterious effects that justify contraindication to MRI examinations.

2.8 Conclusions

The biological effects of static electric and magnetic fields have been relatively little studied, if one compares the available data with data concerning the fields of 50/60 Hz. They are rarely encountered at high levels in the environment. The magnetic field is usefully employed by certain animals for orientation and even by humans using a compass.

For MRI, no significant health effects have been demonstrated to date, whether for patients or technical personnel. During exposure, effects linked to magnetic field gradients and to movements within the field can occur in a transitory manner. No irreversible or serious health consequences linked to these effects have been demonstrated. They are sometimes disagreeable, but they do not affect everyone.

On the other hand, considerable prudence is necessary for persons fitted with metal-containing implants and for any other indirect effects due to the violent attraction of metal objects by the superconducting magnet.

To Find Out More

Institute for magnetic resonance, safety, education and research (IMRSER) <http://www.imrser.org/>

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