narda
Safety Test Solutions

# Everything you always wanted to know...

## Safety in electric, magnetic and electromagnetic fields – Basic facts

# Preface

Electric, magnetic and electromagnetic fields exist wherever voltages and currents are present. Broadcasting facilities for radio, television and telecommunications emit electromagnetic fields, as do industrial facilities and medical equipment.
In the case of high-voltage power lines, such radiation is an undesired byproduct, while in telecommunications it is exploited purposefully to transmit information. We tend to use the terms "environmental electromagnetic compatibility" and "electromagnetic fields" (EMF) when referring to fields that influence the environment and particularly humans. Don't confuse EMF with EMC, which relates to the electromagnetic compatibility of equipment. EMC guidelines say how much spurious radiation equipment is allowed to emit and what amount of electromagnetic radiation it needs to withstand. The CE mark is a guarantee of compliance with these guidelines. When it comes to how electromagnetic fields affect humans, we must use different values than are used for EMC.

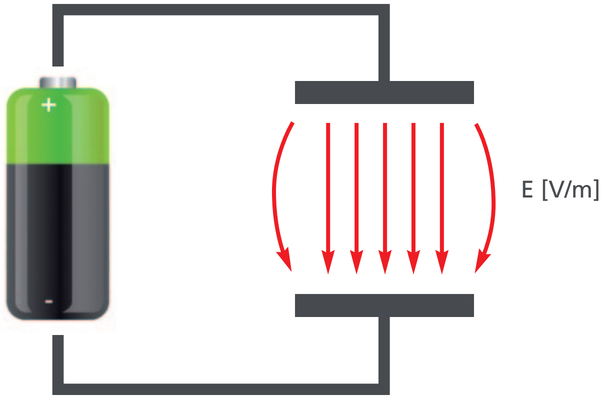
Limits for human exposure are stipulated in the relevant EMF recommendations, standards and regulations. These values are important in occupational safety and for protection of the general public.

This brochure examines the basic principles of EMF. It includes an overview of biological effects that occur in humans due to field exposure and describes protective measures, which by necessity involve measurement of the field levels. While this brochure can help you get acquainted with EMF, it is not intended to replace in-depth training in EMF safety.

**EMC:** Electromagnetic compatibility (relating to devices)
**EMF:** Electromagnetic field (relating to environmental electromagnetic compatibility)
**EMI:** Electromagnetic interference

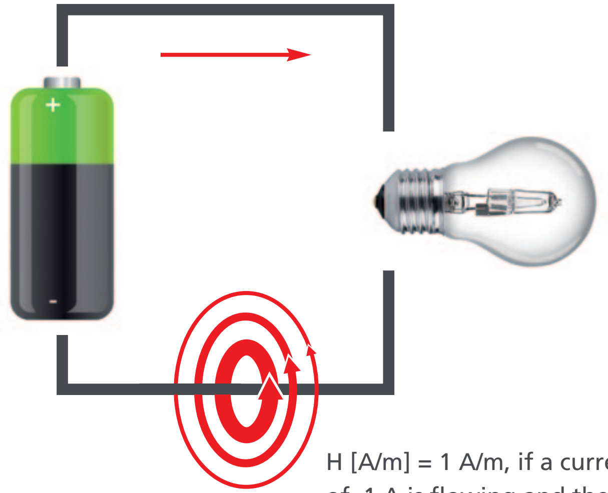
### How electric fields arise

When two metallic plates are connected to a battery, an electric field forms between the plates due to the electric voltage. The electric voltage has units of volts [V]. For example, if a battery generates 1.5 V, then the voltage between the plates will equal 1.5 V. If the plates are located one meter apart, then the electric field strength E between the plates will equal 1.5 volts per meter [V/m].




### How magnetic fields arise

Suppose we connect a lamp to a battery so that it emits light. Current will flow, which is measured in Amperes [A]. A magnetic field will form as soon as current flows. The magnetic field strength H is expressed in amps per meter [A/m]. The field lines are circular, centered on the conductor where the current is flowing.

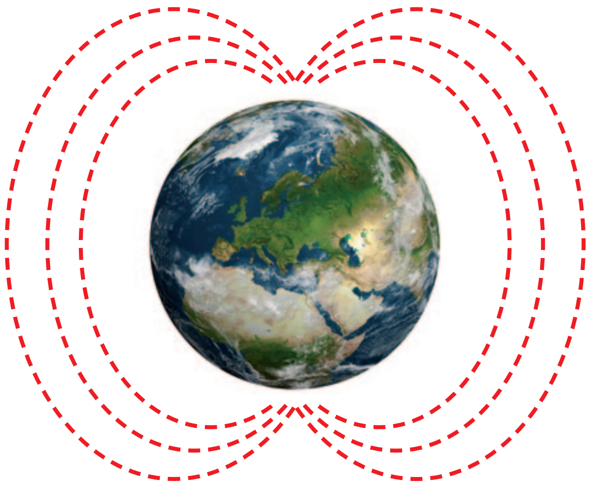



**Electric fields**
are produced in cables even when the equipment they are connected to is not in operation. Magnetic fields are produced when current flows, i.e. when the equipment is switched on.

**A:** Ampere, unit of electric current
**A/m:** Amperes per meter, unit of magnetic field strength
**B:** Magnetic induction or flux density; typically used to describe low frequency magnetic fields
**E:** Electric field
**G:** Gauss, alternative units for B
**H:** Magnetic field
**kV:** 1 kilovolt = 1000 Volt
**kW:** 1 kilowatt = 1000 Watt
**T:** Tesla, units for B
**V:** Volt, units of electric tension
**V/m:** Volts per meter, units of electric field strength
**W:** Watt, unit of power

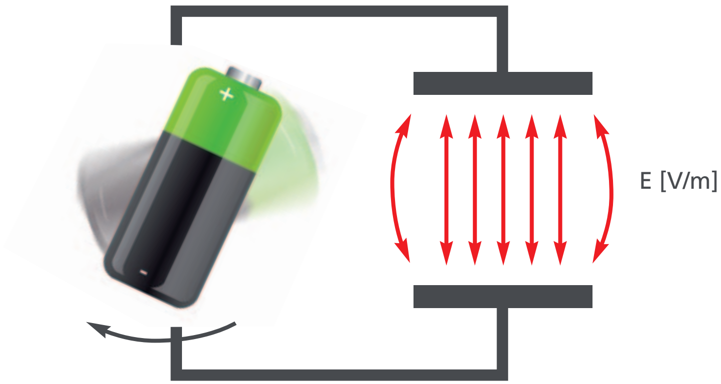
**Static vs. alternating fields**

Electric fields are oriented from a positive pole to a negative pole. Static fields have a polarity that remains constant over time. During clear weather, the earth's natural static field has a value of 0.1 to 0.5 kV/m. During storms, it can increase up to 20 kV/m. Manmade static electric fields are used in powder coating machines, for example.



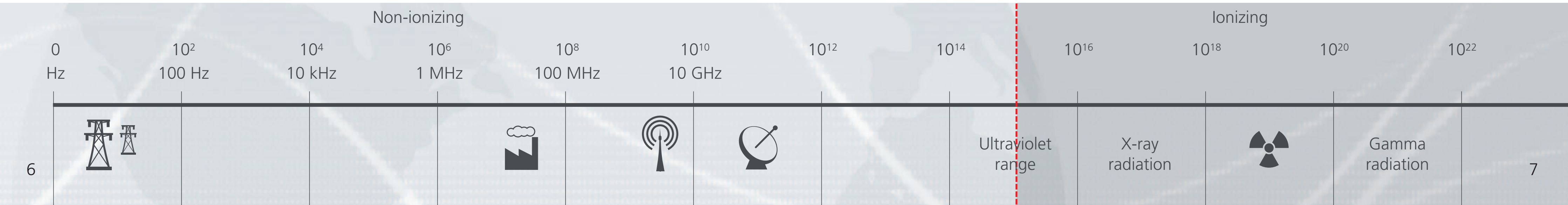
The earth's magnetic field is also static. It has a magnitude of approx. 40 µT (microtesla) in central Europe. Static magnetic fields arise (or are used) in subways and high-speed trains and also in nuclear spin tomography.
The battery in our example above also generates a static field. If we continuously rotated the battery (turning its poles), this would produce an electric field with a continuously changing direction.

This is known as an "alternating field". Two changes of direction produce an oscillation. The number of oscillations per second is known as the "frequency". The frequency of an alternating field is expressed in Hertz [Hz]. If the field changes direction 100 times per second, this produces 50 oscillations and thus a frequency of 50 Hz. This frequency is used for AC power in many countries (60 Hz is also used, e.g. in USA).




**Low frequency (LF) vs. high frequency (HF)**

Alternating fields are divided into low frequency fields (up to about 100 kHz) and high frequency fields (from 100 kHz up to 300 GHz). There are 11 common subdivisions of these two ranges. Above this lie the infrared range, visible light, ultraviolet light, x-rays and gamma radiation. The limit between ionizing and non-ionizing radiation lies in the ultraviolet range. At low frequencies, it is traditional to specify the magnetic flux density in Tesla [T] or Gauss [G] instead of the magnetic field strength. At high frequencies the magnetic field strength is always measured in amperes per meter [A/m].



**Typical applications of electromagnetic fields**

Static electric fields
are used in galvanization, powder coating, metallurgy and metal refining, for example.

Static magnetic fields
are used or arise in nuclear spin tomography, particle accelerators, subways and trains, nuclear reactions and maglev trains (support and guidance magnets).

High frequency electromagnetic fields
are used in cellular radio, broadcasting, satellite communications, radar systems, industrial processes such as melting, smelting, heating, curing and plastic welding, and semiconductor production and microwave systems.

Low frequency fields
typically occur in power systems, industrial processes such as melting, smelting and welding, and electric railways.

In all of these application areas, radiation exposure is possible, so it is important to pay attention to the relevant limits. For reasons relating to occupational safety and environmental protection, it becomes necessary to measure the radiation levels. Regular monitoring is important in some cases. If the relevant limits are violated, protective measures are required as stipulated in the relevant national or corporate guidelines.



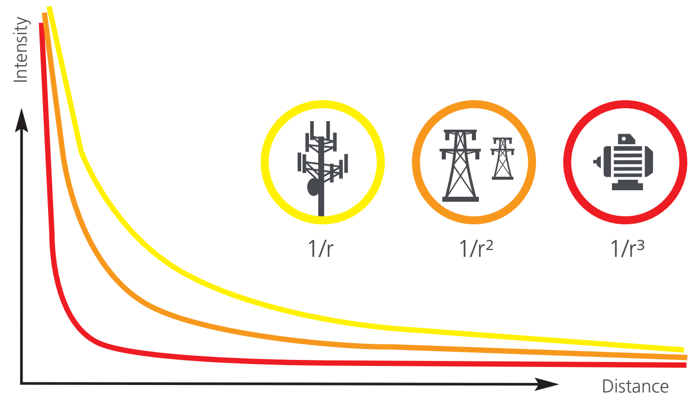


**How far does a field reach?**
Field strength decreases rapidly the further you are from the field source, so keeping your distance is the simplest form of protection.

| Distance from antenna* | Field strength |
|---|---|
| 1 m | 100 V/m |
| 2 m | 50 V/m |
| 3 m | 33,3 V/m |
| 10 m | 10 V/m |

*e.g. dipole antenna, 900 MHz

Warning!
ICNIRP 1998
Occup. limit
exceeded!
!




Electric fields are easy to shield, for example, using a thin, grounded metal foil or a protective suit when it is necessary to work in strong high frequency fields. Unfortunately, low frequency magnetic fields will penetrate most materials unimpeded. Large-scale shielding is extremely costly.

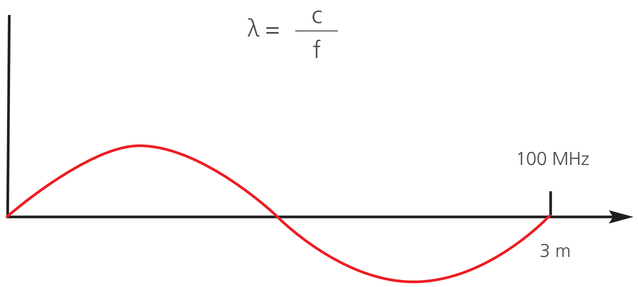
**Field fade characteristics**
(r = distance from field source)

**1/r:**
Single-conductor systems, E and H in far field (typically all wireless communications, such as GSM, pagers, radio, TV)

**$1/r^2$:**
Systems with two or more conductors, B in near field (typically power lines in buildings and transmission lines)

**$1/r^3$:**
Coils, B in near field (typically transformers used in power trans-mission, electric motors, generators)

**Wavelength – critical for defining near and far fields**
Electromagnetic radiation propagates as a wave at the speed of light (300.000 km/s). The higher the frequency, the shorter the wavelength λ. 50 Hz means a wavelength of 6.000 km, 900 MHz (cell phone antenna) means a wavelength of 33 cm and 20 GHz (satellite communications) means a wavelength of 1.5 cm.



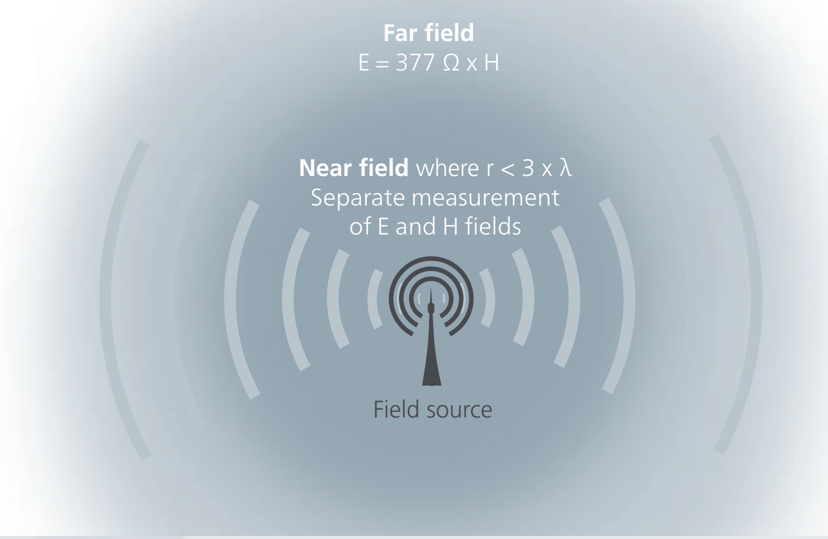

Signals will be picked up particularly well by equipment that has dimensions equal to the wavelength of the transmitted frequency. Let's first consider water waves to get an idea of how this works. For example, small waves do not affect a long log. The log simply floats right across them. Only when the waves are at least half as long as the log, the energy of the motion is transferred to the log and it follows the wave movement completely. This is known as the "resonance effect". Antennas work in a similar way. For example, a domestic antenna is built to handle different frequencies, as shown by the separations and lengths of the elements. These dimensions are based on the wavelength ranges of the signals to be received.

When the distance from the radiation source is less than three wavelengths, we are in the "near field" (rule of thumb). In the low frequency (LF) range, this is almost always the case due to the extremely large wavelengths encountered (6000 km at 50 Hz).
If we are at a distance that is greater than three wavelengths from the source, then we are in the "far field". This distinction between the near and far fields is important when making measurements in the RF & microwave range.
There is an exception for radar antennas due to the large diameter D: Here, the limit between the near and far fields is computed as follows:

$$R > \frac{2\,D^2}{\lambda}$$

For example, if f = 1.7 GHz, λ = 17.7 cm, D = 10 m:

$$R_{Limit} = \frac{2 \times 10^2\ m^2}{0.177\ m} = 1130\ m$$




**λ** wavelength
**c** speed of light
**f** frequency
**D** diameter
**R** distance to transmitting antenna

In the far field, the H field can be calculated from the EW field measurement using the equation:

$$H = \frac{E}{Z_0}$$

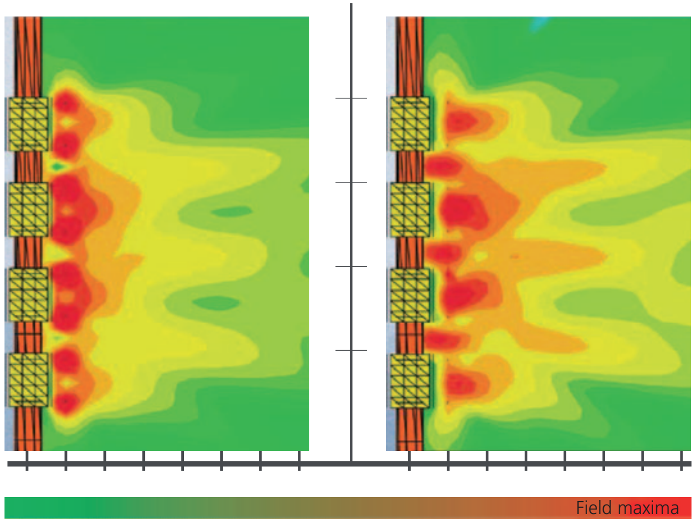
**$Z_0$** is the impedance of free-space. It is equal to 377 Ω (Ohm)

High frequency conversion examples
($E = Z_0 \times H$ under far field conditions)

| E [V/m] | H [A/m] | S [W/m²] |
|---|---|---|
| 5.0 | 0.0133 | 0.0663 |
| 10.0 | 0.0265 | 0.2653 |
| 50.0 | 0.1326 | 6.6313 |
| 100.0 | 0.2653 | 26.5252 |

**Properties of near and far fields**
In the near field, the ratio of the electric and magnetic fields is not constant, as can be seen in the figure below. Close to the antenna, there are regions where the there is virtually only an electric field or a magnetic field. This is why we have to measure the two components E and H separately.

Distribution of field intensity in the near field of a VHF transmitter (100 MHz)




Varying field distribution of local maxima in the H field

Varying field distribution of the local maxima in the E field

At increasing distances, however, the ratio of the electric and magnetic radiation tends more and more towards a constant value. This means in the far field it is no longer necessary to measure the E and H fields separately in case of electromagnetic radiation. We can just measure one component and calculate the other one. Besides the E and H field strengths, we can also compute the power density S in watts per square meter [W/m$^2$] or [mW/cm$^2$] under far-field conditions. For example, we get S by multiplying the electric and magnetic field strengths: S = 50 V/m x 0.1326 A/m = 6.6313 W/m$^2$.





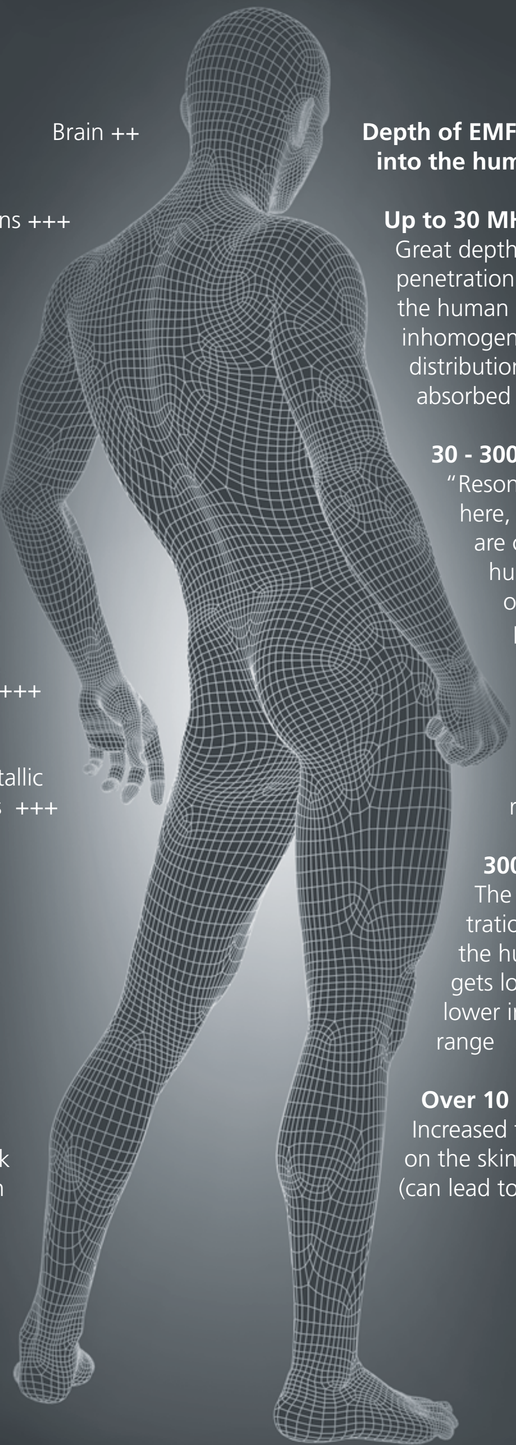
Electromagnetic fields can have certain biological effects which may be detrimental to human health. A biological effect has occurred in humans if the influence of electromagnetic radiation produces physiological changes in the biological system which can be detected in some way. A health impairment occurs if the influence goes beyond what the body can normally compensate for.

The effects of electromagnetic fields depend on:
- the frequency
- the field strength
- the field type (E or H field)
- the duration of exposure
- the extent of exposure (part of body or entire body)
- the signal shape



**Effects of high frequency fields** (HF)
HF fields of frequencies between 1 MHz and 10 GHz penetrate body tissue and the absorbed energy heats it up. The depth of penetration decreases at higher frequencies. Since the heating occurs from the inside, it is not felt (or it is felt too late) because we feel heat primarily through receptors situated near the skin surface. The body can cope with heating resulting from small amounts of HF energy through its normal thermoregulation processes.
HF fields above 10 GHz are absorbed at the skin surface. Only a small portion of the energy penetrates into the underlying tissue. Very high field strengths are needed to produce problems such as cataracts or skin burns. These will not occur in normal everyday exposure to radiation, but can occur in the immediate vicinity of powerful radar systems, for example. Such facilities are generally fenced off over a wide area.

Energy absorption in tissue due to HF fields is specified by the specific absorption rate (SAR) within a certain mass of tissue, measured in units of watts per kilogram [W/kg]. Limits for HF fields are based on the SAR.




**Depth of EMF penetration into the human body**

**Up to 30 MHz**
Great depth of penetration into the human body; inhomogeneous distribution of absorbed power

**30 - 300 MHz**
"Resonance range"; here, the wavelengths are close to the typical human size (or that of individual body parts). Most of the field energy is absorbed, so the lowest exposure limits are specified for this frequency range

**300 MHz -10 GHz**
The depth of penetration of EMF into the human body gets lower and lower in this range

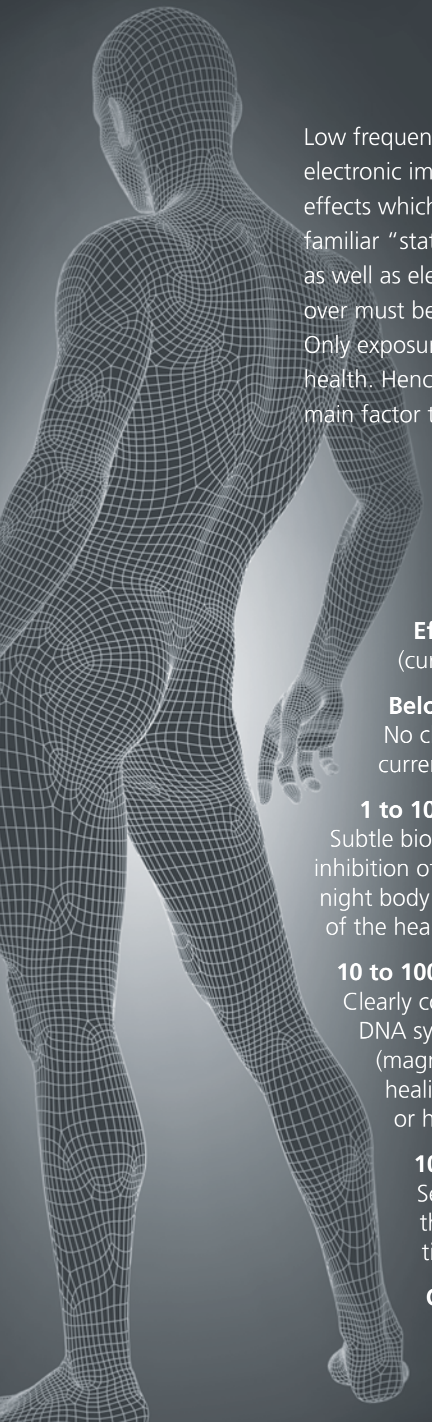
**Over 10 GHz**
Increased temperature on the skin surface (can lead to burns)



The long-term effects of low intensity HF radiation are currently being studied as part of an international EMF project sponsored by the World Health Organization (WHO). Previous scientific studies have not managed to agree on whether exposure to HF fields can cause cancer or make it more likely. Other effects on cells, enzyme activity and genes have been detected under certain conditions (frequency, signal shape, intensity). However, it is still unclear whether any of these effects actually influence human health. Research continues in this area.

The extent to which a body part will absorb heat caused by HF fields depends on the blood circulation and thermal conductivity. For example, our kneecaps and the lenses in our eyes are particularly susceptible since they have little or no circulation. In contrast, the heart, lungs and skin are not very sensitive due to their excellent circulation. However, the secondary effects of fields can indirectly affect our health. For example, mobile phones can influence navigation equipment in airplanes, and the function of electronic implants like pacemakers can also be impaired by radiation from HF equipment and antennas.

**Effects of low frequency fields**
Low frequency magnetic fields cause currents to flow in the body, and in the case of low frequency electric fields, we speak of "induced body currents". The predominant effect is stimulation of nerve and muscle cells.
Low frequency limits are based on the current density model, which basically explains how the stimulating current density depends on the frequency.
In low frequency fields, we mostly see frequency dependent stimulation of sense, nerve and muscle cells. The greater the field strength, the more pronounced the effects. While the human organism can withstand weak interactions, more intense signals can result in irreversible damage to health in some cases.
It has not yet been clearly established whether low level LF fields increase the incidence of cancer. Scientific studies on the effects of low frequency fields are being carried out around the world.



Low frequency fields can also influence pacemakers and other electronic implants. There are also specific limits for these secondary effects which must not be exceeded. Static fields can produce the familiar “static electricity” which causes our hair to stand on end, as well as electrostatic discharges. The possibility of voltage spark over must be taken into account when in strong static E fields. Only exposure to very powerful magnetic fields (> 4 T) affects health. Hence, the force exerted on ferromagnetic objects is the main factor to be considered when setting limit values.

**Effects of low frequency fields on the human body**
(current density in mA/m²)

**Below 1**
No clear effects; within the range of natural background current densities in most organs

**1 to 10**
Subtle biological effects such as altered calcium flows or inhibition of melatonin production (which controls our day/night body rhythm, etc.). The background current density of the heart and brain are in this range.

**10 to 100**
Clearly confirmed effects, e.g. changes in protein and DNA synthesis, changes in enzyme activity, clear visual (magnetophosphenes) and possible nervous effects; healing processes in broken bones can be accelerated or halted.

**100 to 1000**
Sensitivity of the central nervous system is altered; this is a range in which effects are observed in all tissue that is capable of stimulus.

**Over 1000**
Minor to severe impairment of heart function; acute damage to health





**Limits and regulations for human safety**
To help avoid damage to human health as a result of exposure to electromagnetic fields, organizations such as the ICNIRP have authored a number of different international guidelines and standards. ICNIRP stands for the “International Commission on Non-Ionizing Radiation Protection”. The ICNIRP is a non-governmental organization comprising independent scientists from the whole world. It works closely with the World Health Organization (WHO).

**How are EMF limits determined?**

Research investigates the biological effects

▼

Scientific bodies, e.g. ICNIRP, determine the potential risks

▼

Agreement on basic limits

▼

Derivation of international and national permitted limit values



The latest basic limit values result form considering the short-term effects. There are still many studies under way concerning the long-term effects, but with no conclusive results so far, so there are no recommendations in this area as yet.
Since the basic limits can only be measured using expensive laboratory techniques, reference limits that are easy to measure have been derived from them.

**Units for basic limit values**

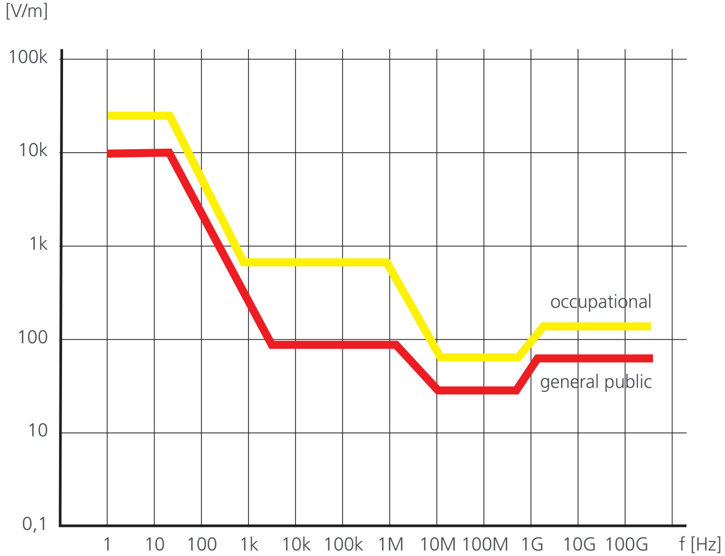
For high frequencies:
specific absorption rate **SAR** in **W/Kg**

For low frequencies:
Current density **J** in **mA/m²**

Derived limit values:
**E field** in **V/m**
**H field** in **A/m** or **B field** in **T** or **G**
Power flux density **S** in **mW/cm²**

Individual countries have different approaches to the limits stipulated in the various regulations, standards, norms and recommendations. In general, limits for the general public are more stringent than those that apply to occupational exposure since it is assumed that workers are experienced and regularly informed. They will know about potential radiation sources and protective measures and have access to suitable test equipment. An EMF safety concept should be in place, which includes basic EMF information and safety precautions. Since this is cannot be assumed for the general public, the limit values are lower to protect them.

EMF limit value curves ICNIRP 1998




**Measurement – The first step in effective protection**
Many different combinations of high frequency and low frequency radiation can be present in the work environment. Suitable measuring devices are the only way to accurately assess EMF exposure. It is difficult to accurately simulate or compute fields since they can be amplified as a result of complex reflection patterns. Leaks in antenna lines can only be detected by measurement. Preventive safety begins with the choice of location for production facilities and equipment that produces electromagnetic fields. Workplaces where limits might be violated need to be equipped with proper safety equipment. Personnel that will be operating, managing and monitoring equipment that produces electromagnetic radiation needs to receive training in the relevant safety measures, which should include the following:

- Basic principles of electromagnetic radiation
- Measurement methods, test equipment and preventing measurement errors
- Practical training in making measurements and logging results
- Individual protective measures
- What to do if limits are violated



**EMF limit value curves from international organizations:**

**ICNIRP** (International Commission on Non-Ionizing Radiation Protection)

**IEEE** (Institute of Electrical & Electronics Engineers)

**CENELEC** (European Committee for Electrotechnical Standardization)

**Not the same as product standards**
Besides environmental standards, equipment standards also exist, which stipulate the maximum permissible radiation for e.g. monitors (e.g. TCO). The CE mark confirms that a given device has proper radiation immunity. This ensures that different devices will not interfere with one another. This seal of quality applies to products. It has nothing to do with health issues or occupational safety.

**Important protective measures when limits are exceeded**
The hazardous area needs to be secured by suitable organizational procedures, which might include fixed measurement systems. Depending on the extent of the hazard, this can also involve locks, shielding or enclosures to ensure that the proper distance is maintained. A warning sign must also be provided.
If the hazardous area must be entered (e.g. for maintenance work), different rules may apply depending on the relevant standard or operating instructions, such as:

- Selecting a time frame when the system utilization is lower so the EMF emissions are reduced
- Regulations for approaching the field source
- Possible reduction in power levels, or
- Complete system shutdown

People who enter such hazardous areas should wear protective gear and carry a measuring device or personal monitor along with site access plans. Many system operators require that protective clothing is worn when working on broadcasting facilities. It is also important that any procedural regulations in force in the country (or facility) in question are followed. When working on transmitting equipment, a personal monitor is just as essential as a gas detector is when working underground in a mine.



**Requirements for EMF measuring devices**
Depending on the frequency range, EMF measuring devices must be capable of determining electric field strength E, magnetic field strength H, magnetic flux density B and power density S. Such devices must also meet the requirements stipulated in standards and include features such as averaging, RMS values, peak values and isotropic (non-directional) probes. Advantages are provided by practical features, including data memories, alarm functions, automatic zero alignment and straightforward operation.

**Preparing for measurement**
- Get the technical specifications for the field sources from the operator (frequencies, generator power, radiation characteristics, modulation, line currents and voltages).
- Determine the exposure conditions and information about the exposed persons (locations and times, shifts, groups).
- Establish the assessable operating status of facilities with variable operating parameters.
- Select the measurement methods and test equipment depending on the technical conditions and local regulations.
- Perform a function check and zero adjustment of the test equipment, and make sure that the manufacturer's recommended calibration interval has not run out.
- Make an estimate of the expected field strength or power flux density so that any necessary protective measures can be taken and the right test equipment and probes can be selected.

**Measurement procedure**

Get information about the object of the measurement
▼
Preliminary measurement
▼
General analysis of the facility
▼
Set the reference points and work areas
▼
Determine the outline conditions
▼
Make the measurement
▼
Produce a record

**Making the measurement**
Measurements need to be made at the maximum power level that occurs during operation. If this is impossible, the values should be extrapolated accordingly. When measuring in work areas, no one should be present since the human body can influence fields (and cause measurement errors). The person making the measurement should not stand between the field source and probe or antenna during the measurement. Measuring devices that can be remotely controlled are very useful here.

A broadband measurement detects all of the signals that are present within a certain frequency band. The overall exposure affecting the human body can be seen in this way.



**What test equipment is needed, and when?**

**Personal safety**
Personal monitor; handy, practical, weighted frequency response, essential when working on HF equipment, simple to operate (switch on and monitor)

**For general measurements complying with EMF standards:**
Broadband EMF test equipment with exchangeable E field and H field probes for measuring the entire spectrum (that the body is also exposed to)

**For identifying and correlating frequency and field strength:**
Selective EMF test equipment which displays the entire spectrum and shows each frequency and its associated field strength separately.

Special "shaped probes" can be used to measure the total exposure as a percentage of the relevant limit. This avoids time-consuming calculations and comparing the results with limit tables.
A selective measurement is used to determine the percentage contribution of individual frequencies to the overall exposure level. An overview measurement determines the frequencies of the predominant signals, after which a measurement can be made at each relevant frequency. A frequency selective system is ideal for such measurements. The measured values are displayed directly as field strength vs. transmitted frequency.
A record of the measurements must be produced after the measurement. It should include all of the details required by the relevant local or national regulations.

**Peculiarities of high frequency fields**

Since it is impossible to precisely determine the propagation direction of waves in a free field, isotropic probes must be used. This is even more important when making measurements in environments involving multiple field sources.
To suppress brief, irrelevant limit violations, results are averaged – over an interval of 6 minutes as required by many standards – using the averaging function provided in the measuring device.

Hot spots (e.g. under antennas) and blank spots due to standing waves and reflections can result in local field maxima and minima. This sort of problem can be handled using a higher density of test points and by making measurements near to objects that cause reflections.

The field distribution is rarely homogeneous. Reasons for this include reflections due to neighboring antennas, buildings with metallic panels, screens, fences and cranes. To assess full-body exposure, measurements at multiple locations must be made. The quadratic mean (spatial average) of these values is then determined. This is a pushbutton function provided by superior test equipment.



Because of its size, the human body responds differently to EMF depending on the frequency of the field source. This is why human safety limits vary according to frequency. After the measurement, the field strengths at the different frequencies must be evaluated. The latest measuring devices use "shaped probes" to automatically provide this kind of frequency response evaluation. The device then displays the exposure level as a percentage of the relevant limit. When using shaped probes, you don't need to know anything about field strength limits and frequencies. This type of equipment is particularly useful in multi-frequency environments.

The usual modulation types, such as amplitude modulation (AM, low modulation factor), frequency modulation (FM) and digital modulation (GSM, UMTS) do not affect the measurement result very much. But the opposite is true for pulsed signals used in radar facilities; here, thermocouple probes are very useful for making precise measurements of EMF radiation with extreme pulse/pause ratios. These probes are much better at determining RMS values than diode probes, for example.

If measurements have to be made in the presence of high field strengths or if long-term measurements are needed, the measuring device should include a data memory and/or an optical interface for remote control and data readout.

The human body can also affect the measurement result in HF fields. Resonance overshoots and blank spots can occur with E and H fields depending on the frequency, body size and distance to the measuring device. Separate measurement of the E and H fields avoids gross underestimation of the values. Overestimation of field strengths at certain frequencies is unavoidable, but this is acceptable in the interests of "safety first". Measurements should be made as far as possible from the body, e.g. with the arm outstretched or using a tripod and remote control of the measuring device.

## High frequency field source examples

### Radio, broadcasting

The E and H fields must be recorded separately in the near-field region of antennas. Often, several antennas broadcasting different services at different frequencies are mounted close together (e.g. on a TV transmitter tower). The use of a shaped probe simplifies the measurement considerably.

### Searching for leaks

Waveguides and rotating couplers in antenna lines are subject to a lot of wear and tear and must be checked regularly. Very high field strengths can occur when there is a fault. Virtually destruction-proof sensors are needed to measure these levels.

### Radar

Test equipment that can tolerate high drive levels is needed to make accurate measurements of extremely high pulse power levels. True RMS devices (e.g. with thermocouple sensors) are usually preferred.



### Cellular radio (mobile phones)

The large number of base stations and the kind of signal modulation used means that cellular radio equipment is looked at very closely scientific bodies and regulatory authorities. Special precautionary measurements can be made to extrapolate to the maximum possible field strength when the base station is fully loaded.

### Satellite communication

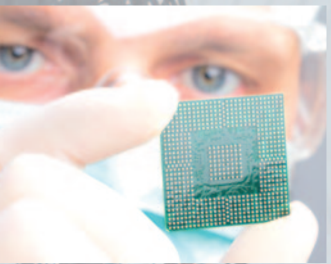
Generally, very low field strengths are found around terrestrial stations. The test equipment and probe used therefore must have excellent measurement sensitivity.

### Melting/smelting

High magnetic field strengths can occur in melting/smelting processes. The field strengths increase greatly close to the field source. To protect personnel and test equipment, industrial ovens should be approached slowly and with caution.

**Heating & tempering**
Systems for heating metals operate in different frequency bands. The frequencies used differ according to the production conditions. High magnetic field strengths can also occur. The measuring device must have a wide measurement and frequency range.

**Welding**
Very high field strengths can occur locally close to the welding electrodes. The E and H fields must be measured separately.



**Semiconductor production**
Semiconductor production facilities tend to use specific ISM frequencies, e.g. 13.56 MHz, 27.12 MHz, 2.45 GHz (ISM stands for industry, science and medicine). The E and H fields must be measured separately to verify compliance with the relevant limits.

**Microwave oven**
Wear and tear can cause leaks around the door seals, supply cables and the RF source, so regular checks must be made.

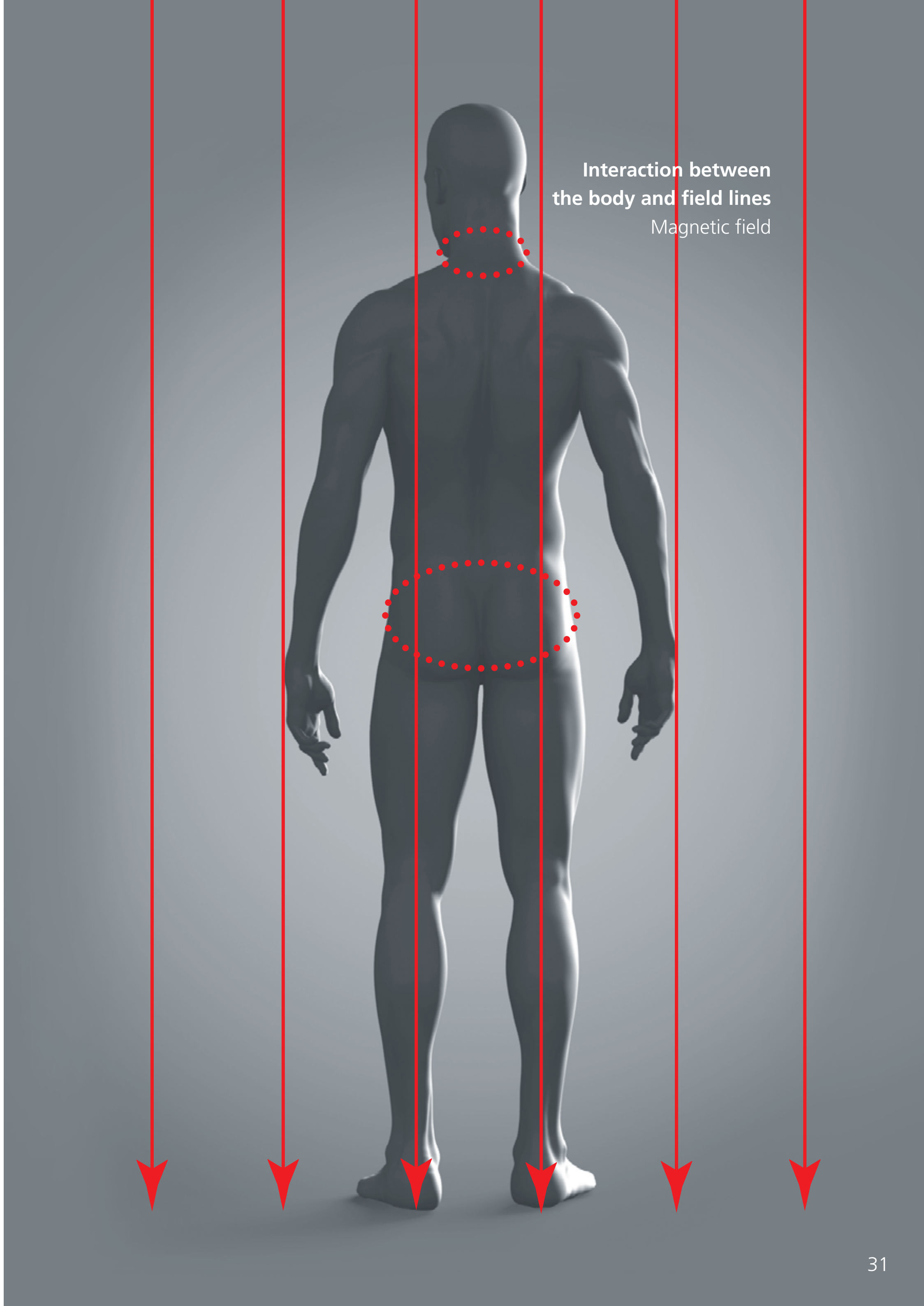
**Peculiarities of low frequency fields**
The electric and magnetic fields must be measured separately for low frequency (LF) fields because the two components are independent of one another, and we are almost always in the near field region. It is usual to find several field sources producing low frequency radiation in industrial environments. Isotropic (non-directional) measurements are needed to measure the radiation exposure properly. With a single axis probe, this means holding the measuring device in three different directions and calculating quadratic mean (or root sum square RSS) of the results. This is unnecessary with measuring devices with isotropic probes with sensors designed to measure all three spatial directions simultaneously.

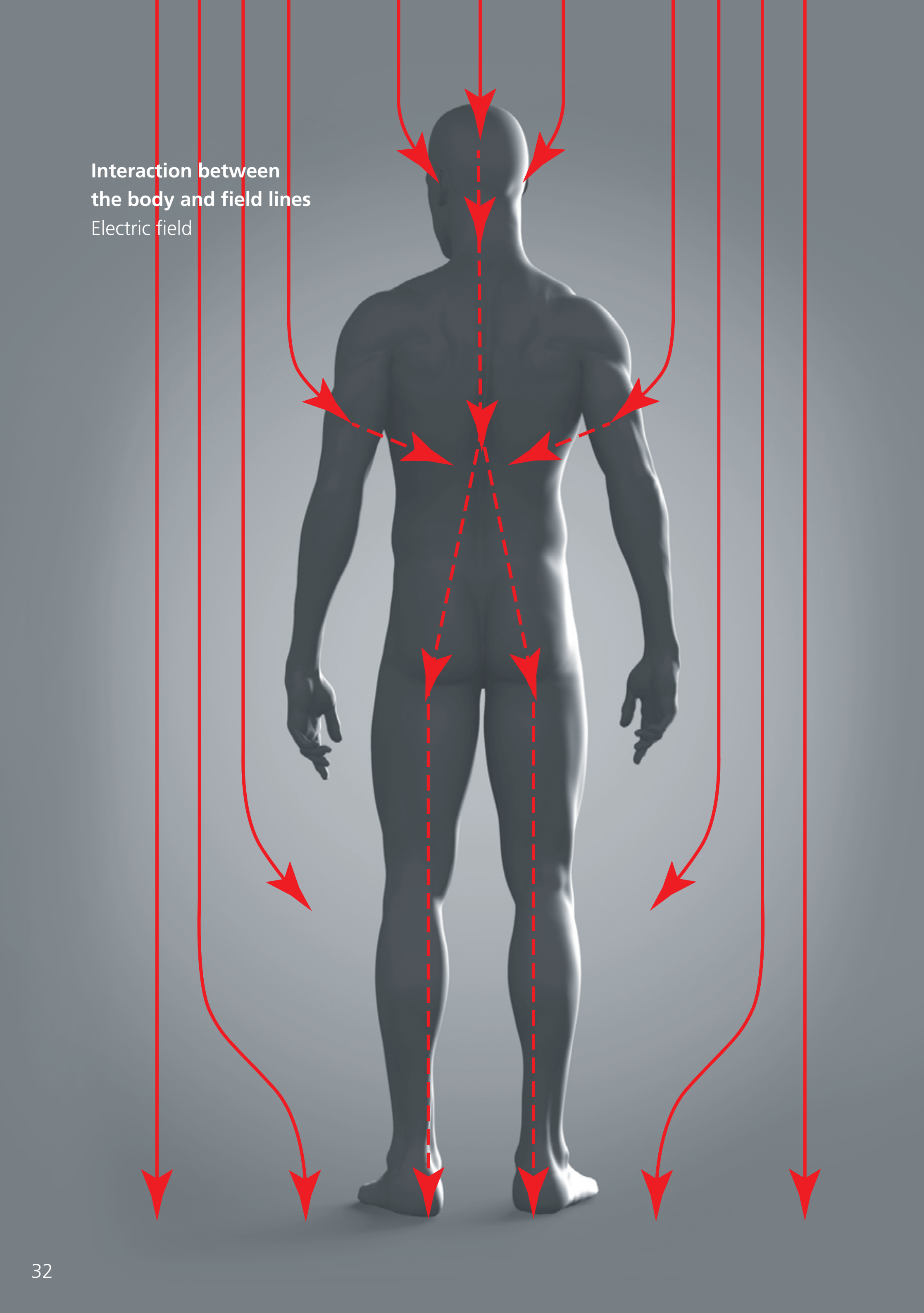
Broadband measuring devices show the overall exposure for all of the field strengths within a specified frequency range. Individual signals can be assessed selectively using filters or calculations or analyzed in terms of their frequency components using computational techniques (e.g. fast Fourier transformation). Some measuring devices provide convenient band pass and band stop filters along with suitable spectrum analysis methods. Measurements according to national and international or EU standards can be made easily by applying special frequency response curves (shaping).

Multi-frequency signals in the LF range can be assessed quickly with spectrum analysis. The time-domain version of the signal captured using a probe is automatically transformed into the frequency domain using a fast Fourier transformation (FFT). The spectral components are analyzed at the same time. A look at the spectrum quickly reveals the distribution of the field strengths, fundamental frequency and harmonics.

To assess exposure to low frequency fields properly, it is often necessary to have in-depth knowledge of the field and the measuring devices. Measurement methods that automatically evaluate the frequency response (weighted peak, or shaped time domain = STD) can greatly simplify everyday work. The way the limit values depend on frequency is automatically taken into account. Suitable detectors are needed to measure the RMS and peak values. When making isotropic measurements, the phase of the individual components is taken into account.
The B or E field is measured in real time and displayed as a percentage of the limit over the entire frequency range. Signals occupying one or more frequencies are evaluated correctly, as are pulsed signals.
Whereas ambient conditions have little effect on the magnetic field, the presence of people, condensation, humidity and/or fog can affect the electric field. To eliminate any possible influence by the body (particularly by the test personnel), measurements must always be made at a proper distance, using remote E field measuring devices or probes with a tripod if necessary.

If field strength levels need monitoring or long term measurements are needed, use a measuring device with a data memory. The measurement results can then be transferred over the device’s optical interface to a PC for further analysis. Remote control is usually also possible using these interfaces.





**Interaction between the body and field lines**
Electric field



## Examples of low frequency field sources

### Power supply

The magnetic field predominates around transformers, while the electric field dominates around transmission lines. As more and more transmitting facilities are installed on high-voltage pylons, carrying a personal monitor to check for the presence of HF fields when working on such equipment has become essential.

### Railways & transport

Magnetic fields can interfere with safety equipment or computer facilities. Railway communication systems need to be tested and monitored regularly using proper RF test equipment.

### Industrial applications

Production systems used for heating, melting, smelting and welding need to be tested by making magnetic field measurements close by to ensure compliance with occupational safety regulations.

- **Guidance on Determining Compliance of Exposure to Pulsed Fields and Complex Non-Sinusoidal Waveforms below 100 kHz with ICNIRP Guidelines**
  International Commission on Non-Ionizing Radiation Protection 2003. Download from www.icnirp.org

- **Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields**
  (up to 300 GHz), International Commission on Non-Ionizing Radiation Protection (ICNIRP), published in: Health Physics, Vol. 74, No.4, pp. 436-522, April 1998

- **Guidelines on Limiting Exposure to Non-Ionizing Radiation**
  International Commission on Non-Ionizing Radiation Protection (ICNIRP) and World Health Organization (WHO), July, 1999;
  ISBN 3-9804789-6-3

- **Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields**
  (0 Hz to 300 GHz) (1999/519/EC). Official Journal of the European Communities L 199/59, 30.7.1999

- **Directive 2013/35/EU of the European Parliament and the of Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).**
  Official Journal of the European Union L 179 of 29 June 2013

- **EN 62311:2008: Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields**
  (0 Hz - 300 GHz) (IEC 62311:2007, modified)

- **EN 62233:2008: Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure**
  (IEC 62233:2005, modified)

- **Regulation for execution of the Federal Immission Protection Act (Regulation on Electromagnetic Fields)**
  (in German; 26. BImSchV) Bundesgesetzblatt 1996 I 66, Bonn, December 1996

- **RF Radiation Handbook** (2nd Edition), October 2001, by Ron Kitchen. Published by Butterworth-Heinemann, ISBN 0750643552




**Internet addresses**

Narda Safety Test Solutions:
**www.narda-sts.com**

World Health Organisation (WHO), EMF Projekt:
**www.who.int/peh-emf/**

International Commission on Non-Ionizing Radiation Protection:
**www.icnirp.org**

You can find an up to date list of important standards, laws and regulations for each country under:
**www.who.int/docstore/peh-emf/EMF-Standards/who-0102/worldmap5.htm**

**A**

Alternating current / voltage:
: Constantly changes direction

Ampere [A]:
: Unit of electric current

Ampere per meter [A/m]:
: Unit of magnetic field strength

**C**

Calibration:
: Checking instruments against national standards

CE mark
: Indicates compliance with EMC guidelines

Current density:
: Measured in A/m

**D**

Direct current:
: Flows constantly in one direction

**E**

E: Designates electric field strength

Electric field:
: Occurs e.g. in all supply cables even if the device is switched off

Electric field strength (E):
: Measured in volts per meter [V/m]

Electric tension (voltage):
: Expressed in units of volts

Electric current:
: Expressed in units of amperes [A]

EMC:
: Electromagnetic compatibility (of devices)

EMI:
: Electromagnetic Interference

EMF:
: Electromagnetic fields. Also used to describe environmental electro-magnetic compatibility (as opposed to electromagnetic compatibility of devices, EMC)

**F**

Far field:
: Distance from radiation source is more than three wavelengths

Frequency:
: Expressed in units of Hertz [Hz]

**G**

Gauss [G]:
: Alternative unit of magnetic induction

Gigahertz [GHz]:
: 1 billion Hertz

**H**

H: Designates magnetic field strength

Hertz [Hz]:
: Unit of frequency of alternating current / voltage

High frequency (HF):
: from 100 kHz to 300 GHz

**I**

Isotropic:
: Non-directional (three dimensional)

**K**

Kilohertz [kHz]: 1000 Hertz

Kilovolt [kV]: 1000 volts

Kilowatt [kW]: 1000 watts

**L**

Low frequency (LF):
: Up to 100 kHz

**M**

Magnetic field:
: Occurs when current flows

Magnetic field strength (H):
: Measured in amperes per meter (A/m)

Magnetic induction or flux density (B):
: Measured in Tesla [T] or Gauss [G]

Megahertz [MHz]:
: 1 million Hertz

**N**

Near field:
: Distance from the radiation source is less than three wavelengths

National standard:
: Measurand specified by national institutions

**P**

Power:
: Measured in watts [W]

Power density:
: Measured in watts per square meter [W/m$^2$]

**S**

SAR:
: Specific absorption rate (radiation power converted to heat referred to body mass), measured in W/kg

**T**

Tesla [T]:
: Unit of magnetic induction

**V**

Volt [V]:
: Unit of electric tension

Volts per meter [V/m]:
: Unit of electric field strength

**W**

Watt [W]:
: Unit of power

# THE NARDA RANGE OF MEASURING DEVICES

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