

Electromagnetic Fields: Basic Concepts

Electromagnetic fields are natural phenomena that have always been present in our environment and that birds and fish use, for example, to orient themselves. While some are visible, such as rainbows, most are invisible to the human eye, such as the magnetic field that causes compasses to orient themselves or sunlight.

The waves that form these fields (electromagnetic) are those used in mobile telecommunications.

What types of waves exist?

When you listen to the radio or watch television, your receiver is receiving waves. If you have ever thrown a stone into a swimming pool, you will have noticed that the impact with the water produces a wave.

All these types of waves, apparently so different, can be classified as follows:

Mechanical waves: They are those that need a physical medium to spread (such as water or air).

Electromagnetic waves: They are the ones that do not need a medium to propagate. On the contrary, electromagnetic waves propagate rapidly through the air. Moreover, their power decreases as you move away from the source of emission with a ratio inversely proportional to at least the square of the distance, so that at twice that distance you have four times less power.

What types of electromagnetic waves exist?

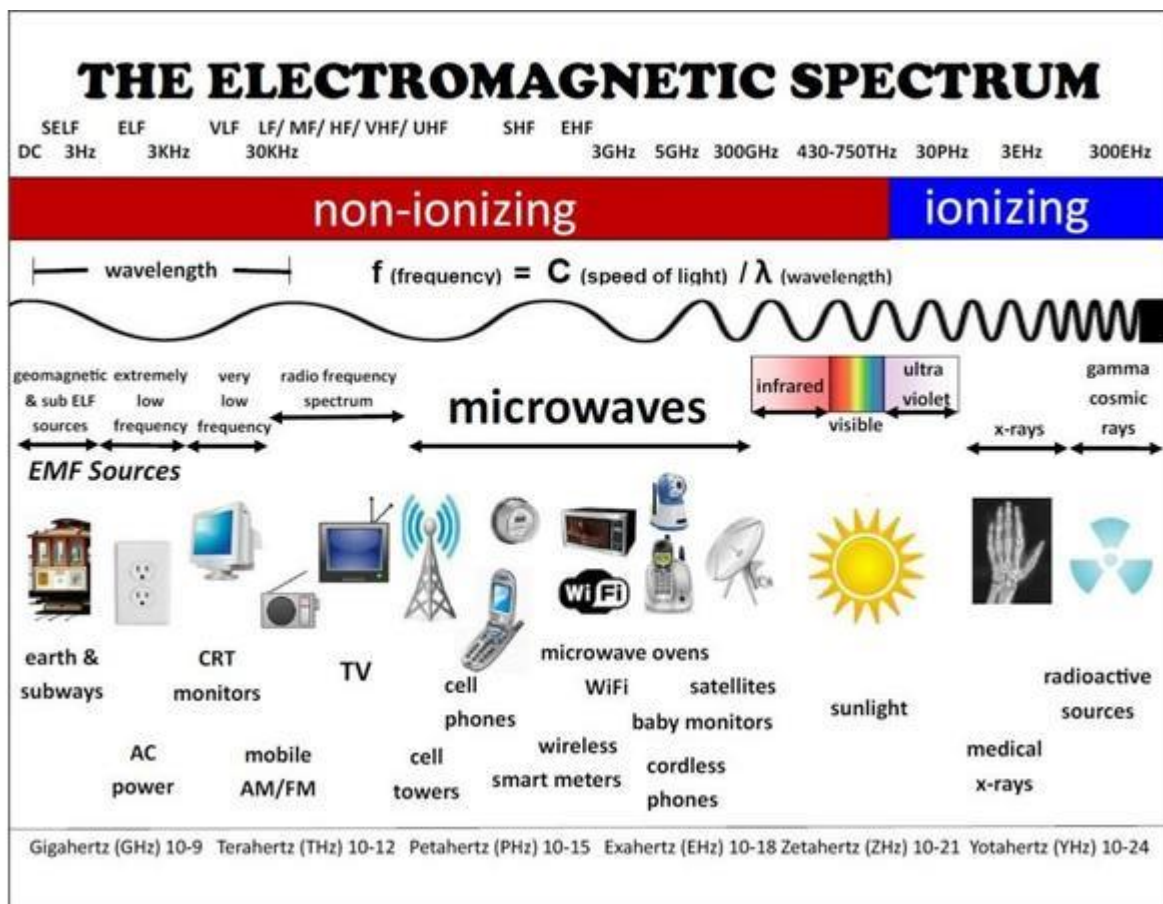
The main characteristic of electromagnetic waves is frequency, which indicates the number of times the wave repeats itself per second, differentiating one wave from another. Frequency is measured in hertz (Hz).

Depending on their frequency, electromagnetic emissions could be of two types:

Ionizing: These are extremely high frequency electromagnetic waves (X-rays and gamma rays), which contain sufficient photon energy to produce ionisation (conversion of atoms or parts of molecules into positively or negatively charged ions) by breaking the atomic bonds that hold molecules together in the cell.

Non-ionizing: These are produced by mobile telephony. They have so little energy that they cannot cause ionisation in a biological system.

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Is Radioactivity the same as Radiation (or Emission)?

No, radioactivity refers to very high energy emissions that may be purely electromagnetic in nature, such as gamma rays, or associated with the emission of subatomic particles, such as alpha and beta rays, which are produced by radioactive materials. These very high-energy emissions can break molecular bonds, damaging living cells.

The term radiation refers, however, to the property of electromagnetic energy fed to an antenna to radiate into free space, i.e. to propagate and reach another point, where a receiving antenna can retrieve the message and decode it. Electromagnetic waves used for telecommunications are non-ionising, i.e. they cannot modify the structure of matter, as the energy associated with these waves is very low.

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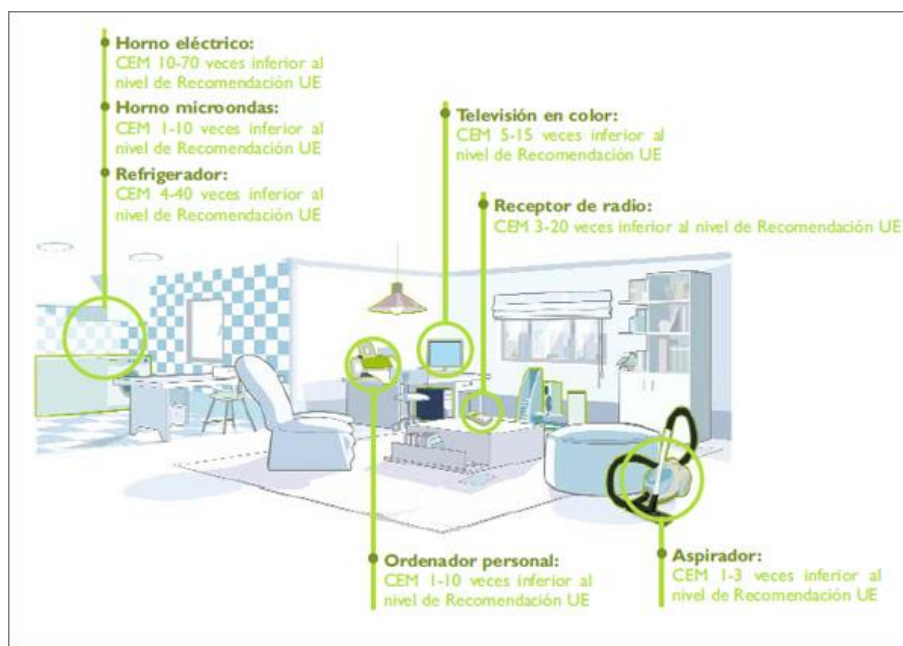
How are Electromagnetic Fields (EMF) measured?

The energy transmitted by high-frequency electromagnetic waves is often expressed equivalently in power density, measured in W/m² (watts per square metre) or other similar measures.

The biological effects of emissions depend on the exposure time and the absorption rate of the radio power, which is quantified in the so-called SAR (Specific Absorption Rate) and expressed in W/Kg (Watts/kilograms).

What electromagnetic fields are we exposed to within our homes?

The fact that you can talk on a mobile phone, listen to the radio and watch television in a house indicates the presence of electromagnetic waves. On the other hand, electrical current and household appliances generate electromagnetic fields at a frequency of 50 Hz. Additional fields are also generated by television screens and computer monitors, or by cordless phones and mobile phones.



All radio, television and mobile phone emissions come from outside. Also, the antennas of medical emergencies, fire brigades, police and civil protection; radar systems and satellite communication systems.

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Are the differences between mobile phone base station antennas and other types of radio and TV transmitting antennas important in assessing their potential impacts on human health?

Yes, the radiofrequency radiation generated by some antennas (particularly radio, television and radar broadcasting antennas) is more powerful than mobile phone antennas.

How much do emissions from mobile telephony infrastructures represent in relation to the total level of exposure to electromagnetic emissions?

According to a study by the UK Radiocommunications Agency and the Institute of Magnetism at the Complutense University of Madrid, only 2-5% of the total electromagnetic emissions received by humans come from mobile phone antennas.

Specific Absorption Rate (SAR)

What is SAR?

Radio waves are electromagnetic energy. Since they do not have sufficient energy to damage cellular structures, they are known as "non-ionizing".

The unit of measurement of the amount of radio wave energy absorbed by the body when using a mobile phone is known by the parameter SAR (Specific Absorption Rate), the Specific Absorption Rate. SAR is expressed in units of watts per kilogram (W/kg).

The biological effects of emissions depend on the exposure time and the quantified SAR; therefore, the SAR is used by ICNIRP (International Commission on Non-Ionising Radiation Protection, which publishes exposure limits and recommendations) as a unit of dosimetry to establish exposure limits. The European Standard EN 50360 established by ICNIRP establishes a maximum SAR level of 2 W/kg, which must be tested by international measurement protocols that are mandatory for all mobile phone manufacturers.

To find more SAR information on your mobile phone, visit the manufacturer's website or visit the Mobile Manufacturers Forum (MMF).

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How SAR value is determined?

The SAR of mobile phones is determined at the highest level recorded in laboratory conditions. However, the actual SAR level of the phone in operation is usually well below this value. This is because the phone is designed to use the minimum power needed to reach the network.

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Mobile Phones



Mobile phones communicate with the base stations of the mobile phone system by means of electromagnetic waves. A mobile phone is in coverage when it receives electromagnetic waves strong enough from at least one base station.

Generally, a mobile network is designed on a "cellular grid" basis covering a geographic area. The number of base stations required for a given area will depend on the terrain and the number of people using mobile phones. The more people using mobile phones simultaneously, the more capacity is needed, so more base stations need to be installed and the closer together.

Terminals, mobile devices and base stations are perfectly designed to meet strict national and international safety standards and, of course, all World Health Organisation recommendations.

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Why are we running out of signal?

Mobile phones only work properly if they have coverage, i.e. if they receive the electromagnetic waves emitted by the base station antennas, as happens with the reception of radio signals or a television. As we move away from the antenna, the power of the waves exchanged between mobile phones and base station antennas increases up to a maximum safety limit established by Spanish regulations and guaranteed by the handset manufacturer. Once this limit is reached, coverage is lost as a protective measure: therefore it is important for mobile phones to be close to the antennas, as they will then operate at the minimum power and have the best coverage.

At what frequencies do base stations and mobile phones broadcast?

Current mobile phone systems use the 900, 1800 and 2000 MHz bands. The 900 MHz frequency band is very close to that used by television (television uses frequencies up to 850 MHz). Frequencies close to 1800 MHz are used by cordless phones in homes.

What is the maximum power emitted by a mobile phone?

Mobile phones must comply with various technical standards in order to operate correctly in the mobile phone network and with the appropriate guarantees for the user in terms of exposure to electromagnetic fields. Among all the parameters that must be met, telephones have a maximum power value for which they are designed and tested.

For commonly commercially available terminals, typical maximum average power values range from 125 mW to 250 mW, depending on the type of terminal and the frequency band used.

However, under normal conditions, mobile phones emit at levels significantly lower than their maximum powers, since the power value emitted at any given moment is controlled by the base station, through a feature called power control, so that the minimum power necessary to maintain communication is used. This makes it possible to minimise exposure levels and avoid interference in the system.

This power value depends to a large extent on the distance to the base station and is generally lower the closer the base station is. If a higher power value than the maximum possible is necessary to maintain the communication, the communication will be interrupted, as the telephone cannot transmit more power than this in any case.

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What are 2G, 3G, 4G and 5G networks?

5G is the acronym for the fifth generation of mobile phone technologies. It is a further step in mobile communication technology, following the previous generation (4G), which aims to make mobile data communication much faster and more reliable.

Each generation introduced important innovations: the first generation (1G) gave birth to mobile phones; the second generation (2G) introduced digitalisation and SMS text messaging; the third generation (3G) enabled Internet access; the fourth generation (4G) increased data transmission speeds, making possible, among other things, massive video streaming. Now, the fifth generation (5G) will make it possible to manage even more connected devices with higher data transmission speeds and shorter transmission times, and will make new services such as the autonomous car, virtual reality, industrial automation and the Internet of Things a reality.

Should I be worried about 5G?

A document published in February 2020 by the Scientific Advisory Committee on Radio Frequencies and Health (CCARS) entitled '[5G and Health](#)' concludes that, based on the scientific evidence available to date, the general public can be reassured about the alleged health implications of the radio frequency emitted by this technology, as the foreseeable exposure levels are not expected to change significantly and, in any case, will not exceed the maximum permissible limits that guarantee public health with respect to electromagnetic emissions.

In addition, the guidelines of the International Commission for non-ionising radiation Protection ([ICNIRP](#)) set exposure limits for non-ionising electromagnetic waves, including radio frequency waves proposed for 5G. These guidelines contain exposure limits that have been established based on existing scientific evidence and include a substantial margin of safety for the protection of the general public.

These recommendations have been widely adopted throughout the world, including the European Union, through its Recommendation 1999/519/EC and are endorsed by the World Health Organisation ([WHO](#)). In Spain, these limits were adopted through Royal Decree 1066/2001.

Other wireless technologies

Other technologies that make use of radio waves for their operation are Bluetooth, Wifi or NFC. Bluetooth can be used to communicate with devices in proximity, such as headsets and hands-free devices. Wifi allows you

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to access the internet with your smartphone, tablet or PC without the need for a cable connection. And with NFC we can carry out operations such as payment using our mobile phone.

Exposure Limits

Exposure limits are electromagnetic field levels that must not be exceeded in inhabited places. These limits are distinct from the levels emitted by base stations. Exposure limits are specified in electric field levels (volts per metre) or power density levels (watts per square metre). These levels can be calculated and measured by objective methods.

How are determined?

Using a method identical to that used to protect against the effects of any physical or chemical emission: research institutes, scientists and international health protection committees, after reviewing all the published science, assess the risk and recommend levels that ensure that no adverse health effects occur. These values are safe, but health authorities further analyse them and decide whether additional safety factors need to be applied. In the case of mobile telephony, the reduction factor is 50, which the WHO considers ensuring that populations are protected.

Which agencies set exposure limit regulations?

Exposure limits to electromagnetic fields have been established by independent scientific organisations, mainly by the International Commission on Non-Ionising Radiation Protection (ICNIRP), an independent body formally recognised by the World Health Organisation (WHO). ICNIRP evaluates and assesses the state of the science so far, identifies exposure levels for which possible effects on humans can be observed and incorporates a margin of safety based on aspects such as environmental conditions, the possible increased sensitivity of certain population groups such as the elderly, children and the sick, and differences in the absorption of electromagnetic energy by individuals of different sizes.

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What are the limits complied with in Telefónica?

At Telefónica we comply with ICNIRP regulations in all facilities in all countries where we operate.

Base Stations

Base stations have several elements:

Antennas: They allow communication with users within the coverage area of the base station. They are responsible for emitting or receiving the radio waves that are exchanged with the mobile phone. The closer the mobile phones are to the antennas, the better the coverage and the lower the power that both the phone and the base must emit.

Mast: This is the structure on which the antennas are installed. They have different heights, shapes or sizes depending on where they are located. Antennas normally need to be elevated to ensure correct emissions and reception of the waves.

Equipment cabinet: For the antennas to be able to exchange radio waves with the mobile phone, they need a set of equipment which is installed in a specially designed cabinet.

How do base stations work?

The mobile network consists of a network of base stations that can locate the terminal making a call and carry its communication. The coverage area is divided into small cells; hence the network is also called cellular, which can cover an area with a radius of approximately 100-200 metres in urban areas and 5-8 kilometres in rural or open areas. The powers emitted by the mobile and the station are automatically regulated to the minimum level to ensure a good connection quality. When the signal is not enough, the communication is transferred to a neighbouring cell, which is called hand over.

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What is the maximum power emitted by a base station antenna?

Mobile phone antennas typically emit with maximum radiated powers of a few hundred watts (W), and in the vast majority of cases with absolute maximum levels below 1,500–2,000 W EIRP (Equivalent Isotropic Radiated Power). Moreover, the actual radiated power is typically much lower than these maximum values, which would be theoretically achievable only under extreme operating conditions, as the actual transmit power level is automatically regulated to the minimum necessary to maintain communications and only the channels occupied and active at any given time are broadcast, so that the theoretical values described above are actually unattainable in practice. This feature, which is essential in the operation of systems such as mobile telephone systems, is not present in radio and television broadcasting transmitters.

Thus, the power levels emitted by mobile phone base stations are much lower than those used by radio and TV broadcasters, which can emit several tens of kilowatts (thousands of several, 1 kW= 1000 W) or even Megawatts (millions of watts, 1 MW=1,000,000,000 W).

Is the maximum emission level always used?

No. In fact, it is very rarely used. The power used depends on the number of simultaneous communications and the distance between the different mobile phones and base stations communicating, or the obstacles between them. To reduce emission levels and avoid interference, the levels are self-regulated to the lowest possible values.

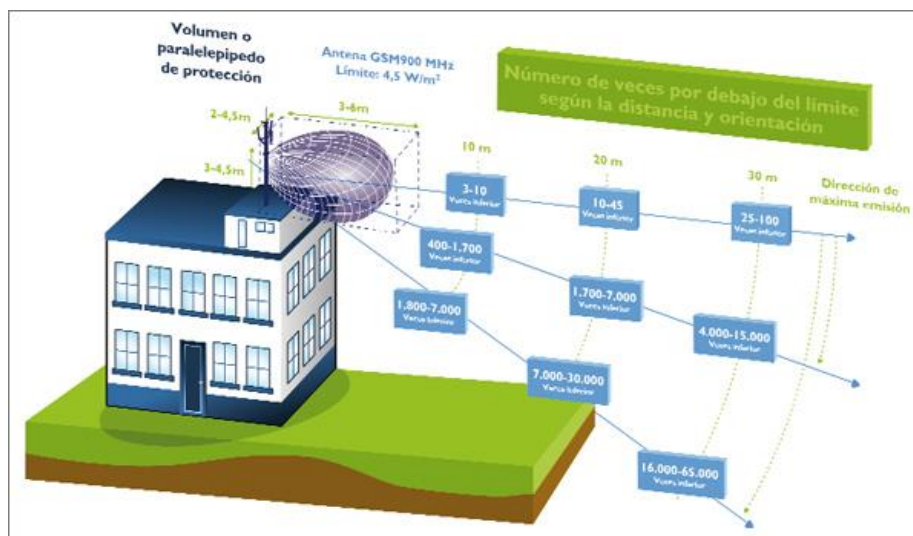
What is the safety distance to a base station antenna?

Base station antennas are directional, which means that they direct power in certain directions. Antennas used for mobile telephony emit in the direction perpendicular to the antenna, mainly in a forward, fan-shaped direction, and emit almost no power backwards or towards the ground.

The safety distance varies according to the transmitted power in each direction, which in turn is determined by the radiation pattern. The figure shows the typical emission characteristics of mobile phone antennas.

Therefore, a standard distance cannot be determined, but has to be calculated on a case-by-case basis. On the other hand, any obstacles in the path of the wave (such as walls or ceilings) greatly attenuate the level of the electromagnetic field, so the distance is reduced proportionally. It is important to remember that the power density decreases with the square of the distance.

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The calculation of the safety volume is defined by a parallelepiped as shown in the figure, the lengths of which are defined from the data for this antenna.

Where to locate base stations?

From a technical point of view, base stations must be evenly distributed in order to provide adequate coverage. It is therefore necessary to arrange them in an orderly manner in cities and it does not make sense to locate them far away from users. The more stations are installed in cities, the better the coverage and quality of service. The reason is that the number of users that can communicate at the same time per base station is limited to, at best, a few tens. Therefore, in areas where there is a high density of users, the cells must be small and numerous so that the number of users in the coverage area is not excessive. This is called base station capacity, which, together with coverage, determines whether the service can be provided with good quality.

On the other hand, it should also be noted that the denser the antenna network, the lower the power levels that the bases and mobiles must use to communicate with each other and, in this way, the lower the level of exposure to electromagnetic fields.

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Why is it necessary to locate them in city centres?

Both for service reasons (if base stations were not built in inhabited areas, these areas would not have coverage) and for capacity reasons (without enough base stations it would not be possible to serve all the communication demands of all users). In addition, to minimise the power levels emitted and thus exposure to electromagnetic fields, it is necessary to position antennas as close as possible to the phones. The best position is for antennas not to be removed from urban centres, as this would allow operators to emit at lower power and bring radiation levels well below safety limits, while moving antennas away from urban centres would force both base station and mobile to emit at higher power, raising radio levels considerably and impairing quality of service.

Does the size of the mast supporting the antennas influence its emissions?

No. An antenna and a tower (or mast) are two different things. The tower or mast is a structure necessary to support the antennas of a base station, these structures do not emit any radiation. It is the antennas that emit and receive mobile phone signals.

Biomedical aspects

Do health authorities have evidence on the health risks associated with living or working near mobile phone base station antennas?

No. According to the WHO and health authorities, it cannot be concluded from the various studies that base stations produce adverse health effects.

All scientific reference committees in this field agree to exclude any health risk at such low emission powers. In residential areas close to base stations, field levels are well below the limit values set in legislation (more than 1,000 times).

According to current scientific research, the established limits guarantee the protection of people from electromagnetic fields.

What are thermal effects?

The electromagnetic fields generated by base stations and mobile phones cause a transfer of energy that, when it encounters the human body, dissipates as heat through the biological tissues. In the presence of a

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source of heat of any nature (natural or artificial), the body reacts by removing the heat passively through the blood and actively by sweating. These effects are known as thermal effects.

What are non-thermal effects?

Scientists differentiate between thermal effects (increase of temperature) and non-thermal effects, that is, effects that are not related to heat. The criticism levied against mobile phones focuses on the possibility that they may cause non-thermal effects such as sleep disorders, sensory alterations, etc. The exhaustive research programmes that have been set in motion to investigate these claims have not been able to ascertain any of these effects.

If there are no health issues related to antenna emissions, how do you explain the public alarm caused and the setting up of Committees of People Affected by antenna radiations?

We must not confuse public alarm with medical alarm. In this case, since there is no health alarm, experts talk of a distorted perception of risk, that is, believing that there is real danger when objectively there is none. The spreading of reliable information will undoubtedly dispel these fears.

Do children need more protection against electromagnetic emissions?

The radio frequency exposure limits set in Spanish regulations (RD 1066/2001) assume the criteria of health protection against electromagnetic fields established in the EU Health Ministers' Council Recommendation, dated 12th July 1999. These limits are those set by the International Commission of Non-Ionizing Radiation Protection (ICNIRP). Said values provide the public at large, including children, with a enough margin of safety. In the opinion of the ICNIRP "there is no need or justification for a specific proposal for the protection of children or other special groups from the general population."

This Commission is made up of the most distinguished experts on the matter at the international level. Together with the World Health Organisation they protect the safety of the general public.

What is hypersensitivity?

The WHO in its note no. 206 on sensitivity to electromagnetic fields published in December 2005 says:

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The same scientific studies that endorse the existence of the Electromagnetic Hypersensitivity Syndrome (EHS) state that its symptoms:

Are NOT correlated to the exposure to electromagnetic fields

CAN be caused by environmental factors

“The Electromagnetic Hypersensitivity Syndrome is characterised by a variety of non-specific symptoms, which affected people ascribe to an exposure to electromagnetic fields (EMFs). The most commonly experienced symptoms include dermatological symptoms (skin redness, tingling and burning sensations) and neurasthenic and vegetative symptoms (fatigue, tiredness, concentration problems, vertigo, nausea, heart palpitations and digestive disorders). This set of symptoms is not part of any recognised syndrome.”

There is some evidence suggesting that these symptoms could be due more to pre-existing psychiatric conditions and to stress reactions as a result of the worries about the health effects of electromagnetic fields than to the exposure to electromagnetic fields itself.

Is there any proof of any long-term effect caused by electromagnetic fields?

No. All the research that has been carried out up to date has not found any evidence of long-term exposure to electromagnetic fields being detrimental to human health. Nevertheless, continuing with this line of research is recommended.

Are there any radio frequency experts who are concerned about possible health risks derived from mobile telephony base station antennas?

The mission of a scientist is to consider problems and give answers to them. Therefore, there is an interest in finding out more about the effects and applications of radio frequencies and knowing them better, which is why research goes on as in other scientific fields.

For a more detailed analysis of the health issues associated with mobile phones, we suggest you look up the exhaustive information available at the WHO's website on electromagnetic fields.

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How much research on electromagnetic fields and health has been carried out so far?

The World Health Organisation (WHO) maintains an up-to-date database of scientific research that includes studies on the possible effects of radio frequencies and public health. WHO reviews of possible biological effects related to exposure to electromagnetic fields from telecommunications equipment highlight more than 50 years of research in this field. This database, available on the organisation's website, shows that there are more than 1,900 scientific publications and more than 630 studies on the use of mobile phone networks.

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