REPORT ON

RADIOFREQUENCY AND HEALTH

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COMITÉ CIENTÍFICO ASESOR EN RADIOFRECUENCIAS Y SALUD (CCARS).

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Presentation

Deployment of the infrastructures necessary to service mobile telephony (MT) and other communication technologies continues generating certain objections among some groups in our society. The media periodically feature news on health, legal, financial or risk perception issues related to the installation of base stations (antennas and transmitting equipment).

Social concern arising from any aspect related to radiofrequency and health has led institutions and advisory committees in most countries in our area, to take on the task of guiding and providing scientific rationality to the debate. This function has been commissioned to agencies created specifically for this purpose or it has been included in the agendas of committees or bodies with the general mission of providing government advice on technical or healthcare matters.

In Spain, there was no such entity, body or agency since the dissolution of the Independent Expert Committee created in 2000 by the General Department of Environmental and Occupational Health of the Ministry of Health and Consumer Affairs, until the General Foundation of the Complutense University of Madrid took the initiative of collaborating in the task of evaluating the effects of electromagnetic fields. With this purpose, it promoted the creation of the Scientific Advisory Committee on Radiofrequency and Health (CCARS) in July 2005.

CCARS is an independent institution, comprised of renowned experts in Medicine, Physics, Chemistry, Biology, Epidemiology and Law. The current composition of CCARS can be found in the Committee's web page (www.ccars.es), where information is also provided on the activities and objectives of CCARS.

One of the main objectives of CCARS since its creation is to provide scientific guidance and updated information, clearly and independently, to all public and private organizations, as well as to the general public, on the exposure to radiofrequency (RF) electromagnetic fields (EMF) and its effects on human health. This information intends to be useful to make the best political and healthcare decisions based on the results of scientific research.

In October 2006, CCARS issued a report on the scientific evidence of exposure to radiofrequency and health [CCARS-2006]. This report was prepared at the request of the Ministry of Industry, Commerce and Tourism (MICyT) with the purpose of reviewing all scientific data on the effects on health of exposure to the radiofrequency EMF used by MT. The Committee assessed the scientific evidence published and the conclusions reached, to date, by bodies, agencies and committees competent in the matter.

Since then, we have continued researching and various reports and experimental studies have been published on the effects on health of exposure to RF EMF generated by MT base stations (antennas) and by the use of terminals (mobile telephones). This report provides an update of all information available to date on whether exposure to RF used in MT is directly associated to or is a risk factor of certain diseases or has hazardous effects on human health.

This text aims to summarize the generalized view among national and international expert committees when assessing the risks related to exposure to radiofrequency signals, primarily radiocommunications, in residential, public or work settings. Thus, the conclusions included in this text are shared by most experts on the matter, although there are a few dissenting minorities. Unanimity is difficult to achieve in science given its very nature. The core text of this document was prepared by Dr. Francisco Vargas, and the various sections it is comprised of were reviewed by the corresponding experts, members of CCARS. The initial section "Considerations on electromagnetic fields" was written by Prof. Antonio Hernando. Sections 3 and 4 "Experimental studies on the effects of radiofrequency electromagnetic fields on health" and "Epidemiological studies" were reviewed by Dr. Isabel Varela, Dr. Alejandro Úbeda and Dr. Manuel Desco. Sections 5 and 6 were reviewed by Dr. Mercedes Martínez and Prof. José Luís Sebastián. Drafting of the Report was coordinated by Dr. Patricia Crespo, Executive Secretary of CCARS, under the supervision of its Chairman, Prof. Emilio Muñoz.

This report summarizes [1] the results which have appeared in prestigious publications in the last two years. We have analysed the conclusions and recommendations of bodies, committees and agencies competent in the matter of assessment of risks resulting from exposure to RF and human health, specifically emissions from base stations and mobile telephones. These competent bodies include, among others, the World Health Organization (WHO), the European Union Scientific Committee on Emerging and Newly Identified Health Risks, (SCENIHR), the International Commission for Non-Ionizing Radiation Protection (ICNIRP), the Swedish Radiation Protection Authority, (SSI), the UK Mobile Telecommunications and Health Research Programme, (MTHR) and the Health Council of the Netherlands.

The contents of this report are divided into two sections. The first one focuses on a description of the most relevant findings of experimental, clinical and epidemiological studies related to exposure to MT RF. The second one summarizes the results published on the levels of exposure to RF EMF to which the population is subject to, obtained from measurements conducted across Spain and Europe.

Finally, we summarize the recommendations put forward by the various studies and research programs as well as by the competent bodies on the matter regarding the areas and lines of research that should be undertaken in greater depth in the next few years.

The annexes of this report include the results of the measurements conducted of the exposure of the general population to radio electric emissions from radiocommunications stations up to the last year available, 2007, and published by the MICyT, as well as a description of the operation of the radiocommunications systems (data provided by the Association of Telecommunications Engineers).

[1] The views expressed in this publication are those of the authors and do not necessarily represent those of the institutions they work for.

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1. Executive summary

This report summarizes the results which have appeared in prestigious publications in the last two years. We have analysed the conclusions and recommendations of bodies, committees and agencies competent in the evaluation of risks derived from exposure to RF, specifically emissions from base stations and mobile telephones.

None of the experimental *"in vitro"* and *"in vivo"* studies conducted recently have found any conclusive evidence of genotoxic or carcinogenic effects resulting from exposure to RF fields. In some cases, alterations in cell dynamics were reported, but the lack of standardized measurements hinders study comparisons.

With regard to epidemiological studies, most were aimed at identifying the effects of the prolonged use of mobile telephones and the possible relationship with the onset of brain tumors. Available data indicate that exposure to mobile telephones for periods of less than 10 years by healthy adult users does not increase the risk of developing a brain tumor. No conclusive studies have been conducted on exposure for longer periods.

As a whole, studies of people who claim to suffer electromagnetic hypersensitivity, have provided no evidence that exposure to RF EMF from base stations and terminals is a causal factor of their symptoms.

With regard to emissions from base stations (mobile telephony antennas), a limited number of studies have been conducted which, as a whole, show values of exposure to radiofrequency electromagnetic radiation which are far below the reference values established by Spanish legislation under Royal Decree 1066/2001 [RD 1066/2001]. These limits were established by the International Commission for Non-Ionizing Radiation Protection (ICNIRP), an organization endorsed by the World Health Organization (WHO), and by the European Union. See, for example, the "Report on the general population's exposure to radio electric emissions from radiocommunications stations, 2007" by the Spanish Ministry of Industry, Trade and Tourism (Ministerio de Industria, Turismo y Comercio, MICyT) [MICyT-2007].

Finally, we have put forward the priorities for future research on the possible health effects of RF. These include expanding epidemiological and experimental evidence (evaluation of the effects of exposure during periods of more than 10 years, evaluation of children and adolescents) and perfecting dosimetry equipment and strategies.

2. Considerations on electromagnetic fields

2.1 Electromagnetic interaction as the basis for matter and life

According to the most widely accepted theory of the origin of the Universe, since the start of the Big Bang there was an enormous number of photons, electrons, positrons and neutrinos and a small contamination of protons and neutrons. Photons are the quanta of electromagnetic fields. The interaction between charged particles, electrons, positrons and protons, known as electromagnetic interaction is – together with the strong interaction that keeps the particles that make up the atomic nucleus together, the weak interaction and the gravitational interaction governing condensation of galaxies and the movement of planets around the stars- one of the four protagonists in the history of the Universe. Yet perhaps it is the most familiar on the scale on which we humans are accustomed to moving on our Planet. Electromagnetic attraction is responsible for the grouping of electrons and protons into atoms and then for these to condense into molecules and subsequently into solids or macromolecules such as proteins and viruses. Chemistry and biology are manifestations of electromagnetic interaction. Cells are the result of the electromagnetic coupling of organic molecules by means of the chemical binding which is merely the result of the electromagnetic attraction of atoms.

Life can exist exclusively in an appropriate electromagnetic environment ruling the rates of radiation by maintaining the necessary temperature range. Also, the electromagnetic radiation formed by photons is an essential component of the chlorophyllous function responsible for the existence of life in its current form. The synthesis of water and carbon dioxide generates sugars which help store energy. The excess potential energy a sugar molecule has compared to the initial molecules is obtained from electromagnetic energy, or sunlight, which is absorbed during synthesis only if chlorophyll, which acts as a catalyst, is present. The formation of sugars is the basis of all food synthesis for various forms of organized life.

Electromagnetic radiations consist of photons with different energy levels. Recently, at the turn of the 20^{th} Century, Planck discovered that the energy of a photon depends on its frequency. The frequency of the photon or the frequency of the electromagnetic wave determines, for example, colours. The difference between a green light and a red one is their frequency. The capacity to impress our visual organ is restricted to a very reduced band of possible frequencies. If f is the photon frequency, its energy E is proportional to f with a proportionality constant which has been defined since Planck's times with the letter h. Therefore, the formula relating energy and frequency is simply $E=h \cdot f$.

The purpose of this introduction is to increase awareness on the relevance of electromagnetic interactions in the development of the Universe, the Earth, Nature and Life. It can be stated that electromagnetic fields and waves are found in the most intimate texture of all matter and trying to do without them is akin to doing away with matter, light, food and life.

2.2 Ionizing and Non-Ionizing Radiations

The Sun, as a source of energy, is directly responsible for life on Earth in all its forms. The transmission of energy from the Sun, where it is continuously produced by nuclear fusion, to the Earth takes place through photons or radiation. The atmosphere buffers the ultraviolet radiation which corresponding to the most energetic band around the visible spectrum could cause burns if it had a greater intensity. This is the first example of the balance required for development of life. While we need the Sun's radiation, an excess would disintegrate us. The critical dose of ultraviolet radiation is set by the ozone layer in the atmosphere, whose state so worries, and rightly so, a society increasingly aware of the fragile balance upon which the possibility of life lies, since the molecules that form bodies are bound by electromagnetic forces which are susceptible to being broken by external forces of the same magnitude. High energy photons, within a magnitude range of *0.1* to *1 eV*, can break molecules since the energy of the chemical bond is in the same interval. (Note, 1 electron-volt, *eV*, is the energy an electron acquires in a 1 volt potential). The kinetic energy with which a nitrogen molecule moves forming part of the air in our room at *20* degrees Celsius is *0.026 eV*. Photons with energy below *0.1 eV* cannot break the chemical bonds and are known as non-ionizing, since the break-up of the bonds results in the formation of ions which are the atoms initially bonded after violently splitting up. If you consider that Planck's constant is $h=6.6 \cdot x10^{-34}$ *joule-second* or $6.6 \cdot x10^{-15}$ *eV·second* all photons with a frequency *f* lower than 10^{13} sec^{-1} or 10^{13} *Hz* (the unit *Hz* means hertz or one per second; the number of hertz is the number of times in a second the direction of the electric field in a photon is reversed; 10^{13} means ten billion since it indicates a number with thirteen digits) have an energy lower than *0.01 eV* and can be considered as non-ionizing radiations or not molecule breakers. This is why, radiations termed as non-ionizing cover the frequency spectrum that ranges between static fields - or not variable in time – for which $f=0$ *Hz* and those with a frequency of *300 GHz* or *300 gigahertz* $= 3 \times 10^{11}$ *Hz* (*1 GHz* are one thousand million hertz or 10^9 *Hz*).

We all know that gamma radiation or X-rays, since they are ionizing, can have hazardous effects on tissues. But it should be noted that the existence of high energy photons is not sufficient to cause damages, it is also necessary that the number of photons is high enough. The dependence of damages on the number of photons or the intensity of radiation allows speaking of tolerance and safety doses, even for high energy or ionizing radiations.

We can thus conclude that photons or electromagnetic waves with a frequency ranging from zero hertz to a billion hertz do not have enough energy to break molecules and therefore they are considered non-ionizing. They are, therefore, incapable of directly causing genetic alterations by breaking down DNA.

2.3 Electromagnetism as a science

Although electromagnetism has existed since the beginning of the Universe, over ten thousand years ago, human beings have not properly known about it until relatively recently. The experimental method enabled a set of researchers- Coulomb, Gauss, Poisson, Oersted, Ampère, Faraday and Maxwell, covering the period from the late 18^{th} Century to the second half of the 19^{th} Century- to discover the laws that rule how electromagnetic interactions take place. Later, Einstein, with his Theory of Restricted Relativity, concluded that the speed of electromagnetic waves (the speed of light) is the same in all reference systems, thus showing that the consistency of Maxwell's equations is greater than that of Newton's laws of dynamics. The subsequent establishment of Quantum Electrodynamics, was the last step that allowed closing the electromagnetic theory at an atomic and subatomic level. Today, Electromagnetism is a closed and completed science. The effects of magnetic fields on matter, electromagnetic interactions, are perfectly known. The forces that the fields exert on electric charges – either at rest or in movement- and magnetic moments can be calculated precisely.

The last assertion in the above paragraph is particularly important to clearly focus the issue of the interaction of electromagnetic fields with living matter. Whatever the effect produced by a field of a certain intensity and frequency it should be able to be explained as a consequence of the electromagnetic forces which are perfectly known. The difficulty to explain its effects on health arises from the lack of sufficiently detailed knowledge on all the physical-chemical mechanisms that make up life. Obviously, this lack of knowledge is due to the enormous complexity of the details of biological phenomena. Yet these are the ones that must be researched. In other words, it is a mistake to consider that electromagnetic fields can produce effects on life which are different from the ones they produce on charged particles. There is no need to invent new properties for electromagnetic fields to justify their action upon that which is alive, rather we should delve into the mechanisms which rule the course of charged particles, present in cells, so that, based on the well-known forces of electromagnetic fields on these charges, we can explain their effect on biological mechanisms.

As is known, all advances in theoretical knowledge in a science are accompanied by technological advances. Reciprocally, technological advances generate new core knowledge. Within this dialectical framework, the establishment of the laws of Electromagnetism was accompanied by the genesis of a vast horizon of technological possibilities such as those outlined below.

2.4 Electromagnetism as a tool for development and welfare: Faraday's revolution. The possibility of creating electromagnetic fields artificially

Computer hard disks, videos, recording tapes, credit card strips, security codes, engine, transformer and generator nuclei, television, telecommunications equipment, all of these elements which are so familiar in the year 2000, are based on the effects of electric and magnetic fields. These systems, unlike all the chemistry of Nature, which is also essentially the result of the laws of Electromagnetism, do not exist spontaneously, they are the fruit of the research efforts of man. It can be said that since the turn of the 20^{th} Century, the magnetic fields created artificially by humanity exceed the electromagnetic fields which have existed naturally for millions of years on the surface of the Earth.

The most revolutionary application of electromagnetic fields was undoubtedly the one which took place in that century (20^{th} Century) thanks to Faraday's discovery in the mid 19th Century. This brilliant experimental English physicist discovered in his laboratory that electric fields, of which until then it was known that they were created by electric charges, were also created, with no need for an electric charge, with magnetic fields variable in time. The possibility of creating variable magnetic fields with mechanical apparatus that made, for example, magnets turn, was immediate. This enabled building electric field "factories" and by means of conductors, transport electricity to faraway points. This transport was in fact a transport of energy which given its principle of conservation, consisted of the energy spent by the mechanical apparatus to make the magnetic field turn. The energy could be stored as chemical or mechanical energy, turned into an electric field, transmitted at a distance – similarly to how the Sun's nuclear energy is transmitted to the Earth by means of photons- and then reconverted into usable energy at the places of consumption: homes, offices and factories. The possibility of using energy anywhere with no need to be near the source, represents the scientific outcome which most contributed to achieving the level of welfare, culture, health safety and industrial capacity of the most developed populations. It is giddying to start to discern how the world would change if there were no energy supply in homes, hospitals or factories. This is a perfect example of how the discovery of laws ruling the electromagnetic phenomena inherent to matter since the Universe exists, allows society to use said phenomena to improve its culture and lifestyle. It is easy to ascertain that every positive advance has in essence, contradictions. If we use energy, there is a price to pay. This price is the beauty of the countryside and cities scarred by towers holding the supply conductors, the ecological disturbance of the site where the energy is stored (hydraulic dam, thermal or nuclear plant), increased environmental intensity of electromagnetic fields of 50 Hz, the possibility of electrocution, etc. Fortunately, many of these factors can be evaluated precisely and rigorously. Others cannot, as for example, those pertaining to aesthetics. When delimiting the scale of the dialectics leading to the radical question: Is progress worthwhile?, it would be advisable to take into account the damages derived from a certain technology, for example, that of electromagnetic fields, can never be greater on average than those we are already exposed to due to the natural existence of electromagnetic fields. The question thus only allows an answer following a rigorous analysis. The benefit/risk ratio needs to be examined dispassionately and in perspective. As in the case of solar ultraviolet radiation, we need to find the critical condition of balance to limit intensities which will depend on each frequency range.

Another point to consider when undertaking a detailed analysis of the risks that allows assessing the current state of knowledge of biological phenomena is that relating to magnetic field intensity associated to the transmission of energy as electricity. The electric fields generated by the conductors comprising the transmission lines are of 50 Hz. The magnetic field below a normal line never exceeds 20 microteslas. The continuous magnetic field we are born and live in varies from one point on the Earth's surface to another, but it is around 50 microteslas. The magnetic field acting on a patient undergoing a Nuclear Magnetic Resonance test is four million microteslas or four teslas.

3. Experimental studies on relevant health effects of radiofrequency electromagnetic fields

3.1 Core literature

The aim of this section is to provide a brief overview of the recent advances of experimental studies. For this purpose, we have decided to limit references to specific articles and, instead, refer readers to review works conducted by national or international committees. These papers, which are listed below and can be immediately accessed on the Internet, provide the reference of the articles consulted to prepare this text:

[SCENIHR-2007] The European Commission's Scientific Committee on Emerging & Newly Identified Health Risks (SCENIHR). Report on Possible effects of Electromagnetic Fields (EMF) on Human Health (2007).

[HCNL-2007] Health Council of the Netherlands Electromagnetic Fields Annual Update 2006 (February 2007).

[DCMNR-2007] Irish Government's Expert Group on Health Effects of Electromagnetic Fields Report (2007).

[SSI-2008] Swedish Radiation Protection Authority’s Independent Expert Group's: Report on Electromagnetic Fields (2008).

[IET-2008] Institute of Engineering and Technology (IET): Position Statement on the Possible Harmful Biological Effects of Low-Level Electromagnetic Fields of Frequencies up to 300 GHz (2008).

[USNC-2008] US National Cancer Institute factsheet on Cellular Telephone Use and Cancer Risk (2008).

[MTHR-2007] “Mobile Telecommunications and Health Research Programme, MTHR (2007).

3.2 *In vitro* studies

In the research on the potential biomedical effects of RF radiations, the studies on tissue or cell cultures, human or animal, transformed or not, are highly interesting, as they represent models, generally well described where control of the exposure and experimentation conditions is significantly greater than in live animals or human volunteers. Given their relative simplicity, the *in vitro* models are ideal to research the basic mechanisms of the bio-effects of physical agents such as RF radiations. However, that same simplicity is a serious limitation to obtain, based on a given cell response, conclusions on the potential relevance, in terms of safety and health, of the effect observed experimentally.

3.2.1 Recent results of genotoxic effects of radiofrequency signals

The variability of experimental results on *in vitro* models or cell cultures is significant, given the significant number of cell strains used, variables measured and experimental conditions.

Since the photon energy of RF radiations is too weak to break chemical bindings, it has been generally accepted that these radiations do not directly damage DNA molecules. This has been shown by several past and recent studies. However, there is speculation on the possibility that these radiations could have indirect genotoxic effects, for example, by altering the cell repair mechanisms for DNA damaged by other agents. Mostly, these studies were not seeking direct oncogenic effects, but rather alterations of cell metabolism related to exposure to electromagnetic fields.

Thus, some experimental data obtained within the REFLEX project, showed indications of breakage in DNA following exposure to theoretically subthermal levels of signals with typical mobile telephony frequency [REFLEX-2004]. However, subsequent attempts to replicate these results have been limited and have not been able to confirm the effect, therefore it has been considered advisable to expand research on this issue.

In a recent *in vitro* study of fibroblast and human lymphocyte cultures [Schwarz-2008] the authors observed no effects in the case of lymphocytes but there was an increase in fibroblast DNA damage, with an existing dose-response relationship. However, this article has given rise to certain controversy, through a letter to the editor of the journal criticizing the statistical methodology employed. Given how recent the publication is, it is best to wait to properly assess this contribution.

Another very recent article presents results which are partly contradictory to those above, since they observed an effect on the repair of human lymphocyte DNA [Belyaev-2008]. The study was carried out with a very small sample (10 volunteers and 10 individuals who reported hypersensitivity to EM fields), and describes the effects found in some patients, without observing any differences between either subgroup. Again, to confirm this trial and clarify the discrepancies with other studies, it is necessary to replicate these results with larger samples.

In vitro results tend, in general, to present biological effects on various cell functions, the interpretation of which is complex and whose possible harmful impact has not been clearly established.

3.2.2 Non-genotoxic effects of radiofrequency signals

Research has also been conducted on the possible action of RF signals on other phenomena which, without actually being genotoxic, could influence tumor processes already initiated. Among other factors studied are: alterations in the rate of apoptosis, or programmed cell death, in the modulation of gene regulation, in cell cycle kinetics, in cell stress markers, such as thermal shock proteins, in the activity of immune system cells and the level of free radicals, potentially capable of interacting with DNA. Taken as a whole, the block of results provides scarce evidence of the subthermal effects of RF signals, considered relevant for health (see references indicated in 3.1). However, some studies have shown indications of changes in the gene expression of cells exposed to RF levels close to the limits proposed by international regulations for protection against this type of signals. If confirmed, these results would be a major advance in the understanding of the mechanisms of interaction between RF and living tissues. As for its relevance to health, this could only be determined with complementary information, obtained from *in vivo* studies and with humans.

3.3 *In vivo* studies

Initially, the results obtained from studies with animals, generally experimental laboratory rats and mice, allow drawing conclusions on the response of superior complex organisms to physical or chemical environmental agents. In general terms, the relevance of these conclusions to assess the effects of an agent on health, would have a greater weight than the one corresponding to the conclusions of *in vitro* studies. In contrast, the control of experimental conditions and the exposure levels is significantly more complex and uncertain than in research with cell biosystems. Furthermore, the very characteristics of the species for experimental use and their anatomical and genetic differences from humans, mean that, in many cases, the outcomes obtained in animals cannot be extrapolated directly to humans.

3.3.1 Carcinogenic effects of radiofrequency signals: exposure-cancer relationship

From a methodological perspective, an essential aspect to be taken into account is the existence of a dose-response relationship. A higher frequency or intensity of the effects at greater exposures speaks in favour of the existence of a real effect, since this is the behaviour of all known factors (chemical, ionizing radiations, etc.). On the contrary, the so-called "window effects", only observed with certain levels of exposure, and no clear relationship between what occurs with higher or lower doses, leans in favour of the observation being merely the result of chance. This "window effect" is also frequently detected in epidemiological studies, in which the effects are only described in subgroups of the sample studied. A typical case is the description of effects (generally small) only in certain age ranges or subgroups (for example, women or patients with certain established pathologies), without the study having been initially designed to find effects in these subgroups. This leads to the well-known statistical fallacy (termed "multiple comparisons") by which, for the usual levels of certainty used (*$p<0.05$, see section 4.2*), at least one out of every twenty comparisons will have false positive results. Ruling out the illegitimate nature of these results requires their replication in new trials aimed specifically at the suspect subpopulations.

It is a mistake to analyse scientific literature on this matter merely in quantitative terms, such as the "number of studies which find an effect" versus the "number of studies which do not find any effects". This approach makes it extraordinarily difficult to draw conclusions, since the passing of time only adds more articles to each category, in an unstructured manner.

A proper assessment of these scientific contributions requires, firstly, a detailed analysis of the methodology used, since not all contributions provide the same quality and careful execution. In general, a temporary trend is observed, in the sense that the most recent ones are usually the most reliable, since prestigious publications are less inclined to accept carelessly prepared papers. In any case, it is always advisable to consider conclusions according to the quality of the study and to reinterpret prior studies in light of new, increasingly rigorous evidence. Replication of previous results endows them with greater reliability, while at times we face studies which are solid refutations of previous experiments, so that these should be discarded and ignored to a great extent in subsequent analyses.

Recently, two general types of studies have been carried out. In the first group, the possible carcinogenic effects of RF radiations were studied, exclusively, applied to animals, normal or genetically predisposed to developing certain types of cancer. In the second group of studies, the RF fields were applied on animals pre-treated with chemical or physical carcinogenic agents. The set of these two types of studies has not revealed consistent indications of carcinogenic activity with weak exposures, within the safety limits proposed by international regulations.

However, as already mentioned, most studies present methodological limitations regarding the limited type of exposure parameters employed and/or the protocol of use of co-carcinogenic agents.

In this regard, it is highly illustrative to note what occurred with various studies related to the possible carcinogenic effect of exposure to radiofrequency corresponding to the MT GSM-900 band on transgenic Eμ-Pim1 type mice, a strain especially prone to developing tumors (lymphomas).

The first paper on this type of mice, published in 1997 [Repacholi-1997], presented statistically significant results regarding the increased incidence of lymphoma in mice exposed to RF of 900 MHz (GSM band). The study had several deficiencies as far as the dosimetry and experimental design, which clearly recommended confirming the results. An initial replication five years later [Utteridge-2002] improving the dosimetric control of the first study, concluded there was no significant increase of lymphomas following an exposure of two years (versus 18 months in the previous study). However, this second study had other differences compared to the first one, for example, using mice of different origin and a different exposure protocol, which was why it generated considerable controversy and was not able to firmly refute the initial results, as its authors had intended.

In this situation of "contradictory results", so common in this area, another paper has been recently published [Oberto-2007] which has now exactly replicated the initial approach, although with a larger sample size and better control of dissymmetric conditions. This study found no increase in the development of tumours in the groups exposed to RF, nor any dose-response relationship for tumors or any other non-carcinogenic effects, so it can well be considered the first firm refutation of the initial study. As can be seen, high biological variability together with a notable methodological variability makes it difficult to draw conclusions, but increasingly rigorous studies are helping increase the evidence in favour of the hypothesis of a lack of carcinogenic effects of RF at the doses studied.

The largest *in vivo* study, completed in 2007, is the multinational project PERFORM A: *"In vivo Research on Possible Health Effects of the Use of Mobile Telephones and Base Stations (Carcinogenicity Studies in Rats and Mice)"* [PERFORMA-2007]. The Project integrated four subprojects that employed different experimental models (PERFORM A1 – A4). The animals, rats or mice, were submitted during long periods (up to 24 months, 5 days a week) to brief exposures (2 h/day) to typical mobile telephony signals. During the periods of exposure, the animals were stuffed in plastic containers that completely restrained their mobility. The purpose of this immobilization was to achieve homogeneous exposure and facilitate numeric dosimetric calculations. The general conclusion of the project was that "three of the four studies did not reveal any evidence that exposure had any effects on the incidence or severity of neoplastic or non-neoplastic conditions. Only one border effect was observed in the study (PERFORM-A3) which researched the effects (of RF) on the response of DMBA (a powerful carcinogen)-induced breast tumors. In any case, the results of the PERFORM-A project are also subject to criticism as a whole, since the restriction of movement during the experiment could generate in the animals a stress level capable of influencing in itself on some of the biological parameters studied. This has been shown by certain results of the study, which indicated significant differences between the animals with limited mobility and their controls, jailed but free to move.

With regard to the results of the subproject PERFORM A3 above mentioned, participants have published the results of their thorough study aimed at researching progression of DMBA-induced breast cancer according to exposure to RF similar to that of mobile telephony, at 3 different doses, for 6 months [Hruby-2008]. No difference in survival was observed, although there was a greater number of tumors in the group exposed to the maximum dose of RF versus the group with simulated exposure, although no dose-response relationship was noted. This outcome has, as pointed out by the authors, a questionable interpretation, so much so that the control rats left in their cages presented a similar rate of tumors than that observed in animals exposed to the maximum dose. This study is a replicate of another similar one (with a somewhat worse control) carried out in 2006 [Yu-2006], which found no RF effect. The authors concluded that the small differences observed (dissenting from the prior study) are the result of the high biological variability of the model used, and still no RF effect on the progression of tumours has been found.

Other recent studies [Sommer-2007] have not found an increase in the onset of lymphoma in mice of the AKR/J strain (who develops lymphomas spontaneously) either, when subject to UMTS mobile telephony type RF emissions, confirming prior findings of the same group [Sommer-2004].

Studies programmed for the future have been designed to avoid the abovementioned methodology flaws, which have limited the scope of conclusions of *in vivo* studies.

3.3.2 Effects on the nervous system

Some previous studies which showed effects of non-thermal RF on animal learning and memory, have not been corroborated by more recent research. There *is* a broader block of evidence on subtle changes in electroencephalographic (EEG) activity and in neurotransmitters not linked to alterations in auditory functionality, in specimens exposed to RF signals with a low specific absorption rate (SAR). While this type of effect has not been found in other *in vivo* studies, changes detected in animal EEGs are partly consistent with the electroencephalographic responses observed in studies with volunteers.

3.3.3 Effects on development

From the various studies on the effects of RF fields in the development of superior vertebrates (birds and mammals, primarily), no consistent evidence has been found of teratogenic effects induced by exposure to non-thermal levels. However, understanding of the potential effects of prenatal exposure on postnatal development is still insufficient.

3.4 Studies in volunteers

3.4.1 Effects on the nervous system in healthy volunteers

Although the results do not match in all studies, there is a block of evidence of subtle and transitory effects in the electroencephalographic pattern, in the structure of sleep or in some cognitive processes in volunteers exposed experimentally to telephony RF signals in laboratory controlled environments. No indications have been found that said responses are influenced by an action of the radiofrequency fields on auditory system functionality. The evidence accumulated is not indicative that the transitory effects described, whose origin has not yet been clearly defined, directly impact behaviour or memory, or are susceptible of triggering pathologies.

3.4.2 Studies on Perceived Electromagnetic Hypersensitivity

Some people report they suffer a set of non-specific symptoms, which include headaches, disorientation, dizziness, fatigue or insomnia, when exposed to RF signals in residential, public or work environments. Since these symptoms are self-referred or perceived and are only present in a small percentage of the population, it has been termed Perceived Electromagnetic Hypersensitivity Syndrome (EHS).

The fact that the possible biological mechanisms of this hypersensitivity are unknown does not allow ruling out their existence a priori. This is only possible by means of well-controlled trials to detect the existence of this hypersensitivity, whose mechanism (if any), would be resolved subsequently.

Studies tending to identify the real existence of individuals capable of detecting or reacting to low intensity EM fields are highly relevant scientifically, for should this effect be proven, it would be an indication of the existence of a biological mechanism, unknown until now.

Experimental studies on this matter are defined as “provocation”, since the aim is to provoke in subjects a response before RF exposures in controlled laboratory environments. The small number of provocation studies in healthy volunteers exposed to RF signals with typical telephony intensity, have provided no consistent evidence of the provocation of the typical symptoms of EHS, nor an ability in subjects to distinguish between periods of exposure and control phases, when the signal was suppressed.

Some earlier studies had revealed indications of response provocation in patients with EHS following exposure to GSM or UMTS telephony signals. However, the results of more recent research, using more advanced protocols and under better controlled conditions do not support the conclusions of these earlier studies. At present, it is considered that although the symptoms of EHS are real and can be severe, a causal relationship has not been established between these symptoms and exposure to telephony RF signals. Nonetheless, the number of studies which have researched the issue is limited and it is necessary to expand knowledge on the causes and conditions leading to EHS.

In this regard, an excellent review was published in 2008 [Röösli-2008] on the possible existence of individuals hypersensitive to EM fields, and on the possible higher frequency of symptoms in these individuals. From this review it is gathered that there is no evidence on the existence of said hypersensitivity in those groups of people who claim to have it, when studied in double-blind conditions. However, these people did show a much higher rate of false alarms than the control group. Should this hypersensitivity exist, it would affect a much smaller number of people and most certainly with no relation whatsoever to their subjective perception. The existence of this minority is very difficult to prove and is a pending research task.

With reference to the existence of symptoms derived from exposure to RF from mobiles or base stations, and based on the review of eleven randomized prospective studies (see definition in section *4.1*), it has been found that only one reported the existence of an association between the onset of symptoms and exposure to RF, which disappeared when statistically controlling an imbalance in the order the stimuli were presented. In the whole of the studies, no significant relation was observed between non-specific symptoms reported by the subjects and exposure to EM fields, but there *is* evidence of the existence of a marked nocebo effect.

In the same way that due to the placebo ("I give pleasure", in Latin) effect patients can undergo improvement merely because they believe they are being treated, with the nocebo effect ("I cause pain", in Latin) a subject who knows he is being exposed to a possibly harmful stimulus (RF emissions, in this case) can undergo negative objectifiable effects, but not due to the stimulus being used. In some cases, severe reactions have been reported in individuals subject to a simulated exposure [Rubin-2006], which proves with what a distorted perception of reality subjects experience the symptoms derived from a nocebo effect. This is why the blind nature of these trials is essential, as it is the best way to control the possible existence of this nocebo effect.

It is interesting to note that, unlike what happens with the randomized and prospective trials described above, many observational studies have indeed described associations between symptoms and exposure to RF, and it is of great interest to analyze the causes for this remarkable methodological discrepancy. Possible reasons in favour of observational studies could be the usually longer duration of exposure, or the smaller sample size of the randomized studies, which hinders the statistical detection of differences (although the nocebo effects can be perfectly detected). The main arguments against observational studies are the difficulty to objectively characterize the level of exposure and, above all, the high possibility of epidemiological biases (of information or selection), as well as the nocebo effect, since they are non-blind trials. In any case, it is interesting to note that in other kinds of medical trials (testing of new drugs, etc.) the superiority of randomized trials versus observational studies is overwhelmingly and universally accepted, which is why it would be most advisable if the resources devoted to researching the effects of EM fields were aimed preferably at randomized studies.

3.4.3 Effects on blood pressure

The limited number of studies carried out in the last few years have not provided consistent results that sufficiently support prior observations of drops in blood pressure of healthy volunteers exposed to mobile telephony signals. However, increased blood flow in the outer ear of exposed volunteers has been observed. This effect is interpreted as due to local vasodilation caused by the transmission of heat from the telephone's electric operation.

4. Epidemiological studies

There is concern about two major types of possible effects, those leading to very severe diseases, such as cancer, and those appearing as certain discomforts due to non-specific symptoms (headaches, ...).

Epidemiological research of this type of phenomena is very difficult and involves significant financial and time investments. Retrospective studies (termed "case-control") are the most common ones, due to their simplicity and low cost, but they are highly exposed to various types of biases, therefore their reliability is quite limited, unless the results are replicated independently in other studies.

The other type of epidemiological study is the prospective one (termed "cohort study"), where a given group is followed in time. Its methodological soundness is considerably greater, although with a far higher cost and execution time. This is why it is particularly interesting to follow the results of studies of this type being carried out, including the INTERPHONE study, an epidemiological research project (case-control study) with the participation of 13 countries with a common methodology, and whose overall results are expected to be published in early 2009.

To help readers who are not specialized in this topic to understand this and other documents, an initial section has been included with the terminology used in epidemiology (sections 4.1, 4.2 and 4.3). Any reader interested in learning about the latest results reported can skip to section 4.4.

4.1 Epidemiological studies: some definitions

Epidemiology can be defined as the scientific discipline that studies the distribution and the determining factors of health states of human populations, as well as the application of techniques for their control. In the context of this report, the biological effects of electromagnetic emissions, epidemiological studies hold a predominant position. The other possible approach of this field is through experimental methods, either *in vitro*, with animals or even humans. Experimental methods have the advantage of being able to explain the mechanisms of the possible effects detected. The epidemiological approach lacks this explanatory capacity, but can be immensely more sensitive to detect small effects or locate especially affected subpopulations.

Epidemiological studies usually employ very specific terminology, which one must be precisely aware of in order to better understand and assess results. An **event** is a situation whose appearance is being studied. It can be a positive event, as with studies to determine the efficacy of a drug (cure or improvement), or an adverse one (death or onset of a disease).

A **risk factor** is any circumstance which increases the probability of the onset of an adverse event. Those individuals with these circumstances are said to be exposed. This **exposure** may be dichotomic (yes or no) or graded, in which case it is extremely important to precisely measure the level of exposure of the study subjects. This latter situation is characteristic of studies on the effects of radiofrequency emissions, since the dose received by each individual can be different.

The most usual parameter to measure the level of association between a risk factor and an event conditioned by it, is that known as the *“odds ratio” (OR).* This represents how many times more it is likely for the event to occur in the presence of the risk factor than without it. A value of 1 means the factor does not influence the outcome, values of less than 1 mean the factor has a protective nature. It is common (and highly necessary) to also provide a confidence interval of 95%. If this interval includes value 1, then the factor does not represent a statistically significant effect, and equals a $p>0.05$ (see below).

There is a significant variety of possible designs for epidemiological studies. Some of them are merely **descriptive**, but others, termed **analytical**, attempt to clarify the existence of associations between risk factors and the onset of certain events. Without going into too much detail, we can say that analytical epidemiology uses three basic types of studies: case-control, cohorts and randomized clinical trials.

A **case-control study** examines a group of people presenting the event (cancer or another pathology), termed ‘cases’, and compares them to another group of people, selected by the researcher, not presenting this event, termed ‘controls’. To undertake the analysis, it is necessary to determine (retrospectively) how many people in each group and to what extent were exposed to the risk factor analyzed.

In a **cohort study**, on the contrary, a study sample is defined (‘cohort’) comprised of a group of healthy individuals whose exposure or not to the risk factor during the study is known, and it is prospectively followed in time to determine in how many cases the adverse event occurs.

Finally, a **randomized clinical trial** is a type of study in which participants are subject to the risk factor in a controlled manner by the researcher, deciding in an entirely randomized manner which individuals will be exposed and which ones will not. Additionally, the study is termed **blind** if the patient does not know whether he is exposed or not, and **double blind** if the researcher does not know it either until the moment the results are analysed. Randomized trials are always prospective.

Although case-control and cohort studies can seem similar, there are major methodological and reliability differences between them. Case-control studies are necessarily retrospective, since we start off by knowing the event has occurred. This circumstance means they are generally easier to approach, starting for example with hospital databases, but it also makes them less reliable, given their likelihood of presenting epidemiological biases. This is the name given to those circumstances that generate a systematic error in the outcome, due essentially to problems with data collection and selection criteria of controls. Below are details on some types of common biases. Cohort studies, in turn, are usually prospective since the research team is closely monitoring the evolution of patients. This makes them more immune to the existence of biases and, therefore, more reliable. Unfortunately, their execution is far more complex and costly, and they usually require a lot of time before results can be obtained. With regard to randomized trials, these are the most reliable (particularly if they are double-blind), but also their execution is the costliest and at times, not exempt from ethical problems.

In order to conduct a critical analysis of the results provided by different epidemiological studies, it is of great importance to verify which type they belong to. Fortunately, as time goes by, it is becoming increasingly common to find prospective cohort studies, sometimes of a significant size, whose conclusions should replace those reached by small previous case-control studies. The option of numerically entering the various studies as "in favour" or "against" following certain reviews (see below) is rather simplistic and does not help advance knowledge, but rather generates endless confusion. A modern, prospective and well-designed study must replace and obliterate many prior papers, conducted with a methodology prone to errors, such as case-control trials that are not very meticulous or merely descriptive studies.

Randomized trials provide the same reliability, as pointed out above, to the extent that today it is unthinkable to launch a new drug in the market until one or more randomized trials have proven its efficacy. However, with regard to studying the effect of electromagnetic fields, this type of design is rather infrequent, given the enormous difficulty of maintaining and controlling prolonged exposures, sometimes for several years. The few there are in literature, provide highly reliable results, but normally limited to small samples and brief periods of exposure.

4.2 Problems of epidemiological studies: bias and confusion, multiple comparisons

4.2.1 Biases

Epidemiological studies can be quite prone to achieving erroneous results if they have not been very carefully designed. A **bias** is the existence of a systematic error derived from methodological flaws in the study, normally related to the selection of participants or the collection of data regarding the exposure or the existence of events. As a result of these biases, the outcomes achieved are not a reflection of reality. It is important to note that a bias is derived from a methodological systematic error, and not due to a simple variability of data, or sampling error. The most common biases are outlined below.

Selection bias (very typical of case-control studies) occurs when the individuals of the population analysed have different probabilities of being recruited according to their level of exposure or presentation of an event. For example, it is frequent that ill and exposed patients have a higher probability of inclusion, whether because awareness of their circumstances encourages them to seek medical attention, or because it is easier for researchers to identify and access this subpopulation. This lack of randomness in the sampling affects the statistical results, distorting them. This is why it is essential in order to assess a study, to carefully examine the procedures for sampling and recruitment of participants, which unfortunately do not always assure lack of a selection bias.

Information bias results from the systematic tendency of the participating individuals to be classified in erroneous exposure or outcome categories. There are several variants of this bias. A very typical variant in studies of electromagnetic fields effects is the **memory bias**, which arises when the cases and the controls differ in their appreciation of the level of exposure in the past. It is common, for example, that cases (patients) believe they have suffered higher exposure levels than the controls, even if the objective situation of both is the same. Again, the risk of this bias is much greater in case-control studies. Another variant is the so-called **interviewer bias**, similar to the above but due to the fact that the researcher, who is not blind to the existence of the disease, emphasises differently (whether consciously or not), questions addressed at cases or controls.

4.2.2 Confusion

Confusion is the term given to the observation of an association between two variables not derived from any causal relationship, but rather from the influence of a third (confusing) variable associated to the first two. This phenomenon is easily understood with an example linked to the subject matter of this article: analyzing data from various cities, there is always a strong statistical association between the number of telephony antennas and the number of cancers of any type. Yet this says nothing about the effect of radiofrequency, the association derives from the indirect effect of a confusing variable which is the size of the city. Any other circumstance linked to the size of the population, such as the volume of soft drinks consumed, or the number of churches, would similarly be related to the number of cancers given the effect of confusion with the city size.

As we can see, the confusion is not derived from the incorrect execution of the study, as in the case of biases, but rather from not having been able to imagine the existence of a possible confusion. All types of epidemiological studies are likewise susceptible of experiencing this problem. Ensuring an apparent observed relationship is real and not derived from a problem of confusion is a question of common sense and experience to be able to imagine possible confusing factors. In any case, the best support for the existence of an association detected by means of epidemiological studies is the confirmation of its causal mechanism with experimental studies.

4.2.3 Multiple comparisons

The final source of difficulties analyzed in this brief epidemiological overview, is the problem of **multiple comparisons**. In classical statistical reasoning, the result of a test is expressed as a value named "*p*", aimed at representing the probability that a result as extreme as or more than the one found is due to chance. It is quite common to consider that the *p* obtained must be below *5%* (that is, $p<0.05$) in order to accept that the results suggest the existence of any real effect. Although many studies have found lower significance levels than this, we believe the figure arbitrarily chosen of $p<0.05$ is quite condescending, as it accepts that one out of every twenty *tests* conducted is falsely positive. Note we are talking about one out of every twenty *tests*, not studies, and that every study can include several *tests*, so that the number of results reported which may be merely due to chance, could be quite high. This is the basis of the problem of multiple comparisons. There are certain statistical techniques to address this issue, but many authors do not apply them, or do not do so rigorously; another side of this problem, the one verging on professional ethics, arises when authors do not reveal how many tests they have conducted before finding a significant result in one of the, at times, very many variables analysed. This approach, known as "*data fishing*", is facilitated even more when the study subjects are subgrouped into different categories, for which independent *tests* are conducted, thus multiplying even more the number of comparisons. It is crucial in order to assess the results of a study that the comparisons between the subgroups are planned in advance, or they will be the result of data fishing. Only the ethics of researchers protect us from passing one off for the other.

4.3 Descriptive studies and clusters

Epidemiological descriptive studies are far less interesting for the subject matter of this text, and tend to focus on reporting situations of a high incidence of events of some type around radiofrequency transmitters. Temporary or geographical distribution of epidemiological events (different types of cancer, non-specific complaints, etc.) is random. This does not mean, unlike what one may naively think, it should be more or less standard in time or space, but quite the opposite. Truly random distributions are characterised by an accumulation of cases, known as '*clusters*'. A very common statistical fallacy is to calculate *a priori* the probability of finding an accumulation of a given size, and mechanically applying it backwards to prove that said accumulation of cases "cannot be random". The probability of finding this accumulation, it is said, is of *1 in 1000*, or *1 in 10,000*, or any other figure, with the intention of supporting the existence of an underlying cause. Yet this probability refers to finding this accumulation as a result of a random sampling, and it is not applicable if the selection has been done precisely in accordance with its rarity and not randomly. In any case, a basic principle of caution advises not ignoring observations of this type, since despite all they could be the first indication of a problem. The reasonable action, if appropriate for the case, is to examine the possible local causes, and, in any case, refer to prior analytical epidemiological studies, or to propose a new one if necessary.

4.4 Advances in the last two years

As already mentioned above, we should be pleased because the average quality of the studies published most recently (in prestigious scientific journals) is growing steadily. It is becoming more and more difficult to see a study published with obvious methodological errors, although the consequences of the biases and confusion explained above may be subtle and difficult to detect.

Determining the levels of exposure in epidemiological studies, which as described, is one of the major causes of bias, is usually very difficult in the case of exposure to electromagnetic fields. Firstly, due to the abundance EM sources of every type which hinder an objective dosimetry, and, secondly, with regard to the use of mobile telephones, due to the difficulty to remember how we use it (memory bias) and the near impossibility today of finding non-exposed controls. In a very recent study [Söderqvist-2009] with 2000 Swedish adolescents, the use of mobile telephones amounted to 99.6% of the population surveyed, therefore it would be extremely difficult to find controls for a study. It is interesting to note that in that same paper, an association was found, not very intense but significant, between the level of telephone use and the participants' perception of non-specific symptoms, such as fatigue, headache, anxiety, sleep disorders, etc. A similar association has also been found in other recent studies [Koivusilta-2007] and [Punamäki-2007]. However, all authors agree that this observation is probably due to a confusing factor, since a higher use of mobile telephones is also associated to other variables such as a lower social class, broken homes or more time devoted to watching television. As already indicated, one of the best ways of ruling out confusing factors is an analysis of the supposed effect by means of controlled experiments. The various random blind trials that have been conducted in this respect have not been able to prove any influence of radiofrequency exposure on the non-specific symptoms reported by trial participants.

A very brief review recently published [Hardell-2008] presents the point of view of a group termed "The Bioinitiative Report" [BioR-2007], whose conclusions and proposals to a great extent contradict those of most experts in this area. The article cited is not a formal review or meta-analysis, given its brevity and limited references, but rather should be interpreted as a certain positioning in the issue. For further details, the article refers readers to the full report, which can be consulted in the web page mentioned, but is not available as a structured review article in any prestigious publication (at least not when this report was prepared). The article provides no new studies or experiments in this area, but is rather an interpretation of the evidence available from "intellectually courageous" postulates, in the words of the authors, which differ to a great extent from the most commonly accepted interpretation, and which lead the authors to propose a greater restriction of the dose limits currently in effect. It is probable and desirable that we will shortly have scientific articles that analyze this report with a strict methodological perspective. In any case, some conclusions can be easily assumed, such as the need for long-term studies to verify possible long-term effects and additional well-designed research to dispel some remaining doubts in certain little studied pathologies. However, in our interpretation of the data, old studies which have later been soundly refuted, should be entirely discarded, which is something the "Bioinitiative Report" does not appear to accept. The "Bioinitiative Report" has been questioned by several committees and expert panels such as the Health Council of the Netherlands [HCNL-BioR-2008]. CCARS endorses the opinion provided by this Health Council. In the CCARS web page is the translation into Spanish, carried out by CCARS, of the commentary on the "Bioinitiative Report" prepared by the Health Council of the Netherlands [HCNL-ES-Bio-2008].

Two very distinct examples of recent reviews are described below. One is an article reflecting the conclusions of a World Health Organization workshop [Valberg-2007] which includes an interesting comparison table of the energy deposited by mobile telephones and that derived from solar light or other elements such as light bulbs or microwave ovens, as well as a structured review of studies with different orientations. The second review covers the possible effects of electromagnetic fields on children [Otto-2007]. This latter article provides an interesting and systematic update on the topic, as well as the classification of the various precautionary measures employed, depending on the level of scientific evidence supporting them. As a whole, it points towards the non-existence of studies proving an increased risk related to RF exposure.

Probably, the most important scientific contribution in the last two years has been the INTERPHONE study, which is covered in greater detail below. The INTERPHONE study is a clear example of a modern effort, well-designed, with a large scale and multinational. Although it is based on a case-control model, always prone to biases, the authors have been especially careful to try to control any source of bias as much as possible. The scientific community is looking forward to the full presentation of results, expected in early 2009, although several partial country results have already been issued. To date, none of these articles have reported positive results regarding the association of RF exposure to any type of tumor included in the study: acoustic neurinoma, glioma, meningioma and parotid tumors (the latter only in some countries).

4.4.1 Base stations

The World Health Organisation (WHO) assessed the effects of electromagnetic fields in its descriptive note in 2006 [WHO-2006] and concluded that:

"Taking into account the very low levels of exposure and the results obtained from research to date, there is no convincing scientific proof that the weak RF signals emitted by base stations and wireless networks have harmful effects on health"

As we mentioned above, conducting epidemiological studies on exposure to the electromagnetic fields emitted by mobile telephone antennas and their effects on health is no easy task; there are multiple RF EMF transmitters (TV aerials, AM-FM radio broadcasting, TETRA (Terrestrial Trunked Radio), emergency, radar, etc.), apart from the aforementioned MT base stations. With regard to exposure to EMFs emitted by MT antennas, it seems logical to expect that there are no health consequences owing to the fact that exposure intensity is extremely low. Furthermore, exposure to MT derived EMFs has a ubiquitous nature and the continuous mobility of subjects under study hampers quantification of exposure. Therefore, studying their possible impact on human beings meets with numerous methodological limitations, such as the study of magnitude, time, exposure characteristics and an analysis of the power of association.

All of these factors combined with the frequent presence of selection bias, classification and other confusing factors, have a bearing on the validity and reliability of epidemiological studies of the theoretical relationship between exposure to RF EMFs used in mobile telephony and health effects. To these limitations we must add the objective difficulties of obtaining proper dosimetry from people exposed to MT-RF EMFs, obstacles which make it almost impossible to quantify exposure.

For all these reasons, most current research is devoted to studying the effects of the use of handsets (the mobile phone).

In Europe, the British research programme MTHR has no plans, for the moment, to earmark more funds to study the effects of antennas though it will await with interest the findings of programmes carried out in other countries. In its 2007 report [MTHR-2007] it concludes that none of the research studies funded has demonstrated that exposure to MT RFs causes harmful biological effects or is a health hazard.

4.4.2 Mobile telephones

The majority of epidemiological studies published to date have concentrated on the association between mobile phone use and the incidence of tumours in the central nervous system. Specifically, meningiomas, gliomas, acoustic and parotid gland neurinomas.

One of the most exhaustive epidemiological studies published to date was the study conducted in Denmark on a cohort of mobile telephone users. Over a monitoring period of 8.5 years on average, 14,249 cases of cancer were observed against the 15,001 cases expected according to the usual rates among the adult Danish population [Schüz-2006]. No evidence was found of either a short term or long term association between the risk of cancer and mobile telephone users. Among the over 10 years old user group a significant increase in the appearance of brain tumours was not observed.

The last report published by the European Union Scientific Commission, SCENIHR, reviews the studies published since 2001.

In its conclusions, published in its 2007 report [SCENIHR-2007] it is established that harmful health effects below the limits set by the ICNIRP - an organisation endorsed by the WHO - have not been consistently demonstrated [ICNIRP-1998].

The report published in 2008 by the Swedish Radiation Protection Authority (SSI) [SSI-2008] finds in its conclusions that it is not proven, in volunteer subjects, that RFs have effects on cognitive functions, sleep or hypertension.

These conclusions are similar to those reached by the MTHR in the United Kingdom. With regard to brain tumours, this body concludes that *“an epidemiological association has not been observed in* *mobile telephone users over a period of less than 10 years"*.

The findings of both studies confirm that, there is no evidence of an increase in the number of cases of cancer in adult mobile telephone users during periods of less than 10 years.

The INTERPHONE study is an epidemiological research project (case-monitoring study) in which 13 countries have participated with a common methodology. Details of the protocol and procedures used in the study have already been published [Cardis-2007].

Its purpose is to determine whether mobile telephone use increases the risk of cancer, and, specifically, whether the radio frequencies transmitted by mobile telephones are carcinogenic. This study included approximately 2,600 gliomas, 2,300 meningiomas, 1,100 acoustic neurinomas and 400 parotid gland tumours, which makes it the broadest study conducted to date. Some of its findings have already been published and the final analyses are expected to be presented during 2009. With regard to meningiomas and acoustic neurinomas, most Spanish studies published to date find no evidence that an increase in risk exists. A German INTERPHONE project study of 97 cases of acoustic neurinoma [Schlehofer-2007] found no increase in the number of this type of tumour in mobile telephone users.

Generally speaking, data concerning users over 10 years of age are disparate, but most studies do not detect an increase in tumours of the nervous system except for a slight increase in glioma incidence [Lahkola-2007]. The authors of this study assert that, "although globally our findings do not indicate an increase in the risk of glioma in relation to mobile telephone use, it is necessary to continue investigating possible long-term risks to the most exposed parts of the brain before reaching definite conclusions".

If we want to obtain more evidence of a possible connection between mobile telephone use and cancer we must plan prospective studies that ensure a reliable measurement of long-term exposure [Auvinen-2006]. More monitoring studies must be conducted to verify whether there is a relationship between chronic, low intensity exposure and certain types of cancer.

5. Studies of exposure levels due to base stations and handsets

5.1 Electromagnetic radiation

Electromagnetic radiation is the process of wave transmission through space or some material medium. For electromagnetic radiation to be propagated the existence of a material medium is not necessary; however, the speed, intensity and direction of the energy flow transporting the radiation may be modified in the presence of matter.

As we have already mentioned in section 2, electromagnetic radiation may be classified into two large groups: ionising and non-ionising radiation. From the point of view of normal exposure, non-ionising radiations are considered to be the frequencies ranging from *0* to *300 GHz* (*1 GHz =*10^9 *Hz*). **Radio frequencies** are encompassed within the range known as **non-ionising radiations.**

The origin of electromagnetic fields (EMF) is very broad (those generated by high-voltage cables, transformers, TV, AM and FM radio, systems for medical applications, electrical appliances, etc.). In particular, radio frequency (RF) EMF sources have increased sharply over the last ten years due to the introduction of new telecommunications technologies (TM, TETRA, LMDS; radio links, WIFI, WIMAX; Bluetooth, etc.),

In order to objectively assess the risks attributed to the RF EMFs used in base stations (MT antennas and auxiliary elements) it is necessary to ascertain the exposure levels of the population. Knowing these levels may enable us to identify whether there exists some exposure-derived effect.

5.2 Magnitudes characterising exposure. Exposure limits

In order to avoid the possible harmful effects of radio frequencies exposure restrictions must be set, so that certain limits are not exceeded in what is called the Specific Absorption Rate (SAR), a parameter which is obtained from a knowledge of the internal electrical fields in the different parts of the human body, which are a consequence of the interaction of the field of exposure with biological tissues. However, safety standards also specify levels which are easier to measure than the SAR, called benchmark levels, such as the intensity of external electrical and magnetic fields, E and H, or the density of equivalent plane wave power, S, in the place where the person is located.

In Europe, the precaution principle set down in the Maastricht Treaty obliged the agencies responsible to implement measures to protect citizens against non-ionising radiations. In this regard, the Council of Europe adopted, in July 1999, Recommendation 1999/5191/CE, concerning the exposure of citizens to electromagnetic fields of frequencies ranging from 0 to 300 GHz [EU-1999]. This Recommendation, which restricts exposure to radiations within the aforementioned range of frequencies, is based on the guidelines published in 1998 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [ICNIRP-1998], on the basis of the known effects of these radiations, which are basically thermal in the case of radio frequency transmission and current induction effects in the case of low frequencies. The basic restrictions were adopted in the Recommendation with a safety factor of 50 with respect to the harmful effects proven, and *2 W/kg* was established as the specific absorption rate (SAR) limit when calculated locally. However, for practical purposes, the benchmark levels (*Table I*) are used, which ensures even greater safety, so that, hypothetically, the benchmark levels might not be complied with and the basic restrictions could be verified.

In situations where individuals are close to the base of an antenna there is virtually no exposure, as they are situated beyond and under the antenna's main radiation beam. Radiation far from the antenna, received for practical purposes as electromagnetic plane waves, decreases in a certain direction with the square of the distance from the antenna.

Table I. Reference levels for electrical, magnetic and electromagnetic fields (0Hz-300GHz, unperturbed RMS levels)

Frequency range (f)	E-field strength (V/m)	H-field strength (A/m)	Field B (μT)	Equivalent plane wave power densityS (W/m²)
0.1 Hz	------	3.2×10^4	4×10^4	------
1 - 8 Hz	10000	3.2×10^4/f2	$4 \times 10^4/f^2$	------
8 - 25 Hz	10000	4000/f	5000/f	------
0.025 - 0.8 kHz	250/f	4/f	5/f	------
0.8 - 3 kHz	250/f	5	6.25	------
3 - 150 kHz	87	5	6.25	------
0.15 - 1 MHz	87	0.73/f	0.92/f	------
1 – 10 MHz	87/ f½	0.73/f	0.92/f	------
10 – 400 MHz	28	0.073	0.092	2
400 – 2000 MHz	1.375 f½	0.0037f½	0.0046 f½	f/200
2-300 GHz	61	0.16	0.20	10

5.3 Exposure levels of the public in general to radio emissions from radio base stations

5.3.1 Spain

Royal Decree 1066/2001 of 28 September [RD 1066/2001], approving the Regulations establishing the health protection measures against radio emissions and which establishes the exposure limits for the public in general to radio emissions, establishes that the Technical Services of the MITyC (Ministry for Industry, Trade and Tourism) will draw up inspection plans to verify whether transmitting facilities and, among them, mobile telephony base stations, comply with the provisions of the Regulations.

The last report published in 2008 by the MICyT, corresponding to projects implemented in 2007 [MICyT-2007] sets out and analyses the results obtained in the inspections and work carried out by the services of the General Directorate for Telecommunications and Information Technologies, to ascertain the state of the radio plant of telecommunications operators established in Spain and the certifications carried out by the competent technical personnel.

The amounts of energy measured close to mobile telephone antennas installed in Spain are very small, in magnitudes hundreds or thousands of times inferior to the benchmark levels (in power density) permitted for UMTS band emissions, (955 μW/cm^2) and GSM (450 μW/cm^2).

The report states that:

"all of the measurements performed countrywide have produced radio exposure levels which are much lower than those set out in Royal Decree 1066/2001 as a benchmark, which ensures that people's health is not at risk".

These measurements are carried out in accordance with the provisions of RD 1066/2001, and those of Ministerial Order CTE/23/2002 of 11 January [ORDEN CTE/23/2002], which set conditions for the submission of certain studies and certificates by radio communication services operators.

The MICyT information on MT base station emissions is public and free of charge; it may be viewed on the MICyT website:

http://www.mityc.es/telecomunicaciones/Espectro/NivelesExposicion/Paginas/niveles.aspx

Measurements taken in sensitive places

Sensitive zones, areas or places are defined as those where due, to their nature, a greater perception of risk in exposure to EMFs is considered to exist; exposure levels ought to be minimised in these places, in accordance with article 8.7 of the Regulations contained in Royal Decree 1066/2001.

The abovementioned places include, among others, crèches, pre-school centres, health centres, hospitals, and public parks.

As outlined in the MICyT 2007 report, the first measures taken within the framework of the 2007 Inspection Plan were those implemented in the so-called sensitive areas. The experience accumulated and the results obtained in measurement campaigns carried out in previous years, serve as a basis with regard to identifying the sensitive places. A total of 3,818 areas are regarded as such.

The new installations implemented by operators, mainly third generation UMTS automatic mobile telephony base stations, have preferably been located close to the existing ones for the GSM and DCS.1.800 modalities, so that, in general, new stations situated in the environs of sensitive spaces that had not already been identified in previous years have not appeared.

During 2007, a total of 149 sensitive spaces were measured, located within a radius of approximately 100 m of any mobile telephony base station. They comprised 73 schools, 18 hospitals and 58 public parks. Distribution by province and Autonomous Region of the measurements performed and the results obtained are shown in *APPENDIX I*, which includes the figures published in the MICyT's 2007 report in addition to the distribution by school, health centre, hospital and public park [MICyT-2007].

Analysis of exposure levels in sensitive places

The Inspection Services of the General Directorate for Telecommunications and Information Technologies carry out the field intensity or power density measurements in accordance with the provisions of the protocol of Ministerial Order CTE/23/2002.

As outlined in the MICyT 2007 Report, the average radio exposure levels, considered at Regional level, range from the maximum of 2.320 μW/cm² in Madrid (which represents a reduction of 6% in the maximum radiation level recorded in Madrid the previous year) to the minimum of 0.024 μW/cm² in Melilla (virtually the same as the minimum radiation level recorded the previous year, also in Melilla). The national radiation level average in 2007 was 0.452 μW/cm², 25.53% lower than the national radiation level average for 2006.

Bearing in mind that the benchmark level is 450 μW/cm² for the 900 MHz frequency, it can be seen that the results obtained are significantly lower than the benchmark levels.

From the measurements taken at the 149 sensitive points, of the total of 3,818 identified, we may deduce that the results obtained are still below the benchmark levels set in Royal Decree 1066/2001.

The conclusion to be drawn from the data outlined is that, in sensitive areas, exposure levels to radio radiations continue to easily comply with the benchmark safety levels set by the strict current regulations.

Audits of annual certifications

In the framework of the inspection plans audits are performed on the certifications presented by operator companies the objective of which is to examine and verify on site the validity of the information provided. The MITyC report has analysed 46,084 stations included in the certifications provided by operators. Such a large number of installations on which information is available is probably one of the most comprehensive in Europe.

The maximum level measured in the MITyC's audit was 14.76 μW/cm² at a UMTS station in Madrid province; the minimum was below the threshold level of the measuring equipment used. Considering that the benchmark level is 1000 μW/cm² the conclusion is that the emission levels measured remain below the benchmark values.

In the whole sample measurements of exposure levels were taken; these are displayed, for each station within each province, in the 2007 MICyT report and are included in *Appendix II*.

5.3.2 Europe

In the European context, the following reports Mobile Telecommunications and Health Research Programme (MTHR) [MTHR-2007] may be mentioned. The latter cites two specific measurement studies, one on 17 antennas [Mann-2000] and another on the 100 antennas measured annually by the United Kingdom Office of Communications (Ofcom, formerly the Radiocommunications Agency), in addition to the one performed by the UK Health Protection Agency, www.hpa.org.uk. These measurements were recommended by the UK IEGMP (Independent Expert Group on Mobile Phones) In its report published in the year 2000, also known as the Stewart Report [IEGMP-2000]. The results of the measurements taken by Mann and collaborators indicated that exposure levels were between *0.01-0.1* mW/m^2 (*0.001-0.01* $\mu W/cm^2$) and did not exceed *10* mW/m^2 ($1 \mu W/cm^2$) which represents 0.2% of the measurements set out in the recommendations of the ICNIRP and the European Commission.

Subsequent studies conducted by Ofcom and the HPA produced similar findings. Finally, it should be stated that Spanish law has adopted the most conservative recommendations from the point of view of safety and human health which are included in the aforementioned documents: in RD 1066/2001 and in Ministerial Order CTE/23/2002.

With regard to mobile telephones, no scientific test conducted to date has shown that using the latter entails any health hazard, neither in adults nor in children, provided that European Recommendations are complied with. However, given that children might be more sensitive to any possible effect as their organisms are developing, and might accumulate higher exposure throughout their lives than earlier generations, and given the possible increase in SAR in their brains compared to adults' brains that ought to be studied thoroughly, it is recommended that parents encourage their young children to use the mobile phone in moderation, until epidemiological studies on this sector of the population become available. In any case, mobiles used by children should always have the speakerphone feature activated.

With regard to the validity of the exposure limits set out in the European Recommendation, most international reports, on the basis of the scientific evidence available, consider that they do not need to be reformed. However, some international agencies, such as the European Environment Agency, are in favour of lowering the current limits on precautionary grounds which are not based on scientific evidence. The limits set in the 1999 European Recommendation are currently in force.

6. Dosimetry. Normalisation and occupational exposure activities.

In Europe in the last two years, for the purpose of ensuring people's protection against exposure to electromagnetic fields produced by radio waves, in accordance with the 1999 European Recommendation 1999/519/CE [EU-1999], normalisation activities have continued following the European Commission directives M/132 and M/351; the latter addresses the exposure of workers. The European standardisation group comprising CENELEC (European Committee for Electrotechnical Standardisation, http://www.cenelec.eu), CEN (European Standardisation Committee http://www.cen.eu) and ETSI (European Telecommunications Standardisation Institute http://www.etsi.org), with the Spanish participation of the AEN/CTN215 AENOR committee (Spanish Association for Standardisation and Certification, http:/www.aenor.es) and in collaboration with the International Electrotechnical Commission (IEC), it has worked to improve existing standards and to draw up new ones on measuring and calculating EMFs produced from different sources and on the specific absorption rate (SAR) in the human body. In drawing up these standards, the presence of numerous wave sources in real worker exposure conditions is being taken into account. All of these standardisation efforts are aimed at improving the methods to assess compliance with the benchmark levels and basic restrictions set down in the 1999 Recommendation which will lead to better protection of citizens' health.

With regard to work exposure to EMFs, European Directive 2004/40/CE was approved [EU-2004] (Corrigenda [EU-2004b] and [EU-2004c]) concerning the minimum safety and health provisions for worker exposure to hazards deriving from physical agents (electromagnetic fields). This Directive is based on the recommendations of the International Commission on Non-ionising Radiations (CIPRNI) for workers. However, implementation of this Directive has been postponed until 2012, due to the need to re-examine in detail the possible impact of its application on the use of medical procedures based on the medical image and on certain industrial activities.

7. Communication and perception of risks

For almost fifty years, with the development of nuclear energy, the breakthroughs enabled by the application of emerging new technologies have been subjected to public scrutiny by the mobilisation of groups and organisations which, driven by ideologies, beliefs or other kinds of values, as is normal in all groups of individuals, have expressed their reactions, generally against, to life technologies or, more recently, to some applications of the large group of technologies information and communication technologies, which answers to the familiar acronym of ICT, which are responsible for the major social change we are going through, with the evolution towards what has been called the "information society", a feature of a globalised world which champions services.

This social reaction has attracted the attention of politicians, as is particularly evident in the European Union, although the impact of these movements is also being felt in the United States.

By means of the Eurobarometer, the instrument of sociological analysis regularly used by the European Commission to test European citizens' sensitivity to and position on current or fundamental issues for governance in the EU, surveys are being conducted on attitudes towards some of these scientific developments and technological applications.

Whenever one of these technical-scientific issues generates concern among citizens in the face of potential hazards: food crises, toxic dumping in seas and rivers dams bursting with contaminating elements, development of plants and food products by means of genetic modification, harmful effects of some new drug, the media, as indeed they should, report on these issues.

Obviously, the way the media reports these stories will be influenced, apart from the quest to provide reliable news, by the editorial line of each medium- newspapers in all countries and all places do not have the same editorial bias; a newspaper such as the New York Times, for example, is not the same as USA Today.

At all events, there is no doubt that the media play a major role in people's perception of hazards. Current society's capacity to access a large amount of information from their own homes or places of work is a challenge which experts in each and every subject being disputed must face when their expertise is requested. The media cannot be expected to carry out educational tasks; they have another vision, mission and capacities. However, they should be asked to act responsibly, to seek out the best sources in order to verify their information and to help to identify reliable experts. Responsible citizenry must, in turn, demand the best possible education for all, so that support for education and educators should be a national priority to which all-party agreements and the greatest amount of resources possible should be devoted. Experts should contribute with major dedication and the best of their expertise to this educational commitment. It is on the basis of very well-informed society - because it is well educated - that it will be possible, without disdaining fears, to debate and reflect on issues without sensationalism, seeking to educate citizens in issues such as science and health, which should be progressively brought closer to citizens' interests. This will lead to a situation in which quacks and charlatans are not given equal billing with scientists and experts when the former cause needless alarm and encourage the consumption of useless miracle products.

CCARS is committed to providing reliable, up-to-date information to the citizens and media that request it [www.ccars.es].

It is interesting to note that the greatest concern of Europeans on the issue of exposure to electromagnetic fields is related to the presence of antennas [Eurobarometer-EMF-2007]. However, it is the correct location of the antennas that ensures good mobile telephone signal reception, reducing the transmitting power that the handset needs to maintain constant transmission quality and, therefore, individual exposure. The principle is that a larger number of antennas with optimal distribution and complying with the legal limits reduces the exposure level of mobile phone users. Correct telephone use by adults is a guarantee of safety.

CCARS also undertakes to continue reporting on the epidemiological studies that will shortly be made public, especially as a result of projects funded by the European Commission.

8. Priorities for future research

Information may be found on projects in the implementation phase or recently completed on the EMF-NET project website: *"Effects of exposure to electromagnetic fields: From science to public health"* [EMF-NET].

Among the major lines of research those devoted to the following are worthy of note:

- Research into whether chronic exposure increases the risk of mobile telephone users or workers subjected to high-power RF fields developing brain tumours or of suffering alterations to the nervous system.
- Ascertain whether children or people suffering from certain neurological diseases are particularly sensitive.
- Improve knowledge of the causes and conditions of perceived electromagnetic hypersensitivity syndrome .
- Enhance knowledge of potential neurological, cognitive or modulator effects of the EEG pattern in volunteers exposed to RF signals.
- Improve the accuracy of dosimetry equipment and strategies in RF exposures.
- Enhance experimental studies with biosystems, *in vivo* and *in vitro*, to identify the biological mechanisms involved in potential non-thermal biological responses. Among these studies priority is being given to those performed on animals in conditions of non-restricted mobility, and to studies of cells exposed, simultaneously or sequentially, to multifrequency signals.
- In all of these studies it is necessary to combine the interest in not duplicating efforts with the need to independently replicate important findings.
- Likewise, it is necessary to reconcile the urgency in studying responses to specific signals of interest (GSM, UMTS, TETRA, radar) with the search for simplified biological models, exposed to basic signal parameters, to enable identification of the general mechanisms involved in the response to non-thermal signals.

9. Conclusions

1.- The exposure levels of Spaniards to MT RFs are extremely low; the limits measured by the competent authorities are lower than those set as safe.

2.- The negative perception of base station waves does not tally with the available data. Verification of the low exposure levels allows us to assert that it is unlikely that TM RFs are a health risk factor.

3.- TM RFs are not considered a causal factor of the symptoms of persons who claim to be hypersensitive to EMFs.

4.- When dealing with situations of alarm or possible accumulation of cases, the Administration must act rapidly and openly. The information provided to parties concerned must be objective and comprehensible.

5.- The use and exposure of adult individuals to waves from mobile telephones over a period of less than 10 years is not associated with an increase in the number of brain tumours.

6.- With regard to longer exposure periods in adults or the situation of the child population, there is not sufficient data available and rational use of this tool is to be recommended.

7.- It is advisable that the competent, and especially the health, authorities implement programmes and develop informative and educational activities on the effects of RFs.

8.- As a whole, the national and international committees for protection against RF waves unanimously conclude that recent scientific/ technical breakthroughs do not justify changes in the present RF benchmark levels and exposure limits for the public and for workers.

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Bibliographical References

[Auvinen-2006] *"Epidemiological risk assessment of mobile phones and cancer: Where can improve?".* Auvinen A., Torvo T., Tokola K.. Eur. J Cancer Prev. 2006, 15(6): 516-23

[Belyaev-2008] *"Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes".* Belyaev I.AND., Markovà E., Hillert L., Malmgren L.O., Persson B.R.. Bioelectromagnetics. 2008 (in press).

[BioR-2007] *"BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)"* http://www.bioinitiative.org/report/docs/report.pdf

[Cardis -2007] *"The INTERPHONE study: design, epidemiological methods and description of the study population".* Cardis E., Richardson et *al.* Eur. J. Epidemiol. 2007; vol 22(9): 647-664. http://www.springerlink.com/content/x88uu6q103076p53/

[CCARS-2006] *"Informe sobre la situación actual de las evidencias científicas sobre la exposición a radiofrecuencias y salud (2006)".* http://www.ccars.es/docs/informes/CCARS_informe_03.pdf

[DCMNR-2007] *Irish Government's Expert Group on Health Effects of Electromagnetic Fields Report (2007)* (Department of Communications, Marine and Natural Resources) http://www.dcmnr.gov.ie/NR/rdonlyres/9E29937F-1A27-4A16-A8C3-F403A623300C/0/ElectromagneticReport.pdf

[EMF-NET] *"Effects Of The Exposure To Electromagnetic Fields: From Science To Public Health".* http://web.jrc.ec.europa.eu/emf-net/

[Eurobarometer-EMF-2007] *"Electromagnetic Fields Report (June 2007)"* http://ec.europa.eu/public_opinion/archives/ebs/ebs_272a_en.pdf

[EU-1999] *Council recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz).* Official Journal of the European Communities 30.7.99, L199/59-L199/70.
http://ec.europa.eu/enterprise/electr_equipment/lv/rec519.pdf

[EU-2004] *Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC) European Union.*
Official Journal of the European Union 30.4.2004, L159/1-L159/26.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:159:0001:0026:EN:PDF

[EU-2004b] *Corrigendum to Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC)*
Official Journal of the European Union 24.5.2004, L 184/1-L184/9.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:184:0001:0009:EN:PDF

[EU-2004c] *Corrigendum to Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC) Official Journal of the European Union. L159 of 30 April 2004. Corrected version in Official Journal of the European Unión.*
Official Journal of the European Union 4.8.2007, L204/29.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:204:0029:0029:EN:PDF

[Hardell-2008] *"Biological effects from electromagnetic field exposure and public exposure standards"*. Hardell L., Sage C.. Biomed Pharmacother. 2008; 62(2):104-9

[HCNL-2007] Health Council of the Netherlands *"Electromagnetic Fields Annual Update 2006"* (February 2007) (English version starts at page 53) http://www.healthcouncil.nl/pdf.php?ID=1505&p=1

[HCNL-BioR-2008] *The Hague: Health Council of the Netherlands, 2008; publication no. 2008/17E.* http://www.gr.nl/pdf.php?ID=1743&p=1

[HCNL-ES-Bio-2008] *Spanish translation of document* [HCNL-BioR-2008] *done by CCARS*
http://www.ccars.es/docs/comunicacion/081016%20Traduccion.pdf

[Hruby-2008] *"Study on potential effects of "902-MHz GSM-type Wireless Communication Signals" on DMBA-induced mammary tumours in Sprague-Dawley rats"*. Hruby R, Neubauer G, Kuster N, Frauscher M., Mutat Res 2008; 649 (1-2): 34–44.

[ICNRP-1998] International Commission on Non-Ionizing Radiation Protection , ICNRP Guidelines: *"Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)"(1998)"*
http://www.icnirp.de/documents/emfgdl.pdf

[IET-2008] Institute of Engineering and Technology (IET). *"Position Statement on the Possible Harmful Biological Effects of Low-Level Electromagnetic Fields of Frequencies up to 300 GHz (2008)"*
http://www.theiet.org/factfiles/bioeffects/postat02final.cfm?type=pdf

[IEGMP-2000] U.K. Independent Expert Group On Mobile Phones *"Mobile Phones And Health"* (2000), Also known as *Stewart Report* (2000)
http://www.iegmp.org.uk/report/text.htm

[Koivusilta-2007] *"Orientations in adolescent use of information and communication technology: a digital divide by sociodemographic background, educational career, and health"*. Koivusilta L.K., Lintonen T.P., Rimpelä A.H. Scand. J. Public Health. 2007; 35(1):95-103,

[Lahkola-2007] *"Mobile phone use and risk of glioma in 5 North European countries"*. Lahkola A., Auvinen A., Raitanen J., Schoemaker M.J., Christensen H.C., Feychting M., Johansen C., Klaeboe L., Lönn S., Swerdlow A.J., Tynes T., Salminen T. Int. J. Cancer 2007 120(8): 1769-75.

[Mann-2000] *"Exposure to Radio Waves Near Mobile Phone Base Stations"* Mann S.M., Coooper T.G., Allen S.G., Blackwell R.P., Lowe A.J. (2000). UK: National Radiological Protection Board NRPB-R321 Chilton

[MICyT-2007] Spanish Ministry for Industry, Trade and Tourism *"Report on exposure of the general public to radio communication station radio waves, 2007* (Ministerio de Industria, Comercio and Turismo (MICyT)) *"Informe sobre la exposición del público en general a las emisiones radioeléctricas de las estaciones de radiocomunicaciones (año 2007)"*.
http://www.mityc.es/telecomunicaciones/Espectro/NivelesExposicion/Informes/Informes%20anuales/informe_2007.pdf

[MTHR-2007] U.K. *Mobile Telecommunications and Health Research (MTHR) Programme Report (2007)*
http://www.mthr.org.uk/documents/MTHR_report_2007.pdf

[Oberto-2007] *"Carcinogenicity study of 217 Hz pulsed 900 MHz electromagnetic fields in Piμ1 transgenic mice"*. Oberto G, Rolfo K, Yu P, Carbonatto M, Peano S, Kuster N, Ebert S, Tofani S., Radiat Res. 2007; 168(3):316-26]

[ORDEN CTE/23/2002] *ORDEN CTE/23/2002, de 11 de enero, por la que se establecen condiciones para la presentación de determinados estudios y certificaciones por operadores de servicios de radiocomunicaciones* http://www.boe.es/boe/dias/2002/01/12/pdfs/A01528-01536.pdf

[Otto-2007] *"Electromagnetic fields (EMF): do they play a role in children's environmental health (CEH)?"* Otto M., von Mühlendahl K.E., Int J. Hyg Environ Health. 2007; 210(5):635-44

[PERFORMA- 2007] Project PERFORM-A *" In vivo Research on Possible Health Effects of the Use of Mobile Telephones and Base Station (Carcinogenicity Studies in Rats and Mice)* http://www.item.fhg.de/english/business_activities/hygiene/pdf/performa.pdf

[Punamäki-2007] *"Use of information and communication technology (ICT) and perceived health in adolescence: the role of sleeping habits and waking-time tiredness".* Punamäki R.L., Wallenius M., Nygård C.H., Saarni L., Rimpelä A., J Adolesc. 2007; 30(4):569-85.

[RD 1066/2001] *REAL DECRETO 1066/2001, de 28 de septiembre, por el que se aprueba el Reglamento que establece condiciones de protección del dominio público radioeléctrico, restricciones a las emisiones radioeléctricas y medidas de protección sanitaria frente a emisiones radioeléctricas.* http://www.boe.es/boe/dias/2001/09/29/pdfs/A36217-36227.pdf

[REFLEX-2004] Final Report of the Project *"Risk Evaluation of Potential Environmental Hazards From Low Frequency Electromagnetic Field Exposure Using Sensitive in vitro Methods.* http://www.itis.ethz.ch/downloads/REFLEX_Final%20Report_171104.pdf

[Repacholi-1997] *"Lymphomas in E-mu-Pim1 transgenic mice exposed to pulsed 900 MHZ electromagnetic fields".* Repacholi MH, Basten A, Gebski V, Noonan D, Finnie J, Harris AW. Radiat Res. 1997; 147(5):631-40

[Röösli-2008] *"Radiofrequency electromagnetic field exposure and non-specific symptWHO of ill health: a systematic review".* Röösli M. Environ Res. 2008; 107(2):277-87

[Rubin-2006] *"Are some people sensitive to mobile phone signals? Within participants double blind randomised provocation study".* Rubin G.J., Hahn G., Everitt B.S., Cleare A.J., Wessely S., BMJ. 2006 Apr 15; 332(7546):886-91.

[SCENIHR-2007] The European Commission's Scientific Committee on Emerging & Newly Identified Health Risks (SCENIHR). Report on *"Possible effects of Electromagnetic (EMF) on Human Health (2007)* http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf

[Schlehofer-2007] *"Environmental risk factors for sporadic acoustic neuroma" (Interphone Study Group, Germany).* Schlehofer B., Schlaefer K., Blettner M., Berg G., Bohler E., Hettinger I., Kunna-Grass K., Wahrendorf J., Schüz J., 2007 Eur. J. Cancer 43(11): 1741-7.

[Schüz-2006] *"Cellular telephone use and cancer risk: Update of a nationwide Danish cohort".* Schüz J., Jacobsen R., Olsen J.H., Boice J.D. Jr., McLaughlin J.K., Johansen Ch. J. Natl. Cancer Inst. 98, 1707-1713 http://jnci.oxfordjournals.org/cgi/reprint/98/23/1707

[Schwarz-2008] *"Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes".* Schwarz C., Kratochvil E., Pilger A., Kuster N., Adlkofer F., Rüdiger H.W. Int Arch Occup Environ Health. 2008 May; 81(6):755-67

[Sommer-2004] *"No effects of GSM-modulated 900 MHz electromagnetic fields on survival rate and spontaneous development of lymphoma in female AKR/J mice".* Sommer A.M., Streckert J., Bitz A.K., Hansen V.W., Lerchl A. BMC Cancer. 2004; 11; 4:77. http://www.biomedcentral.com/content/pdf/1471-2407-4-77.pdf

[Sommer-2007] *"Lymphoma development in mice chronically exposed to UMTS-modulated radiofrequency electromagnetic fields".* Sommer AM, Bitz AK, Streckert J, Hansen VW, Lerchl A., Radiat Res. 2007;168(1):72-80

[Söderqvist-2009] *"Use of wireless telephones and serum S100B levels: A descriptive cross-sectional study among healthy Swedish adults aged 18-65 years".* Söderqvist F., Carlberg M., Hardell L., Sci Total Environ. 2009; 407(2):798-805

[SSI-2008] Swedish Radiation Protection Authority's Independent Expert Group's*: Report on Electromagnetic Fields (2007)*
http://www.who.int/EHS-emf/publications/reports/SWEDENssi_rapp_2007.pdf
Note : SSI web page is http://www.ssi.se

[USNC-2008] U.S. National Cancer Institute *factsheet on" Cellular Telephone Use and Cancer Risk (2008)"*
(http://www.cancer.gov/cancertopics/factsheet/Risk/cellphones)

[Utteridge-2002] *"Long-term exposure of E-mu-Pim1 transgenic mice to 898.4 MHz microwaves does not increase lymphoma incidence"*. Utteridge T.D., Gebski V., Finnie J.W., Vernon-Roberts B., Kuchel T.R., Radiat. Res. 2002; 158(3): 357-64]

[Valberg-2007] *"Workgroup report: base stations and wireless networks-radiofrequency (RF) exposures and health consequences"*. Valberg P.A., van Deventer T.E., Repacholi M.H., Environ. Health. Perspect. 2007 Mar; 115(3): 416-24,
http://www.pubmedcentral.nih.gov/articlerender.fcgi?tool=pubmed&pubmedid=17431492

[WHO-2006] Fact sheet N°304, *Electromagnetic fields and public health: Base stations and wireless technologies (May 2006)*
http://www.who.int/mediacentre/factsheets/fs304/en/index.html

[Yu-2006] *"Effects of 900MHz GSM Wireless communication signals on DMBA-induced mammary tumours in rats"*. Yu D., Shen AND.H., Kuster N., Fu AND.T., Chiang H. Radiat. Res. 165 (2006) 174–180

Appendices

Appendix I: MEASUREMENTS IN SENSITIVE PLACES (from the 2007 MICyT report, [MICyT-2007])

Appendix II: CERTIFICATIONS AUDIT (from the 2007 MICyT report, [MICyT-2007])

Appendix III: HOW MOBILE TELEPHONY SYSTEMS WORK (from the Association of Telecommunication Engineers, [MICyT-2007])

Appendix I: Measurements taken in Sensitive Places

(Information extracted from the Ministry for Industry, Trade and Tourism Report "Report on exposure of the general public to radio communication station radio waves, 2007" [MICyT-2007])

Table AI-1. Measurements of radiation levels by type of sensitive places located close to radiant automatic mobile telephony antennas for points exceeding 0.45 μW/cm²

Autonomous Region	Schools	Hospitals	Public Parks	Total Sensitive Points	Average (μW/cm²)	Reference (μW/cm²)
Andalusia	6	2	16	24	1.34	450
Aragon	3	0	0	3	0.204	450
Balearics	1	0	0	1	0.119	450
Canaries	10	3	10	23	1.173	450
Cantabria	1	0	0	1	0.205	450
Castile and Leon	7	0	4	11	0.221	450
Castile-La Mancha	2	0	3	5	0.264	450
Catalonia	10	1	2	13	0.189	450
Ceuta	1	0	0	1	0.04	450
Madrid Autonomous Region	11	6	0	17	2.32	450
Valencia Autonomous Region	4	0	4	8	0.076	450

Autonomous Region	Schools	Hospitals	Public Parks	Total Sensitive Points	Average (μW/cm²)	Reference (μW/cm²)
Extremadura	1	0	1	2	0.099	450
Galicia	6	3	0	9	1.155	450
La Rioja	0	0	1	1	0.031	450
Melilla	3	2	1	6	0.024	450
Navarre	0	1	0	1	0.069	450
Basque Country	6	0	12	18	0.238	450
Principality of Asturias	1	0	3	4	0.669	450
Murcia Region	0	0	1	1	0.157	450

NB: In provinces where this level was not exceeded a single measurement was taken

National Total	Schools	Hospitals	Public Parks	Total Sensitive Points	Average (μW/cm²)	Reference (μW/cm²)
	73	18	58	149	0.452	450.000

Table AI-2. Measurements of radiation levels by type of sensitive places located close to radiant automatic mobile telephony antennas for points exceeding 0.45 μW/cm²

Autonomous Region	Province	Schools	Hospitals	Public Parks	Total Sensitive Points	Average (μW/cm²)	Reference (μW/cm²)
Andalusia	Almería	1	0	1	2	0.934	450
Andalusia	Cádiz	1	1	0	2	3.501	450
Andalusia	Córdoba	0	0	2	2	1.28	450
Andalusia	Granada	1	0	2	3	0.323	450
Andalusia	Huelva	0	0	1	1	2.72	450
Andalusia	Jaén	0	0	1	1	0.27	450
Andalusia	Málaga	2	1	2	5	0.388	450
Andalusia	Sevilla	1	0	7	8	1.308	450
Aragón	Huesca	1	0	0	1	0.041	450
Aragón	Teruel	1	0	0	1	0.191	450
Aragón	Zaragoza	1	0	0	1	0.38	450
Balearics	Balearic Islands	1	0	0	1	0.119	450
Canarias	Palmas (Las)	4	2	7	13	0.134	450
Canarias	Santa Cruz de Tenerife	6	1	3	10	2.212	450
Cantabria	Cantabria	1	0	0	1	0.205	450
Castile-La Mancha	Albacete	0	0	1	1	0.332	450
Castile-La Mancha	Ciudad Real	0	0	1	1	0.898	450

Autonomous Region	Province	Schools	Hospitals	Public Parks	Total Sensitive Points	Average (µW/cm²)	Reference (µW/cm²)
Castile-La Mancha	Cuenca	0	0	1	1	0.006	450
Castile-La Mancha	Guadalajara	1	0	0	1	0.076	450
Castile-La Mancha	Toledo	1	0	0	1	0.006	450
Castile and Leon	Ávila	1	0	0	1	0.27	450
Castile and Leon	Burgos	1	0	0	1	0.089	450
Castile and Leon	León	2	0	1	3	0.091	450
Castile and Leon	Palencia	1	0	0	1	0.006	450
Castile and Leon	Salamanca	1	0	0	1	0.034	450
Castile and Leon	Segovia	1	0	0	1	0.845	450
Castile and Leon	Soria	0	0	1	1	0.22	450
Castile and Leon	Valladolid	0	0	1	1	0.291	450
Castile and Leon	Zamora	0	0	1	1	0.147	450
Catalonia	Barcelona	6	1	2	9	0.669	450
Catalonia	Gerona	2	0	0	2	0.026	450
Catalonia	Lérida	1	0	0	1	0.057	450
Catalonia	Tarragona	1	0	0	1	0.005	450
Ceuta	Ceuta	1	0	0	1	0.04	450
Madrid Autonomous Region	Madrid	11	6	0	17	2.32	450

Autonomous Region	Province	Schools	Hospitals	Public Parks	Total Sensitive Points	Average (μW/cm²)	Reference (μW/cm²)
Valencia Autonomous Region	Alicante	2	0	2	4	0.065	450
Valencia Autonomous Region	Castellón	0	0	1	1	0.067	450
Valencia Autonomous Region	Valencia	2	0	1	3	0.097	450
Extremadura	Badajoz	1	0	0	1	0.012	450
Extremadura	Cáceres	0	0	1	1	0.185	450
Galicia	La Coruña	2	0	0	2	3.157	450
Galicia	Lugo	0	1	0	1	1.01	450
Galicia	Orense	1	0	0	1	0.06	450
Galicia	Pontevedra	3	2	0	5	0.392	450
La Rioja	Rioja (La)	0	0	1	1	0.031	450
Melilla	Melilla	3	2	1	6	0.024	450
Navarre	Navarre	0	1	0	1	0.069	450
Basque Country	Álava	1	0	0	1	0.016	450
Basque Country	Guipúzcoa	0	0	1	1	0.18	450
Basque Country	Vizcaya	5	0	11	16	0.517	450
Principality of Asturias	Asturias	1	0	3	4	0.669	450
Murcia Region	Murcia	0	0	1	1	0.157	450

Autonomous Region	Province	Schools	Hospitals	Public Parks	Total Sensitive Points	Average (μW/cm²)	Reference (μW/cm²)
Total measurements		73	18	58	149		

Appendix II: Certifications Audit

(Information extracted from the Ministry for Industry, Trade and Tourism Report "Report on exposure of the general public to radio communication station radio waves, 2007" [MICyT-2007])

Table AII-1. Global data of the 2008 Audit, corresponding to 2007 certifications

Total base stations audited	267
Total measurements taken	1348

NUMBER OF MEASUREMENTS PER AUTONOMOUS REGION

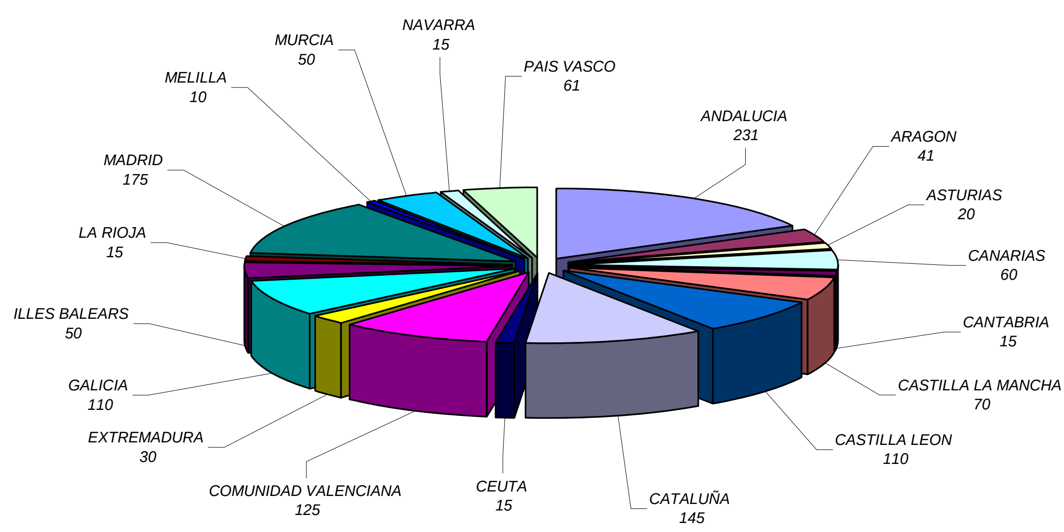
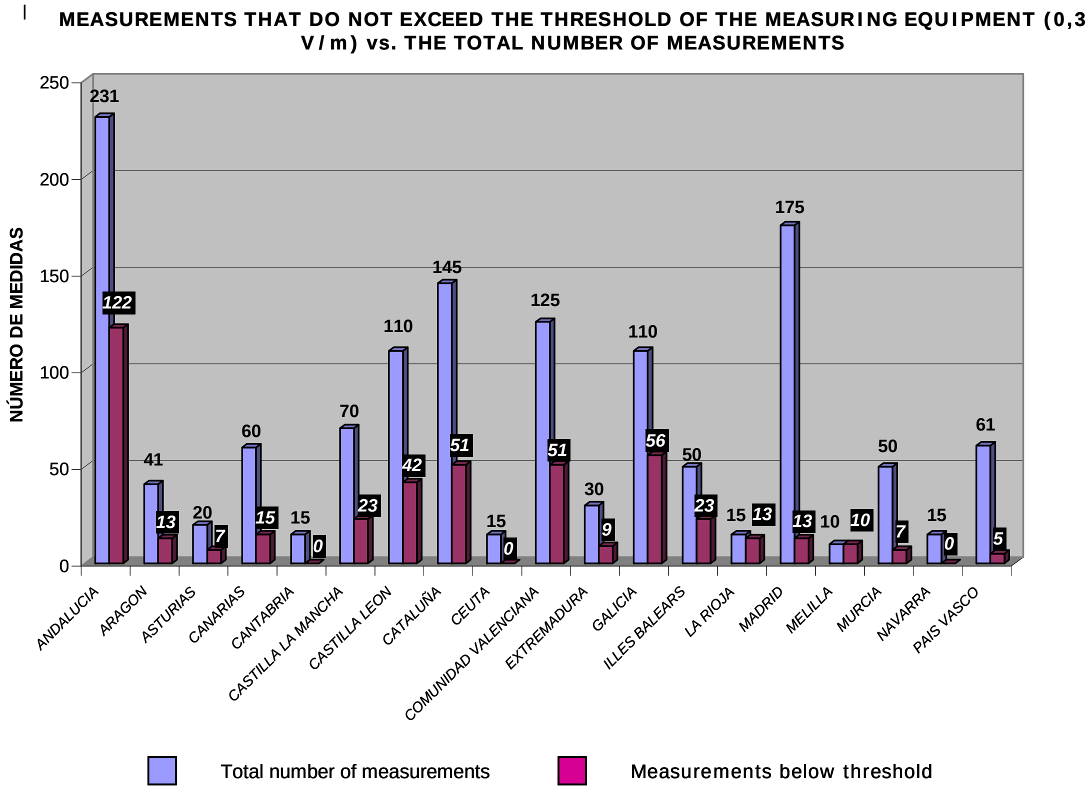


Figure AII-1. Number of measurements taken per Autonomous Region



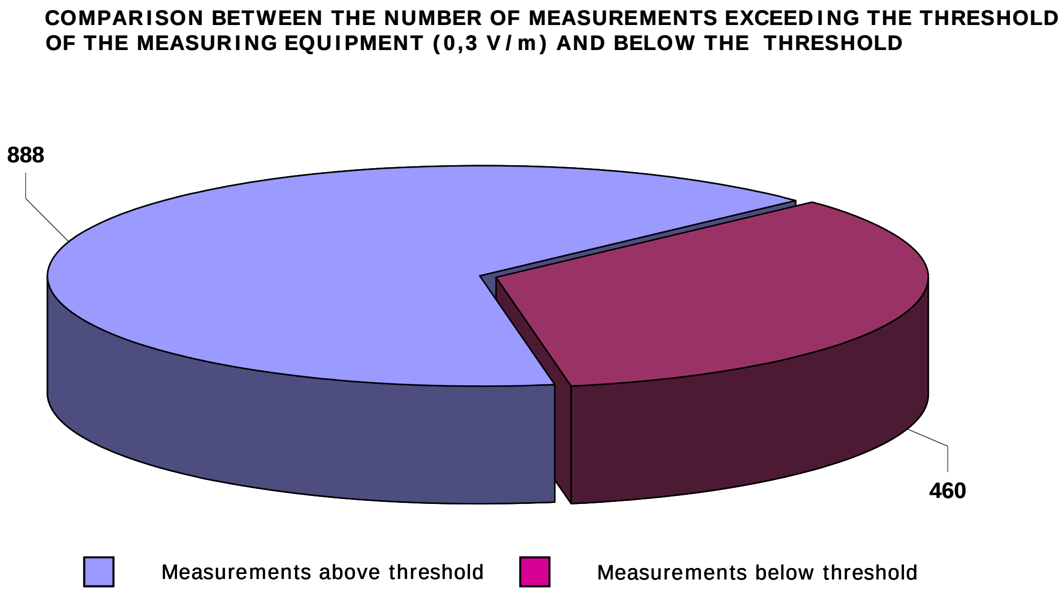


Figure AII-2. Measurements that do not exceed the threshold of the measurement equipment against the total number of measurements taken.

Table AII-2. Maximum levels measured in power density (µW/cm²) compared with the average level and the most restrictive reference level

Autonomous Region	Maximum Level (µW/cm²)	Reference Level (µW/cm²)
Andalusia	8.62	445.89
Aragón	0.56	445.89
Canarias	7.62	445.89
Cantabria	0.28	445.89
Castile-La Mancha	1.49	445.89
Castile-Leon	6.66	445.89
Catalonia	1.54	445.89
Ceuta	0.06	445.89
Madrid Autonomous Region	14.76	445.89
Valencia Autonomous Region	1.79	445.89
Extremadura	0.25	445.89
Galicia	7.73	445.89
Balearic Islands	0.15	445.89
La Rioja	0.59	445.89
Melilla	0.02	445.89
Navarre	0.19	445.89
Basque Country	2.73	445.89
Principality of Asturias	0.27	445.89
Murcia Region	7.37	445.89
Average	**3.30**	**445.89**

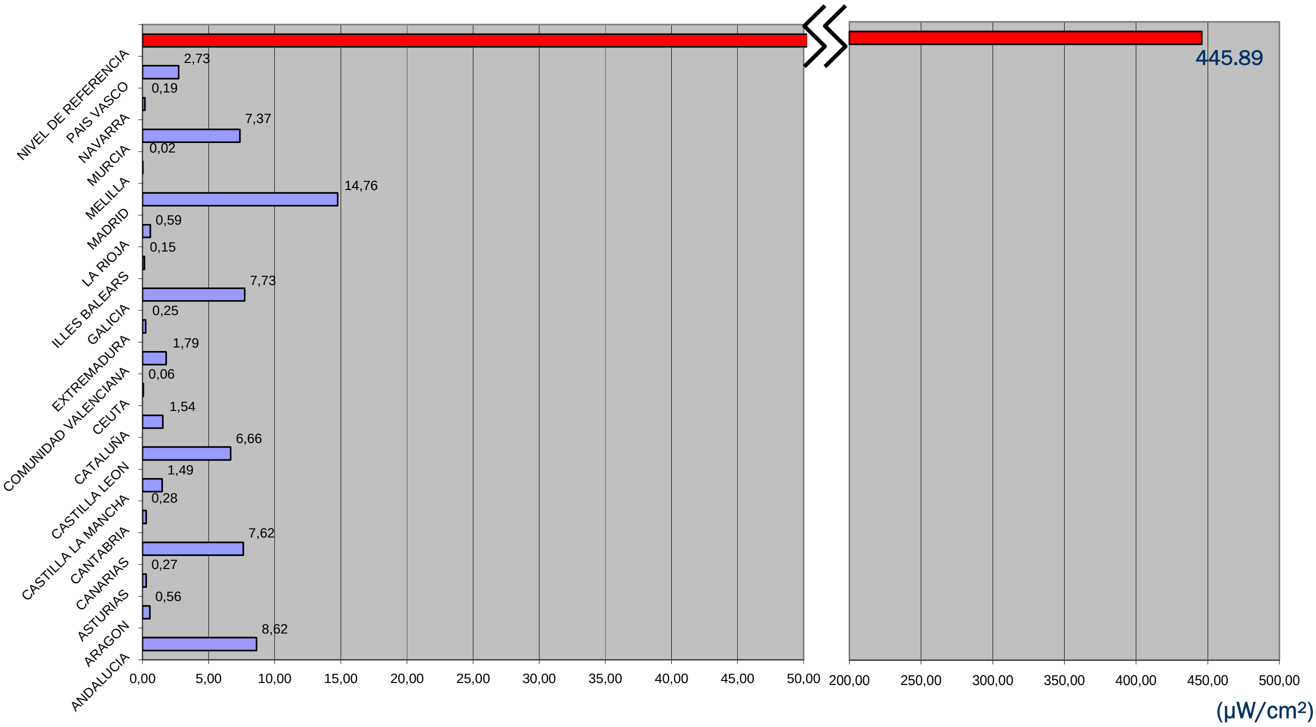


Figure AII-3. Representation of the maximum levels measured in power density (µW/cm²) in each Autonomous Region

Appendix III: How Mobile Telephony Systems Work

(Information supplied by Adrián Nogales and Noelia Miranda from the Association of Telecommunication Engineers (Colegio de Ingenieros de Telecomunicaciones), Narcís Cardona from Valencia Polytechnical University (Universidad Politécnica de Valencia) and Javier Gozálvez from Miguel Hernández University of Alicante Universidad Miguel Hernández de Alicante)

Radio communication systems are based on the transmission and reception of electromagnetic waves, which enables information to be transmitted to any point, whether fixed or mobile, through the use of specific powers and frequencies. Some of the major applications are:

- Radio and television
- Mobile Communications
- Radio links and satellite communications
- Radio navigation, teledetection and telecontrol

In order to establish a communication the following elements are necessary:

Transmitter station, which generates an electromagnetic signal that is sent out to space by means of an aerial and which is propagated to the receiver equipment. In this way, the information transmitted is inserted into an electromagnetic wave (carrier) by means of modulation techniques.

Receiving equipment, detects the signal emitted by the transmitter station and extracts the information, which may be voice, images, data or all at the same time, through demodulation of the carrier wave.

What are electromagnetic fields?

They are regions in space where matter is subjected to a certain electrical and magnetic force. Electromagnetic radiation is the product of the periodic variation of the electrical and magnetic fields.

This electromagnetic field is composed by two fields:

Electric field

It is the set of force vectors caused by the presence of electrical charges in a specific region of space. Electric fields are measured in newtons per coulomb (force per charge unit), or the equivalent in volts per metre (V/m).

Magnetic field

There are materials which naturally exhibit magnetic properties. Magnetism is the force of attraction or repulsion produced by magnetic materials, especially those that contain iron and other elements such as nickel and cobalt, and it is the force which is due to the movement of electrical charges. Magnetic fields are measured in units called teslas, which measure magnetic induction in newtons per ampere and per metre, *1 T = 1 N/1 A·m.*

Electromagnetic waves

Electromagnetic fields are propagated as electromagnetic waves. These waves are characterised by different parameters (wavelength and frequency, amplitude and energy transported, etc.). The amplitude of a wave is not of a fixed magnitude; rather it varies continuously between its maximum and minimum value. The number of times per second that this variation occurs is called "frequency" and it is measured in hertz. One hertz corresponds to 1 variation or "cycle" per second.

Wavelength is measured in metres and is defined as the inverse of the frequency multiplied by the speed of propagation. Wavelength corresponds to the distance between two consecutive waves.

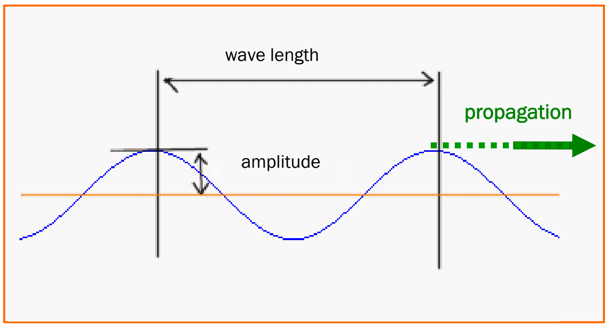


Figure AIII-1: Characterisation of a wave

In order to quantify the energy transported by an electromagnetic wave the power that passes through a surface unit or "power density" must be determined. It is calculated as the product of the amplitude of the electric field by the intensity of the magnetic field and is measured in watts per square metre (W/m^2). Therefore, far from the source that generates the waves, the surface on which they are distributed is larger and, therefore, its power density is much smaller. That is why at a few metres distance from a wave source (for example, a mobile telephone antenna), exposure is minimal.

Propagation of waves

Electromagnetic waves propagate by means of different mechanisms:

Propagation in free space

When electromagnetic waves generated by antennas meet with no obstacle, they propagate equally in all directions, the power density diminishing inversely with the square of the distance and with the square of the frequency.

Reflections

When electromagnetic waves meet obstacles in their path, part of their energy is reflected (reflected wave) and part of their energy is transmitted through the obstacle. The reflected wave depends on multiple factors (type and thickness of material, frequency of incident wave, angle of incidence, etc.)

Diffractions

They are attenuated waves that propagate in all directions, the result of the incidence produced by a wave on edges of obstacles. Diffracted waves depend on multiple factors (angle of incidence, type of material, the shape of the edge, etc.)

The electromagnetic spectrum

The electromagnetic spectrum is the representation of all the array of possible frequencies that electromagnetic waves may adopt. *Figure AIII-2* shows the electromagnetic spectrum and indicates the subdivision of the spectrum according to frequency bands. It must be stressed that radio communication system operating frequencies are far lower than ionising waves; they therefore clearly belong to the non-ionising group.

The radio wave exposure limits in Spain, established by Royal Decree 1066/2001, of 28 September [RD 1066/2001], adopt the health protection against electromagnetic fields criteria set in the Recommendation of the Council of Health Ministers of the European Union, of 12 July 1999 [EU-1999] which were taken, in turn, from the ICNIRP [ICNRP-1998]. These limits are endorsed by the World Health Organisation.

The amount of energy an electromagnetic wave is capable of depositing in an organism and the way it is absorbed by the latter depends on the frequency of the wave. The SAR (Specific Absorption Rate) is the unit of measurement of the amount of energy absorbed by the organism.

In the case of mobile telephony, although the SAR is determined at the highest certified power level in laboratory conditions, the effective SAR level of the telephone in normal operation is far lower than that level. This is due to the fact that the telephone is designed, as is all the mobile telephony network, to use the minimum power necessary. In practice, mobile telephones transmit significantly below *2 W*.

Therefore, the closer one is to a base station, the lower effective SAR level is likely to be. SAR variations do not mean that there are variations in safety. Although there may be differences in SAR levels between different phone models, all cell phones must meet RF exposure criteria.

In Europe, mobile telephones bear the EC brand, as proof that the products comply with the relevant European requirements and standards. The greater the coverage of and the fewer base station changes a mobile telephone has to make, the less power it will need to transmit, and, in consequence, the longer the battery will last.

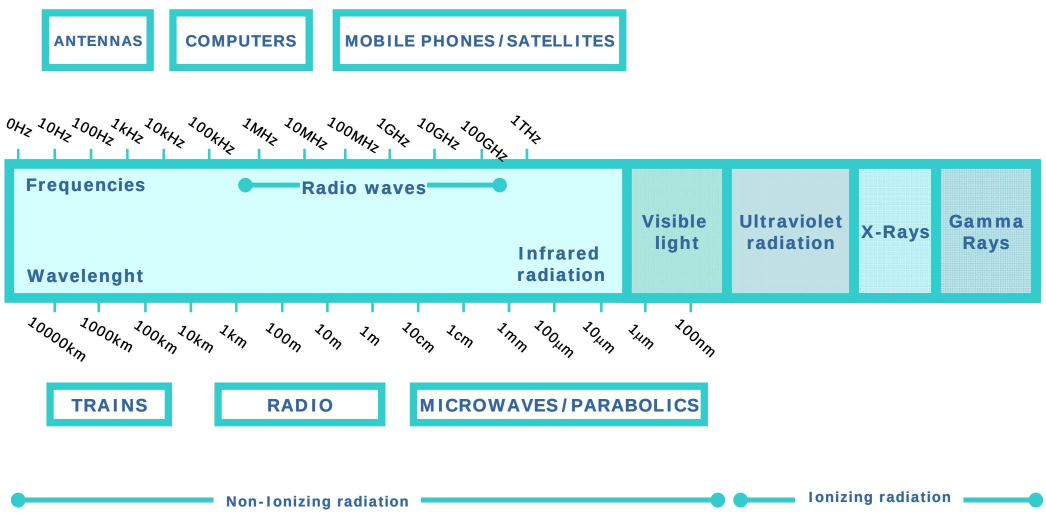


Figure AIII-2. The electromagnetic spectrum

Table AIII-1 Exposure limits for frequency bands associated with telecommunications. Reference levels

SERVICE	SYSTEM	f(MHz)	Reference level			
			(mW/cm²)	(μW/cm²)	(V/m)	(W/m²)
Radiobroadcasting	AM	0.5	---	---	87	---
		1.5	---	---	71.03	---
Radiobroadcasting	FM	100	0.2	200	28	2
Terrestrial TV	UHF	470	0.235	235	29.8	2.35
		830	0.415	415	39.6	4.15
Mobile telephony	TACS	450	0.225	225	29.2	2.25
Mobile telephony	GSM	900	0.45	450	41.2	4.5
Mobile telephony	DCS	1800	0.9	900	58.3	9
Mobile telephony	UMTS	2000	1	1000	61	10
Local wireless network	IEEE802.11b (Wi-Fi) Bluetooth	2400	1	1000	61	10
Fixed wireless telephony	LMDS	3500	1	1000	61	10
Local wireless network	IEEE802.11a/h (Wi-Fi)	5000	1	1000	61	10
Fixed wireless telephony	LMDS	26000	1	1000	61	10

Table AIII-2 Exposure limits. Basic restrictions

FREQUENCY RANGE	Whole body average SAR (W/Kg)	Localised SAR (head and trunk) (W/kg)	Localised SAR (limbs) (W/kg)
10 MHz -10 GHz	0.08	2	4

Mobile telephony systems

Mobile telephony is a telecommunication service provided to a user whose location is not fixed (mobile) and who is situated within a defined area. The goal is to offer access via radio to mobile telephone subscribers, so that they can avail of a quality service within the coverage area of the system. There are two types of mobile telephony systems: cellular systems and *cordless* systems, whose range is much smaller.

The bands assigned by the CNAF (*Cuadro Nacional de Atribución de Frecuencias, Table of National Frequency Allocation)* to cellular mobile telephony in Spain are located in the RF range.

In order to avoid interferences between different systems, each operator is exclusively allocated a part of the mobile telephony frequency band. In this way, they have different portions of the spectrum and can ensure that their networks function independently. Additionally, each operator uses different groups of frequencies to transmit from each base station (descending link from the base station to the handset) and for transmission from the mobile handset (ascending link from the handset to the base station).

Mobile telephony signals propagate over limited distances. As we have seen above, the propagation of electromagnetic waves is complex thus causing the latter to diminish with distance. Due to this limitation in terms of distance, for traffic capacity requirements and in order to provide the service among users who are far apart, it is necessary to plan and divide the area of coverage into cells, each one with base station at its centre. Generally speaking, the area to be covered is made up of a mesh of hexagonal cells with a base station at its centre, although this structure is not usually regular owing to landscape features and the capacity needed in each cell. This network configuration enables the re-use of frequencies in cells which are far apart. Base stations that are sufficiently distant from one another can reuse the same frequencies, as the signals transmitted by each one will not reach the other or, to put it another way, they will not interfere with each other. Cells that share frequencies are called “co-channel”.

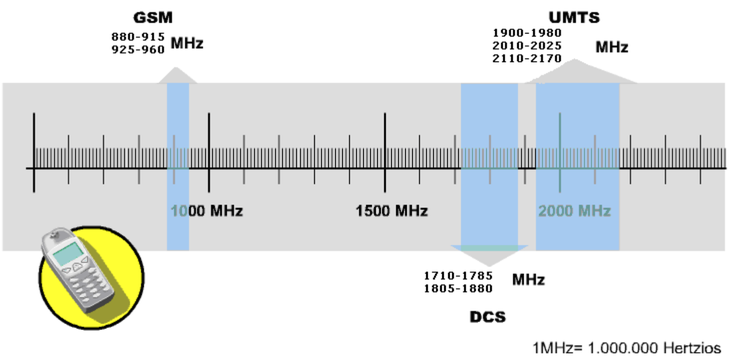


Figure AIII-3.Frequency bands used in mobile telephony

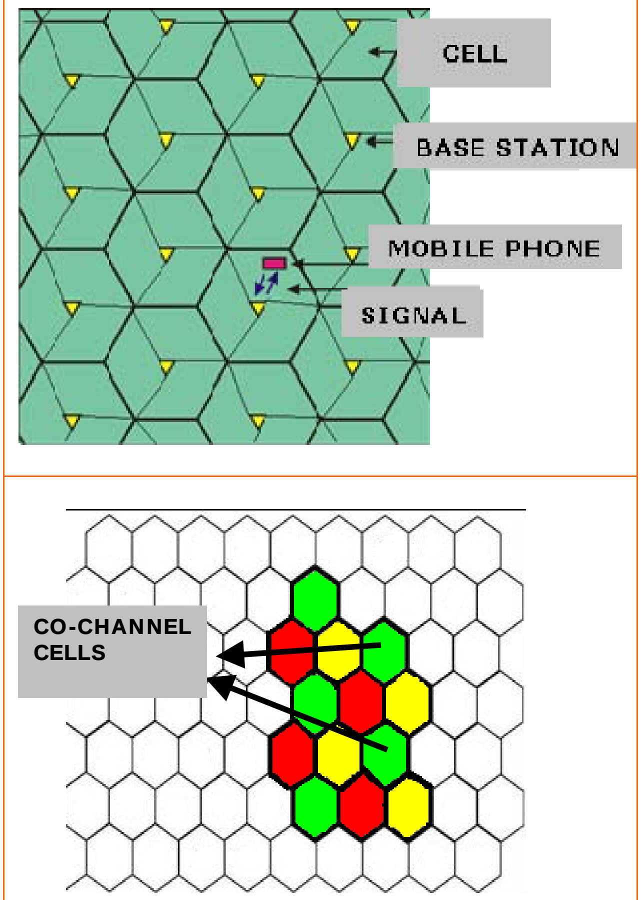


Figure AIII-4 Structure of a cellular network (I)

Due to the spectacular increase in mobile telephone use, the size and complexity of the network has also grown and with it the size of the cell has gradually got smaller. This is because in order to provide services to all the users located in a specific area, especially in highly populated area, many simultaneous connections would be needed and as each base station has a limited number of simultaneous connections, it is necessary to reduce the area of coverage and increase the number of base stations to cover that area. Therefore, in urban areas microcells and picocells must be installed.

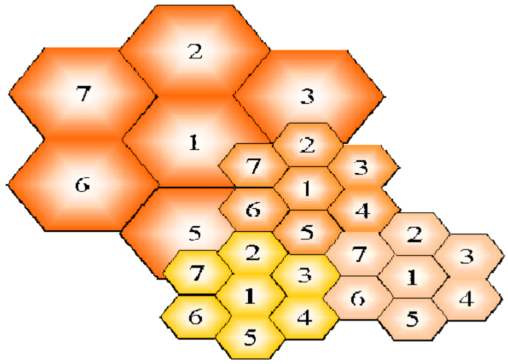


Figure AIII-5 Structure of a cellular network (II)

All the systems making up the mobile telephony network include power control, (both base stations and mobile handsets) which enables the power transmitted to be adjusted to the minimum level in order to ensure the feasibility of the link established (signal reception of sufficient quality) and avoid interference with adjacent cells. Mobile telephony networks, due to their very structure, are optimally designed in accordance with the minimum transmission possible principle, (ALATA, or *as low as technology allows*).

Unlike other radio communication systems, such as, for example, radio broadcasting systems (which are characterised by high power, in the region of hundreds of kW, and large coverage), mobile telephony systems require low power (minimum waves) and limited cell coverage to reduce interference.

Mobile phone users can communicate with one another provided they are within the coverage area or area covered by a station. The size of the cell will depend on call traffic density. If the number of users exceeds a cell's capacity, it must be divided into smaller cells. Each user establishes a connection via the nearest base station, which is also connected to the other cells and other telephony systems.

Communication while mobile is thus ensured and users can pass through different coverage cells.

In order to avoid interference between the different antennas and optimise the power necessary, antennas always transmit with the minimum power necessary to enable communication. Likewise, they transmit directionally, so that transmission power is only transmitted in certain directions. As a result, electromagnetic field levels are only high close to antennas and only in certain directions. This means that a slight deviation in the direction of maximum aim (maximum transmission) entails a significant reduction in the power transmitted.

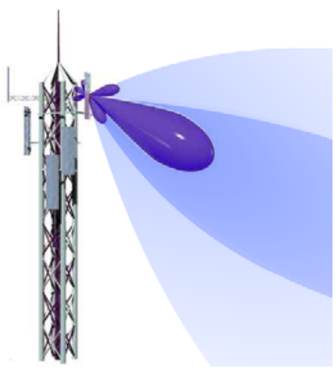


Figure AIII-6. Transmission characteristics of a directional mobile telephone antenna

Each location is leveraged to the full and a reduction in the system's interference levels is achieved when sectorisation is used. Many base stations are divided into three sectors, which will act as independent cells. Normally, if there is more than one antenna installed in each sector, one of them transmits (from the base station to the mobile) and the others only receive. The signals captured by the recipient antennas are combined to improve the quality of the signal received, thus minimising the power transmitted by the mobile. This procedure is called reception diversity. There is antenna technology currently available which integrates transmission and reception channels in a single element, in this case using diversity of polarisation.

The huge increase in the number of mobile phone users, especially in areas of greatest population density, leads to a reduction in base station coverage cells and an increase in the number of base stations necessary. The more base stations an operator deploys, the lower the power transmitted by the base station and the handset. Both pieces of equipment are continuously testing the signal levels they receive so as to transmit with the minimum power necessary. In this way, although a handset is capable of transmitting one or two watts of power, in most situations, it transmits lower power. Moreover, the handset and the base station antenna only transmit during conversations; during the periods of silence transmission is suspended. The field levels transmitted are, in practice, much lower than the system is capable of transmitting.

Base stations are installed in high places to avoid obstacles interfering with propagation (buildings, trees, etc). There are two advantages:

- Electromagnetic field levels in contact with people are reduced.
- The systems work better because there are fewer obstacles.

The height of antennas is restricted, in many places, for aesthetic and for town planning related reasons, although new camouflage techniques help to reduce the visual impact. Therefore, when planning where to locate antennas both technical and environmental aspects are taken into account.

Why is it not advisable to move antennas away from town centres?

The idea of sitting antennas outside town centres so that they will be as far as possible from residential areas would entail base station and mobile telephone antennas having to increase transmission levels in order to establish communication. Therefore, base stations would have to increase their transmitted power in order to provide a service at a greater distance. Similarly, handsets would need to transmit with more power in order to make a connection with stations, this would entail higher power density radiated over users and an increase in handset battery consumption.

Furthermore, this would lead to a reduction in service quality as coverage would be more irregular. Placing base stations farther apart and at a greater distance from urban environments, therefore, is contrary to the principle of minimum transmission possible.

To illustrate our point, we might compare it with the following situation: Let us imagine that we remove all urban street lights in a town and replace them with powerful spotlights located around the urban perimeter. This would mean that some parts of the town would be badly lit and others, close to the spotlights, would be very brightly lit and very hot.

Elements necessary in mobile telephony

Mobile telephony requires a number of basic elements:

Mobile handsets (MS, Mobile Stations). These are the mobile telephones. They are the end equipment supplied by the service required by users. Mobile handsets comprise the following elements: a loudspeaker, a microphone, a liquid crystal display screen, a keypad, an aerial (currently integrated), a battery, radio frequency circuit board and a user interface circuit board. In addition, in order to perform data compression and decompression, mobiles have a digital signal processor which carries out all keypad tasks, controls base station signals and performs all functions to coordinate the latter.

Base Stations (BTS). Their mission is to maintain the radio link with the mobile handsets, that is, they are the connection point of the mobile handset with the cellular network. The base station is the element responsible for managing all mobile communications carried out in its area of coverage and linking them up with the rest of the system, from where they are routed to other alternative fixed or mobile networks. Base stations are classified according to the size of the area of coverage and the power transmitted:

- Macrocells. The power transmitted by these stations is usually a few dozen watts (20-40). Their function is to provide coverage to large areas of between 1-15 km. That is why the antennas are installed at a height above the ground of between 15 and 40 metres on rooftops or towers. The length of antennas is usually about a metre.

- Microcells. Their power is generally small, around a few watts (1-2). Microcells are urban cells which provide street-level coverage and whose antennas are installed at a height of between 3 and 6 metres. Their range is usually less than 1 km.

- Picocells. These are the stations that transmit least power (<1 W). They are used to provide coverage inside buildings and the antennas are installed on walls or ceilings. Antennas for picocells are small, in the shape of rods or boxes 10 to 50 cm in length.

Figure AIII-7. Different types of base stations (I)

Base stations are mainly composed of:

Antennas or radiant systems: radio signals transmitter and receiver. They adapt the guided waves that are transmitted by conductors or wave guides that propagated in free space and vice versa.

RF generation and reception **equipment and** monitoring devices.

Batteries to ensure operation in the event of a power failure.

Cooling systems to enable equipment to operate properly during the hottest times of the year.

Support or tower for different types of antenna according to the type of station.

Hut, access road and other associated elements.

Base Station Controller (BSC). It manages a group of base stations under its supervision. For example, one of the functions it performs is to manage the change from the channel occupied by a mobile handset when it transfers to the area of coverage of another base station.

Mobile Switching Centres (MSC). These are the centres that enable connection with public and private networks and the interconnection of users located in different geographical areas.

Figure AIII-7. Different types of base stations (II)