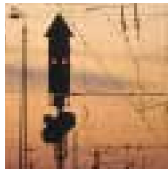
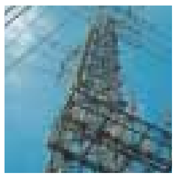
Basic insights

Safety in electric, magnetic and electromagnetic fields



- Fundamental principles
- Biological effects
- Regulations and standards
- Protective measures



narda
Safety Test Solutions
an L3 Communications Company

FOREWORD

EMC:
Electromagnetic compatibility (relates to equipment)

EMF:
Electromagnetic fields (relates to environmental electromagnetic compatibility)

EMI:
Electromagnetic interference

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.

When it comes to fields which influence the environment and particularly humans, we tend to use the terms “environmental electromagnetic compatibility” and “electromagnetic fields” (EMF).

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.

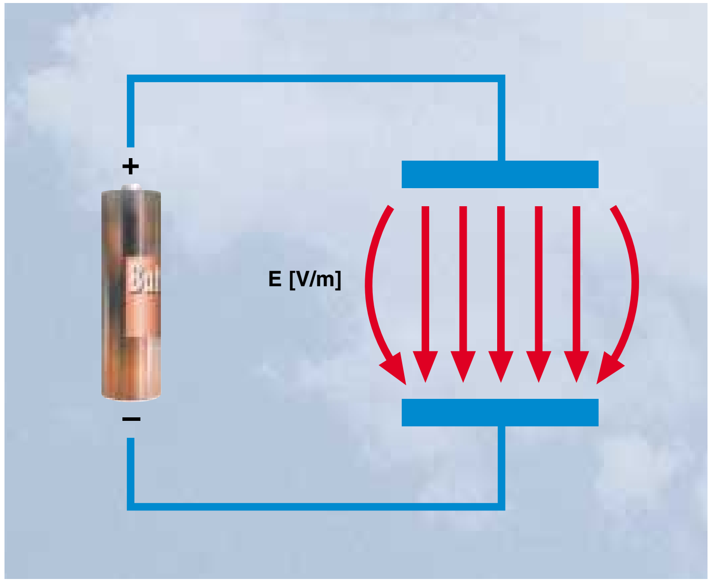
CONTENTS

Electric fields are produced in cables even when the equipment they are connected to is not in operation.

Magnetic fields are produced whenever current flows, meaning only when the equipment is operated.

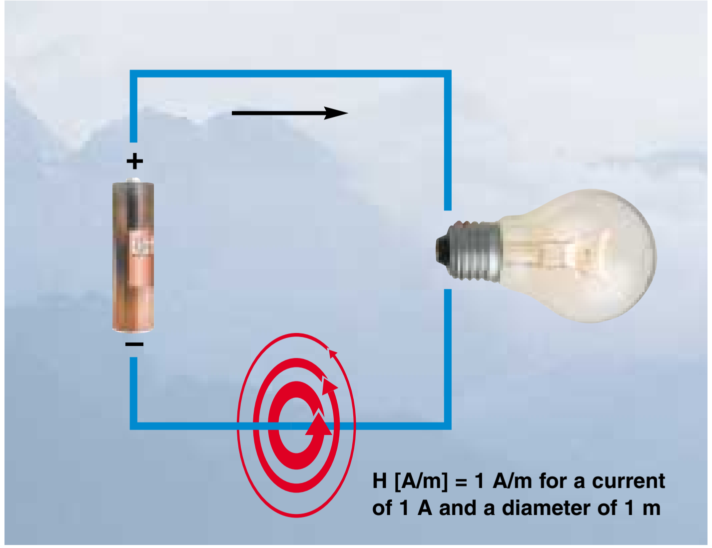
How electric fields arise
When two metallic plates are connected to a battery, an electric field is formed between the plates due to the electric voltage. The electric voltage has units of volts [V].

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 an incandescent lamp to a battery so that it emits light. Current will flow, which is measured in amperes [A]. As soon as the current begins to flow, a magnetic field will be produced. The magnetic field strength H has units of amperes per meter [A/m].

The magnetic field lines assume a circular shape around the conductor the current is flowing through.



Voltage x current = power
Say that the electric voltage in our lamp example is equal to 1.5 V and the current is equal to 1 A. We can compute the resulting power in watts [W] as follows:
1.5 V x 1 A = 1.5 W.

V:
Volts (unit of electric voltage)

kV:
1 kilovolt = 1000 volts

E:
Electric field

V/m:
Volts per meter (unit of electric field strength)

A:
Ampere (unit of electric current)

H:
Magnetic field

A/m:
Amperes per meter (unit of magnetic field strength)

W:
Watt (unit of power)

kW:
1 kilowatt = 1000 watts

B:
Magnetic induction or flux density (typically used with low-frequency magnetic fields)

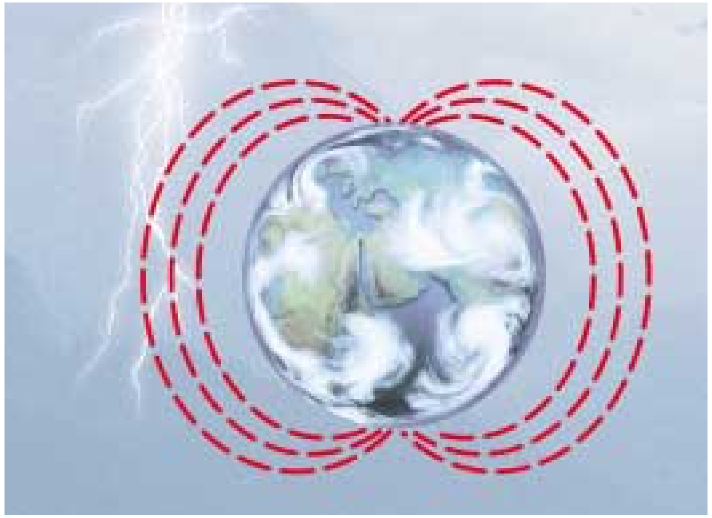
T:
Tesla (unit of B)

G:
Gauss (alternative unit of B)

Static fields vs. alternating fields

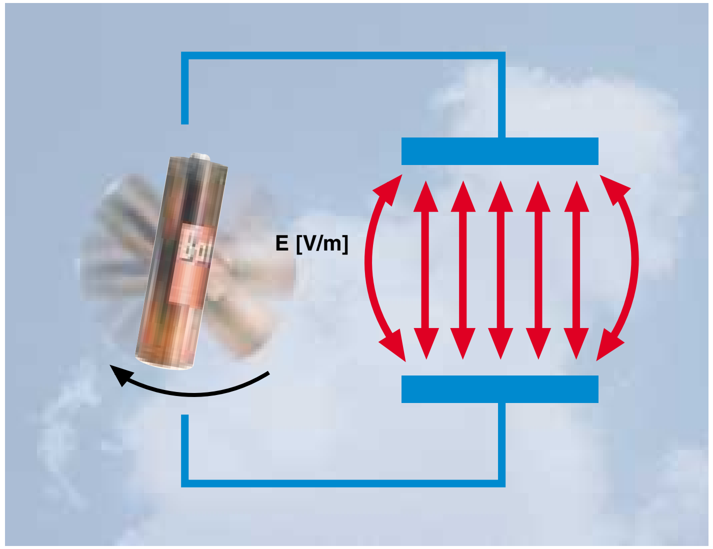
Electric fields are oriented from a positive pole to a negative pole. Static fields have a polarity that remains constant over time. During clear weather, the earth's natural static field has a value of 0.1 to 0.5 kV/m. During storms, it can increase up to 20 kV/m. Manmade static electric fields are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

The earth's magnetic field is also static. It has a magnitude of approx. 40 µT (microteslas) 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 generates a static field. If we continuously rotate 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 has units of Hertz [Hz].

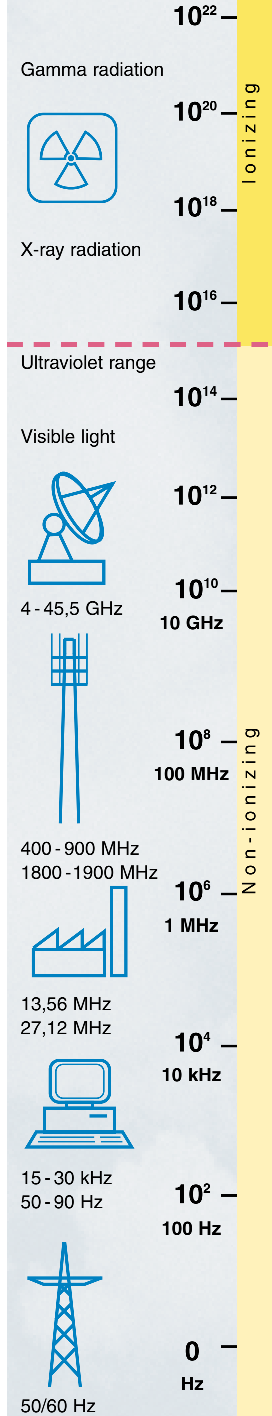
If the field changes direction 100 times per second, this produces 50 oscillations and thus a frequency of 50 Hz. This frequency is used for AC power in many countries (or 60 Hz in the United States).



Low frequency (LF) vs. high frequency (RF & microwave)

Alternating fields are divided into low-frequency fields (up to about 100 kHz) and RF & microwave 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 (instead of the magnetic field strength) the magnetic flux density in teslas [T] or gauss [G].

In the RF & microwave range, 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, high-speed trains, nuclear reactions and maglev trains (from the support and guidance magnets).

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

RF & microwave electromagnetic fields are found in mobile radio, radio & TV broadcasting, satellite communications, radar systems, industrial processes such as melting, smelting, heating, curing and plastic welding, semiconductor production and microwave systems.

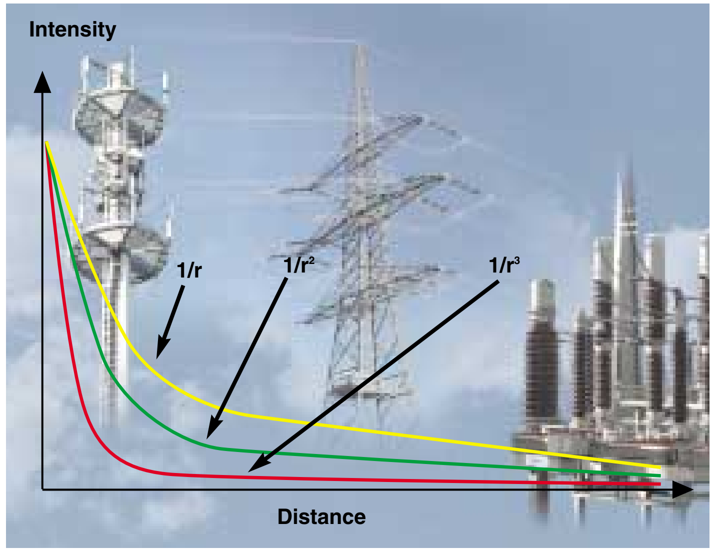
In all of these application areas, radiation exposure is possible so it is important to pay attention to the relevant limits. For reasons relating to occupational safety and environmental protection, it becomes necessary to measure the radiation levels. Regular monitoring is important in some cases.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

Range of influence of fields

Field strength decreases rapidly the further we are from the field source. This means that maintaining proper distance from a source is a simple way to provide protection.

DISTANCE FROM ANTENNA*	FIELD STRENGTH	
1m	100 V/m	Caution: Limit violation as per ICNIRP Occupational
2 m	50 V/m	
3 m	33,3 V/m	
10 m	10 V/m	

**e.g. dipole antenna, 900 MHz*



Shielding of electric fields is simple. For example, we can use a thin, grounded metal foil or a protective suit when if it is necessary to work in the presence of strong RF & microwave fields.

Unfortunately, low-frequency magnetic fields will penetrate most materials unimpeded. Large-scale shielding is extremely costly.

Field decay
(r = distance to field source)

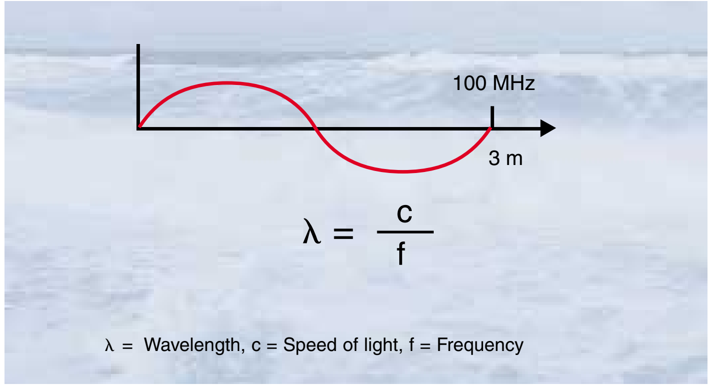
1/r:
Single-conductor systems, E and H in far field (typically all wireless communications equipment such as GSM, pagers, radio, TV)

$1/r^2$:
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 transmission, electric motors, generators)

Wavelength is 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 (mobile radio antennas) means a wavelength of 33 cm and 20 GHz (satellite communications) means a wavelength of 1.5 cm.

Equipment will tend to pick up signals if it has dimensions similar to the wavelength of the transmitting frequency.



Let's first consider waves in water to get a better idea of how this works. For example, small waves do not influence a big log. The log will simply float right across them. However, if the waves are at least half as long as the log, energy of the motion will be transferred to the log and it will participate in all of the wave motion. This is known as a "resonance effect".
Antennas work in an analogous way. Antennas are built to handle different frequencies. The frequency depends on the separation and length of the individual elements. These dimensions are determined based on the wavelength ranges of the signals to be received.
The rule of thumb says that when the distance from the radiation source is less than three wavelengths, we are in the "near field". In the low-frequency (LF) range, this is almost always the case due to the extremely large wavelengths encountered (6000 km at 50 Hz).

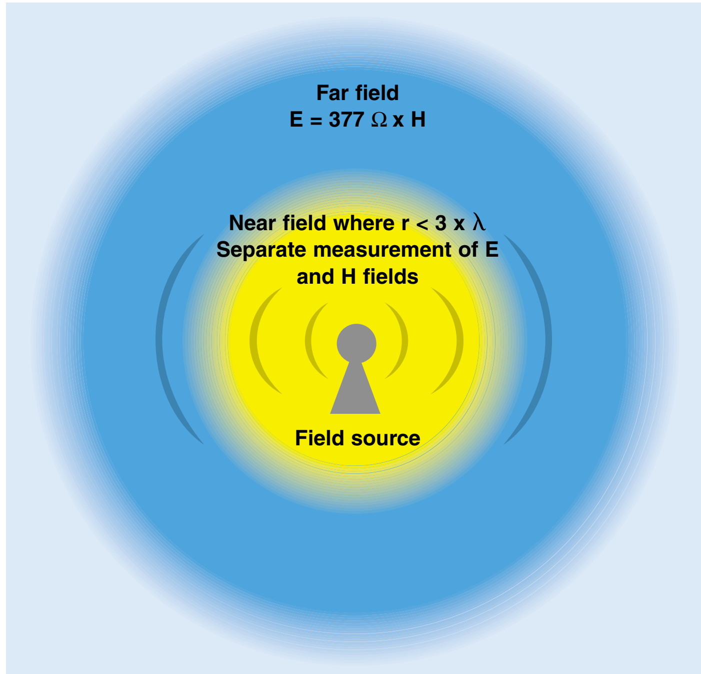
If we are at a distance that is greater than three wavelengths from the source, then we are in the "far field". This distinction between the near and far fields is important when making measurements in the RF & microwave range.

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:

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

Here is a sample calculation where
f = 1.7 GHz, l = 17.7 cm, D = 10 m:

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



f:
Frequency

λ:
Wavelength

D:
Diameter

R:
Distance to transmitting antenna

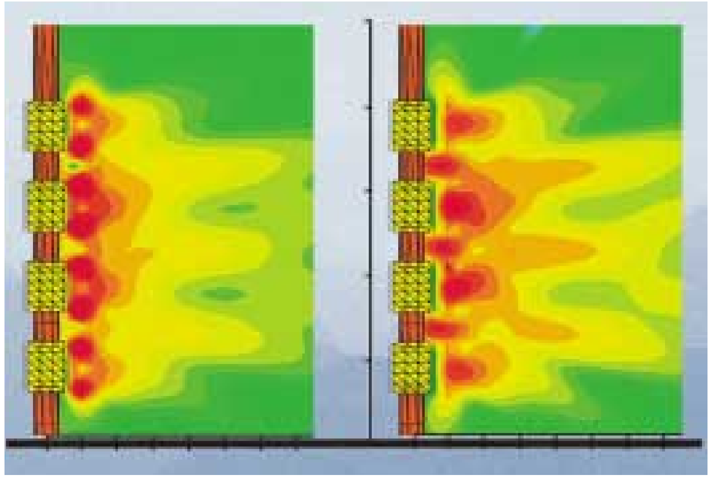
In the far field, we can compute the H field using the following formula if we first measure the E field:

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

Z_0 is the free-space impedance. It is equal to 377 Ω

Properties of near and far fields
In the near field, the ratio of the electric and magnetic fields is not constant, as is clear from the figure below. In the immediate vicinity of the antenna, there are regions where the electric or magnetic field predominates almost exclusively. This is why we have to measure the two components E and H separately.

Intensity distribution in the near field of an FM broadcaster (100 MHz)



Field maxima

Field distribution of local maxima in the H field

Field distribution of 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/m²] or [mW/cm²] under far-field conditions. For example, we obtain S by multiplying the electric and magnetic field strengths as follows:
S = 50 V/m x 0.13 A/m = 6.63 W/m².

RF & microwave conversion examples (assuming far-field conditions)

E [V/m]	H [A/m]	S [W/m²]
5	0.01	0.07
10	0.03	0.27
50	0.13	6.63
100	0.27	26.53

Electromagnetic fields have certain biological effects which can be detrimental to human health.

We say that 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.

Health impairments are said to occur if the influence goes beyond what the body can normally compensate for.

The effects of electromagnetic fields are dependent on the following:

- Frequency
- Field strength
- Field type (E or H field),
- Duration of exposure
- Extent of exposure
  (part of body or entire body)
- Signal shape

Consequences of RF & microwave fields
RF fields at frequencies between 1 MHz and 10 GHz penetrate bodily tissue and heat it due to the absorbed energy. The depth of penetration decreases at higher frequencies. Since the heating occurs from the inside, it is not perceived (or it is perceived too late) since we perceive heat primarily through receptors situated near the skin surface. The body is capable of handling heating as a result of small amounts of RF energy through its normal thermoregulation processes.

RF 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.

They will not occur through normal everyday exposure to radiation, but they can occur in the immediate vicinity of powerful radar systems, for example. Such facilities are generally cordoned off over a wide area.

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 very close to the typical human size (or the size of individual body parts). The field energy is absorbed to a great extent. The lowest limits are found in this frequency range.
300 MHz-10 GHz:	The depth of penetration of EMF into the human body decreases in this range
Over 10 GHz:	Increase in temperature at the body surface (skin burns are possible)

SAR:
Specific absorption rate, measured in W/kg

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

The long-term effects of low-intensity RF radiation are currently under study 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 RF fields can cause cancer or make it more likely. Influences on cells, enzyme activity and genes have been ascertained 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 as a result of RF fields is dependent on the blood circulation and thermal conductivity. For example, 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, secondary effects of fields can indirectly influence our health. For example, mobile phones can affect navigation equipment in airplanes. Electronic implants such as pacemakers can also be impaired by radiation from RF equipment and antennas.

Consequences of low-frequency (LF) fields
Low-frequency magnetic fields cause currents to flow in the body. In the case of low-frequency electric fields, we speak of "induced body currents". The predominant effect is a stimulus of nerve and muscle cells.

Low-frequency limits are based on the current density model which is used to explain the dependency of the stimulating current density on frequency.

In the case of low-frequency fields, we mostly note stimulation of sense, nerve and muscle cells as a function of frequency. The greater the field strength, the more pronounced the effects. While the human organism is capable of withstanding weak interactions, more intense signals can produce irreversible damage to the health under certain circumstances. It has not yet been clearly established whether low-level LF fields increase the incidence of cancer. There are a number of scientific studies underway around the globe to assess the consequences of low-frequency fields.

Low-frequency fields can also influence pacemakers and other electronic implants. There are specific limits which must be upheld to prevent problems from arising due to these secondary effects.

Static fields can produce familiar “static electricity” which causes our hair to stand up as well as electrostatic discharges. The potential for voltage sparkovers needs to be taken into account when working with strong static E fields.

Health consequences occur only through exposure to very powerful magnetic fields (> 4 T). For the limits, the force influences on metallic objects are relevant.

Current density (mA/m²)	Consequences
Below 1	No clear effects; range of natural background current densities in most bodily organs
1 to 10	Subtle biological influences 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	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 impairments of heart functioning; 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).

Where do the limits for EMF come from?

RESEARCH EVALUATES THE BIOLOGICAL EFFECTS

▼

SCIENTIFIC COMMITTEES SUCH AS THE ICNIRP EVALUATE THE POTENTIAL RISK

▼

BASIC LIMITS ARE AGREED UPON

▼

NATIONAL AND INTERNATIONAL LIMITS ARE DERIVED

For the current limits, short-term effects are most important. There are still many studies underway concerning long-term effects, but there are no conclusive results as of yet. This is why there are not yet any recommendations in this area.

Since evaluation of the basic limits requires expensive laboratory techniques, reference limits have been derived which are simple to measure based on suitable models of the body and simulations.

EMF limits by international organizations:

ICNIRP (International Commission on Non-Ionizing Radiation Protection)

IEEE (Institute of Electrical & Electronics Engineers)

CENELEC (European Committee for Electrotechnical Standardization)

No relationship with product standards

Besides environmental norms, there also exist equipment norms which stipulate the maximum permissible radiation for, say, 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.

UNITS FOR THE BASIC LIMITS

RF & MICROWAVE:
SPECIFIC ABSORPTION RATE (SAR) IN W/KG

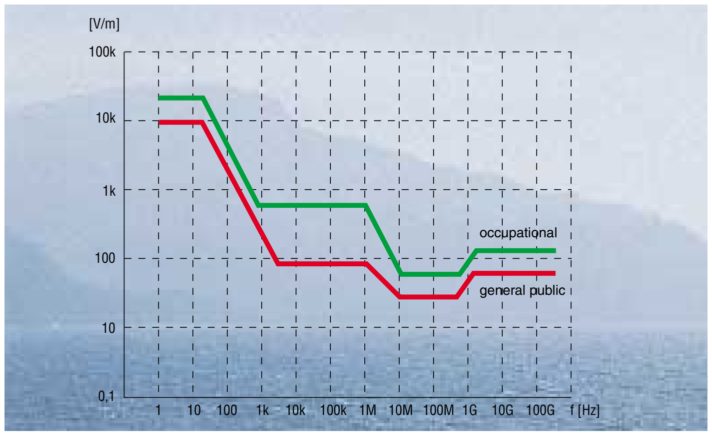
LOW-FREQUENCY:
CURRENT DENSITY J IN MA/M^2

DERIVED LIMITS

E FIELD IN V/M

H FIELD IN A/M OR B FIELD IN T OR G
POWER FLUX DENSITY S IN MW/CM^2

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 will have better access to information about the potential effects of EMF. In other words, employees will know about potential radiation sources and protective measures and have access to suitable test equipment. Ideally, employers should provide their workers with an EMF safety concept which includes information about EMF fundamentals and safety precautions. Since this is not possible for the general public, those limits are lower.



EMF limit curves ICNIRP 1988

Measurements – The first step towards effective protection

At the workplace, many different combinations of LF and RF radiation can exist. The only way to accurately assess EMF is through the use of suitable measuring devices.
It is difficult to accurately simulate or compute fields since they can be amplified as a result of complex reflection patterns. Measurements are also required to detect leaks in antenna lines.

Preventive safety begins with the choice of where to locate 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 involved in operating, managing and monitoring equipment that produces electromagnetic radiation needs to receive training in the relevant safety measures. This should cover the following:

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

Important protective measures when limits are violated

Any hazardous area will need suitable organizational measures which might include a fixed measurement system. Depending on the extent of the hazard, this can also involve locks, shielding or enclosures to ensure that the proper distance is maintained. Of course, a warning sign is a must.

For persons who must enter hazardous areas (e.g. for maintenance work), there are different possibilities depending on the relevant standard or operating instructions, e.g.:

- Selection of time frames with lower system utilization (and thus lower EMF emissions)
- Techniques for approaching the field source
- Possible reduction in power levels
- Complete system shutdown

Persons who enter such hazardous areas should have protective gear as well as suitable measuring devices (or a personal monitor) and access plans. During work on broadcast facilities, protective suits are required by many system operators. It is also important to heed the procedural regulations that apply to the country (or facility) in question. When working on broadcast facilities, you should always carry a monitor (just as you would carry a gas detector when working underground in a mine).

What test equipment is needed and why?

Personal safety: *Personal monitor; handy and practical, evaluates frequency response, required when working in an RF & microwave environment; easiest to operate (just switch on and monitor)*

For general measurements in compliance with EMF standards: *Broadband EMF test equipment with exchangeable E-field and H-field probes for measuring the entire spectrum (bodily exposure)*

Identification of frequency and field strength relationships: *Selective EMF test equipment which displays the entire spectrum and shows the different frequencies and field strengths*

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/or 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. Practical features include data memories, alarm functions, automatic zero alignment and straightforward operation.

Preparing for measurement

- Technical specifications for the field sources should be obtained from the operator (frequencies, generator power, radiation characteristics, modulation, line currents and voltages).
- Exposure conditions and information about the exposed persons (locations and times, shifts, groups) must be procured.
- The operating status must be assessed in case of facilities with variable operating parameters.
- The measurement techniques and test equipment must be selected depending on the technical conditions and local regulations.
- A functional check and zero alignment must be performed on the test equipment. It is also important to make sure that the calibration interval specified by the manufacturer has not expired.
- The expected field strength (or power flux density) should be estimated in order to facilitate any necessary personal safety measures and determine what test equipment and probes are needed.

PROCEDURE

OBTAIN INFORMATION ABOUT THE EQUIPMENT UNDER TEST
▼
PRELIMINARY MEASUREMENT
▼
GENERAL ANALYSIS OF THE FACILITY
▼
DETERMINE REFERENCE POINTS AND WORK AREAS
▼
DETERMINE BOUNDARY CONDITIONS
▼
MAKE THE MEASUREMENT
▼
PREPARE THE MEASUREMENT RESULTS

Making the measurement

Measurements need to be made at the maximum power level that occurs during operation. If this is impossible, then 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 in certain cases.

A broadband measurement detects all of the signals that are present within a certain frequency band. This is useful for determining the overall exposure affecting the human body. Special "shaped probes" can be used to display the total exposure as a percentage of the relevant limit. This helps to avoid time-consuming computations and comparison of results with limit tables.

A selective measurement can be used to determine the percent contribution of individual frequencies to the overall exposure. Overview measurements are useful for determining the frequencies of the predominant signals. Then, a measurement can be made at each relevant frequency. A selective system is useful for such measurements. Measured values are displayed directly as field strengths vs. transmitting frequency.

A measurement log needs to be prepared after the measurement. It should include all of the details required by the relevant local regulations (country-specific).

Peculiarities of RF & microwave 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 in case of measurements in environments involving multiple field sources.

To suppress brief, irrelevant limit violations, results must be averaged over an interval of 6 minutes (as required by many norms). Some measuring devices provide an averaging function for this purpose.

Hot spots (e.g. under antennas) and cancellations 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 for the test points and by making measurements in the vicinity of objects that are causing 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 the full-body exposure, it is necessary to make measurements at multiple points. The quadratic mean should then be formed from this measured value (using spatial averaging). Better test tools provide this function at a keypress.

Based on its size, the human body will respond differently to EMF as a function of the frequency of the field source. This is why personal safety limits vary depending on the frequency. After making a measurement, the field strengths should be evaluated at the different frequencies. The latest measuring devices use "shaped probes" to automatically provide this sort of frequency response evaluation. The device then displays the exposure as a percent of the relevant limit. When using shaped probes, it is no longer necessary to know anything about field strength limits and frequencies. This sort of equipment is particularly useful in multifrequency environments.

The different types of modulation such as amplitude modulation (AM, low modulation factor), frequency modulation (FM) and digital modulation (GSM, UMTS) do not have much of an influence on the measurement result. However, the opposite is true for pulsed signals used in radar facilities: Thermoelement probes are very beneficial when we need to make precise measurements of EMF radiation with extreme pulse/pause ratios. Thermoelement probes are better at determining RMS values than, say, diode probes.

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

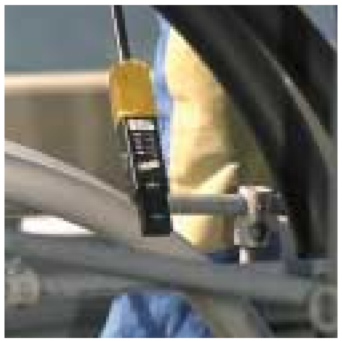
In RF fields, the human body also has an influence on the measurement result. Resonance overshoots and cancellations can occur with E and H fields depending on the frequency, body size and distance to the measuring device. By separately measuring E and H fields, it is possible to avoid grossly underestimating the values. Overevaluation of field strengths at certain frequencies is unavoidable, but this must be accepted to put 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.

Examples of RF & microwave sources

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.

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 thermosensors) are usually preferred.

Searching for leaks
Waveguides and rotating couplers in antenna lines are subject to a great deal of wear and tear and need to be checked regularly. In case of defects, very high field strengths can occur. Destruction-proof sensors are needed to measure these levels.



Satellite communication
Very low field strengths are generally found around terrestrial stations. The test equipment (or the related probe) will need excellent measurement sensitivity.

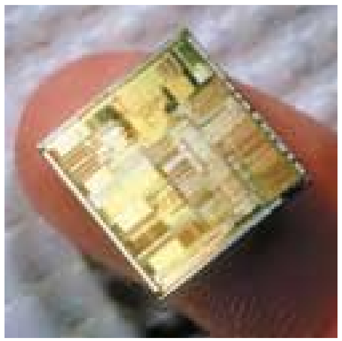
Mobile radio
The large number of base stations and the nature of the signal modulation used means that mobile radio equipment is subject to particular scrutiny by scientific bodies and regulatory authorities. Special prophylactic measurements allow extrapolation to the maximum possible field strength when the base station is fully loaded.

Melting/smelting
High magnetic field strengths can occur in melting/smelting processes. The field strengths increase greatly in the vicinity of the field source. To protect the personnel and test equipment, always approach industrial ovens with extreme caution (slowly!).

Heating & curing
Systems for heating metals operate in different frequency bands. The frequencies used will change depending on the production conditions. High magnetic field strengths can also occur. The measuring device must have a wide measurement and frequency range.

Plastic welding
Very high field strengths can occur locally in the vicinity of 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
Leakage can occur near door seals, supply lines and RF sources due to wear and tear. Regular monitoring is an absolute must.

Peculiarities of LF fields
As a basic rule, electric and magnetic fields must be measured separately in low-frequency (LF) fields since the two components are independent of one another. Here, we are almost always in the near field.

In industrial environments, it is common to encounter several field sources that produce low-frequency radiation. To properly measure the radiation exposure, isotropic (i.e. non-directional) measurements are required. This requires holding the measuring device in three different directions and computing the quadratic mean of the results. This is unnecessary with measuring devices that have isotropic probes with sensors that are designed so that all three spatial directions can be measured simultaneously.

Broadband measuring devices show the overall exposure for all of the field strengths within a specified frequency range. Using filters or computational techniques, it is possible to selectively assess individual signals. Or, the signal can be analyzed in terms of its frequency components using computational techniques (e.g. fast Fourier transformation). Some measuring devices provide convenient bandpass and bandstop filters along with measurement techniques for performing spectrum analysis.

Multifrequency signals in the LF range can be quickly assessed using 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.

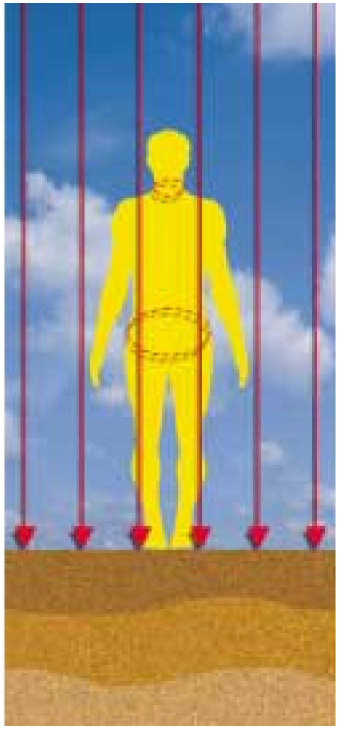
Harmonic analysis is useful for assessing the entire harmonic spectrum. This function is available in certain test equipment. The display of the device will show the fundamental frequency and the harmonics (multiples of the fundamental frequency) to provide a fast overview of the quality of service in the power system. This function is also useful for determining the percent share of nonharmonics.

To properly assess exposure to low-frequency fields, it is necessary in many cases to have in-depth knowledge of the field and the measuring devices. Here, measurement techniques where the frequency response is evaluated automatically will greatly simplify everyday work (shaped time domain = STD). The frequency dependency of the limits is automatically taken into account. Suitable detectors should be available for measuring the RMS and peak values. When making isotropic measurements, the phase of the individual components is taken into account. In real time, the B or E field is measured 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.

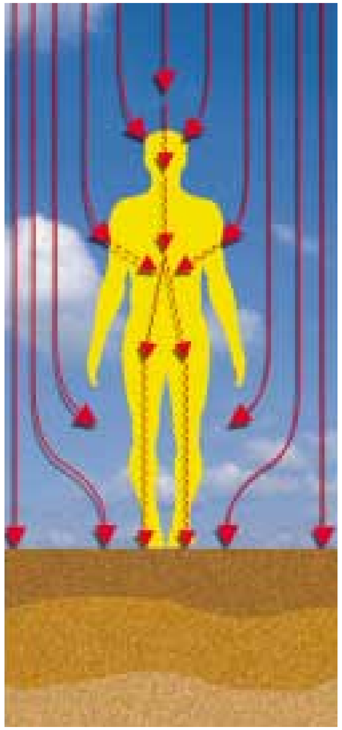
Whereas ambient conditions have little influence on the magnetic field, the presence of people, condensation, humidity and/or fog can influence the electric field. To eliminate any possible influence by the body (particularly by the test personnel), always make your measurements at a proper distance and use remote E-field measuring devices or probes with a tripod if necessary.

If you need to monitor field strength levels or make long-term measurements, try to use a measuring device with a data memory. You can transfer the measurement results via the device's optical interface to a PC for further analysis. Remote control via these interfaces is usually another option.

Interaction between the body and field lines

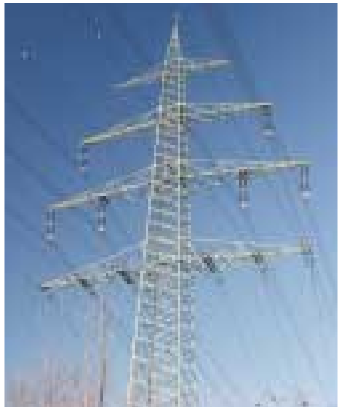


Magnetic field



Electric field

Examples of low-frequency (LF) field sources



Power systems
Around transformers, the magnetic field is dominant, while the electric field is dominant around transmission lines. As more and more transmitting facilities are installed on high-voltage towers, it has become critical to carry a personal monitor when working on such towers to check for the presence of RF & microwave fields.

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 should be tested using magnetic field measurements in their immediate vicinity to ensure compliance with occupational safety regulations.

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

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

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

For a current overview of important standards, laws and regulations on a country-by-country basis, see:
www.who.int/docstore/peh-emf/EMF-Standards/who-0102/worldmap5.htm

Alternating current (AC):
AC constantly changes the direction it is flowing in

Ampere [A]:
Unit of electric current

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

Calibration:
Testing and alignment of measuring devices with respect to national standards

CE mark:
Guidelines for EMC that relate to equipment (not environmental EMC!)

Current density:
Measured in A/m

Direct current (DC):
DC always flows in the same direction

Electric current:
Measured in amperes [A]

Electric fields:
Produced in cables even when the equipment they are connected to is not in operation

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

Electric voltage:
Measured in volts [V]

"Electrosmog":
A popular term in Germany for spurious (ambient) electromagnetic radiation

EEMC:
Environmental electromagnetic compatibility

EMC:
Electromagnetic compatibility

EMI:
Electromagnetic interference

EMF:
Electromagnetic field EMF is related to environmental EMC (EEMC)

Far field:
A distance of more than three wavelengths from a radiation source

Frequency:
Measured in Hertz [Hz]

Gauss [G]:
An alternative unit for magnetic induction

Gigahertz [GHz]:
1 billion Hertz

Hertz [Hz]:
Frequency unit for alternating current or voltage

Isotropic:
Non-directional (three-dimensional)

Kilohertz [kHz]:
1000 Hertz

Kilovolt [kV]:
1000 volts

Kilowatt [kW]:
1000 watts

Low frequency (LF):
Up to 100 kHz

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

Magnetic fields:
Magnetic fields arise when current is flowing

Magnetic induction or flux density (B):
Measured in teslas [T] or gauss [G]

Megahertz [MHz]:
1 million Hertz

National norms:
Measurement quantities stipulated by national standardization bodies

Near field:
A distance of less than three wavelengths from a radiation source

Power:
Measured in watts [W]

Power density:
Measured in watts per square meter [W/m2]

RF & microwave (RF):
100 kHz to 300 GHz

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

Tesla [T]:
Unit of magnetic induction

Volt [V]:
Unit of electric voltage

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

Watt [W]:
Unit of power

Narda Safety Test Solutions GmbH offers a wide range of equipment for use in making safety measurements in the workplace and for the public and private sectors. Examples include:

Selective Radiation Meter SRM-3000

- Measurement of RF & microwave electromagnetic radiation from FM radio to UMTS
- Evaluation of results in compliance with common personal safety standards
- Selective measurement: Display of overall results and individual contributions produced by telecom services (e.g. mobile radio), operators or transmission channels using field strength units or as a percentage of the permissible limit

HF Radiation Meters, EMR and 87XX series

- Measurement of RF & microwave electromagnetic radiation from broadcast radio up into the radar range
- Display of overall results in numerical format using absolute field strength values or evaluated in compliance with common personal safety standards
- Simple operation

Low frequency test equipment

Broadband RF & microwave test equipment

NARDA'S LINE OF EQUIPMENT

Field Analyzer, EFA series

- Measurement of low-frequency electric and magnetic fields
- Evaluation in compliance with common personal safety standards
- Patented STD technique for reliable results

Exposure Level Tester ELT-400

- Measurement of low-frequency magnetic fields
- Immediate display of results, even in complex field environments (e.g. industrial welding systems)
- Standardized evaluation (EN 50366 also possible)

RadMan/Nardalert

- Personal monitors for safety in electromagnetic fields
- Notification of limit violations using visual and audible indicators
- Easy to carry in a pocket or on your belt

Area monitoring stations

Radiation monitors for personal safety

Selective RF & microwave test equipment

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