Guide

Electromagnetic fields in working life
A guide to risk assessment

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Foreword

We are all constantly exposed to electromagnetic fields (EMFs) generated by electric charges in the environment, such as the earth´s static magnetic field. However, there are other electric and magnetic fields, generated by manmade sources, which can affect people's health and be causes for concern, particularly at the workplace. Among the many devices or activities liable to generate electromagnetic fields in the working environment one can mention welding, induction devices, medical devices (magnetic resonance imaging, scanners and electrosurgery units), telecommunications antennas, radar systems, security-related equipment, etc.

Exposure to these fields, which are by definition invisible to humans, has increased due to technological development in many of the aforementioned sectors, notably telecommunications and medical devices.

More recently, since the late 1970s, studies have shown small increases in leukaemia or brain cancer in groups of people living or working in high magnetic fields of extremely low frequency. In high frequency situations severe burns can occur, whereas in low frequency contexts, the nervous system can be affected. Exposed individuals can also experience vertigo, nausea or a metallic taste in the mouth. The consequences will vary according to the intensity, proximity to the sources and the intrinsic characteristics of the electromagnetic field.

This Guide is aimed at employers, trade union representatives and, of course, workers potentially exposed to EMFs. It is also designed as an aid to understanding the new EU Directive on occupational exposure to EMFs (2013/35 EU), which will enter into force in 2016. The Guide presents an overview of occupational exposure to electromagnetic field according to frequency: static fields, low, intermediate and radio frequencies.

It focuses on certain occupations, on risk assessment and on the determination of exposure, which needs to be done according to the general provisions of EU Directive OSH "Framework Directive" 89/391/EEC. A specific chapter is dedicated to workers who face particular risks, e.g., persons with medical implants, pregnant women or persons taking certain medications.

The Guide also presents recommendations as to how a precautionary approach can help to reduce high exposure.

— *Aída Maria Ponce Del Castillo*
Head of the Working Conditions, Health and Safety Unit, ETUI

Why pay attention to electromagnetic fields?

Electromagnetic fields (EMFs) are present everywhere in our environment, in particular because of the use of man-made electric current. Workers can be exposed to EMFs in many sectors of activity: industrial processes such as electrolysis, welding, sealing, broadcasting, electricity generation, etc., or in medical procedures such as Magnetic Resonance Imaging (MRI). The exposure characteristic is significantly different from that of the general public: workers can be exposed to higher levels than the general public, they are often closer to the sources, and the modulation (frequency composition) of the EMF is more complex.

The health consequences of overexposure can be different depending upon the intensity and proximity to the sources. The symptoms of acute effects are well defined. In the high frequency range (i.e., broadcasting, radars), severe burns may occur, whilst in the low frequency range (i.e., welding, electricity production and distribution), induced currents can cause effects on the function of the central or peripheral nervous system, and exposed persons can also experience vertigo, nausea, metallic taste feelings or magnetophosphenes (flashes in the eyes). In very rare cases, dramatic indirect safety effects have also to be deployed when strong magnets attract a ferromagnetic object and crash it into a person inadvertently positioned between the magnet and the metallic object. The main principles of protecting workers exposed to EMFs were already covered at EU level in 1989 by the general EU occupational safety and health "Framework Directive" (89/391/EEC) and in 2004 by minimum requirements regarding specific provisions and limits of exposure with the adoption of Directive 2004/40/EC of the EP and the Council. But this Directive was not transposed by the large majority of Member States and is now replaced by Directive 2013/35/EU on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields). The directive will enter into force in 2016.

What are electromagnetic fields?

EMFs are described in terms of electric and magnetic fields. Electric fields are created by differences in voltage: the higher the voltage, the stronger the resultant field. Magnetic fields are created when electric current flows: the greater the current, the stronger the magnetic field. An electric field will exist even when there is no current flowing. If current does flow, the strength of the magnetic field will vary with power consumption but the electric field strength will be constant. The strength of the electric field (E) is measured in volts per metre (V/m). The strength of the magnetic field (H) is measured in amperes per metre (A/m); more commonly in EMF research and practice, scientists specify a related quantity, the flux density (B) (in microtesla, μT) instead.

Natural electric fields are produced by the local build-up of electric charges in the atmosphere associated with thunderstorms. The earth's magnetic field causes a compass needle to orient in a North-South direction and is used by birds and fish for navigation. Besides natural sources the electromagnetic spectrum also includes fields generated by human-made sources: The electricity that comes out of every power socket has associated low frequency electromagnetic fields. Various kinds of higher frequency waves are used to transmit information – whether via TV aerials, radio stations or mobile phone base stations. Mobile telephones, television and radio transmitters and radar produce radio frequency (RF) fields. At radio frequencies, the electric and magnetic fields are closely interrelated and we typically measure their levels as power densities in watts per square metre (W/m^2).

Figure 1

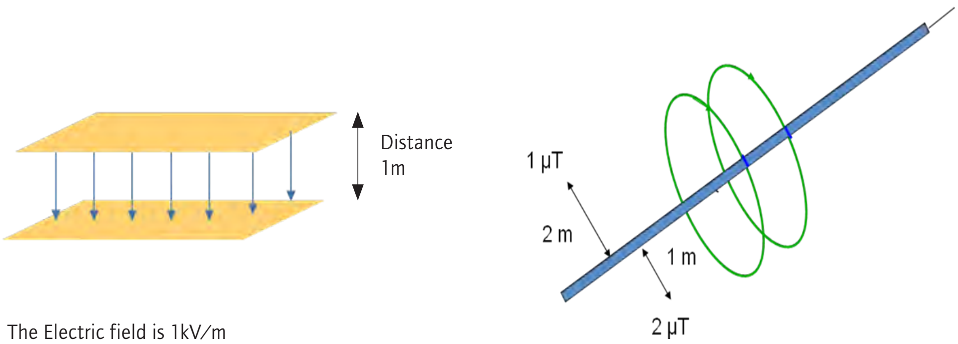
An electric field (E) is created as soon as there is a potential – voltage – difference between two points. A magnetic field (B) is created when there is a current flowing. The E field is given with the unit volts per meter, V/m, and the magnetic field is given by the flux density, B, with the unit Tesla (T). Both E and B are vectorial quantities, i.e. they have both magnitude and direction. The fields are usually displayed by means of field lines, and in Fig 1 an example of this is given. The E field is always starting in a positive charge and ends on a negative charge. The B field in forming closed loops, i.e. the field lines has no beginning and no end.
Electric field; two large plates are separated by 1 m and the potential difference between them is 1000 V (1 kV). The E field between the plates is than E=1000 V/m = 1 kV/m.
Magnetic field; a current I of 10 A is running in a straight conductor. The magnetic field at a distance of r m from the conductor is given by the formula B=0.2xI/r (μT), and this gives for 10 A and 1 m a value of B=2 μT, and at 2 m distance from the conductor B=1 μT.

ELECTRIC FIELD (E) V/M

Applied voltage 1kV

MAGNETIC FIELD (B)

The current I=10A



The Electric field is 1kV/m

What makes the various forms of electromagnetic fields so different?

One of the main characteristics which define an electromagnetic field is its frequency and its corresponding wavelength. Fields of different frequencies interact with the body in different ways. One can imagine electromagnetic waves as series of very regular waves that travel at an enormous speed – the speed of light. The frequency simply describes the number of oscillations or cycles per second, while the term wavelength describes the distance between one wave and the next (see Figure 2). Hence wavelength and frequency are inseparably intertwined: the higher the frequency, the shorter the wavelength.

In our daily life we are exposed to fields from the earth´s static magnetic field to high frequency fields from communication devices such as mobile phones and their base stations. For fields with low frequency, from for instance power lines or welding equipment, we need to distinguish between the electric and magnetic field, but when we are dealing with fields of frequencies in the MHz-range (millions of oscillations per second) or higher there is a fixed relation between the fields.

What is the difference between non-ionizing electromagnetic fields and ionizing radiation?

Electromagnetic waves are carried by particles called quanta. Quanta of higher frequency (shorter wavelength) waves carry more energy than lower frequency (longer wavelength) fields. Some electromagnetic waves carry so much energy per quantum that they have the ability to break bonds between molecules. In the electromagnetic spectrum, gamma rays given off by radioactive materials, cosmic rays and X-rays carry this property and are called ionizing radiation. Fields whose quanta are insufficient to break molecular bonds are called non-ionizing radiation.

Electromagnetic fields are usually divided according to their frequency. The wave propagates with the speed of light, in a vacuum $c=3x10^8$ m/s, and the relation between wavelength, λ, and the frequency, f, is $c=f\lambda$. We can cite as examples that for fields with 50 Hz the wavelength is 3000 km and for a mobile phone operating at 1900 MHz the wavelength is about 16 cm.

There is an international classification of the electromagnetic spectrum into different frequency bands. However, in practice the division used in occupational health is slightly different. Here the notation Low Frequency (LF) is used for fields with frequencies up to about 100 kHz with a subclass called Extremely Low Frequency (ELF) for frequencies up to about 300-400 Hz. Power frequency means the frequency of currents used for electrical power transmitting and of the EMFs it produces (50 Hz in Europe, 60 Hz in North America). The next band is called Intermediate Frequency (IF) and it goes up to about 10 MHz (M=mega, 10^6), and this is followed by Radiofrequency (RF). EMFs of frequency in the range 300 MHz – 300 GHz (G=giga, 10^9) are called microwaves (MW). The MW wavelength is sufficiently short for the practical use of waveguides to transmit or receive it. An EMF of any frequency which is useful for telecommunication is called a radiofrequency (RF) EMF.

Figure 2 A schematic drawing of the electromagnetic spectrum

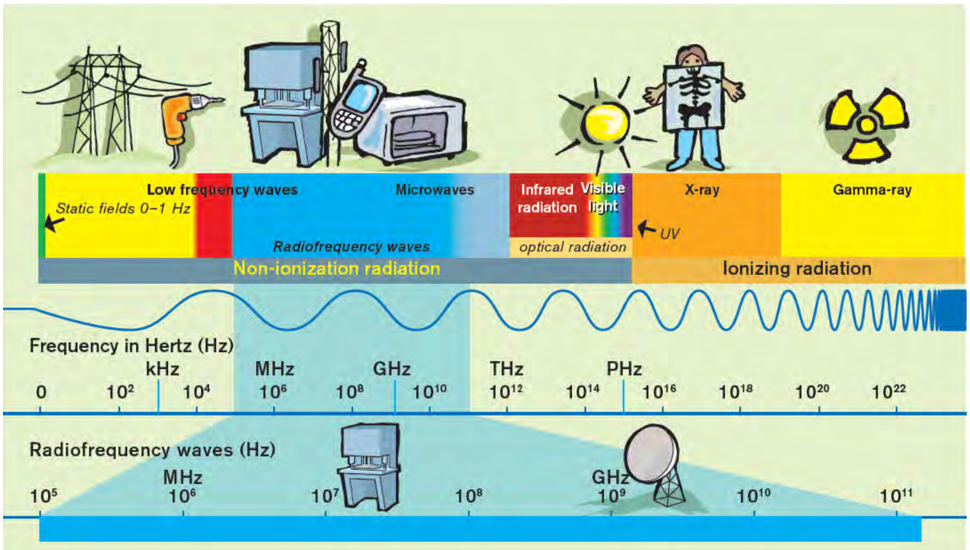


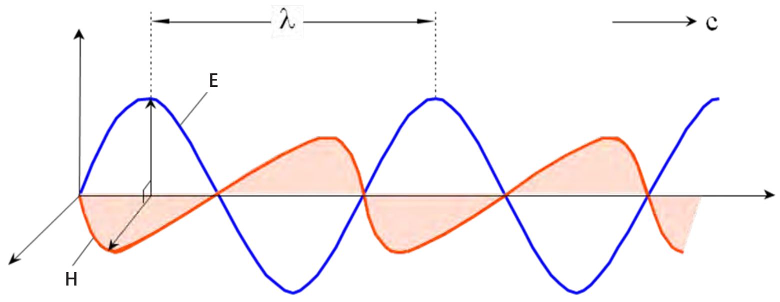
Illustration by Guldbrand&Guldbrand

When the fields are time varying there is a connection between them, as given by Maxwell's equation of 1865. In free space and at some distance from the source the fields interact so as to give rise to an electromagnetic wave. The electric and magnetic fields are perpendicular to each other and to the direction of travel. The relations between the field strengths is $E=377xH$ where H is the magnetic field strength in A/m related to the flux density by $B=\mu_0 H$ ($\mu_0 = 4\pi x10^{-7}$, permeability in air). The unit for density is Tesla but this is a very large quantity and it is therefore also used with the prefix m (milli, 10^{-3}) or μ (micro, 10^{-6}) to give the values as mT or μT.

The wave is usually described by its power density given by the product of ExH and this represents the energy transport per second across a section of 1 m^2. The power density is given in the unit W/m^2, or sometimes as mW/cm^2 ($1\ mW/cm^2=10\ W/m^2$). Using the relation between E and H, the power density can also be expressed as the equivalent power density (S), $S_E=E^2/377$ or $S_H=377\ H^2$. This means that for a plane wave one only needs to measure either E or H and not both. However, for most cases below 300 MHz we do not have this exact relation between the fields and it is necessary to measure both. For further information about electromagnetic fields the reader is referred to standard physics text books, or information texts by Hansson Mild 1998a,b. See also the WHO web page www.who.ch/emf for more information and fact sheets about EMFs.

Figure 3
An electromagnetic wave consist of an electric and a magnetic component and at large distance from the source they are perpendicular and have the relation E = 377 H. If the frequency is 50 Hz the wavelength is 5000 km and if the frequency is that of microwave ovens, 2450 Hz, the wavelength will be 12 cm.

ELECTROMAGNETIC WAVE



The following physical quantities can be measured directly and are used to describe the exposure to electromagnetic fields (Directive 2013/35 EU):

Contact current (IC) is the current that appears when a person comes into contact with an object in an electromagnetic field. It is expressed in amperes (A). A steady state contact current occurs when a person is in continuous contact with an object in an electromagnetic field. In the process of making such contact, a spark discharge may occur with associated transient currents.
Electric field strength (E) is a vector quantity that corresponds to the force exerted on a charged particle regardless of its motion in space. It is expressed in volts per metre (V/m).
Limb current (IL) is the current in the limbs of a person exposed to electromagnetic fields in the frequency range from 10 MHz to 110 MHz as a result of contact with an object in an electromagnetic field or the flow of capacitive currents induced in the exposed body. It is expressed in amperes (A).
Magnetic field strength (H) is a vector quantity, which, together with the magnetic flux density, specifies a magnetic field at any point in space. It is expressed in amperes per metre (A/m).
Magnetic flux density (B) is a vector quantity, resulting in a force that acts on moving charges, expressed in Tesla (T). In free space and in biological materials, magnetic flux density and magnetic field strength can be interchanged using the equivalence 1 A/m = $4\pi 10^{-7}$ T.
Power density (S) is the appropriate quantity used for very high frequencies, where the depth of penetration in the body is low. It is the radiant power incident perpendicular to a surface, divided by the area of the surface, and is expressed in watts per square metre (W/m^2).
Frequency (f) is given in Hertz, number of oscillations per second. In the description of quantities characterizing EMFs and their sources, the prefix k (kilo= 10^3), M (mega=10^6), G (giga = 10^9), m (mili = 10^{-3}), μ (micro = 10^{-6}) is used to give the higher or lower quantities.
Electromagnetic fields (EMF) are defined in Directive 2013/35/EU: static electric, static magnetic and time-varying electric, magnetic and electromagnetic fields with frequencies up to 300 GHz. An electric field (E) is created as soon as there is a potential – voltage – difference between two points. A magnetic field (B) is created when there is a current flowing. Both E and B are vectorial quantities, i.e., they have both magnitude and direction. The fields are usually displayed by means of field lines, and an example of this is given in Fig 1. The E field always starts on a positive charge and ends on a negative charge. The B field forms closed loops, i.e., the field lines have no beginning and no end.

Occupational exposure to EMFs

We are everywhere in our daily life exposed to electromagnetic fields of various frequency and intensity. In most cases the levels are low and we do not need to take any action to avoid them, but in some cases the occupational exposure can be quite high and close to or even over the workers' exposure limits, in which case special attention to these situations is needed. In this section we will describe some examples of typical exposures, and the section is divided according to field frequency.

Static magnetic fields

A high static magnetic field is associated with superconductive high current installations, permanent magnets and direct current (DC)/rectified alternating current (AC) which contains DC components, high power-supplying cables. There are only a few groups of workers with very high levels of exposure, e.g., operating NMR (nuclear magnetic resonance) spectrometers, MRI (magnetic resonance imaging) scanners, scientists and maintenance technicians working with thermonuclear reactors and particle accelerators. Lower levels of exposure can be found in the vicinity of all DC/rectified AC high current cables, e.g., from electrolytic installations or DC motors. The current can in these cases reach several hundred kA. Workers operating the sources of high static magnetic field are usually exposed within the area of static magnetic field of significant spatial heterogeneity. In the case of superconductive devices, like MRI scanners, the static field is permanently switched on, and non-medical staff such as cleaners and repairmen can also be exposed to high fields.

Low frequency fields

Since every electrical device, apparatus or machine is in fact an ELF source of EMFs, there are so many sources that it is impossible to consider them all. Hence, the guidance is based only on our experience with the exposure assessment of industrial high exposure LF sources. Industry or the workplace in general is a very vast domain of low frequency field (LF) EMFs of which extreme low frequency (ELF: 30 – 300 Hz) field sources are important representatives. Since there is still no clear definition of the borderlines of the frequency ranges within the non-ionizing frequency spectrum, the LFs that this guidance is dealing with range from 0 Hz up to 20 kHz.

The most important industrial high exposure LF sources:
– electrical installations for electrolysis (DC and ripple)
– high voltage power plants (50 Hz)
– electrical arc furnaces (50 Hz)
– induction ovens (300 Hz – 10 kHz)
– arc welding (DC, AC, ripple)
– resistance or spot welding (DC, 50 Hz – 20 kHz).

High voltage power lines and transformer stations do not usually lead to high level occupational exposure, because they are switched off before technical operations. However, very high exposure to magnetic fields can occur during very specific types of work, like "live cable" work.

Figure 4
Strong magnetic field with various frequencies can be found near the welding cable. Depending on how the cable is positioned it can lead to high unnecessary exposure. Here the welder has the cable in a loop around the head.

Intermediate frequency fields

Significant occupational exposure to EMFs in the IF range is caused by various sources:
– induction heaters, operating usually from 1 kHz to a few MHz
– welding devices - common sources of ELF EMFs but can be also a source of EMFs of tens/hundreds kHz
– medical devices (electrosurgery units, usually sources of 300 kHz - 1.5 MHz)
– anti-theft devices and many others.

Radiofrequency fields

The use of RF fields in our workplaces has increased rapidly during the last decade, mainly due to the increased use of wireless communication techniques, security devices and medical applications. However, worker exposure in these cases is in general low and not in conflict with the EU Directive. But there are exceptions.

In office, industry and transportation environments alike, wireless communications are frequently used. The indoor base stations as well as different Bluetooth equipment and WLANs (Indoor Wireless Networks) used for man-to-machine or machine-to-machine communication have a low output power and therefore the possible exposure of workers does not exceed EU Directive limits.

Low exposure can also be expected when the sources are enclosed. Examples in industry are plasma metallization and polymerization, plasma deposition and etching and microwave heating for vulcanization of rubber, for instance. These processes are normally performed in closed chambers, but there might be leakages especially after reconstructions or changes in process and therefore a simple recurrent check might be a part of the assessment.

The number of devices used for security purposes, like anti-theft and personal access control, has increased rapidly in shops, libraries, airports and restricted areas. These devices work at different frequencies depending on what technique is used. Several work below 100 kHz, but the RFID equipment (Radiofrequency Identification Device) works for example at 120-154 kHz and there are also devices working at 4.9 GHz. Electronic Article Surveillance (EAS) systems usually work in the MHz range both in continuous swept frequency and at fixed pulsed frequency at the detector. Normally, the staff only pass through and are therefore only exposed for a short period at exposures not exceeding EU Directive limits. However, there might be devices situated near a permanent working place - a checkout operator for instance - in which case actions must be taken to ensure that the national regulations are fulfilled.

Examples of RF exposures that need special attention

In some workplaces it will be necessary to make exposure assessments to show compliance with the national legislation transposing the EU Directive. Examples of such workplaces are given below:

Dielectric heaters

RF sealers and glue dryers are two examples of dielectric heaters frequently used in industry to seal plastic objects and to glue wood details. In workplaces where these devices are used it is necessary to perform detailed assessments both of the electric and magnetic fields as well as contact and induced currents. Field strengths of the order of some hundreds V/m and magnetic fields up to some A/m are not uncommon – so worker exposure exceeding Directive limits may be expected. To make an exposure assessment for these types of machines, specialists are often needed to perform the measurements, and these should be done on a recurrent basis- perhaps once a year or every time the work procedure changes.

Induction heating

Induction heaters usually operate in the frequency range of a few Hz up to 10 MHz. In some processes, the operator comes close to the device for visual control of the object and might therefore be highly exposed. The magnetic field intensity close to the inductor may easily be in excess of the limits, and worker exposure assessment is often needed.

Figure 5
Operating a plastic welding machine the operator often are very close to the electrodes and the exposure to RF electromagnetic fields can be substantial. It is necessary to perform measurement and safety instructions should be given.

Industrial microwave ovens and microwave drying

Often these ovens are closed and no access is given to areas where high intensity microwaves can be encountered. However, there may be leakage in some cabinets and connections, and a regular maintenance program is recommended, including periodical EMF exposure assessment.

Microwaves are also used for drying of water damage in buildings. These applications are usually high-powered devices and with an applicator that has some potential leakage. Due to the high intensity microwave energy used it is also possible to receive exposure on the other side of the wall or floor where the applicator is located. Great care in the use of these devices is needed, and in some countries there is a demand for the use of these machines to be licensed.

Radar

In general, it would be exceptional to find cases of staff being exposed to direct emissions of radar signals from antennas. Often measurement is not needed and the exposure assessment can be done by numerical calculations. Radar beams usually radiate far from human body locations, but serious non-compliance with exposure requirements may exist during manufacturing and in the case of technical malfunction of the device. The use of radar in military installations may be very powerful and special safety guidelines need to be followed. On naval vessels, for example, the radar can have an output power so high that the safety distance for use of the radar is hundreds of metres.

Medical applications

There are three main applications in medicine of interest in this context: physiotherapeutic use of diathermy, surgical diathermy and magnetic resonance imaging (MRI). In medical clinics, RFs are used in physiotherapy in shortwave or microwave diathermy treatment. In these cases the applicators are open, and possible overexposure of the staff can occur. Strict adherence to safety instructions is needed, but national law could define if there is a need to take periodic measurements.

In operating theatres, surgical diathermy is used. RF energy is used to cut and coagulate, and since unshielded electrodes are used the fields are rather intense and special attention is needed to ensure compliance with the Directive on occupational exposure. Electrosurgery scalpels and supplying cables produce high level electric fields, which can be sufficiently assessed by measurement of the exposure level in the case of medical staff members who are not in direct contact with the EMF source. However, in the case of surgeons manually holding the device, internal measures of EMF exposure should usually be considered: induced/contact currents or local thermal effects.

MRI units make use of three different magnetic fields: a strong static field, a switched gradient field in the low frequency range and a radiofrequency field. With normal MRI applications only the RF field of intensity inside the magnet bore is high enough to cause concern. With use of interventional MRI the RF exposure of medical personnel might be of concern, and an exposure assessment is needed. However, the static field can attain values high enough to be of concern up to several metres away, and the limit of 0.5 mT is often marked on the floor. The gradient field is strong in the immediate vicinity of the bore.

Although not strictly RF, another medical use of interest here is transcranial magnetic stimulation (TMS). TMS uses a strong pulsed magnetic field which induces electric currents causing depolarization or hyperpolarization in the neurons of the brain. The uses of TMS can be divided into diagnostic and therapeutic uses. But the pulsed field from the coil also exposes the staff to fields that are above the limits, and safety distances need to be introduced, as well as special information and training on handling the device.

Broadcasting and other communications

Radio and TV broadcasting installations are usually safe workplaces. However, there is a potential for involuntary, accidental intense exposure of staff. In most cases, technical staff working with radio/TV broadcasting equipment are technically well-informed and -trained. EMF emissions from mobile phone base stations usually comply with the exposure limitations for the general public, but high-level occupational exposure can occur when workers carry out technical activities in close proximity to the base station antenna. Rooftop workers near base station antennas might be exposed to RF fields at frequencies of 900–2000 MHz. Examples of such workers are sheet-metal workers, chimney sweepers and painters. In these cases, the emission properties are well-defined and simple instructions are more relevant than measurements.

Common occupational EMF exposures

Table 1 contains a summary of examples of common occupations/workplaces where there is a potential risk of exposure to EMFs in different frequency ranges. It is important to note that various types of work activities in the vicinity of particular EMF sources can result in various exposure patterns.

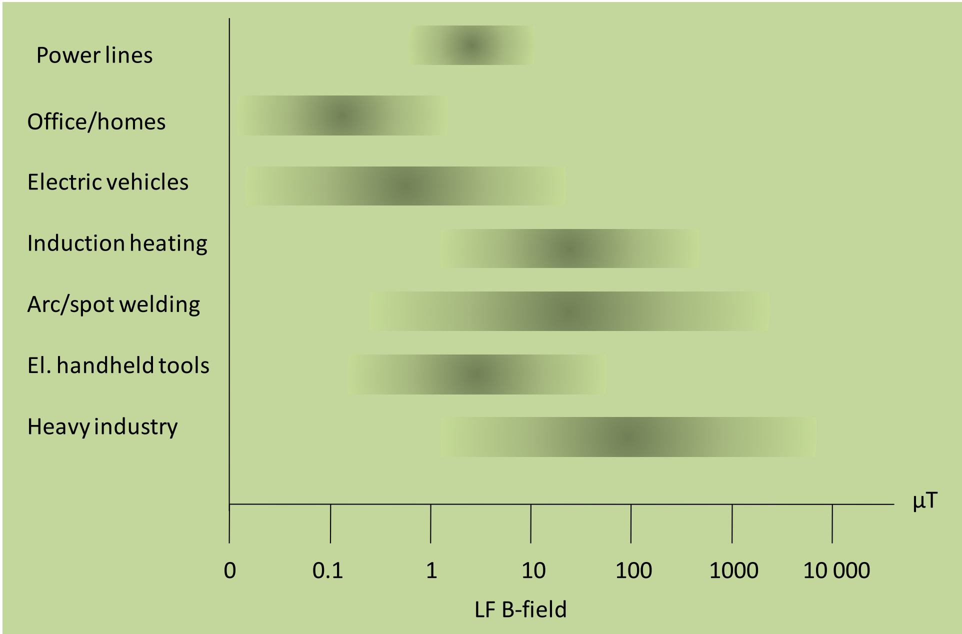
Table 1 Different EMF sources and corresponding frequency range of the emission

	Frequency range			
EMF source	Static field	LF field	IF field	RF/ MW
Industry				
Induction heating		xx	x	
Industrial magnetisers/demagnetisers	x	xx		
Dielectric heating (RF: glue drying and plastic welding)				xx
Industrial microwave ovens				xx
Electrochemical or other installations using microwaves (e.g., chemical activation of processes)				xx
Electrolytic installations	x	xx		
Welding				
Arc welding (MIG, MAG, TIG, etc.)	xx	xx	x	
Spot welding	x	xx	x	
Medical applications				
NMR/MRI medical diagnostic equipment	xx	xx		xx
Surgical and physiotherapeutic use of diathermy			xx	xx
Communication				
Radar and other systems				xx
Broadcasting systems and devices (radio & TV: AM, VHF/UHF)		xx	xx	xx
Mobile phone base stations				xx
Wireless local area networks (WLANs)				xx
Cordless phones		x		xx
Bluetooth devices and hands-free kits				xx
Others				
Military and research radiofrequency systems			x	xx
RFID/EAS and other anti-theft equipment	x	xx	x	xx
Electricity supply networks and electricity distribution and transmission equipment	x	xx		
Electric handheld tools		xx	x	
Electric vehicles (trains, trams, metros)	x	xx		

XX – the main emission frequency
X – other frequencies used

In Figure 6, rough estimations of magnetic field exposure to different common sources in the LF range are plotted. Other examples of EMF exposure may be found in sources referenced at the end of this guide. But it needs attention because existing guides elaborated on the basis of Directive 2004/40/EC have to be reconsidered and updated on the basis of Directive 2013/35/EU.

Figure 6 Examples of EMF exposure levels in the low frequency range



What do the regulations and guidelines protect against?

The health consequences of overexposure can be of different kinds depending not only upon the intensity and proximity of the EMF sources, but also upon the characteristics of the electromagnetic radiation itself, e.g., its frequency or wavelength. The symptoms of acute effects are well defined. In the high frequency range (i.e., broadcasting, radars), severe burns may occur whilst in the low frequency range (i.e., welding, electricity production and distribution), induced currents can cause effects on the function of the central or peripheral nervous system and exposed persons can also experience vertigo, nausea, metallic taste feelings, magnetophosphenes (flashes in the eyes). In very rare cases, dramatic indirect safety effects have also to be deployed when strong magnets attract a ferromagnetic object and crash it into a person inadvertently positioned between the magnet and the metallic object.

When exposed to low-frequency electric or magnetic fields, circulating electrical currents are induced in the human body. If the current in the body is sufficiently large then there is a risk of electric shock – just like touching a live conductor. Induced currents in head and trunk have effects on the central nervous system in the range up to 10 MHz. The exposure limits in this frequency range are set to prevent nerve excitation due to an internal electric field. See Figure 7.

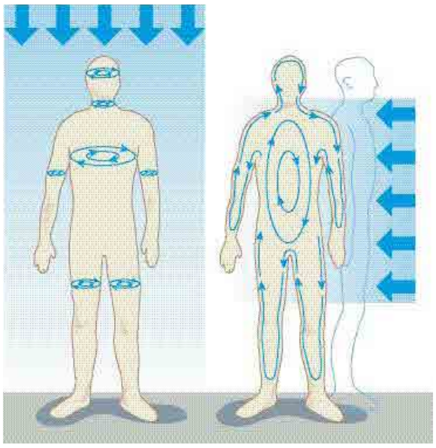


Figure 7
When a person is exposed to a magnetic field it results in induced currents in the body. Depending on the orientation of the field the current will flow in different paths and with different strengths.

For EMFs in the intermediate frequency range (100 kHz – 20 MHz) both limitations (heating and nerve excitation) should be considered. For static magnetic fields, protection was established against vertigo and nausea sensations and adverse influence on blood flow, amongst other things.

Within the RF frequency range, different established adverse effects can be expected if the RF field intensity is high enough. When our body absorbs the RF fields it might cause body temperature to increase, and in extreme case internal overheating can occur. Compare the heating of food in a microwave oven. The levels of heat burden the body can tolerate with ease, what level is required to activate thermoregulation - for example by increasing sweating – and what level the body's thermoregulatory mechanism cannot accommodate are well known, and the exposure limit values for high frequency EMFs in the Directive are set at a level that will restrict any heating of the body to levels that the body can tolerate comfortably.

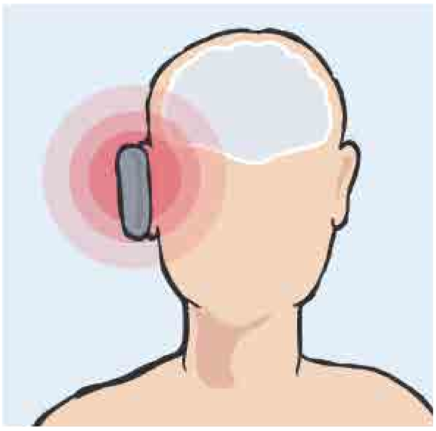


Figure 8
When exposed to RF energy it can be absorbed in the body. This is usually described by how much energy per unit time and mass in what is called the Specific Absorbtion Rate (SAR) given in the unit watt/kg (W/kg). In the special case of mobile phone use the exposure limit is given in SAR, and since all phones sold in the EU are in compliance with the directive there is no need to measure EMFs from phones.
Illustration by Guldbrand&Guldbrand

In addition to the direct effects of EMF exposure and interaction of the fields with the human body, indirect effects can also be a significant source of hazards related to contact currents, coupling of EMFs with medical devices (see Figure 9, p.22), transient discharges.

The EU Directive

Already in 1989 the EU published the general framework Directive (89/391/EEC) on the introduction of measures to encourage improvements in the safety and health of workers at work. It contains general principles concerning the prevention of occupational risks, the protection of safety and health, the elimination of risk and accident factors, the informing, consultation, balanced participation in accordance with national laws and/ or practices and training of workers and their representatives, as well as general guidelines for implementation.

This Directive has since been followed by four separate Directives on physical hazards, namely:
– Directive 2002/44/EC - vibration
– Directive 2003/10/EC - noise
– Directive 2004/40/EC - electromagnetic fields
– Directive 2006/25/EC - artificial optical radiation.

The 2004 EMF Directive was not implemented because of problems on how to deal with the specific exposure situation for workers near magnetic resonance imaging machines (MRI). Now it is finally accepted as Directive 2013/35 EU and Member States need to comply with the Directive at the latest by July 1st 2016.

It is stated in Directive 2013/35/EU that it is now necessary to introduce measures protecting workers from the risks associated with electromagnetic fields, owing to their effects on the health and safety of workers. The Directive addresses all known biophysical effects and indirect effects caused by electromagnetic fields, in order not only to ensure the health and safety of each worker on an individual basis, but also to create a minimum basis of protection for all workers in the Union. However, it does not address suggested long-term effects of exposure to electromagnetic fields including possible carcinogenic effects.

The Directive states that the employer shall make an assessment of all risks and determination of the exposure and, if necessary, measure and/or calculate the levels of electromagnetic fields to which workers are exposed.

It is specifically stated that when carrying out the risk assessment the employer shall give particular attention to any effects on the health and safety of workers at particular risk, in particular workers who wear active or passive implanted medical devices, such as cardiac pacemakers, workers with medical devices worn on the body, such as insulin pumps, and pregnant workers.

Taking account of technical progress and the availability of measures to control the production of electromagnetic fields at the source, the employer shall take the necessary actions to ensure that risks arising from electromagnetic fields at the workplace are eliminated or reduced to a minimum.

It is stated that the exposure can be more effectively reduced by incorporating preventive measures into the design of workstations and by giving priority, when selecting work equipment, procedures and methods, to reducing risks at source.

Exposure limit values and action levels

In order to facilitate assessment, the Directive gives exposure limit values (ELVs) for health effects as well as sensory effects and action levels (AL) for the EMFs. Since the exposure limits values are given in quantities that are not possible to measure in a workplace, the action levels will become in most cases the de facto limits. The ALs are given for electric and magnetic fields, induced and contact currents which are measurable quantities. The ELVs and the ALs are based on the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and should be considered in accordance with ICNIRP concepts.

When it has been demonstrated that the relevant ALs are not exceeded, the workplace shall be deemed in compliance with the health and sensory effect ELVs.

Once the relevant ALs are exceeded and if it has not been shown that the ELVs are not exceeded (very difficult to show without intensive work by experts!) the employer must devise and implement an action plan that shall include technical and/ or organizational measures to prevent exposure exceeding the health effect ELVs and sensory effect ELVs, taking into account other working methods giving less exposure, choosing equipment emitting less intense EMFs, and making technical measures with, for instance, the use of interlocks and/or shielding.

In the case of exposure to electric fields, measures and procedures to manage spark discharges and contact currents should be undertaken. As an example, the exposure limit values for the frequency range below 10 MHz are given in internal electric field in V/m. The values are set to prevent nerve excitation. For instance, for frequencies between 1 Hz and 3 kHz the ELV is set at 1.1 V/m (peak) in all peripheral and central nervous system tissues in the body (including head) for health effects and for sensory effects at 0.0028 x f V/m (peak, and f is the frequency) in central nervous system tissue in the head for frequencies 25 Hz to 400 Hz where f is the frequency in Hz. Since these quantities are not measurable, they have been transformed under worst case conditions to ALs in electric and magnetic fields which can be measured. The Directive expresses two levels of ALs: Low ALs and High ALs. In both cases the internal electric field does not exceed the ELV, but for High ALs specific protection measures shall be taken. For instance, for a pure electric field with frequency 50 Hz the AL becomes 10 kV/m and High AL becomes 20 kV/m. The corresponding values for the magnetic field Low ALs = 1.0 $x10^3$ μT (1.0 mT) and High ALs = 6 mT. For localized fields to the limbs a 3-fold higher value than High ALs applies, which for 50 Hz becomes 18 mT, a value that is very seldom seen in industry. Compliance with the High ALs ensures that health effect ELVs are not exceeded, but the effects related to retinal phosphenes and minor transient changes in brain activity are possible.

For radiofrequency fields, the ELVs are set in Specific Absorption Rate (SAR), unit W/kg, which tells how much energy per time unit and mass unit the body is absorbing from the external field. However, SAR cannot be measured in the workplace and therefore the ALs are given in E and H fields for frequencies up to 6 GHz, and then the ALs are also given in power density. The values are in principle the same as those the ICNIRP recommended in 1998. The Directive also gives ALs for contact currents and induced limb currents. In the RF frequency range all values are to be time averaged over a six minute time period for frequencies up to 10 GHz, and over a shorter period for higher frequencies – to compensate for progressively shorter penetration depth as frequency increases.

In order to make a full risk assessment of, for instance, a factory with RF sealers one will need instruments to measure frequency, electric and magnetic field, and induced current. There are not so many manufacturers that can provide all these instruments!

For full details of the new Directive we refer the reader to the original text at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:179:0001:0021:EN:PDF.

Precautionary approaches

Occupational exposure to EMFs is covered by regulations and guidelines and they are based on known human health risks, primarily acute effects; nerve excitation in the low and inter medium frequency range and temperature increase in the RF range. However, since the late 1970s when the first epidemiological study indicated that long term exposure to low level magnetic fields in the ELF range might cause leukaemia in children, a large number of epidemiological studies all over the world have been performed, mainly focused on low level general public exposures. Many of these studies report small increases in leukaemia or brain cancer in groups of people living or working in high magnetic fields of extremely low frequency (ELF). Also for radiofrequency fields, epidemiological reports have suggested associations between exposure at levels lower than the ELVs and some adverse health effects. However, causation has not been shown.

In 2001, the International Cancer Research Organisation (IARC) classified low frequency magnetic field as a possible carcinogen, Class IIB (IARC Monograph N° 80). This was then followed in 2012 by a similar classification for RF fields also as Class IIB (IARC Monograph N° 102). Thus, both in the low frequency range and in the RF range, exposure to these fields is classified as possibly carcinogenic.

Normally, substances that have such a classification are also restricted according to this, but so far for the EMF only the acute effects are limited in the EU Directive. On the national level, some countries have implemented various measures with respect to protecting against the delayed results of EMF exposure, mainly focused on the general public or workers at particular risk.

Research is continuing in many countries into possible health effects from EMF exposure, and when new results are at hand, these will be reflected in the regulations. This is also clearly spelled out in Directive 2013/35 EU. However, science cannot, in principle, prove absolute safety and any risk assessment will be associated with some degree of uncertainty. While science provides the starting point for assessing risks, a decision on what constitutes an acceptable risk is essentially a value judgement. It has been suggested that "better safe than sorry" approaches (that means taking precautionary measures in order to cope with the remaining uncertainties) might be useful as a substitute for absolute assurance, given the existing weak evidence of a health risk. The type of precautionary approach chosen critically depends on the strength of evidence for a health risk and the scale and nature of the potential consequences.

What do we mean by precautionary approaches?

There are many expressions used in this context of limited scientific evidence on any health risk:

- **Better safe than sorry**: a very socially and politically attractive expression often applied when the risk has already been established. ALARA: as low as reasonable achievable and mainly used in the context of ionizing radiation.
- **Prudent avoidance**: that means taking simple, easily achievable low-cost measures to reduce EMF exposure even in the absence of demonstrable risk.

Finally we have the **Precautionary principle**. There are a wide variety of definitions and interpretations of the expression "precautionary principle". These definitions include the basic approaches: uncertainty, no cause and effect relationship, and harm not certain. In the EMF range it is particularly problematic because it is not clear which aspect of the exposure, i.e., duration or field intensity or a combination thereof, should be avoided.

Examples of precautionary approaches in occupational exposure

Just as individuals can exercise prudent avoidance, government regulators, electric power companies and other companies where EMF exposure may occur, can also exercise prudence. Below, some examples are given, divided into two different categories according to EMF frequencies. First we will deal with the ELF range, and then with RF fields and microwaves.

ELF

Certain occupations are associated with high field exposures. The Swedish Trade Union Confederation (LO) was early in making demands that all workplaces should be surveyed for ELF magnetic fields and practical measures should be taken to reduce high exposures. This can be done by, for instance, marking of zones of exposed areas, reduction of magnetic fields, relocation of workplaces and an altered organization of work. One important way is to encourage manufacturers of electrical appliances to consider alternatives that reduce magnetic fields at a minimal cost.

For the individual who is concerned about possible health effects a first step is to try to get as much information as possible about the workplace and the possible exposure to EMF that exists. A most efficient way of reducing exposure is to increase the distance from the EMF sources. Since magnetic fields often drop off dramatically within about 1 m from the source, workers can stand back from electrical equipment, and work stations can be moved out of the 1 m range of stronger EMF sources. One should also use low EMF design wherever possible. One should also look for the possibility of reducing the EMF exposure times.

RF and microwaves

Most guidelines for occupational exposures state that exposure should be kept low and not exceed the limit values. However, in many situations there may be a very fine distinction between being within or above the limits. Therefore, with respect to this kind of work it is perhaps of even more importance to apply a precautionary approach in order to stay within the limits. This is especially true for work near RF dielectric heaters and sealers, which usually operate at 27 MHz. Here it is very important to strictly adhere to good work practice, including maintenance and operating procedures. Improper maintenance may lead to excess leakage from the machine, and small changes in the near environment may also lead to higher exposure levels. In an International Labour Office (ILO) publication (1998) several practical examples are given for the application of shielding devices and effects on ground plates and reflectors on operator exposure.

Generally, a plastic welder workplace should be designed in such a way that it is unnecessary for the operator to have direct contact with the machine while welding and that the welding electrode is placed as far away from the operator as possible.

It is also important that the machine is well maintained and in good condition. It is especially important to ensure that all the screws holding the metal parts together in the machine chassis are in place and properly tightened. The radio frequency fields could otherwise "leak out" from gaps in the panels, screw holes and so on. It is very important to use a grounding bar. If it is dismounted, the return current will not go back to the earth and exposure will increase considerably around the machine. The earthing bar will not function as it should if too much plastic material comes between the bar and the bench.

The machine must also be properly earthed. It is not enough to use the thin copper wires used for earthing ordinary electrical equipment – a proper strip of metal is required. Earthing can be difficult, and you may need to turn to an expert such as the machine manufacturer for help. However, it is of importance for exposure that the operator is NOT in contact with the ground, because if so the absorption of RF energy will increase substantially. It is therefore recommended that if the floor in the factory is reinforced concrete, which it usually is, then the operator should be standing on a non-conducting material that gives a distance of 5 - 10 cm from the floor, such as a rubber mat or wood platform. Note that this has to be made so that the ergonomics of the workplace are not impeded.

New employees must go through introductory training on how to work safely with a plastic welder.

For most people, even in working life, the most common source of RF exposure is connected with mobile phone use. In the absence of conclusive information about any possible risk, concerned individuals can take a few simple steps to minimize potential risks. Time is a key factor in how much exposure a person receives. Those people who spend long periods of time on their hand-held mobile phones may consider holding lengthy conversations on conventional phones and reserving the hand-held models for shorter conversations or for situations when other types of phone are not available. People who must conduct extended conversations every day could switch to a type of mobile phone that places more distance between their bodies and the source of the RF, since the field strengths drop off dramatically with distance. For example, they could switch to a headset (hands-free device) and carry the mobile phone at the waist or in the hand.

The U.S. Food and Drug Administration (FDA) has urged the mobile phone industry to design mobile phones in a way that minimizes the user's exposure to any RF fields which are not necessary for the device's function. This recommendation has also been given by the UK Committee on Science and Technology: *We recommend that the industry and the National Radiological Protection Board explore ways in which the design of the mobile phones might limit personal exposure to radiation as a means of assisting consumer choice* (see further: http://webarchive.nationalarchives.gov.uk/20140714084352/ http://www.hpa.org.uk/Publications/Radiation/HPAResponseStatementsOnRadiationTopics/nrpbResponseStatement99).

There have also been demands from many national authorities for the manufacturers of mobile phones to publish the values of the specific absorption rate (SAR) for the various phone models, i.e., how much of the microwaves are absorbed in the user's head. It is known that the differences between various makers and models with respect to the SAR values can be twenty-fold or more. A precautionary approach would be to use a phone with a low value rather than one that only just meets the recommended standard.

Information needs

To be able to act prudently, individuals need a better understanding of the sources of EMFs in order to identify options to limit their exposure. Educational material on EMFs provides this kind of information and gives people and organizations the opportunity to make such informed choices.

Workers at particular risk/with special needs

The European Directive concerning health risks associated with EMF exposure gives the minimum requirements for protection of workers. The exposure limit values (ELVs) as well as actions levels (ALs) give protection as regards to established health effects. However, there are workers that have special needs, for instance workers having declared themselves as wearing an Active Implantable Medical Device (AIMD) and women having declared themselves to be pregnant shall be considered to be persons at particular risk, as stated in Article 5(4). For these workers, the employer shall adapt the measures aimed at reducing risks and where applicable make individual risk assessments.

Where a worker has declared the use of an Active Implantable Medical Device (AIMD), the employer shall carry out an assessment to determine what restriction on where they can work is needed to avoid interference to their implanted device. Advice on how to do this is provided by CENELEC (see EN 50527 and associate parts). It may be noted that the principle underlying the CENELEC guidance is that interference will not occur when the field is below the Reference Levels given in Council Recommendation 1999/519/EC on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). Where a worker has declared to her employer that she is pregnant then the requirements of Council Directive 92/85/EEC on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding apply. The employer shall enable the worker to avoid having to enter areas where exposures exceed the exposure limits for the general public given in Council Recommendation 1999/519/EC, or its subsequent revisions.

Medical implants can be affected by EMF

Both the range and number of medical implants in people of working age has increased during the last decades. At the same time, the population exposure to electromagnetic fields (EMFs) due to the use of electricity and electronic devices has increased. Electromagnetic fields can interfere with medical implants in different ways depending on the appearance and frequency of the field as well as type of implant. In general there are two types of implants: active and passive.

Active implants

An active implantable medical device (AIMD) is surgically introduced into the human body and usually consists of a small battery-powered box with electronic circuitry and leads, electrodes and sensors which detect a biological function and/or deliver some sort of stimulus. The most common are pacemakers, intra-cardiac defibrillators (ICDs), insulin pumps and hearing implants.

How do pacemakers and ICDs work?

A healthy heart produces electrical signals that give the heart a correct cardiac rhythm. If this rhythm is incorrect - in most cases too low - the pacemaker can by its electrodes detect the heart activity (sensing) and if needed send electrical signals to the heart (pacing). The pacemaker can be active in one or many chambers of the heart. See Figure 9.

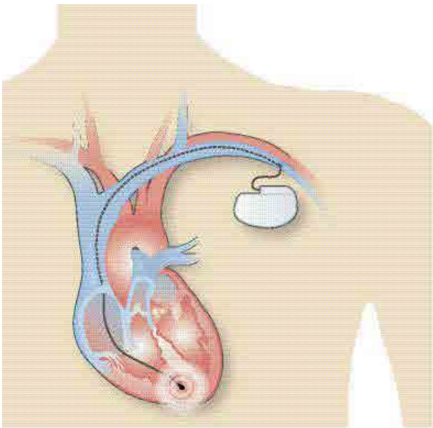


Figure 9
A pacemaker can send electrical signals to the heart.
Illustration by Guldbrand&Guldbrand

ICDs are designed to detect and treat ventricular fibrillation of the heart by sensing the electrical activity of the heart. The ICD can, if needed, send a mild electrical stimulation or an electric shock in order to break the rhythm disorder.

Further reading can be found in the brochure ”Working in electromagnetic fields with a cardiac pacemaker” from the Finnish Institute of Occupational Health.

The paper is available at http://www.ttl.fi/en/publications/Electronic_publications/Pages/Working_in_electromagnetic_fields.aspx.

Infusion pumps

An infusion pump is a person-borne unit for automatic administration of - for instance - medical products or nutrition. The most common use is insulin dosage. The insulin is delivered through a thin hose fitted with a needle attached to the subcutaneous fat of the abdominal wall.

Hearing implants

There are many different types of hearing implant but all are more or less sensitive to external electromagnetic fields. They are all a part of a system where sound is converted to electrical signals. The most common hearing implant is the cochlear implant which consists of an external audio processor and a receiver implanted behind the ear and an electrode connected to the cochlea. The sound picked up by the processor is converted into electrical signals and transported to the receiver and further to the auditory nerve which the brain perceives as sound. See Figure 10.

Figure 10
Cochlear implant is one of the most common hearing implants.
Illustration by Guldbrand&Guldbrand

Passive implants

Passive implants contain no electronic parts but metallic parts and sometimes moving structures. Common devices are joint prostheses i.e., knee and hip prostheses. They are manufactured in plastic, ceramic materials, composite material or non-ferromagnetic metals. Different kinds of nails, screws, pins and plates are often used to fix fractures and are usually also manufactured in a non-ferromagnetic material like titanium or stainless steel.

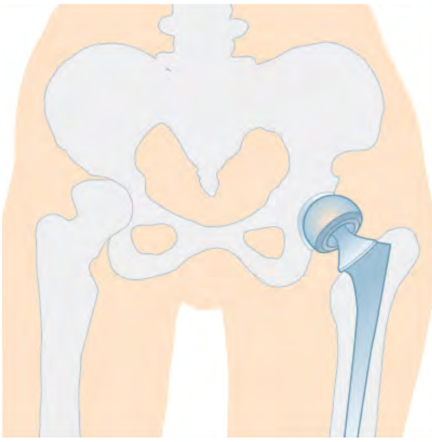


Figure 11
A joint prosthesis replaces a damaged hip joint.
Illustration by Guldbrand&Guldbrand

How do interferences occur?

Active medical implants are in most cases not affected by the electromagnetic fields that we normally encounter in our environment, but in special circumstances - e.g., in an EMF-exposed workplace - a distortion can occur. Different implants react in different ways, for instance, when a modern pacemaker is exposed to a very high external electromagnetic signal it reverts to a pre-programmed rhythm or pulse. Some examples of function disorder that can occur in different types of active implants are given in Table 2.

Table 2 Possible function disorders in some active implants when exposed to EMF

Disorder	Pacemakers	ICDs	Infusion pumps	Hearing implants
Asynchronous pacing, transition to basic frequency	Possible	Possible	-	-
Inhibition of pacing	Possible	Possible	-	-
Transition to max frequency	Possible	Possible	-	-
Inadequate defibrillation shock/	-	Possible	-	-
Inhibiting of defibrillation/	-	Possible	-	-
Pump stop	-	-	Possible	-
Wrong dosage	-	-	Possible	-
False alarm	-	-	Possible	-
Sound sensation	-	-		Possible
Permanent damage of the implant	Unlikely	Unlikely	Unlikely	Unlikely

European standards

There are two types of regulation concerning EMFs and implants. First of all we have regulations for emission limits for electric and electronic devices. Secondly, there are documents that specify the field strength tolerated by the implant before any interference may occur. These guidelines and test procedures are drawn up in a number of European, international and national standards and Directives. The European Committee for Electrotechnical Standardization (CENELEC) has produced a document (EN 50527-1), that gives instructions for risk assessments for workers with active medical implants.

The standard establishes high demands on the AIMD concerning EMF interference. In general, the AIMD can be exposed to EMFs up to the limit for the general public in the frequency range from 1-300 GHz. These limits are stated in Council Recommendation 1999/519.

Some AIMDs can contain ferromagnetic material, even if this is very unusual. A ferromagnetic material can be affected by static magnetic fields (projectile risk) by rapid movement towards the source (for instance a piece of Iron towards a magnet). A newly published review by the ICNIRP stated that no interference with electronic devices has been seen below 0.5 mT which can be seen as a limit in the frequency range less than 1 Hz (ICNIRP 2009). Directive 2013/35/EU provides related ALs for static magnetic fields at 0.5 mT to prevent interference with active implanted devices and 3 mT to prevent attraction and projectile risk in the fringe field of high field strength sources (> 100 mT).

One has to remember that the above discussion is a simplified approach and cannot be taken as a safety limit where no problems can occur. First of all we have to consider individual factors and secondly every AIMD is unique and therefore it is of importance to contact the company that delivered the product to get information about the implant's specific interference properties.

Passive implants are normally manufactured from materials that are not affected by EMFs. However, depending on the construction of the implant, form, size and location in the tissue, a concentration of the field can occur resulting in a temperature increase in nearby tissue. If the implant is less than 20 mm one can assume that no such increase can occur. Some passive implants can contain ferromagnetic material and therefore be affected by static fields. As for AIMDs, a passive implant should not be exposed to static magnetic field levels exceeding 3 mT.

Risk occupations and situations

Returning to work after having an AIMD or even passive implant fitted, a risk assessment should be done at the workplace. Sometimes it can be a very simple procedure, but some workplaces need a more strict procedure that includes EMF measurements. Depending on the emission level and therefore the worker exposure level, workplaces can be divided into different categories from low to high risk levels. In Table 3, some examples of common workplaces/occupations are listed depending on plausible EMF levels and therefore low to high risk for interference. Offices, shops and all kinds of day-care facilities normally have no equipment contributing to potential risks. Some libraries have handheld equipment used for magnetizing/demagnetizing books. This equipment emits quite high magnetic fields that might cause problems. Cooking is normally not a problem, but in some restaurant kitchens, rice cookers or other induction heaters are used and quite high magnetic fields can be found in the immediate vicinity of such equipment.

Table 3 Workplaces with low to high risk for interference on AIMD

Workplace/Occupation	EMF level		
	Low	Medium	High
Office	x		
Shop	x		
Home-based day-care/cleaning	x		
Library		x	
Electric truck driver		x	
Engine driver		x	
Restaurant kitchen (induction hobs)		x	
Roof worker (base station)		x	
Glue drying			x
Induction heating			x
MRI work			x
TMS work			x
Electric welding			x
Plastic welding			x
Surgical diathermy			x
Electrolytic cells			x
Heavy industry			x
Energy production/distribution			x

Risk management of workers with medical implants

The following risk management framework gives generic advice on procedure:
Risk identification: Procedures need to be implemented to ensure identification of workers who have implants, collecting data about the specific implant, and characterization of the EMF field emission sources. According to Directive 89/391/EEC, the worker is obligated to co-operate with the employer to identify possible risks, like the possible interference from EMFs on the AIMD at the workplace.
Risk assessment: The next step in the procedure is to gauge the susceptibility of interference with the device taking actual EMF exposure into account. This step might include experts on EMF as well as medical expertise. Measurement of EMFs at the workplace might be a part of this procedure.
Conclusion and advice: The risk assessment procedure will result in appropriately worded advice that should be given to the worker regarding their safety and any necessary changes of work practices.
Follow up: The result of risk assessment procedures must be kept up to date. The procedure shall be installed to ensure that the employer is informed about any changes in the risk situation. Such a change in the risk situation occurs when the worker receives a new AIMD, when the clinical situation of the worker changes, when the settings of the AIMD change and when the EMF exposure at the workplace changes.
More about the risk management procedure can be found in EU document EN 50527-1.

Electromagnetic hypersensitivity (EHS)

Symptoms attributed to electromagnetic field (EMF) exposure have been reported since the 1970s. The symptoms reported vary widely, as do the sources to which the symptoms are attributed. A number of labels other than "electromagnetic hypersensitivity" have been used, for instance "hypersensitivity to electricity" and "electrical sensitivity". In a WHO workshop in Prague in 2004 the meeting proposed the term "Idiopathic environmental intolerance attributed to electromagnetic fields" (IEI-EMF), a label that has now been established to describe the phenomenon.

> Idiopathic environmental intolerance (IEI) is a comprehensive name for subjective illness with non-specific symptoms attributed to different kinds of environmental agents - chemical, biological or physical - and at levels that are tolerated by most people. The symptoms occur in the absence of consistent objective diagnostic physical findings or laboratory tests to define the illness.

What are the symptoms?

Among the most common EMF-related symptoms are facial skin symptoms (e.g., erythema; sensations of heat, tingling and/or tightness; rashes), neurasthenic symptoms (e.g., dizziness, fatigue, feelings of general discomfort, headache, sleep disorders) and cognitive symptoms (concentration difficulties and memory loss). A variety of other symptoms are, however, also reported by afflicted individuals. It has been observed that groups that attribute their symptoms to different EMF sources to some extent also differ with respect to the symptom picture, but the variation within these groups is still high. People with symptoms attributed to electrical equipment in general tend to report more symptoms than people with symptoms attributed to a single EMF source, and to report more neurasthenic symptoms.

For several individuals with symptoms attributed to electrical equipment in general, the symptoms were first perceived in association with the use of a single EMF source to generalize with time, and the view on EMF-related symptoms as progressive, gradually extending from few sources and symptoms to many is not uncommon.

Prevalence differs between countries

Studies have shown that the prevalence of IEI-EMF among the general public varies between European countries from 1.5 to 5%. Also, the nature of the symptoms differs. In Sweden, skin symptoms predominate whereas in Germany and Austria neurasthenic symptoms were most commonly reported.

Is there an association between symptoms and EMF exposure?

In recent decades a great number of studies have been performed in order to find out if there is a causal association between exposure to EMF and symptoms. Most of the studies have been done in laboratories where the exposure setups were carefully controlled. The most common generated signals in these provocation studies were either mobile phone signals or power frequency fields in order to imitate real life situations of mobile phone calls or being near electrical equipment or power lines. One problem - to find if there is a causal connection between field exposure and symptoms - is, as far as we know today, that we have no biological sensor of weak fields in our body. Consequently, the principal outcomes of the studies were self-reported and measured either the ability to detect if the field was on or off or if the symptoms appeared or increased during the provocation sessions.

Despite several attempts it has not been possible to confirm an association between EMF exposure and symptoms in provocation studies.

Other outcomes – such as effects on reaction times, short-term memory, sleep patterns - have also been tested but with inconsistent results, and overall, no difference could be seen in IEI-EMFs compared to control subjects due to EMF exposure.

However, many studies indicate that people with IEI-EMFs differ from healthy subjects concerning both psychological and physiological aspects and one of the main problems for evaluation of research is the lack of uniform criteria and classification of the phenomenon.

What can be done?

Despite all the research that has been done, IEI-EMF is a poorly defined sensitivity and there are so far no diagnostic criteria. However, the symptoms are real and efforts should be made to improve sufferers' health conditions.

In general a structured approach is advisable which should be designed to:
– provide information
– offer medical help at an early stage
– treat people with severe and long lasting symptoms

In the case of persisting symptoms for which a medical explanation cannot be found, focus on reducing disability rather than searching for a specific causal factor. It is not generally recommended to measure EM fields since there is no scientific support for a causal connection between EMF and symptoms. Read more about IEI-EMF in the WHO 2004 Prague workshop.

Worker information and training

The EU Directive points out the obligation for the employer to train and inform workers about the possible exposure to EM fields and how to work in a safe way. The following is a summary of article 6 of the Directive:

The workers who are likely to be exposed to risks from electromagnetic fields at work and/or their representatives shall get the necessary information and training relating to the outcome of the risk assessment concerning in particular: measures taken in application of this Directive; the results of the assessment, measurement or calculations of the levels of exposure to electromagnetic fields, how to detect adverse health effects of exposure and how to report them; the possibility of transient symptoms and sensations related to effects in the central or peripheral nervous system; circumstances in which workers are entitled to health surveillance, safe working practices to minimise risks resulting from exposure, workers at particular risk.

Risk assessment in general

European Standard EN 50499 specifies how to perform an assessment of the levels of worker exposure to EMF and to demonstrate compliance with the limit values of the old EU Directive (2004/40/EC). The assessment is based on zoning.

To summarize:
– **Zone 0** is a workplace where exposure levels are in accordance with national limit values for general public exposures
– **Zone 1** exposures may be greater than national limit values for general public exposures but will be compliant with the occupational exposure limit

– **Zone 2** exposures may be greater than the occupational exposure limit. If access is possible to Zone 2, then remedial measures to reduce exposure or to restrict or limit access should be taken.

The assessment might include information about product standards and data, technical measurements and numerical calculations.

If the assessment is performed at a workplace, we recommend using the full EN 50499 concept. Note that the approaches outlined in the standard, are intended to be simple, allowing most employers to make an assessment with the minimum of technical knowledge and effort, and cover the Directive's essential requirements, but it was published in 2008 and might be updated depending on the requirement in the new Directive.

Summary

The Directive on the exposure of workers to electromagnetic fields (EMFs) was published in the Official Journal of the EU on 29 June 2013, and the Member States have until 1 July 2016 to transpose the new provisions.

The EMF Directive is part of the "package" of four directives on the exposure of workers to the risks arising from physical agents: noise, vibration, EMFs and optical radiation. It is an individual directive under Framework Directive 89/391/EEC on the introduction of measures to encourage improvements in the safety and health of workers at work.

The new text is based on the recommendations published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 2009 and 2010. It introduces a system of exposure limit values (ELVs) "on the basis of biophysical and biological considerations, in particular on the basis of scientifically well-established short-term and acute direct effects, i.e., thermal effects and electrical stimulation of tissues." However, it does not address long-term effects since there is currently not enough scientific evidence for this. But it provides that the Commission will take into account new scientific knowledge arising from the data in this area.

The Directive also allows for exceptions in medical applications using magnetic resonance imaging (MRI), for some special sectors subject to the Member State's decision, but only if the circumstances duly justify exceeding the ELVs, and this on a temporary basis.

Determination of exposure and assessment of risks

A large number of workers are exposed to high field strengths. Some categories of worker are at special risk, like pregnant workers and workers wearing metal medical implants. Of special interest are workplaces were workers have access and work in close proximity to high power sources, for instance installation and maintenance of field producing equipment, rectifiers (AC/DC converters) in electrochemical processes, induction heating used in alloying smelter furnaces, welding equipment, medical applications, broadcasting antennas and mobile phone masts.

It is the obligation of the employer to carry out a risk assessment to be done by the appropriate services and at regular intervals. The assessment must take into consideration among other things the level, frequency spectrum, duration and type of exposure and possible indirect effects, such as interference with medical electronic equipment and devices, fires and explosions resulting from ignition of flammable materials.

Provisions designed to avoid or reduce risks

Once the action values are exceeded, employers must devise and implement an action plan comprising technical and/or organizational measures intended to prevent exposure from exceeding the exposure limit values (modification of working methods, choice of appropriate work equipment, better design of work stations, etc.).

Worker information and training

Exposed workers or their representatives must receive all necessary information and training, particularly relating to the outcome of the risk assessment, the measures taken by the employer, safe working practices, the detection of adverse effects and the circumstances in which workers are entitled to health surveillance.

Health surveillance

The Directive provides a requirement of appropriate surveillance of the health of exposed workers with the objective of preventing any adverse effects due to exposure to electromagnetic fields. Where exposure exceeds the limit values, a medical examination is foreseen.

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