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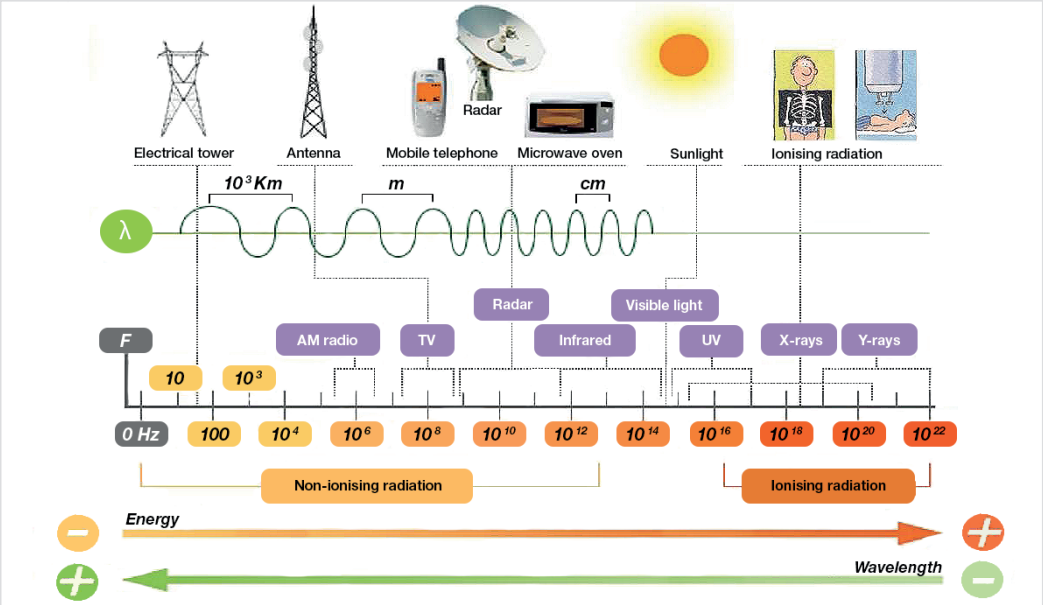
The non-ionising electromagnetic spectrum

Signals to transport energy and communicate

Key ideas

- Electromagnetic waves are generated by both nature and as a result of human activity.
- We have been unable to establish any association between the different forms of exposure to non-ionising electromagnetic waves and the appearance of certain disorders or adverse effects for intensities and frequencies under the safety thresholds.
- More research is needed in the areas of long-term exposure and hypersensitivity.



Non-ionising radiation and ionising radiation (Source: Internet).

Introduction

The first manifestations of electrical and magnetic phenomena, which were initially observed through the forces that acted on charges and currents, were systematised during the 19th century with the observations by Oersted, first, on the influences between electrical currents and magnetic phenomena, and later with the studies by Ampère and Faraday. They culminated with Maxwell's equations which interrelated electrical and magnetic phenomena and ended up predicting the existence of electromagnetic waves, which were ultimately corroborated by Hertz at the end of that same century.

The description of these waves can be understood, as mentioned above, by their effect – force – on charges and currents, even though it is more practical to introduce the concept of field for the purposes of more systematically studying the phenomena of radiation and propagation. These waves, or their associated fields, are generated by the movement of electrical charges when they experience acceleration that varies – oscillates – over time. Like pendulums, these oscillations can have a repetition frequency that ranges from very slow variations of a few cycles per second – Hertz (Hz) – to billions of cycles per second (GHz), such as microwaves, or trillions of cycles per second, such as light waves, and even higher, like X-rays. In physical terms, they are signals that travel at the speed of light, which are usually expressed as waves with a certain aggregate energy composed of a set of quantified elementary energies that we call *photons*. These waves are generated both spontaneously by nature (sun, lightning, etc.) and as the result of human activity (engines activity, electrical energy propagation or information in our radio, television and mobile communication signals). In all of these cases, they have a shared characteristic, namely that low levels of exposure (aggregate wave energy) and frequency (under ultraviolet, where the elementary energy of the photon is beneath the level needed to ionise atoms or molecules) are inoffensive and can even be beneficial: think of the sun or physiotherapy treatments, although we must always bear in mind that overexposure can be harmful. Aware of this, science and technology have studied and established safety levels, usually far below the minimum levels, to ensure that their use, in terms of power and frequency, have no harmful effects for either people or for animals and plants, or even for the nature around us. For energy transport applications and communications, the subject of this report, we will always be referring to low-intensity and non-ionising waves.

A bit of history

Even though we have always lived with these signals in many different ways, their huge presence in our lives and the natural tendency to protect ourselves from potential dangers have sparked concern over the nature of these waves. Thus, every so often, especially every time there are

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The latest wave of connectible devices has given this issue new visibility. (Source: Pixabay)

major scientific or technological breakthroughs, there has been a phase of keen societal concern, such as when electrical grids spread in the early 20th century to bring electricity to homes, or when first radio and then television broadcasting spread after the mid-20th century, and more recently mobile communications.

Within the framework of this last technology, mobile communications, around 15 or 20 years ago there was a societal debate which unquestionably helped to set better precautionary mechanisms regarding the safety levels needed. Indeed, the Parliament of Catalonia addressed this issue in a study commission held during the sixth legislature[1] on the effects of high-tension lines and mobile telephone installations on human health. This study commission, which enlisted the participation of different experts, concluded that "no noncompliance with the Catalan and Spanish regulations on maximum levels of electromagnetic fields determined by the different international bodies was found". Therefore, we should stress that the situation at the outset did not entail a lack of control, noncompliance with regulations or lack of knowledge on the part of the public administration.

Currently, the new wave of connectable devices, or the Internet of Things – in which this connectivity mostly comes via electromagnetic waves and is associated with what we call "the fifth generation of mobile communications" (5G), which covers the current frequencies up to 60 GHz and will extend them up to 300 GHz in the middle term – has once again placed this issue in plain view of social and citizen groups, and it thus seems reasonable to further study the potential effects of these new devices and disseminate the results.

This societal concern is not only ours; indeed, many places share the same concern with information and the need to ensure that all the applications around us comply with the precautionary mechanisms and safety measures. In this sense, the European Union and the European Parliament have reported on the issue and carried out recent studies which shall serve as a foundation for the information we are providing in this newsletter.

Some general concepts on the interaction between electromagnetic waves and human beings

In order to understand how electromagnetic waves interact with matter, we must first make a distinction based on whether they are ionising or not. Radiation is said to be ionising if it has enough energy to free an electron from an atom or a molecule, which then becomes an ion. The energy from radiation is proportional to its frequency, and it is common knowledge that only radiation at frequencies corresponding to ultraviolet or higher can be ionising. Thus, ultraviolet rays and X-rays are ionising, while visible light, infrared light, radio waves and the frequencies of electrical lines are not ionising. Therefore, when speaking about the effects of radio waves on matter, we must stress that this is non-ionising radiation.

The interaction of electromagnetic fields with the human body partly depends on the behaviour of the tissues, and this behaviour varies according to the frequency. At low frequencies under 100 KHz, tissues are moderately good conductors, while at higher frequencies human tissue is a dielectric (generally more insulating) with loss. This variation in behaviour means that at low frequencies the field effect induces electrical currents, while at high frequencies the interaction of non-ionising radiation with the body is basically in the form of heat. The absorption of the waves leads to a temperature increase; in fact, this is the effect that is used when heating foods in microwave ovens. Therefore, the regulations that limit electromagnetic fields were made to guarantee that the interaction of electromagnetic fields with the human body do not alter its normal functioning. This means that at low frequencies, induced currents not only do not cause a sense of discomfort, but they are also much lower than the currents produced by the body's own normal bioelectrical activity. At high frequencies, it is essential to guarantee that the human body's absorption of energy associated with an electromagnetic wave is offset by the body's own thermoregulation mechanisms. It should be borne in mind that changes in air temperature, performing physical exercise and exposure to sources of heat require the body to constantly activate thermoregulation mechanisms to maintain the body temperature within strict margins. The limits of protection against electromagnetic radiation are established by adding safety margins to values that are themselves considered innocuous in the sense that they cause no stress to the human body's thermoregulation mechanisms. Given that the penetration of electromagnetic fields, as well as the ability to absorb them, depends on frequency, the limits of protection end up being expressed in maximum field values that vary in the different frequency bands.

The thermal effect, and the proper protection that the regulations stipulate to avoid it, are accepted, incontrovertible facts. There are many biological mechanisms with an electrical basis. Therefore, once we have discarded ionising and thermal effects, the question is whether exposure to electromagnetic fields at frequencies that are not ionising and at intensities that do not produce appreciable thermal effects can somehow harm the normal functioning of the biological mechanisms of the human body. The answer to this question can be approached in three different ways. Just as the effects of ionising or thermal radiation can be modelled and studied theoretically, the first point is whether we can theoretically establish the possibility of altering the normal functioning of known biological processes with non-ionising, low-intensity electromagnetic radiation. The second aspect is based on *in vivo* experimentation on either cells or animals. In this case, controlled amounts of electromagnetic

The European Union monitors the effects of electromagnetic waves on health. (Source: Pixabay)

radiation are applied on a test population in the laboratory, and we study whether they develop alterations, either physical or behavioural. The third approach involves epidemiological studies which examine whether it is possible to establish a relationship between the prevalence of a certain disease or health disorder and exposure to electromagnetic fields. The actions of scientific working groups in international organisations, such as the World Health Organisation (WHO), consist in exhaustive surveys of the evidence published in scientific journals in order to answer the question of whether there are adverse biological effects associated with exposure to electromagnetic fields with intensities lower than the levels set to avoid thermal effects, and therefore whether any additional protective elements need to be established based on any of the three possible approaches described above. To date, the answer has been no.

Monitoring in the European Union. The current regulatory situation

The European Union's (EU)[2] actions with regard to electromagnetic waves (or electromagnetic fields) is based on the recommendations of the Council of the European Union on limiting public exposure to these fields (0 Hz-300 GHz)[3]. It proposes: a) establishing a set of basic restrictions and the corresponding reference levels; b) creating baseline elements for EU legislation on product safety; c) asking the European Commission to regularly review any effect that electromagnetic fields may have on health; and d) providing the governments of the different states with guidelines.

a) The restrictions and reference levels proposed by the recommendation are based on the guidelines of the International Commission on Non-Ionising Radiation Protection (ICNIRP, a group of scientific experts recognised by the World Health Organisation) which were accepted by the EU's Scientific Committee in 1999 and since then have been periodically reviewed by a committee and are the object of four specific scientific reports on the health effects of exposure to electromagnetic fields.

b) For the implementation of legislative measures in the EU, recommendations serve as the foundation of updates of the different directives: i) Directive 2013/35/EU, which establishes minimum health and safety requirements regarding the exposure of workers to the risks arising from electromagnetic fields; ii) Directive 2014/35/EU, which has to do with low-voltage electrical equipment; and iii) Directive 2014/53/EU, which covers radio and telecommunication terminals.

c) The EU's tracking of the potential health effects has led to different reports and documents from the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) and different studies and opinions have been issued that have provided no scientific justification that might entail the need to revise the current limits set on exposure (basic restrictions and reference limits). Despite this, they recognise that the basic data used to evaluate certain risks is still limited, especially for low-level exposure for long periods of time, such that more research is needed on the issue. The Commission has summarised the contents of more than 700 studies – most of them from 2009 or later – in a document related to electromagnetic fields called "Does electromagnetic field exposure endanger health?".[4] After reviewing a few general aspects such as the fact that electromagnetic fields are not a solely human phenomenon, since they also exist in nature, nor are they recent, since we have been living with electromagnetic fields produced by electrical distribution lines for over a century, the text then summarises the following information: a) the results of the most recent research show that there is no evidence of adverse effects on health if the exposure levels are below the thresholds set by the current standards; b) studies that suggest an association between the electromagnetic fields produced by mobile devices and increases in the risk of certain forms of cancer or Alzheimer's are unconfirmed, and the incidence levels of these diseases have not changed since mobile phones were introduced; c) epidemiological studies that relate exposure to low-frequency fields such as transport lines or electrical distribution lines with much higher levels of leukaemia in children have not been corroborated or reproduced in laboratories through studies of cells or with animals; d) the problems that certain people express regarding symptoms such as headaches, sleep problems or fatigue when they are exposed to electromagnetic fields, known as hypersensitivity, is a real concern for them, yet no scientific evidence of these problems has been found; e) despite everything contained in the previous points, there is still an imperative need to keep researching to confirm or dispel the possible causes of the association between electromagnetic fields and certain adverse effects; and f) even though it may seem like the exposure levels might be rising due to the increase in the number of devices, since the levels being emitted are much lower for both safety and energy-savings reasons, in all the studies on exposure these levels may be decreasing, although it may depend on the location or lifestyle.

d) The European Parliament has adopted different resolutions on electromagnetic fields and regularly sends written questions to the Commission. In this sense, we should highlight two documents: i) the information sheet on the most common questions and answers regarding electromagnetic fields[5] (15 questions and answers); and ii) the easy-to-read summaries of scientific opinions: potential health effects of exposure to electromagnetic fields.[6][7][8]

On its own initiative, the European Economic and Social Committee (an EU advisory body) has developed a document on electromagnetic hypersensitivity,[9] an issue that is worrisome because some people are particularly sensitive to electromagnetic fields. This document concurs with previous studies in the sense that: i) no adverse effects can be identified; ii) more research

There is a perception of risk associated with exposure to electromagnetic fields which is unwarranted bearing in mind scientific knowledge and administrative control measures.
(Source: Internet)

on the topic is needed; and iii) all precautions and radiation levels must remain under the established limits.

The safety of electromagnetic waves

The reference levels of public exposure to electromagnetic waves, that is, the maximum level for a site where the public has general access, comes from Council of the European Union Recommendation 1999/519/EC dated 12 July 1999, which sets basic restrictions and reference levels on exposure of the general public to electromagnetic fields based on the directives published by the ICNIRP[10] in its report from April 1998.[11] For exposure of the general public, the basic restriction is set at fifty times lower than the threshold considered safe.

The perception of risk

Exposure to electromagnetic fields in general, and those with human origins in particular, associated with either electrical distribution lines or the use of communication systems like radio or television broadcasting or mobile telephones, is not a new phenomenon and has been part of our everyday lives for more than 100 years, even more widely in the past 20 to 30 years. The existence of regulations that limit exposure to electromagnetic fields, as well as the availability of the means to predict and measure exposure levels, have developed parallel to this spread. Despite this, there is still a perception of risk associated with exposure to electromagnetic fields which is unjustified bearing in mind scientific knowledge and administrative control measures. One of the factors that promotes this unwarranted increase in the perception of risk is the confusion between radiation – that is, the transmission of energy via waves – and radioactivity – a totally different physical phenomenon. On the one hand, opposition to the spread of highly visible infrastructures like high-tension lines or certain mobile telephony lines turns into opposition based on the health risks posed by these installations. Ultimately, the poor image of the companies operating these electrical distribution and mobile telephony services, as well as the existence of a small yet active sector seeking business opportunities in parascientific activities that foster and exaggerate this perception of risk, means that when there is a situation of conflict, strong citizen opposition movements are generated unless the government acts swiftly to provide information.

Conclusions

In accordance with the considerations outlined above, we can reach conclusions about some of the most significant aspects:

– The existence of electromagnetic fields and the consequent exposure to them is neither a recent phenomenon (we have been living with electrical transport and distribution lines for more than a century) nor is it due solely to human activity, since nature also produces electromagnetic fields.

– All the studies and research conducted have been unable to establish any association between the different forms of exposure and the appearance of certain diseases or adverse effects (or detect any increase in the general levels of incidence among the population), as long as this exposure is under the safety levels established and is effectively enforced.

– Even though no scientific evidence has been found on possible adverse effects, it is essential to stress the need to keep researching to confirm or dispel possible causes of association between electromagnetic fields and certain adverse effects due to specific situations, such as long-term exposure or phenomena like hypersensitivity.

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